GLOBAL DIFFUSION OF GREEN BUILDING CERTIFICATION SYSTEMS (GBCS): A LEAD AND LAG MARKETS MODEL

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Yusuf Furkan KAYA

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ABSTRACT

GLOBAL DIFFUSION OF GREEN BUILDING CERTIFICATION SYSTEMS (GBCS): A LEAD AND LAG MARKETS MODEL

Global crises in our planet's sustainability emerged in recent history. Hence, the construction industry, which has the largest share in this situation, have witnessed the accelerated proliferation in the number of Green Building Certification (GBC) systems (such as LEED, BREEAM and Green Star) in the last two decades. GBC systems have received massive attentiveness from academics from numerous disciplines as a reasonable response to its accelerated proliferation. The general concepts described in preceding research endeavours on GBC systems comprise (1) evaluation benchmarks used in rating and weighting, (2) incentives and handicaps for acquiring a GBC system, (3) efficacy of a GBC system, (4) comparison of numerous GBC systems, and (5) systematic reviews of the research and studies. The research presented herein pays particular attention to a relatively disregarded research area on GBC systems: global diffusion behaviours. It conceptualises a GBC system as a product rating service provided in certain nations and employs the Mixed Influence Model to investigate this certification service's cross-national diffusion behaviours. Initially, this model was used to investigate population growth. Thereafter, its application has been widened to explore the diffusion of industrial systems such as goods, services, and innovations. The Mixed Influence model was constructed incorporating data from one of the oldest GBC systems, LEED. The results of the Mixed Influence model reveal the cross-national diffusion behaviours of the GBC systems.

ÖZET

YEŞİL BİNA SERTİFİKASYON SİSTEMLERİNİN (YBSS) KÜRESEL YAYILIMI: BİR ÖNCÜL VE ARDIL PAZARLAR MODELİ

Yakın tarihte gezegenimizin sürdürülebilirliğinde küresel krizler ortaya çıktı. Bu nedenle, bu durumda en çok pay sahibi olan inşaat endüstrisinde son yirmi yılda Yeşil Bina Sertifikasyon (YBS) sistemlerinin (LEED, BREEAM ve Green Star gibi) sayısının hızla artmasına tanık olunmuştur. İvmeli çoğalışına anlamlı bir yanıt olarak, YBS sistemleri çok sayıda disiplinden akademisyenlerden büyük ilgi gördü. YBS sistemleri üzerine yapılan önceki araştırmalarda açıklanan genel kavramlar, (1) derecelendirme ve ağırlıklandırmada kullanılan değerlendirme kıyaslamaları, (2) bir YBS sistemi edinmeye yönelik motivasyonlar ve engeller, (3) bir YBS sisteminin etkililiği, (4) çok sayıda YBS sisteminin karşılaştırılması ve (5) yapılmış araştırma ve çalışmaların sistematik incelenmesi. Burada sunulan araştırma, YBS sistemlerinde nispeten göz ardı edilen bir araştırma konusuna özellikle dikkat eder: küresel yayılma davranışları. Farklı ülkelerde sağlanan bir ürün derecelendirme hizmeti olarak YBS sistemlerini kavramsallaştırır ve bu sertifika hizmetinin uluslararası yayılma davranışlarını araştırmak için Karışık Etki Modelini kullanır. Başlangıçta, Karışık Etki modeli nüfus artışını araştırmak için kullanıldı. Daha sonra, mallar, hizmetler ve yenilikler gibi endüstriyel sistemlerin yayılımını incelemek için uygulama alanı genişletildi. Karışık Etki Modeli, en eski GBC sistemlerinden biri olan LEED'den elde edilen veriler işlenerek oluşturulmuştur. Karışık Etki modelinin sonuçları, YBS sistemlerinin uluslararası yayılma davranışlarını ortaya koyar.

TABLE OF CONTENTS

LIST OF FIGURES

Figure	**Page**

LIST OF TABLES

LIST OF ABBREVIATIONS

BEE	: Building Environmental Efficiency
BREEAM	: Building Research Establishment's Environmental Assessment Method
BSAS	: Building Sustainability Assessment Tool
CASBEE	: Comprehensive Assessment System for Building Environmental Efficiency
GBCA	: Green Building Council Australia
GBC	: Green Building Council
GBCS	: Green Building Certification System
GBRT	: Green Building Rating Tool
HQE	: Haute Qualité Environnementale
JaGBC	: Japan Green Building Council
JSBC	: Japan Sustainable Building Consortium
LEED	: Leadership in Energy and Environmental Design
MAPE	: Mean Absolute Percentage Error
MLE	: Maximum Likelihood Estimation
NLS	: Non-linear Least Square
PS	: Parameter Stability
OLS	: Ordinary Least Square
SPSS	: Statistical Package for the Social Sciences
UNEP	: United Nations Environment Program
USGBC	: United States Green Building Council
WGBC	: World Green Building Council

CHAPTER 1

INTRODUCTION

Our world has maintained its existence for billions of years in the balance of cycles decorated with incredible details. Some of these states of equilibrium have deteriorated to worrying levels over the past thirty years. Eventually, this situation causes noticeable climatic changes, seasonal shifts and thus degradation of nature. Consequently, this alarming conjuncture has rendered the concept of sustainability to gain popularity, on which academics and scientists from almost every field, study and seek solutions for a couple of decades (Costanza and Patten 1995). Even though there is a pair of initial framing and definition trials for the terms sustainability and sustainable development before (Meadows 1972), the most widely known definition has been made by the World Commission on Environment and Development (1987) as *"sustainable development is the development which meets the needs of the present without compromising the ability of future generation to meet their own needs.*". In line with this statement, due to the described changes in the natural balance of the world, there emerged a viable common sense that the lives of future generations would conceive difficulties in numerous aspects unless the search for precise solutions is not carried out.

The vital crisis, which played a significant role in the degradation of all these balances, known as Global Warming, is predominantly caused by the excessive increase in the amount of CO_2 gas found in nature. While manufacturing processes are directly effective in forming this gas, the amounts released in the energy generation used in these production processes should also be taken indirectly into account. Looking at the situation from both sides, the construction industry alone has the largest share of 36% in global energy use and 39% in global CO_2 gas emissions (UN Environment and International Energy Agency 2017). When these statistics are taken into consideration, the construction industry can be regarded as making the most negative contribution to the earth's sustainability among other sectors.

Real estate production is remarkably effective in creating value for the sake of the community, contributing to economic expansion, and creating employment opportunities. This industry alone represents 7-10% of the global economy, which corresponds to rates ranging from 5% to 15% of nations' GDP in general. Moreover, the number of employees in the construction industry has exceeded one hundred million people worldwide (World Economic Forum 2016). It has already been proven that it is an indispensable sector for the benefit of society and the economy. Aside from its good features, a much faster-growing industry has emerged on account of meeting the needs due to the increasing global population in recent years. Therefore, this industry represents a tremendous amount of consumption of global sources like (Doan et al. 2017):

- 15-17% of the freshwater,
- 25% of the wood,
- 40% of the raw materials.

In addition to this consumption, it also accounts for 30-40% of the world's waste generation (Vijayan and Kumar 2005). When these excessive resource consumption and waste generation values are considered together with the construction industry’s high shares in energy consumption and greenhouse gas production, a radical change seemed inevitable. For this reason, discussions on a sustainable industry and green building, idea generation and feasibility studies for the groundwork began within the global construction industry.

Conceptualising the powerful impact that a change and transformation can have on the world’s sustainability, construction industry leaders have introduced different initiatives such as building regulation amendments and Green Building Councils (GBCs). GBCs, whose aim is to ensure that industry stakeholders are motivated to produce buildings with higher performance than regulations necessitate, have played an active role in the emergence and dissemination of Green Building Certification Systems (GBCSs) in this pursuit (Ade and Rehm 2019b). GBCSs, which are known as green building rating tools that basically sets out the prerequisite conditions for green building construction, aims to measure the performance of these structures, to control whether economic, ecological and social sustainability (which are the three main branches of sustainability) can be achieved, and finally to accelerate the evolution of the industry in a more environmentally friendly direction (Xiaoping, Huimin, and Qiming 2009). Building Research Establishment’s Environmental Assessment Method (BREEAM), which emerged in 1990 in the United Kingdom to serve these purposes, is the first GBCS globally. The following GBCS, founded in the United States in 1998 after a break of almost ten years, Leadership in Energy and Environmental Design (LEED) has made this time gap insignificant with its rapid growth figures and has approached to become the most common GBCS. Following this, the industry has adopted this environmentally friendly orientation at such a fast pace that nearly 600 green product rating systems are currently mentioned giving services in different nations (Vierra 2011). And under the umbrella of the World Green Building Council (WGBC), there are over 90 GBCs pioneering and managing these rating tools (Ade and Rehm 2019b).

1.1. Problem Statement

The GBCSs, which started to emerge from the beginning of the 90s across the globe, were met with an intense adoption in a short time by the construction industry. As a result, this situation did not escape the attention of researchers from all fields and became a relevant topic. Hence, the rapidly increasing research of academics from several disciplines on GBCSs has intensified, especially in the last decade (Darko and Chan 2016, Doan et al. 2017, Lazar and Chithra 2020, Li et al. 2017).

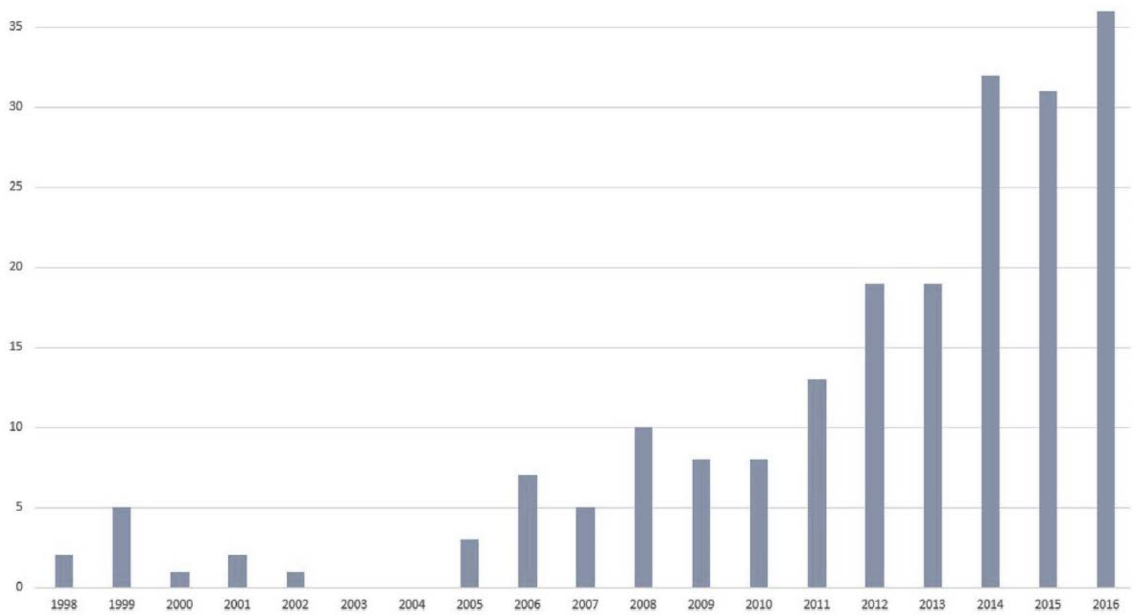

Figure 1. Number of Articles with First Generation GBCSs (BREEAM, LEED,CASBEE, and Green Star NZ) Content by Years (Source: Doan et al. 2017)

This concentration on studies related to these systems is also very diverse due to the large number of GBCSs. The main ones can be listed as follows:

- Evaluation benchmarks in rating and weighting (Reed et al. 2009, Vierra 2011),

- Incentives and handicaps for acquiring a GBC system,
- The efficacy of a GBC system (Vijayan and Kumar 2005),
- Comparison of numerous GBC systems (Doan et al. 2017, Li et al. 2017),
- Systematic reviews of the research and studies (Shan and Hwang 2018).

In the last few decades, when transportation and telecommunication technologies have reached a remarkably advanced level and became accessible at the community level, globalization has become inevitable for every field. Therefore, GBCSs, which contribute to a sustainable world, are now generally serving in cross-national markets simultaneously rather than a single market. The industry leader LEED serving over 160 countries can be shown as an excellent example of this (Doan et al. 2017). On the one hand, while the need for a globally valid GBCS has been revealed by many researchers (Reed et al. 2009, Reed, Krajinovic-Bilos, and Reed 2017), the first collaborative studies of the systems are also emerging (Kennett 2009).

Despite such comprehensive and diverse research, the international diffusion behaviours of GBCSs manifest themselves as an unstudied niche. No study has tried to understand the adoption of GBCSs over cross-national markets and explored the agents that influence this diffusion. When any GBCS emerging in a particular market begins to serve in another market during its expansion in the first, its propagation behaviour is expected to alter in both markets due to several different types of interactions between these countries (Helsen, Jedidi, and DeSarbo 1993). The time differences between entering these markets are seen as the primary point that has an influence upon this change. The cross-regional learning effect defines those interactions' logic because of the temporal differentiation mentioned above (Kumar, Sunder, and Ramaseshan 2011).

For the construction managers and executive boards of institutions that provide products and services to international markets, it is crucially advantageous to understand and foresee the previously mentioned dynamics of adopting a product or service before entering a new market. This situation has been a shortcoming in the past studies on GBCSs and constitutes the main problem to be addressed during this study.

1.2. Objectives of the Research

The available literature concerning GBCSs fails to provide insight into the cross-national diffusion dynamics and the elements that influence these behaviours of the rating tools' global adoption. The steps to the goal include explaining innovation diffusion theory, assimilating the logic behind innovation diffusion modelling, understanding the concept of sustainable development and construction, and clarifying the process of GBCSs formation and development. Thus, the main points to be reached as a result of these intermediate steps for the objectives of the research presented herein are as follows;

- To grasp the diffusion behaviours of GBCSs in the national domains
- To examine the theory and dynamics of Cross-National Diffusion
- To analyse and interpret the dynamics of Cross-National Diffusion of GBCSs

1.3. Scope of the Research

This study presented here in this thesis concentrates on the LEED GBCS. In this research, which focuses on the diffusion dynamics of green building certification processes carried out by LEED in three different regions such as North America, Asia and Latin America, there are several main reasons why LEED is preferred as the certification system. The first reason is that LEED, one of the oldest certification systems globally, serves in more than 160 countries and is considered the world's most extensive and most international certification system. The second is that BREEAM focuses only on the European region, and LEED is just after BREEAM in the number of certifications.

1.4. Outline

This study, which aims to analyse and understand the global diffusion of GBCSs, consists of six main chapters. The first chapter calls attention to the problem statement, objectives of the research, and finally, the scope of the study. The second chapter highlights the evolution of the innovation diffusion theory. In addition, it provides an extended literature review for the concept of innovation diffusion and cross-regional adoption. The third chapter begins with the emergence of sustainability and sustainable development and continues with the comprehensive examination of the literature for the GBCSs. In the fourth chapter, an elaborate explanation of the research design (i.e., sampling, data preparation and analysis) is presented. The fifth chapter includes the results and related interpretations of the applied model to the selected GBCS. Lastly, the summary of the overall approach of the thesis and its contribution to the construction management literature is discussed in the sixth chapter.

CHAPTER 2

DIFFUSION OF INNOVATION

This chapter begins with conceptualizing the Innovation Diffusion Theory. After the relevant framework is formed, it explains the main elements of this theory and their effects on it. In the continuation, the second part examines the External Influence (Coleman Function), Internal Influence (Logistic Curve), Internal Influence (Gompertz Curve), and Mixed Influence models (Bass Model), which are the fundamental Influence Models used to study and describe Innovation Diffusion. After mentioning the mathematical foundations of these models in the previous section, the additions and modifications made to these models are analysed. To get the results of the Influence Models, the approaches of determining the models' parameters at the first stage are explained in the next section. Finally, the methods and techniques used to model how the concept of Innovation Diffusion behaves in International (Cross-National, Cross-Regional, Cross-Country, Multi-National) Markets are studied.

2.1. Innovation Diffusion Theory

The modelling and forecasting of innovation adoption have attracted a lot of attention from numerous practical and academic specialities since the early 1960s and continues to be studied with the same vitality in these sixty years. Innovation Diffusion Theory bodied by Rogers (1983) bases itself on those properly grounded studies such as Anthropology, Rural Sociology, Education, Public Health and Medical Sociology, Communication, Marketing and Geography (Rogers 1983, 45).

And this Innovation Diffusion Theory, defined by Rogers (1983), allows an understanding of the adoption process of innovation. According to this theory, *"the process by which an innovation is communicated through certain channels over time among the members of a social system"* is the definition of diffusion. This description indicates that the adoption of innovation has four main components:

- Innovation,
- Time,
- Communication Channels,

- Social System.

According to Merriam-Webster (2021), the definition of innovation is *"a new idea, method, or device"*. Innovation can be handled in two different categories. The first typology is that innovation can directly be a technical novelty like a creation, process, system, or apparatus (Daft 1978). In other words, concrete or tangible. The second option is that it can be managerial like organizational scheme, management structure or education curriculum that is new to the adopting company (Daft 1978). Again, with another expression, abstract or intangible.

The concept of time can be equated with pace and acceleration in this context. Considering the general situation when an innovation is adopted in a time frame, it explains how quickly and rapidly that innovation is adopted.

Communication channels are another critical point for innovation diffusion. It is crucial to an adoption analyst which parts of society (i.e., individuals, couples, groups, organisations, etc.) transfer information and interact with other parts of the social system. The whole with this diversity of elements and a wide range of interactions is called the social system.

According to the time that their members adopt innovation, this social system is divided into several groups, as depicted in Figure 2 (Moore 2009, Rogers 1983).

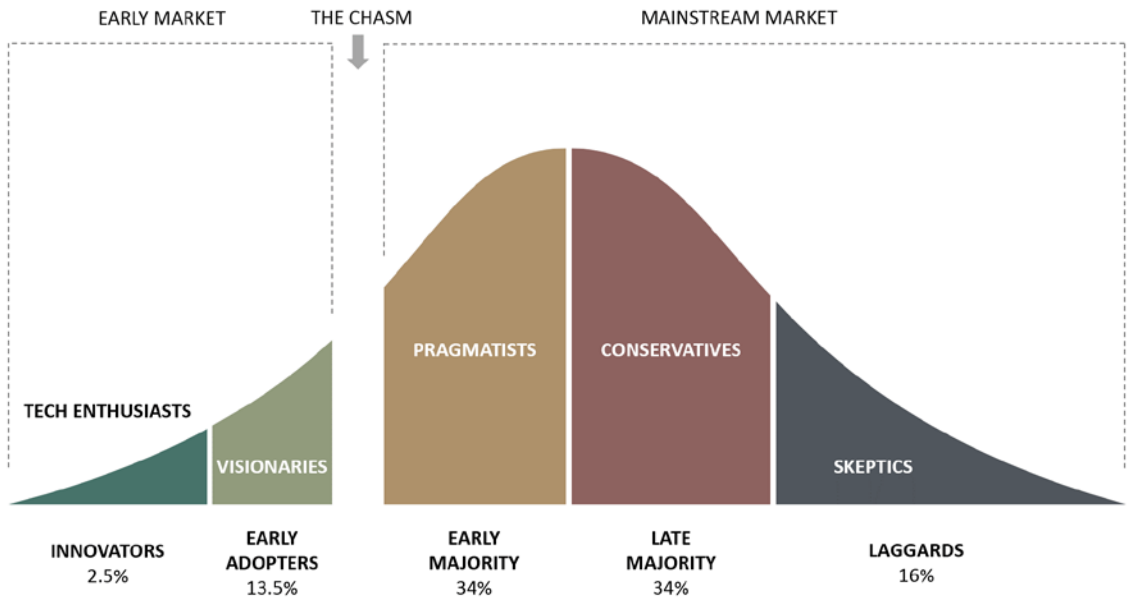

Figure 2. Innovation Diffusion Life Cycle and Adopting Groups
(Source: Moore 2009)

Innovators (Tech Enthusiasts, Venturesome) are the ones who are eager to learn, try and experience new things. Generally, this group of individuals, whose financial power is good enough to suspend the adoption of this innovation, can easily access communication paths due to the same curiosity and economic power (Rudd and Simonds 2016). The successor group, Early Adopters (Visionaries, Respectable), are thought leaders who are qualified mentors and role models in the societies they belong to. As (Moore 2009) puts the *"the chasm"* between this Early Adopters group and followings, this group must adopt that innovation. This situation is because these people are seen as pioneers in society, and a significant part of society imitates their ideas and behaviours. Next comes the Early Majority (Pragmatists, Deliberate). Individuals in this group adopt the philosophy of not being the first to try a novel but at the same time not staying at the end, and when they see enough benefit in that innovation, they adopt it (Rogers 1983). The Late Majority (Conservatives, Sceptical) group, which has a very close character to Early Majority, but is more doubtful, adopt it if the intense pressure of their peers or the oppressive atmosphere in the society occurs (Moore 2009). Laggards (Traditionalists, Sceptics), the last group, prefer to imitate the older generations when adopting innovation with their ultra-traditionalist structures. They have hardly any connections with society. They also have limited resources economically (Rudd and Simonds 2016).

Looking at their percentile in the whole social system, Innovators constitute the smallest minority with 3.5%. Early Adopters and Laggards groups, which perform opposite behaviours even though they have close rates, form one-third of the social system with 13.5% and 16%, respectively. The early and late majority groups, which make up two-thirds of the social system they are in, with 34% shares, are the groups that cause the adoption to exhibit the most accelerated behaviour and change the direction of the graph.

These four factors, which are explained in detail, are shown as factors that play an active role in the spread of innovation and determine the diffusion behaviours. Moreover, it also determines the formation moments of the above groups and how the graphs are formed.

2.2. Modelling the Diffusion of Innovation

Questioning the effects of these four fundamental factors, coupled with many intermediate factors, on how an innovation is adopted by a particular part of a social system is the underlying phenomenon of Rogers (1983) Innovation Diffusion Theory. Since the time that Innovation Diffusion began to be discussed, different working approaches have been taken to understand the effects of those factors on the possible adopters who is/are a part of the social system (Rogers 1983).

In this context, Influence Models, which aims to calculate the pace and behaviours of innovation adoption over space or time, come to the fore (Mahajan, Muller, and Bass 1990). While trying to understand the diffusion of innovation and the behaviours in the process, using Influence Models provides convenience and benefits in many ways (Goldenberg and Libai 2001). First, Influence models effortlessly conceptualize the social system and make the interactions and behaviours meaningful straightforwardly and understandably. Second, the Influence Models are relatively inexpensive and effortless, yet fed by a theory based on a very strong and well-established foundation. Our last item, the third, is that it can be used by the steering committees or managers both for a wide range of innovations and for social systems and components with very different features with its high adaptability.

2.2.1. Influence Models

The decade covering the 1960s is regarded as a period in which an unbelievable density was experienced, and the foundations were laid for the emergence of Influence Models (Fourt and Woodlock 1960, Mansfield 1961, Chow 1967, Coleman, Katz, and Menzel 1967, Bass 1969). Since those years, Innovation Diffusion research has been mostly done on the changes made on the models and providing flexibility for adapting the models to different contexts (Meade and Islam 2006).

A common point reached by these studies on Influence Models since the 1960s is that the process of embracing innovation over time follows an S-shaped graph (Mahajan, Muller, and Bass 1990, Mahajan and Peterson 1979, Meade and Islam 2006). This S curve consists of 3 primary parts;

- Inception and enforcement,

- Diffusion period,
- Repletion phase.

From Figure 3 below, it is understood how the cumulative diffusion of an innovation is transferred to the S curve consisting of these three stages. During the formation of this S curve, it can be observed which group of the social system contributed to what period.

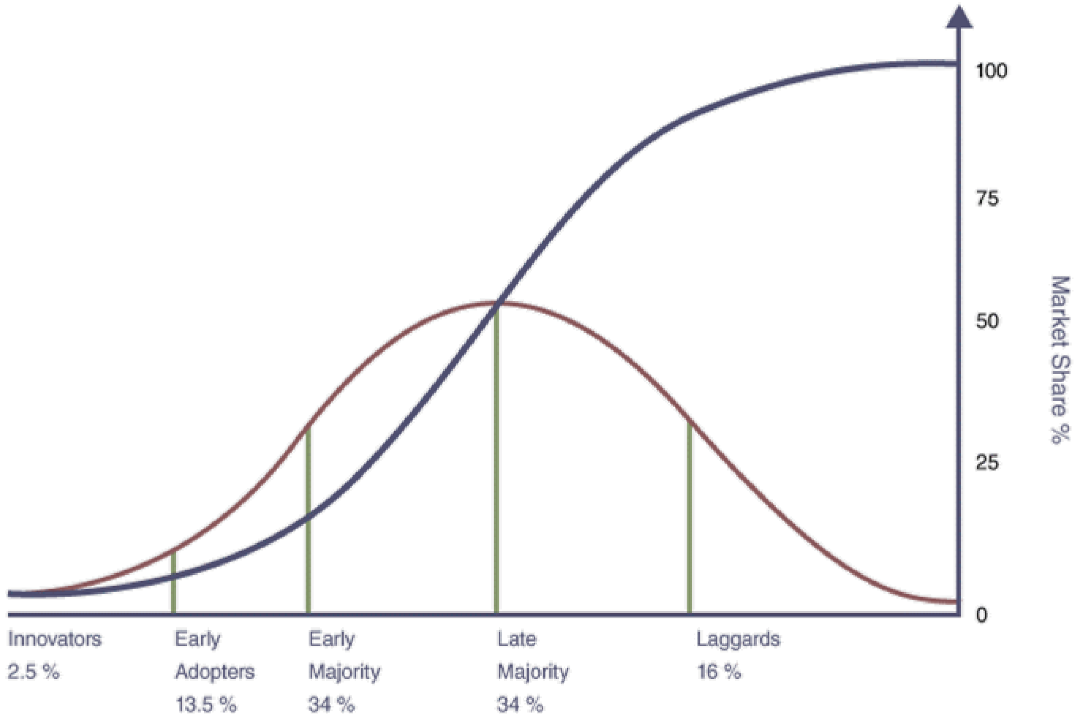

Figure 3. The S Curve Graph of the Cumulative Adoption of an Innovation
(Source: Rogers 1983)

For different S curves of various innovations, a few of the eight distinct Influence modelling methods (Bass, Cumulative Lognormal, Cumulative Normal, Gompertz, Log Reciprocal, Logistic, Modified Exponential, Weibull) have been featured and preferred more (Meade and Islam 2006, Teng, Grover, and Guttler 2002). The diffusion ratio is proportional to the number of possible adopters at the moment T, which is seen as the common spot of these models. The most known and frequently used models among them;

- Internal Influence Model (Mansfield 1961)
- External Influence Model (Coleman, Katz, and Menzel 1967)
- Mixed Influence Model (Bass 1969)

2.2.1.1. Internal Influence Model

The Internal Influence Model is built on the hypothesis that adaptation of innovation is possible only with agents' interactions within a social system. This attitudes and interactions style is called Imitative Behaviour (Mansfield 1961). Abrahamson and Rosenkopf (1993) argue that there are two underlying theories in the realization of this act of imitation during the diffusion of an innovation. These are;

- Rational Efficiency Theory
- Fad Theories (Bandwagon Proposals) (Abrahamson 1991)

Supporters and advocates of the Rational Efficiency hypothesis emphasize that innovation must have an advantage in return for that effort or investment adopted by the relevant industry. This theory highlights that behind the adoption of innovation in the relevant sector, the companies rationally examine the benefits (productivity, profitability resulting from this efficiency, increase in market share) of that innovation and act with that expectation (Farrell and Saloner 1985, Katz and Shapiro 1985). As a result of this, the increase in the number of companies adopting the innovation implicitly leads to an increase and spread of knowledge about the advantages and returns of that innovation. Farrell and Saloner (1985) and Katz and Shapiro (1985) argue that as a natural result of this increase in knowledge and spread, innovation is also adopted by companies that have not yet adopted it.

Fad theory, otherwise, argues that there are two primary stages (Early Stage, Late Stage) of diffusion, and contrary to rational efficiency theory, there can be intense adoptions even in the early stage of innovation diffusion before the benefits of this innovation are yet known. The concept of bandwagon pressure is used to explain this situation (Abrahamson and Rosenkopf 1993). According to this concept, if too many companies adopt or reject an innovation within an industry, it puts pressure on the rest of the companies. Behind this pressure, instead of questioning why so many companies have adopted it, lies the answer to the question of which companies and how many of them in total have adopted this innovation (Abrahamson and Rosenkopf 1993, DiMaggio and Powell 1983). It is argued that there are two primary bandwagon effects. These are;

- Institutional Bandwagon,
- Competitive Bandwagon.

Institutional Bandwagon Pressure corresponds to the concern of companies losing their legitimacy and withdrawing the support of their base stakeholders. This status is explained by the fact that too many companies in an industry adopt an innovation, causing those who do not adopt it to look abnormal or unjustified. Otherwise, the fear of a company losing its competitive power and advantage due to not embracing innovation is defined as a Competitive Bandwagon (Abrahamson and Rosenkopf 1993).

The Internal Influence Model, which argues that propagation occurs only as a result of the interaction of agents in the social system, can be expressed as the following equation 1:

$$\frac{dN(t)}{dt} = qN(t)[m - N(t)] \tag{1}$$

where

$N(t) =$ Cumulative number of adoptions of innovation at time t,
$m =$ All potential adopters within a social system,
$q =$ The coefficient of Imitation (Internal Influence),
$dN(t)/dt\ =$ Diffusion rate at time t.

In this equation, q and m are supposed to be positive ($q \geq 0, m \geq 0$). The integration of the equation (1) provides the Logistic Curve, which gives the cumulative adoption function (Teng, Grover, and Guttler 2002):

$$N(t) = \frac{1}{\frac{1}{m} + c\exp(-bt)} \tag{2}$$

One of the very similar functions to the logistic curve is the Gompertz Function (Gompertz 1825). It is based on the idea that the adoption rate is a logarithmic function of the number of potential adopters:

$$\frac{dN(t)}{dt} = qN(t)\big[\ln(m) - \ln\big(N(t)\big)\big] \tag{3}$$

The distribution of the cumulative number of agents that are adopting the innovation of this model is (Mahajan and Peterson 1985):

$$N(t) = m \exp(-c \exp(-qt)) \tag{4}$$

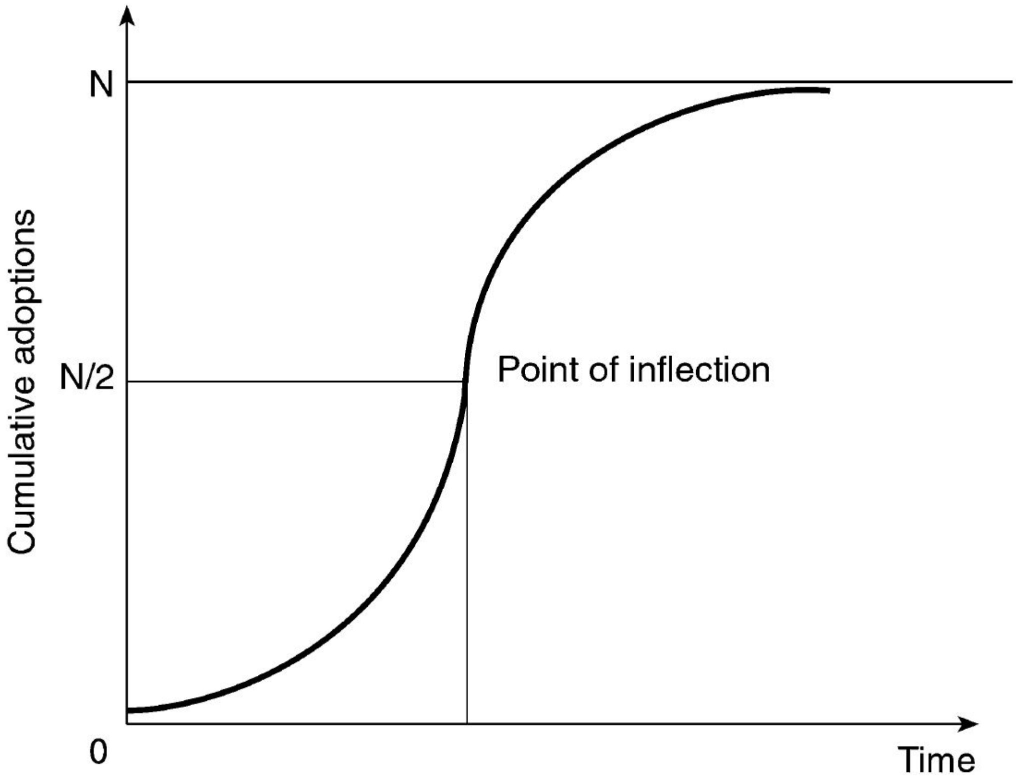

Figure 4. The diffusion Curve of the Internal Influence Model

The Logistics curve breaks symmetrically from the inflexion point, where the highest growth ratio of adopters occurs, in the middle of the total adoption number, as in Figure 4 (Mansfield 1961). On the other hand, Gompertz (1825) Curve breaks unsymmetrical from the inflexion point located at 37% of the cumulative adoption. This situation is accepted as the most fundamental and significant difference between these two internal models.

The External Influence Model (Coleman, Katz, and Menzel 1967), which claims opposite to the hypothesis that the adoption discussed in the Internal Influence model occurs only as a result of the interaction of agents within a social system, explains this spread in another way.

2.2.1.2. External Influence Model

Contrary to the Internal Influence Model, the External Influence Model assumes no interaction between agents in a social system. Parallel to this idea, the External Diffusion Model argues that the diffusion of innovation proceeds only through standard communication tools (Mass Media) outside the social system (Coleman, Katz, and Menzel 1967). Therefore, this model claims that behind the diffusion ratio at any possible time t is a simple imitation process.

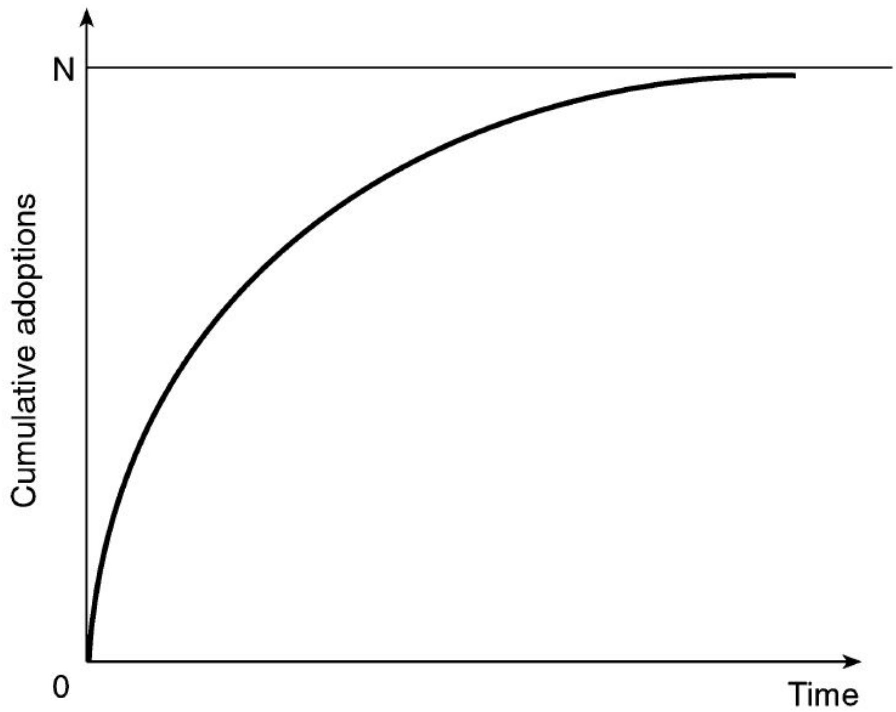

Figure 5. The Diffusion Curve of External Influence Model

This model contends that adopting innovation as a hypothesis is neither for rational efficiency nor for bandwagon suggestions, but mainly because of impositions (changes in the legislation, consultation company advice, customer, and stakeholder demand) outside the social system. The External Influence Model can be shown as in the following equation 5:

$$\frac{dN(t)}{dt} = p[m - N(t)] \tag{5}$$

where p is the external influence coefficient and p is supposed to be positive ($p \geq 0$). Cumulative adoption function over time is obtained by integrating equation 5 (Mahajan and Peterson 1985):

$$N(t) = m[1 - \exp(-pt)] \tag{6}$$

The external Influence model, which creates a concave graph with a negative exponent, expresses that innovation is adopted with a gradually decreasing acceleration. This statement describes itself quite simply in Figure 5.

2.2.1.3. Mixed Influence Model

After the introduced Internal and External Influence models, at the end of the 60s, Bass (1969) stated that behaviours from both models were included in the adoption of an innovation and presented the Mixed Influence Model. According to this model, both the interaction of the agents in that social system and the effects outside the system contribute to adopting an innovation. Therefore, in the equation of this model, both internal influence and external influence coefficients from the previous models find their place.

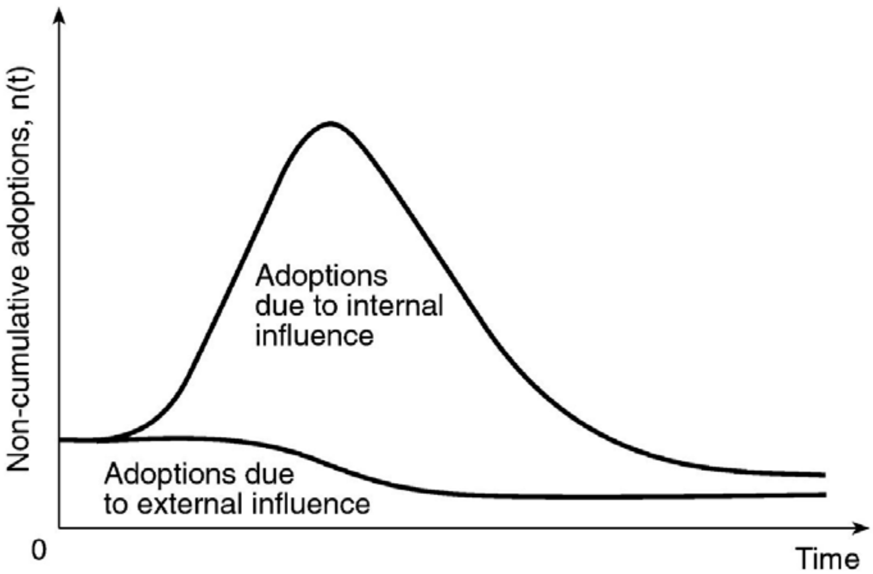

Figure 6. Change of Adoption Figures in Mixed Model with Time in Terms of Internal and External Influences

The Mixed Influence Model, which is nourished by both imitation behaviour and impact emerging from outside the social system, can be shown as follows:

$$\frac{dN(t)}{dt} = [p + qN(t)][m - N(t)] \tag{7}$$

The cumulative adopter function of this model can be generated by integrating equation 7 (Mahajan and Peterson 1985):

$$N(t) = m\left[\frac{1 - \exp(-(p+q)t)}{1 + \frac{q}{p}\exp(-(p+q)t)}\right] \tag{8}$$

As in the graphics of other models, the size of the coefficients q and p is effective in forming the representations of the Mixed Influence Model. The coefficient p refers to the innovation behaviour, and the coefficient q refers to the imitation behaviour in this model. The positioning of the reflection point of the graphic of this model takes place within the first 50% section.

With the aim of understanding the determinants of diffusion potential of long-lasting merchandises, groceries or software and hardware technologies; internal, external, and mixed influence models have been frequently employed in the marketing realm (Bewley and Fiebig 1988, Chow 1967, Fisher and Pry 1971, Fourt and Woodlock 1960, Kale and Arditi 2005, 2006, Sultan, Farley, and Lehmann 1990, Teng, Grover, and Guttler 2002).

The fact that these models fundamentally simplify the market dynamics and social systems and handle them in that way has been a fundamental reason for the experts in the field of marketing to prefer them. However, for a long time, by arguing that this simplification is superficial and that some market dynamics should be integrated into these models, change and transformation practices have been applied to those influence models.

2.2.2. Parameter Estimation in Diffusion Modelling

The Bass (Mixed Influence) Model is one of the most employed models to observe, understand and predict the adoption of innovation with its simplicity based on three different parameters. Therefore, for this model to serve its purpose, it is necessary to determine the m value, the market potential, the value a, the imitation (internal influence) coefficient, and the value b, the innovation (external influence) coefficient.

Especially in the 1980s, many different parameter estimation procedures were introduced into the literature. Sultan, Farley, and Lehmann (1990) determined that these predicted parameters were directly influenced by the selected estimation method, with their study on 15 previous research with 213 different applications. The amount of diffusion data available is the most decisive issue when deciding on the process to be selected among many options while estimating the parameter after innovation diffusion modelling. There are suitable parameter estimation methods for the existence or non-existence of diffusion data of previous time periods.

2.2.2.1. Parameter Estimation Methods in the Absence of Preliminary Data

For many professionals, it is preferable to try to model the diffusion of a product without sufficient knowledge of market behaviour. If there is under an adequate amount of data, according to Putsis (1996), dividing the small amount of available annual data into quarters and benefiting from that data gives better estimation results than yearly data. If not, either acting by using analogies or benefiting from management experience and decisions are among the options that can be made in the absence of data (Mahajan, Muller, and Bass 1990).

Mahajan and Sharma (1986) propose a process that involves three pieces of knowledge of executive experience, which are (1) the potential of the market (m), (2) the level of diffusion at the climax moment, and (3) the timing of this climax in the non-additive graph. Emphasizing that someone with this information can predict the coefficients of internal and external influence, Mahajan and Sharma (1986) were criticized by (Bass 1986) the same year, who stated that the purpose of doing diffusion modelling is to generate two of these data anyway, because the innovation diffusion modelling becomes meaningless.

Another method of estimating parameters without adequate data is to act on the logic of knowing the total value of the external and internal influence coefficients. At this point, an analogical point of view comes into play. Parameter estimation can be performed using the influence coefficients arising from the market dynamics of similar products and the algebraic assessment method proposed by Lawrence and Lawton (1981). Lawrence and Lawton (1981) arguing that by knowing three information as (1) the total value of the influence coefficients, (2) the total market potential, and (3) the number of adoptions in the first time period, diffusion modelling and estimation can be made. Therefore, along this line, Sultan, Farley, and Lehmann (1990) found that the external influence of these coefficients was averaged with a slight standard deviation of around 0.03, while the other internal influence coefficient was averaged around 0.38 with a more unbalanced and higher standard deviation as a result of their 213 applications. This leads to the conclusion that the coefficient sums are around 0.41. Lawrence and Lawton (1981), who put forward this parameter estimation method, conducted a study on this subject and claimed that the totals of these coefficients were around 0.66 for industrial products and 0.50 for consumer products. Again according to the same research (Lawrence and Lawton 1981), the first time frame adoption number (s_1) can be represented by the following equation 9:

$$\frac{m\left(1 - e^{-(q+p)}\right)}{\left[1 + \left(\frac{b}{a}\right) e^{-(q+p)}\right]} \tag{9}$$

and thus p/q equals:

$$\frac{\left[n\left(1 - e^{-(q+p)}\right) - S_1\right]}{s_1 e^{-(q+p)}} \tag{10}$$

In the light of these relationships, they argue to predict m and $s_1$and go from these equations to find the exact moment of highest adoption. Since the $q + p$ value is centred in the 0.5 bands as determined in the meta-analysis studies above (Lawrence and Lawton 1981, Sultan, Farley, and Lehmann 1990), estimating these parameters with this method gives beneficial results (Lawrence and Lawton 1981, 535).

2.2.2.2. Parameter Estimation Methods in the Existence of Preliminary Data

While discussing the Mixed Influence Model argued by Bass (1969), the parameter estimation of that model was made using the ordinary least square (OLS) method. As stated by this method, the detached or regression equivalent of the differential equation of the Mixed Influence Model yields:

$$N(t+1) - N(t) = pm + (q-p)N(t) - \frac{q}{m}N^2(t)$$
$$n(t+1) = \alpha_1 + \alpha_2 N_{(t)+\alpha_3} N^2(t) \tag{11}$$

where $\alpha_1 = pm$, $\alpha_2 = q - p$, and $\alpha_3 = -q \,/\, m$. Regression analysis is used to find those α_1, α_2, and α_3 which in the end, will be used to find the market potential (m) and the influence coefficients (q, p).

Nevertheless, Schmittlein and Mahajan (1982) observed that there are fundamental deficiencies in the OLS process. To come through those, they emphasized the maximum likelihood estimation (MLE) technique, which they believed is a better methodology. According to this study (Schmittlein and Mahajan 1982), the three most basic weaknesses of the OLS system are:

- Parameters are unsteady and can have incorrect signs
- The process does not ensure the assessed values' standard errors
- Time interval deviation

After a while, Srinivasan and Mason (1986) put forward a study that states that MLE only considers sampling errors and therefore neglects many different errors and emphasizes the need to use the non-linear least square (NLS) method deals with all these errors. This research found a close parameter prediction shot between NLS and MLE, but both were more effective than the OLS method (Srinivasan and Mason 1986). However, they argue that the NLS method obtains slightly better results in typical applications. While there was sufficient data available, the parameter estimation methods were methods in which the parameters were independent of time and always considered constant.

Sultan, Farley, and Lehmann (1990) included the Bayes procedure in the innovation diffusion literature with their study. They argued that the parameters could change over time and that this method gave a healthier result. This method involves creating updated parameter values by taking the weighted sum of the first estimates of the parameters and the estimates calculated from the innovation diffusion data. While doing this, this method can use any technique, such as the procedure used by Srinivasan and Mason (1986).

2.2.3. Improvements and Extensions of Diffusion Models

In this study presented here, it was previously stated that the Bass model allows an effortless examination of a social system and the whole of relations or interactions within it. In order to make this complex social system, which is influenced by many factors and has many parameters, so simple, it acts on many assumptions. These assumptions of the Bass (1969) model started to be seen as deficiencies or weaknesses by other scholars in the field and to develop solutions for this (Mahajan, Muller, and Bass 1990).

The first and the most fundamental of these is the acceptance that the market capacity of the innovation (m) remains constant throughout diffusion. Instead, many different research studies deemed it appropriate to define the market potential as a function of the product price (Chow 1967), increase in the number of the family unit (Mahajan and Peterson 1978), population expansion (Sharif and Ramanathan 1981), the profitability of innovation, and increased number of dealers (Jones and Ritz 1991) and model it over it. As one of the researchers who approached with this perspective, Kalish (1985) modelled the market potential ($m(t)$) as a function of the price of innovation and reduced uncertainty as in the following equation 12, recognizing that the awareness of the adopters is at the highest point:

$$m(t) = m_0 \exp\left[-dP(t)\left(\frac{e+1}{e+\frac{N(t)}{m_o}}\right)\right] \qquad (12)$$

where m_0 is the probable adoption at the entry to the market, and moreover d and e are constants.

The second of these assumptions is that the premise of innovation does not affect its market share performance. However, especially technological innovations are updated and introduced on an annual basis and can be preferred intensely due to the success of its previous equivalent. Norton and Bass (1987) created two basic equations that model the agents' interactions effect and replacement effect for the diffusion of sequential innovations, and in these equations, they assumed the value of τ_2 as the time when the second generation was identified:

$$S_1(t) = m_1 F_1(t) - m_1 F_1(t) F_2(t - \tau_2) \tag{13}$$

$$S_2(t) = m_2 F_2(t - T_2) + m_1 F_2(t) F_2(t - \tau_2) \tag{14}$$

where equation 13 refers to the first launched innovation, and equation 14 is for the second generation. The second parts of both equations represent the acceleration or deceleration effect.

Another superficializing assumption of the Bass model is that it looks at the diffusion of innovation only from the time perspective. In fact, Mahajan and Peterson (1979) conducted a study in the agricultural sector of the United States for innovation diffusion modelling logic, which cannot be independent of both time and space. For this, Mahajan and Peterson (1979), who studied the diffusion of tractors in 25 different states in the United States over 40 years, argue that this innovation was introduced in a central state and that an inversely proportional relationship was established with the distance to that state with the adoption rates of others.

Advertising, depicting the final value of the invention, campaigns, and other marketing policies, directly relates and affects innovation diffusion. Especially after the innovative work of Robinson and Lakhani (1975), intensive work has been done on including this parameter in the calculation of the model. Jones and Ritz (1991) 's research on supply growth and the work on characterizing the selling capacity as a function of the price of Kalish (1985) can be counted as instances. Although the studies done for this effort are theoretically promising, they suffer from a lack of empirical sampling and reinforcement.

Bass (1969)'s Mixed Influence model, which generalizes the characteristics of the market and the product and does not include them directly in its calculations, was seen as a deficiency by the peers. Because with many empirical studies, the effect of market and product characteristics on the diffusion of innovation was clearly seen. It was tried to be developed in this aspect after a while, and these parameters were also attempted to be included in the model (Rogers 1983). Two studies attempting to describe market or product characteristics as a function of internal or external influence coefficients argue that these coefficients change due to changes in characteristics over time. Gatignon, Eliashberg, and Robertson (1989) investigate the influence of market characteristics on the cross-national diffusion of innovation. On the other hand, Kalish and Lilien (1986) are the only studies that examine the consumer point of view that perceives the change in product characteristics and reflects this change to their calculations.

2.3. Cross-Regional Innovation Diffusion Modelling

Rogers (1983) stated that diffusion is the procedure by which an invention is transmitted via several ways over time between participants of a communal organisation. However, cross-regional innovation diffusion, a relatively new concept, has begun to be discussed with the globalizing world. This concept argues that there is an innovation diffusion within a social system and that there are interactions between these social systems at the upper and regional scales. Many studies examining the international behaviour of innovation diffusion have agreed on several common primary findings (Helsen, Jedidi, and DeSarbo 1993, Ganesh and Kumar 1996, Ganesh, Kumar, and Subramaniam 1997, Kumar, Ganesh, and Echambadi 1998, Kumar and Krishnan 2002, Michalakelis et al. 2008, Kumar, Sunder, and Ramaseshan 2011, Duan et al. 2018).

Cross-regional diffusion studies are fundamentally altered with two different points of view. The first perspective expects researchers to examine innovation diffusion behaviour in two other regions and focus on understanding the social and cultural reasons behind the differences that have occurred between adoption rates (Gatignon, Eliashberg, and Robertson 1989, Takada and Jain 1991, Helsen, Jedidi, and DeSarbo 1993, Kumar, Ganesh, and Echambadi 1998).

The second perspective approaches with a more explicit logic and defends that the effect arising from the introduction of innovation in two countries at different times is the most determining factor and constructs the diffusion model accordingly. On the other hand, the four expectations of Rogers that quicken the diffusion process in the case of knowing them which are (1) benefit of the innovation, (2) relevance with the expectation of the potential adopters, (3) testability, and (4) observability of a product can be experienced, and the uncertainties are reduced in time. Accordingly, the fact that innovation was introduced before in one of the two countries argues that the country that follows behind learns those four elements from the first country adoptions thanks to this time difference (Eliashberg and Helsen 1995, Kalish, Mahajan, and Muller 1995). This situation is called the lead-lag effect, or in other words, the learning effect. Ganesh, Kumar, and Subramaniam (1997) studied what caused this effect and found some hot points and relationships.

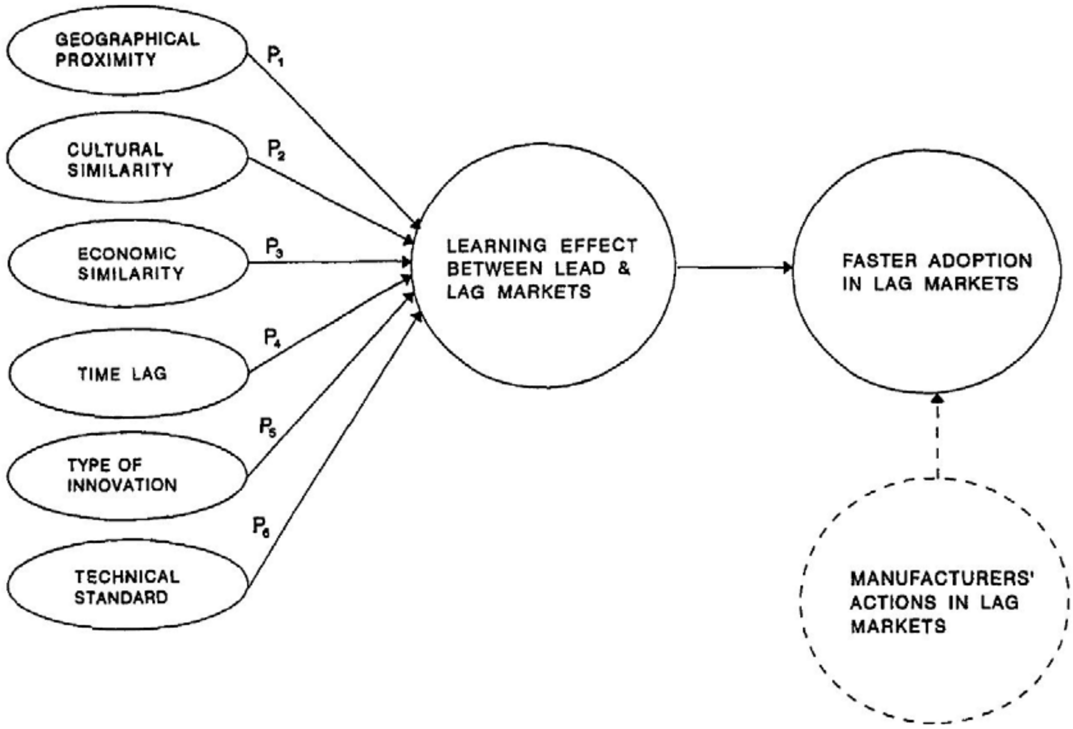

Figure 7. Concepts Affecting the Learning Process
(Source: Ganesh, Kumar, and Subramaniam 1997)

According to this study, as the closeness and similarities increase, the learning effect also gets more robust. The less the distance between the lead and lag country, cultural difference, and economic difference, the stronger the learning effect becomes. On the other hand, the increase in time difference affects learning positively. All of these situations seem even more potent in continuous innovation rather than discontinuous ones. If an overall technological standard has been established and implemented in the industry, it supports the learning effect to be further strengthened.

Putsis et al. (1997), who calculate the simultaneous interaction of two different social systems by going beyond these two main approaches, carry out this examination with a model they define as the mixing model. However, a significant handicap of this model is that innovation should be introduced simultaneously in both countries. They called this form of interaction the simultaneous effect.

In the light of these essential research studies in this field, cross-regional diffusion behaviours can be summarized with the following three items:

- Due to its occurrence within a defined social system, innovation diffusion, which is directly dependent on the cultural characteristics of that system, is affected by its parameters such as cosmopolitanism, mobility and sex roles in the labour force (Gatignon, Eliashberg, and Robertson 1989).
- Since they can observe Rogers (1983)' expectations for adoption and get satisfactory answers due to the time gap, the later innovation is introduced to one market than another, the faster it is adopted compared to the first region. This situation is called the learning effect or lead-lag effect (Takada and Jain 1991).
- Country segments bonded on the diffusion factors vary according to the spirit of the innovation and are not fixed. At the same time, these segments do not comply with the segments derived from traditional analysis with cross-regional macro-level data (Helsen, Jedidi, and DeSarbo 1993).

There are two elements in the formation of these interactions between social systems. These are named weak ties and signals (Kumar, Sunder, and Ramaseshan 2011). Weak ties are the concept that emerges from the direct interaction of agents in these different social systems. The firm's interactions in one market with a different firm in another market at any level can be given as an example. The second, Signals, can be defined as the message or perceptions that emerge from the entire social system. The best example of this can be given as the rate and pattern of innovation adoption observed by the other country. Although there are two different types of effects in theoretical terms, the lack of a model that can make this distinction yet can be seen as an essential point for future research.

Another benefit of studying cross-regional innovation diffusion is using this information as managers shape their entry strategies into different markets. This field, which can answer the question of whether it would be more advantageous for a company to announce the innovation it introduces to many different markets simultaneously (Sprinkler strategy) or to present it in consecutive time intervals (Waterfall strategy), makes a significant contribution to global working companies (Kalish, Mahajan, and Muller 1995).

The form that the Bass model takes in terms of including the learning effect (Kumar, Sunder, and Ramaseshan 2011):

$$\frac{\partial F_i(t)}{\partial_t} = \left[pi + q_i F_i(t) + cF_j(t)\right] \times [1 - F_i(t)] \tag{15}$$

where

$F_j(t)$ = Diffusion rate of the j region,

c = Learning coefficient between the region i and j,

p_i = The coefficient of Innovation (External Influence),

q_i = The coefficient of Imitation (Internal Influence),

i = Lag region, and

j = Lead region.

This equation is used to describe and explain the innovation diffusion plot of the Lag region. As it is understood, it is possible to talk about an effect proportional to the multiplication of the diffusion rate at time t in the other country and the learning effect in between them. The coefficient c which refers to the learning effect has been reported to be in the range of 0.006 - 0.014 (Kumar, Sunder, and Ramaseshan 2011), 0.00013 – 0.02556 (Michalakelis et al. 2008) and 0.002 – 0.009 (Kumar and Krishnan 2002). As can be understood from the closeness of the result coefficients obtained by these studies, it is possible to observe the learning effects with macro models.

CHAPTER 3

A CONCEPTUAL FRAMEWORK FOR THE EVOLUTION OF GBCSs

This chapter, which is covering three sub-categories, begins with an explanation of the concept of sustainability. It clarifies the emergence process of this concept and its different definition forms. In the second section, the notion of green building is explained by focusing on how sustainability is transferred to the construction industry and how it is interpreted there. Therefore, the occurrence of sustainable construction and how it is perceived is described in detail. The final part explains the point that GBCSs, whose international diffusion dynamics are to be examined in the following chapters, have reached since their emergence, including their diversity, content, and usage style with a comprehensive scan.

3.1. The Concept of Sustainability

The industrial revolution is an essential factor that defines today's life and cities in many respects. The most vital of these impacts is the unlimited and ever-increasing production and consumption cycle it brings to society. To explain this situation with data, although the population has increased many times, our rate of raw material consumption per capita has increased 4-8 times compared to the pre-revolutionary period (Sustainable Europe Research Institute 2009). Nowadays, the numerical equivalent of the consumption amount is 60 billion tons per year. This endless energy and resource consumption and the accompanying waste production of humanity is an obvious situation that can be observed for many years.

Oil, which was used as the primary energy source by the world's leading countries after the Second World War, created a global crisis with the embargo that followed in 20 years when it was consumed more than its production. Both environmental, economic, and social repercussions of this consumption and predicament have been experienced very painfully. With this crisis, life comes to a standstill; the disruption of transportation, production, and related activities was observed worryingly, and social systems started searching for solutions.

In the 1970s, the concept of sustainability started to be discussed to prevent all these streams of events from happening again (Meadows 1972). After a while, the United Nations Environment Program (UNEP) was founded. A couple of years later, in a UNEP congress where the meaning and scope of sustainability were debated, it was emphasized that forthcoming generations should be considered and long-term preparation should be made (Cocoyoc Declaration 1975). However, it can be accepted that the "Our Common Future" report published in 1987 was the beginning of the sustainability concept (World Commission on Environment and Development 1987). In this report, published by a team known as the Brundtland Commission, sustainability is defined as follows: *"sustainable development is the development which meets the needs of the present without compromising the ability of future generation to meet their own needs."*. The fact that this definition is inclusive and generally legitimate is the main reason why it is accepted as a milestone.

As it can be understood from the inclusiveness of this definition, the concept of sustainability remained as a vague area as it started where dozens of different descriptions can be made, and people interested in the field resisted not coming up with a widespread definition (Hopwood, Mellor, and O'Brien 2005, Robert, Parris, and Leiserowitz 2005). The following items are among the main reasons for this situation;

- Temporality (time dependency),
- Multiple levels of the associated time and space scale (locality),
- Social aspect and connection.

Answering the question of how much further into the future should it be evaluated is crucial for assessing the degree of sustainability because of the term’s temporal aspect. Hence, the life expectancy of a unit, system, raw material or living thing increases in direct proportion to its size and quantity together with its renewal rate. Therefore, it should not be forgotten that the expected amounts of sustainability are directly related to the qualitative and quantitative characteristics of the subject (Costanza and Patten 1995). As shown in Figure 8, emphasizing that this is a complex issue, Costanza and Patten (1995) tried to explain the situation with a humble graphic. The locality is another notion to which this concept is effectively connected (Brand and Karvonen 2007). It is impossible to measure the sustainability of many subjects regardless of their context. Temporality and locality both have multiple-scale interconnections to consider and understand.

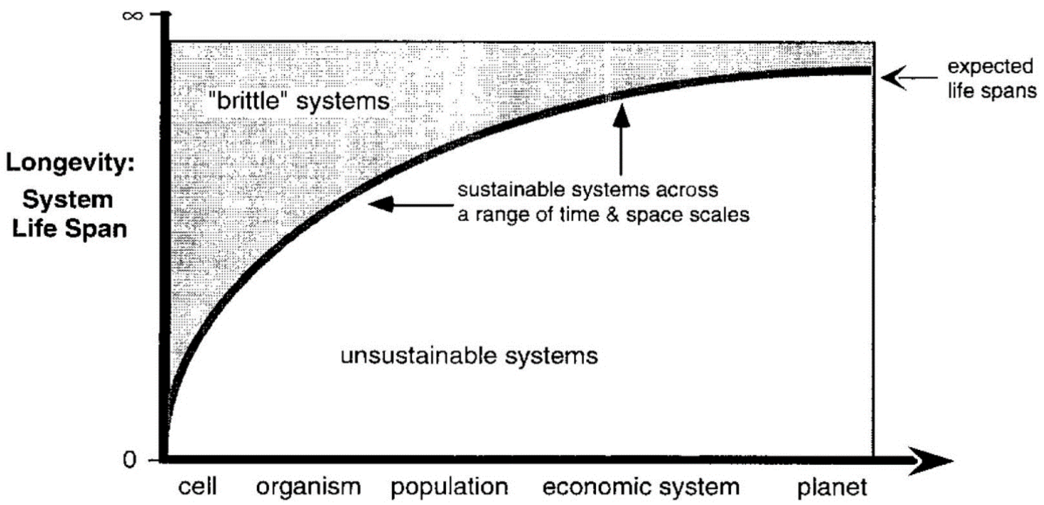

Figure 8. Scale Dependency of Sustainability
(Source: Costanza and Patten 1995)

As described in the World Commission of Environment and Development (1987) report, sustainability has been branched into three sub-categories: economic, ecologic, and social. Even though the dominancy of the environmental aspect is apparent, neglecting the social and financial part of the concept since it is in direct interaction with the society and human life will cause the process not to be fully realized (Robert, Parris, and Leiserowitz 2005).

The concept of sustainability, which is a matter of discussion that keeps up to date with 272% growth in the research papers in the first decade of the 21st century, still hosts many different ideas and understandings in terms of the interpretation of the main pillars used in its content and definition (Buter and Van Raan 2013). As an example of one of these, a theory that thinks that one of the pillars of sustainability is institutionalism and that it plays a fundamental role in its adoption and dissemination can be shown (Spangenberg 2002). However, in recent years, there has been a tendency towards strengthening and emphasizing the economic and social pillars of sustainability rather than the environmentalist approach (Berardi 2013).

Considering the tremendous impact of the construction industry on the sustainability of our planet with its high energy and resource consumption statistics, a majority have believed that a world consisting of much healthier cycles is possible with the improvements and innovations made within this industry. With this righteous way of thinking, the first seeds of the sustainable construction industry have been planted.

3.2. The Evolution of Sustainable Construction and Green Building

Sustainable development, which surfaced in the 1970s and was heavily discussed, gave way to the emergence and discussion of concepts such as sustainable construction, green building and building performance in the 1990s. Fundamental changes and transformations were inevitable for the construction industry, which is on the agenda due to its adverse effects on nature and its environment, excessive consumption of natural resources and energy, and the resulting unacceptable amount of waste and greenhouse gases. At that time, nobody predicted that this change movement of the industry, which cannot escape from radical change due to its negative impact on nature and nature's sustainability, will become a part of the industry today and turn into a permanent culture (Ding 2008).

The process of dealing with the planning, design, utilization, and reuse or demolition of buildings in accordance with the pillars of sustainability has been initiated so that the built environment interacts harmoniously with its surroundings, consumes less energy, give humans healthy spaces to live and is more in peace with nature (Kibert and Knovel 2008). Due to this process and handling, the structures formed are called green building, high-performance building, holistic designed building, or sustainable building in many different sources (Robichaud and Anantatmula 2011).

As in sustainability, many different ideas have emerged in the definition of green or sustainable building. It was evident that these definitions, some of which are included in Table 1, have common points. The purpose of a green building that can be deduced from these points is (Xiaoping, Huimin, and Qiming 2009);

- Supporting sustainability and minimizing or reducing harmful effects on nature, non-renewable energy sources and the ecosystem.
- To maximize the physical and mental health and indirectly productivity of those living in and around it.
- To create value for society, ensure the continuity of the economic cycles, and develop financial payback to its manufacturer.

In line with these purposes, during the communication of the producers with end-user customers, there was a need for a tool that could explain the sustainable features and robust performance of this product. This tool should also determine the degree of performance and sustainability of the building. In precisely this direction, Building Sustainability Assessment Tools (BSASs) formations have been observed.

Table 1. Several Definitions of Green Building (Robichaud and Anantatmula 2011)

Term	Definition	Quoted Source
Sustainable design	A design philosophy that seeks to maximize the quality of the built environment, while minimizing or eliminating negative impacts to the natural environment.	McLennan _2004_, The Philosophy of Sustainable Design
Green buildings	Buildings that are designed, constructed, and operated to boost environmental, economic, health, and productivity performance over conventional building.	U.S. Green Building Council _2003_, Building momentum
Green building	The careful design, construction, operation, and reuse or removal of the built environment in an environmentally, energy-efficient, and sustainable manner; may be used interchangeably with high performance building, green construction, whole building design, sustainable building, and sustainable design.	McGraw-Hill Construction _2006_, Green building smart market report
Green building	The practice of 1 increasing the efficiency with which buildings and their sites use energy, water, and materials and _2_ reducing impacts on human health and the environment through better siting, design, construction, operation, maintenance, and removal—the complete building life cycle.	Cassidy 2003 , quoting the Office of the Federal Environmental Executive White Paper on Sustainability
Green building	The process of building that incorporates environmental considerations into every phase of the homebuilding process. That means that during the design, construction, and operation of a home, energy and water efficiency, lot development, resource-efficient building design and materials, indoor environmental quality, homeowner maintenance, and the home's overall impact on the environment are all taken into account.	National Association of Homebuilders _2006_, Model green homebuilding guidelines
Sustainable construction	The goal of sustainable construction is to create and operate a healthy built environment based on resource efficiency and ecological design with an emphasis on seven core principles across the building's life cycle: reducing resource consumption, reusing resources, using recyclable resources, protecting nature, eliminating toxics, applying life cycle costing, and focusing on quality.	Kibert 2005 , quoting the Conseil International du Batiment CIB , Sustainable Construction: Green Building Delivery and Design

Even if they seem to mean the same Green Building, High-Performance Building or Sustainable Building do not precisely correspond to the same. They differ sharply from each other, even though they seem to be with minor nuances. Reed, Krajinovic-Bilos, and Reed (2017) express the subtle differences that the definitions correspond to in enlightening visualisation methods like Figure 9 and Figure 10.

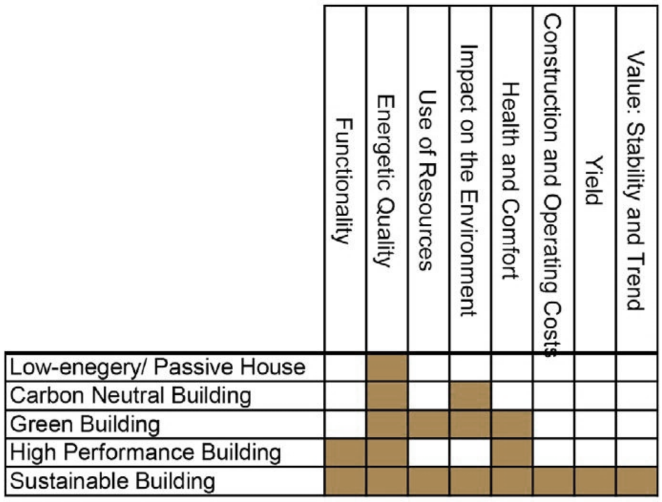

Figure 9. Features of Building Concepts
(Source: Reed, Krajinovic-Bilos, and Reed 2017)

As it can be deduced from Figure 9, the concept of Sustainable Building is more comprehensive than any others. On the other hand, apart from sustainable building, each defined model focused on different points. Overall, the energetic quality of the building is considered by all the concepts. Low Energy/Passive House pays attention to the energy consumption of the structure. On the other hand, Carbon Neutral Building focuses on the impact on the environment and energy consumption rates to reduce the carbon footprint of the buildings.

Furthermore, Green Building Concept is more comprehensive than those mentioned above by caring about the health and comfort of the users and the usage of the natural sources for the construction process. Moreover, High-Performance Building concentrates on the performative aspects of the structures like thermal, acoustic, and illuminance, which also directly affects the final-end users' health, comfort, and productivity. Finally, Sustainable Building is the most comprehensive concept by including the environmental pillar of sustainable development and the economic and social ones.

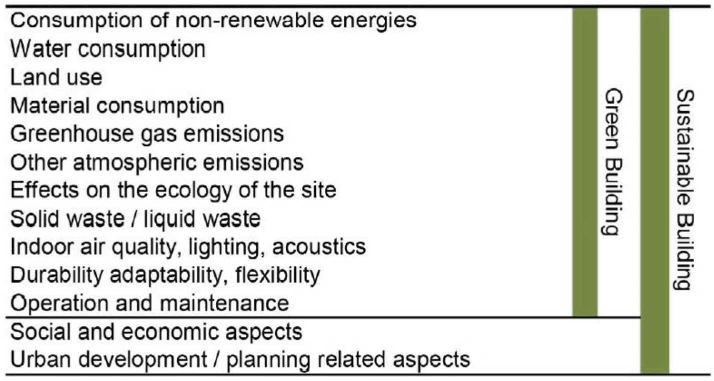

Figure 10. Comparison of the two Building Concepts
(Source: Reed, Krajinovic-Bilos, and Reed 2017)

It is clearly understood from Figure 10 that Green Building neglects social and economic sustainability while it deals with the subject with a more environmentalist approach. However, recently, the effect of implementing an application that appeals to all columns to ensure a healthy implementation of sustainability and to achieve successful results has been brought to the agenda (Ameen, Mourshed, and Li 2015).

BSASs have emerged to evaluate and measure these substances and transfer these values between the producer and the end consumer. Thus, the product developer has documented the qualitative and quantitative data of the structure and added value to the building. The end consumer makes the purchase process by knowing the performance criteria of the estate and considering the benefits it will provide in its use. These BSASs, which meet the needs of both parties, have been subjected to different interpretations over time, and therefore, evaluation tools with different perspectives have evolved.

Among these interpretations, GBCS is the most widely known evaluation tool. The following section includes a comprehensive explanation of GBCSs, which aim to evaluate the building from the perspective of the Green Building Concept.

3.3. Green Building Certification Systems (GBCSs)

It is possible to handle GBCSs, which is a type of BSASs, from many different aspects. Looking at the past studies related to GBCSs, points researched can be listed like (1) evaluation benchmarks used in rating and weighting, (2) incentives and handicaps for acquiring a GBC system, (3) the efficacy of a GBC system, (4) comparison of numerous GBC systems, and (5) systematic reviews of the research and studies. In this section, a comprehensive review of these studies has been made.

3.3.1. The Emergence and Development of GBCSs

In the 1990s, the debates on the construction industry to be more environmentally friendly and sustainable raised the problems of what the criteria were and how to measure it. To address these concerns, different reactions of various countries occurred. These include broadening and improving the scope of building codes or establishing organizations to answer these questions (Ade and Rehm 2019b). Affiliated with the World Green Building Council, these organizations called GBCs aim to define sustainability standards in their region and produce solutions to measure them. Green Building Rating Tools (GBRTs), or GBCSs as they are known, are the leading suggestions for these solutions by those GBCs (Lazar and Chithra 2020).

There are over ninety GBCs established in different countries (Reed, Krajinovic-Bilos, and Reed 2017). Sixty-nine of them are associated with WGBC, demonstrated in Figure 11 (World Green Building Council 2020). While there are 54 different GBCSs under those GBCs affiliated to WGBC (World Green Building Council 2021), it is known that there are more building assessment instruments worldwide (Nguyen and Altan 2011).

The history of such a large number of GBCSs and their affiliated GBCs is very recent. The pioneer of these systems with a history of only 30 years is the BREEAM certification tool introduced by Building Research Establishment (BRE) in 1990 (Ade and Rehm 2019a). BREEAM, which is as powerful as it is the first GBCS in history with a total of more than five hundred and fifty thousand certification numbers today (Doan et al. 2017), was followed by the French HQE (Haute Qualité Environnementale) system after 3-4 years. Subsequently, LEED, the most international GBCS serving in more than

Figure 11. GBCs Associated with WGBC
(Source: World Green Building Council 2020)

160 countries globally, was founded by the U.S Green Building Council (USGBC) (Vijayan and Kumar 2005). After the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), Japan's GBCS was established in 2001 and Green Star Australia in 2002; the first generation has completed its emergence (Reed et al. 2009). From the timeline in Figure 12, it is possible to follow the formation of this first generation. It then follows the updates and adaptations of the first generation with the second generation new GBCSs from 2005 onwards.

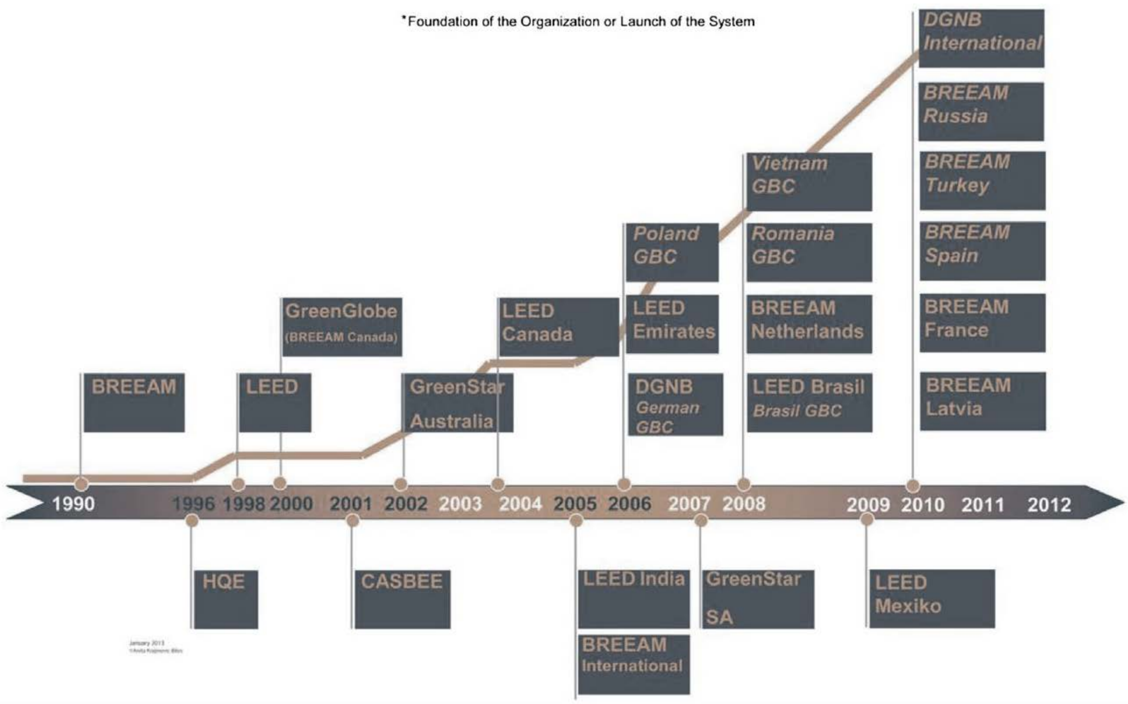

Figure 12. The Emergence Timeline of GBCSs
(Source: Reed, Krajinovic-Bilos, and Reed 2017)

3.3.1.1. BREEAM

At the beginning of the timeline, BREEAM, which started its operations as the first in its field, was established by the state institution BRE in 1990 and continued to serve, being privatized at the end of the same year. It creates its rules with rational and solid foundations, and it is a tool that all other GBCSs who follow it are affected (Doan et al. 2017).

BREEAM rapidly expanded by responding to the need in the European market with the BREEAM Global version launched in 2005 and became the world's top certification company over the years. More than 594,011 certifications, 2,313,475 registered buildings, and serves in 89 different countries is the numerical explanation of this situation (BREEAM 2021). It is possible to observe the change in the number of certifications over the years until 2012 from Figure 13.

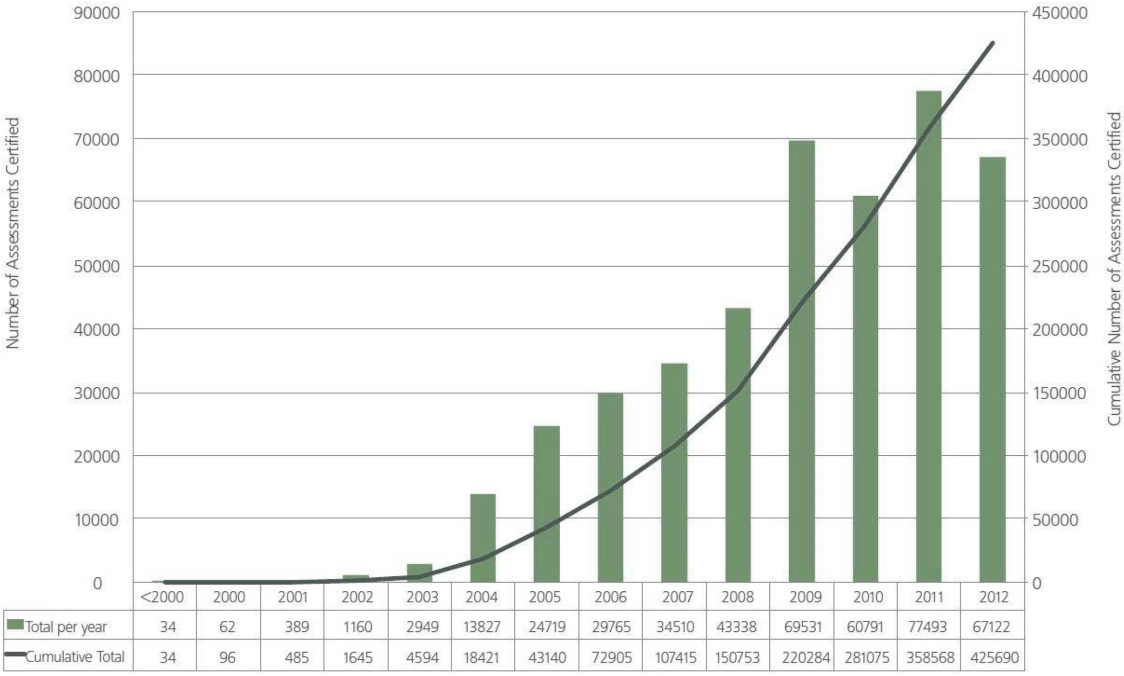

Figure 13. Number of Certifications by BREEAM between 1990 and 2012
(Source: BRE 2014)

When BREEAM weighting, which succeeds in addressing every aspect of sustainability, is involved, the environmental element becomes more prominent. It provides this versatility by examining a project with many different factors and sub-headings such as Management, Health and Wellbeing, Energy, Transport, Water, Materials, Waste, Land and Ecology, and Pollution (Mattoni et al. 2018). As a result of examining these items, the project is included in one of the following classifications: Pass, Good, Very Good, Excellent, and Outstanding (Gabe and Christensen 2019). BREEAM, which has undergone many updates and adaptations for different countries and regions, continues its certification services actively.

3.3.1.2. LEED

LEED is the last GBCS established before 2000 by the USGBC. Since it has a very transparent and understandable rating scheme and criteria, it always continues to be a candidate for being a rapidly adaptable and global system (Xiaoping, Huimin, and Qiming 2009). Moreover, compared to BREEAM, LEED, which has a certification number of only over 134000, is known to be the most widely used GBCS, as it achieves this number by serving in more than 160 different countries (LEED 2021b).

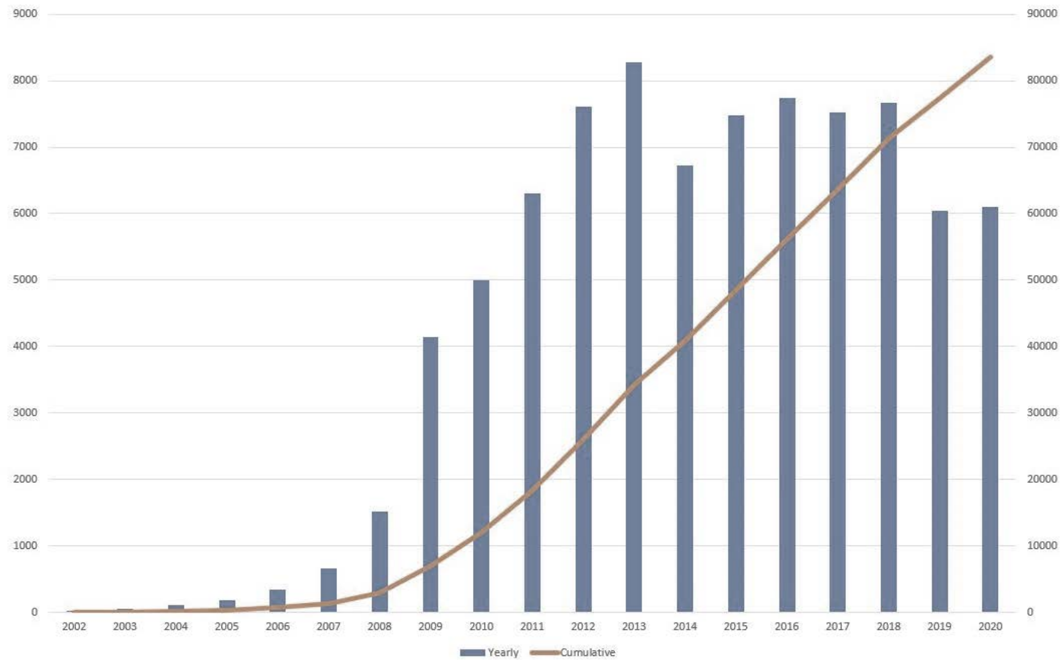

Figure 14. Number of Certifications by LEED between 2002 and 2020
(Source: LEED 2021b)

LEED allows grading in a wide range of buildings from project design and design stages to end-use performances and stands out from the others with this aspect. This system, which spread at a constant pace with LEED V4.1 that was launched in 2016, has undergone eight updates and changes in total until today and has always managed to renew itself in line with the needs and transformation of the sector and has maintained to be preferred. Accordingly, it divides the projects it examines into Platinum, Gold, Silver and Certified rating classes that it makes with the criteria like Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and

Atmosphere, Materials, and Indoor Environmental Quality (Mattoni et al. 2018). In addition, projects that can collect a total of 100 points with these parameters may receive a 10-point bonus with LEED's specific Innovation and Regional Priority parameters. These items, together with the extras, can be examined in detail in Figure 15 below. This approach, which encourages creativity and innovative solutions for sustainability, is one of the distinctive features of LEED (Mattoni et al. 2018).

0	0	0	**Location and Transportation**		**16**
			Credit	LEED for Neighborhood Development Location	16
			Credit	Sensitive Land Protection	1
			Credit	High Priority Site	2
			Credit	Surrounding Density and Diverse Uses	5
			Credit	Access to Quality Transit	5
			Credit	Bicycle Facilities	1
			Credit	Reduced Parking Footprint	1
			Credit	Electriv Vehicles	1
0	0	0	**Sustainable Sites**		**10**
Y			Prereq	Construction Activity Pollution Prevention	Required
			Credit	Site Assessment	1
			Credit	Protect or Restore Habitat	2
			Credit	Open Space	1
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
0	0	0	**Water Efficiency**		**11**
Y			Prereq	Outdoor Water Use Reduction	Required
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	2
			Credit	Water Metering	1
0	0	0	**Energy and Atmosphere**		**33**
Y			Prereq	Fundamental Commissioning and Verification	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Enhanced Commissioning	6
			Credit	Optimize Energy Performance	18
			Credit	Advanced Energy Metering	1
			Credit	Grid Harmonization	2
			Credit	Renewable Energy	5
			Credit	Enhanced Refrigerant Management	1
0	0	0	**Materials and Resources**		**13**
Y			Prereq	Storage and Collection of Recyclables	Required
Y			Prereq	Construction and Demolition Waste Management Plannir	Required
			Credit	Building Life-Cycle Impact Reduction	5
			Credit	Building Product Disclosure and Optimization - Environmental Product	2
			Credit	Building Product Disclosure and Optimization - Sourc	2
			Credit	Building Product Disclosure and Optimization - Mate:	2
			Credit	Construction and Demolition Waste Management	2
0	0	0	**Indoor Environmental Quality**		**16**
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Low-Emitting Materials	3
			Credit	Construction Indoor Air Quality Management Plan	1
			Credit	Indoor Air Quality Assessment	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight	3
			Credit	Quality Views	1
			Credit	Acoustic Performance	1
0	0	0	**Innovation**		**6**
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0	**Regional Priority**		**4**
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	0	0	**TOTALS**	Possible Points:	**110**

Certified: 40 to 49 points, **Silver:** 50 to 59 points, **Gold:** 60 to 79 points, **Platinum:** 80 to 110

Figure 15. LEED V4.1 Scoreboard
(Source: LEED 2021a)

3.3.1.3. CASBEE

Comprehensive Assessment System for Built Environment Efficiency (CASBEE) is another rating tool initiated in 2001 and based in Japan, another enthusiastic participant of the Green Building Industry. Japan Green Building Council (JaGBC) is the institution behind it (Xiaoping, Huimin, and Qiming 2009). This system, which could only exceed 500 certifications annually in 2015, can be considered at the beginning of the road compared to its peers (JSBC 2021).

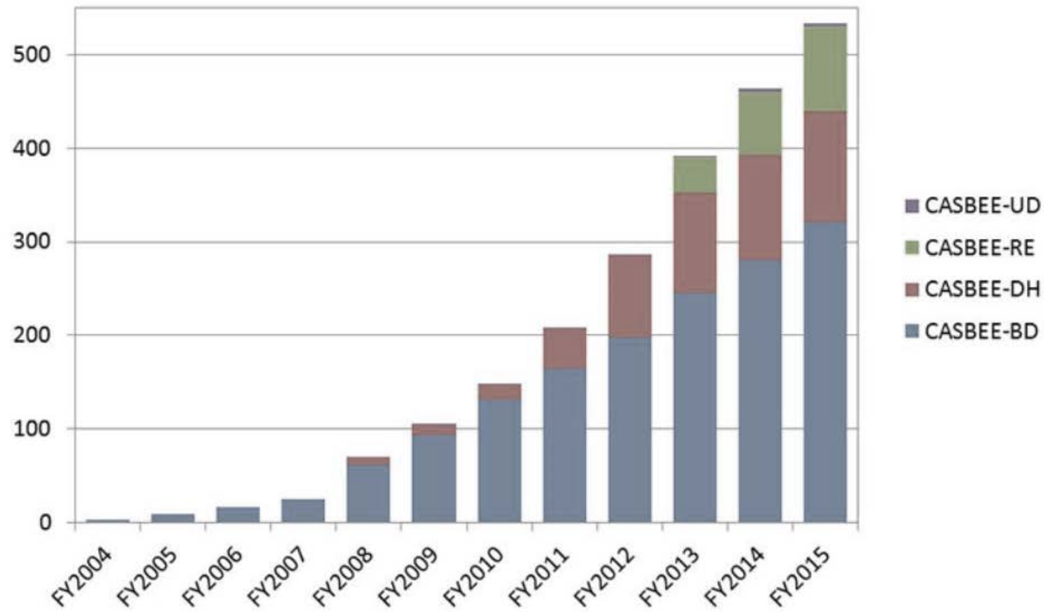

Figure 16. Number of Certifications by CASBEE between 2004 and 2015
(Source: JSBC 2021)

Unlike other GBCSs, CASBEE uses the Building Environmental Efficiency (BEE) ratio in its calculation method and calculates this ratio by dividing the building quality and performance over its loads on the environment. With the results obtained from this ratio, projects included in one of the Superior, Very Good, Good, Slightly Poor and Poor classes and are evaluated heavily in terms of the energy performance of the building (Mattoni et al. 2018).

To date, CASBEE has four basic options for different building typologies like Pre-Design, New Construction, Existing Building, and Renovation. Furthermore, some versions derived from these are available for less common intermediate typologies Temporary Construction, Heat Island, Home and Urban Development (Xiaoping, Huimin, and Qiming 2009).

3.3.1.4. Green Star

Green Building Council Australia (GBCA) is founded in 2002 to lead the green building movement in Australia after the Sydney Olympics became famous as the "Green Games". Closely following LEED and BREEAM, the organization planned to adopt one of them. Nevertheless, with a radical change of decision, GBCA formed its technical committee and created its own GBCS, known as the Green Star (Ade and Rehm 2019b). Although it lags far behind LEED and BREEAM with its certification numbers, Green Star, close to CASBEE, has not yet succeeded in exceeding 500 certificates per year. However, these numbers place it among the most preferred and known GBCSs (GBCA 2020).

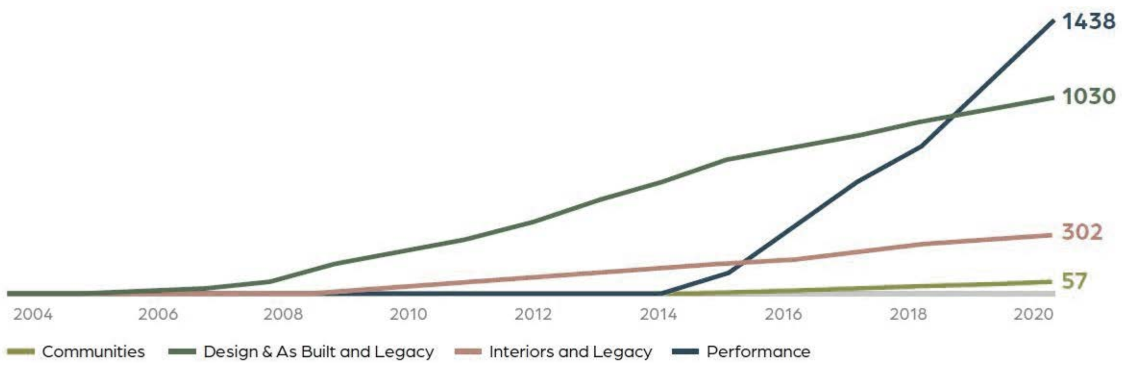

Figure 17. Cumulative Number of Certifications by Green Star between 2004 and 2020 (Source: GBCA 2020)

There are differentiated versions of Green Star that work with different criteria for four different categories. All of these have a common classification logic. Hence, Green Star, serving with a 100-point score table under eight different headings, classifies its projects with a 6-star rating. Minimum (1 Star), Average (2 Star), Good (3 Star), Best (4 Star), Australian Excellence (5 Star) and World Leadership (6 Star) classes are distributed over 100 points in different weights. Branches are spread over 100 in different weights. The first 44 points correspond to the lowest three levels, while Best Practice up to 59 points and the Australian Excellence up to 75 points, and then the last 25 points corresponding to the World Leadership category (Mattoni et al. 2018).

As can be understood from what has been explained so far, mainstream GBCS have strong common points as well as essential areas where they differ. The intensity of the studies on GBCS has been to compare and evaluate these differences and similarities.

3.3.2. Comparison of Mainstream GBCSs

The impact and importance of context in building performance are indisputable. As a result, context is of vital importance also in GBCSs that are essentially evaluating building performance (Awadh 2017, Shan and Hwang 2018). Therefore, each nation has tried to come up with its GBCS in pursuit of green structures that are compatible with the characteristics of their geography and can give the highest performance in that geography. This endeavour can happen with a completely new scheme, as in BREEAM, or sometimes by taking inspiration from pioneering GBCSs or adapting them, as seen in the Green Star example. In any case, there are a lot of GBCSs, from large to small.

GBCS, which has a common goal of obtaining a more sustainable building stock, assesses by giving different importance to different criteria in line with this purpose.

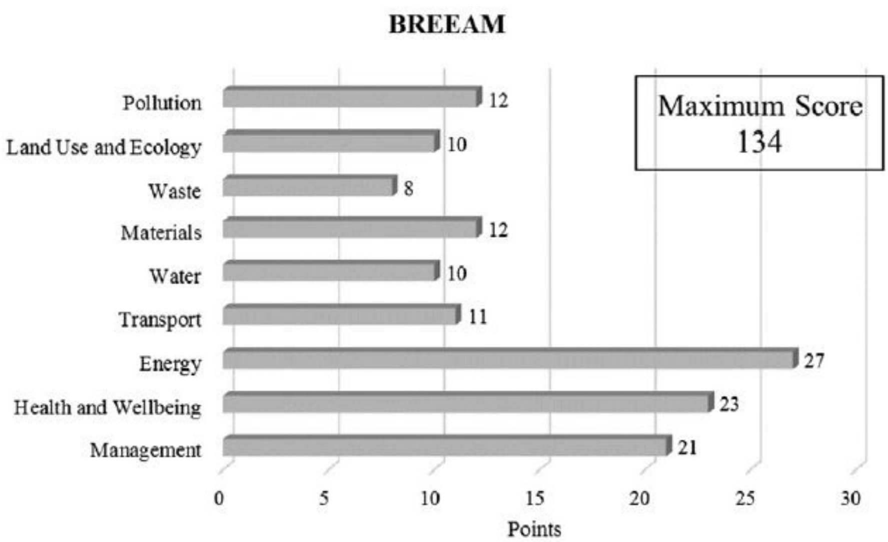

Figure 18. BREEAM Rating Areas and Ratios
(Source: Mattoni et al. 2018)

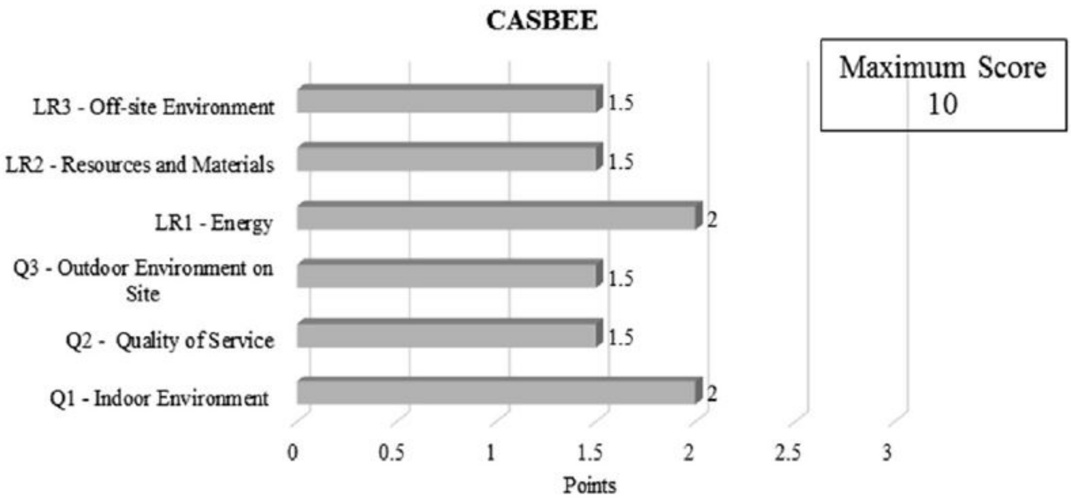

Figure 19. CASBEE Rating Areas and Ratios
(Source: Mattoni et al. 2018)

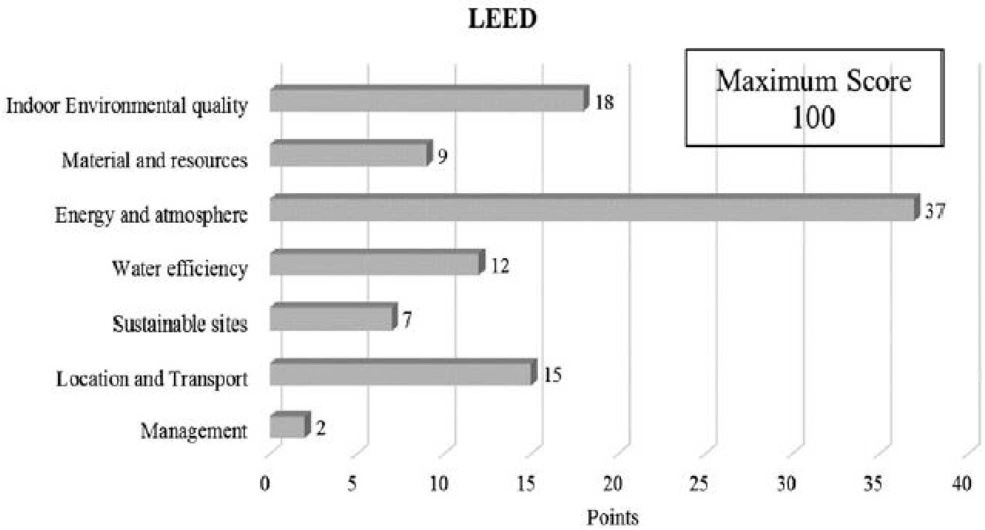

Figure 20. LEED Rating Areas and Ratios
(Source: Mattoni et al. 2018)

Figure 18 to Figure 21, the graphics clearly reveal these items and their share in the outcome evaluation for each specific GBCSs. When a general comparison is made by examining the graphs mentioned above, it is undoubtedly seen that the most crucial point is Energy Performance (Awadh 2017, Gabe and Christensen 2019, Shan and Hwang 2018). With this criterion, GBCSs concentrate on the savings in the energy consumption of the buildings and all of the applications made in this direction. Even if different names identify them, indoor quality and related health and wellbeing areas follow energy performance with the highest scores in every GBCSs. This criterion, on the other hand, has determined the requirements and goals for the place to be better, taking into account the lighting, acoustic, visual qualities, hygiene, clean air cycle, and thermal comfort. Things start to change after these two common items.

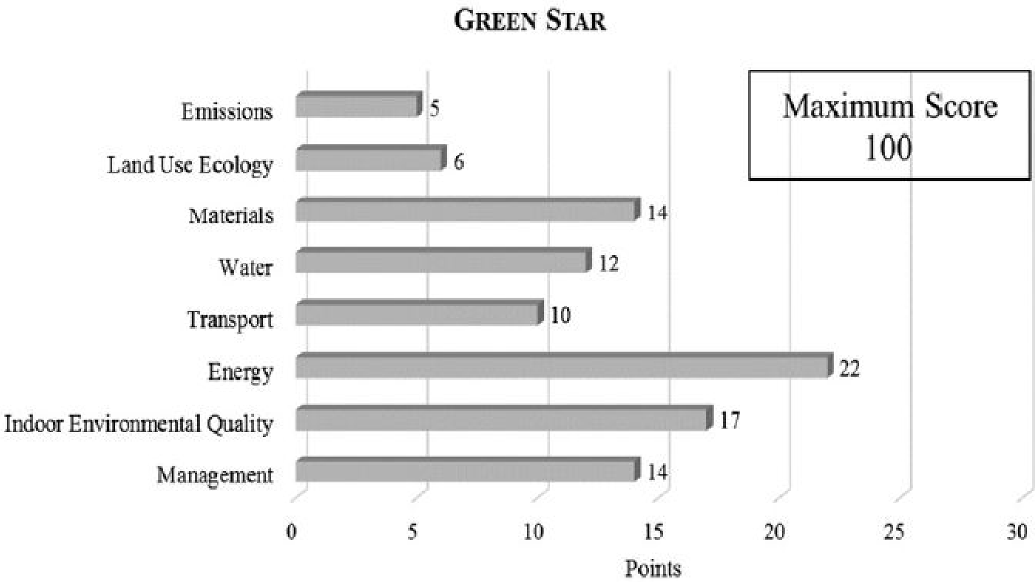

Figure 21. Green Star Rating Areas and Ratios
(Source: Mattoni et al. 2018)

According to Figure 18, BREEAM's most important areas after energy performance are Materials, Pollution, and Management. With these items, BREEAM emphasizes the importance it gives to the design and construction phases of the building as much as the building's end-user performance.

With the weighting it uses in Figure 20, LEED has clearly demonstrated that the most critical thing in green building is energy performance and efficiency (LEED 2021a). The fact that the closest other items are half in their weighted score is a clear expression of this. On the other hand, the fact that LEED gives a meagre rate in the distribution to the Management item reveals that its focus is not paid much attention to the construction process of the building.

CASBEE differs from all other mainstream GBCS by scoring only out of 10 points and keeping the weights of all domains very close to each other, as demonstrated in Figure 19. This weighting system, which can be deduced that each item has a significant role in ensuring sustainability for CASBEE, made the BEE coefficient more meaningful.

The fact that the weight of the water-related substance is ahead of the other systems for the Green Star certification system, which is used mainly in Australia, reveals the importance given to water in the arid climate there. On the other hand, the fact that the emission value is among the primary substances compared to other systems emphasizes the sensitivity shown to this issue.

Shan and Hwang (2018) examined the evaluation areas and their percentages, which are the most present in their content, over 15 different GBCS. This study understood that Energy, Site, Indoor Environment, Land and outdoor Environment, Material, Water, and Innovation areas are common rating areas.

Table 2. Weightings of Mainstream GBCSs (Shan and Hwang 2018)

	Energy	**Site**	**Indoor E.**	**Outdoor E.**	**Material**	**Water**	**Innovation**
Average Percentage	25%	20%	14.78%	13.25%	10.98%	10.71%	7%
Standard Deviation	9%	8.4%	3.4%	4.1%	4.1%	6.1%	2.9%

As it can be understood from Table 2, it is evident that while Energy and Site are the most valuable rating areas, mainstream GBCSs do not reach a consensus about how to weighting them with the highest standard deviations. On the other hand, it is seen that they agree that Innovation should be among the evaluated criteria, and its weight should be in the range of 5% - 10%.

These comparisons reveal that a common GBCS is likely to exist in a globalizing world. Reed et al. (2009) explain that in today’s globalized world where people want to buy properties in different regions’ markets, understanding the Green Building notion for those markets is confusing. This makes the purchasing process more complex and challenging than it is. Therefore, even though there is common sense in GBCSs evaluation criteria, the consumer may be faced with purchasing something different from the green building definition he/she is used to in his/her own country due to several critical differences. With this aforementioned need stated by Reed et al. (2009) and the degrees of common approach put forward by Shan and Hwang (2018), many studies have evolved towards a common global language and scheme for GBCSs (Awadh 2017, Reed et al. 2009, Reed, Krajinovic-Bilos, and Reed 2017, Vijayan and Kumar 2005).

CHAPTER 4

RESEARCH METHODOLOGY

This section aims to explain the methods and techniques of the research and studies made to achieve the purpose of this thesis. This study was initiated by the questioning of GBCSs' behaviours in the global diffusion domain. The international green property purchasing process has become very complicated due to the information pollution caused by the complexity of dozens of certification systems. In the literature, although they are heavily influenced by regional climate, condition, and context; It emphasizes that there should be an international standard in certification systems and, if possible, a unified GBCS around the world (Reed et al. 2009, Reed, Krajinovic-Bilos, and Reed 2017). At the same time, the lack of knowledge on multi-regional market movements is emphasized. Parallel to this situation, there are many advanced studies on this subject in marketing, sociology, and communication. Therefore, the general framework that emerged from the knowledge and experience of previous research on multi-regional market movements was used in this research methodology to contribute the knowledge in the construction management area.

4.1. Research Strategy

A comprehensive and in-depth literature review was carried out at the beginning of the research study in the field of GBCSs. This literature review revealed a very fundamental shortcoming. GBCSs International propagation behaviours have emerged as a niche that has not been studied before. Still, when viewed from a larger scale in the continuation of the research, it is understood that multi-zone market movements have not been studied in the field of construction management either.

The main stages shown in Figure 22 were put into operation. At this point, the research question and purpose, which is the basis on which the research will be built, has been determined. After an intensive literature review was carried out for this purpose, obtaining data that could answer this question was initiated. This procedure was done by choosing the most suitable representative GBCS and accessing its certification data. After

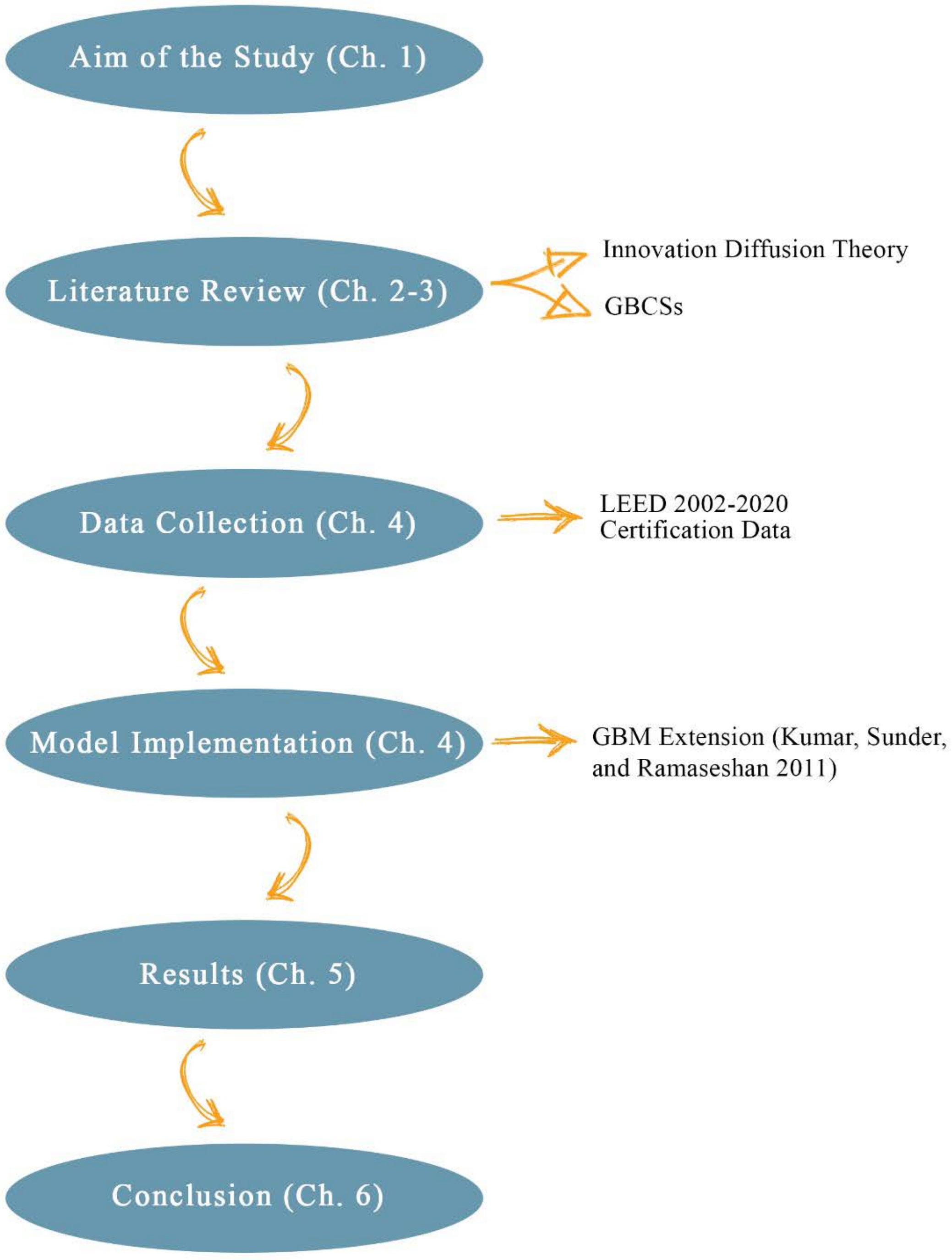

Figure 22. The Process of the Thesis

determining the most appropriate system and accessing its raw data, the obtained statistics were arranged to model international diffusion behaviours. Then, the data divided into three different continents according to the introduction and spread of GBCSs were classified for nearly two decades annually. While North America was the first region where GBCSs were introduced, Asia followed it, and finally, the Latin American continent met GBCSs. The interaction relationships established by considering these regions and their order of getting presented with GBCSs are shown in Figure 23. While North America performed its first certification in 2002, one year later, Asia in 2003 and 2 years after that, Latin America achieved it in 2005. According to these time differences, the learning effect that has emerged as a result of different studies in the literature has been tried to be modelled.

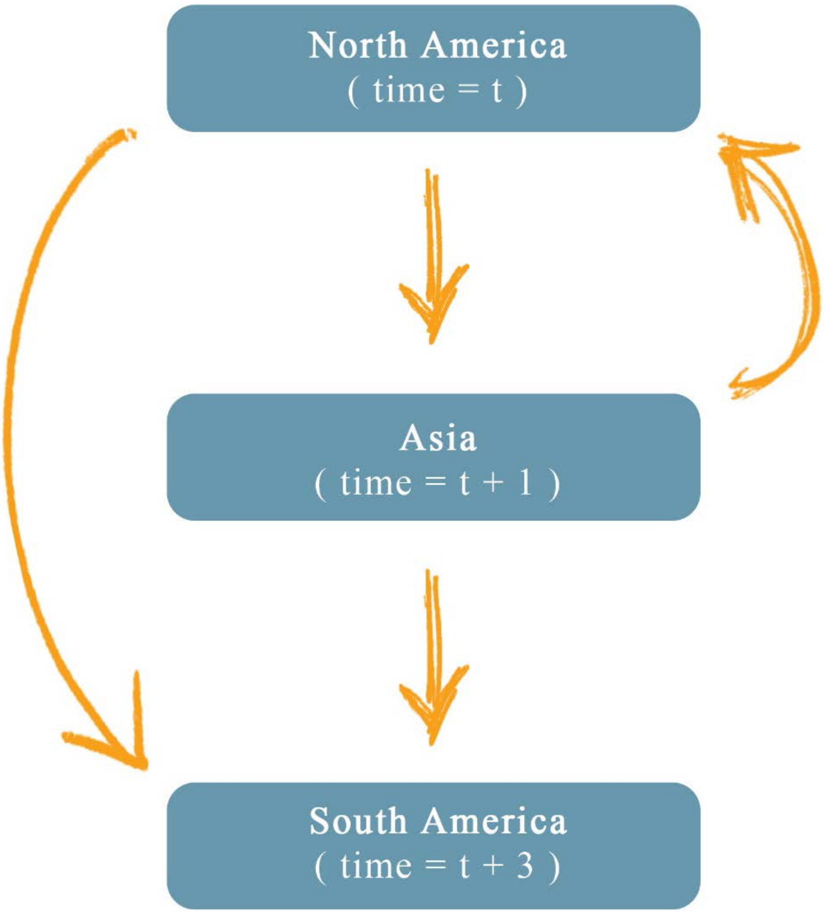

Figure 23. Cross-Regional Diffusion Relationship of GBCSs

While preparing the data, studies were carried out on the determination and selection of the model that can process this data and best serve the research purpose. As understood from the literature review, it was decided that the most effective model for understanding and predicting innovation diffusion behaviour was the Mixed Influence Model proposed by Bass (1969). Many different interpretations and versions of this model have been modified or transformed to suit different contexts and parameters. The version that includes the so-called Learning Effect was discussed by Ganesh and Kumar (1996) for the multi-national diffusion. One of the most recent studies can be expressed by equation 15 that Kumar, Sunder, and Ramaseshan (2011) put forward in parallel with the study of Ganesh, Kumar, and Subramaniam (1997). For this equation to give a one-way learning effect, the following equation is obtained by extending it as explained by Kumar and Krishnan (2002):

$$\frac{f_2(t)}{1 - F_2(t)} = [p_2 + q_2 F_2(t)]\ x \left[1 + b_{12} \frac{dF_1(t)}{d_t}\right] \tag{16}$$

where b_{12} refers to the First Region's learning effect on the following Region 2. This effect is called the lead-lag effect in the literature (Michalakelis et al. 2008, Kumar and Krishnan 2002, Ganesh, Kumar, and Subramaniam 1997, Ganesh and Kumar 1996, Eliashberg and Helsen 1995, Gatignon, Eliashberg, and Robertson 1989). To be able to calculate equation 16, it is differentiated with the approach taken by Bass, Krishnan, and Jain (1994):

$$F_2(t) = \frac{1 - \exp[-(p_2 + q_2)\{t + b_{12}F_1(t)\}]}{1 - \frac{q_2}{p_2}\exp[-(p_2 + q_2)\{t + b_{12}F_1(t)\}]} \tag{17}$$

The use of the inverse of this equation is applied to calculate the effect of Region 2 that was introduced to the innovation later on the diffusion rate in Region 1 that was previously acquainted with it. This effect is called the lag-lead effect in the literature (Kumar, Sunder, and Ramaseshan 2011). After these calculations, the equation is expanded as follows to calculate the third region, which is likely to be affected by two regions that have met with innovation before it:

$$F_3(t) = \frac{1 - \exp[-(p_3 + q_3)\{t + b_{13}F_1(t) + b_{23}F_2(t)\}]}{1 - \frac{q_3}{p_3}\exp[-(p_3 + q_3)\{t + b_{13}F_1(t) + b_{23}F_2(t)\}]} \tag{18}$$

Using equation 17 and vice versa, as well as equation 18 as a set, the p (external influence coefficient), q (internal influence coefficient) values and learning effects of each region can be easily predicted. At this stage that comes after, parameter estimation mechanisms and methods come into play.

In 1969, Bass (1969) discussed the Mixed Influence Model using the OLS parameter estimation method at the same time. Later, the OLS method was criticized due to a few basic deficiencies and instead, the non-linear least square parameter estimation method was recommended (Mahajan, Muller, and Bass 1990, Schmittlein and Mahajan 1982). This method, which has been used by several different researchers (Teng, Grover, and Guttler 2002, Venkatraman, Loh, and Koh 1994), has proven itself in estimating these parameters. In this study presented here, Levenberg (1944) and Marquardt (1963) NLS estimation method was preferred to estimate the parameters. Statistical Package for the Social Sciences (SPSS) 21.0 was used to perform the NLS parameter estimation method.

Pseudo R^2 (the *Pseudo* Coefficient of Determination) is used to evaluate the success of the mixed influence model used in this research. Moreover, the approximation power of the model was also checked by comparing the Mean Absolute Percentage Errors (MAPE) obtained by increasing the time series one at a time. The equation used to find these MAPEs:

$$MAPE = \sum_{t=1}^{k} \left| \frac{A_t - P_t}{A_t} \right| \frac{1}{k} \tag{19}$$

where A_t is the real adopters' number at time t, and P_t is the predicted adopters' number at time t. As the MAPE value approaches the value of 0, the performance rate of the model approaches to be perfect. Another study conducted in this research to verify the model's reliability and the data is to find the PS (Parameter Stability) value for each parameter estimated by considering the time series with the same attitudes applied for MAPE. PS can be found with the following equation:

$$PS = \sum_{i=1}^{n} \left| \frac{P_\mu - P_{t-i}}{P_\mu} \right| \frac{1}{n} \tag{20}$$

where P_t is the estimation of the parameter at year t, P_{t-i} is the estimation of the parameter at year t-i, and n is the total number of years. It is understood that the closer the PS value to 0, like the MAPE value, the more stable the parameters are. The MAPE and PS analyses made with a decrease of the years in each calculation are explained in a comprehensive table in the next section.

4.2. Data Preparation

Examining the international diffusion behaviours of GBCSs can only be done by processing the certification statistics in different regions. In this direction, the most significant among crucial points is the determination of the systems that make international certification and examine their status. When the literature is scrutinized, two certification systems stand out:

- BREEAM,
- LEED.

They both dominate each other in many different domains. For example, after BREEAM was introduced as the world's first certification system, it has been recognized as the system with the highest number of certifications by signing more than five hundred and fifty thousand certifications until today (BREEAM 2021). However, most of this number has been realized in the European region, which can be considered as a limited region. Therefore, the total number of countries with which it has certified is below ninety. On the other hand, LEED, which was established in 1998 after BREEAM and HQE and is considered one of the leading certification systems, takes its place in the literature as the second-largest system after BREEAM with the number of certifications it has. This number of certifications, which is just over one hundred thirty thousand in total, is carried out in more than 160 countries, making LEED known as the world's most preferred and most international certification system (LEED 2021b).

In the light of the above data, LEED, which is by far the most preferred international certification institution in terms of regional and market diversity, was chosen to be examined in this study. For innovation diffusion models to give healthy and beneficial results, the time series is preferably desired to be as long as possible. With this framework, when you enter the projects directory web page of LEED (LEED 2021b), the portal shares the entire certification process history since 2002, when it started its certification activities, even including those who have applied but have not approved until now. The organization shares all these data in Excel format at the top of this page, a part of which you can see in Figure 24 so that you can download and process it. When you open and examine the data in Excel, you can reach all of the details such as the application date, address and country of residence, project size, typology, how many points it has received, what level it is certified, and the time of certification. You can examine the raw version of all this information in Figure 25.

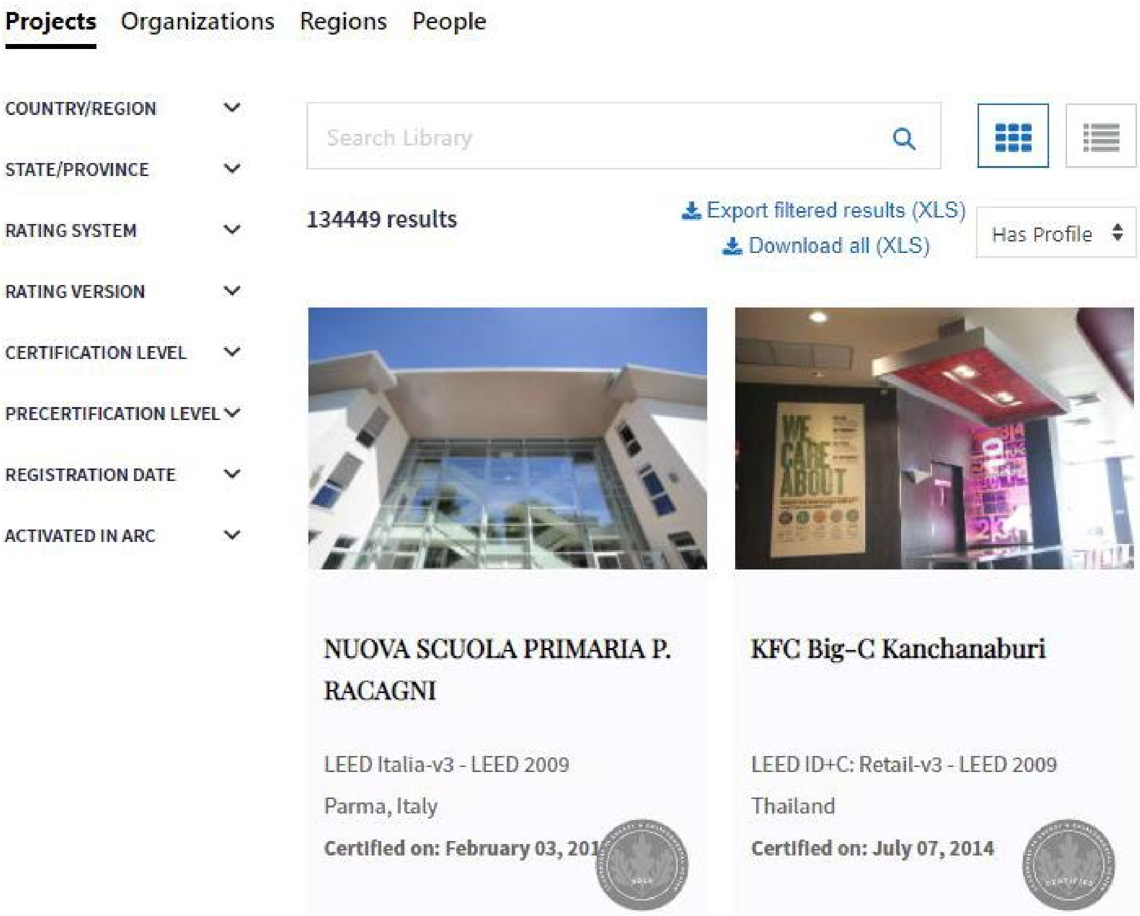

Figure 24. LEED Projects Directory Web Page
(Source: LEED 2021b)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	ID	ProjectName	City	State	Country	LEEDSystemV	Poin	CertLevel	CertDate	IsCertified	GrossSqFc	TotalPropAr	ProjectTypes	Registratio
2	0010000000	PNC Firstside C	Pittsburgh	PA	US	LEED-NC 2.0	33	Silver	2000-10-01	Yes	202923.05	202923.0000	Commercial O	2000-03-31
3	10000001	Confidential	Confident	IN	US	LEED-NC 2.0				No	130637.16	130637.0000	Commercial O	2000-06-01
4	0010000002	Bethel Comme	Chicago	IL	US	LEED-NC 2.0	45	Gold	2007-11-05	Yes	27500.000	27500.0000	Commercial O	2001-08-01
5	0010000003	Confidential	Confident	NY	US	LEED-NC 2.1				No	190000.00			2006-09-19
6	0010000004	The Chicago Ce	Chicago	IL	US	LEED-NC 1.0 F	38	Platinum	2003-06-17	Yes	28356.000	28356.0000	Industrial, Cor	2000-06-01
7	0010000005	625 Broadway (	Albany	NY	US	LEED-NC 2.0	33	Silver	2002-06-11	Yes	470000.00		Commercial O	2000-06-09
8	0010000006	Seattle Central	Seattle	WA	US	LEED-NC 2.0	34	Silver	2004-11-22	Yes	60964.008	60964.0000	Library	2000-06-20
9	0010000007	NRDC Southerr	Santa Mor	CA	US	LEED-NC 2.0	56	Platinum	2004-11-12	Yes	15000.000		Commercial O	2000-06-22
10	0010000008	Renovation of	Monroe	MI	US	LEED-NC 2.0	27	Certified	2006-08-02	Yes	300000.00		Multi-Unit Res	2000-06-26
11	0010000009	Sabre Corporat	Southlake	TX	US	LEED-NC 2.0	34	Silver	2003-02-04	Yes	6793132.3	6793132.000	Commercial O	2000-07-03
12	0010000010	Plaza Building,	Tucson	AZ	US	LEED-NC 1.0 F	22	Bronze	2002-10-28	Yes	870914.40	870914.0000	Higher Educat	2000-07-19
13	0010000011	Whitehead Bio	Atlanta	GA	US	LEED-NC 2.0	34	Silver	2002-08-29	Yes	324964.00	324964.0000	Laboratory	2000-07-19
14	0010000012	Confidential	Confident	WA	US	LEED-NC 2.0				No	130637.16	130637.0000	K-12 Educatio	2000-07-21
15	0010000013	North Cascade:	Diablo Lak	WA	US	LEED-NC 2.1	37	Silver	2009-02-05	Yes	876015.00	876015.0000	Interpretive C	2000-08-11
16	0010000014	Confidential	Confident	VA	US	LEED-NC 2.0				No	23253.000			2000-08-01
17	0010000015	Student Cente	Seattle	WA	US	LEED-NC 2.0	26	Certified	2006-09-21	Yes	87091.440	87091.0000	Higher Educat	2000-08-08
18	0010000016	City of Seattle	Seattle	WA	US	LEED-NC 2.0	33	Silver	2004-08-12	Yes	0.0000			2000-08-11
19	0010000017	French Wing A	Concord	NH	US	LEED-NC 2.0	44	Gold	2003-03-10	Yes	4267480.5	4267481.000	Commercial O	2000-08-18
20	0010000018	Marion Courth	Salem	OR	US	LEED-NC 1.0 F	22	Bronze	2002-08-26	Yes	87091.440	87091.0000	Public Order/:	2000-08-23
21	0010000019	Regional Traini	Gresham	OR	US	LEED-NC 2.0	39	Gold	2002-08-29	Yes	740277.24	740277.0000	Industrial	2000-08-29
22	0010000020	Herman N. Hip	Greenville	SC	US	LEED-NC 2.0	40	Gold	2003-07-11	Yes	56609.436	56609.0000	Higher Educat	2000-09-05
23	0010000021	Mount Holyoke	South Had	MA	US	LEED-NC 2.0	27	Certified	2004-06-10	Yes	111122.00		Laboratory	2000-09-13
24	0010000022	Confidential	Confident	WA	US	LEED-NC 2.0				No	130637.16	130637.0000	Commercial O	2000-09-25
25	0010000023	New Public Lib	Eugene	OR	US	LEED-NC 2.0				No	43545.720	43546.0000	Library	2000-09-28
26	0010000024	Mathematics a	Atlanta	GA	US	LEED-NC 2.0	28	Certified	2005-09-13	Yes	170949.00	170949.0000	Higher Educat	2000-10-04
27	0010000025	Lake View Terr	Lake View	CA	US	LEED-NC 2.0	50	Platinum	2005-11-18	Yes	1.0000	1.0000	Library	2000-10-11

Figure 25. Downloaded Excel Table of LEED Projects Directory
(Source: LEED 2021b)

When this data is started to be processed, the information required to establish the diffusion model is in which country the project is located and in which year the certification process was carried out. After clarifying these two pieces of information for all projects certified since 2002, they were grouped on the basis of continents, which is the following higher scale. Finally, a cross-national diffusion model was created with these data classified under three different groups: North America, Asia, and Latin America, and the results were presented.

CHAPTER 5

RESEARCH FINDINGS AND DISCUSSIONS

The following chapter presents the current situation of GBCS diffusion in the selected regions and their insights, time series analysis of the research data, the integrity of the fit of the model and the interpretation of the research findings. In the first part of this section, the certification statistics, general situation, and diffusion behaviours of LEED in target countries and regions since 2002 will be inferred from the data. After the application and results of the selected model to the data, the second part, how close the behaviours are and how successful the model is to imitate the data, is explained together with the time series analysis through tables and graphs. Finally, in the last part, the interpretation, evaluation and comparison of these results and findings with the literature findings have been made.

5.1. Current Outlook

LEED can be counted as the most widely used GBCS globally and has the highest number of international certification regions. LEED, which succeeded in reaching every continent of the world and performing certification procedures there, was introduced at different times and exhibited other diffusion behaviours. Undoubtedly, most certification procedures have been carried out in the North American continent, where the United States of America, the country of birth of LEED, is located.

Although there is a massive gap in the number of certifications with the numbers in its own country, it is considered to have reached serious numbers in Asia, Europe, and finally Latin America, respectively. Entering the Asian market one year after having its first certification in the American continent in 2002, LEED started serving Latin America in 2005 and Europe in 2006. Although it has achieved significant certification numbers in the European continent, its behaviour in the European continent has not been taken into account since LEED is deemed non-existent and the certification numbers of BREEAM, which is by far the market leader. And even though there are some certification processes in other continents and regions like Africa and Australia, it is not included because it does

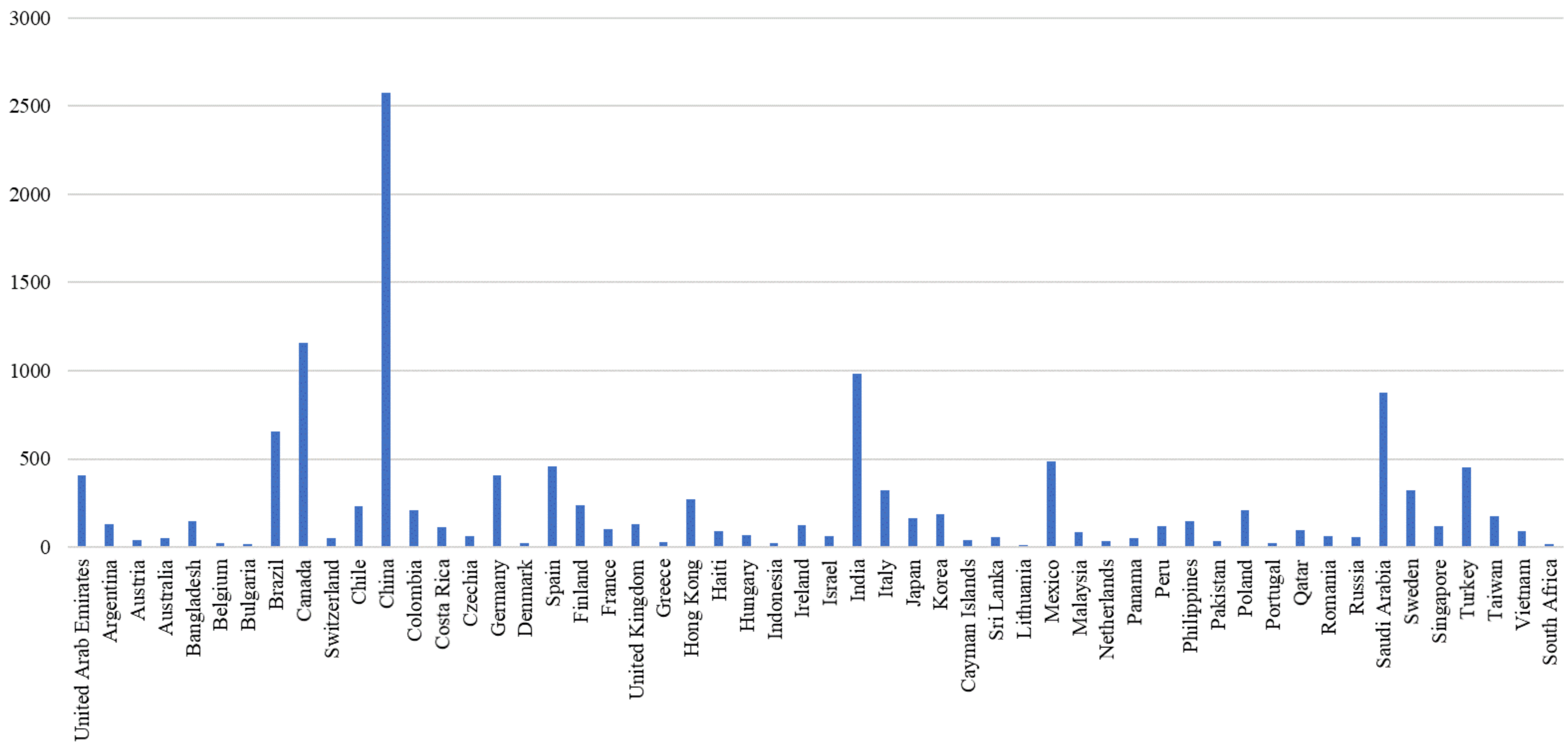

Figure 26. Number of LEED Certification by Country

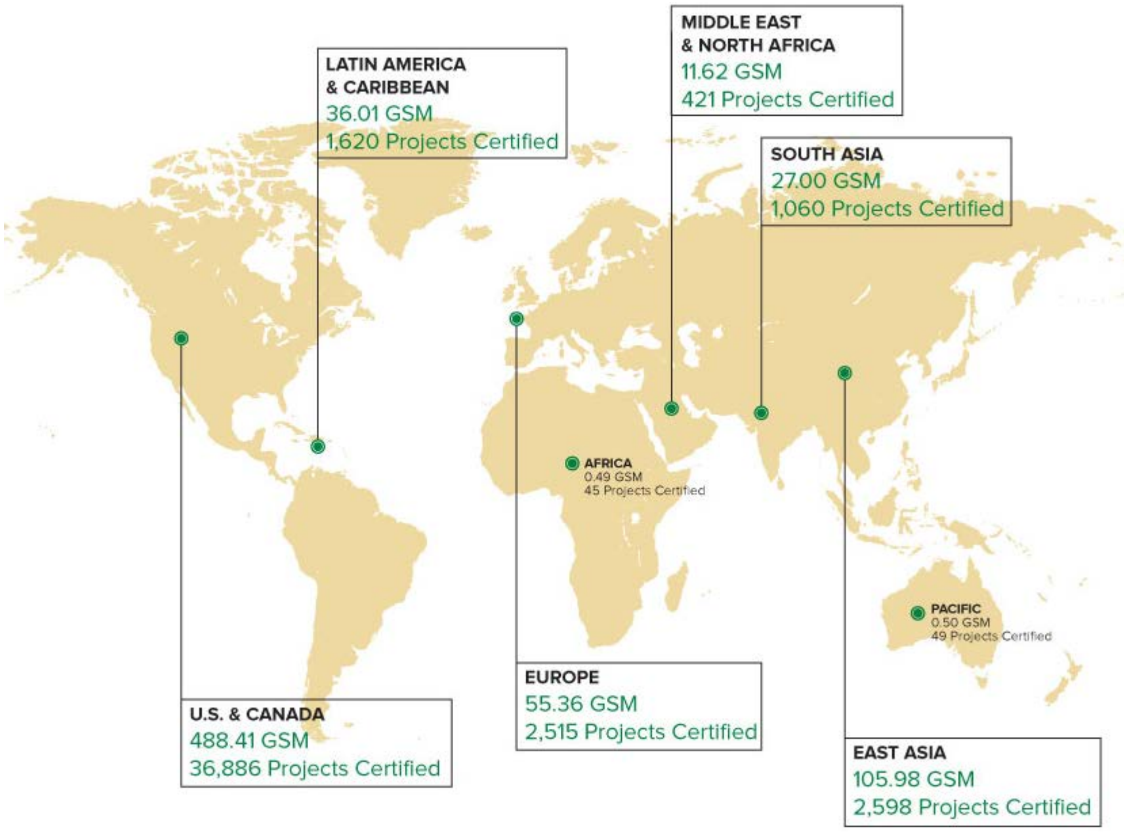

Figure 27. LEED Worldwide Certification Statistics (2018)
(Source: Stanley 2019)

not have an annual level of stability and is considered absent compared to the number of certifications in the mentioned regions. The total number of certificates of all countries except the USA, which is included in the research calculations presented here, can be examined from Figure 26. And the map in Figure 27 can also be explored, which summarizes the general situation of LEED in the world in 2018 from the uppermost scale.

5.1.1. North America

North America is the continent where the LEED certification system discussed in the thesis presented herein was established in 1998. It performed the certification procedure in 2002 for the first time, four years after its establishment. LEED certifies in two of the most well-known countries in North America. The United States of America, the country where it was founded, and Canada have very close ties. Even if the certification process was started with a small-time gap of 5 years, the United States showed a much faster development than Canada, with a total of 98% share in the North American certification statistics, which can be examined from Figure 29. When looking at the United States and thus the North American continent, it is possible to observe a diffusion that has been subjected to sharp declines and recoveries after 2013, while it is observed that LEED was adopted consistently until that year. The momentum of this upward movement is stronger than ever, especially between 2008 and 2012. In 2013, when it was the highest, it reached an all-time high with 7388 certifications.

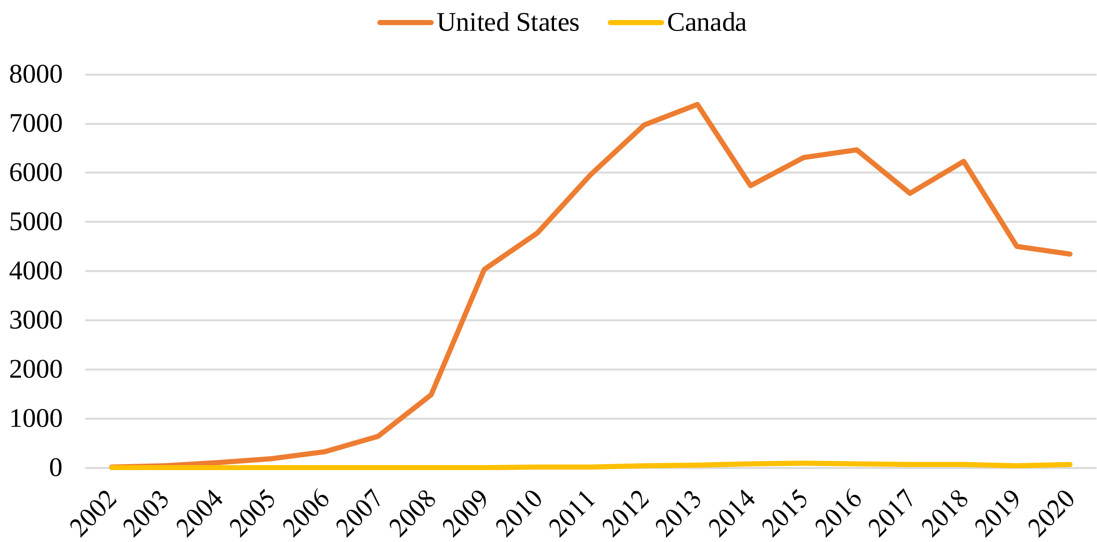

Figure 28. North American Countries' Yearly Certification Statistics

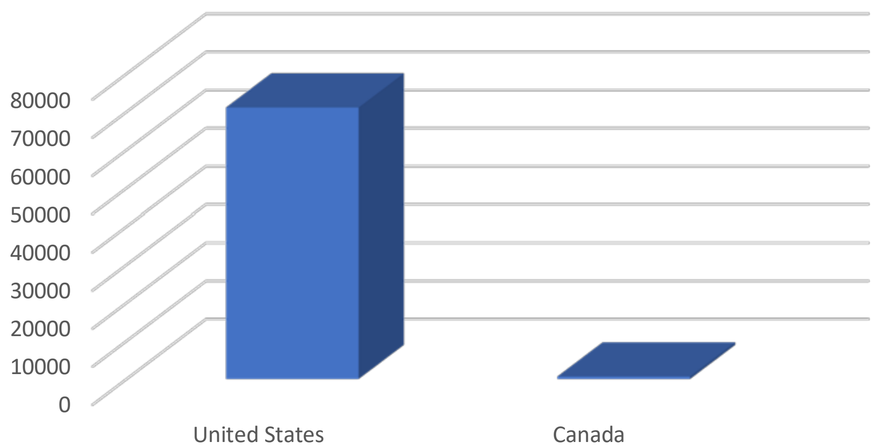

Figure 29. North America Certification Number Percentages

On the other hand, a slow but steadily increasing diffusion can be mentioned for Canada, which makes certification processes with minimal numbers compared to the United States. Canada has not yet succeeded in exceeding 100 certifications annually. Allowing these inferences to be made in-depth, Figure 28 quickly reveals the vast difference in volume between the US and Canada. When examined in terms of area or housing stock in parallel, it is understood from Figure 30 that both the USA and Canada represent a considerable part of North America

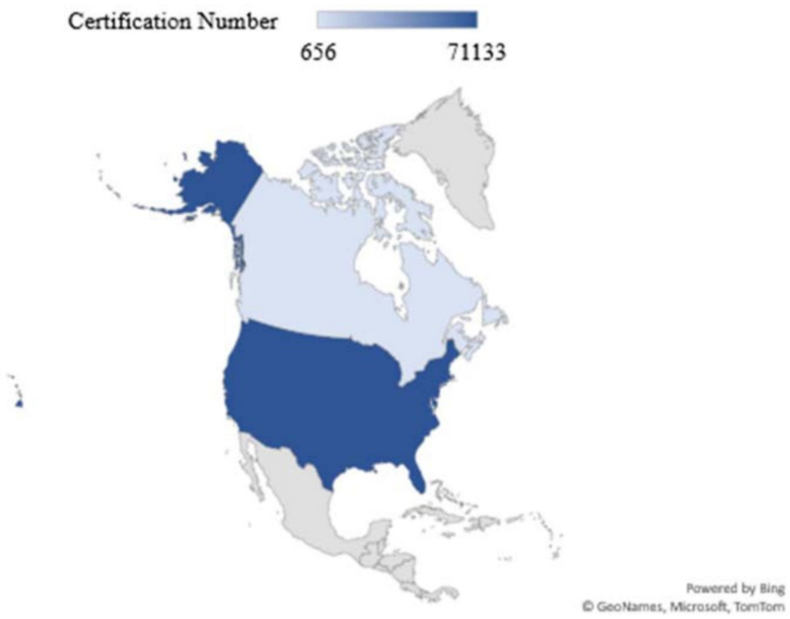

Figure 30. North America Certification Map

5.1.2. Asia

Shortly after North America, the continent where it was founded and most widely used, Asia also met LEED after as little as one year in 2003. Asia, which is more significant than North America in terms of the number of countries it contains and its surface area, is known as the continent with the highest share after North America in LEED statistics. But compared to North America, this GBCS certifies in 19 different countries on the continent, as shown in Figure 32. From the same image, it is argued that only half of Asia's surface area is represented and that only 19 out of 48 countries include green buildings certified by LEED. A region extending from Russia in the north, from

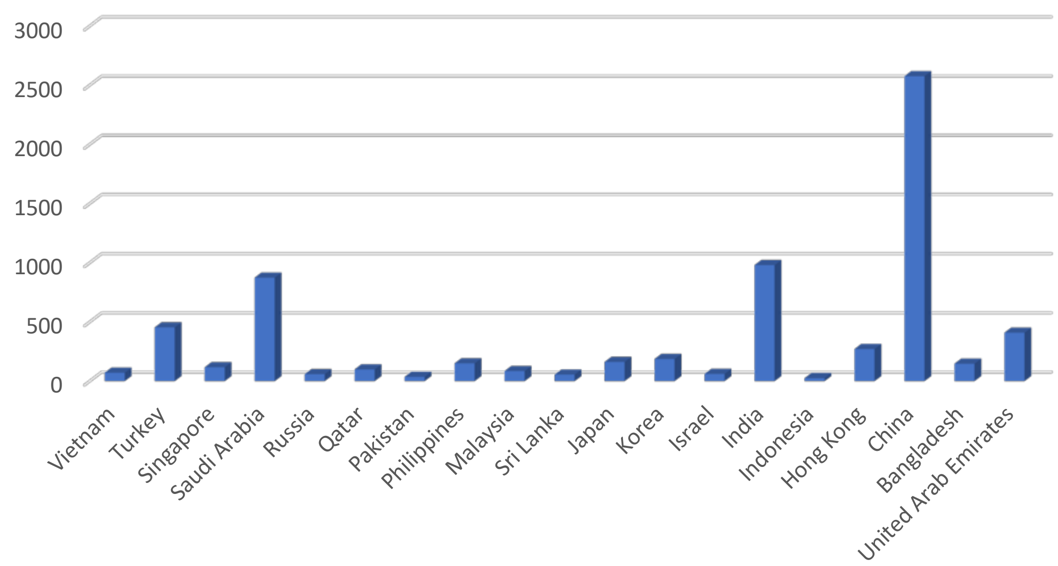

Figure 31. Asia Certification Number Percentages

Turkey to the Arab Emirates to the south and Japan to the east is mentioned. Figure 33 and Figure 33 show that China is the most dominant country in the Asia green building certification market with a 38% share. On the other hand, while Russia has been certificating as much as other countries for many years, it is among the most striking diffusion behaviours that exceeded 600 in 2017. After China, India and Hong Kong are among the influential countries in Asia's green building certification market, with 14% and 13% tranches ahead of the remaining countries.

With a share of less than 3%, almost all of the remaining countries are observed to be the slowest adopting attitude in green building certification diffusion. As a result, the annual certification numbers of these countries are below 50. On the other hand, the typical situation observed in all except Russia is that they have steadily increasing certification numbers.

From these analyses, it can be clearly stated that the Asian green building certification market for LEED is first shaped by China and then Honk Kong and India. Looking at North America, it can be seen that the USA alone has overwhelmingly dominated and is the representative of the market for LEED. Still, China cannot be said to have the same representation power for the Asian market. This situation is one of the main differences observed between these continents handled in this research presented herein.

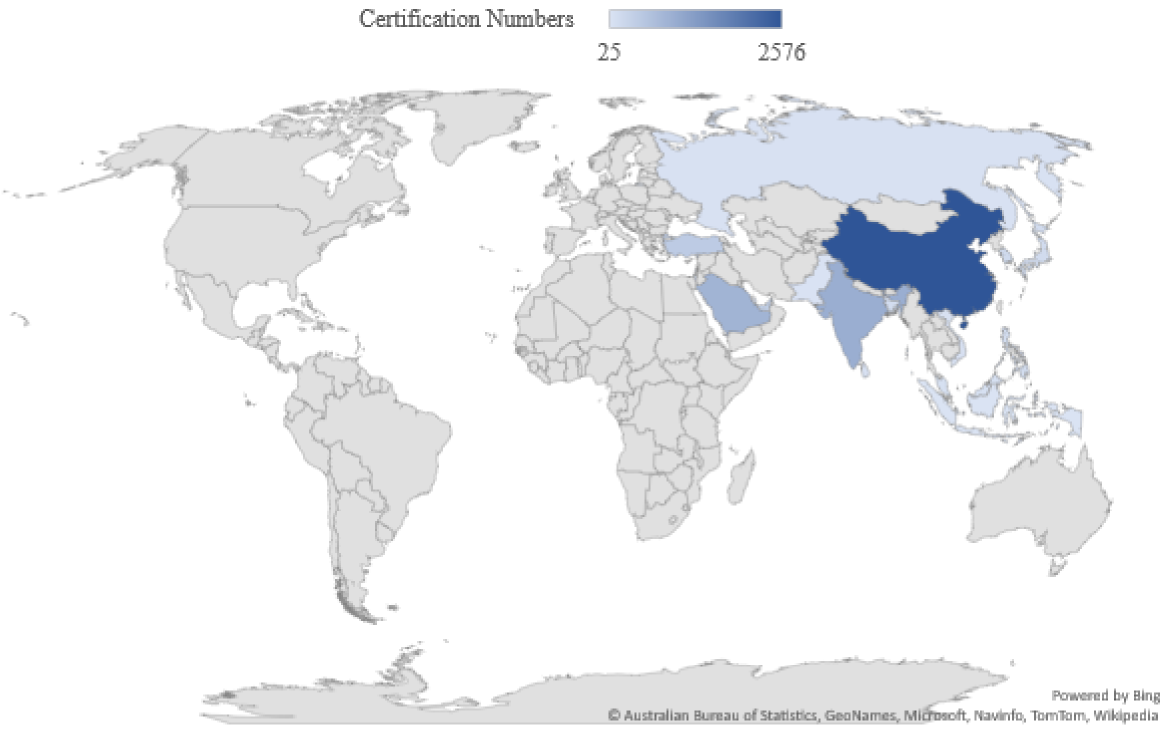

Figure 32. Asia Certification Map

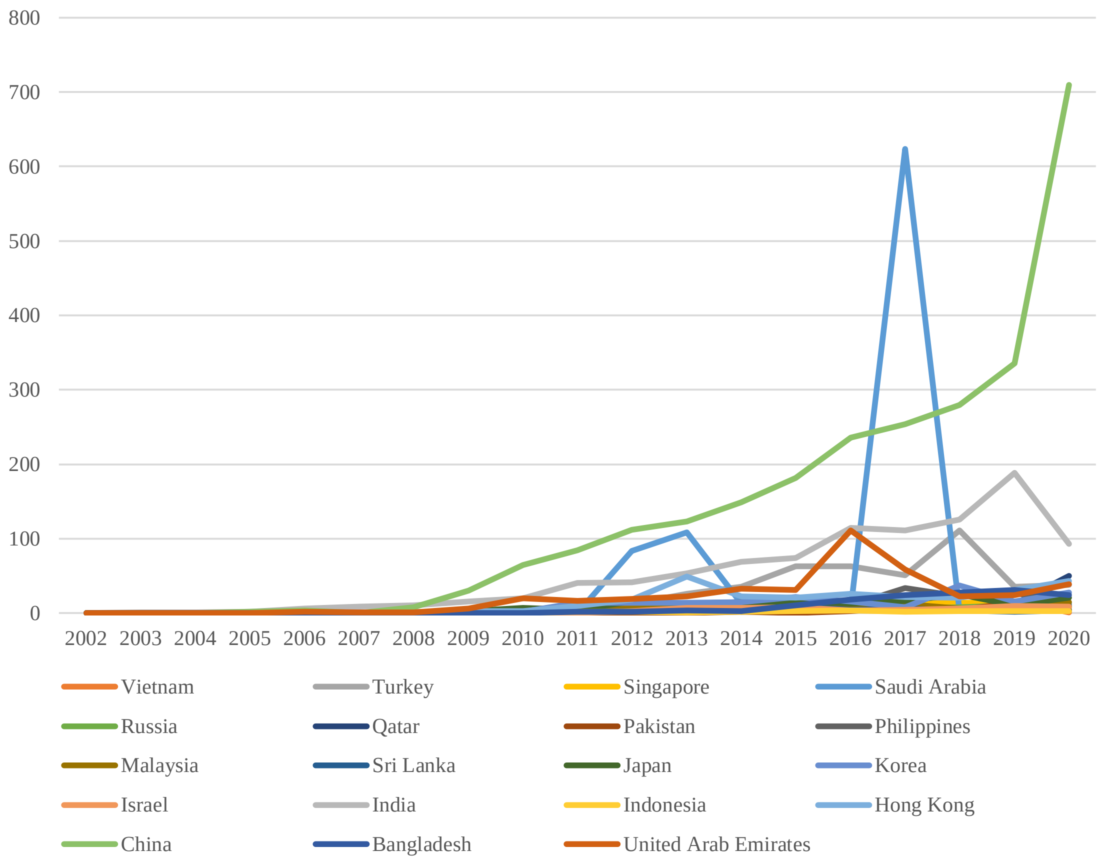

Figure 33. Asian Countries' Yearly Certification Statistics

5.1.3. Latin America

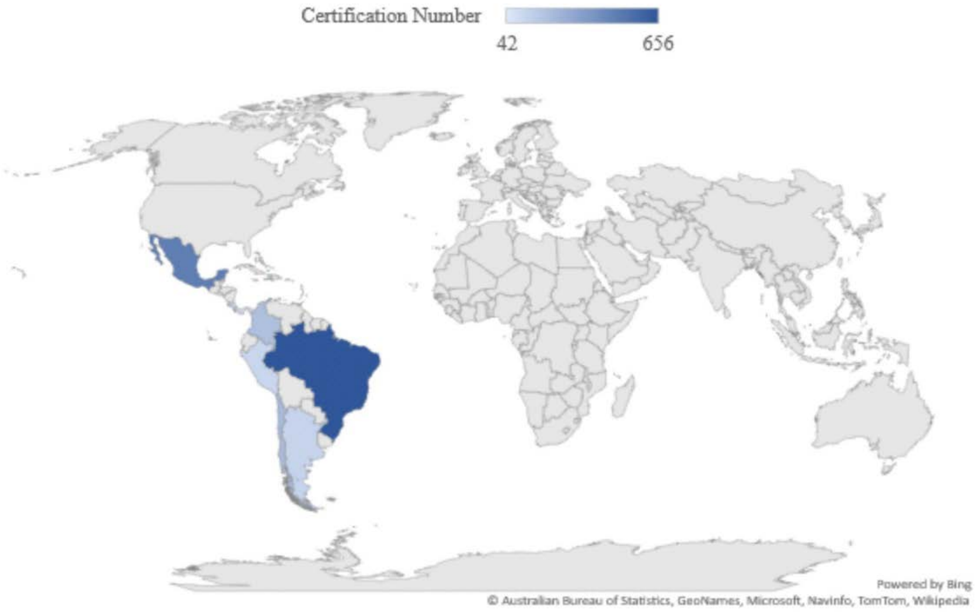

Figure 34. Latin America Certification Map

Among the continents discussed in the research, the last region that meets green building certification is Latin America. In this continent, which includes 33 large and small countries, LEED continues its certification services in 10 countries. Looking at these ten countries as surface area, it covers a massive part of it, representing only one-third of the continent in terms of country numbers. It is possible to read this observation on the world map shown in Figure 34.

It can be argued that there is a much more homogeneous national distribution in all certification numbers compared to the other two regions considered. Even if Brazil and Mexico behave as the leading countries in this adoption with their shares, it cannot be said that they are direct representatives of the region since there is no overwhelming difference compared to other countries. When the chart shown in Figure 36 is examined, this balanced, and almost homogeneous distribution clearly reveals that Latin American green building certification diffusion behaves differently from the others.

In Latin America, the number of green building certification, which increased rapidly from 2010 to 2015, entered a stagnation period after 2015. For this continent, it is possible to see from Figure 36 that all countries are below 100 certification processes per

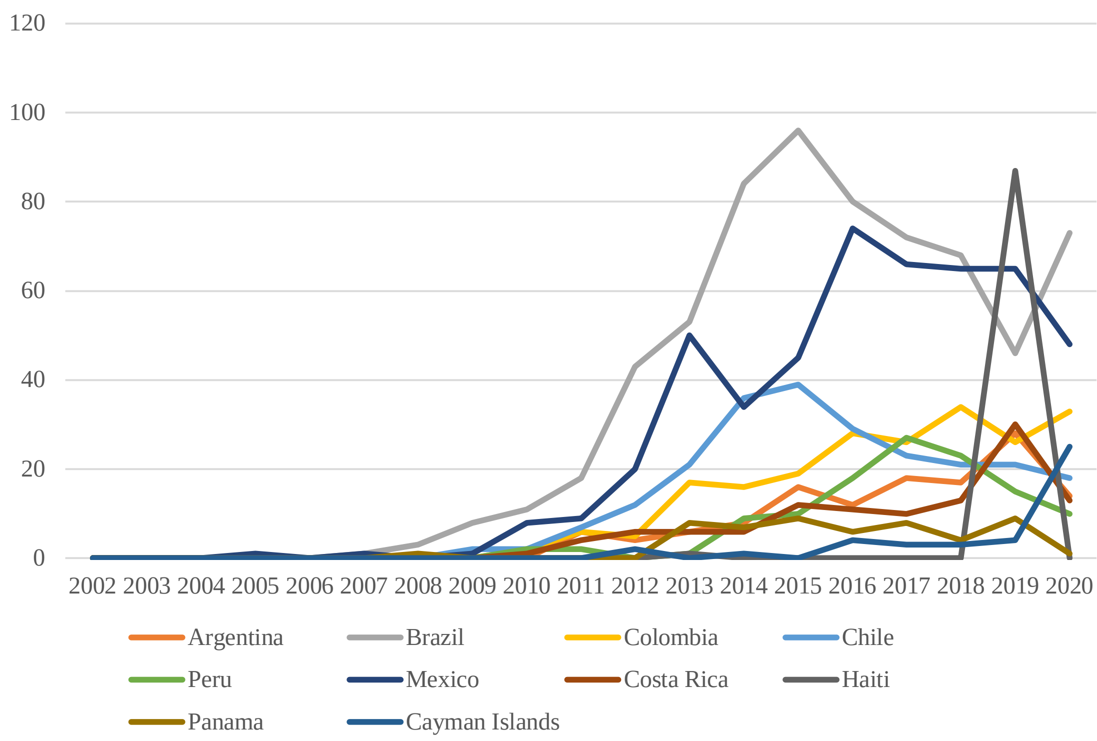

Figure 35. Latin American Countries' Yearly Certification Statistics

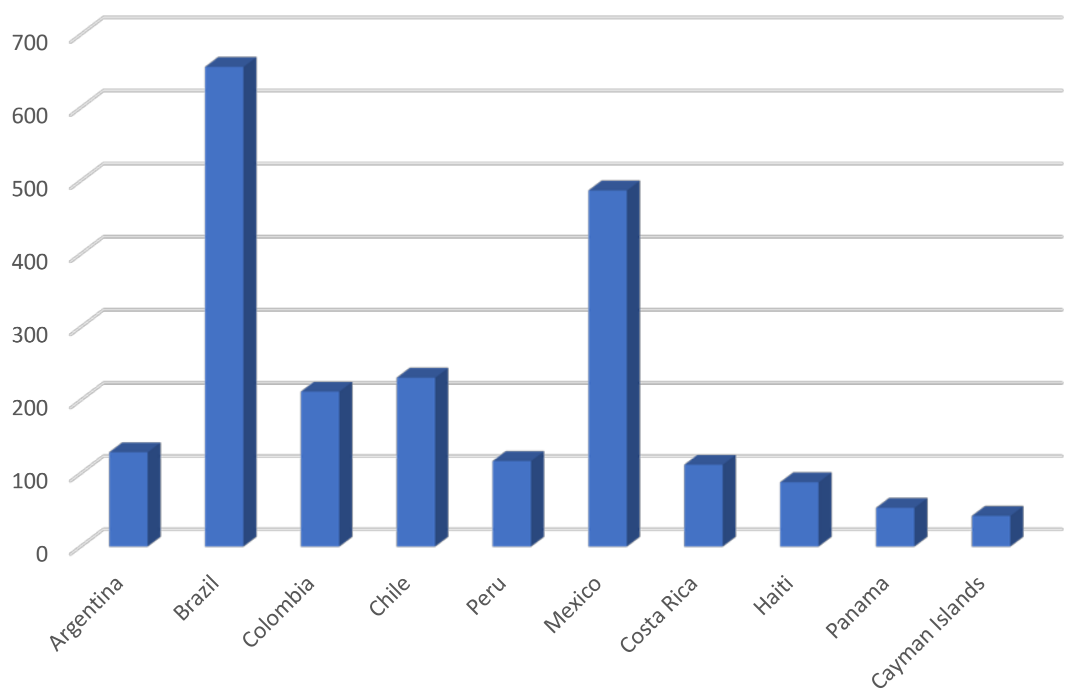

Figure 36. Latin America Certification Number Percentages

year. Apart from the sharp decline in Brazil in 2015 and the peak in Haiti in 2019, adoption behaviour shows decisive and steady movements.

5.2. Results and Discussions

Table 3 effectively clarifies the results of the nonlinear least-square examination (Levenberg 1944, Marquardt 1963) of the extended Mixed Influence Model of Bass (1969) by Kumar, Sunder, and Ramaseshan (2011). It is understood from the general review of the results that the innovation and imitation coefficients for all three regions contribute to diffusion simultaneously by taking positive values other than zero ($p \neq 0, q \neq 0$). This evaluation justifies the choice of Mixed Influence Model instead of either Internal Influence or External Influence models.

The pseudo coefficient of determination (R^2) values of all three zone models have an approach success of more than 80%, which is much higher than different innovation diffusion models used in several studies (Kale and Arditi 2005, 2006, 2010). This situation shows that this model can easily be used to explain the diffusion of GBCSs.

Another analysis supporting this projection capability is the MAPE values measured at different time series (t-i) lengths. MAPEs range from 0.1 to 4.5 claim that the projection capability of the model is solid across the entire study scope. Together with these values that can be studied from Table 4, the Parameter Stability (PS) can also be examined to verify the data's internal validity. The PS values calculated separately for the innovation coefficient (p), imitation coefficient (q), and total market potential (m) of each region show that the parameters are valid throughout any length of time series,

Table 3. Cross-Regional Diffusion Model Results

						Learning Effect	
Region	First Data Point	R^2	p	q	m	From North America	From Asia
North America	2002	.82	0.0038	0.34	83916	———	**n.s**
Asia	2003	.89	0.0008	0.35	11425	**0.009**	———
Latin America	2006	.96	0.0006	0.40	2929	**0.0018**	**n.s**

All models are significant $p < 0.05$

Note: n.s: nonsignificant

Table 4. Parameter Stability and Predictive Ability of the Model over Different

Study Period	Model Parameters for North America			MAPE (%)	Percentage (%) of Total time Series	Model Parameters for Asia			MAPE (%)	Percentage (%) of Total time Series	Model Parameters for Latin America			MAPE (%)	Percentage (%) of Total time Series
	p	*q*	*m*			*p*	*q*	*m*			*p*	*q*	*m*		
t	0.0038	0.336	83916	3.1	100	0.0008	0.345	11425	4.2	100	0.0006	0.400	2937	3.1	100
t-1	0.0035	0.352	80939	2.9	95	0.0003	0.447	8083	1.5	94	0.0006	0.392	3014	3.4	94
t-2	0.0033	0.364	78707	2.8	89	0.0004	0.427	8637	2.0	89	0.0002	0.518	2133	1.6	88
t-3	0.0026	0.413	70342	2.2	84	0.0000	0.321	6472	4.5	83	0.0001	0.575	1886	1.1	81
t-4	0.0021	0.448	65233	1.8	79	0.0007	0.432	5642	3.0	78	0.0001	0.620	1697	0.8	75
t-5	0.0014	0.521	56413	1.2	74	0.0003	0.614	3236	0.8	72	0.0001	0.688	1426	0.5	69
t-6	0.0009	0.601	49005	0.6	68	0.0000	0.838	2265	0.2	67	0.0000	0.834	990	0.1	63
PS	0.0011	0.098	13122			0.0003	0.180	3179			0.0003	0.158	750		

Note: PS: Parameter Stability, and MAPE: Mean Absolute Percentage Error taking minimal values. Since these values, which vary from 0.0003 to 0.18, are very low compared to the parameters they are calculated and are close to zero, the models' parameters can be considered constant throughout the entire time series.

When the innovation and imitation coefficients obtained by nonlinear least-square analysis for North America are observed, it can be seen that they are 0.0038 and 0.34, respectively. The same coefficients were 0.0008 and 0.35 for Asia and 0.0006 to 0.40 for

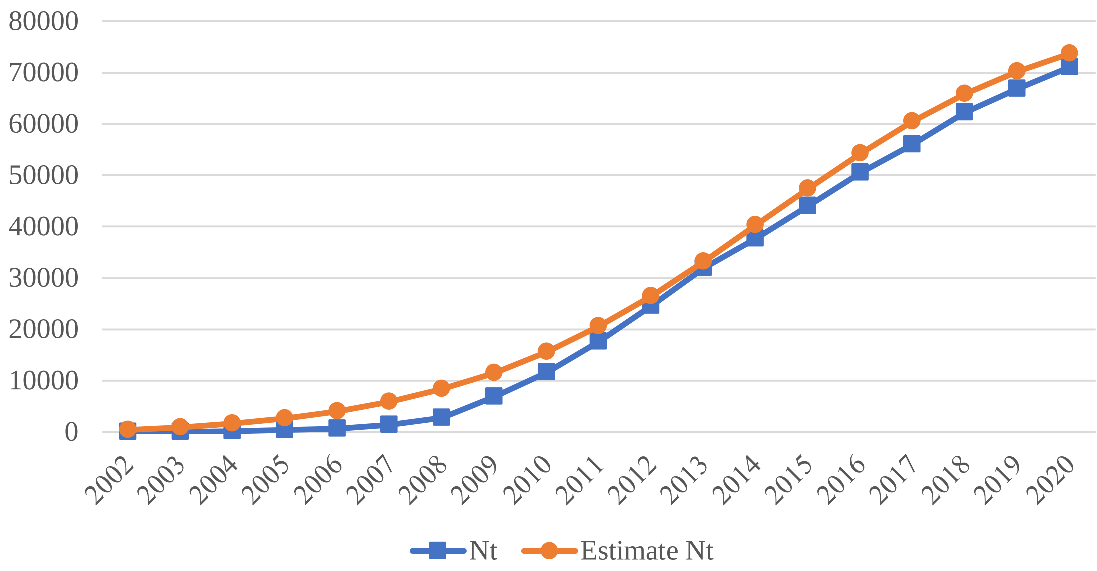

Figure 37. Cumulative Cross-Regional Diffusion Model Fit for North America

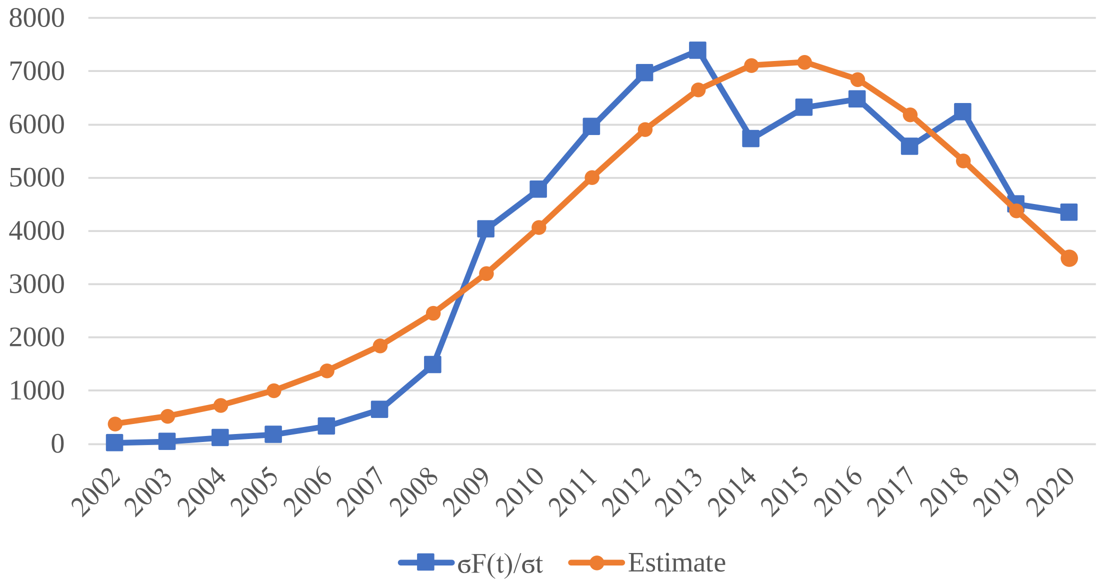

Figure 38. Yearly Cross-Regional Diffusion Model Fit for North America

Latin America (Table 3). The common point of the coefficients of the three regions is that the imitation coefficient (internal influence) is much greater than innovation (external influence). This condition supports that internal influence, the interaction and information exchange between agents in a social system, is the most influential factor in green building certification adoption processes. This detection supports the findings of

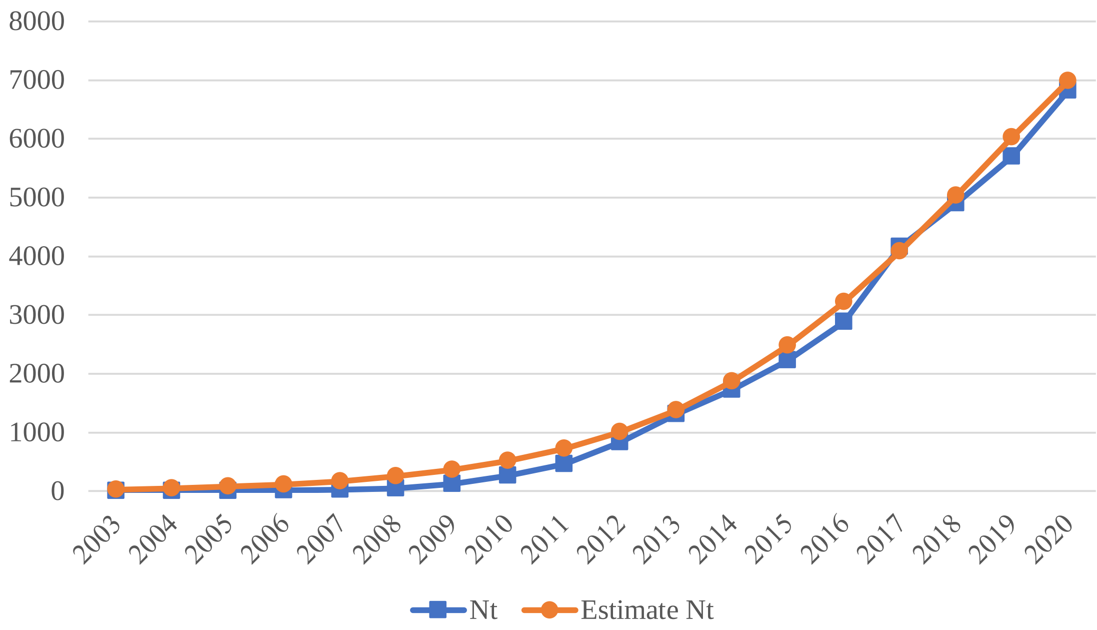

Figure 39. Cumulative Cross-Regional Diffusion Model Fit for Asia

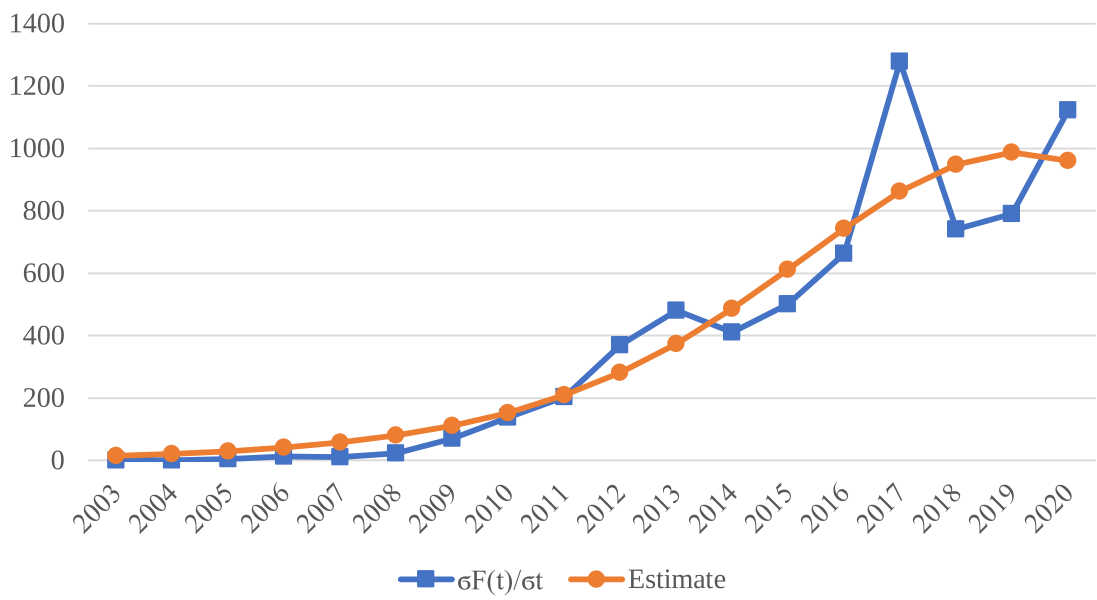

Figure 40. Yearly Cross-Regional Diffusion Model Fit for Asia

previous studies (Mahajan, Muller, and Bass 1990, Teng, Grover, and Guttler 2002, Venkatraman, Loh, and Koh 1994). On the other hand, Latin America has the highest value in the imitation coefficient (internal influence). This status indicates that, unlike North America, it displays a more conservative and timid attitude towards green building certification processes.

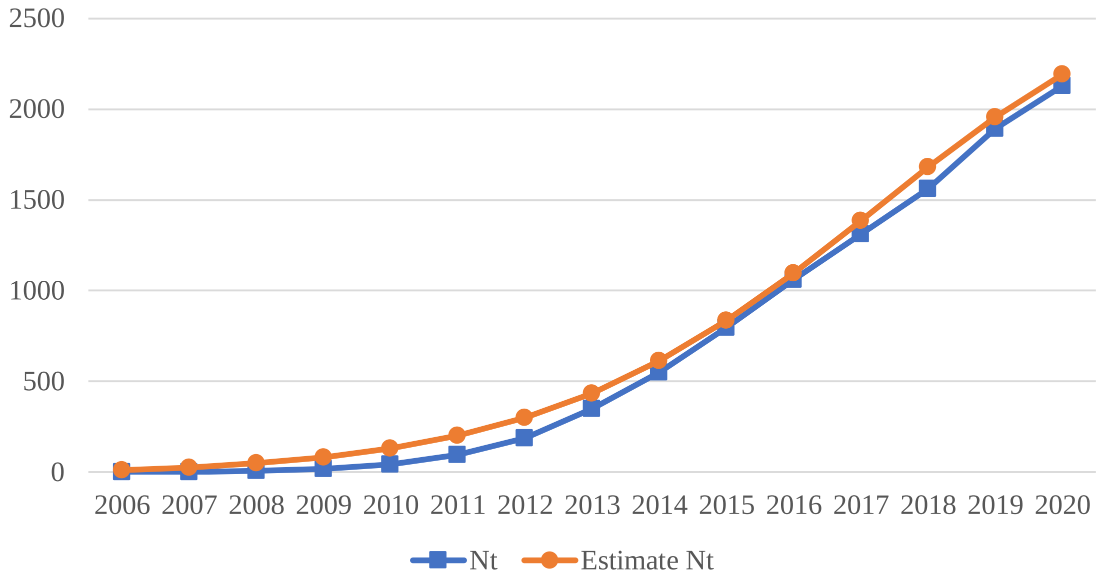

Figure 41. Cumulative Cross-Regional Diffusion Model Fit for Latin America

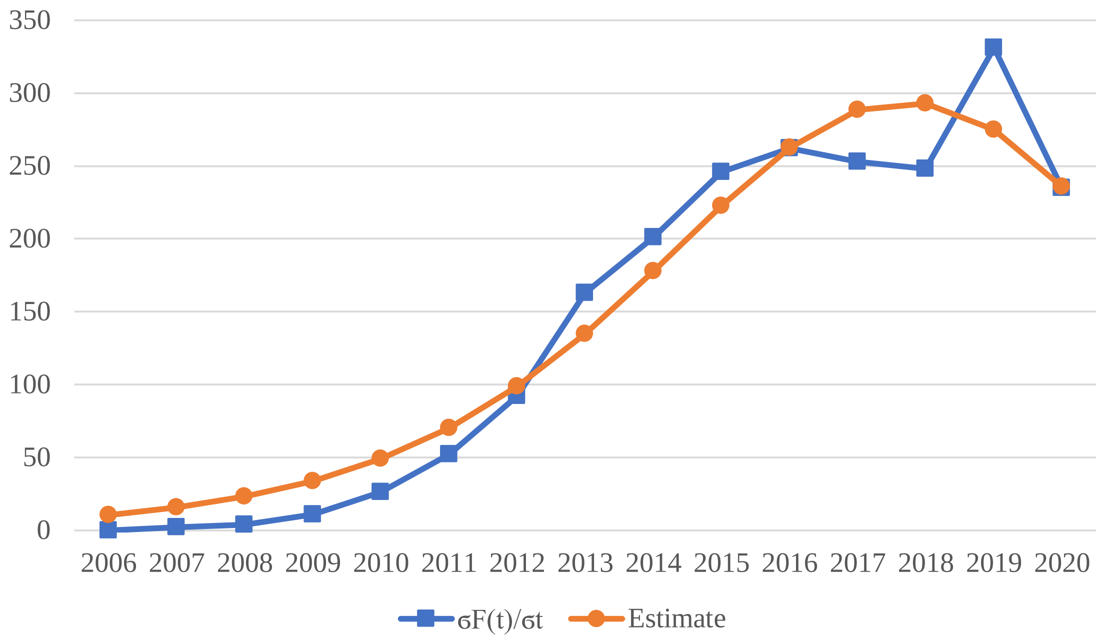

Figure 42. Yearly Cross-Regional Diffusion Model Fit for Latin America

When the annual charts of all three regions are examined from Figure 38, Figure 40, and Figure 42, it is possible to observe a weakening or even a decrease in the number of certification in 2015 and beyond. Looking at the cumulative graph curves in Figure 37, Figure 39, and Figure 41, it can be observed that North America has reached a certain saturation. However, the other two regions are still in the very early stages of diffusion. Considering that the purpose of the model used in the research presented herein is to reach and forecast the cumulative diffusion curves, it is seen from the graphs that it is pretty much close to this. R^2 values confirm this situation.

In addition to these descriptions, Table 3 also answers the main research question of whether a cross-regional learning effect has any impact on the diffusion of green building certifications. Accordingly, when the model was established, it was a matter of curiosity that three different regions met with green building certification at certain time intervals and, therefore, whether there was a lead-lag learning effect between them. The results show that North America affects both other regions. It affects Asia followed by a one-year interval and Latin America two years after it with the learning effect coefficients of 0.009 and 0.018. On the other hand, Asia's not affecting Latin America, which came two years after it, is among the results found for the lead-lag learning effect. Again, besides these findings, the lag-lead learning effect between Asia and North America was nonsignificant. While all these findings reveal the existence of learning effects at various scales between different regions, their different proportions and the fact that some of them being nonsignificant reveal that the reasons for the formation of this effect should be understood.

Ganesh, Kumar, and Subramaniam (1997) provide a practical framework for understanding these factors that can be examined comprehensively from Figure 7. According to this study, the factors determining the strength and rate of learning impact can be counted as follows: learning the benefits of the innovation from adopters, geographical proximity, cultural similarity, economic similarity, time lag, type of the market or product or users, and whether technical standard exists or not. These allow the interpretation of the results obtained from the models to make sense of the quantitative results and gain qualitative aspects.

When these factors are analysed in terms of the regions covered by the research presented herein, it will not be difficult to explain the strong learning effect of 0.018 between North America and Latin America. The most crucial element can be seen as the existence of an optimum time lag. This 4-year time gap can prepare the ground for the maturation of different situations in many respects for diffusion. Firstly, the benefit of green building certification can be observed. To put it more clearly, this time period is the cornerstone for the potential adopters in the lag country to be free of concerns about the product and to have an idea about its efficiency and performance by answering the question marks. At the same time, the time difference between the lead and lag regions can enable them to get information about the benefits of the product from those who have adopted it. Another factor that supports this is that the interaction between the agents of social systems is more accessible due to the high geographic proximity. It is a fact that geographic proximity directly affects the consumption of these commodities, especially when it comes to real estate. The further you move away from your habitual residence, the less likely you will own property in that area. Naturally, the rate of interest in the quality of the property in that region will decrease in the exact parallel. In our example, the flow of information for a property in a nearby area to have a green building certificate will directly awaken the interest in it and will consequently end by adopting it when the time is right. The adoption of a product has a direct link to the economic situation of the potential adopters. The better the consumer has a good income and the individual economy, the faster he/she adopts the innovation in direct proportion to this. Therefore, the learning effect increases with the proximity of the economies of different regions.

Another duo identified by the model to have a strong learning effect is North America and Asia. The learning effect coefficient determined by the model for these two regions is 0.009. Unlike the previous pair, only a 1-year time difference is mentioned here. For this couple, essential factors such as geographic proximity or a good time lag are in an opposite logic to explain this powerful learning effect. Because, as mentioned, there is only a one-year time difference, which raises the question of whether this is enough for green building certification to be heard and known. And when the situation is viewed in terms of geographic proximity, the two regions are very far from each other. This requires one to think that the transfer and sharing of information through agents between the two social systems are weak. Therefore, there is neither enough interaction nor time to observe the possible benefits of innovations. Consequently, it can be thought that the two main factors that make the most significant positive contributions to the learning effect do not contribute to this example. But here, the similarities of both economies are powerful, and the opposite characteristics of the markets have a decisive shaping role in the learning effect. The first contribution of economic similarity is interaction. The countries within these two regions that can be described as representatives of the region are among the world's largest economies. This situation can cause them to closely follow each other and have economic interactions in many different areas. The second contribution stems from the character differences of economies and markets. It is known that entrepreneurs and organizations of countries representing North America tend to take risks by developing much bolder strategies. As a result, the market has consistently demonstrated a more innovative character. On the other hand, the economies of the representatives of the Asian continent have always preferred to stay more cautious, guarantee and risk-free. In its most natural form, this situation causes the market to be more traditional and far from innovation. As a result of all this, the abstention of the Asian market causes it to act more like an imitator of innovative markets and adopt innovations mostly later. This interaction and character analysis may also explain the strong interaction despite the distance between regions and the short time interval.

Two different nonsignificant interactions were determined between the results obtained from the model used in the study presented herein. One of them represents the absence of lead-lag and the other of lag-lead learning effect. Continuing through the lead-lag learning effect, as in the above two interactions, it has been determined that Latin America is not under the influence of Asia in any way, despite the 3-year time lag. When this situation is examined and interpreted with the framework created by Ganesh, Kumar, and Subramaniam (1997), it appears that many items in the frame are not suitable for this pair. To begin with, it can be said that there is no geographic proximity. This status may conclude that the interaction between agents of social systems is minimal. In terms of economic similarity, it is possible to talk about markets that differ significantly from each other. While the Asian region has the decisive monetary power in the world, on the other hand, seeing the much weaker economy of Latin America with its country, which has adopted many socialist models, may explain the absence of interaction in this economic point of view. On the other hand, the lack of technical standards for green building certification in Latin America can be a vital barrier to its adoption, stimulating the learning effect. Although there was an ideal time difference, it can be explained that the learning effect did not occur since none of the other interaction factors prepared the appropriate ground.

When it comes to the last interaction, it is understood from the model results being nonsignificant that North America is not exposed to lag-lead learning effect from Asia. In contrast, the reasons cited above for Asia's influence from North America can be used to explain the absence of learning effect here as well. The fact that North America is more innovative rather than imitative may be the most robust explanation for the lack of a lag-lead learning effect. North America is not affected by Asia because it is a market that prefers to be more innovative and assertive rather than following different market dynamics and breakthroughs. The fact that the time difference between them is as short as one year can be seen as a factor that supports this effect to remain very weak. The fact that the adoption mobility in Asia in this short period of time was not strengthened enough may have caused it to not be on the radar of adopters in North America. Another reason can be seen as the geographical distance. The probability of interaction between these regions, which are very far from each other, is very low compared to the close regions.

CHAPTER 6

CONCLUSION

This research recognizes green building certification processes as one of the most valuable services provided in the last 30 years for a sustainable world. The potential of being in the construction industry that can contribute the most to the environment by removing its negative impacts, which offers the most damage to the environment due to its high energy consumption and excessive greenhouse gases and waste production, can be seen as the emerging point of this innovation. Drawing attention to the fact that although many aspects of this innovation have been studied, the dynamics of its adoption have not yet been examined; at this point, this study presented in this thesis aims to investigate the dynamics of the cross-regional diffusion effects of the GBCSs.

This research examines the diffusion dynamics of LEED, which is recognized as the most international certification system with its service in more than 160 countries around the world. This study aims to reveal the diffusion dynamics in North America, Asia, and Latin America regions and whether there is an interaction between these regions in adopting innovation with an empirical study. In doing so, it uses an extended version of the Mixed Influence Model proposed by Bass (1969) and extended by Kumar, Sunder, and Ramaseshan (2011).

By effectively addressing any social system with the least effort, the amount of adoption of innovation within that system can be observed with the Mixed Influence Model mentioned above. While doing this examination successfully, the model is easy to establish and simplify the social system it deals with, provided by the assumptions accepted in selecting the model. Acting on these assumptions, this model can explain the spread of innovations in any context with excellent performance rates. Some deductions, which are overshadowed by this success rate but need to be addressed for a good understanding of the model's functioning, are deemed too superficial and sometimes misleading by some scholars. These assumptions are as follows: each agent within the social system has only one adoption, there is no restriction or deficiency in the supply process of the innovation delivered to the market, and the production is always on track, marketing mechanisms and policies do not affect diffusion, the diffusion of an invention

Table 5. A Comparison and Review of the Empirical Research Studies in Cross-Regional Diffusion

Product / Field	Authors	Product Categories	Countries or Regions Studied	Range of "*p*" Values	Range of "*q*" Values	Range of Learning Effect Coefficient Values
Consumer Durable Goods / Marketing	Gatignon, Robertson, and Eliashberg (1989)	Dishwashers, Deep Freezers, Car Radios, Color TVs	Europe	0.1 - 0.26	0.08 - 1.77	------------
	Takada and Jain (1991)	Washing Machines, Room A/Cs, Passenger Cars, Calculators, Vacuum Cleaners, Radios	Pacific Rim Countries (Japan, South Korea, Taiwan, U.S)	------------	0.13 - 0.81	------------
	Helsen, Jedidi and DeSarbo (1993)	Color TVs, VCRs, CD Players	Europe	0.002 - 0.02	0.26 - 0.73	------------
	Kumar, Ganesh, and Echambadi (1998)	VCRs, Cellular Phones, Microwave Ovens, Home Computers, CD Players	Europe	0.0013 - .039	0.24 - 0.91	------------
	Kumar and Krishnan (2002)	Microwave Ovens, Home Computers, CD Players, Cellular Phones	Europe and U.K.	0.0005 - 0.026	0.38 - 0.61	0.002 - 0.009
	Michalakelis et al. (2008)	Mobile Phones and ISDN Connections	Eastern / Western Europe, North / Latin America, Greece - Italy	------------	------------	0.00013 - 0.02556
	Kumar, Sander, and Ramaseshan (2011)	Customer Relationship Management	North America, Europe, Asia-Pacific	0.000234 - 0.0059	0.35 - 0.68	0.006 - 0.014
GBCS / Construction Management	Present Study	GBCS (Green Building Certification System)	North / Latin America, Asia	0.0006 - 0.0038	0.34 - 0.4	0.0018 - 0.009

is independent of the propagation behaviour of other innovations initiated simultaneously, the propagation behaviours of an innovation's pioneer or successor do not affect the adoption of that innovation, adoption behaviour has only two aspects, that is, it is either adopted or not, and that there are no intermediate stages, the market potential of innovation always remains constant from the first time it is introduced till the end of its life cycle, in the spread of an invention, the rates of internal and external influence always remain the same.

When the results are examined by being aware of these assumptions and considering their two primary purposes, this research reveals some essential research findings. The first of these is that the mixed influence model has been seen to have very good convergences in explaining the diffusion of GBCSs and demonstrated that it could be used in future studies. The second is that GBCSs adoptions occur due to the combined effect of behavioural patterns with the external influence (innovation) coefficient, which has an average value of around 0.0018, and the internal influence (imitation) coefficient is an average value of 0.36. Third, as an interpretation of the second finding, internal factors are much more prominent in GBCS diffusion due to efficiency returns and bandwagon pressures. The findings so far are the results obtained to understand the diffusion behaviours of GBCS at the national level, which is the first purpose of the research. After this point, the findings are the results of the second purpose of the study, which is the question of whether different regions and markets have any interaction with each other.

Fourth, in the diffusion dynamics of GBCSs, cross-regional learning effects can occur in various situations. Those situations can directly vary through the relationships of these regions in different subjects. As a result of these relationships, two different degrees of lead-lag learning effect, 0.009 and 0.018, were detected between two of the several interactions of the three regions studied. This learning effect is thought to be directly related to the country characteristics, giving results that support the previous cross-regional diffusion studies. And the resulting results have been interpreted in this context. However, this status and similar empirical macro diffusion models can only draw a general framework for the triggers behind adoption. For more explanation and understanding, micro diffusion models need to be applied in line with this framework, and the results should be examined.

Along with these findings, it is possible to observe from Table 5 that it is the first study in the field of construction management among empirical studies examining cross-regional diffusion dynamics. Thanks to the research findings, which made a profound contribution to literature in this respect, some results can serve as a road map or guide in the hands of senior executives who produce marketing strategies in the construction industry.

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