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Measuring Optimum and Code-Plus Design Criteria For the High Rise Environment

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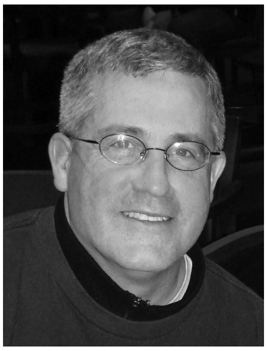

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Biography

Robert is the Assistant Vice President for Building and Life Safety Codes at NFPA. He oversees the operations of the department whose projects include NFPA 101, Life Safety Code and the NFPA Building Construction and Safety Code ™. Upon graduation from the University of Maryland, he worked with the Naval Facilities Engineering Command in Charleston, SC. Since 1986, he has held several positions at NFPA, including staff liaison for the NFPA water extinguishing systems projects. He has been an editor for several technical handbooks for NFPA including the Automatic Sprinkler Systems Handbook, NFPA Fire and Life Safety Inspection Manual, first edition of the NFPA Building Construction and Safety Code Handbook and he currently serves as an Associate Editor for the NFPA Fire Protection Handbook 20th Edition.

He has been active with numerous investigation projects for NFPA including the DuPont Plaza hotel fire, Meridian Plaza office fire, The Station nightclub and the Greenwood nursing home fire. He has managed much of NFPA's effort in developing code analysis and subsequent changes following the 2001 attacks on the Word Trade Center.

He is an active member of the JCAHO Committee on Healthcare Safety; Chairman of the Healthcare Interpretations Task Force; the Council on Tall Buildings and Urban Habitat; the AISC Fire Engineering Steering Committee; the UL Fire Council; the Building Security Council Advisory Council, The Infrastructure Security Partnership; and he serves as Secretary-Treasurer of the World Organization of Building Officials.

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Abstract

An initiative underway at NFPA involves the development of a document, utilizing a Risk Indexing System, to provide a measure to categorize and quantify the impact of selected design features that would be applied to high rise buildings based on a strictly voluntary basis. This building evaluation tool is referred to as the *Leadership in Life Safety Design* (**LLSD**) model. LLSD is an innovation crafted by the NFPA High Rise Building Safety Advisory Committee – HRBSAC. The LLSD concept builds on the content of the CTBUH *Building Safety Enhancement Guideline* that was released in May of 2002.

In general terms, LLSD takes a specific building parameter, such as building configuration or elevator use and assigns a point score for meeting a certain enhanced or code plus design feature. The development of these values will be derived based upon judgment and experience input using a Delphi panel or some similar approach. The LLSD model will describe features that could be included in the design to provide some level of performance over and above the typical *de-minims* criteria that safety codes and standards normally provide.

Safety criteria, structural design criteria and operational criteria dictate additional provisions that work to minimize the impact of various hazards on the building. While fire, seismic and wind loads are commonly accounted for in the design process, a wide spread (and controversial) debate continues with regard to defining the appropriate levels of performance and safety associated with high rise buildings. LLSD is one model that can be considered by developers, owners and the design community to measure the impact of providing some redundant system, feature or enhancement to advance the level of safety

Keywords: Plus; Extreme Event; Leadership in Life Safety Design; Optimum Design; Risk Indexing System

Introduction

Acute attention has been directed at the level of safety in high rise buildings since the September 11, 2001 terrorist attacks. High rise buildings have traditionally received special scrutiny due to their unique nature, the potential to accommodate large building populations and the challenging conditions presented to first responders during fire fighting and rescue operations. Modern day code requirements – circa 1980 – have provided for extensive use of fire resistive construction, installation of automatic sprinkler systems, installation of building wide fire alarm systems that incorporate a voice communication component, back up power and other features that work to increase the safety of occupants and first responders.

In the six years since the terrorist's attacks, codes and standards organizations including NFPA, International Code Council and the American Society of Civil Engineers among many others have made some changes, or are in the process of making changes, to key codes and standards that have a direct impact on high rise criteria. These organizations have worked to strike a balance between making meaningful changes to improve safety in some manner but to limit the expectation that a building (high rise or even non-high rise) can be made to be one hundred percent safe from all design hazards – natural, human caused, hostile acts – all of the time.

In certain circles', these design hazards are referred to as 'extreme hazard events'. One definition of an extreme hazard event is: *Extreme hazard events are incidents that make demands on a building, its systems, and its occupants that go beyond the usual design parameters imposed by codes, standards, and good professional practice.* The concepts that have emerged from this discussion require careful deliberation of two fundamental issues-what are the appropriate levels of performance to be considered and what are the consequences of providing multiple levels of safety?

In the case of the first question, any changes to codes or any changes to the building features should be appropriate and meaningful. Architects, engineers, developers and owners can agree to make changes but it should be clear that changes are not expected to be made solely for the sake of change. In the case of the second question, organizations like NFPA that develop codes and standards must be prepared to establish a set of criteria that distinguishes between the code norms (minimum standards) versus a program or supplemental design instrument that speaks to design choices that would be viewed as being in excess of the minimum rules and regulations.

A three year study concerning the building failures at the World Trade Center complex was conducted by the National Institute of Standards and Technology (NIST).[i] This study, completed in October of 2005 established 30 major recommendations, many directed at the codes and standards organizations, to carefully evaluate the design criteria for high rise buildings that existed prior to September 11, 2001. The NIST recommendations provided very broad (and in some cases, open to interpretation), ideas that required various levels of effort to arrive at the need to make an amendment to established codes and standards. If agreed upon changes were in order, the next challenge centered on how to change the existing criteria, including establishment of an adequate rationale to revise the regulation.

Activity to Date

NFPA technical committees involved with NFPA 101, *Life Safety Code* and NFPA 5000, *Building Construction and Safety Code* had (independently from the NIST Study) incorporated myriad changes into NFPA 101 and NFPA 5000 in both the 2003 and 2006 editions of the two Codes that addressed enhanced safety in high rise buildings. The 2008 edition of NFPA 70, *National Electrical Code* includes a new article dealing with hardened/redundant power supplies. This new provision, contained in Article 708 is entitled *Critical Operations Power Systems* (COPS). This article looks at acceptable methods to increase both the reliability and functionality of crucial power supply systems under potentially adverse circumstances.

Concurrent with these technical committee activities, the NFPA Standards Council formed the High Rise Building Safety Advisory Committee (HRBSAC) in 2004. The scope and purpose of the HRBSAC was to assist NFPA with the process of reviewing the NIST recommendations, assigning specific recommendations from the NIST studies to specific NFPA technical committees for further analysis, review and follow-up and to independently determine any other provisions that may provide for enhanced levels of safety in the high rise environment.

As a part of the HRBSAC deliberations for this task, a concept emerged as it related to the level of safety that could or would or should be provided in the high rise environment. As previously noted, numerous changes to NFPA 101 and NFPA 5000 were made that had a direct effect on high rise buildings. Other changes, however, either could not be readily codified or they were viewed as an optimum level of performance. These discussions lead to the launching of the Leadership in Life Safety Design, LLSD, concept.

LLSD grew out of the *Building Safety Enhancement Guideline* that was published by the Council on Tall Buildings and Urban Habitat (CTBUH) in May of 2002. This Guideline established a set of broad building component categories and complimented it with a series of enhancements or upgrades that could be voluntarily provided by the building owner to improve the level of safety, reliability, performance or all three. At this time, the HRBSAC model is being reviewed by the Fire Protection Research Foundation (FPRF). The ongoing effort is to establish a method to categorize and quantify the performance levels of the 12 building parameters selected for enhancement in the LLSD model and to develop a Risk Indexing System (RIS) that could be applied to the building design. The result being a building design that could be given a performance level utilizing a relative descriptor such as bronze – silver – gold – platinum. Each category would have to show some minimum level of enhancement to show how optimum or "code plus" design options have been included in the design of the building.

While any number of differences and challenges are presented by this concept, two of the more obvious are: Why would an owner/ developer want to pay for non-required design enhancements and what method would be of most benefit to determine the scoring systems for multiple enhancements –some that have interdependence on other features and some that are independent all together.

LLSD and the companion RIS that would be integral to its use would be applied on a voluntary basis only. An owner or developer could market a property based partially on its LLSD rating. Two similar systems that parallel the LLSD are the *Leadership in Energy and Environmental Design* (LEEDs) and the in-progress Building Security Council (BSC) *Building Security Rating System*. Both of these programs are intended to be applied on a voluntary basis with each providing a menu of superior or upgraded building features that can be selected and applied to a structure to enhance the performance level.

In the case of the LEEDs program, the benefits would be reduced energy demands, improved efficiencies in heating and cooling demands, use of low impact construction materials and a rating based on the emerging popularity of green building design concepts. The BSC *Building Security Rating System* provides a menu of project enhancements that range from site improvements, security measures, enhancements to structural systems and augmentation of building systems (HVAC, electrical, fire safety) through increased robust/redundant design. The proposed rating of the BSC classification would be based on a verification of the level of additional features or enhancements that the project incorporated.

Development of the LLSD concept within NFPA has been turned over to the Fire Protection Research Foundation-FPRF. FPRF is an independent organization whose primary mission is to plan, manage and communicate research in support of the NFPA mission. Research programs range from automatic sprinkler performance and protection for specific hazards, to alarm and detection to fire fighter safety issues.

FPRF Project Goal

The goal of the FPRF project is to fully evaluate the LLSD concept and its implementation options. This will be done through the following:

- review the work done to date on the concept;
- define and describe the various building attributes and related parameters that would make up the evaluation process;
- clarify the proposed point scoring system such as the previously mentioned Risk Indexing System;
- summarize the applicable literature;
- provide a comparison to similar related concepts and programs; and
- summarize the perceived advantages and disadvantages to all who would have a relationship to the LLSD concept implementation.

The FPRF evaluation of the LLSD concept is actually part of a larger on-going project to develop a methodology to measure the effectiveness of code compliance enforcement as it relates to fire safety. The principal application of the code compliance effectiveness measurement methodology is as a management tool for use by state and local fire prevention personnel and others responsible for code compliance activities. The LLSD concept is being explored as a secondary application to this larger project on the measurement of code compliance effectiveness since it is a comprehensive evaluation protocol for buildings. LLSD is one direct application to a proposed methodology.

The LLSD concept would conceivably provide a comprehensive fire safety evaluation of an eligible building, and would lead to formal, public recognition of those buildings achieving higher levels of safety and protection than are required by applicable building and fire safety codes and regulations. A code compliance effectiveness measurement system as envisioned in the larger FPRF project would generate data on safety-related conditions, and it could be a valuable component of the evaluation protocol envisioned for LLSD. As a minimum, a recognized building will need to be fully compliant with applicable codes and regulations so that its enhancements can be recognized as improvements to safety rather than as compensation for deficiencies in other aspects. Full compliance should be subject to determination through a well-designed code compliance effectiveness measurement system, and LLSD is considered appropriate for this application.

Application and Elements of the LLSD

The HRBSAC has completed some preliminary work on the LLSD concept. At this point in time, the LLSD approach is viewed as a voluntary model that can be applied to provide various enhancements to a building design project in order to provide an optimum or most favorable design to the structure. LLSD application to a building will allow for design hazards that are outside the norm to be addressed by the building design team.

The LLSD program is configured and established to provide an analysis tool for building owners, building operators and designers to evaluate the impact of various building features that could be added or enhanced to provide an increased level of building performance. Those additions would be considered and applied on a purely voluntary basis and would translate to increased levels of safety to the occupants and first responders. Improvements to the resiliency of the structure and its component systems will also allow for better performance related to mission and business continuity.

The draft LLSD model is devised to address twelve major categories that relate to attributes such as building geometry, component/cladding features, construction, systems and operational features among others. Each of those major categories is further divided into a specific feature that if applied, will predictably provide some further enhancement for the structure.

A risk indexing system (RIS) is the central focus of the LLSD worksheet. The RIS provides for a weighted point score system that offers positive values for the applied enhancement. Conversely, the RIS results in a negative value for a provision that is deemed to be a negative indicator for that particular feature. This does not intend to state that the building is inherently unsafe; it is simply to point out that the structure has some element that may increase its potential as an attractive target or it may have a feature that is disadvantageous. The number of stories, icon status, high profile tenants, and number of occupants are among the attributes that may increase the likelihood of a building being higher in a target list thus increasing the need for more enhanced features.

While the LLSD may have its origin in trying to judge other design features and elements that may mitigate or greatly minimize the impact of an extreme event-technological, natural, hostile act- on the structure, these features may also greatly work as an intervening measure to provide protection against other events that fall well short of an extreme event. These measures may help with accidental power failures, select weather events and general security threats. Improvements to occupant safety, first responder safety and continuity of operations are among the derived benefits of applying the LLSD as part of a comprehensive building analysis.

Building Program Elements and Parameters

The LLSD establishes twelve building parameters that are evaluated to determine what enhancements should be considered and the point value that is to be applied to that particular enhancement. The twelve building parameters are:

- **1.0** Building Configuration, General Conditions
- **2.0** Building Enclosure
- **3.0** Fire Resistive Construction
- **4.0** Elevator Use and Configuration
- **5.0** Stairs and Enclosure
- **6.0** Areas of Refuge/Special Escape Systems
- **7.0** Building Systems
- **8.0** Structural Systems
- **9.0** Security Protocols
- **10.0** Chem-Bio Criteria
- **11.0** Operational Requirements
- **12.0** Innovation Special Design

These twelve building program elements serve as the foundation for the LLSD and are the basis for the evaluation and its associated series of building enhancements that can be considered and applied. For the most part, these elements and associated enhancements are independent from one another. However, interdependence between elements may emerge as different enhancements for different programs elements are applied. The LLSD does not attempt to specifically account for these conditions but it does recognize such circumstances.

An example of this would be a combination of standoff distance and blast resistant design and construction features that obviously can maximize protection of the occupants and the structure. While each individual feature provides an enhancement, collective application of these elements will provide a greater margin of performance. In other cases, an incidental improvement to one enhancement feature may be all that is necessary to gain credit for another enhancement feature. An example of this would be a full analysis of the structural frame concerning fire performance (structural frame approach) that may result in the use of a more resilient connection that may enhance performance under a blast load and a fire event and that will incur no additional cost or a minimal incremental cost.

Through utilization of this approach, the intent will be to strive for increases to building safety and survivability by voluntary compliance with the enhancements developed form the RIS checklist. The LLSD approach will allow for some but not all suggested enhancements to be applied to a given feature or design.

It is currently envisioned that prerequisites (does the building meet some basic criteria) be established or determined. Some of these prerequisites will have little to no flexibility. As an example, location of the structure or proximity to other icon status buildings may not have any flexibility for scoring purposes in the RIS. Enhancements to increase the desired level of safety would be given a "positive" score while a less than ideal or detrimental attribute would be given a "negative" score with regard to the overall life safety of the building. Desired outcomes are buildings that contain systems, equipment & design features superior to those that meet minimum requirements.

As noted, the twelve Program Elements provide the basis for the LLSD and the approach to an analysis. Application of the enhancement features should consider their impact not only on that element, but also so that it does not inadvertently have a negative impact on some other element. If parameter 9.1 (security screening for all occupants and visitors) is applied, the screening location and any related equipment must not have a negative impact on parameter 1.1, which would require design of a means of egress system that allowed for unfettered access to a public way. An overview for each Program Element follows.

1.0 Building Configuration. This element consists of various geometries associated with the design of the building, some of which may not be under control of the designer. Siting issues in densely populated urban spaces may simply have no flexibility or allowance. The building lot may simply be in a specific location or plot that is adjacent to other privately held lots under different ownership.

The number of stories of the building drives a consideration that prescribes an increase to the risk associated with the building with many stories. While a high rise building with 10, or 40 or 100 stories is not inherently dangerous, should a hazardous situation develop in that building, the consequence of that event does increase as the building height increases. More occupants of the building would be at risk and failure of a façade element has a greater potential to affect surrounding properties.

2.0 Building Enclosure. Building envelope systems may serve to provide for efficiencies in heating and cooling loads among other benefits. Additionally, the facade design may also provide both natural and artificial lighting.

The materials used for the building enclosure also play an integral role in containing fire and flame spread between floors as well as between adjacent structures. Façade designs can also consider and integrate the use of materials of construction and techniques that can provide some level of protection against localized blast loads. Many of the parameters associated with element 2.0 relate to element 8.0.

3.0 Fire Resistive Construction. Building construction types generally fall into the five broad categories. In accordance with NFPA 5000, these include:

- Type I
- Type II
- Type III
- Type IV
- Type V

These construction types range from the fire resistive (Type I) to basic wood frame (Type IV). Nearly all high-rise building construction is limited to Type I and Type II. The selection of construction type will drive the allowable floor plate per story as well as the allowable height that the building can be built to.

An important feature of the construction type will also provide for default, hourly fire resistance ratings that would be applied to key structural systems and elements. This includes hourly fire resistance ratings for columns, beams, girders, exterior load bearing wall systems, roof support systems and floor slabs.

Hourly ratings of these systems might be achieved through various means including use of mechanic enclosure, concrete materials, fire resistant steel (FRS), composite designs or some combination there of.

4.0 Elevator Use and Configuration. Historically, elevator use in a building is limited to everyday "normal" use. Rapid transport of occupants to aid from upper floor levels provides for a very important convenience to the occupants. From the practical standpoint, building heights would likely not extend much more than ten stories if it were not for elevators.

Programs and projects are under development at this time to determine under what conditions, circumstances and situations that passenger elevators could remain in use during certain building emergencies, including fires. Effective and efficient evacuation of large building populations is possible if the elevators are designed to remain in service for as long as possible. Such efforts will also benefit the disability community by providing a more realistic means for occupants who are unable to negotiate stairs to escape sooner. A side benefit will involve better reliability of the elevators when being used by fire department personnel.

Component and equipment design for elevators to allow them to remain in service for longer periods of time is feasible and will likely be a reality by 2009. Integral to the equipment design is the operational aspect. Operational aspects would consider familiarization of the building occupants with regard to the use of the elevators. See additional discussion on this under 11.0, Operational Requirements.

5.0 Stairs and Enclosures. Configuration, location, separation and design of stairs have always been an integral part of the means of egress design for all buildings. Remoteness of stairs is intended to provide physical separation of some sort to minimize the possibility of a single event (usually a fire) from rendering the stairs out of service. Alternatives to the spacing rules used in US codes, adding additional egress capacity through increases to stair width or through use of scissor stairs are the types of concepts to be considered. Stairs are, and will likely continue to be the primary means for occupants to move out of buildings or structures during most types of emergencies.

6.0 Areas of Refuge/Special Escape Systems Use of 'refuge floors' would be one example of a design enhancement in this category. A dedicated floor (or multiple floors) is typically set aside as an accumulation point for occupants from different floors to relocate to. Such spaces may be provided with supplemental provisions (water, flashlights) and would include components for communications with fire authorities so as to keep information for occupants up to date.

7.0 Building Systems. This category includes use of design approaches that provide for hardened, robust and redundant features for building utilities. The use of physically separated and independent electrical power risers to critical electrical supplies throughout out the building or structure would be an enhancement feature for the electrical systems.

8.0 Structural Systems. Enrichments to the building structural systems have a variety of options that fall under this enhancement category. Wind tunnel analysis, mitigation features for progressive or disproportionate collapse and enhanced connectivity for structural components are among the features that can be considered for stepped up structural enhancement. At present time, US organizations such as the American Society of Civil Engineers (ASCE) and the National Council of Structural Engineering Associations (NCSEA) are working on standards to codify such analysis procedures.

9.0 Security Protocols. In place and active measures for screening of building occupants and use of visible ID cards can be used to gain plus points in this category. Restrictions on vehicle proximity to buildings such as no parking within the structure, or no parking immediately adjacent to the structure work to remove potential threats from the building. Video monitoring and integration of *situation awareness* concepts are added considerations that would fall into this category.

10.0 Chem-Bio Criteria. This is one of the emergent technology areas. Certain elements in this category include location and positioning of HVAC intakes. Other considerations in the not too distant future are likely to include sensing devices that are designed to monitor air quality for a variety of foreign substances.

11.0 Operational Requirements. The list of elements proposed in this category encompass everything from the credentialing for the design professionals who administer the LLSD program, to the establishment of a formalized commissioning program for the selected and applied enhancements. Another key element in this category includes development, application and utilization of a dynamic planning guide for the building occupants. The guide should consider the types of emergencies that should be considered, the appropriate action to be taken depending upon the nature of the event, the role that elevators would play in managing relocation or evacuation action plans and an element to practice or drill the occupants on their actions.

12.0 Innovation Special Design. This is the last category to be considered. Buildings or building components designed using a performance based design (PBD) approach might be one consideration for use in this grouping. Concepts and content seem to crop up every month with regard to untried (or in some cases, unheard of) technologies, material or systems that attempt to further mitigate the range of design hazards that currently exist, or that are now being discussed in the design community.

Implementation Issues and Conclusions.

The background given here provides a starting point for an enhanced building design approach. Various papers and texts have been developed on this notion over the years. In 2006, the text *Extreme Event Mitigation in Buildings; Analysis and Desig* was published. This text provides for an extensive review of the realm of hazards that may fall into the category of an extreme hazard event. While the design community is far from achieving a consensus on many of the issues that the LLSD would address, there is obvious interest in working to have a full disclosure and open debate on the pros and cons of establishing any enhanced building design features. The number, type, nature and relative values of the presence (or lack) of a given feature will likely be a topic of great debate and deliberation. A sampling of 3 of the 12 categories described is presented below so as to give an idea of the format and concept of several elements. Work in this area will be in progress for several years. It is expected that during this time, some of the suggested parameters may indeed become mainstream or even transition from being optional or offline concepts to more mainstream.

Element 1.0 Building Configuration, General Conditions

Prerequisite	**1.1**	**Meet All Local Building Codes and Standards**
POINT VALUE		
	1.2	**Building / Site Separation**
1		≥ 12’-0” lot line
1		≥ 24’-0” lot line
1		Maximize Building Protection in Adjacent Scenarios
1		Maximize Building Standoff Distance from Explosive Source
	1.3	**Building Height**
		0-8 Floors
(1)		9-40 Floors
(2)		0-80 Floors
(3)		0-120 Floors
(4)		> 120 Floors
	1.4	**Building Use / Function**
(1)		Iconic Status
(1)		Critical Function
(1)		At Risk User
	1.5	**Vehicular Stand-off**
1		No Vehicular Access at Building Footprint
1		12’-0” Vehicular Separation
1		24’-0” or Greater Vehicular Separation

Element 3.0 Fire Resistive Construction

Prerequisite	**3.1**	**Superstructure Protection Per Local Code**
POINT VALUE		
1	**3.2**	**Columns, Girders, Beams 3-Hour Rated**
1	**3.3**	**Increase Slab Construction 1-Hour**
1	**3.4**	**Increase at Stair, Elevators, Vertical Shafts and Corridor 1-Hour**
1	**3.5**	**Use of Impact Resistant and Adhesion Enhanced Fireproofing**

Element 7.0	HVAC / Fire Protection / Electrical	
Prerequisite	7.1	Per Code - Emergency Power Dual Source Fire Command Center Building Management System

POINT VALUE

1	7.2	**Dual Feed Sprinkler with 2-Hour Back-up Water Source (water storage tanks)**
1	7.3	**Separate Electrical Feeds (back-up generator) for Fire Pump(s)**
1	7.4	**Floor Pressurization / Smoke Evacuation System (purge)**
1	7.5	**Increase Fire Protection (sprinkler design area) by 100%**
1	7.6	**Structurally Enhanced Impact Resistant Enclosures for Sprinkler Storage and Emergency Electrical Risers**
1	7.7	**Reinforce Equipment Anchorages to Prevent Failure During Event and Prevent Further Destruction of Main Structure**
1	7.8	**Fire Brigade Cache Rooms; Direct Access to Egress Stairs or Dedicated Fire Brigade Elevator**
1	7.9	**Redundant Water Service**
1	7.10	**Redundant Water Pumps at Remote and Protected Areas of the Building**
1	7.11	**Connect All HVAC Systems to Building Information System and Security**
1	7.12	**Separate Public and Tenant HVAC Systems**
1	7.13	**Air Intakes Not at Street or Ground Level of Property**
1	7.14	**Air Filtration Systems for All Intake Air**
1	7.15	**Air Quality Detection System Connected to BIS**

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CTBUH Council on Tall Buildings and Urban Habitat, Lehigh University, Bethlehem, PA -USA

LEED ***Green Building Rating System***™ US Green Building Council Washington, DC -USA

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