Helwan University
Faculty of Engineering-Mattaria
Architectural Department

Sustainable Rating System for Architectural Evaluation of Bridges in Egypt

Thesis Compiled and Presented by
Architect: Mohamed Osama Saied Ahmed

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Architectural Engineering

Under the Supervision of

Assistant Professor Doctor. Sahar Morsy Mohamed
Assistant professor- Architectural Department
Faculty of Engineering- Mattaria - Helwan University

Doctor. Emad Kamel Fahim
Teacher - Architectural Department
Faculty of Engineering- Mattaria - Helwan University

Cairo, 2016
Part 2: Analytical Study
Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge’s Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture
Chapter 4: The Relationship between the Bridge and its Context
Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form

Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study
Developing an Egyptian Sustainable Bridge Rating System

Chapter 10: Sustainability Assessment Concepts
Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12: Conclusion and recommendations

Appendices
Chapter 7: The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

Chapter 7 structure: The Effect of Aesthetical Considerations and Creativity on Bridge Architectural Design.
Chapter 7: The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design

Introduction

Bridge design is a process requiring the use of science, technology, and artistic judgment for its finest design solution. Aesthetics, the study of the mind and emotions as they relate to the sense of beauty, is concerned with visual appearance and quality. In bridge design, as in architecture, excellence is achieved by integrating science, technology, and aesthetics. The bridge designer must strive to understand the creative artistic process, as well as scientific and technical principles, and merge the most fundamental concepts into a unified theme for an expressed purpose. The principles of aesthetics that stimulate the senses in most viewers are proportion, order, simplicity, balance, color, and texture. Design excellence requires designers to orchestrate these aesthetic principles with the physical and geometric components of a structure. The appropriate application and integration of these principles, together with sound structural and functional design, can result in bridge forms that exhibit strong visual character and quality.1

The two visual concepts used to develop, describe, and express visual ideas are: visual design elements and aesthetical qualities.

Visual design elements and characteristics define visual perception. These elements include line, shape, form, color, and texture. They can be used to articulate visual concepts.

Aesthetical qualities result from employment of visual design elements and are used to describe a visual composition. Aesthetical qualities of design are intangible, perceived qualities arising from the relationships of design elements. The properties of aesthetic qualities are proportion, rhythm, order, harmony, balance, contrast, scale, and unity. These properties are basic elements of creative design compositions common to all fine arts as well as bridge architecture. The discussion below describes these basic qualities as they relate to aesthetical design.2

7-1- Fundamentals of Aesthetical Design and Aesthetic Qualities

Fritz Leonhardt, German author and bridge designer, expressed the concept of geometric proportion very succinctly: "For structures it is not sufficient that their design is 'statically correct.' A ponderous beam can be as structurally correct as a slender beam but it expresses something totally different. Proportion helps to successfully define the relationship among structural elements and implies the order of significance of the elements. In design, the most obvious proportional relationships are based on relative size and shape of the elements. There can also be proportional degrees of surface texture and color."3

7-1-1- Proportion

Proportion is a method of creating a sense of order by assigning appropriate relative sizes to the various elements. The goal is appropriate proportions between the various parts of a structure comparing its height, width and depth, solids and voids, and

---

1 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p1-3.
2 - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012-p 44
3 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p 41-42.
Comparing areas of sunlight and shadow.\footnote{1}

As shown in table (7-1), most important proportion consideration during bridge design are studied.

**Table 7-1: Important Proportion Consideration during Bridge Design**

<table>
<thead>
<tr>
<th>The slenderness ratio</th>
<th>The proportion between depth of superstructure and bridge span is an important ratio.</th>
<th>Captain Cook Bridge over the Georges River has a ratio of 1:18 and together with its gentle vertical curve has a very slender appearance.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The relationship between the bridge height and span</td>
<td>As a general rule the higher the bridge the wider the span. It is generally not practical to vary span with height unless two or more superstructure types are used.</td>
<td>Elsalam bridge in Egypt As an example for relationship between the bridge height and span.</td>
</tr>
<tr>
<td>The relationship between pier thickness And superstructure depth</td>
<td>The ratio of pier width to superstructure depth should also be considered carefully. Bridges with all thin piers relative to superstructure depth can appear odd, as can the opposite.</td>
<td>The pier widths used on this bridge In Kerrigan- USA appear too thin and almost spindly in comparison to the depth of the girder and parapet.</td>
</tr>
<tr>
<td>The relationship between deck overhang and parapet depth</td>
<td>The ratio of deck overhang relative to parapet depth is also considered a significant aesthetic proportion.</td>
<td>The generous deck overhang is important to consider as part of the bridge cross section. Stockon</td>
</tr>
</tbody>
</table>

References: http://www.arabcont.com/projects/images/canl-3-1.jpg

**7-1-2-Rhythm**

Is the regular recurrence of any like elements in, on, or around a structure. It requires that the elements have some similarity of visual characteristics in addition to a modulated placement. In bridges, for example, major rhythms are created by the repetition of similar pier shapes. Minor rhythms may be created by the spacing of light poles, post spacing within a railing, or even the horizontal rustication on a pier.

Modulating the placement of these elements can create visual flow or movement across the scene. A good example of this is when pier spacing gradually increases near the

\footnote{1} Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges" - Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p 41-42.
main span when a bridge crosses a wide river or lake.\textsuperscript{1} Figure (7-1)

\textbf{7-1-3-Order}

Order refers to arrangement. It is the arrangement of design elements so that they work together as a unit without visual confusion. The whole arrangement works as a unit with each element having a proper place and function. The selection of a constant girder depth throughout the structure is an element of good order. Order is also achieved by limiting the lines and edges of a structure to only a few directions. Under the rule of order, the regular recurrence of similar elements in a composition creates a natural flow, known as rhythm, that is satisfying to the eye. Figure (7-1)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{rhythm_order}
\caption{Rhythm and order}
\end{figure}

\begin{itemize}
\item \textbf{Complexity and Order}
\end{itemize}

As Leonhardt (1984) writes, this should not lead to overall monotony through endless repetition. To avoid confusion and displeasure, he also gives advice to limit the number of spatial directions into which the lines and edges of the structure run. He also cautions to consider the three-dimensional appearance of substructure and superstructure. “We must also check the appearance of the design from all possible vantage points of the future observer. Often the pure elevation on the drawing board is entirely satisfactory, but in skew angle views unpleasant over lapping are found. We must also consider the effects of light and shadow”.\textsuperscript{2} Figure (7-2)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{complexity_order}
\caption{Rearranging the Parts Provide an Ordered and Pleasing Shape}
\end{figure}

\textbf{7-1-4- Harmony}

Harmony is the relation between the elements of a design based on similarity of their visual characteristics. The relationship must be complementary. If the planes or lines in a design have more dissimilar characteristics than they have similar characteristics, they are not likely to be perceived as harmonious. This is most readily achieved by using the Law of the Same or the Law of the Similar. \textit{Law of the Same}: Harmony may be perceived or created in a structure or composition of structures that attains order through the repetition of the same elements, forms, or spaces. \textit{Law of the Similar}: Harmony may be perceived or created in a composition that attains order through the repetition of similar elements, forms, or spaces.\textsuperscript{3} Figure (7-3)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{harmony}
\caption{Harmony}
\end{figure}

\textbf{7-1-5- Balance}

Visual balance is the perceived equilibrium of design elements around an axis or focal

\textsuperscript{1} "Bridge aesthetics around the world"- Committee on General structures, subcommittee on bridge aesthetics- Transportation research board- National research council- Washington- USA-1991- p 115
\textsuperscript{3} "Bridge aesthetics around the world"- Committee on General structures, subcommittee on bridge aesthetics- Transportation research board- National research council- Washington- USA-1991- p162.
point. Rather than a physical balance, it may also refer to equilibrium of abstract elements of the design such as masses, visual weights, texture, etc. Visual balance is fundamental to all successful compositions.  

Figure 7-3: Harmony and Balance

7-1-6- Contrast
One principle of contrast is the dynamic relationship among parts of a design based on complementary opposition of visual characteristics. Contrast relieves the monotony of simple harmony by complementing harmonious characteristics of some design elements with their opposites, thus adding a heightened awareness of each other. Swiss bridge engineer, Christian Menn, exemplified this concept in some of his works. In one instance, he erected a delicate and graceful concrete structure in a rugged, gray alpine gorge. This graceful bridge is foreign to the natural character of the craggy mountain background. Yet by sharply contrasting this elegant bridge with the rugged mountain setting the strongest qualities of each were dramatized.

A second principle of contrast is that of dominance. This concept relates to one of two contrasting elements commanding the visual attention over the other. One becomes the supporting background. In terms of design, a dominant theme is essential in organizing the design into a pleasing aesthetics experience.  

Figure 7-4: Contrast in Bridges Design

7-1-7- Scale
Scale refers to the size relationship among various features of the structure and between the total structure and its surroundings. Since design concerns itself with things that are to be used by people, a connection exist between the human body and designed objects. We often refer to structures that respond to the size of the human form as having human scale. This would be particularly true for a pedestrian bridge or any bridge with high pedestrian usage. When a bridge becomes exceptionally large, many of the component

1 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p-43-44.
3 - https://www.pinterest.com/pin/381680137139837898/
elements lose their human scale. Elements such as piers, pylons, or superstructure members may take on monumental scale. Here it becomes more important that the structure be in scale with the surrounding environment. In architecture we deal primarily in 4 scales:

- Human scale (The Man size scale).
- Intimate scale.
- Monumental Scale.
- Shock Scale.

**Human scale** (The man-sized scale) is what we are used to. Our houses are typically built to this natural scale. A man feels comfortable walking through our doorways. The ceiling neither bumps his head, nor is lost in the shadows.

**Intimate scale** are smaller than what is normal. Not Lilliputian. These do not shock you, but they are smaller than what we expect. Not everybody would recognize intimate as a separate category. It is more of a sub-category of human-scale

**Monumental scale** is impressive. Our public buildings are monumental. This is a statement of hierarchy. Those institutions represented by those buildings are bigger than us and we should stand in awe of them.

**Shock scale** can be either smaller or larger, but it is so out of the ordinary that it jolts us. You sometimes see it in art, and in architecture that strives to shock.  

**7-1-8- Simplicity**
Refinement of design should generally be pursued. Embellishments and ornamentation often do little to change the basic aesthetics of a structure.

Refinement of a structure, so that it better represents the forces that it is designed to withstand, is generally a feature of a bridge of aesthetic merit. This is often referred to as honesty of form and design integrity.

Nonetheless, it is unwise to insist that a bridge is perfect only if nothing can be omitted; there may be good reasons for avoiding total refinement based upon local context.

**7-1-9- Illusion**
What people perceive is not always what is really there. Our vision is susceptible to manipulation and illusion. Designers can use illusion to improve the appearance of an element. For example, placing a series of vertical grooves on a column will make it appear thinner.

**7-1-10- Unity**
Unity is presented last because it encompasses the perfect application of all the other qualities. It refers to the combined effects of all other aesthetical qualities applied simultaneously. Unity is the condition, or state, of full resolution of the site and project functions. Unity implies harmony where all of the elements are in accord, producing an undivided total effect. Unity provides the observer with a sense of wholeness, generated by some central or dominating perception in the composition. Figure (7-5)

**7-1-11- Consistency**
Consistency of form is an important aesthetic consideration. This is not to say that everything must look the same but that in a particular context there should be a relationship between elements. As shown in table (7-2) examples of Fundamentals of aesthetical design and Aesthetic qualities in bridges are overviewed.

---

2 - "Design manual for roads and bridges" volume 1 highway structures- approval procedures and general design- section 3 general design- part 11- the design and appearance of bridges- USA-1998- p 4/2.
3 - Bridge aesthetics source book"- The American association of state highway and transportation officials - USA- 2010- p45.
4 "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 45
Part 2 Chapter 7 The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

7-2- Aesthetical Design Objectives to Aid Designers in Visualizing, Evaluating, and Articulating Bridges Design

Throughout the design process, designers should have aesthetic goals or objectives for the bridges they design, just as we have engineering objectives for safety, economy, serviceability, etc. As with engineering objectives, aesthetic design objectives should be established prior to the start of the design process so they can serve as an aesthetic compass, of sorts. These aesthetical objectives should be considered throughout the design process when decisions are being made about the structure and its setting. Established objectives referred to during the decision making process will help guide designers toward a successful visual design.

Ideally, aesthetical objectives would be quantitative and therefore easily measured. But, given the subjective nature of aesthetics, visual design goals will necessarily have to be qualitative. Only through subjective evaluation can the success of the visual design objective application can be measured. When evaluating a bridge, designers should evaluate each part of the structure in terms of the whole, and the whole structure in terms of the setting and the context.

7-2-1- Functional Clarity

- The purpose of a bridge needs to be defined. Therefore, a fundamental requirement is that the bridge design must fulfill its purpose.
- The structural design must provide an honest structural response to the load-carrying.
- The bridge should reveal itself in a pure and clear form.
- The structure must also serve the physical circumstances of its particular location.
- Geometry of the roadway, the topography, and the presence or absence of other structures or buildings are all design considerations in the selection and development of bridge types and configurations.
- When evaluating functional clarity, designers should ask: Does the bridge serve its function in both deed and appearance? Is the form of the structure appropriate to the function of the structure?

7-2-2- Scale and Proportion

The structure should be in scale with its surroundings. The primary structural elements, span lengths, girder depth, abutment height, should have good proportional and environmental considerations. The structure form should have an appearance of lightness.

relationships to each other. Generally, no single element should dominate the visual composition. The collective design of the structure should be in scale with the site.

Figure 7-5: Unity and illusion

### Table 7-2: Examples of Fundamentals of Aesthetical Design and Aesthetic Qualities in Bridges Design.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Order</strong></td>
<td>Order is the arrangement of design elements so that each element has a clear place and function with no visual confusion.</td>
</tr>
<tr>
<td><strong>Proportion</strong></td>
<td>Proportion is a method of creating a sense of order by assigning appropriate relative sizes to the various elements.</td>
</tr>
<tr>
<td><strong>Rhythm</strong></td>
<td>Rhythm is a method of creating a sense of order by repeating similar elements in, on or around a structure.</td>
</tr>
<tr>
<td><strong>Harmony</strong></td>
<td>Harmony means that elements of a design have visual similarity. The relationship must be complementary.</td>
</tr>
<tr>
<td><strong>Balance</strong></td>
<td>Visual balance is the perceived equilibrium of design elements around an axis or focal point.</td>
</tr>
<tr>
<td><strong>Contrast</strong></td>
<td>Contrast is complementing the characteristics of some design elements with their opposites.</td>
</tr>
<tr>
<td><strong>Scale</strong></td>
<td>Scale refers to the size relationship among various features of the highway and between the highway and its surroundings.</td>
</tr>
<tr>
<td><strong>Unity</strong></td>
<td>Unity provides the observer with a sense of wholeness. This is generated by some central or dominating perception in the composition.</td>
</tr>
<tr>
<td><strong>Illusion</strong></td>
<td>An optical illusion is a visual stimuli that is comprehended by the brain in a way that is different from reality.</td>
</tr>
</tbody>
</table>

When evaluating the scale and proportion of a structure, designers should ask: Are the substructure elements proportional to the superstructure? Is the size of each bridge element consistent with its respective structural assignment? Is the structure size suitable for its setting and purpose? Does the superstructure seem slender without appearing delicate, or is it ponderous?

7-2-3- Simplicity and Continuity
- The bridge form should appear straightforward and uncomplicated. Simplicity of form and clean lines are align considered attributes of attractive structures.
- The architectural features should enhance the overall appearance. The design should express an overall continuity in appearance.
- Shapes used to form elements should be from the same family. For instance, beveled piers should be used with a beveled barrier rail design; rounded pier designs with a rounded railing.
- The number of materials, colors, and textures should be kept to a minimum. Details should appear consistent.
- When evaluating the simplicity and continuity of a structure, designers should ask: Does the visual composition present a consistent design theme? Can a viewer comprehend the bridge in a glance, or does it require concentration of the viewer?

7-2-4- Order and Balance
- The bridge should exhibit a natural progression of assemblage. Order is achieved by limiting the direction of lines to a minimum. Repetition of visual elements should be used sparingly to develop rhythm; if used to excess it can create monotony.
- The orientation and interaction of the design elements should suggest balance between the elements. The layout and alignment of the elements should promote harmony rather than confusion.
- When evaluating the order and balance of a structure, designers should ask: Does the arrangement of components work together as a unit or promote visual confusion? Are the lines of the bridge limited to a few directions? Does the visual weight, texture, and mass of the members promote visual balance?

7-2-5- Site/Environmental Integration
- Bridges must be integrated with their environment, landscape, cityscape, or surroundings.
- This is particularly true where dimensional relationships and scale are concerned, as pedestrians are uneasy and uncomfortable with heavy, brutal forms. The dimensions of the structure must relate to human scale when pedestrians are involved. Bridges should make a positive contribution to the immediate environment in which they are placed.
- When evaluating environment integration, designers should ask: Does the structure type, color, and color scheme complement its surroundings? Does the bridge visually conflict with its adjacent buildings or landscape? Are the materials, and finishes of the bridge native or foreign to the setting?

7-2-6- Refining the Form
- In many cases bodies formed by parallel straight lines appear stiff and static, production uncomfortable optical illusions, So the bridges architect has to check the appearance of the design from all possible vantage points of the future observer.

1 - "Design manual for roads and bridges" volume 1 highway structures- approval procedures and general design -section 3 general design- part 11- the design and appearance of bridges- USA-1998- p 4/1.
Part 2 Chapter 7 The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

- Often the pure elevation on the drawing board is entirely satisfactory. but in skew angle views unpleasant overlapping are found.

7-2-7- Bridge Architectural Character
- A bridge should have a certain deliberate effect on people. the nature of this desired effect depends on the purpose, the situation, the type of society and on sociological considerations.

7-2-8- Shade and Shadow
- Shade and shadow are important in areas of comparative darkness caused by the interception of light by intervening parts of the bridge or another nearby object.
- Shadow is the term usually used when the intervening object can easily be identified. The shadow that the deck overhang of a girder bridge casts on the outside girder can be a very strong component of the appearance of the bridge. figure (7-6)

Overhangs proportional to fascia depth creates a strong shadow line

Surface inclination effects perceived depth

Figure 7-6: Shade and Shadow

7-2-9- Reflections
Images of a bridge visible in the water below can be a very important part of the impression made by a bridge. Reflections of light from the ground below or other nearby objects can also help illuminate the underside of a bridge and influence our impression of it.

7-2-10- Symmetry and Asymmetry
- Symmetrical, or formal balance, is also known as bilateral symmetry. It is created by repeating the reverse of a design on the opposite side of the vertical axis each side, in essence, becomes the mirror image of the other. Symmetrical balance is considered formal, ordered, stable and quiet.
- It can also be boring. Symmetrical balance is often used in architecture.
- While symmetry achieves balance through repetition, asymmetry achieves balance through contrast. Asymmetrical, or informal balance, involves different elements that

1 - جورج الصحي راغب: "الجمال والابداع في عمارة الكبارى" - رسالة دكتوراه. كلية الهندسة جامعة القاهرة، 2007.
2 - Frederick Guttmann: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p40.
3 - http://i.telegraph.co.uk/multimedia/archive/03131/Brooklyn-bridge_3131494b.jpg
4 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p4-9.
5 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p40-41.
have equal visual weight; the weight is equal but the elements are not identical.
- Asymmetrical balance is casual, interesting and more dynamic than symmetrical balance.
- **Radial balance** occurs when all the elements radiate out from a central point and the visual weight is distributed equally.
- Radial balance creates a strong focal point in the center of the design. Clock faces and daisies are examples of radial balance.
- **Crystallographic balance**, or an allover pattern, is created by repeating elements of equal weight everywhere. Emphasis is uniform; there is no distinct focal point. Quilts and chessboards are examples of crystallographic balance.\(^1\)
- Another important aspect of form is symmetry. Symmetrical bridges as a general rule are often more aesthetically pleasing than non symmetrical bridges since they appear balanced and refined.\(^2\) Figure (7-8)

**Figure 7-7: Examples of Bridges Reflectivity in Water**

**Symmetry**

**Asymmetry**

**Radial balance** - **Crystallographic balance**

**Figure 7-8: Symmetry and Asymmetry**\(^3\)

### 7-3- Visual Design Elements.

The two major goals of color, texture, ornaments and other surfacing materials used for the enhancement of a bridge’s aesthetics are:
- To create a positive response from the viewer.
- To differentiate the various parts of the structure's lines so that the structural form and shape is clarified and enhanced.

#### 7-3-1- Color

Coloring is paid much attention to by the visual arts. In entertainment and advertising

---

2 - “Bridge aesthetics- design guideline to improve the appearance of bridges in NSW”. Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 42-43
3 - http://thumbs.dreamstime.com/z/medieval-bridge-houses-lagrasse-reflection-wa-water-france-35436763.jpg
4 - https://s-media-cache-ak0.pinimg.com/236x/53/4e/c3/534ec3856abe0e593f0e5b575f36bf1.jpg
5 - http://nwrain.net/~tersiisky/design/balance.html
colors contribute much to the image that ought to be conveyed to the audience. Although structures work in a completely different setting, they nevertheless attract people’s attention. The Golden Gate Bridge in San Francisco, built from 1933 to 1937, spanning the bay with unique elegance, is much cited as an example of how a bridge can enhance its setting. Brown gives pronounced statement in his comprehensive work on bridges when he calls the red bridge spanning the San Francisco Bay “the world’s largest Art Deco sculpture.”

Choosing a specific color strongly influences the impression that an object makes. Red usually symbolizes alert and attention, green and brown colors are related to quiet nature, yellow can stand for happiness, and blue can symbolize freshness, energy, and flow. Figure (7-9)

Figure 7-9: Bridge Colors Effect on Bridge Shape

There are differing theories on the use of color. One theory suggests that colors chosen for a bridge should reflect and harmonize with the predominant colors of the highway environment in which it is located. The other viewpoint holds that manufactured objects should look manufactured and should not attempt to match the color of trees, grass, sky or shrubbery because they are not related to such natural features by form. Rather, harmonious colors should be utilized.

Both views have value. Success often depends on the purpose of the project, and how well and consistently a color scheme is designed and carried out. Overall design intentions may be to either contrast or integrate with the surroundings.

The use of color can be very subjective. Some Used approaches include:
- Very light colors may be hard to distinguish especially in direct sunlight.
- Darker colors will fade over time and any flaking will be more noticeable.
- Light colors help to emphasize shadows and provide contrast.
- Bright red, yellow and brown colors tend to emphasize the presence of size and form.
- Light blue and green colors are less bold and tend to diminish the visual importance.
- Reversing the intensity of color can reverse the effect.

5 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p 2-3and2-4.
When selecting a color or color scheme, it should be recognized that the colors will appear different at various stages over the project life because of different hue of different seasons and day times. Colors can be applied to the steel components of bridges through the use of paint, galvanizing and atmospheric corrosion resistant material. Concrete components of bridges can be colored by using special cements in the mix or by applying pigmented sealers and coatings. Care should be taken to ensure that the application of paints and coatings does not significantly increase maintenance costs. There are big differences between coloring concrete and coloring steel; paints specs should be taken into consideration during design process.

A pedestrian screen is less obvious when its color is black. Black tends to lose itself against most backgrounds. A light gray color is also acceptable. Because signs have strong characteristic colors, the presence of a sign, and its size, on a bridge should be taken into account in the color selection of the bridge.  

There are big differences between coloring concrete and coloring steel; paints specs should be taken into consideration during design process.

A pedestrian screen is less obvious when its color is black. Black tends to lose itself against most backgrounds. A light gray color is also acceptable. Because signs have strong characteristic colors, the presence of a sign, and its size, on a bridge should be taken into account in the color selection of the bridge.

Figure 7-10: The impacts of different colors on same bridge

7-3-2-Concrete Quality

Bridge aesthetics can be affected by the quality of the concrete finish. This is particularly important if the bridge structure is visible and accessible. It is preferable to use steel shuttering and pre-cast factory made elements for highly visible bridge parts such as piers, girders and parapets to ensure a controlled, high quality finish. Retardants and sealants should be tested to ensure that they do not result in staining when the shuttering is removed. Concrete surfaces close to traffic and accessible to the public should have a class one finish. If the bridge is only visible from a distance then in

---

5 - "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-3
part 2 chapter 7 the effect of aesthetical considerations and creativity on bridge’s architectural design.

Aesthetic terms the finish is not so critical, although it should be noted that variation in concrete coloration due to staining can be noticed from a wide area.\textsuperscript{1} figure (7-11)

Good concrete quality at pedestrian bridge - Cairo Alex road
Bad concrete quality - 6\textsuperscript{th} of October bridge
Bad concrete quality - new constructed bridge - Dumitta

\textbf{Figure 7-11: The Effect of Concrete Quality on Bridge Shape}\textsuperscript{2}

\section*{7-3-3-Texture and Patterns}

Texture is found on the surface of all objects and is closely related to form. Texture helps define form through subtle surface variations and shadings. It can be used to soften or reduce imposing scale, add visual interest, and introduce human scale to large objects such as piers, abutments, and tall retaining walls. Distance alters our perception of texture. When viewed from a distance, fine textures blend into a single tone and appear flat. As a rule, the greater the distance or the larger the object, the coarser or larger the texture should be.\textsuperscript{3} figure (7-12)

\textbf{Figure 7-12: Bridge Texture and Pattern Examples}\textsuperscript{4}

The keys to Successful Use of Patterns are:

Surface textures and ornamentation can be used to differentiate and clarify the various components of a bridge. Surface textures and ornamentation become more important at street and pedestrian speeds.\textsuperscript{5}

\begin{itemize}
  \item Make sure that the pattern is subordinated to, and enhances, the overall design features and proportions of the structure itself.
  \item Make the pattern large enough to be distinguished from a distance when it will be seen primarily from a moving vehicle on the roadway.
  \item Horizontal lines should be continuous, and should either be level or follow the major lines of the roadway. They must be carefully controlled, as any irregularities will be immediately obvious.
  \item Textural elements need to be large enough to be read at highway speeds a dimension of about four inches is necessary in elements such as grooves and recesses, and the grooves should be deep enough to create defined shadows.\textsuperscript{1} Figure (7-13)
\end{itemize}

\begin{itemize}
  \item 1 - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 88
  \item 2 - By researcher
  \item 3 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p2-2.
  \item 4 - "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- p V-3
\end{itemize}
7-3-4- Brick, Stone and Other Non-structure Materials and Finishes
Non-structural facing materials, such as brick, stone, and pre-cast panels, have been used to provide color or texture on surfaces. These find their most logical application for facings of abutments and retaining walls.
Random fieldstone appears to work best since its size and texture make it visible in the highway environment. Precast concrete panels can work well. The major concerns are surface color and texture and the location of panel joints.
Other types of surface texturing can be used to create patterns, add visual interest and introduce subtle surface variations and shading, which in turn soften or reduce the scale or mass of abutments, piers and walls. There are a variety of form liners available. Some mimic other materials, while others have more abstract or geometric designs.
Consider the following when specifying form liners:
- When simulating another material, such as stone or brick, form liners should be made as realistic as possible. Use color in addition to texture to assist in the simulation.
- When using form liners to simulate another material, avoid suggesting material that would not be utilized in that application. For example, stone texturing on a cantilevered pier cap surface creates disharmony since a stone cantilever would not be stable if constructed.
- When a geometric pattern or texture is used, consider its relationship to the overall bridge composition. The parts must relate to the whole.
- Care should be exercised in the use of form liners for girder fascias or parapet exterior faces. Inappropriate use may disrupt the superstructure lines.

7-3-5- Ornamentation
Ornamentation created by add-ons should be kept to an absolute minimum unless the structure is in a very special location.
The goal of the engineer should be to develop strength from the shape of the structure and let that structural shape produce the aesthetic impact on its own. However, ornaments can be used to articulate and emphasize the structural shape.

1 - "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-10 to V-10.
3 - "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-10 to V-12.
4 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009-p32.
The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

Figure 7-14: Bridge Finishes Examples
Many of the classical systems of architectural ornamentation had their beginning in the elaboration of structural elements. However, ornamental and non-structural surface materials can disguise, detract from or destroy the structural form. Ornament can add additional levels of interest and richness. It is best when restricted to those locations with a high level of importance and exposure. Make sure that the ornamentation emphasizes, rather than camouflage, the structural form. If a bridge is a gateway to a special community, such as a state capital, pylons on the bridge may be appropriate to identify the importance of the structure as a gateway. While attitudes regarding the appropriateness of ornamentation in bridge design have varied over time, some best practices have evolved. Avoid using false structure as ornament. Aside from requiring additional costs to construct and maintain, adding false structure will rarely improve a design and is often viewed as extraneous clutter. Do not use ornament as “make up” to disguise an inappropriate design. The form and composition of an inappropriately designed bridge can rarely be improved by applying ornament. If ornament is appropriate, use it sparingly. Less is generally better than more.

Figure 7-15: Bridge Ornamentation Examples

7-4- Bridge Visual Characteristics
Bridge visual could be defined as how the bridge is received by the passengers and it could be received as a line, shape or form.

1 - http://www.reckli.net/formliner/designs/abstract-patterns/
3 - "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-14
4 - "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005- pV-10 to V-14 and V-15.
5 - Frederick Gottmoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p33.
6 - http://www.lonwalk.ndirect.co.uk/bridsum.htm
Part 2 Chapter 7
The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

7-4-1- **Line (One Dimension)**

A line is a direct link between two points, either real or implied. The strongest lines on a highway are created by the pavement edges. Other prominent lines are created by railings, girders, piers, abutments and the top edges of retaining walls and noise walls. A line may be thought of as a direct link between two points, either real or implied. Lines within the context of a bridge are seen in the profiles of railings, spans, piers, abutments, and wing walls. They are likewise seen in the juncture of different materials and construction joints. Manufactured lines on the landscape may include roads, fences, and the outlines of structures. Lines that are long and straight tend to dominate natural settings that consist of predominantly short line segments.

As shown in figure (7-16), (6-17) and (6-18) the bridge design perception by the viewer as a line, shape or form is illustrated.

![Bridge received as a Line because of parallel curvilinear lines.](image)

**Figure 7-16: Examples of Bridges that Precept as a Line**

7-4-2- **Shape (Two Dimensions)**

Shape is the outline of a two-dimensional surface with spatial directions of height and width.

When a line closes, it forms a two-dimensional surface with spatial directions of height and width. This two dimensional surface can be called shape. While shape delineates horizontal and vertical dimensions, it excludes depth and volume. Sought by the eye, shape quickly identifies many objects. The purest of shapes is a back-lit elevation view, or a silhouette. Depending on one's position and the time of day, bridges may appear as a silhouette. Shape stands out most when an object is clearly separated from the background, either by tone or color contrast, and when viewed from head on. Color contrasts also call attention to shape as the outlines are accentuated.

7-4-3- **Form (Three Dimensions)**

Form is the three-dimensional array of an object, adding depth to its height and width. The visual experience of moving under or over a bridge is primarily influenced by the form of the bridge, its geometry, span arrangement, horizontal alignment, vertical

---

1 - Frederick Gottemoller: "Bridge Aesthetics Sourcebook Practical Ideas for Short and Medium Span Bridges"- Subcommittee of the American Association of State Highway and Transportation Officials (AASHTO)- USA-2009- p38.
2 - Same Previous Reference
4 - http://www.aholgate.com/unbltarchtexts/unbltarches1.html
5 - http://cambriahistory.org/?p=659
profile, relationship to adjacent structures and its relationship to the space or sets of spaces that create its environment.¹

Examples of shape concepts
Bridge in Herzegovina
Chengyang Bridge, China

Figure 7-17: Examples of Bridges that Precept as a Shape ²

Form reveals objects in three dimensions, adding depth to the height and width of shape. The visual experience of moving under or over a bridge is primarily influenced by the form of the bridge, its geometry, span arrangement, horizontal alignment, vertical profile, and relation to adjacent structures.

The form of a bridge is seen in the context of space or sets of spaces that create its environment. Although the eye gathers stereoscopic cues, form is primarily revealed as volumes modeled in light and shadow. Nothing delineates the configuration of a surface as well as a shadow line.³

Difference between shape and form
The three-dimensional form of a bridge is a result of the interaction of all its solid elements.⁴

Figure 7-18: Examples of Bridges that Precept as a Form

7-4-4- Determinates of Bridge Appearance

How people react to an object depends on what they see and the order in which they see it. This means the largest parts of the bridge — the superstructure, piers and abutments have the greatest impact. Surface characteristics (color/texture) come next, then details. Therefore, design decisions should be approached in the following order of importance. Before there is a concept for a bridge, the roadway geometry creates a ribbon in space that can be either attractive or unattractive. The geometry establishes the basic lines of the structure, to which all else must react. A graceful geometry will go a long way toward fostering a successful bridge, while an awkward or kinked geometry will be very difficult to overcome. Examples include:

• Many urban grade separations or viaducts may have minimal clearance above grade and may be perceived by the community as barriers or tunnels. At the opposite extreme, the profile grade of an urban highway may extend upward past the horizon line and raise concerns related to blocking the view shed.⁵ Figure (7-19)

3 - "Aesthetics guidelines for bridge design"- Office of bridges and structure- Minnesota Department of Transportation- USA- 1995- p2-2and 2-3.
Part 2 Chapter 7 The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

In the design of a bridge, the horizontal and vertical geometry of a bridge will:
• Be selected to satisfy the requirements of the site conditions
• Relate to the type of bridge crossing.
• Wide bridges that are relatively close to grade often create visual barriers. In this case, use of post-tensioned caps increased the transparency of the substructure when viewed from an oblique angle
• For highway bridges, be selected by the roadway designers to satisfy traffic movement and safety concerns. ¹ Figure (7-20)

7-5- Creativity
In one form or another, different definitions state the creativity involves the capacity to make products, either tangible or intangible. Which are both new and valuable. It is not present purpose to arrive at a single definition is generally accepted. Definitions differ according to whether they refer to potential, activities or products.

7-5-1- Definitions
Creativity
Is the integrated socio-individual process (Individual within a community or society) which results in an original work within a certain domain (Art, Science, Business, etc..) That's recognized as a valuable and useful by a society at some point in time.²

Creative Thinking
A way of looking at problems or situations from a fresh perspective that suggests unorthodox solutions (which may look unsettling at first). Creative thinking can be

---

² Abdel Raouf: "A Creativity in Architecture"- Phd thesis- Architecture department- Faculty of engineering- Cairo University- Egypt- 2010- p46.
**Part 2 Chapter 7**
The Effect of Aesthetical Considerations and Creativity on Bridge's Architectural Design.

These bridges have good proportions, with pleasing span to depth ratios

The horizontal and vertical geometry of the roadway at this river crossing have resulted in a bridge with an ordinary appearance.

The designers of these river crossings bridges worked within the constraints of the roadway geometry to achieve structures with pleasing appearances.

Large valleys with competent rock foundations allow designers to select long span arch structures providing unobstructed views.

**Figure 7-20: Horizontal and Vertical Geometry Design examples**
stimulated both by an unstructured process such as brainstorming, and by a structured process such as lateral thinking.

**The Creative Process:**
The creative process was divided by "George Kneller in 1965" in five stages:

1. **First insight:** The creator must have his first insight: The apprehension of an idea to realized or a problem to be solved.
2. **Preparation:** A thought investigation of the possibilities of the germinal ideas.
3. **Incubation:** A time of non conscious activity in which the creator's idea go underground.
4. **Illumination:** Suddenly, the creator grasps the solution to this problem, The concept that focuses all his facts, The thought that completes the claim of ideas on which he is working.
5. **Verification:** Intellect and judgment must complete the work that imagination has begun.

Alex Osborne (1963) has divided creativity up in more detailed list:

---

4. [http://www.businessdictionary.com/definition/creative-thinking.html](http://www.businessdictionary.com/definition/creative-thinking.html)
Orientation, Preparation, Analysis, Hypothesis, Incubation, Synthesis and Verification.  

7-5-3- Characteristics of Creative Product:
As the creativity is generating new ideas, evaluating them effectively, taking action to turn them into new products and services. To classify any product as a creative product it should have many characteristics as:  
- **Novelty**: it means that it is the first time to see such a product.
- **Appropriate**: appropriate for two things: Utility and aesthetics
- **Utility**: appropriate for the requested function
- **Aesthetics**: Beauty is considered a key feature for innovative product.
- **Validity**: the created product could be executed not just a theoretical idea.

7-5-4- Types of Creativity
There are several types of creativity, but most related creativity types to bridges are shown in figure (7-21):

<table>
<thead>
<tr>
<th>Types of Creativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Creativity</td>
</tr>
<tr>
<td>Artistic Creativity</td>
</tr>
<tr>
<td>Technological Creativity</td>
</tr>
<tr>
<td>Form Creativity</td>
</tr>
<tr>
<td>Structural Creativity</td>
</tr>
</tbody>
</table>

The Iron Bridge is a bridge that crosses the River Severn in Shropshire, England. Opened in 1781, it was the first arch bridge in the world to be made of cast iron, and was greatly celebrated after construction owing to its use of the new material.

Figure 7-22: An example of Creativity (The iron bridge)
Technological Creativity: Iron material was developed to be used in several bridges after this bridge.

Form Creativity: Slender structure elements were used instead of old heavy structure systems, and the outcome is an attractive shape. Grey color was used instead of common beige color these days.

Structural Creativity: steel girders are used to transfer loads for the first time instead of brick or stone arches commonly used in these era.

7-6- Conclusion

In this chapter, The effects of aesthetical considerations and creativity on bridge architectural design were studied. These considerations could be sorted under several points as Fundamentals of aesthetical design and Aesthetical qualities which discuss proportion, rhythm, order, etc., and Aesthetic design objectives to aid designers in visualizing, evaluating, and articulating their designs which discuss functional clarity, scale and proportion, refining the form, etc.... Also Visual design elements as bridge colors and concrete quality were discussed, bridge perception by the viewer were studied under title bridge visual characteristics. Finally creativity, Characteristics of creative products and types of creativity were studied.

7-6-1- Concluded Prerequisites

AP: Bridge Aesthetical Considerations Integration
AP: Fundamentals of Aesthetical Design and Aesthetical Qualities:
AP: Aesthetical Design Objectives.
AP: Bridge Visual Design Elements:

7-6-2- Concluded Credits

PR: Fundamentals of Aesthetical Design and Aesthetical Qualities:
Chapter 8 : Design Process of a Sustainable Bridge and Architect's Role

8-1-1-The nature of engineering
8-1-2-Functional Requirements for Structure and Interdependencies
8-1-3-The Engineers Aesthetical and Structural Art

8-2-1-The mechanisms of the Design Process
8-2-2-The relation between bridge design process and the bridge's honor .
8-2-3- Architects role in bridge's design process
8-2-4-The argument about architects rule in bridge's design process in Egypt
8-2-5-International architects who designed bridges
8-2-6-Bridge design as a competition

8-3-1- Conventional Bridge's team members
8-3-2- Conventional bridge process (Design, Construction and operation of a conventional bridge).

8-4-1- Integrated design definitions
8-4-2- Integrated Project Team Members
8-4-3- Sustainable bridge integrative process
8-4-4-System thinking

8-5-1- Beauty versus cost in bridge's design
8-5-2- Green bridge Cost

8-6-1- Concluded prerequisites
8-6-2- Concluded credits

Chapter 8 structure: Design Process of a Sustainable Bridge and Architect's Role
Chapter 8: Design Process of a Sustainable Bridge and Architect’s Role

Introduction
Seeking a balance amongst practicality, long life, safety, serviceability, constructability and cost efficiency, has been the fundamental challenge of bridge design since the beginning of time. New trends including the use of innovative construction materials and the detailed consideration of the environmental effects of bridge designs, have become more important. This process has been paralleled by extensive public involvement in the design process, consideration of environmental sustainability, and an increased focus on the way bridges connect with the people who use them. All these considerations must be taken on the design process also it will not be achieved unless an existence of strong collaboration between involved parties in bridge design, construction and maintenance.

8-1- Bridges Design Philosophies
In recent years it has become apparent that the real problems of bridge design include more than the structural or construction issues relating to the spanning of a gap. The public often expresses concern over the appearance of bridges, having recognized that a bridge’s visual impact on its community is lasting and must receive serious consideration.¹

8-1-1- The Nature of Engineering (The Three Dimensions of Structure)
Its first dimension is a scientific one. Each working structure or machine must perform in accordance with the laws of nature. In this sense, then, technology becomes part of the natural world. Methods of analysis useful to scientists for explaining natural phenomena are often useful to engineers for describing the behavior of their artificial creations.²

The second dimension of structure is a social one. In the past or in primitive places of the present, completed structures and machines might, in their most elementary forms, be merely the products of a single person; in the civilized modern world, however, these technological forms, although at their best designed by one person, are the products of a society. The public must support them, either through public taxation or through private commerce. Economy measures the social dimension of structure. Figure(8-1)

The third dimension of technology is symbolic, this dimension that opens up the possibility for the new engineering to be structural art. Although there can be no measure for a symbolic dimension, we recognize a symbol by its elegance and its expressive power. Thus, the Sunshine Skyway has become a symbol of both Florida’s Tampa Bay area and the best of late-20th-century technology.³

8-1-2- Functional Requirements for Structures and Interdependencies
Functionality, safety, economy, and aesthetics are the four main goals of all engineering efforts. Although technology has advanced considerably during the last century and provided engineers with new challenges in implementation, these four prime issues of engineering have always remained the same. On the other hand, the structure in service need not only be safe but also has to serve its function in an acceptable manner, as also determined by codes and regulations. Serviceability relates to issues such as durability of the structure against deterioration and to adequate stiffness, bridge must not develop

excessive yet structurally harmless deflections that would reduce the driving comfort. It must be wide enough for the traffic to safely pass it at an acceptable speed and should not have sudden changes in alignment. Also according to thesis main goal, Environmental sustainability should be added to the structures requirement as will be discussed. Figure (8-2)

Figure 8-1: The Three Dimensions of structure

Figure 8-2: Functional Requirements for Structures and Interdependencies

---

2 - www.dot.state.mn.us
3 - http://www.aviewoncities.com/sf/goldengatebridge.htm
4 - http://www.skywaybridge.com/home.htm
5 - http://www.panoramio.com/photo/29847487
6 - Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge": Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- p 99.
8-1-3- The Engineer’s Aesthetical and Structural Art

“Aesthetics” is a mysterious subject to most engineers, not lending itself to the engineer’s usual tools of analysis. Many contemporary engineers are not aware that a long line of engineers have made aesthetics an explicit element in their work, beginning with the British engineer Thomas Telford. In 1812, Telford defined structural art as the personal expression of structure within the disciplines of efficiency and economy. Efficiency here meant reliable performance with minimum materials, and economy implied the construction with competitive costs and restricted maintenance expenses. Within these bounds, structural artists find the means to choose forms and details that express their own vision.

A. Design philosophy

Characterizing for the engineering design process is that it is highly subjective and individual. It is not a predetermined path that is laid out in any professional code, the process is rather similar to the process that artists go through when creating a new piece of art. As there are many ways in which the process can be carried out, there will also be many possible outcomes. One specific optimum solution for a project can hardly exist, as every designer will acknowledge. Designing is a complex process consisting of several steps and consideration of a great amount of information is involved. Environmental, technical, and cultural factors give the frame in which the designer performs his work of structural design. In any case, engineering is always seeking for a good compromise between these many factors.¹

B. The nature of engineering

Engineering can be placed between the three areas of science, technology, and arts since it incorporates features from all of them. With science it shares analytical and experimental approaches to investigate and better understand material properties and structural behavior, mostly based on models of the real structure. The knowledge extracted hereof is then used on the technological side in finding a practical way of putting the structure in place by technical means and methods.

More requirements than just pure functionality need to be fulfilled by the structure while being under construction and during its service life. An important consideration for highly visible structures as bridges is their appearance.

To design a truly satisfactory bridge, the engineer needs aesthetic sensibility as an artist does, too. Creativity is of prime importance to comply with the requirements on structures and make the whole project a successful undertaking.³

As shown in figure (8-4) Factors Influencing Design and Construction of bridges are overviewed.

¹ - Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge"- Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- p 95.
² - Burke, M. P: "Achieving Excellence in Concrete Bridge Design"- Paper- Concrete International Conference-1995
³ - Same Previous Reference.
Part 2  
Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

---

**Figure 8-4: Factors Influencing Design and Construction of bridges**

**8-2- Parties Involved in Bridge Design Process**

**8-2-1- The Mechanisms of the Design Process**

According to the British experience of bridges design there are five mechanisms to design a bridge related to performance and final shape of bridge. these mechanisms proposals depends on how to choose designer, contractor through previous works evaluation or cost which are discussed at table (8-1).

**8-2-2- Relation between Bridge Design Process and the Bridge's Owner.**

One of major factors on bridge design is the bridge owner, most of Egyptian bridges owner is the Egyptian government, the Government main goal is to construct the most safe bridge with the least cost, so a result is a lot of aesthetically poor prototypes of bridges which do not have any relation with architectural design, heritage or Egyptian culture were constructed.

**8-2-3- Architects Role in Bridges Design Process**

Bridge design is a very complicated process because of the involvement of a group of parties planners, architects, civil engineers, electrical engineers and contractors to construct the strong structure which achieves a certain goal with a pleasant shape. There is a big argument about who is responsible of bridge's design architect or structure engineer? the answer is that both architects and structural engineers have a

---

1 Gunnar Lucko: "Means and Methods Analysis of a Cast-In-Place Balanced Cantilever Segmental Bridge". Master of Science-Civil Engineering-Virginia Polytechnic Institute and State University- USA- 1999- P120.

major rule in bridge's design process. without architects, the result will be aesthetically poor and non-functional bridge and without structural engineer, the result will be Non-safe bridge. So architects and structural engineers should be collaborative from the conceptual design stage of bridge to operation and maintenance stages. 

Table 8-1: The five Mechanisms of the Design Process

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Advantages and Disadvantages</th>
<th>Reflection on bridge architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Design and supervision by the owner or a design consultant has been chosen according to previous work or good reputation. Consultant fees is a percentage from bridge cost. Choosing contractors by tenders presented.</td>
<td>The owner controls the design. The bridge's initial costs defined by proposed tenders. The bridge's final cost is unknown until the final stage. Designers may be chosen according to financial reasons not excellence.</td>
</tr>
<tr>
<td>2</td>
<td>Tenders presented from consultants. the most expert consultant and the least fees is chosen.</td>
<td>Least consultant fees Least fees leads to least creativity</td>
</tr>
<tr>
<td>3</td>
<td>According to announced specs brochure, many contractors present their design proposals and tenders by specific fees.</td>
<td>Accurate cost and time schedule more than the previous mechanisms The owner has no control on design and the chosen design is the most easy to be constructed.</td>
</tr>
<tr>
<td>4</td>
<td>Many contractors present tenders and proposals without cost, two or three proposals are chosen as acceptable designs, then the contractors present costs, fees and time schedule and the least price offer is accepted.</td>
<td>Accurate cost and time schedule more than the previous mechanisms The best design is excluded if it was not the least price.</td>
</tr>
<tr>
<td>5</td>
<td>Presented designs by a design competition.</td>
<td>New ideas and the owner may get new and valuable ideas competitions waste long time</td>
</tr>
</tbody>
</table>

As shown in figure (8-5) Golden gate bridge is considered as an example of the importance of Architects role in bridges design process. Golden gate bridge is a San Francisco landmark. Sometimes but not always an architect is involved in the process. One-on-one replacements until now are usually done without an architect. At the moment many
bridges are about to be replaced in clusters. Per cluster there is a design by an architect, this will create a unity in the city. These designs stay available to use for replacements of bridges later on. Only on special occasions an architect is involved for a one-on-one replacement, for example for a one-of-a-kind innovative type of bridge in the city center, which gives charisma to the city.¹

<table>
<thead>
<tr>
<th>Architect</th>
<th>Joseph B. Strauss</th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Eng</td>
<td>Leon Moisseiff</td>
</tr>
<tr>
<td>Location</td>
<td>San Francisco, California</td>
</tr>
<tr>
<td>Date</td>
<td>1933 to 1937</td>
</tr>
<tr>
<td>Structure</td>
<td>suspension bridge</td>
</tr>
<tr>
<td>Style</td>
<td>Structural Modern with some Art Deco details</td>
</tr>
</tbody>
</table>

One of the longest bridges in the world, a powerful and elegant human structure in an equally beautiful natural location.

Figure 8-5: Example of the importance of Architects role in bridges design process (Golden gate bridge)²

8-2-4- The Argument about Architects Role in Bridge's Design Process in Egypt
In Egypt, architects are excluded from bridge design process and this design process is fully authorized to structural engineer. So, as a result most of Egyptian bridges did not achieve their original functions because of the lack of functional studies during design stage. Also, these bridges are aesthetically poor bridges which did not follow any architectural school. Figure (8-6).

Figure 8-6: The Difference between Bridges designed with and without the Architects in Egypt.

8-2-5- International Architects who Designed Bridges:
As shown in table (8 - 2) the most important pieces of work made famous by global architects are overviewed.

8-2-6- Bridge Designs a Competition:
Recently, there are competitions all over the world for bridges designs, these

---

⁴ - http://www.ahram.org.eg/Archive/2005/1/4/43128_13m.jpg
competitions are calling for architects from across the globe to come forward with exceptional and inspiring designs for a new bridges.¹ Figure (8-7)

Table 8-2: Bridges Examples by Global Architects

<table>
<thead>
<tr>
<th>Architect</th>
<th>Bridge Example</th>
<th>Location/Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zaha Hadid</td>
<td>The Sheikh Zayed Bridge in Abu Dhabi- UAE 2010</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Danjiang Bridge Competition in Taiwan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Zaragoza Bridge Pavilion in Spain- 2008</td>
<td></td>
</tr>
<tr>
<td>Frank Lloyd R.</td>
<td>The Butterfly Bay Bridge Frank Lloyd Wright and J.J. Polivka's design for the Bridge on display at SF Museum of Art, 1953.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fargo-Moorhead Cultural Center Bridge- 1978</td>
<td></td>
</tr>
<tr>
<td>Michael Graves</td>
<td>Michael Graves designed the Fargo-Moorhead Cultural Center and Bridge as a replacement for a vehicular traffic bridge spanning the Red River and physically connecting the states of Minnesota and North Dakota.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Millau bridge</td>
<td>Millau, France 2004</td>
</tr>
<tr>
<td>Norman Foster</td>
<td>Millau bridge</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Millau, France</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>Santiago Calatrava</td>
<td>Santiago Calatrava is a structural engineer but he designs very aesthetically rich bridges.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pont de l'Europe-Orléans- 1996</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peace Bridge -Calgary- 2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manrique Footbridge -Murcia- 1999</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Margaret Hunt Hill Bridge- Dallas-2012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Campo Volantin Footbridge Bilbao- 1997</td>
<td></td>
</tr>
</tbody>
</table>

http://www.eichlernetwork.com/article/architecture-made-dreams  
http://www.calatrava.com/projects.html?project_type=bridges  
http://www.fosterandpartners.com/projects/millau-viaduct/  
http://www.moma.org/collection/works/92?locale=en  
http://www.dezeen.com/2008/06/16/zaragoza-bridge-pavilion-by-zaha-hadid/

¹ - http://www.citylab.com/commute/2015/02/its-beginning-to-look-a-lot-like-london-has-a-fancy-bridge-fetish/385946/
8-3- Conventional Bridge Process

8-3-1- Conventional Bridge's Team Members:
In the conventional bridge process, specialists usually worked in isolation, focusing on their separate area of project expertise and interacting and working together only when absolutely needed. Figure (8-8). As shown in table (8-3) Team Members Responsibilities of Conventional Bridge Projects are discussed.

8-3-2- Conventional Bridge Process (Design, Construction and Operation of a Conventional Bridge).
In the traditional planning and design process, project systems were viewed as separate elements; site, structure, systems, use, and design decisions were each based on budget and/or schedule considerations. Such as design changes in order to meet a certain budget or follow an accelerated schedule did not take into account the final performance of the completed project.4

Initiation: A Requirements Plan is made with the requirements for the new bridge. These are technical requirements (length, capacity) but also easy to maintain is an

---

2 - http://www.e-architect.co.uk/london/nine-elms-pimlico-bridge-competition
important requirement and the costs during the whole lifecycle are taken into account. The requirements used to be very restrictive, often even including material already. Nowadays the requirements are based on function and not specifying how this function has to be fulfilled (for example: make it possible for people to go to the other side of the water instead of place a bridge with steel beams, composite deck and wooden railings).¹

- **Design phases of a conventional bridge**

  **Design program**: This phase involves the development of the program (or brief) for the project. The bridge owner requirements are developed. Ideally, the design team will be involved with this phase, although this information is often developed by a separate specialist consultant.

  **Conceptual Design**: An outline of one or more proposed design solutions is developed during conceptual design. The primary purpose of conceptual design is to obtain buy-in from the client and design team on a solution that will be further pursued.

  **Schematic Design**: This phase of design is essentially the proof-of-concept phase. The project directions outlined in conceptual design are verified as being technically feasible, within budget, and able to deliver on design intents. Hopes meet reality during schematic design.

  **Design Development**: Design development might be best described as the analysis and production phase of a project. Schematic design decisions are validated, systems are optimized, details are developed, specific equipment selected, and drawings and specifications initiated.²

  **Final design**: In the final design phase more details are added to the design. Not much can be changed anymore to the core properties.

- **Construction Plans**:

  **Construction Documents**: Construction documents are the construction drawings, specifications, and related documents that convey the aspirations of the owner and design team to the contractor. These become a major part of the contract between an owner and a contractor and are the basis for construction.

  **Statement of work**: The writing of the statement of work is an important phase because now the responsibility goes from the design office to the contractor. Traditionally, the procedure of contracting is based on lowest price.³

- **Construction Phase**:

  **Bidding process**: Construction estimating consists of three parts: Quantity Survey, Price Extension and Bidding.

  **Construction**: During construction, the architect, client, contractor team converts the construction documents to physical reality. Sometimes requests for substitutions occur during bidding and construction. Such requests should be carefully reviewed for their impact on design intent. Construction is not the time to abandon design intent and criteria.

  **Usage, Occupancy and end-of-life phases**:

  **Usage and occupancy**: On most projects, the design team has historically had little (if any) interaction with the occupied building. This, however, is a really bad idea for a green bridge. Many passive (or unconventional active) systems require informed operators (who are often the bridge users). Design team development of User’s Manual.¹

---

End-of-life phase In the use phase the bridge is the overseer’s responsibility. The overseer decides which maintenance is needed and when the bridge has to be replaced.

There are three main reasons to replace a bridge:
1. Technical value. The technical lifetime has exceeded, the bridge is not safe anymore and maintenance is no longer profitable. 2. Use value. The functional requirements have changed, so the bridge is no longer sufficient, for example: the bridge has to be broader due to in increase in traffic load, or a separate road for bikers is needed. Because technically the bridge is still valuable, it would be desirable to be able to move the bridge to another location. The current bridges are not suitable for this.
3. This counts for the now existing wooden bridges. When the bridges were placed, financing was determined for the theoretical technical lifetime. For a wooden bridge this is 25 years. After this 25 years there is no financing for maintenance anymore causing the bridge to degrade fast and a replacement will be needed soon. Besides these reasons politics play an important role. 3

Table 8-3- Team Members Responsibilities of Conventional Bridge Projects (by researcher)

| A | decision replacement - overseer decision new bridge | • Requirements • building code • low maintenance • cheap lifecycle • fast building • fitting in environment |
| B | Design - Architect | • Aesthetics of bridge • Shape of bridge • Approximately the material |
| C | preliminary design - Engineers | • Measuring • Environmental inspection • Global construction • Approximately the size • Material |
| D | Final design - Engineers | • Exact calculation • Final construction • Adjust Design to Environment • Costs |
| E | Statement of work - Engineers | • depends on the detail of the final design • Way of contracting • Requirements concerning fencing trucks |
| F | Bridge - contractor | • Details as far as not in the statement of work • Construction and completion • Check Engineering |
| G | Use / maintenance - overseer | • Inspection construction • Maintenance • At end of life instruction for new one |
| H | End of life - overseer | • Instruction to engineering for replacement including demolition |

8-4- Sustainable Bridge Integrative Process.
To achieve bridge integrated process, there should be an integrative design team.

8-4-1-Integrated Design Definition
is a process that applies the skills and knowledge of different disciplines and the interactions of different building systems to synergistically produce a better, more

2 - Astúa de Moraes, F: "The Integration of Sustainability in the Fuzzy Front End of Innovation within the context of SMEs- Paper- Transportation Unit Delft - Netherlands- 2010
efficient, and more responsible building occasionally for lower first cost, but more typically for lower life-cycle cost. Integrated design considers the relationships between elements that have often been seen as unrelated. The project phases of an integrative process are different than the conventional process. There are many criteria of integrative sustainable process. An integrative process is an approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, construction, and ongoing operations.

**8-4-2-Integrative Project Team Members**

During the integrative process team members work together and communicate throughout the process of the building’s design and construction. Professions that traditionally may not communicate do so, and the process evaluates how design decisions and components will affect (or be affected by) other site decisions and components. The integrative process results in greater efficiencies, with some estimates showing that single projects employing integrative project teams can achieve savings of 2-10% in the cost of construction. (Figure 6-8)  

The integrative process requires collaboration among key stakeholders and design professionals from conception to completion. A stakeholder may be the building owner, a major tenant, or an end user customer, like a college student who uses a building for classes. Decision-making processes and complementary design principles should be established early in the planning, satisfying the goals of multiple stakeholders while still achieving the overall objectives of the project. Stakeholder meetings may be hard to schedule or may include stakeholders opposed to new technologies or green strategies, but even if a project encounters stakeholders who resist this new way of planning a project, they can still be beneficial. Project teams can work to alleviate these concerns, which will lead to a happier stakeholder group at the project’s delivery.

The integrative process of a project is what contributes to reaching the sustainability goals established by the project team. Every aspect of building design is considered cohesively, beginning in the pre-design phase, and continuing to the end of the building’s lifecycle. A fully integrative process is only possible with an integrative project team. Everyone involved in a building project has to be of like mind and work together to achieve the goals of an integrative process. This includes not only the people who are designing and constructing the building, but also the people that own and manage the building. Figure (8-8)

The success of a project team depends on:

- Setting specific goals that can be measured and validated.
- Developing strategies that will meet the goals and Proper planning.
- Creating processes that foster communication of all team members.
- All team members being on board with the goals and being held accountable for reaching those goals.
- Continuous monitoring of progress throughout the development process and ensuring goals are being achieved.

---

2 - "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014, p 14
8-4-3- Sustainable Bridge Integrative Process

The project phases of an integrative process are different than the conventional process:

A. Pre-Design
B. Design
C. Construction plans
D. Construction phase
E. Commission the building
F. Occupancy and Re-commissioning
G. Building end of life reuse or demolition/recycle

Conventional project practice usually involves a linear project handoff from architect to engineer to contractor to occupant. By contrast, the integrative process front-loads the process, bringing the client, designers, engineers, contractors, occupants and operators together early in the design process to collaboratively establish project goals, strategize innovative approaches and resolve conflicts in advance. These disciplines then continue to work together in an iterative process toward the project’s high performance goals. ²

- Pre-Design

Start with a project vision, and then define green building goals while getting input from stakeholders. Next, create a team and identify a budget. Brainstorm about opportunities to gain incentives and cooperation with government organizations. Create a timeline and methodology then decide which measurement tools to be used to identify progress. Finally calculation of the return on investment and identifying risks.³

Probably the most critical phase of the integrative process is the pre-design phase. It is in this phase where the groundwork is laid for the entire project. The integrative process increases the level of effort during early design phases, resulting in reduced

---

1 - "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014, p 13
2 -LEED Principles and Green Associate Study Guide": Green Building Education Services -USA- 2014, p 13
documentation time and improved cost control and budget management, all of which increase the likelihood that project goals, including schedule, life cycle costs, quality and sustainability will be achieved.

The pre-design phase will include several new steps:

i. Life Cycle Approach: This approach does not just focus on the delivery of the completed project but goes much further to the life of the project and eventual reuse of the project or its demolition and hopefully recycling.

ii. Developing a Clear Statement of the Project's Vision: Summarize what is trying to be accomplished.

iii. Defining the Green Goals of the Building: Goals should:
   - support the project vision
   - be clear so all team members can relate and understand
   - cover the entire project
   - be measurable (qualitatively or quantitatively)
   - be achievable in the space and time of the project (applicable)

iv. Setting Priorities: The team will need to prioritize the green building goals according to the budget or schedule.

v. Selection of the Project Team: The project team is a collaborative group involved in design and problem solving during all steps of the project. The project team will incorporate people and trades from every aspect of the building process and even the building’s end users. Every member of the team will need to be committed to the green building goals and the project’s vision. The team has to include some green building experts to help the project along if this is a new process and unchartered territory for a majority of the team members.

   i. Assigning Small Task Groups
   ii. Defining Green Building Budget Items Green building has a few added expenses compared to traditional building. In addition to the design fees and construction costs, project budget estimation has to include:
      - Life-cycle cost analysis;
      - Design and cost advice from experienced green building professionals;
      - Contingencies for research of unconventional techniques or materials.
      - Green building studies have shown the cost of green project can be the same as that of traditional project. Green projects have hard and soft costs just like traditional projects, but the project team also considers life cycle costs.
      - Reviewing Applicable Laws and Standards.

- **Design**

In the design phase for the integrative process there will be some additional steps:

- Develop a project budget that covers green building measures
- Test and select green technologies and strategies
- Check costs
- Finalize design decisions

- **Construction plan and construction phase**

After the design phase, the remaining steps look quite similar to traditional design; Construction plans, Bidding process, Construction phase. The main differences is that in each of these steps the project team is always reviewing and verifying that green building goals are being met at every point in the process. Additionally the team is always working together and collaborating.

---

Also, construction plans through occupancy is quite different than conventional bridge construction plan during occupancy, as in sustainable bridge all sustainable goals should be taken into consideration to not effect on environment, economic, people social live and time schedule during construction through occupancy.

As shown in table (8-4) Classification of the building Rotation as a sustainable building using the integrated design process are studied according to project phases.

**Table 8-4- Classification of the building Rotation addressing phases and transitions as a sustainable building using the integrated design process**

<table>
<thead>
<tr>
<th>Major Phases</th>
<th>Major Categories</th>
<th>Sub Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility study pre-design Design</td>
<td>Owner and Designer</td>
<td>For Site</td>
</tr>
<tr>
<td></td>
<td>Site - bridge - Material - Energy</td>
<td>Bio diversity - Land utilization - Alternate transportation - community development - energy saving For material Low environmental impact materials - reuse - recycle</td>
</tr>
<tr>
<td>Construction Management/ Planing</td>
<td>Pre construction</td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>Construction commissioning</td>
<td></td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>Survive and support</td>
<td></td>
</tr>
<tr>
<td>Decommissioning</td>
<td>Source and disposal</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Figure (8-9) description of each step in the design process, and the text below the pictures describes the main responsible person(s). Those stated in brackets should be available for consultancy, if needed, during the current design step.

**Figure 8-9- A simple description of the total integrated design process**

- **Occupancy and commissioning**
  These newly added steps to the sustainable bridge is to guarantee the bridge success to achieve its sustainability goals. Also to make sure then the bridge achieved the designed function and accommodate added functions.

- **Building end of life reuse or demolition/recycle**
  From bridge design stage, the designer should have an end-of life plan to reduce consumed materials and reuse, recycle the used bridge materials, also the bridge team

---

should have a best end of life plan to minimize bad effects on environment and have best economical income. As shown in table (8-5) and (8-6) : Green Construction management versus Conventional construction management are studied.

**8-4-4-Systems Thinking**

Systems thinking is similar to integrative design in that in systems thinking project teams are supposed to view each part of the project in relationship to other parts of the project. 

In a sense a series of small systems are connected to become a more complex system in which the parts all affect each other. These nested systems can represent a building project, a community, or a city. Systems thinking tries to avoid designing a solution to one problem that results in a problem in another system.

To understand systems we must understand the types and how to affect them. There are different types of systems and the difference between them is determined by how the system relates to the world around it.

- **Closed Systems** - A set of actions/materials with a closed loop. For example, plants growing in a field, grow, produce oxygen, take in water, then die and decay which helps plants grow.

Closed systems can be linked so one system uses the byproducts of another. Closed systems are considered to be the most sustainable because there is no “waste” or final end product. The system continues on and on independently.

- **Open Systems** - Unlike closed systems, an open system is a system that constantly takes in items from outside the system, uses them and then released them as waste. This system has no feedback loop. Think of a normal home where groceries, products, or water come into the home, are used and then released as waste water or garbage.

Open systems are less sustainable because they require new inputs and create waste. Only if that waste can be used in another system can an open system become closer to a closed system and be more sustainable. An example of two open systems working to be sustainable could be a factory that produces a product, but gives scrap material to another factory to create a different product. Think of a lumber mill that creates 2x4s as one product and uses the wood chips and dust to create paper at another factory.

System thinking requires a project team to access how small systems work together in the larger system to be the most efficient as possible. For example a project team may assume that a recycling program is reducing waste, but if they are not careful to check the recycle removal process, the recycled material could be added to the waste stream. This can happen in office buildings when the cleaning staff is not properly trained on the recycling program. Sometimes recycled materials are sorted in the office but cleaning teams simply treat all recycle material and trash as waste. In this situation teams need feedback to see if the system is working properly.

**There are Several Ways to Affect How a System Works.**

- **Leverage Points** - leverage points are a point in a system where a small change can lead to large changes in results. This means small actions that can be free or a small cost might mean large savings or improvements on a project.

- **Positive and Negative Feedback Loops** - Both positive and negative feedback loops effect a system. Feedback is essentially information or results of the system.  

---

Table 8-5: Green Construction management versus Conventional construction management (Feasibility and design stages)

<table>
<thead>
<tr>
<th>Phase 1: Feasibility</th>
<th>Conventional Construction</th>
<th>Sustainable Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project need assessment</strong></td>
<td>Define need based on market conditions, physical needs, or other narrow scopes.</td>
<td>Need definition, in addition to market conditions, physical needs, etc., includes environmental goal, LEED certification level, as well as the amount of capital investment toward green initiatives.</td>
</tr>
<tr>
<td><strong>Project manager selection</strong></td>
<td>Select a manager or hire one to serve as the project manager. Selection may or may not happen this early in the project.</td>
<td>Hire an experienced green building consultant/project manager who is familiar with the product type and market and has exposure to all phases of sustainable construction; a LEED accredited professional is optimal and strongly recommended.</td>
</tr>
<tr>
<td><strong>Preliminary site analysis and plan</strong></td>
<td>Develop a preliminary budget estimate based on past or benchmarked traditional projects; unit costs are applied to a preliminary scope of work.</td>
<td>Finalize economic and ecological goals based on cost/benefit analysis. Consider site characteristics and weigh building needs against ecological issues. The preliminary budget is aligned with the project’s unique goals, and is often accomplished by creating a cost model that aligns resources with program goals to ensure project priorities are not mismatched to resources.</td>
</tr>
<tr>
<td><strong>Design charrette</strong></td>
<td>Charrettes may or may not be implemented during a conventional project. They are often perceived as economic waste or schedule inhibitors.</td>
<td>Must include all key external stakeholders, including surrounding property owners and other community representatives. Diverse representation from the project team functions design, architecture, building contractor, environmental engineer, real estate consultant, etc. is optimal. The final report serves as one of the guiding documents for the design and construction process.</td>
</tr>
<tr>
<td><strong>Final site selection</strong></td>
<td>Select site based on traditional pro forma with little stakeholder involvement.</td>
<td>Select site based on stakeholder involvement including community input. At this point, the construction team is in place the owner, the project manager, the architect and the Contractor and all parties have a stake in site selection.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase 2: Design</th>
<th>Conventional Construction</th>
<th>Sustainable Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial budget and schedule</strong></td>
<td>Budgets are typically developed by an architect based on a formula or unit costs, which can vary as much as 15% from actual costs. They are often created and expended with little consideration of future operating and maintenance costs.</td>
<td>Complete preconstruction estimates with input from the builder, project manager, architect, and real estate consultant. Estimating costs associated with specialized areas like green-building products require experience. The budget may also include an emphasis on life cycle costing, shifting focus from short-term return on investment to long-term gains from operational savings.</td>
</tr>
<tr>
<td><strong>Initial budget and schedule</strong></td>
<td>At this point in the project, this is often the first time regulatory agencies have seen design concepts or site plans.</td>
<td>The zoning approval process can often go more smoothly after an inclusive charrette process has been completed because the project will be less likely to face community resistance.</td>
</tr>
<tr>
<td><strong>Design team selection</strong></td>
<td>Select the architect or general contractor depending on the type of contract.</td>
<td>Usually, the core design team has already been selected by this time. Additional experts for technical systems may be interviewed and selected.</td>
</tr>
</tbody>
</table>

---

### Table 8-6: Green Construction management versus Conventional construction management (Construction and Implementation stages)

<table>
<thead>
<tr>
<th>Phase 3: Construction and Implementation</th>
<th>Conventional Construction</th>
<th>Sustainable Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction document development</td>
<td>Although the design is finalized by this time, often green initiatives are considered, causing rework.</td>
<td>Because the integrated team has participated in the planning and design process, construction documents can be developed more efficiently and with little design modifications.</td>
</tr>
<tr>
<td>Government permitting review</td>
<td>Plans are often reviewed for the first time for engineering compliance grading, erosion control, and storm water Standards, building codes, water and sewer systems, etc.</td>
<td>Government stakeholders are involved at earlier stages to ensure compliance with local, state and federal guidelines. The regulation of these important environment systems like wastewater and erosion control are significantly connected to LEED requirements.</td>
</tr>
<tr>
<td>Project bidding</td>
<td>“Hard bid” methods are most common, where the lowest bid cost is awarded and subcontracts are negotiated by the contractor on a closed-book basis.</td>
<td>Reed and Gordon 2000 recommend an “overhead/fee bid with an open-book subcontracting process” for green projects. Stipulations for minimum number of bids and cost savings allocations can also be included. “Open book” subcontracting allows the owner to have access to the estimates and pricing submitted by subcontractors.</td>
</tr>
<tr>
<td>Contracting</td>
<td>Traditional contracts like cost-plus percentage or cost-plus-fixed fee are applied. Sometimes work is further divided into multiple contracts, depending on uncertainty surrounding the project.</td>
<td>Integrated development requires a different kind of client/ architect and client/contractor. Contracts should include performance agreements, incentives, and bonuses for implementing sustainable practices and exceeding sustainability goals. Contracts should also include specific provisions for LEED points, Energy Star requirements, the use of recyclable materials, on-site recycling requirements, and agreements to return unused materials to vendors, among others.</td>
</tr>
<tr>
<td>Construction</td>
<td>Weekly site inspections are typically reported by architect or builder. There is little cross-communication among the site workforce, including subcontractors.</td>
<td>Launch construction with kickoff meeting that includes a sustainable education component for on-site construction personnel; monthly on-site meetings are required by entire site workforce and include periodic education and training sessions on green building. Sustainability requirements are reviewed with each subcontractor prior to commencing work.</td>
</tr>
<tr>
<td>Inspections</td>
<td>Field changes caused by fragmentation in the owner-architect-builder relationship can require additional government inspections, which create cost and schedule inefficiencies.</td>
<td>At this point, government regulators are working as a partner in the project, as opposed to an outside influence. Less rework and field adjustments decrease the chances of having to request reinsertions.</td>
</tr>
<tr>
<td>certification</td>
<td>Typically not applicable. If the project is seeking certification, documentation can be difficult to assemble from multiple sources.</td>
<td>The ongoing efforts of the project manager, coupled with the benefits of an integrated team and specialized technology, can make compiling and submitting documentation more efficient for the project’s schedule and budget.</td>
</tr>
</tbody>
</table>

---

- This feedback can encourage the system or stop it. A feedback loop cannot work unless information or results flow in the system.
- **Negative Feedback Loop** - a system where the output may signal the system to stop changing, i.e. a thermostat - at a certain point the temperature feedback will tell the system to cut off. The information of temperature must be made available to the thermostat for this system to work.
- **Positive Feedback Loop** - a system where energy is taken from the output of a system and reapplied to the input, or A produces more of B which in turn produces more of population growth – Adults make children whom in turn make more Adults.

As we see in the positive feedback example, this type of feedback actually increases the speed or encourages the system. Urban sprawl happens because people move to the suburbs, forcing cities to provide utilities and roads for the new communities. Once the new location is urbanized it can encourage people to move even further away since now what used to be far from the city is viewed as being quite close.  

### 8-5- Bridge Economical Evaluation

There are major points to estimate the bridge's cost with reference to value engineering.

A. Estimate the total cost and full consideration from the very first stages of the conceptual design.

B. Accurate estimating is difficult unless it based on considerable experience of similar work. It is reasonably easy to estimate material costs, but plant and man-hour content as well as overheads are often difficult to quantify without previous experience so it is important to use corporations hat previous experience in same projects.

C. It is consequently necessary to update estimates regularly as the design proceeds and details become better defined.

D. During the total period of design and construction, it should be objective to optimize costs in terms of utility. This is naturally part of the design process and requires knowledge, experience proficiency and the ability to innovate.

E. In order to make valid cost comparison between alternative solutions there are two important factors to guide any evaluation:
   - That comparison should be made on a common basis.
   - That significantly varying items should be identified so that they can be examine more closely where necessary.  

There are no permanent rules about the comparative costs of differing solutions for construction, because changes take place in the relative cost and availability of labor and materials from one time to another, and developments in constructional techniques or new materials can also make a significant impact.  

Cost savings can be achieved by several means, such as optimization of material use in the structure; partial prefabrication if cost for the pre-casting yard, transportation, and placement of the elements are less than cost for cast-in-place facilities on site and schedule optimization with respect to labor allocation.

---


Use of local materials in bridge construction for earthwork, concrete aggregates, and perhaps stone masonry contributes both to aesthetics and cost cutting of the bridge project, as long distances of transportation are avoided.\(^1\)

**8-5-1- Beauty versus cost in bridge's design:**
Good architect can work under any budget, and good design could be achieved with any budget. Frederick Gottemoeller\(^2\) summarized his opinion concerning beauty versus cost case in some points at his book (Bridgescape - The art of designing bridges). Table (8-7)

<table>
<thead>
<tr>
<th>Bridge form from its structure</th>
<th>The good design of bridge mostly related to its structure system, and the hierarchy of forces through different parts of bridge will be reflected on bridge's lines smoothing So the beautiful bridges is also economical bridges and not vice versa. (^4) Example: Salginatobel Bridge 1929-1930 - Switzerland. Represent that beauty follow good structure(^5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost versus public opinion</td>
<td>Bridge is considered one of the biggest objects affects on the visual image of the bridge's surrounding, especially if the bridge surrounding is a historical place. Bridge design should follow the architectural character of the historic place, also the bridge may have another function instead of carrying people from one place to another, to a land mark. Example: London Tower Bridge 1894 by John Wolfe Barry -and adding London tower bridge exhibition(^6)</td>
</tr>
<tr>
<td>Cost versus Design</td>
<td>One of the ugly bridges designs arguments is the bridge's design process takes big time and this time consumes money but as a defense if the bridge designer provided with good computer skills a man power, the good design will be present with minimal cost and minimal time.</td>
</tr>
</tbody>
</table>

**8-5-2- Green Bridge Costs**
Looking down the line to ultimately save dollars impacts the economic bottom line, because of the impact of rising fuel costs and energy costs. In the past when constructing a new building the long term costs were never taken into consideration. Green building studies have shown the cost of building green can be the same as that of traditional building. Green building projects have hard and soft costs just like traditional building, but the project team also considers life cycle costs.

- life cycle cost (LCC)
- Life Cycle Assessment (LCA)

A life cycle cost differs from life-cycle assessment (LCA), which is the investigation and valuation of the environmental impacts of a given product or service caused or necessitated by its existence. LCA addresses environmental impacts while LCC addresses economic impacts. Used together LCC and LCA can provide the cost of material, environmental and energy analysis of a building, from construction to demolition, needed for decision making.

---

2 - Frederick Gottemoeller has more than 42 years of experience in bridge and highway design, transportation planning, transportation management, and citizen participation. Using his skills as both an architect and engineer he creates transportation projects that incorporate the goals and aspirations of their communities while integrating both visual and technical criteria. His goal is to work with communities to develop transportation facilities that are as elegant as they are cost effective.(http://bridgescape.net/web/)
5 - http://structuree.net/structures/salginatobel-bridge
A life cycle cost differs from life-cycle analysis (LCA), which is the investigation and valuation of the environmental impacts of a given product or service caused or necessitated by its existence. LCA addresses environmental impacts while LCC addresses economic impacts.\(^1\)

**There are some definitions needed to best evaluate LCA and LCC:**

**Soft construction costs:** Are costs not directly related to building, construction, etc. These include architectural, legal, financing, engineering fees and other costs incurred before and after construction. These costs make construction possible but are not directly related to building the project.

**Hard costs:** deal with fixed assets. They are directly related to improving real property. Green building also differs from traditional design by considering the operating and maintenance costs of the building over its lifetime, not just the construction costs. A lifecycle cost analysis helps define the long-term operations and maintenance costs. For example, if Carpet A costs $10,000 but only lasts 5 years, and Carpet B costs $20,000 but lasts 20 years, Carpet B is a better choice because it has lower lifecycle costs. During the pre-design phase, project teams should set their goals for life cycle costs rather than "first cost" value-engineering.\(^2\) The use of a well-defined cost-benefit analysis could also be used to demonstrate the benefits of going green.

**Table 8-8- The goals and benefits of green construction**\(^3\)

<table>
<thead>
<tr>
<th>Planet/Environmental</th>
<th>Profit/Economic</th>
<th>People/Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reduce energy consumption 50%</td>
<td>• Reduce energy costs 50%</td>
<td>• Be a good corporate citizen</td>
</tr>
<tr>
<td>• Reduce greenhouse gas emissions 50%</td>
<td>• Reduce water costs 50%</td>
<td>• Provide a healthy work environment</td>
</tr>
<tr>
<td>• Reduce water usage 50%</td>
<td>• Reduce maintenance costs</td>
<td>• Reduce greenhouse gas emissions</td>
</tr>
<tr>
<td>• Reduce waste produced during construction and during operations</td>
<td>• Increase productivity</td>
<td>• Maximize utilization of resources</td>
</tr>
<tr>
<td>• Protect biodiversity</td>
<td>• Owners payback targets are &lt;10 years</td>
<td>• Reduce overall carbon footprint</td>
</tr>
<tr>
<td></td>
<td>• Reduce risk of sick building-related issues</td>
<td></td>
</tr>
</tbody>
</table>

In table (8-8), the goals and benefits of green construction is discussed from the planet’s (environmental), profit (economic), and social point of view with the possible constrains faced by each party.

The main structure of eco-cost as a single indicator of LCA will be shown at figure 8-16. Early in the design process, little is fixed and no big investments are made, therefore there is still a lot of freedom to change the design. A downside of this is that there is not much information available about the design. On the other hand, at the end of the design process the total design is already fixed, a lot of time and money is spend, and to change things is costly. There is however a lot of information available about the design. This dilemma is made visible. Figure (8-10).

To make a full LCA much information is needed about the design. For that reason a LCA is made at the end of the design process, when the design is finished. However, when the design does not score well on the LCA, not much can be improved.

To make really innovative improvements it is needed to take sustainability into account during the whole design process.\(^1\)

---

8-6- Conclusion

Conventional bridges design process usually involves a linear project handoff from architect to engineer to contractor to users. By contrast, the integrative design process front-loads the process, bringing the client, designers, engineers, contractors, occupants and operators together early in the design process to collaboratively establish project goals, strategies innovative approaches and resolve conflicts in advance. These disciplines then continue to work together in an integrative process toward the project’s high performance goals. As shown in table (8-9) Summary of how process and bridge strategies could be compared. Also, as shown at figure (8-11) Organizational chart of a design team of bridges are illustrated.

---

2 - Vogtländer, J.G: "A practical guide to LCA for students, designers and business managers- cradle-to-grave and cradle to cradle- Delft University of Technology - Netherlands- 2010- p 30.
Figure 8-11- Concluded Organizational chart of a design team of bridges

Table 8-9- Summary of how process and bridge or building strategies be compared

<table>
<thead>
<tr>
<th></th>
<th>Traditional project delivery</th>
<th>Integrative process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terms</td>
<td>Hierarchal, working independently only as needed</td>
<td>Collaborative, Integrative, Assembled as early as possible before any designing</td>
</tr>
<tr>
<td>Process-schedule</td>
<td>Linear, working in silos</td>
<td>Concurrent, shared information, iterative</td>
</tr>
<tr>
<td>Risk</td>
<td>Individual risk</td>
<td>Shared equally</td>
</tr>
<tr>
<td>Compensation</td>
<td>Individually based</td>
<td>Based on team success</td>
</tr>
<tr>
<td>Communication</td>
<td>Paper based</td>
<td>Digital and virtual, use of computer model</td>
</tr>
<tr>
<td>Materials-Strategies</td>
<td>Least expensive to meet code</td>
<td>Life cycle analysis, cost</td>
</tr>
<tr>
<td>Project phases</td>
<td>Design -occupancy</td>
<td>Pre design phase, green building goals, review.</td>
</tr>
</tbody>
</table>

8-6-1- Concluded prerequisites
AP: Bridge Design / Construction Proposals
AP: Integrated Team Members and Architect Role
AP: Bridge Integrated Costs

2 - "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014- p24
Sustainable Rating System for Architectural Evaluation of Bridges in Egypt

Introduction

Part 1: Theoretical Study
    Bridges and Sustainability Overview
    Chapter 1: Bridge’s Art, Science and Construction Historical Development
    Chapter 2: Sustainable Bridges

Part 2: Analytical Study
    Developing a Rating System for Egyptian Bridges Architectural Evaluation
    Section 1: The Factors Influencing in Bridge’s Architecture through Design and Construction Stages
        Chapter 3: Different Types of Bridges and Architecture
        Chapter 4: The Relationship between the Bridge and its Context
        Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
        Chapter 6: Bridge's Different Parts and their Relation with Bridge's Shape and Form
        Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.
        Chapter 8: Design Process of a Sustainable Bridge and Architect’s Role
    Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage
        Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study
    Developing an Egyptian Sustainable Bridge Rating System
    Chapter 10: Sustainability Assessment Concepts
    Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation
    Chapter 12: Conclusion and recommendations

Appendices
Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with the Surrounding Curtilage and Community (Operation and Usage Stage)

Chapter 9 structure: Bridges Synchronizing with the Surrounding Curtilage and Community (Operation and Usage Stage)
Chapter 9: Bridges Synchronizing with the Surrounding Curtilage and Community (Operation and Usage Stage)

Introduction

The curtilage of a bridge is the space around and under the bridge. It is integral to the visual success of a structure, just as a garden is integral to a house. It is distinct from the context of the bridge in that it should be considered as part of the project, rather than the existing environment. The design of the bridge curtilage is integral to the success of the bridge as a whole.

9-1- Bridges Influence on Cities Visual Image all Over the World

As shown in table (9-1), Bridges influenced on cities visual image (The influence of bridge on The city's character and Bridges as a touristic monuments). and table (9-2) Bridges influenced on cities visual image (Bridges as an evidence of cities evolution or Backwardness) Positive and negative effects of bridge on the surrounding curtilage and community are discussed.

9-2- The Consequence of Bridge Usage on the Surrounding Cartilage

Bridge curtilage could be divided to:
- The space around the bridge
- The area under the bridge

9-2-1- The Space around the bridge

The space around the bridge, as an interface between the bridge and its context, serves several aesthetic functions.
- It is the setting in views to the bridge.
- It is the foreground in views from the bridge.
- It provides an opportunity to frame and contrast the bridge.

Generally there should be continuity between the existing landscape and the space around the bridge. Where possible the space should be designed so that it complements the adjacent landscape character.1

9-2-1- Under the bridge as a public area

Area a bridge must be considered in the concept design phase of the bridge and integrated into the design of the whole structure. Figure (9-1)

If these spaces are not considered then bridge aesthetics will be impaired by the presence of dead or dying plants and ‘eroded rubbish strewn’ surfaces. Also valuable space will be lost. There are range of strategies in dealing with this space which includes the following:
- Consider the surface treatment of the space. These spaces tend to be very dry and if in deep shade plants are unlikely to survive. Where plants are used they should be located to the outside of the space and irrigation may be required. Generally only the most shade and water tolerant plants should be used
- Consider the function of the space. (Footpath and cycle way networks can benefit from the additional connectivity the space under a bridge provides.
- With high urban bridges the potential use of this space for future development should be considered. It may be that the bridge aesthetics would benefit from undercroft development.

1 - "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012- p 66-69.
### Table 9-1: Bridges influenced on cities visual image (The influence of bridge on The city's character and Bridges as a touristic monuments).

<table>
<thead>
<tr>
<th>9-1-1-The influence of bridge on The city's character</th>
<th>9-1-2-Bridges as a touristic monuments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Venice Bridges</strong>: Venice canal is at in the shape of an ‘s’ in the whole city, there are only four opportunities to cross the Canal Grande throughout the city, which are all worth to be visited. From left: Ponte di Calatrava, Ponte di Rialto, Ponte dell'Accademia, and Ponte degli Scalzi.</td>
<td><strong>Galata Bridge</strong>: Galata Bridge is the heart of Istanbul, spanning the Golden Horn from Karaköy on the north to Old Istanbul, built in 1992. The lower level is consists of some restaurants.</td>
</tr>
<tr>
<td><strong>Paris Bridges</strong>: Below is a list of some of the bridges that cross the Seine river in central Paris. You can move the mouse over the map on the right to see where they are located. From left: Passerelle Léopold-Sédar-Senghor Bridge, Passerelle des Arts (aka Pont des Arts) bridge, Passerelle Simone de Beauvoir bridge and Pont au Double bridge.</td>
<td><strong>Love-Lock Bridge</strong>: it has become a tradition of lovers in Paris, France, both French and foreign, to attach metal locks to the bridge to seal their love.</td>
</tr>
<tr>
<td><strong>Amsterdam Bridges</strong>: Amsterdam has so many picturesque bridges. With more than 1,200 bridges, some are historic (the oldest is from 1648), and several are awe-inspiring feats of engineering. From lift nuncio bridge, jan schaefer bridge and borneo-sporenburg bridge</td>
<td><strong>Blackfriars Bridge</strong>: Built in 1869 in London, Blackfriars Bridge gained notoriety in 1982 when Vatican bank Chairman Robert Calvi was found hanging from it.</td>
</tr>
<tr>
<td><strong>London Bridges</strong>: Many of London’s iconic bridges along Thames river give unique views and access to some of the city’s most popular sights, tours and events.</td>
<td><strong>Albert Bridge</strong>: is a road bridge crossing the Thames in West London. It is one of only two road bridges in London to never have been replaced</td>
</tr>
</tbody>
</table>

http://www.visitlondon.com/things-to-do/sightseeing/london-attraction/bridge  
http://www.visitlondon.com/things-to-do/sightseeing/london-attraction/bridge  
http://blog.smartfares.com/tag/canopy-walk-in-ghana  
http://www.#!/en/paris/bridges.htm  
http://www.davestravelcorner.com/journals/destination-europe/the-4-bridges-crossing-the-canal-grande-in-venice/
### Table 9-2: Bridges influenced on cities visual image (Bridges as an evidence of cities evolution or Backwardness)

<table>
<thead>
<tr>
<th>9-1-3-Bridges as an evidence of cities evolution</th>
<th>9-1-4-Bridges as an evidence of cities Backwardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>One of evidence of cities evolution is bridges construction as a symbol of technology and transportation solution, Also because bridges are considered one of the major landmarks in modern cities.</td>
<td>Students Crossing a damaged suspension bridge, Lebak, Indonesia</td>
</tr>
<tr>
<td><strong>Abu Dhabi : Sheikh Zayed bridge by Zaha Hadid 2010, UAE</strong></td>
<td>Kids traveling through the forest across a tree Root Bridge, India</td>
</tr>
<tr>
<td><strong>New bridge to boost Bahrain trade links with Saudi Arabia, KSA</strong></td>
<td>Crossing a broken bridge on the snow to get to school in Dujiangyan, Sichuan Province, China</td>
</tr>
<tr>
<td><strong>Tianjin Eye Bridge, China</strong></td>
<td>People walking on a tightrope 30 feet above a river, Padang, Sumatra, Indonesia</td>
</tr>
<tr>
<td>The Egyptian ring road and Pedestrian bridge, using it by pedestrians, using the Area under the bridge as Garbage dump and Some Kids are crossing a water way From school Using weak piece of wood (by researcher).</td>
<td></td>
</tr>
</tbody>
</table>
• Where the underside of the bridge is visible, consideration should be given to the
design of the soffit. Clean uncluttered surfaces, neat connections and simple layout
of girders will help to give a suitable appearance.

The design of the new Iron Cove Bridge considered the
local setting. A bridge curtilage was created that
respects King Georges Park in Rozelle and the Bay Run.

The timber boardwalk under the
triple bridge over Brunswick River traverses an area of
relocated mangroves, preserved sea grasses and rocky outcrops
with views towards the ocean and surrounding mountains.

In this example in Canberra
the stabbed girder creates a
smooth lightly textured
surface. LED lighting
enhances the effect and also
identifies the bridge.

Interchange on the Pacific
Highway at Ballina. The
bridge design and the setting
were a single composition

The curtilage of the bridge over
the Woronora River provides a
significant public domain, sense
creation of local park.

fauna corridors was created
and help reconnect habitats.
under Bonville Bypass
bridge included many fauna
connections.

Figure 9-1: Examples of Bridges Curtilage in Australia.¹

public space definition: A place, in wide definition, for everybody to enjoy their
coeistence and represent their collectivity and common interest without drowning or
disaggregating their diversity.²

"Ashihara" divided the public spaces to positive spaces and Negative spaces according
to users ejection and attraction

• Positive spaces: relatively enclosed, outdoor space has a definite and distinctive shape.
it is conceivable, can be measured and has a definite boundaries. We could imagine it
being filled with water, which subsequently runs out relatively slowly. It is
discontinuous (in principle), closed, static but serial in composition. Its shape is as
important as that of the buildings surrounding it.

• Negative space is shapeless, e.g. the amorphous residue left over around buildings
which are generally viewed as positive. It is 'inconceivable' continuous and lacking in
perceivable edges or form. It is difficult to imagine such space being filled with water
because -quite simply - it is difficult to conceive of the space.³

¹ "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads
and maritime services- New south Wales- Australia-2012- p 66-69.
³ - Matthew Carmona, Tim Heath, Toner Oc and Steven Tiesdell: "Public places - Urban spaces"- The Dimensions of Urban Design
Conditions to format public spaces: As shown in Table (9-3) Main conditions for formatting public spaces, with examples from Egypt are discussed.

**Table 9-3: Main conditions for formatting public spaces, with examples from Egypt.**

<table>
<thead>
<tr>
<th>Available Space</th>
<th>The existance of an outdoor or semi-outdoor space, this space may be rectangular or circle space or has no defined form. Space under the bridge is an available public space, so people illegal using it for different activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility</td>
<td>The space could be converted to contain any new activity or to be connected with an existing activity. The area under the bridge, is a flexible area which could be formed to harmonize the requested activity.</td>
</tr>
<tr>
<td>Connectivity</td>
<td>A strong relationship between the space and streets or main axes for pedestrians and vehicles. Most of areas under bridges are the perfect connected areas to main axes for pedestrians.</td>
</tr>
<tr>
<td>Activities</td>
<td>The existance of the activity itself, like commercial activities, car parkings or any other activity. The activity is determined by the bridge location and the surrounding activities or by the need of certain activity.</td>
</tr>
</tbody>
</table>

**9-3- The consequence of Bridge Usage on the surrounding cartilage in Egypt**

**9-3-1- The space around the bridge**

Usually, Spaces around Egyptian bridges are previously developed, because most of Egyptian bridges are located to solve traffic problems, so the space around the bridge is mostly another roads, river or any previously mentioned obstacles. figure (9-4)

---

1 - http://media.linkonlineworld.com/img/Large/.jpg
2 - http://www.n-cairo.com/ar/?p=3244
3 - http://gallery.egyroom.com/cairo/cairo98.html
9-3-2- The Area under the Bridge
There are some factors affecting the area under the bridge usage, but before studying these factors, some definitions should be studied. Area under the bridge is a public space. Public space is considered one of the major affects on the urban spaces because it considered the small unit which forms the urban spaces. The form of large urban spaces like expressways and downtowns as well as small urban spaces like streets and neighborhoods, plays a key role in how a city works and how it is experienced.¹ Figure (9-3).

Elsaawy Cultural wheel as an example of area under the bridge usage as a public space - Under 15th may bridge - Giza by researcher

The sensitive use of sandstone paving and bollards, at the heritage abutments under the new Iron Cove Bridge in Rozelle, has created a place to view the evolution of harbour crossings at this point – from early ferries to timber truss to Art Deco steel truss to concrete incrementally launched girder.

Figure 9-3- Examples of Under the bridge as a public area²

9-4- Incorporeal Factors Affecting on Usage of the Bridge Surrounding Curtilage in Egypt
As shown in table (9-4), The Incorporeal factors affecting on bridge usage on the surrounding curtilage in Egypt are reviewed.

9-5- Conclusion
In this chapter, the effect of bridge on the surrounding curtilage was discussed, Bridge curtilage means area under and around the bridge which is affected by bridge construction and usage. Also the Influence of bridges on cities visual image all over the world, this influence may affect on bridge character, evidence of cities evolution or deterioration, Also bridge may be considered as a touristic attraction. Bridge curtilage examples from Egypt and all over the world were studied to evaluate Bridges Synchronizing with surrounding curtilage and community.

9-5-1- Concluded Prerequisites
AP: Bridge Curtilage Development Report:

9-5-2- Concluded Credits
CR: Influence of Bridges on Cities Visual Image
CR: The Space around the Bridge
CR: The Area under the Bridge
CR: Bridges Maintenance from Architectural Perspective

¹ - Figure taken from: "The sensitive use of sandstone paving and bollards, at the heritage abutments under the new Iron Cove Bridge in Rozelle, has created a place to view the evolution of harbour crossings at this point – from early ferries to timber truss to Art Deco steel truss to concrete incrementally launched girder.
² - Same previous reference
### Table 9-4: Factors affecting the Bridge Surrounding Curtilage usage in Egypt

<table>
<thead>
<tr>
<th>Urban planning Factors</th>
<th>Social Factors</th>
<th>Government</th>
<th>Environmental factors</th>
<th>Economical factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-Bridge Location,</td>
<td>Homeless and criminals under Egyptians several bridges and at pedestrian bridge.</td>
<td>From Lift: Feisal Traffic department - Giza and Orabi bridge in front of Elzeraa college metro station - Commercial activities and Misr bank under the bridge- Cairo</td>
<td>The illegal usage of the area under El-tunsi bridge at Elsayeda-eisha converts it to slums</td>
<td>From lift: Maarad Bridge - Tanta (shops were built under the bridge), Street vendors under Giza bridge- Giza square and under 6th of October bridge, Ramsis square</td>
</tr>
<tr>
<td>B- Bridge relationship with roads and axes,</td>
<td>Converting the area under the bridges by homeless to a residence.</td>
<td></td>
<td>Garbage dumps, From lift Qalyob bridge, Ezbet Elnakhel Metro station pedestrian bridge</td>
<td></td>
</tr>
<tr>
<td>C- The obstacle which bridge crosses,</td>
<td>Using area under the bridge for illegal activities.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D- City visual image and visual connectivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E- The surrounding neighborhood main activity (industrial, commercial, agricultural areas)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The negative impacts from using area under the bridge as a garbage dump.
- The impact from illegal usage of area under bridge for commercial activities.

**Sources:**
- http://www.albawabnews.com/upload/photo/gallery/21/6/700x500/585.jpg
- http://www.el-balad.com/1292915
- https://www.youtube.com/watch?v=dS0EiAv9TQ
Part 3: Inductive Study

Developing Egyptian Sustainable Bridges Rating System

Chapter 10: Sustainability Assessment Concepts

- Introduction
- 10-1- Introduction to environmental classification systems
- 10-2- Tools for environmental evaluation
- 10-3- Criteria for evaluation and selection of Rating system
- 10-4- Major Sustainability Rating Systems on the market
- Conclusion

Chapter 10 Structure: Sustainability Assessment Concepts

Page 189
Chapter 10: Sustainability Assessment Concepts

Introduction
In 1990, in the United Kingdom, the first comprehensive environmental classification system was introduced: Building Research Establishment Environmental Assessment Method (in short BREEAM). This classification system was an initiative from the construction industry in the U.K.

Today there are many different energy and environmental assessment systems. An environmental classification is primarily a certification and guarantee that the building constructed should be green. The large number of energy and environmental assessment systems indicate that the awareness in today's construction and real estate market has increased. The overall use of environmental systems is to offer an overview of a range of ways to enhance buildings' environmental performance. Sustainable bridge design is still in development, and clear standards and recommendations have not been formalized as they have in building design. So our purpose in this chapter is to overview the main rating systems for sustainable roads and buildings in the market and to select the most convenient rating systems to be well studied to develop the Egyptian sustainable bridges rating system.

10-1- Introduction to Environmental Classifications
In this part, Building assessment, measuring sustainability and concepts for environmental evaluation will be studied.

10-1-1- Building Assessment
Building assessment tools were developed to help with the evaluation of a building’s impact. Ecologically, economically and socially, all aspects of the building need to be eco-friendly, safe and should work harmoniously to promote the health and improve the productivity of its occupants. There are the Green Building tool (GB Tool) and the UK British Research Establishment’s Environmental Assessment Method (BREEAM) model. In addition to those two, the Green Building Initiative (GBI) Green Globes tool, the built green program, the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) method, the VERDE method and the Leadership in Energy and Environmental Design (LEED) method are briefly discussed.

10-1-2- Measuring Sustainability (Rating Systems Definition)
The rating and certification systems can be considered as a way of quantifying the level of sustainability of a building, based on the awards in the form of credits, points and prestigious certifications which are given as per the amount of effort that goes into the construction of the building.

10-1-3- Concepts for Environmental Evaluation
There are two main affecting concepts on environmental evaluation
- Life cycle cost analysis (LCC) - As previously mentioned.
- Life Cycle Assessment (LCA) - As previously mentioned.

Used together LCC and LCA can provide the cost of material, environmental and energy analysis of a building, from construction to demolition, needed for decision making.

3- Same Previous Reference p 12.
Also There are Main Concepts for Environmental Evaluation:

- **Life cycle thinking (LCT) concept**
  LCT takes into consideration the impact of any product from cradle-to-grave to include environmental impacts along its whole life cycle, process or activity.

- **Life cycle management (LCM)**
  LCM's goal is to have continuous environmental enhancement from a life-cycle point of view. It can use national or international standards and indicators.

- **Design for environment**
  Clean technology cares for the whole life cycle of the product.

- **Cleaner technology**
  It is a concept used in the industrial community to refer to preventing pollution and waste at source. Cleaner Production is defined by the UNEP (United Nations Environment Program (UNEP, 2006) as —the continuous application of an integrated preventive environmental strategy applied to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment. Cleaner production requires; change of attitudes, environmental management and evaluating technology.

- **Dematerialization**
  It refers to a considerable decrease in the amount of resources used to meet human needs, while increasing the quality.

- **Eco-efficiency**
  The term eco-efficiency was introduced by the World Business Council for Sustainable Development (World Business Council for Sustainable Development (WBCSD, 1993). It is defined as —the delivery of competitively priced goods and services, which satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle. Eco-Efficiency can be used as a practical approach as well as a measurable performance indicator for production because consumption processes can be calculated according to the general formula:

  \[
  \text{Eco-Efficiency} = \frac{\text{Environmental impact}}{\text{cost}}
  \]

- **Industrial ecology**
  It is the multidisciplinary study of industrial systems and economic activities and their link to fundamental natural systems.

- **End-of-Life (EOL) management**
  It is the management of products at the time their functional life has ended when it enters the waste phase focusing on the environmental aspects of a product.

Tools for environmental evaluation Tools are operational methods based on concepts and supported by technical elements such as models and software. Environmental tools may differ in their structure and technical details, but generally target complete environmental assessment. Tools are classified into analytical and operational ones.

---

classified into analytical and operational ones.\textsuperscript{1}

\textbf{10-2-1- Analytical Environmental Tools}
Analytical tools study the consequences of a choice. The most popular analytical environmental tools are: Refer to table (10-1)

\begin{itemize}
\item A. Life-cycle assessment (LCA)
\item B. Material intensity per service unit (MIPS)
\item C. Material flow accounting (MFA)
\item D. Cumulative energy requirements analysis (CERA)
\item E. Environmental input/output analysis (IOA)
\item F. Environmental risk assessment (ERA)
\item G. Checklists for eco-design, life-cycle costing (LCC)
\item H. Total cost accounting (TCA)
\item I. Cost-benefit analysis (CBA)
\end{itemize}

\textbf{10-2-2- Operational Environmental Tools}
Procedural tools focus on measures towards environmental performance. The most popular operational tools are:

\begin{itemize}
\item A. Environmental management system (EMS)
\item B. Environmental audits (EA)
\item C. Environmental performance evaluation (EPE)
\item D. Environmental labeling (EL)
\item E. Eco-design (ED)
\item F. Green procurement (GP)
\item G. Total quality environmental management (TQEM)
\item H. Rating systems\textsuperscript{2}
\end{itemize}

\textbf{10-3- Criteria for Evaluation and Selection of Rating System}
As shown in Figure (10-1), Criteria for evaluation and selection of rating system is illustrated.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure10_1.png}
\caption{Criteria for evaluation and selecting of Rating system}
\end{figure}

\begin{itemize}
\item \textbf{Measurability:}
Knowing if the rating system uses measurable characteristics to demonstrate the extent of sustainable design incorporated into the building.
\item \textbf{Applicability}
It is to know if the rating system can be used for all building types (e.g. commercial,

\textsuperscript{1} A. M. Papadopouloa and E. Giama: "Rating systems for counting buildings environmental performance"- International Journal of Sustainable Energy- Laboratory of Heat Transfer and Environmental Engineering- Department of Mechanical Engineering- Aristotle University Thessaloniki- Thessaloniki- Greece - 2010
residential, offices, hospitals, etc.).

- **Availability**
  It is to understand the possibility of the interchangeable use of different rating systems between countries to rate the same building.

- **Development**
  It is to know on which methodology is the rating system based, whether on the requirements of standards and legislation or on life-cycle concept or on EMS philosophy, etc.

- **Usability**
  Making sure it is practical and easy to be implemented by the user, by having practical guides with separated implementation information depending on the building’s type.

- **System's maturity**
  This criterion is related to when the system was developed, its final revision date and the number of buildings’ registered and certified.

- **Technical content**
  This deals with the environmental aspects examined during the certification process.

- **Communicability**
  This ensures that a certified building is well known to outsiders at the end of the evaluation process.

- **Cost**
  This criterion is clearly very essential to the user (building developer, owner, inhabitant, etc.) and takes into account all the costs that arise during the buildings’ certification process. All systems evaluate buildings environmentally.¹

### 10-4- Major Sustainability Rating Systems on the Market.

In this part, major sustainable rating systems for building and roads will be overviewed to select the most convenient rating systems to be well studied to develop the Egyptian sustainable bridges rating system. The rating systems will be discussed through four tables.

#### 10-4-1- Building Major Sustainability Rating Systems on the Market

In this part, most used sustainable buildings rating systems will be summarized. Figure (10-2) and Figure (10-3).

![Green building rating systems - timeline](image)

**Figure 10-2: Green building rating system timeline¹**

---

10-4-1-1 - BREEAM (Building Research Establishments (Environmental Assessment Method))

BREEAM is the world's foremost environmental assessment method and rating system for buildings.

**What does BREEAM do?** BREEAM addresses wide-ranging environmental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties. BREEAM uses a straightforward scoring system that is transparent, flexible, easy to understand and supported by evidence-based science and research, has a positive influence on the design, construction and management of buildings, defines and maintains a robust technical standard with rigorous quality assurance and certification.

**The scope of BREEAM:** It covers all building types, schools, healthcare buildings, offices, industrial units and more. For the housing sector, there are a number of variants: BREEAM Eco Homes for new homes in Scotland. Figure (10-4)

---

1 - Same Previous Reference, p 29.
2 - http://www.egypt-gbc.gov.eg/about/global.html
3 - http://www.breeam.org/about.jsp?id=66
4 - Michael Bauer, Peter Mosle and Michael Schwarz: "Green Building – Guidebook for Sustainable Architecture", Springer publications- Germany-2010 - p17
edge system for certifying high-performance buildings and sustainable neighborhoods. **About LEED:** LEED was developed by USGBC, and the LEED Green Building Rating System is the USGBC’s primary vehicle for promoting sustainable design and construction. The LEED standard was created through Transform the building market. LEED helps to evaluate a building’s performance throughout the building’s life cycle.¹ Figure (10-5).

![LEED Certification Weighting](image)

**Figure 10-5: LEED® Certification Weighting**²

**10-4-1-3- DGNB (German Sustainable Building Council)**
The German Sustainable Building Council was founded in 2007 by 16 initiators from various subject areas within the construction and real estate sectors. The aim was to promote sustainable and economically efficient building even more strongly in the future.³

![DGNB Certification Weighting](image)

**Figure 10-6: DGNB Certification Weighting**⁴

**10-4-1-4-GRIHA (Green Rating for Integrated Habitat Assessment)**
GRIHA is India’s National Rating System for Green buildings. It has been developed by TERI (The Energy and Resources Institute) and is endorsed by the MNRE (Ministry of New and Renewable Energy). adopting the five ‘R’ philosophy of sustainable development, namely
1. Refuse: to blindly adopt international trends, materials, technologies, products, etc. Especially in areas where local substitutes/equivalents are available.
2. Reduce: the dependence on high energy products, systems, processes, etc.
3. Reuse: materials, products, traditional technologies, so as to reduce the costs incurred in designing buildings as well as in operating them.
4. Recycle: all possible wastes generated from the building site, during construction, operation and demolition.
5. Reinvent: engineering systems, designs, and practices such that India creates global examples that the world can follow rather than us following international examples.

Going by the old adage ‘What gets measured, gets managed; Project scoring:
- 50-60 points is certified as a 1 star GRIHA rated building,

---

¹ "LEED Principles and Green Associate Study Guide"- Green Building Education Services -USA- 2014- p 37-40
² Michael Bauer, Peter Mosle and Michael Schwarz : " Green Building – Guidebook for Sustainable Architecture"- Springer publications- Geermany-2010 -p16
⁴ - Michael Bauer, Peter Mosle and Michael Schwarz : " Green Building – Guidebook for Sustainable Architecture"- Springer publications- Geermany-2010 -p18
10-4-1-5- Estidama.
Launched in May 2008, Estidama which means ‘sustainability’ in Arabic is Abu Dhabi’s contribution to the global debate on how to create sustainable communities, cities and enterprises. Based on the four pillars of sustainability (environmental, economic, social and cultural) it aims to pull off the admittedly difficult trick of balancing all these concerns against the simple pursuit of progress and a better life.²

The Need for Estidama
- Estidama aims to revive the ecological and cultural sensitivity (traditions) of the people to their environment.
- Estidama arose from the need to properly plan, design, construct and operate sustainable developments with respect to the local traditions and climate.
- In order to achieve the goal of Estidama, developers, design teams and even residents need to rethink the design and planning process, the harsh climatic nature of the region.

10-4-1-6- GRPS (The Green Pyramid Rating system).
The Egyptian sustainability rating system GRPS was completed in 2011. Recognizing the unique ecological, industrial and social challenges of the region, the rating system helps to define what constitutes an “Egyptian Green Building”. To accomplish that goal, the rating system builds upon the Egyptian BEECs and integrate proven methodologies and techniques used in successful programs from the United States, Europe, Asia, South America and the Middle East.³

10-4-1-7- CASBEE (Comprehensive Assessment System for Built Environment Efficiency).
The Japanese Green Building Council (JaGBC) has developed a comprehensive family of green building rating tools for many markets and building types. The CASBEE rating systems are designed to analyze building performance at several stages in the building lifecycle. Currently, there are four distinct tools to match building phases from pre-design to renovation for commercial and industrial buildings. All of the rating tools use two general categories of analysis. Q (quality) assessments are taken at the building level, while L (load) assessments look at the building’s impact on the local environment or neighborhood. Buildings are rated using the Built Environment Efficiency (BEE) ratio by taking Q category scores and dividing by L category scores.

Current CASBEE Tools for Commercial, Industrial and Residential Buildings:
- Tool 0 – CASBEE for Pre-Design
- Tool 1 – CASBEE for New Construction
- Tool 2 – CASBEE for Existing Buildings
- Tool 3 – CASBEE for Renovation.⁴

---

¹ - http://grihaindia.org/
² - http://estidama.upc.gov.ae/
³ - http://www.egypt-gbc.gov.eg/ratings/
⁴ - http://www.ibec.or.jp/
10-4-1-8- GSBC (German Sustainable Building Certificate)
A certification system developed by (German Sustainability Building Council) and the federal ministry of Transport, Building and Urban Affairs (BMVBS).
GSBC measures how well a building or community performs in ecological, technical, economical, socio cultural and functional quality, as well as quality of process and location. Used as a planning and evaluation tool, the GSBC covers all relevant topics of sustainable construction, awarding outstanding buildings in the categories of Bronze, Silver, and Gold.\(^1\)

10-4-1-9- GBAS (Green Building Assessment System).
In 2006, the Ministry of Science and Technology (MoST) developed the GBAS in China, which is developed from China's Green Olympic Building Assessment System (GOBAS,2006), and measures basic environmental performance of buildings such as: electricity, water, and energy consumption.\(^2\)

10-4-1-10- IGBC (Indian Green Building System).
The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001.
The IGBC is affiliated with the World Green Building Council as a prospective member. This is a network of over 100 national Green Building Councils worldwide with a total membership of over 27,000 of the most progressive international organizations and businesses making it the largest organization globally influencing the green building market. We participate in the European Network of GBCs to influence policy at a European level.\(^3\)

10-4-1-11- R 2000.
In 1981, the Canadian Home Builders' association (CHBA) and the Office of Energy Efficiency (OEE) of Natural Resources Canada (NRCan) developed the R-2000 in Canada (R-2000).\(^4\)
R-2000 is a voluntary standard administered by Natural Resources Canada (NRCan) and is delivered through a network of service organizations and professionals across Canada.
What is the R-2000 Standard? The R-2000 is an industry-endorsed technical performance standard for energy efficiency, indoor air tightness quality, and environmental responsibility in home construction.
Houses built to the R-2000 Standard typically exceed the energy performance requirements of the current Canadian building codes and are recognized by meeting a high standard of environmental responsibility.\(^5\)

10-4-1-12- Green Buildings in China.
China’s Three-Star certification program is an integral part of the national Green Building Evaluation which established by MOHURD (Ministry of Housing and Urban-Rural Development at 2006 Standard (GBES), which defines green buildings as

---

3- http://www.igbc.ie/about/
4- Vivan Adel Younan: "Developing a green building rating system for Egypt"- Master Thesis- School of Science and Engineering- The American University in Cairo- Egypt- 2011- p 29
“buildings that save a maximum amount of resources (including energy, land, water, and materials), protect the environment, reduce pollution, provide healthy, comfortable and efficient space for people, and exist harmoniously with nature” throughout their lifecycle.

The GBES sets the official definition of green buildings in China, but, there are dozens of other definitions in the country that fall into three broad categories: local, project-based, and international.1

10-4-1-13-CHPS (Collaborative for High Performance Schools).
The Collaborative for High-Performance Schools (CHPS) began in November 1999 in California. Interest in high-performance design grew and CHPS expanded its focus, developing a national version of the standards. CHPS criteria is available for use by any state that does not have their own version2
The goals of CHPS are to fundamentally change the design, construction and operation of schools to: Protect student and staff health, and enhance the learning environments of school children everywhere Conserve energy, water, and other natural resources, Reduce waste, pollution, and environmental degradation.3

10-4-1-14-GREEN GLOBES
Green Globes is an online green building rating and certification tool that is used primarily in Canada and the USA. Green Globes is licensed for use by BOMA Canada (Existing Buildings) and the Green Building Initiative in the USA (New and Existing Buildings). There are Green Globes modules for New Construction/Significant Renovations Commercial Interiors and Existing Buildings (offices, multi-residential, retail, health care, light industrial)
Green Globes for Existing Buildings was developed in 2000 by ECD Energy and Environmental Canada. are needed to reply to the questions. An online manual is also available. Users can see how points are being awarded and how they are scoring.4

10-4-1-15-BEAM (Building Environmental Assessment Method)
BEAM was created by The Hong Kong Green Building Council. The Hong Kong Green Building Council Limited (HKGBC) is a nonprofit, member led organization established in 2009 which strives to promote the standards and developments of sustainable buildings in Hong Kong. The HKGBC aims to raise green building awareness by engaging the public, the industry and the government, and to develop practical solutions for Hong Kong’s unique, subtropical built environment of high-rise, high density urban area, leading Hong Kong to become a world’s exemplar of green building development.5
BEAM provides building users with a single performance label that demonstrates the overall qualities of a building, be it a new or refurbished building, or one that is already in use. A BEAM assessed building will be safer, healthier, more comfortable, more functional and more efficient that a similar building which has not achieved the prescribed levels of performance.6

3- http://www.chps.net/dev/Drupal/node
4- http://www.greenglobes.com/about.asp
5- https://www.hkgbc.org.hk/eng/Abouthkgbc.aspx
10-4-1-16-GGHC (Green Guide for Healthcare)
The Green Guide is the health care sector’s first quantifiable sustainable design toolkit integrating enhanced environmental and health principles and practices into the planning, design, construction, operations and maintenance of their facilities. This Guide provides the health care sector with a voluntary, self-certifying metric toolkit of best practices that designers, owners, and operators can use to guide and evaluate their progress towards high performance healing environments.
The Green Guide is divided into a Construction section and an Operations section. The Construction section is relevant for new construction, renovations, and additions. Existing facilities are encouraged to track their ongoing performance using the Operations section, while making a commitment to utilize the Construction section on future projects.1

10-4-1-17- Green Star (Australia)
Green Star is an internationally recognized sustainability rating system. From individual buildings to entire communities, Green Star is transforming the way our built environment is designed, constructed and operated. Launched by the Green Building Council of Australia in 2003, Green Star is Australia's only national, voluntary, rating system for buildings and communities. Your built environment is currently the world's single largest contributor to greenhouse gas emissions, and also consumes around a third of our water and generates 40 per cent of our waste. Green Star is helping to improve environmental efficiencies in our buildings, while boosting productivity, creating jobs and improving the health and wellbeing of our communities. Whether you're a building owner, operator or occupant, creating a green community or looking to live more sustainably, Green Star offers a framework of best practice benchmarks for sustainability that you - and the marketplace can trust.2

10-4-1-18 -NABERS (The National Australian Built Environment Rating system).
NABERS can be used to rate commercial offices, shopping centers, hotels and homes. NABERS ratings for offices can be used to measure the performance of a tenancy, the base building or the whole building. The tenancy rating includes only the energy or resources that the tenant controls. A base building rating covers the performance of the building's central services and common areas, which are usually managed by the building owner. A whole building rating covers both the tenanted spaces and the base building, and is typically used in an owner occupied building, or where there is inadequate metering to obtain a base building or tenancy rating.3

10-4-2- Road Construction and Transportation major sustainability rating systems on the market
According to AASHTO, the transportation sector worldwide is responsible for 22% of global energy consumption, 25% of fossil fuel use, and 30% of global air pollution along with greenhouse gases. It also accounts for 10% of the world’s gross domestic product (GDP).

1 - http://www.gghc.org/about.history.php
With such significant shares in energy use, and both natural and economic resources, small adjustments to reduce each of these impacts from the transportation sector could lead to important benefits. As mentioned previously, transportation sustainability should at the very least consider environmental integrity, impacts on economic development, and the social quality of life. System effectiveness can be considered as a fourth attribute necessary for transportation system sustainability, since a less effective system would not be an acceptable alternative.

**10-4-2-1- GHP (The Green Highways Partnership)**

(GHP) is dedicated to transforming the relationship between the environment and transportation infrastructure. In its nationwide review of green transportation infrastructure, the U.S. House Subcommittee on Technology and Innovation found the GHP to be “the primary federal vehicle for encouraging the use of green transportation infrastructure by state and local governments and private industry.” Such a finding says that this effort is not only unique to the nation, but is the only one of its type serving this critical purpose recognized by Congress.

The GHP goal is to promote market-driven innovation, stewardship, streamlining, and regulatory consistency. GHP activities are rooted in stewardship, safety, and sustainability, with targeted activities to address its mission and primary benefit of “meeting transportation requirements and applying environmental stewardship so that both are better than before”. The GHP promotes a voluntary, not regulatory approach, and continues to grow as a collaborative effort, through an extensive public-private partnering network of industry, trade, and environmental organizations, private sector (consultants and contractors), and government (local, state, and federal). The benefits of building a Green for communities, it means economic stimulation and re-vitalization of community assets. For ecosystems, it means minimal encroachment and optimal storm water management.

**10-4-2-2-INVEST (Infrastructure Voluntary Evaluation Sustainability Tool)**

The Federal Highway Administration (FHWA) launched INVEST 1.0 in October 2012 with a national webcast, including remarks from the Deputy Administrator and video footage of INVEST in action. INVEST is a practical, web-based, collection of voluntary best practices, called criteria, designed to help transportation agencies integrate sustainability into their programs (policies, processes, procedures and practices) and projects.

Criteria under the INVEST rating system are defined according to sustainable best practices. They fall under one of three headings: project delivery and system planning and processes (17 criteria), project development (20 or 29 criteria depending on whether basic or extended scorecard is used), and operations and maintenance (14 criteria).

---

10-4-2-3- GREENLITES (Green Leadership In Transportation Environmental Sustainability)
Transportation sustainability at NYSDOT who developed GREENLITES rating system to ensure following their philosophies. These philosophies are:
- Protect and enhance the environment.
- Conserve energy and natural resources.
- Preserve or enhance the historic, scenic, and aesthetic project setting characteristics.
- Encourage public involvement in the transportation planning process.
- Integrate smart growth and other sound land-use practices.
- Encourage new and innovative approaches to sustainable design, and how we operate and maintain our facilities.1

10-4-2-4- Envision™ Sustainable Infrastructure Rating System
Envision™ Rating System by Institute of Sustainable Infrastructures to evaluate sustainable infrastructure projects. This rating system evaluates the sustainability for a wide range of infrastructure, including bridges. ISI was formally launched in 2011 and introduced a rating system that was developed by a working group from the American Council of Engineering Companies (ACEC), American Public Works Association (APWA), and American Society of Civil Engineers (ASCE). 2
Envision™ provides a holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects. It evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle.3
Under Envision there are 60 credits distributed under five categories Quality of Life, Leadership, Resource Allocation, Natural World and Climate and Risk. Quality of Life embodies social aspects of sustainability such as appropriateness of project, its holistically effect on the community, and whether it improves the community’s mobility or access to facilities. Leadership measures actual performance of stakeholders in areas such as collaboration, management and planning.4

10-4-2-5- Programs with Academic Origins
There are many programs with academics origins, but these most used programs are studied in this chapter.

- 10-4-2-5-A- Greenroads
The Greenroads sustainability rating system was developed by CH2M HILL and the University of Washington in 2009. Greenroads stimulates sustainability in highway construction by awarding credits to projects that have successfully incorporated sustainable best practices. It provides a holistic means of considering and evaluating roadway sustainability for new construction, reconstruction and rehabilitation through a quantitative method that informs decision making. It also addresses operations and

---

1- NYSDOT (The New York State Department of Transportation): "GreenLITES Project Design Certification Program"-2015, from https://www.dot.ny.gov/programs/greenlites
3- http://www.sustainableinfrastructure.org/rating/index.cfm
maintenance through an Operations and Maintenance Plan, which is evaluated when the project is scored.¹

- **10-3-2-5- B- BE2ST-In-Highways**
  Developed by the Recycled Materials Resource Center (RMRC) based at the College of Engineering at the University of Wisconsin, Building Environmentally and Economically Sustainable Transportation-Infrastructure-Highways (BE2ST-In-Highways) is a sustainability rating system whose main focus is to quantify the sustainability impact of using recycled materials in pavements.
  Projects are analyzed by comparing a reference design (base design) that has no sustainable features, but fulfills statutory and social requirements to proposed designs that satisfy statutory and social requirements, and incorporate sustainable design features. By comparing reference to proposed designs, an accurate, transparent, and replicable measurement, which takes into account tradeoffs, can be implemented to evaluate proposed project performance.²
  Score percentages are presented in comparison to the reference design and prorated to an equivalent score in accordance with the weight for each sub-criterion. A percentage is calculated by dividing the actual score by maximum possible score according to the following levels: Bronze (50%), Silver (75%) and Gold (90%). The system is applicable to highway projects during the design phase, is entirely web based, and offers third party verification as well as voluntary participation alternatives.³
  Using recycled materials in the base course is thus more advantageous and has higher value because larger material quantities are involved in the base course with greater potential for cost savings, as shown in this case study.⁴
  In scoring projects, the rating system utilizes Pavement Life-Cycle Assessment Tool for Environmental and Economic Effects PaLATE and the Life Cycle Cost Analysis (LCCA) Real Cost software program. In addition, it uses Mechanistic-Empirical Pavement Design Guide (MEPDG) to measure service life, Traffic Noise Model Look up (TNM-Look) to assess traffic noise, and International Roughness Index (IRI) simulation to determine life of pavement.⁵

- **10-4-2-5-C- Illinois (Livable and Sustainable Transportation Rating System and Guide)**
  In January 2010, the Illinois Department of Transportation, the American Consulting Engineers Council Illinois Chapter, and the Illinois Road and Transportation Builders Association released a sustainability guide and rating system entitled I-LAST, Illinois was developed by volunteers from these organizations over a two-year period. This paper reviews the reasons for undertaking this project, the contents of the resulting document, and the decisions made during its development.⁶

---

³ RMRC (Recycled material resources center) Report- BE2ST-in-Highways™ at RMAUPG Annual Meeting-2012- http://rmrc.wisc.edu/be2st-in-highways/
⁵ I-LAST™ Illinois -" Livable and Sustainable Transportation Rating System and Guide" -Department of transportation-2012- p 5.
10-4-2-5-D- University of Waterloo Rating system

A recent master’s thesis from the University of Waterloo by Peter Cheuk Pan Chan is a preliminary investigation that demonstrates Ontario’s initiative to provide a green performance rating system for roads. Pan Chan focuses strongly on pavement materials, management, and design, but also considers land use planning, public transit, walkways and bikeways, and alignment – The report additionally utilizes cost as a strong metric with scaling factors.

Pan Chan focused much of his literature review on pavement materials, maintenance, and rehabilitation. He additionally reviewed design and construction practices, as well as several green initiatives such as LEED, Greenroads, and GreenLITES.

Necessary Considerations for the Core Elements of Sustainability

Considering just the materials aspect of sustainability for a moment, there have been initiatives worldwide to improve road materials and standards to better accommodate changes in energy availability and to improve the impact of roads on the environment. The use of improved and recycled materials is one of many methods that can improve construction and maintenance impacts on the environment. The impact of choosing to use a pavement mix that contains recycled content can positively impact the project in many ways. Recycled content may be less costly than purchasing new content it also may reduce costs to both the environment and agency by reducing material transport necessary to arrive at the project site, if it can be utilized from on-site (previously considered) construction waste or come from a local facility. Of course recycling can help construction-related waste from going straight to a landfill, and can aid the reduction in mining natural resources that may or may not be renewable.

10-4- Conclusion

In this chapter, An introduction to sustainability assessment concepts was studied throughout introduction of the tools for environmental evaluation, criteria for evaluation and having an introduction to environmental classification systems. An overview of most used sustainable rating systems for building and sustainable transportation all over the world was done to select the most appropriate rating systems in order to be developed to conclude our own Sustainable Rating System For Architectural Evaluation of Bridges in Egypt (Sustainability prerequisites and credits). Also, As shown in table (10-1) scoring criteria at most important sustainability rating systems are overviewed also, Also, as shown in table (10-2) Summary of Attributes Considered by Major roads Rating Systems are studied.

1- Pan Chan, P. C: "Quantifying Pavement Sustainability for Ontario"- Paper- University of Waterloo- Canada-2010
3- Eisenman.Ana AthaliaPlaut: "Sustainable streets and highways: an analysis of green roads rating systems"- Master Thesis- Faculty of Civil Engineering- Georgia Institute of Technology-2012- p 8
### Table 10-1: Comparison of different Rating Systems for Sustainable Buildings (by researcher)

<table>
<thead>
<tr>
<th></th>
<th>DGNB (Germany)</th>
<th>BREEAM (Great Britain)</th>
<th>LEED (USA)</th>
<th>Green Star (Australia)</th>
<th>CASBEE (Japan)</th>
</tr>
</thead>
</table>
| Key Aspects of Assessment & Versions | - Ecological Quality  
- Economical Quality  
- Social Quality  
- Technical Quality  
- Process Quality  
- Site Quality  
Purpose of the DGNB Certificate: Application for buildings of any kind (Office high-rises, detached residential homes, infrastructure buildings etc.) | - Management  
- Health & Well-being  
- Energy  
- Water  
- Material  
- Site Ecology  
- Pollution  
- Transport  
- Land consumption | - Sustainable Sites  
- Water Efficiency  
- Energy & Atmosphere  
- Material & Resources  
- Indoor Air Quality  
- Innovation & Design | - Management  
- Indoor Comfort  
- Energy  
- Transport  
- Water  
- Material  
- Land Consumption & Ecology  
- Emissions  
- Innovations  
Green Star for:  
- Office – Existing Buildings  
- Office – Interior Design  
- Office – Design | Certification on the basis of “building environment efficiency factor”  
BEE=Q/L  
Q … Quality  
(Ecological Quality of buildings)  
Q1 - Interior space  
Q2 - Operation  
Q3 - Environment  
L … Loadings  
Ecological effects on buildings  
L1 - Energy  
L2 - Resources  
L3 - Material  
Main Criteria:  
(1) Energy Efficiency  
(2) Resource Consumption Efficiency  
(3) Building Environment  
(4) Building Interior |
| Level Of Certification | Bronze  
Silver  
Gold | Pass  
Good  
Very good  
Excellent  
Outstanding | LEED Certified  
LEED Silver  
LEED Gold  
LEED Platinum | 4 Stars: ‘Best Practice’  
5 Stars: ‘Australian Excellence’  
6 Stars: ‘World Leadership’ | C (poor)  
B  
B+  
A  
S (excellent) |
<table>
<thead>
<tr>
<th>Table 10-2: Summary of Attributes Considered by Major roads Rating Systems (by researcher)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FHWA</strong></td>
</tr>
<tr>
<td>WATER</td>
</tr>
<tr>
<td>Runoff Quantity</td>
</tr>
<tr>
<td>Runoff quality</td>
</tr>
<tr>
<td>Aquatic habitat</td>
</tr>
<tr>
<td>Air</td>
</tr>
<tr>
<td>Light</td>
</tr>
<tr>
<td>Noise</td>
</tr>
<tr>
<td>Carbon</td>
</tr>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Regional materials</td>
</tr>
<tr>
<td>Recycling</td>
</tr>
<tr>
<td>Waste</td>
</tr>
<tr>
<td>Electricity</td>
</tr>
<tr>
<td>Fuel</td>
</tr>
<tr>
<td>Ecology</td>
</tr>
<tr>
<td>Community</td>
</tr>
<tr>
<td>History</td>
</tr>
<tr>
<td>Lifecyclye cost</td>
</tr>
</tbody>
</table>

http://chbenson.engr.wisc.edu/images/storcks/pdfs/Sustainability/039.pdf
https://www.fhwa.dot.gov/
http://www.dot.ny.gov/programs/greenlites
http://rmrc.wisc.edu/be2st-in-highways/
Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

Part 1: Theoretical Study
Bridges And Sustainability Overview

Chapter 1: Bridge’s Art, Science and Construction Historical Development
Chapter 2: Sustainable Bridges

Part 2: Analytical Study
Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridges Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture
Chapter 4: The Relationship between the Bridge and its Context
Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
Chapter 6: Bridge's Different Parts and their Relation with Bridge’s Shape and Form
Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.
Chapter 8: Design Process of a Sustainable Bridge and Architect's Role

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study
Developing an Egyptian Sustainable Bridge Rating System

Chapter 10: Sustainability Assessment Concepts
Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12: Conclusion and recommendations
Appendices
Chapter 11: Developing an Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 11 structure: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

11-1-1- Introduction to bridge design, construction and maintenance.
11-1-2- Sustainable bridge design.
11-1-3- Sustainable Bridge Construction.
11-1-4- Sustainable Bridge Maintenance.

11-2-1- MDOT (Michigan Department of Transportation) U.S. sustainable bridges practices.
11-2-3- Sustainable bridges Design - APWA conference.

11-3-1- The Need for sustainable bridge rating system.
11-3-2- Comparative analysis used to develop the rating system.
11-3-3- Summary of the rating systems used to develop Egyptian sustainable rating system for bridges (LEED and Greenroads).

11-2- Previous sustainable bridges rating systems trials.

11-3- New Egyptian sustainable bridges Rating system.

11-4- Conclusion

11-5- Final score card

Developing the Egyptian Sustainable rating system for Bridges evaluation
Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Introduction
During the last twenty years, environmental considerations have become more important and are designed into new projects. Sustainable development is now demanded as a natural part of everyday life. Infrastructure Managers have to fulfill these demands.

A minimal amount of research has been completed to the sustainability rating for bridge designs. The theories and programs available for sustainable buildings and sustainable transportations simply need to be modified to be applicable for bridge design or at least serve as inspiration for a unique rating system.

11-1- Current Sustainable Bridges Practices:
A number of articles, theses, journals, books, and magazines were studied to review current methodologies and approaches used to assess bridges sustainability will be described. The current sustainable practices are concluded in three categories, which are

A. Sustainable Bridge Design.
B. Sustainable Bridge Construction.
C. Sustainable Bridge Maintenance.

11-1-1- Introduction to Bridge's Design, Construction and Maintenance
Building a bridge mainly involves three stages, design, construction, and maintenance. These stages are all related to each other: design practices affect the construction stage and design consequently and construction stages affect maintenance over the lifetime of a bridge. The design stage of a bridge commences with the selection of materials, span arrangements, girder spacing, bearing types, substructure type and geometry, and foundation types. Design of the deck slab, interior and exterior girders, bearing, abutments, piers and foundations are the main steps in design. The bridge design should consider construction and long-term maintenance costs.¹

All these design parameters coupled with environmental conditions, such as location and site, lead to various procurement and construction applications in the next stage. In the long run, maintenance processes to keep bridges operational and safe also are affected by all the decisions made in the design and construction stages. When considering bridge maintenance, preservation techniques should also be considered. Over time preservation treatments can reduce the overall cost of bridge maintenance. All decisions made in the life cycle of a bridge, especially those that are made early in the process, impact consequent stages. They all need to be critically analyzed for environmental and economic effects during the life cycle of a bridge.²

11-1-2- Sustainable Bridge Design
The design of a bridge is an important phase where most decisions can impact later stages. Incorporating sustainability approaches and methods in the design stage is important for achieving sustainability. For example, site selection, material selection for design, service life design, span arrangement, substructure type, geometry, and

¹ - AASHTO- (American Association of State Highway and Transportation Officials Committee Corresponded)- paper-Submitted by the AASHTO TIG Lead States Team for the following technology- USA-2003.
foundation types are some of the factors that should be taken into consideration during the design stage; alternative ways are usually considered to achieve sustainability.\(^1\) High service life design requires the designer to explore outside the current codes, evaluate environmental loading, and establish material performance over a long period; this calls for extrapolation of current knowledge of climate and material properties as well as the extrapolation of material deterioration models. Sustainability objectives for bridges can also be best accomplished by ensuring durable bridges with a long service life and low maintenance inputs that, on a whole-of-life basis, minimize material consumption over the long term. It is likely that such a bridge also has the lowest whole-of-life economic cost.\(^2\)

The durability design process for extended life requires the specific analysis of the environmental conditions in which the structure is placed, the strategic use of a range of materials and an understanding of the means by which they deteriorate and the rate of that deterioration. The process involves:

- Definition of the characteristics of the environment.
- Identification of the potential deterioration mechanisms in that environment.
- Determination of the likely rate of deterioration.
- Assessment of the material life.
- Definition of the required material performance.
- Consideration of a probabilistic approach to the variability of the relevant parameters.
- Assessment and definition of the need for further protection.

**Finally,** Sustainability objectives for bridges are best accomplished by ensuring durable bridges with long service life and low maintenance inputs, that, on a whole-of-life basis, minimize material consumption over the long term. It is likely that such a bridge also has the lowest whole-of-life economic cost.\(^3\)

### A. Economics of Service Life

Definition of service life as the period of time that the structure is expected to be in operation, Design live is the expected service life in design stage.

It could be expected that a structure designed for a very long service life might be more durable than a structure designed for a very short service life.

On the other hand perhaps a structure with a short life would be neglected in the expectation that it will be replaced quicker. Either way it is likely that the structure designed for a very long service life will have a lower annual maintenance cost.\(^4\)

### B. Service Life and Design Life

Targeting a service life performance for a structure, the asset owner needs to be aware not only of the initial cost of creating the structure, but its service life and the long term cost of maintaining and repairing it over that service life, and finally its replacement cost. This can be done on a net present value basis, but requires knowledge of the impact of the durability performance on initial and long term costs.\(^5\)

A service life performance must be formulated into specific design criteria to provide the designer with objectives for the design which are then encapsulated in specification

---

requirements that must be met by the builder during the construction. The codes usually define a design life that implies a particular service life regarded by society as acceptable.  

11-1-3- Sustainable Bridge Construction

- There are two main processes during construction the stage, which are responsible for energy consumption and emissions. These are a) Transportation and b) Operation. In a normal life cycle, main transportation operations occur “to site”, “from site” and “on site”. An evaluation of energy released during transportation, the average distance traveled, and the fuel efficiency of vehicles that travel to and from the site are considered in this life cycle.

- Energy consumed during construction operations is another important factor. Energy consumption is calculated using the weight of equipment, energy it consumes per hour of operation, and the construction duration of a typical bridge deck.

- Different road equipment such as trucks and other vehicles are used during construction operations to transport materials to and from site, which consumes fuel and release wastes to atmosphere. Non-efficient fuel vehicles can increase fuel consumption and also releases GHG (Green-House Gases) emissions. Similarly, various non-road construction equipment such as excavators, bulldozers, compactors, pressure washers, cement and mortar mixers, pumps, trenchers, rollers and other construction equipment used during operation consumes fuel and releases energy. Air emissions from construction equipment contribute significantly to the degradation of the environment. Therefore, it is imperative to use equipment that produces fewer emissions than conventional ones. “Non-road engines are all internal combustion engines except motor vehicle (highway) engines, stationary engines (or engines that remain at one location for more than 12 months), engines used solely for competition, or engines used in aircraft. The non-road standards cover mobile non-road diesel engines of all sizes used in a wide range of construction, agricultural and industrial equipment” So, non-road equipment is used in construction and not on roads like cars, buses, etc. Accelerated construction is used to achieve the construction of structures in the shortest possible time while decreasing delays and traffic disruption. It is not merely building structures rapidly but also entails a variety of techniques, processes, and technologies to reduce congestion due to construction while improving quality. These techniques are used for the construction of new bridges and also the replacement of existing bridges. Using precast bent caps, precast columns, precast deck panels, precast barriers, prefabricated trusses, precast abutments, retaining walls and footings allow manufacturing to take place in a controlled environment, thereby reducing impacts to traffic and environmental impacts.  

11-1-4- Sustainable Bridge Maintenance

Bridge maintenance is a major part of a bridge life cycle. There are a number of activities involved in bridge maintenance that may have significant impacts on the environment. Bridge maintenance usually includes short-term fixes, medium-term fixes, and long-term fixes.

**Short term fixes:** include capital preventive maintenance (CPM). It applies lower-cost treatments to slow the deterioration rate, maintain or improve the functional condition, and extend the pavement's service life.

---

2 - EPA: "Non-Road Diesel Engines" from Environmental Protection Agency-USA-2012 : www.dieselnet.com/standards/us/non-road.php
Medium term fixes: includes rehabilitation. Rehabilitation is the application of structural enhancements, such as multiple course resurfacing or concrete pavement repairs, that improve the roadway or overlaying of a bridge deck and superstructure repair.

Long term fixes: include reconstruction/replacement. Replacement refers to the replacement of the bridge deck, superstructure, or the entire bridge.¹

- Many attempts have been made to reduce the number of maintenance activities, which in turn reduce environmental impacts. The use of durable materials extends the service life of bridge components, thus decreasing the need for future maintenance activities. High performance structural materials and FRP can be used to design bridges for more. Figure (11-1)

![Figure 11-1: Examples on Bridge Maintenance Techniques](image)

Efficient inspection technologies should be used to properly assess the condition of bridges in a timely manner so that necessary maintenance actions can be taken. Use of efficient inspection technologies can ensure improved data quality while simultaneously controlling the cost of data collection. Further development and evaluation of improved visual inspection procedures, innovative nondestructive testing methods, and automated methods to gather and manage data should be encouraged. The focus should be more on quantitative assessment of bridge performance rather than visual inspections and condition ratings. A variety of permanent sensors can be installed on bridges that can automatically detect the data with the change in chemical and electrical properties of materials related to deterioration, aging in coatings, and changes in service environment or exposure. Sensors report to wireless networks and data can be analyzed; deterioration can be detected automatically by computer workstations.³

### 11-2- Previous Sustainable Bridges Rating Systems Trials.

While there is no official sustainability rating system for bridge designs, some researches were done which began to examine the possibility of a rating system for sustainable bridges.

---


3 - George Hearn: "Bridge Maintenance and Management- A Look to the Future"- Paper- Committee on Structures Maintenance and Management- USA- 2008.
11-2-1- MDOT (Michigan Department of Transportation) U.S. Sustainable Bridges Practices.

About MDOT: The Michigan Department of Transportation (MDOT) is responsible for Michigan's 9,669-mile state highway system, comprised of all US routes. MDOT also administers other state and federal transportation programs for aviation, intercity passenger services, rail freight, local public transit services, the Transportation Economic Development Fund (TEDF), and others.¹

MDOT has recently expressed their interest in developing a framework that can be used to categorize sustainable bridges and involve the application of sustainable materials, Standards that aim to reduce environmental pollution and other concepts that contribute toward sustainability.

A: MDOT Design Practices
The following design practices of MDOT were studied in detail:
- General Information Site Condition: Temporary support systems and construction methods, clear zone considerations, concrete QA/QC.
- Preliminary design calculations: Design specifications, design methods, and design stress.
- Design: In design practices bridge materials, span arrangements; girder spacing, bearing types, substructure type and geometry, and foundation type were examined.²

B: MDOT Construction Practices
- Erosion and Sedimentation Control.
- Maintenance Activities and Projects.
- MDOT Storm-Water Management.

C: MDOT Bridge Maintenance Practices
MDOT uses a mix of fixes strategy for bridge maintenance. This strategy uses the combination of long-term fixes, medium term fixes, and short term fixes.³


The European Commission within the 6th Framework Program has developed a project called Sustainable Bridges Assessment for Future Traffic Demands and Longer Lives (2008). The sustainable definition for this group is more focused on longevity. The Sustainable Bridge program targets the enhancement of railway bridges in Europe. Their three main goals are to:
- Increase the transport capacity
- Extend the residual service life
- Enhance management, strengthening and repair systems

These concentrations of interest are very different from the categories on any sustainable rating system, but the underlying theme of specifically improving bridges to help enhance a sustainability driven mindset through infrastructure improvements is fundamentally similar.

This program discusses the importance of R and D (Research and Development) for existing structures. Today and tomorrow existing structures are dominating. Only a small part of the bridge stock is replaced every year. At the same time the society

---

¹ - http://www.michigan.gov/mdot/0,4616,7-151-9623---,00.html
³ - Kasim Armagan Korkmaz, Matt Syal, Ronald S. Harichandran and Sinem Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance"- Michigan State University- School of Planning- Annual Report- USA-2012., p 21
expects that the Infrastructure Managers shall meet new demands. These demands are for higher speeds, higher axle loads, increased availability, less disturbance and reduced maintenance costs. Also environmental and aesthetic considerations have to be considered. Therefore R and D for existing structures is of great importance for the society and the Infrastructure Managers to meet future needs.

Some of the different aspects of maintaining the existing railway bridge heritage.

- Preservation and Conservation
- Protective systems
- Materials Technology
- Dynamic load
- Prefabrication and Assembly
- Accidental impact
- Connections and welding
- Protective systems

11-2-3- Sustainable Bridge Design – APWA Conference

At an American Public Works Association (APWA) conference, a presentation was given by Kelly Burnell (2009) titled “Sustainable Bridge Design.” The focus of the presentation was on the bridge engineer’s impact on a bridge project over its lifespan which helps to demonstrate when engineers have the most influence on the sustainability of a bridge. They examined the life of the bridge to be made up of six components. Those components are:

- transportation system
- determining the bridge function
- design
- construction
- operation
- maintenance
- rehabilitation-demolition-replacement

The potential for sustainable improvements according to Burnell (2009) is the highest in the first stage and decreases exponentially through the other phases before it briefly begins to rise again during the rehabilitation-demolition-replacement. The other element of interest during this presentation was the bridge engineer’s influence during the project life.

This information helped to solidify the notion that this research would be for planned and major rehabilitation bridge projects only. At this stage of the project, the engineer has the most control and therefore can have the most impact available to them over the span of the bridge’s life. The rest of the presentation discusses specific designs and materials that can be used to be more sustainable in terms of lowering the energy input in the bridge, increasing the durability and simplifying the deconstruction. While these are important factors to consider, they are beyond the scope of this research.

As a conclusion from studying these trials, every trial focused on the most appropriate sustainability practices to their needs which achieve sustainability from their point of view. So in Egypt we need to develop our own sustainable rating system which is appropriate for Egyptian Economical, environmental and social sustainability needs. As shown in figure (11-2) the engineer influence in bridge life cycle.

---

This variable in the project started very low in stage one, transportation system, and peaked during the design phase. Right after construction, the influence of the bridge engineer began to slowly rise again to about half of the peak influence during the final stage. Figure 8 depicts a graphic that demonstrates the bridge engineer’s influence and the overall potential for sustainable improvements in the project.

Figure 11-2: Sustainability and the bridge live with Engineer’s Influence.¹

### 11-3- The Egyptian Sustainable Bridges Rating System

In this part, The Need for Developing the Egyptian Sustainable Bridges Rating System, Comparative Analysis Used to Develop the Egyptian Sustainable Bridges Rating System and Summary of the Rating Systems Used to develop the Egyptian Sustainable Bridges Rating System are studied.

#### 11-3-1- The Need for Developing the Egyptian Sustainable Bridges Rating System

Translating sustainability ideas into definable design and construction practices that are likely to result in a more sustainable Bridge.

- Bridges can be more sustainable than they currently are.
- Needing for a rating system suitable for Egyptian resources and conditions
- Current Egyptian standards and decision tools do not fully address sustainability.

A. The goal of this sustainable rating system are:-

- To provide a common standard of measurement for sustainable bridges
- To promote integrated bridge design practices
- To promote sustainable bridge design
- To provide strategies for achieving sustainable bridge design.
- To recognize environmental leadership in the bridge industry

Also the rating systems must have these benefits: ( Ecological benefits, Reduce road and non-road emissions, Reduce air emissions, Reduce wastewater emissions, Reduce soil/solid waste emissions, Reduce consumption, Reduce water use, Reduce fossil energy use, Reduce raw materials use, Create renewable energy, Optimize habitat and land use, Human-centric benefits, User improvement, Improve human health and safety, Improve access and mobility, Performance improvement, Improve business practice,

---

¹ - Louis, Rachel Annette: "Sustainable Bridges: Green Links to the Future"- Master Thesis- Graduate School of The Ohio State University-Civil Engineering Department- USA- 2010- p 19-20.
Increase lifecycle savings, Increase lifecycle service, Interaction improvement, Increase awareness, Improve aesthetics and Create new information).

As shown in figure (11-3) Aspects of the sustainable roadway are introduced.

Figure 11-3: Aspects of the Sustainable Roadway

---

1 - Johnson-Bednar: "An overview on GreenRoads"- Research- University of Washington and CH2M HILL-USA-2010
B. The principles used to determining the criteria for a sustainable bridge are:

- Minimize location impacts (choosing sites tie directly into existing routes, Not using virgin sites and not affecting historical sites).
- Minimize material impacts (reducing materials needed, using recycled material and waste, allowing for future expansion, Embodied energy during construction for various structural forms and materials).
- Minimize traffic by (provide HOV "High occupancy vehicle", pedestrian, bike lanes and reduce time cars are idling).
- Minimize energy consumption: (using material with low embodied energy, minimize energy consumption during bridge construction and operation)

C. All criteria must be

- Meaningful
  The rating criteria should have a direct positive environmental impact. A large part of successful sustainable design is demonstrating the advantages to the owner of the project and getting them to endorse the ideas.
- Measurable
  The rating criteria must be quantifiable. once of the difficulties in developing a rating system such as this is developing quantitative criteria from qualitative concepts.
- Cost effective
  The rating criteria should be relatively cost effective. the criteria with high economic costs should also have high environmental impacts to offset the expenses. there may also be additional finding available for sustainable design. 1

11-3-2- The 3 Comparative Analysis Used to Develop the Egyptian Sustainable Bridges Rating System

1- The focus was on trying to develop a bridges rating system, We can consider the bridge as a building because it has structure, usage, height and finishing. Also the bridge may be considered as a road with pavement, lighting and lanes.
2- The second stage was selecting a best rating systems to be compared, So the most appropriate Building's rating system is LEED for new constructions as we discussed before, And the most appropriate Rating system for roads is Greenroads. Also some credits and prerequisites were taken from another resources (Thesis's, papers and researches) which have a better effect on the rating system and makes it more efficient.
3- This stage is to studying the two previously selected rating systems, some categories are compatible with bridges and some are not, so the methodology will be Select the most compatible prerequisites and credits from both rating systems and study it.

- Define main categories for the Bridges rating system and under every category there will be the credits related to this category from both rating systems (LEED for NC and Green Roads).
- There are similar categories between two rating systems, In this case the most applicable credit is taken and studied.
- The non compatible categories and credits to be removed or calculated as a exemplary performance credits (Example: Indoor environmental Quality category in LEED is not applicable to bridges).

4- During the study of every credit, the credit weight should be studied to the total credits weight at the selected rating system and as a percentage.

5 - New credits to be added to be compatible with Egyptian culture, rules and practice.
6- After developing the preliminary score card, Credit's weight percentage is determined as a percentage from it's original weight in LEED or GREEN Roads. If the credit is in the two rating systems a percentage average is taken in the final score card.

**11-3-3- Summary of the Rating Systems Used to develop the Egyptian Sustainable Bridges Rating System**

It was important to study the points beneath on the selected rating systems (LEED and GreenRoads) to develop our rating system,

- A summary of these rating systems.
- Score card of these rating systems.
- credits and prerequisites.
- scoring criteria.

This study is done as a comparison between LEED and GreenRoads as shown in table (11-1) to conclude reasons for selection of these rating systems to be developed or it could be said Why these rating systems were selected ?

**Why LEED ?**

- A consensus process that has a balanced and transparent committee structure.
- Technical advisory groups to ensure scientific consistency and rigor.
- Opportunities for stakeholder comment and review.
- Member ballot of new rating systems and certain changes to existing rating systems.
- A fair and open appeals process.
- LEED isn’t driven by product manufacturer’s trying to sell the latest technologies, politicians, or the finance industry. LEED comes from everyone that is involved.

**Why Greenroads ?**

- 100% online third-party rating done by independent experts
- 100% owner support from all clients or executive level policy support for their agent organization to participate.
- More than 500 pages of original research that were wrote and tested before its launch on real projects. (Many rating tools may be original creations or variations, but none are comprehensively tested or calibrated like Greenroads).
- Experts that have been in the rating system development business for a decade.
- Saving Money So far, all Certified Greenroads projects have come in at or below budget and no project's costs have increased specifically because of choices made to participate in Greenroads.

Also as shown in table (11-2) Greenroads rating system scorecards are introduced and table (11-3) LEED BD+C rating system scorecards are introduced.

**11-4- The Final Score Card**

Sustainability is now recognized as a key issue which must be addressed in the Design, construction and lifelong maintenance of civil engineering structures specially bridges. A bridge constitutes a large investment of capital, materials, and energy and is associated with significant social, economic, and environmental impacts. Applying sustainable practices to bridge design, construction, and maintenance can enable an environmentally responsible and effective use of resources for this large investment. The focus of this Unit is to develop a framework that assists engineers and managers in developing more sustainable design and construction processes for new bridges, and sustainable maintenance practices. This framework is a developed criteria from existing rating systems (LEED for new construction rating system) and (Greenroads rating
system) and previous researches. Also, there are invented credits and prerequisites by the researcher which helps to upgrade bridge's sustainability and architecture. The final score card is developed containing all these prerequisites and credits which are demonstrated in the Appendices attached to the research "page 221". This Appendices consists of (Appendix A: Architectural Evaluation Prerequisites, Appendix B: Sustainability Evaluation Prerequisites, Appendix C: Architectural Evaluation Credits and Appendix D: Sustainability Evaluation Credits).

11-5- Conclusion

After studying the two rating systems, some prerequisites and credits were selected and others were neglected, also some credits were added by the researcher or from previous researches to reach to the final appropriate score card for Egyptian sustainable bridges which will be demonstrated at the appendices. Also, here is a conclusion about why LEED and Greenroads were selected to be developed:

- Greenroads was selected because it is a research by professors and engineers which is updated and concluded from most used rating systems for roadways also it is not profitable rating system.
- LEED was selected because it is one of the most famous and used all over the world and almost the only rating system used in Egypt.
### Table 11-1: Comparison between LEED BD+C and Greenroads

<table>
<thead>
<tr>
<th>Greenroads</th>
<th>LEED BD+C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Define</strong></td>
<td><strong>Leadership in Energy and Environmental Design.</strong> LEED is a leading-edge system for certifying high-performance buildings and sustainable neighborhoods.</td>
</tr>
<tr>
<td>Is a roadway project that has been designed and constructed to a level of sustainability that is substantially higher than current common practice?</td>
<td>LEED BD+C aims to promote a transformation of the construction industry through strategies designed to achieve these goals: To reverse contribution to global climate change, To enhance individual human health and well-being, To protect and restore water resources and enhance/ restore biodiversity and ecosystem services, To promote sustainable and regenerative material resources cycles and build a greener economy and To enhance social equity, environmental justice, community health, and quality of life</td>
</tr>
<tr>
<td>Roadways can be more sustainable than they currently are. Current standards and decision tools do not fully address sustainability. For instance, while pavements are heavy users of recycled material, their design and construction do not consider life cycle emissions or energy use and ecological considerations can be limited to regulatory compliance. Most roadway sustainability efforts to date have not applied a consistent standard by which the relative importance of efforts are judged. Therefore, comparisons between projects or assessments of improvement are difficult. The science and engineering underlying roadway sustainability can be complex. Decisions by non-experts that often drive project direction or funding can therefore be problematic. Different aspects of roadway sustainability are difficult to compare because they are not normalized to a common value set.</td>
<td>LEED was created to accomplish the following: • Define &quot;green building&quot; by establishing a common standard of measurement and stimulate green competition. • Promote integrative, whole-building design practices. • Recognize environmental leadership in the building industry. • Raise consumer awareness of green building benefits. • Transform the building market.</td>
</tr>
<tr>
<td><strong>Prerequisites</strong></td>
<td><strong>1. Promoting the Triple Bottom Line and Establishing leadership</strong> 2. Creating and restoring harmony between humans and nature 3. Maintaining integrity by using technical and scientific data to help guide decision making 4. Exhibit transparency by having open standards.</td>
</tr>
<tr>
<td>Greenroads is designed to influence decisions regarding sustainability options where they are not precluded by regulation or where regulation allows a choice between options that could have sustainability impacts. It is also meant to encourage organizations to include sustainable practices in their company-wide strategy and daily work practices.</td>
<td></td>
</tr>
<tr>
<td><strong>Categories weighting</strong></td>
<td><strong>11 Project Requirements and 37 Voluntary Credits. Each Voluntary Credit is assigned a point value (1 to 5 points) that corresponds to its impact on sustainability. Higher point values indicate larger impacts. There is also a Custom Credits section where project teams can propose their own Voluntary Credits.</strong></td>
</tr>
<tr>
<td></td>
<td><strong>13 prerequisite and 110 points for credits</strong></td>
</tr>
<tr>
<td></td>
<td>• Integrative process (1/110) • Location and Transportation: (16/110) • Sustainable Sites: (10/110) • Water Efficiency: (11/110) • Energy and Atmosphere: (33/110) • Materials and Resources: (13/110) • Indoor Environmental Quality: (16/110) • Innovation: (6/110) • Regional Priority: (4/110)</td>
</tr>
<tr>
<td><strong>System boundaries</strong></td>
<td><strong>Greenroads is applicable to the design and construction of new or rehabilitated roadways including expansion or redesign. This means that some typical items associated with roadways are considered in specific ways that merit explanation:</strong> 1. Roadway Planning, Paths and Trails 2. Supply-Chain Processes 3. Structures (Bridges, tunnels, walls and other structures) 4. Future Maintenance &amp; Preservation</td>
</tr>
<tr>
<td></td>
<td><strong>There are rating systems that address multiple project types:</strong> Building Design + Construction (BD+C) Building Design + Construction applies to buildings that are being newly constructed or going through a major renovation. (this rating system will be studied) Interior Design + Construction (ID+C) Building Operations + Maintenance (O+M) Neighborhood Development (ND)</td>
</tr>
<tr>
<td></td>
<td>• More sustainable roadways. Provide a credibly accounting system for sustainable roadway projects. • Allow sustainability tradeoffs and decisions to be made in a systematic manner. • Define basic roadway sustainability attributes and confer marketable recognition on sustainable roadway projects.</td>
</tr>
<tr>
<td></td>
<td><strong>Lower operating costs and increased asset value</strong> • Reduced waste sent to landfills • Energy and water conservation • More healthful and productive environments for occupants • Reductions in greenhouse gas emissions</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td><strong>LEED has four levels of certification, depending on the point thresholds achieved:</strong> • Certified, 40-49 points • Silver, 50-59 points • Gold, 60-79 points • Platinum, 80 points and above</td>
</tr>
</tbody>
</table>

---

**References**

- “LEED Principles and Green Associate Study Guide”. Green Building Education Services - USGBC - USA - 2014 - p 18-47

---

**Table 11-1: Comparison between LEED BD+C and Greenroads**

<table>
<thead>
<tr>
<th>Prerequisites and credits</th>
<th>LEED BD+C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>11 Project Requirements and 37 Voluntary Credits. Each Voluntary Credit is assigned a point value (1 to 5 points) that corresponds to its impact on sustainability. Higher point values indicate larger impacts. There is also a Custom Credits section where project teams can propose their own Voluntary Credits.</strong></td>
<td><strong>13 prerequisite and 110 points for credits</strong></td>
</tr>
<tr>
<td></td>
<td>• Integrative process (1/110) • Location and Transportation: (16/110) • Sustainable Sites: (10/110) • Water Efficiency: (11/110) • Energy and Atmosphere: (33/110) • Materials and Resources: (13/110) • Indoor Environmental Quality: (16/110) • Innovation: (6/110) • Regional Priority: (4/110)</td>
</tr>
<tr>
<td><strong>System boundaries</strong></td>
<td><strong>Greenroads is applicable to the design and construction of new or rehabilitated roadways including expansion or redesign. This means that some typical items associated with roadways are considered in specific ways that merit explanation:</strong> 1. Roadway Planning, Paths and Trails 2. Supply-Chain Processes 3. Structures (Bridges, tunnels, walls and other structures) 4. Future Maintenance &amp; Preservation</td>
</tr>
<tr>
<td></td>
<td><strong>There are rating systems that address multiple project types:</strong> Building Design + Construction (BD+C) Building Design + Construction applies to buildings that are being newly constructed or going through a major renovation. (this rating system will be studied) Interior Design + Construction (ID+C) Building Operations + Maintenance (O+M) Neighborhood Development (ND)</td>
</tr>
<tr>
<td></td>
<td>• More sustainable roadways. Provide a credibly accounting system for sustainable roadway projects. • Allow sustainability tradeoffs and decisions to be made in a systematic manner. • Define basic roadway sustainability attributes and confer marketable recognition on sustainable roadway projects.</td>
</tr>
<tr>
<td></td>
<td><strong>Lower operating costs and increased asset value</strong> • Reduced waste sent to landfills • Energy and water conservation • More healthful and productive environments for occupants • Reductions in greenhouse gas emissions</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td><strong>LEED has four levels of certification, depending on the point thresholds achieved:</strong> • Certified, 40-49 points • Silver, 50-59 points • Gold, 60-79 points • Platinum, 80 points and above</td>
</tr>
</tbody>
</table>
| | **Reference**
- “LEED Principles and Green Associate Study Guide”. Green Building Education Services - USGBC - USA - 2014 - p 18-47
Table 11-2: Greenroads Scorecard

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Pts.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-1</td>
<td>Environmental Review Process</td>
<td></td>
<td>Complete a comprehensive environmental review.</td>
</tr>
<tr>
<td>PR-2</td>
<td>Lifecycle Cost Analysis (LCCA)</td>
<td></td>
<td>Perform LCCA for pavement section.</td>
</tr>
<tr>
<td>PR-3</td>
<td>Lifecycle Inventory (LCI)</td>
<td></td>
<td>Perform LCI of pavement section.</td>
</tr>
<tr>
<td>PR-4</td>
<td>Quality Control Plan</td>
<td></td>
<td>Have a formal contractor quality control plan.</td>
</tr>
<tr>
<td>PR-5</td>
<td>Noise Mitigation Plan</td>
<td></td>
<td>Have a construction noise mitigation plan.</td>
</tr>
<tr>
<td>PR-6</td>
<td>Waste Management Plan</td>
<td></td>
<td>Have a plan to divert C&amp;D waste from landfill.</td>
</tr>
<tr>
<td>PR-7</td>
<td>Pollution Prevention Plan</td>
<td></td>
<td>Have a TESC/SWPPP.</td>
</tr>
<tr>
<td>PR-8</td>
<td>Low Impact Development (LID)</td>
<td></td>
<td>Complete a LID feasibility study.</td>
</tr>
<tr>
<td>PR-9</td>
<td>Pavement Management System</td>
<td></td>
<td>Have a pavement management system.</td>
</tr>
<tr>
<td>PR-10</td>
<td>Site Maintenance Plan</td>
<td></td>
<td>Have a roadside maintenance plan.</td>
</tr>
<tr>
<td>PR-11</td>
<td>Educational Outreach</td>
<td></td>
<td>Publicize sustainability information for project.</td>
</tr>
<tr>
<td>EW-1</td>
<td>Environmental Management System</td>
<td>2</td>
<td>ISO 14001 certification for general contractor.</td>
</tr>
<tr>
<td>EW-2</td>
<td>Runoff Flow Control</td>
<td>1-3</td>
<td>Reduce runoff quantity.</td>
</tr>
<tr>
<td>EW-3</td>
<td>Runoff Quality</td>
<td>1-3</td>
<td>Treat stormwater to a higher level of quality.</td>
</tr>
<tr>
<td>EW-4</td>
<td>Stormwater Cost Analysis</td>
<td>1</td>
<td>Conduct an LCCA for stormwater elements.</td>
</tr>
<tr>
<td>EW-5</td>
<td>Site Vegetation</td>
<td>1-3</td>
<td>Use native low/no water vegetation.</td>
</tr>
<tr>
<td>EW-6</td>
<td>Habitat Restoration</td>
<td>3</td>
<td>Restore habitat beyond what is required.</td>
</tr>
<tr>
<td>EW-7</td>
<td>Ecological Connectivity</td>
<td>1-3</td>
<td>Connect habitat across roadways.</td>
</tr>
<tr>
<td>EW-8</td>
<td>Light Pollution</td>
<td>3</td>
<td>Discourage light pollution.</td>
</tr>
<tr>
<td>AE-1</td>
<td>Safety Audit</td>
<td>1-2</td>
<td>Perform roadway safety audit.</td>
</tr>
<tr>
<td>AE-2</td>
<td>Intelligent Transportation Systems (ITS)</td>
<td>2-5</td>
<td>Implement ITS solutions.</td>
</tr>
<tr>
<td>AE-3</td>
<td>Context Sensitive Solutions</td>
<td>5</td>
<td>Plan for context sensitive solutions.</td>
</tr>
<tr>
<td>AE-4</td>
<td>Traffic Emissions Reduction</td>
<td>5</td>
<td>Reduce emissions with quantifiable methods.</td>
</tr>
<tr>
<td>AE-5</td>
<td>Pedestrian Access</td>
<td>1-2</td>
<td>Provide/improve pedestrian accessibility.</td>
</tr>
<tr>
<td>AE-6</td>
<td>Bicycle Access</td>
<td>1-2</td>
<td>Provide/improve bicycle accessibility.</td>
</tr>
<tr>
<td>AE-7</td>
<td>Transit Access</td>
<td>1-5</td>
<td>Provide/improve transit accessibility.</td>
</tr>
<tr>
<td>AE-8</td>
<td>Scenic Views</td>
<td>1-2</td>
<td>Provide views of scenery or vistas.</td>
</tr>
<tr>
<td>AE-9</td>
<td>Cultural Outreach</td>
<td>1-2</td>
<td>Promote art/culture/community values.</td>
</tr>
<tr>
<td>CA-1</td>
<td>Quality Management System</td>
<td>2</td>
<td>ISO 9001 certification for general contractor.</td>
</tr>
<tr>
<td>CA-2</td>
<td>Environmental Training</td>
<td>1</td>
<td>Provide environmental training.</td>
</tr>
<tr>
<td>CA-3</td>
<td>Site Recycling Plan</td>
<td>1</td>
<td>Have a plan to divert waste from landfill.</td>
</tr>
<tr>
<td>CA-4</td>
<td>Fossil Fuel Reduction</td>
<td>1-2</td>
<td>Use alternative fuels in construction equipment.</td>
</tr>
<tr>
<td>CA-5</td>
<td>Equipment Emissions Reduction</td>
<td>1-2</td>
<td>Meet EPA Tier 4 standards for non-road equip.</td>
</tr>
<tr>
<td>CA-6</td>
<td>Paving Emissions Reduction</td>
<td>1</td>
<td>Use pavers that meet NIOSH requirements.</td>
</tr>
<tr>
<td>CA-7</td>
<td>Water Tracking</td>
<td>2</td>
<td>Develop data on water use in construction.</td>
</tr>
<tr>
<td>CA-8</td>
<td>Contractor Warranty</td>
<td>3</td>
<td>Warranty on the constructed pavement.</td>
</tr>
<tr>
<td>MR-1</td>
<td>Life Cycle Assessment (LCA)</td>
<td>2</td>
<td>Conduct a detailed LCA of the entire project.</td>
</tr>
<tr>
<td>MR-2</td>
<td>Pavement Reuse</td>
<td>1-5</td>
<td>Reuse existing pavement sections.</td>
</tr>
<tr>
<td>MR-3</td>
<td>Earthwork Balance</td>
<td>1</td>
<td>Use native soil rather than import fill.</td>
</tr>
<tr>
<td>MR-4</td>
<td>Recycled Materials</td>
<td>1-5</td>
<td>Use recycled materials for new pavement.</td>
</tr>
<tr>
<td>MR-5</td>
<td>Regional Materials</td>
<td>1-5</td>
<td>Use regional materials to reduce transportation.</td>
</tr>
<tr>
<td>MR-6</td>
<td>Energy Efficiency</td>
<td>1-5</td>
<td>Improve energy efficiency of operational systems.</td>
</tr>
<tr>
<td>PT-1</td>
<td>Long-Life Pavement</td>
<td>5</td>
<td>Design pavements for long-life.</td>
</tr>
<tr>
<td>PT-2</td>
<td>Permeable Pavement</td>
<td>3</td>
<td>Use permeable pavement as a LID technique.</td>
</tr>
<tr>
<td>PT-3</td>
<td>Warm Mix Asphalt (WMA)</td>
<td>3</td>
<td>Use WMA in place of HMA.</td>
</tr>
<tr>
<td>PT-4</td>
<td>Cool Pavement</td>
<td>5</td>
<td>Contribute less to urban heat island effect (UHI).</td>
</tr>
<tr>
<td>PT-5</td>
<td>Quiet Pavement</td>
<td>2-3</td>
<td>Use a quiet pavement to reduce noise.</td>
</tr>
<tr>
<td>PT-6</td>
<td>Pavement Performance Tracking</td>
<td>1</td>
<td>Relate construction to performance data.</td>
</tr>
</tbody>
</table>

Custom Credits (CC) – Available for all projects based on context and innovation, subject to approval

| CC-1| Custom Credit 1                                                      | 1-5  | Design a new voluntary credit.                                             |
| CC-2| Custom Credit 2                                                      | 1-5  | Design a new voluntary credit.                                             |

Greenroads Total Points: 118
### Table 11-3: LEED BD+C Scorecard

#### LEED v4 for BD+C: New Construction and Major Renovation

**Project Checklist**

<table>
<thead>
<tr>
<th>Credit</th>
<th>Y</th>
<th>N</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Location and Transportation</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>LEED for Neighborhood Development Location</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Sensitive Land Protection</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>High Priority Site</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Surrounding Density and Diverse Uses</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Access to Quality Transit</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Bicycle Facilities</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Reduced Parking Footprint</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Green Vehicles</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sustainable Sites</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>Construction Activity Pollution Prevention</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Site Assessment</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Site Development - Protect or Restore Habitat</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Open Space</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Rainwater Management</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Heat Island Reduction</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Light Pollution Reduction</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Water Efficiency</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>Outdoor Water Use Reduction</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Indoor Water Use Reduction</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Building-Level Water Metering</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Outdoor Water Use Reduction</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Indoor Water Use Reduction</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Cooling Tower Water Use</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Water Metering</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Energy and Atmosphere</td>
<td>33</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>Fundamental Commissioning and Verification</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Minimum Energy Performance</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Building-Level Energy Metering</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Enhanced Commissioning</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Optimize Energy Performance</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Advanced Energy Metering</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Demand Response</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Renewable Energy Production</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Enhanced Refrigerant Management</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Green Power and Carbon Offsets</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Materials and Resources</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>Storage and Collection of Recyclables</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Construction and Demolition Waste Management Planning</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Building Life-Cycle Impact Reduction</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Building Product Disclose and Optimization - Environmental Product Declarations</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Building Product Disclose and Optimization - Sourcing of Raw Materials</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Building Product Disclose and Optimization - Material Ingredients</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Construction and Demolition Waste Management</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Indoor Environmental Quality</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>Minimum Indoor Air Quality Performance</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Environmental Tobacco Smoke Control</td>
<td>Required</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Enhanced Indoor Air Quality Strategies</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Low-Emitting Materials</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Construction Indoor Air Quality Management Plan</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Indoor Air Quality Assessment</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Thermal Comfort</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Interior Lighting</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Daylight</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Quality Views</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Acoustic Performance</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Innovation</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>LEED Accredited Professional</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Regional Priority</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Credit</td>
<td>Regional Priority: Specific Credit</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Regional Priority: Specific Credit</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Regional Priority: Specific Credit</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Credit</td>
<td>Regional Priority: Specific Credit</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>TOTALS Possible Points:</td>
<td>110</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Certified: 40 to 49 points, Silver: 50 to 59 points, Gold: 60 to 79 points, Platinum: 80 to 110
### Final Score Card

#### Appendix A: Architectural Evaluation Prerequisites (AP)

<table>
<thead>
<tr>
<th>Prerequisite</th>
<th>Category</th>
<th>Reference rating system</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP1</td>
<td>Bridge Goals Analysis</td>
<td>Design process, Researcher</td>
</tr>
<tr>
<td>AP2</td>
<td>Bridge Design / Construction Proposals</td>
<td>Design process, Researcher</td>
</tr>
<tr>
<td>AP3</td>
<td>Integrated Team Members and Architect Role</td>
<td>Design process, Researcher</td>
</tr>
<tr>
<td>AP4</td>
<td>Bridge Integrated Costs</td>
<td>Design process, Researcher</td>
</tr>
<tr>
<td>AP5</td>
<td>Bridge Main Functions</td>
<td>Bridge function, Researcher</td>
</tr>
<tr>
<td>AP6</td>
<td>Bridge Expected Future Functions</td>
<td>Bridge function, Researcher</td>
</tr>
<tr>
<td>AP7</td>
<td>Bridge Functions Achievement</td>
<td>Bridge function, Researcher</td>
</tr>
<tr>
<td>AP8</td>
<td>Taken Considerations to Achieve Functions</td>
<td>Bridge function, Researcher</td>
</tr>
<tr>
<td>AP9</td>
<td>Safety Codes</td>
<td>Bridge function, Researcher</td>
</tr>
<tr>
<td>AP10</td>
<td>Bridge Site Background and Analysis</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP11</td>
<td>Relationship Between Bridges and Road Networks</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP12</td>
<td>Site Natural Delimiters</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP13</td>
<td>Site Constructed Delimiters</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP14</td>
<td>Context Sensitive Design and Solutions</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP15</td>
<td>Historical Site/ Bridge Treatment</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP16</td>
<td>Bridge Surroundings Character</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP17</td>
<td>Expected bridge effect on the Curtilage</td>
<td>Bridge site, Researcher</td>
</tr>
<tr>
<td>AP18</td>
<td>Construction Materials Selection</td>
<td>Bridge structure, Researcher</td>
</tr>
<tr>
<td>AP19</td>
<td>Structure Systems Selection</td>
<td>Bridge structure, Researcher</td>
</tr>
<tr>
<td>AP20</td>
<td>Construction Methods Selection</td>
<td>Bridge structure, Researcher</td>
</tr>
<tr>
<td>AP21</td>
<td>Bridge Parts Architectural Integration</td>
<td>Bridge parts, Researcher</td>
</tr>
<tr>
<td>AP22</td>
<td>Bridge Aesthetical Considerations</td>
<td>Bridge aesthetics, Researcher</td>
</tr>
<tr>
<td>AP23</td>
<td>Bridge Fundamentals of Aesthetical Design/Qualities</td>
<td>Bridge aesthetics, Researcher</td>
</tr>
<tr>
<td>AP24</td>
<td>Aesthetical Design Objectives</td>
<td>Bridge aesthetics, Researcher</td>
</tr>
<tr>
<td>AP25</td>
<td>Bridge Visual Design Elements</td>
<td>Bridge aesthetics, Researcher</td>
</tr>
<tr>
<td>AP26</td>
<td>Bridge Aesthetical Considerations Integration</td>
<td>Bridge aesthetics, Researcher</td>
</tr>
<tr>
<td>AP27</td>
<td>Bridge Curtilage Development Report</td>
<td>Bridge curtilage, Researcher</td>
</tr>
<tr>
<td>AP28</td>
<td>Synchronizing with the Surroundings</td>
<td>Bridge curtilage, Researcher</td>
</tr>
</tbody>
</table>

#### Appendix B: Sustainability Evaluation Prerequisites (PR)

<table>
<thead>
<tr>
<th>Prerequisite</th>
<th>Category</th>
<th>Reference rating system</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR1</td>
<td>Environmental Review Process</td>
<td>-, Greenroads</td>
</tr>
<tr>
<td>PR2</td>
<td>Lifecycle Cost Analysis</td>
<td>Material and Resources, Greenroads</td>
</tr>
<tr>
<td>PR3</td>
<td>Lifecycle Inventory</td>
<td>Material and Resources, Greenroads</td>
</tr>
<tr>
<td>PR4</td>
<td>Quality Control Plan</td>
<td>Sustainable Construction Activities, Greenroads</td>
</tr>
<tr>
<td>PR5</td>
<td>Noise Mitigation Plan</td>
<td>Sustainable Construction Activities, Greenroads</td>
</tr>
<tr>
<td>PR6</td>
<td>Waste (Construction Demolition) Management Plan</td>
<td>Sustainable Construction Activities, LEED - Greenroads</td>
</tr>
<tr>
<td>PR7</td>
<td>Pollution Prevention Plan / Construction Activity Pollution Prevention</td>
<td>Sustainable Construction Activities, LEED - Greenroads</td>
</tr>
<tr>
<td>PR8</td>
<td>Low Impact Development</td>
<td>Sustainable Construction Activities, Greenroads</td>
</tr>
<tr>
<td>PR9</td>
<td>Pavement Management System</td>
<td>Pavement Technologies, Greenroads</td>
</tr>
<tr>
<td>PR10</td>
<td>Site Maintenance Plan</td>
<td>Bridge Maintenance, Greenroads</td>
</tr>
</tbody>
</table>
## Appendix C: (AC) Architectural Evaluation Credits

### Category 1: Bridge Function (BF)

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED weight</th>
<th>G.R. Weight</th>
<th>Research Weight</th>
<th>Final Weight</th>
<th>Reference Rating Sy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC1</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC2</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

### Category 2: Bridge Site (BS)

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED weight</th>
<th>G.R. Weight</th>
<th>Research Weight</th>
<th>Final Weight</th>
<th>Reference Rating Sy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC3</td>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC4</td>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC5</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC6</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

### Category 3: Bridge Structure (BST)

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED weight</th>
<th>G.R. Weight</th>
<th>Research Weight</th>
<th>Final Weight</th>
<th>Reference Rating Sy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC7</td>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC8</td>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC9</td>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

### Category 4: Bridge Parts (BP)

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED weight</th>
<th>G.R. Weight</th>
<th>Research Weight</th>
<th>Final Weight</th>
<th>Reference Rating Sy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC10</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC11</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC12</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC13</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC14</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC15</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

### Category 5: Bridge Aesthetics (BA)

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED weight</th>
<th>G.R. Weight</th>
<th>Research Weight</th>
<th>Final Weight</th>
<th>Reference Rating Sy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC16</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC17</td>
<td></td>
<td></td>
<td>-</td>
<td>1</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC18</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
</tbody>
</table>

### Category 6: Bridge Curtilage (BC)

<table>
<thead>
<tr>
<th>Credit</th>
<th>LEED weight</th>
<th>G.R. Weight</th>
<th>Research Weight</th>
<th>Final Weight</th>
<th>Reference Rating Sy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC19</td>
<td></td>
<td></td>
<td>-</td>
<td>2</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC20</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC21</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
<tr>
<td>AC22</td>
<td></td>
<td></td>
<td>-</td>
<td>3</td>
<td>Researcher</td>
</tr>
</tbody>
</table>
### Appendix D: (SC) Sustainability Evaluation Credits

#### Category 1: Location and Transportation (LT)

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Score</th>
<th>Credits</th>
<th>LEED/Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR1</td>
<td>Site Selection</td>
<td>1/110</td>
<td>-</td>
<td>6/100</td>
</tr>
<tr>
<td>CR2</td>
<td>Historical Site Improvement</td>
<td>-</td>
<td>-</td>
<td>3/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Historical Site Improvement</td>
<td>-</td>
<td>-</td>
<td>1/25</td>
</tr>
<tr>
<td>CR3</td>
<td>Surrounding Density and Diverse Uses</td>
<td>5/110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR4</td>
<td>Footing Pier Location</td>
<td>-</td>
<td>-</td>
<td>2/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2/25</td>
</tr>
<tr>
<td>CR5</td>
<td>Brown Field Redevelopment (High Priority Sites)</td>
<td>2/110</td>
<td>-</td>
<td>2/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2/25</td>
</tr>
<tr>
<td>CR6</td>
<td>Sensitive Land Protection</td>
<td>1/110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR7</td>
<td>LEED For Neighborhood</td>
<td>8-16/110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR8</td>
<td>Context Sensitive Solution</td>
<td>-</td>
<td>5/118</td>
<td>-</td>
</tr>
<tr>
<td>CR9</td>
<td>Scenic View</td>
<td>-</td>
<td>1-2/118</td>
<td>-</td>
</tr>
<tr>
<td>CR10</td>
<td>Safety Audit</td>
<td>-</td>
<td>1-2/118</td>
<td>-</td>
</tr>
<tr>
<td>CR11</td>
<td>Cultural Outreach</td>
<td>-</td>
<td>1-2/118</td>
<td>-</td>
</tr>
</tbody>
</table>
|      | 1-2- Encourage Environmental Friendly Transportation Solution (Traffic Efficiency)
| CR12 | Bicycle Lane                                                                 | 1/110 | 1-2/118 | 1/100          | 1 LEED-GrResearch |
|      |                                                                              |       |         | 1/25           |                |
| CR13 | Walk able Lane "Pedestrian Lanes"                                           | 1/110 | 1-2/118 | 1/100          | 2 GR-LEED      |
|      |                                                                              |       |         | 1/25           | Researcher     |
| CR14 | Green Vehicles & HOV lane "                                                 | 1/110 | -       | 2/25           | 1 LEED-Researcher |
| CR15 | Transit Lane ( Access to Quality Transit)                                    | 1-6/110 | 1-5/118 | 2/25           | 2 LEED-GrResearch |
| CR16 | Lane Adaptability                                                            | -     | -       | 1/100          | 2 Researcher   |
|      |                                                                              |       |         | 3/25           |                |
| CR17 | Tollbooth Transponders on Bridge Entrance                                   | -     | -       | 1-2/25         | 1 Researcher   |
| CR18 | Sponsors , Advertisements & Signs                                            | -     | -       | -              | 2 Researcher   |
| CR19 | Traffic Emission Reduction                                                  | -     | 5/118  | -              | 1 Greenroads    |
| CR20 | Intelligent Transportation System                                            | -     | 2-5/118 | -         | 1 Greenroads    |

#### Category 2: Sustainable Sites & Construction Activities (SC)

##### 2-1- Sustainable Sites

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Score</th>
<th>Credits</th>
<th>LEED/Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR21</td>
<td>Site Assessment</td>
<td>1/110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR22</td>
<td>Site Development - Habitat Restoration</td>
<td>2/110</td>
<td>3/118</td>
<td>-</td>
</tr>
<tr>
<td>CR23</td>
<td>Site Recycling Plan</td>
<td>-</td>
<td>1/118</td>
<td>-</td>
</tr>
<tr>
<td>CR24</td>
<td>Open Space</td>
<td>1/110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR25</td>
<td>Heat Island Reduction</td>
<td>2/110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CR26</td>
<td>Light Pollution Reduction</td>
<td>1/110</td>
<td>3/118</td>
<td>-</td>
</tr>
</tbody>
</table>

##### 2-2- Sustainable Construction Activities

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Score</th>
<th>Credits</th>
<th>LEED/Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR27</td>
<td>Quality Management System</td>
<td>-</td>
<td>2/118</td>
<td>-</td>
</tr>
<tr>
<td>CR28</td>
<td>Fossil Fuel Reduction</td>
<td>-</td>
<td>1-2/118</td>
<td>-</td>
</tr>
<tr>
<td>CR29</td>
<td>Non Road Equipment Emission Reduction</td>
<td>2/100</td>
<td>1-2/118</td>
<td>2/100</td>
</tr>
<tr>
<td>CR30</td>
<td>Contractor Warranty</td>
<td>-</td>
<td>3/118</td>
<td>-</td>
</tr>
<tr>
<td>CR31</td>
<td>Accelerated Bridge Construction Techniques</td>
<td>-</td>
<td>14/100</td>
<td>-</td>
</tr>
<tr>
<td>CR32</td>
<td>Construction and Demolition Waste Management</td>
<td>1-2/110</td>
<td>4/100</td>
<td>1/25</td>
</tr>
</tbody>
</table>

223
### Category 3: Material, Resources & Pavement Technologies (MRPT)

#### 3-1 Material and Resources

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Credits</th>
<th>LEED</th>
<th>Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR34</td>
<td>Life Cycle Cost Analysis</td>
<td>-</td>
<td>5/100</td>
<td>1 Researcher</td>
</tr>
<tr>
<td>CR35</td>
<td>Life Cycle Assessment (Bridge Life Cycle Impact Reduction)</td>
<td>2/5/110</td>
<td>2/118</td>
<td>1 LEED-Gr Researcher</td>
</tr>
<tr>
<td>CR36</td>
<td>Bridge Product Disclosure and Optimization Product Declarations and Certified Wood</td>
<td>2/110</td>
<td>-</td>
<td>1 LEED-Researcher</td>
</tr>
<tr>
<td>CR37</td>
<td>Bridge Product Disclosure and Sourcing Of Raw Material</td>
<td>1/2/110</td>
<td>-</td>
<td>1 LEED</td>
</tr>
<tr>
<td>CR38</td>
<td>Bridge product disclosure and Optimization Material Ingredients</td>
<td>1/2/110</td>
<td>-</td>
<td>1 LEED</td>
</tr>
<tr>
<td>CR39</td>
<td>Earthwork Balance</td>
<td>-</td>
<td>1/118</td>
<td>1 Greenroads</td>
</tr>
<tr>
<td>CR40</td>
<td>Recycled Balance</td>
<td>-</td>
<td>1-5/118</td>
<td>5/100</td>
</tr>
<tr>
<td>CR41</td>
<td>Regional Materials</td>
<td>1-2/110</td>
<td>1-5/118</td>
<td>3/100</td>
</tr>
<tr>
<td>CR42</td>
<td>Reduction in Quantity of Materials</td>
<td>-</td>
<td>1/25</td>
<td>3/100</td>
</tr>
<tr>
<td>CR43</td>
<td>Material Reuse (Salvaged Materials)</td>
<td>-</td>
<td>-</td>
<td>2/100</td>
</tr>
<tr>
<td>CR44</td>
<td>Corrosion Resistant Steel Reinforcement</td>
<td>-</td>
<td>4-8/100</td>
<td>-</td>
</tr>
<tr>
<td>CR45</td>
<td>Cement Replacement - Supplement Cementations Material</td>
<td>-</td>
<td>-</td>
<td>3/100</td>
</tr>
</tbody>
</table>

#### 3-2 Paving Credits

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Credits</th>
<th>LEED</th>
<th>Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR46</td>
<td>Paving Emission Reduction</td>
<td>-</td>
<td>1/118</td>
<td>1 Greenroads</td>
</tr>
<tr>
<td>CR47</td>
<td>Pavement Reuse</td>
<td>-</td>
<td>1-5/118</td>
<td>-</td>
</tr>
<tr>
<td>CR48</td>
<td>Long-Life pavement</td>
<td>-</td>
<td>5/118</td>
<td>-</td>
</tr>
<tr>
<td>CR49</td>
<td>Permeable Pavement</td>
<td>-</td>
<td>3/118</td>
<td>-</td>
</tr>
<tr>
<td>CR50</td>
<td>Warm mix asphalt</td>
<td>-</td>
<td>3/118</td>
<td>-</td>
</tr>
<tr>
<td>CR51</td>
<td>Cool Pavement</td>
<td>-</td>
<td>5/118</td>
<td>-</td>
</tr>
<tr>
<td>CR52</td>
<td>Quit Pavement</td>
<td>-</td>
<td>2-3/118</td>
<td>-</td>
</tr>
<tr>
<td>CR53</td>
<td>Pavement Performance Tracking</td>
<td>-</td>
<td>1/118</td>
<td>-</td>
</tr>
</tbody>
</table>

### Category 4: Energy and Atmosphere (EA)

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Credits</th>
<th>LEED</th>
<th>Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR54</td>
<td>Enhanced Commissioning</td>
<td>2-6/110</td>
<td>-</td>
<td>2 LEED</td>
</tr>
<tr>
<td>CR55</td>
<td>Optimize Energy Performance</td>
<td>2-6/110</td>
<td>-</td>
<td>4 LEED</td>
</tr>
<tr>
<td>CR56</td>
<td>Advanced Energy Metering</td>
<td>1/110</td>
<td>-</td>
<td>1 LEED</td>
</tr>
<tr>
<td>CR57</td>
<td>Renewable Energy Production</td>
<td>1-3/110</td>
<td>-</td>
<td>1 LEED-Researcher</td>
</tr>
<tr>
<td>CR58</td>
<td>Green power and carbon offset</td>
<td>1-2/110</td>
<td>-</td>
<td>1 LEED-Researcher</td>
</tr>
<tr>
<td>CR59</td>
<td>Environmental Management System</td>
<td>-</td>
<td>2/118</td>
<td>-</td>
</tr>
<tr>
<td>CR60</td>
<td>Energy efficiency</td>
<td>-</td>
<td>1-5/118</td>
<td>-</td>
</tr>
</tbody>
</table>

### Category 5: Water Efficiency (WE)

<table>
<thead>
<tr>
<th>CR</th>
<th>Description</th>
<th>Credits</th>
<th>LEED</th>
<th>Researcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR61</td>
<td>Runoff Flow Control</td>
<td>2/3/100</td>
<td>1-3/118</td>
<td>1/25</td>
</tr>
<tr>
<td>CR62</td>
<td>Runoff Quality</td>
<td>-</td>
<td>1-3/118</td>
<td>2-5/100</td>
</tr>
<tr>
<td>CR63</td>
<td>Storm Water Cost Analysis</td>
<td>-</td>
<td>1/118</td>
<td>-</td>
</tr>
<tr>
<td>CR64</td>
<td>Site Vegetation (Water Use)</td>
<td>2/110</td>
<td>1-3/118</td>
<td>-</td>
</tr>
</tbody>
</table>

224
| CR65        | Ecological Connectivity (Avoiding and Minimizing Impacts to Fish and Wildlife) | - | 1-3/118 | 1/100 | 1 | Greenroads - Researcher |
| CR66        | Water Use Tracking (Water Metering) | 1/110 | 2/118 | 2/100 | 1 | LEED - Greenroads |

**Category 6 : Bridge Maintenance (BM)**

| CR67        | Efficient Inspection Technologies | - | - | 3/100 | 2 | Researcher |
| CR68        | Bridge Painting and Coating | - | - | 3-6/100 | 2 | Researcher |
| CR69        | Corrosion Resistant Steel Reinforcement | - | - | 4-8/100 | 1 | Researcher |
| CR70        | Corrosion Control Materials | - | - | 2-3/100 | 1 | Researcher |
| CR71        | Bridge Cleaning | - | - | 1-2/100 | 1 | Researcher |
| CR72        | Bridge Deck Drainage | - | - | 1-3/100 | 1 | Researcher |
| CR73        | Bridge Deck Joints and Deck Joint Seals | - | - | 1-4/100 | 1 | Researcher |

**ICC: Innovation & Custom credits**

| ICC1        | LEED AP | 1/110 | - | - | 1 | LEED |
| ICC2        | Innovation (Custom Credits) | 5-110 | 1-10/118 | 3/25 | 4 | Greenroads |
| ICC3        | Environmental Training | - | 1/118 | - | 1 | Researcher |
| ICC4        | Building Under the Bridge | - | - | - | 3 | Researcher |
| ICC5        | Bridge Rentable Spaces | - | - | - | 2 | Researcher |
| ICC6        | Governmental Rules Monitoring of the Bridge's surface | - | - | - | 2 | Researcher |
| ICC7        | Governmental Rules Monitoring of the Bridge's surrounding areas | 2 | Researcher |
| ICC8        | Regional Priority | 1-4/110 | - | - | 1 | LEED |
| ICC9        | Architectural Creativity | - | - | - | 2 | Researcher |
| ICC10       | Structural Innovative Solutions | - | - | - | 2 | Researcher |

165
Sustainable Rating System For Architectural Evaluation of Bridges in Egypt

Introduction

Part 1: Theoretical Study
Bridges And Sustainability Overview

Chapter 1: Bridge's Art, Science and Construction Historical Development
Chapter 2: Sustainable Bridges

Part 2: Analytical Study
Developing a Rating System for Egyptian Bridges Architectural Evaluation

Section 1: The Factors Influencing in Bridge's Architecture through Design and Construction Stages

Chapter 3: Different Types of Bridges and Architecture
Chapter 4: The Relationship between the Bridge and its Context
Chapter 5: Reflection of Bridge's Structure on bridge's shape and Form
Chapter 6: Bridge's Different Parts and their Relation with Bridge’s Shape and Form
Chapter 7: The Effect of Aesthetical Considerations and Creativity on a Bridge's Architectural Design.
Chapter 8: Design Process of a Sustainable Bridge and Architect’s Role

Section 2: The Factors Influencing in Bridges Architecture over Usage and Operation Stage

Chapter 9: Bridges Synchronizing with Surrounding Curtilage and Community

Part 3: Inductive Study
Developing an Egyptian Sustainable Bridge Rating System

Chapter 10: Sustainability Assessment Concepts
Chapter 11: Developing the Egyptian Sustainable Rating System for Bridges Evaluation

Chapter 12: Conclusion and recommendations

Appendices
Introduction

Throughout this study, bridges history, site selection, context, bridges types, structure systems, construction materials, design process and aesthetical considerations are studied. All these factors form the bridge's architecture. Also bridge sustainability is studied through over viewing sustainability assessment concepts and bridges sustainability previous trials and practices. After studying bridge architecture and sustainability, the researcher developed a Sustainable Rating System for Architectural Evaluation of Bridges in Egypt in addition to some conclusions and recommendations which should be taken into consideration in the new construction bridges projects.

12-1-Conclusion

Many solutions to research's problems are introduced through the research. These solutions will be achieved throughout following the concluded and developed rating systems "Sustainable Rating System for Architectural Evaluation of Bridges in Egypt". Also some results are concluded as shown below:

1. Adhering to the developed rating system which is the first step to create a beautiful and sustainable bridge which well achieve its desired function, This rating system is considered a guideline to lead the design team to reach its goals.
2. The importance of architect role in bridge design, construction and operation process to dominant these process and coordinate between all other team members including civil, structural, mechanical, electrical engineers, bridge owner and users.
3. Bridge architectural design is not only depends on its appearance, but also it depends on the degree of its function performance.
4. Several design solutions are often available for most situations. Therefore, a selection of a design solution has to be the optimum solution not only a possible solution.
5. In mega projects like bridges which consume money, time and resources, decisions are impossible to be taken throughout one person due to the large volume of work and different specialists. Hence the integrated design team plays a very critical role in discussing every single decision taken by specialists to reach to the optimum solutions.
6. Before design phase, all basic information should be available, Functional, aesthetical, sustainable goals and priorities should be defined to guide the design team to take the best solutions and achieve the bridge's desired function. This phase is called "Pre-design phase", which is very important to guarantee creating the most beautiful and sustainable bridge and well achieve desired functions with the lowest price in less time.
7. To achieve bridge sustainability, sustainable sites, sustainable transportations and sustainable construction activities must be integrated. Also materials, energy, water efficiency and bridge maintenance should be formulated through an integrated design, construction and operation process by the integrated design/construction teams.
8. Economics is a fundamental consideration in design/construction process, structure type selection, construction materials/methods and all design decisions but it shouldn't be the only consideration to avoid creating ugly or useless bridges.
9. "Sustainable bridge" doesn't necessarily mean expensive bridge. Sustainability may need extra costs in the beginning, but more costs will be paid back during bridge life through its operation, low cost maintenance and end of life usage solutions.

10. Bridge location is considered as one of the main factors affecting bridge function and form, therefore studying the bridge site, context, surrounding area and natural or constructed delimiters is very important to guarantee a successful bridge.

11. In case of constructing a new bridge next to an existing/historical bridge or creating a bridge in a historical district, a careful study should be developed to respect and preserve the history.

12. Bridge architectural character should be defined as of the beginning of design stage. This character should consider bridge site, architecture character and any other design, function or budget limitations.

13. Bridge original function should be well defined and respected in the pre-design stage. Also bridge further functions by community should be expected and considered in the bridge design.

14. Any bridge is considered a road extension to cross any obstacle, so bridge context sensitive design and solutions should be proposed through respecting the surrounding roads hierarchy, capacity, width, etc. to well achieve its desired function without having adverse impacts on the surrounding road's functions.

15. Bridge is considered a civilian facility which consists of many components. The most important component is its structure. That is why structure system, construction materials, methods and structural parts are very important to bridge architecture.

16. The available construction techniques have significant influence on the selection of the most suitable class of bridge for a particular site so it is important that the designer should at an early stage be aware of the various construction techniques that are economically viable, as well as their advantages and disadvantages.

17. Although feasible configurations of bridge structure are largely dictated by forces and actions on bridge and properties of construction materials, there are usually almost unlimited possible variations in structure systems types, proportions and forms. The designer should select a safely optimum structure system, identify structure parts proportion and form through considering aesthetic improvement within a specific budget.

18. Bridge parts are divided into structural and non-structural parts, each of them has different character, function and design considerations which should be considered and coordinated against each other to create a compatible entity which is regard as an addition to the bridge surroundings.

19. Beauty could not be derived from some simple shortcuts but it depends on a large number of aesthetical values and qualities. Therefore the aesthetical considerations have a major effect on bridge shape and form. Aesthetic design objectives should be defined, Fundamentals of aesthetical design and aesthetical qualities should be met in a creative way to design a pleasant bridge.

20. The four "Rs" (reuse, reduce, recycle and regional materials) are the main factors of sustainable materials, which should be used in sustainable bridges due to their easy maintenance and replacement, low transportations cost. They decrease energy consumption in material's manufacturing and transportation.

21. Bridge monitoring during construction and operation stages is highly important to observe bridge success or failure in achieving its function, deal with new further functions, sustain bridge safety and aesthetics and decrease bridge maintenance or replacement costs.
12-2- Recommendations

The main purpose of this research is to design a pleasant and sustainable bridge which successfully achieves a desired function in a creative way. To reach this purpose an Egyptian Sustainable Rating System to Evaluate Bridges Architecture is developed. Several steps should be followed to design a successful bridge in a creative way:

A. Pre-Design Stage
The architect role is very important in this stage. In this stage, design team should:
- Define bridge functional, aesthetical and sustainable goals.
- A preliminary data is needed at the beginning of the bridge pre-design process.
- A plan of site showing all obstacles (streets, rivers, roads, etc.) should be determined.
- Soil conditions data for foundations, local regulations, weather, environment and topography should be considered.
- The expected cost is compared to the specified budget.
- Design team should be well selected in this stage.

B. The Creative Process:
After studying the design data, designer should imagine the first shape of bridge then convert the imagination to a preliminary sketch. This sketch is to be developed several times to reach the most acceptable sketch ready to be blown up to add details. It is better to make several proposals to choose the perfect proposal after seeking the consulting of the design team. Most of bridges design developed in section not plan and after some trials 3D modeling would be preferable.

C. Conceptual Design Stage:
In this stage, co-operation between architect, civil engineer and the rest of the design team members is significant to decide the perfect structure system and innovative material or innovate new shape of existing structure system.
Also design team should have a combination of innovative mental attribute for deductive and intuitive adapting of proposed several concepts.

D. Design Development Stage:
This stage is the calculation stage, designers and engineers verify safety, function, beauty, cost, sustainability, etc. This includes the following:
- Design stage that gives rise to structure and durability problems.
- Design details that cause difficulties for inspection.
- Aspects of durability that satisfy rules in stimulated design codes.
- Applying all developed rating system categories will be commenced in this stage to
be resumed in later stages.

**E. Design of Maintenance Stage:**
The designed bridge should be maintainable and a maintenance plan should be approved.

**F. Selection Stage:**
It is a very significant stage. It consists of a search for optimal solution through identification of possibilities, followed by evaluation and comparison, make to the final decision. Also most appropriate materials calculating Whole life cost versus initial cost will be used.

**G. Final Design Stage**
After design approval, the final design work can begin with rigorous calculations of forces, stress, loads, etc.. Also, mechanical equipment, construction methods, maintenance and inspection issues, materials and finishing quality, etc...

After these stages, there are construction, operation and maintenance stages which should comply with the approved construction and maintenance plan, and regular inspection should be conducted to guarantee adherence to the rating system and achieving the desired goal. **There are some recommendation to be taken into consideration during the bridge design, construction and maintenance stages which will be discussed below:**

- **Functional Recommendations**
  - Well studying bridge site, bridge characteristics and bridge main and developed functions.
  - Bridge parts and details should be compatible with each other. Every part in a bridge should realize its targeted function and all these parts should unified to achieve the bridge designed function.
  - Bridge shape and form to suit, serve and express bridge function for example railway bridges, in accommodating the heavy weight of trains should generally appear strong and need to be stiffer than road bridges.
  - Bridge width to follow road width at its starting and endings to avoid car rush to facilitate desired function.
  - All safety considerations for cars, pedestrians and the bridge itself should be checked and local regulations must be complied with.
  - Bridge future expansions should be taken into consideration to assimilate future growth.
  - Further functions to the bridge and under the bridge (pedestrians in vehicle bridges, street vendors in pedestrian bridge, etc..) should be considered, and solutions should be provided.

For pedestrian bridges:
- Bridge parts should follow "Anthropometry" human body scale" at all details (bridge and stairs width, handrails, etc..)
- Bridge design should stick to architectural standards at (ventilation and lighting windows, stair's steps numbers, steps dimensions tread and riser, etc..)
- Stairs width should be the same as bridge width to avoid people rush.
Bridge design should consider old people and handicaps, so elevators/escalators must be applied to the bridge design.

- Bridge's handrails should adhere to the safety regulations and the bridge's design concept.
- For pedestrian bridge entrance, good and strong material should be used as marble and granite. The entrance should also be obvious with an attractive design and reflecting the bridge function and architectural character.
- For pedestrian bridge flooring and stairs, strong materials should be used to endure the permanent friction.
- For pedestrian bridges roof, a soft material should be used to be protected from dust sticking.
- The attitude of the bridge's neighborhood population should be studied to be taken into consideration to accomplish the maximum comfort for these population, feeling that the new bridge is an addition to their neighborhood to be carefully use it.
- The area around the bridge is to be thoroughly studied, the major activity of the surrounded community is to be taken into consideration. Strict laws should be applied to protect farmlands around bridges (The Ring Road informal housing surrounding).
- Social and religion considerations are to be well thought-out (as example bad effect of bridges on surrounding houses in Ring Road and 6th of October Bridge).

**Aesthetical Recommendations**

- Architects should be engaged in the starting of the bridge's design process.
- Textures, colors and materials should be coordinated against bridge surroundings either to be in line with or in contrary to the surroundings to make a contrast. They should be appropriate to the color theme of the surrounding site.
- The architectural character for bridge location is to be discussed to make a link between the bridge and the surrounding community.
- The architectural character of the location should be taken into account.
- The bridge should be compatible to the surrounding buildings styles to enhance the visual image of the site. This could be accomplished by avoiding all the visual pollution reasons such as (bad material textures, bad colors, bad maintenance, etc)
- Bridge design should follow rules of aesthetical values such as (ratios, scale, rhythm, etc.) Also The designer should abide by general ratios rules (golden ratio, module, etc)
- Structure elements aesthetical treatment is to be studied to mitigate structure tough relationships.
- Bridge entrances should be obvious. Also forces in structure system should be confirmed by aesthetical treatments.
- Keep the bridge as long and slender as practical. Ramps should also provide a smooth and continuous geometric flow. Sharp breaks and odd angles should be avoided.
- Provide as low a parapet as is possible. The structure is more slender and opportunities for graffiti are reduced.
- Keep the design of the pedestrian screen simple to offer more open appearance

There is no single design parameter that controls the general physical characteristics of a bridge. An attractive bridge is the orchestration of design
parameters employed simultaneously to complement each other. Designers can interpret these design parameters to constitute principal aesthetic design factors.

**Principal Aesthetical Design Factors:** these factors fashion the visual basis upon which the balance of the appearance is built. Designers should concentrate on developing the best design solutions for these design parameters prior to considering other visual treatments. To find the best design solution, designers must consider the aesthetic objectives outlined previously when making decisions regarding these design parameters.

- Superstructure type and shape.
- Vertical and horizontal geometry and their relationship to the surrounding environment.
- Pier placement and shape.
- Abutment placement and shape.
- Interaction between the bridge and its surroundings/ environment.
- Appearance of strength and stability.
- The users of bridges have to feel safe and consequently it must not only in facet be strong and stable, but it becomes an aesthetic requirement that its visual form must generate a sense of security by appearing to be so.

**Secondary Aesthetical Design Factors:** these factors can be used to accentuate the positive qualities that have been treated with the principle aesthetic design factors. The texture, color, and shape can be engaged to draw attention to, or to detract from, the role of structural elements. These factors should consider aesthetical design considerations. These secondary factors such as:

- All-non structural parts and details as (railings, noise walls, safety screens, lighting, joints and access hatches, etc..)
- Surface colors, textures, Concrete surface quality, Cladding and architectural embellishments.

**Structural Recommendations**

- Bridge structure system should be chosen according to many factors (bridge span, architectural design, budget, loads and function)
- Selecting the most appropriate material for both structure system and budget.
- Bridge structure design should be coordinated between civil engineer and architect.
- Using long live structure materials which need minimum maintenance to be suitable for the environment (humidity, rain, dust, etc..)
- Structure system should be coordinated against the bridge design, shape, form and aesthetics.

**Bridge Sustainability Recommendations**

- To design a sustainable bridge, three major steps should be taken: sustainable design, sustainable construction and sustainable maintenance. Every step should be studied to be connected to the next step.
- Determining sustainability goals for designing a sustainable bridge is very important to determine the appropriate approaches to achieve sustainability.
- Mostly important, sustainable bridge design criteria will include these items (sustainable sites, water and energy efficiency, materials and resources conservation and design innovation). Each of these criteria should be studied to be taken into consideration during bridge design, construction and maintenance.
12-3- Subsequent Studies

This study is considered a start that should be continued and developed to increase bridge design awareness in Egypt. Consequently, many studies should be done in the future. These studies can be concluded as below:

**Subsequent studies for architects**:
- This research is considered a guideline to the bridge design team to evaluate new construction bridge's function and aesthetics in Egypt. It is also considered just a start in the sustainable bridges field in Egypt. This start needs to be developed to enable the design team to evaluate the Egyptian existing bridges to facilitate renovation and replacement. So next research will be developing a sustainable rating system for architectural evaluation of existing bridges in Egypt.
- Spread awareness between architects about the importance of architect role in bridge design and construction process and bridge design should not be totally dedicated to structural engineer. Since bridge is like any other construction, it needs to achieve its desired function in a safe way and fine shape and form.

**Subsequent studies to the government**:
- The next step is submitting this rating system to the Egyptian General Authority for Roads and Bridges and The Egyptian Ministry of Transport to include this rating system as a part of any new bridge authorization process in Egypt.
- This study should also be delivered to the responsible entities in Egypt to be developed by expertise from different specialties in order to be applied to the existing construction bridges through Egyptian roads and bridges development plan.

**Subsequent studies for public**:
- Awareness of bridge aesthetics importance should spread between public users. Because of the proliferation of ugly bridges, people thought that the default bridge is an ugly construction which has a function to transport passengers between two points over any obstacle. A bridge is a beautiful structure that should be considered an addition to the city's visual image and has other social and economical functions in addition to its basic function of passengers transportation.
- Increase the interest of Egyptian young people and students to learn more about bridge structure systems and aesthetics. For example, there is a "Bridging our future by Intel" experience in USA, Intel computer appliances company offers an experience to students for using technology to collaborate with peers and industry experts to build a bridge model, from the initial design phase through the final structure testing. 

There is also "Bridges: Amazing structures to design, build and test (Kaleidoscope Kids)" book which describes different kinds of bridges, their history, design, construction, and effects on populations, environmental dilemmas, safety being studied at USA schools.

---

1 - https://www.youtube.com/watch?v=BYMd-7Ng9Y8
References

English Books:

References

67. -----: AASHTO (American Association of State Highway and Transportation Officials Committee Corresponded) - by the AASHTO TIG Lead States Team for the following technology- USA-2003.
68. -----: "Aesthetics guidelines for bridge design"- Office of bridges and structure-Minnesota Department of Transportation- USA- 1995.
70. -----: "Aesthetic Bridges user guide"- Maryland Department of Transportation State Highway Administration- Office of Bridge Development- Maryland- USA-2005.
71. -----: "Bridge aesthetics source book"- The American association of state highway and transportation officials - USA- 2010.
73. -----: "Bridge Design practice"- CALTRANS (The California Department of Transportation) - Chapter 5 (Concrete Design Theory Reference guide)- USA-2015.
References

75. -----: "Beyond the Pavement"- RTA urban design policy- procedures and design principles- Australian Government-Australia- 2009.
76. -----: "Bridge Railing Manual"- Department of Transportation- Texas-USA- 2014.
77. -----: "Bridge aesthetics- design guideline to improve the appearance of bridges in NSW"- Center for urban design- Transport Roads and maritime services- New south Wales- Australia-2012.
79. -----: "Design manual for roads and bridges" volume 1- highway structures- approval procedures and general design -section 3 general design- part 11- the design and appearance of bridges- USA-1998.
80. -----: EPA (Non-Road Diesel Engines)- Environmental Protection Agency-USA-2012- www.dieselnet.com/standards/us/non-road.php
81. -----: "GreenLITES Project Design Certification Program"- NYSDOT (The New York State Department of Transportation)-2015https://www.dot.ny.gov/programs/greenlites
83. -----: "Historic highway bridges of Florida" - Environmental management office- Florida department of transportation- Tallahassee- Florida- USA- 2004.
84. -----: "ICE Manual of Bridge Engineering" -Institution of Civil Engineers-UK- 2008.
85. -----: I-LAST™ Illinois (Livable and Sustainable Transportation Rating System and Guide) -V2.2-Department of transportation-USA-2012. http://www.idot.illinois.gov/
86. -----: "LEED Principles and Green Associate Study Guide"- Green Building Education Services- USGBC -USA- 2014.
88. -----: "LEED version 4 for building design and construction"- Reference guide-USGBC- USA- 2018.
89. -----: "Noise wall design guideline -Design guideline to improve the appearance of noise walls in NSW "-The center for urban design-Roads and maritime services- New South Wales- Australia-2016.
90. -----: "Oregon Bicycle and pedestrian Design guide" 3rd edition- Oregon highway design manual- Appendix N- Oregon department of transportation Bicycle and pedestrian program-USA-2011.
91. -----: "Santa Rosa Bicycle and Pedestrian Bridge"-Feasibility Study- Prepared for the City of Santa Rosa- Transit-Oriented Development in the United States-Texas- USA- 2010.
92. -----: "The appearance of bridges and other highway structures"- The highway agency -HMSO (Her Majesty's Stationery Office) - London- UK- 1996.

Arabic Books

English Thesis:

18. Susan Handy: “Methodologies for exploring the link between urban form and travel behavior"- Transportation Research University of California- USA- 1996.


Arabic Thesis:
1. الفت عبد العظيم سليمان حلوة: "منهجية تصميم المعمارية والعمرة المستقبلية"- رسالة دكتوراة- كلية الهندسة بالموطنية- جامعة حلوان- 2006.


Arabic Articles and Researches:
1. مستقبل الطاقة في مصر - تقرير الهيئة العامة للإضاءة - 2014.

2. مقال بعنوان (أوقوف هذه المزلة - الطريق الداري خطر يهدد الاهدافات - ضمهم إلى الصحف والazines العالم و اليونيكون تحليل - impulses بقوس النزاهة - اد عباس زعتر - ماجستير - قسم الآثار - جمعية الجديد الأخبار - 12-12-1943.

3. علاء بابين - اثر المناخ في شكل العمارتة العربي - مجلة عالم البيئة - مركز الدراسات التخطيطية والعمارية - 2016.

Articles and Researches:
1. Annie Farbman and Leslie Tillman: "How can we design a sustainable bridge" - Presentation project for ENES216- FLEXUS Women in Engineering Seminar- 2012.

3. Astúa de Moraes, F: "The Integration of Sustainability in the Fuzzy Front End of Innovation within the context of SMEs".- Paper- Transportation Unit Delft -Netherlands- 2010.

24. Johnson-Bednar: "An overview on Greenroads" - Research - University of Washington and CH2M HILL-USA-2010


27. La Violette. Mike: "Bridge construction practices using incremental launching" - Research to American Association of State Highway and Transportation Officials (AASHTO)-Highway Subcommittee on Bridge and Structures- Bridge Engineering Center - from Center for Transportation Research and Education -Iowa State University - Ames - Iowa-USA-2007.


29. Lloyd Alter: "Bridges are for People- 7 Bridges that people live and work on" - Article - 2009. atwww.treehugger.com/sustainable-product design.


42. Pan Chan, P. C: "Quantifying Pavement Sustainability for Ontario" - Paper- University of Waterloo- Canada-2010.


49. RMRC (Recycled material resources center) Report. BE2ST-in-Highways™ at RMAUPG Annual Meeting-2012- http://rmrc.wisc.edu/be2st-in-highways/


60. Vogtländer, J.G: "A practical guide to LCA for students, designers and business managers- cradle-to-grave and cradle to cradle". Delft University of Technology- Netherlands- 2010.


63. Wong. Raymond: "Construction of Bridges" - paper- Division of Building Science and Technology- City University of Hong Kong-Japan-2012.


Web Sites:

17. http://bestbridge.net Last accessed (October 2016)
54. http://arab-training.net/ Last accessed (October 2016)
64. http://www.aia.org/ Last accessed (October 2016)
70. http://www.italyguides.it Last accessed (October 2016)
71. http://www.ramboll.co.uk Last accessed (October 2016)
73. http://www.dailymail.co.uk Last accessed (October 2016)
References

97. [http://cob.cdc.selu.edu](http://cob.cdc.selu.edu) Last accessed (October 2016)
99. [https://rainprel.wordpress.com](https://rainprel.wordpress.com) Last accessed (October 2016)
100. [http://homedesignlover.com](http://homedesignlover.com) Last accessed (October 2016)
102. [www.livingbridge-hamburg.de](http://www.livingbridge-hamburg.de) Last accessed (October 2016)
103. [http://www.treehugger.com](http://www.treehugger.com) Last accessed (October 2016)
104. [www.urbanwaterfront.blogspot.com](http://www.urbanwaterfront.blogspot.com) Last accessed (October 2016)
105. [www.livingpod.com](http://www.livingpod.com) Last accessed (October 2016)
106. [http://bridgescape.net](http://bridgescape.net) Last accessed (October 2016)
118. [http://www.bridges.transportation.org](http://www.bridges.transportation.org) Last accessed (October 2016)
120. [https://www.polymersolutions.com](https://www.polymersolutions.com) Last accessed (October 2016)
121. [http://www.brainpop.com](http://www.brainpop.com) Last accessed (October 2016)
123. [http://www.slideshare.net](http://www.slideshare.net) Last accessed (October 2016)
125. [http://www.fit.edu](http://www.fit.edu) Last accessed (October 2016)
References

15. https://structurae.net Last accessed (October 2016)
42. http://www.businessdictionary.com Last accessed (October 2016)
204. [http://www.fosterandpartners.com](http://www.fosterandpartners.com) Last accessed (October 2016)
207. [http://www.designboom.com](http://www.designboom.com) Last accessed (October 2016)
208. [http://www.e-architect.co.uk](http://www.e-architect.co.uk) Last accessed (October 2016)
211. [http://media.linkonlineworld.com](http://media.linkonlineworld.com) Last accessed (October 2016)
221. [http://www.listofwonders.com](http://www.listofwonders.com) Last accessed (October 2016)
225. [http://www.dgnb.de](http://www.dgnb.de) Last accessed (October 2016)
229. [http://www.ibec.or.jp/](http://www.ibec.or.jp/) Last accessed (October 2016)
231. [http://www.chps.net](http://www.chps.net) Last accessed (October 2016)
237. [http://www.igbc.ie/about/](http://www.igbc.ie/about/) Last accessed (October 2016)
239. [http://www.igbc.ie/about/](http://www.igbc.ie/about/) Last accessed (October 2016)
244. [http://www.n-bawab.net](http://www.n-bawab.net) Last accessed (October 2016)
Appendices: Score card prerequisites and credits explanations

Introduction
The focus of this section is to demonstrate the previously developed rating system under study to assist bridge engineers, design team, construction team and operation team in developing more sustainable design and construction processes for new bridges and to architecturally evaluate the same.

This section consists of four parts; first part "Appendix A" includes the architectural evaluation prerequisites, the second part "Appendix B" consists of the sustainable evaluation prerequisites, the third part "Appendix C" entails the architectural evaluation credits and the forth part "Appendix D" deals with the sustainable evaluation credits. Architectural prerequisites and credits are developed by the researcher over this study chapters adding a new criteria for bridges aesthetics, function and curtilage evaluation. Sustainability prerequisites and credits are developed based on two existing rating systems LEED V4 for BD+C (sustainable building rating system) and Greenroads V1.5 (sustainable roads rating system). Also some credits are developed in this part to add a new criteria for the evaluation of bridge sustainability.¹

Rating System Structure:
This rating system could be applied on any new construction bridge "pedestrian, vehicle or railway bridge "to evaluate its architecture and sustainability, it is divided into these main categories:

Architectural evaluation categories:
- **Bridge Site**: Have the design team well studied the site?
- **Bridge structure**: The reflection of the bridge's site, function, design and loads on the selected structure system, construction materials and methods.
- **Bridge parts**: The harmony between bridge parts to achieve function, aesthetics and sustainability goals.
- **Bridge aesthetics**: How to make a good looking bridge?
- **Bridge curtilage**: The reflection of a bridge on the surrounding site after operation and usage.

Sustainability evaluation categories:
- **Location and Transportation**: Does the location preserve environmentally sensitive places and take advantage of existing infrastructure, community resources, and public transit?
- **Sustainable sites and construction activity**: Is the selected site able to maximize sustainability? How to achieve sustainability through site and construction activities?
- **Materials, resources and pavement technologies**: Are the bridge materials and pavement sustainable for the environment, and where does the waste go?
- **Energy and atmosphere**: How to save energy, cut energy costs and encourage green energy development and use?
- **Water efficiency**: What can be done to save on landscaping water use and operation water use?
- **Bridge maintenance**: How to make the bridge operate as long as possible with full capacity?

Innovation and custom credits: what can be discovered to add even further value to the project that is not subject to the rating system?

¹ Note: For detailed criteria and requirements please refer to the main prerequisite/credit at LEED, Greenroads or mentioned references of every prerequisite/credit reference guide.
Appendices: Score card prerequisites and credits explanations

Prerequisites and Credits

**Prerequisites:** Prerequisites do not earn bridge project any points because they are required for the project to be considered. The term “prerequisite” refers to mandatory project characteristic, measurement, quality, value or function as identified within the rating system. Prerequisites represent the key criteria that define successful bridge performance. Each project must satisfy all specified prerequisites outlined in the rating system under which it is registered. Failure to meet any prerequisite will render a project ineligible for certification.

**Credits:** Each category has a group of credits that defines a particular sustainability, aesthetical or functional goals. The goal is referred to as the ‘intent’ of the credit. In fact, in these appendices just below every prerequisite/credit name is a section titled ‘intent’ where the credit goal is defined and a "requirement" is referred to how to achieve the credit/prerequisite also the references which source and standards of the credit/prerequisite.

A bridge project does not have to score all credits. Credits are optional elements. A bridge Project only needs to score enough credits for the certification level the project is aiming for (certified, silver, gold, or platinum). The word “Credit” means a non-mandatory project characteristic, measurement, quality, value or function as identified within the rating system.

Scoring Criteria

**Project Certification:** There are four levels of certification:
- Certified: 50-74 points
- Silver: 75-99 points
- Gold: 100-124 points
- Platinum: 125+ points from 165

A project must satisfy two requirements for certification:
1. Satisfy all prerequisites
2. Satisfy a combination of credits that realize a certain number of points for the desired certification level.

**Credit weightings:** Points are available in each of the credit categories, and the points are weighted to best address the social, environmental, and economic outcomes identified by the original rating system or from a researcher point of view (in case of credits based on specific or several rating systems, the researcher takes the average weighting from the original rating system and compare it with Egyptian sustainability goals. In case of credits developed by the researcher, their importance are evaluated and given the appropriate weight according to their importance.

Credits have different weightings depending on their ability to impact different environmental, aesthetical, functional, economic, social and human health concerns. More points are awarded for these credits that have a greater impact. The impact categories answer the question: “What should a successful bridge accomplish?”

- Achieve the desired functions and adapt the added ones.
- Evaluate selected structure system, construction materials and construction methods to meet desired goals.
- Understand aesthetical goals, requirements, qualities and values.
- Reverse contribution to global climate change.
- Enhance individual human health and wellbeing.
- Protect and restore water and energy resources.
- Protect, enhance and restore biodiversity and ecosystem services.
- Promote sustainable and regenerative material resources cycles.
- Build a greener economy.
- Enhance social equity, environmental justice, and community quality of Life.

All credits could achieve exemplary performance and earn extra points by exceeding the original requirements to achieve the credit, as an example for renewable energy credit, maximum points are 3 points by creating 10% of the whole bridge energy from a renewable resource. But what if 15% renewable energy is generated, more points will be earned/scored.

**General Notes:**
- All architectural evaluation credits are created and developed by the researcher, and to best understanding these prerequisites/credits please refer to the mentioned chapters at every prerequisite/credit.
- Reports are prepared with regard to the credits and prerequisites and final score card achievement to be calculated by bridge design team and be revised and approved by an accredited committee authorized by a certified Egyptian engineering school or any accredited engineering office. This committee job is to double check all achieved prerequisites and credits to certify the bridge project for the final score (Platinum, Gold, Silver or Certified)

**Appendix A: Architectural Evaluation Prerequisites**

**AP1: Bridge Goals Analysis:** (Design Process- Chapter 4)

**Intent:** To determine the main and secondary goals of a new bridge for perfect accomplishment. This goals must contain functional, aesthetical, special and sustainability factors.

**Requirements:** An integrated report concludes all main and secondary goals of a new bridge. This report help the design team to make priorities according to budget, determinants and circumstances. Also it helps the design team to choose the perfect structure system, construction materials and methods and optimum design solutions.

**AP2: Bridge Design/Construction Proposals:** (Design Process- Chapter 8)

**Intent:** Choosing the best bridge design according to project delimiters

**Requirements:** At least three design/construction proposals should be offered and reasons for selection or denials of such depend on the project delimiters (aesthetical and functional goals, site, budget, codes and regulations, etc...).

**AP3: Integrated team members and architect role:** (Design Process- Chapter 8)

**Intent:** Integrity is one of the most important factors for achieving sustainability in a bridge project.

**Requirement:** A report to show the integrity between bridge owner, project manager, architects, design team members, project construction team members, project contractors, suppliers, etc. This report should illustrate every member's role, responsibilities and permissions especially project architect.

**AP4: Bridge Integrated Costs:** (Design Process- Chapter 8)

**Intent:** Preliminary calculations for bridge costs to be compared with the bridge budget to select the optimum design solutions within the budget.
Appendices: Score card prerequisites and credits explanations

Requirements: One of the major factors affecting bridge architecture and sustainability is the project budget, so in this prerequisite a report contains all design, construction, sustainability costs to be calculated and compared to the preliminary budget and design goals to set priorities to be submitted in order to achieve the safest, most pleasant and sustainable bridge within budget.

**AP 5: Bridge Main Functions** (Bridge Function- Chapter 3)

**Intent:** to reach the main goal of bridge construction and well achieve the desired function

**Requirements:** Bridge main function/ functions and the expected benefits from these functions to the community to be approved by design the team (Pedestrian, vehicle, railway, etc...).

**AP6: Bridge Expected Future Functions:** (Bridge Function- Chapter 3)

**Intent:** To design a flexible bridge which could adapts with new functions without Affecting on main function.

**Requirements:** future further functions according to the bridge location, bridge users or the surrounded community to be expected and submitted. Also the effect of these functions on the bridge's main function, architecture and curtilage are well studied and solutions are proffered. This prerequisite should be submitted for approval as a report showing main activities at the surrounding areas, bridge user main activities, an example of similar existing bridge case study and further functions.

**AP7: Bridge Functions Achievement:** (Bridge Function- Chapter 3)

**Intent:** To evaluate bridge success in achieving its targeted function.

**Requirements:** After construction, operation and usage, an evaluation should be executed to assess bridge success in achieving the designed function and its ability to contain the further functions, Also solutions are proposed for any functional problems.

**AP8: Taken Considerations to Achieve Functions:** (Bridge Function- Chapter 3)

**Intent:**Increment bridge ability to the best functional achievement.

**Requirements:** Define all added techniques to help a bridge in achieving the targeted function such as elevators, escalators and stairs to pedestrian bridges; walkways, lanes and entrances or exits for vehicle bridges. These techniques shall be in accordance with local codes.

**AP9: Safety Codes:** (Bridge Function- Chapter 3)

**Intent:** To preserve bridge user life and bridge itself.

**Requirements:** The bridge should fulfill all safety requirements of local codes (Fire resistance materials, firefighting procedures, first aid techniques for accidents, etc.) which should be submitted for approval and attached with the applicable local codes.

**AP10: Bridge Site Background and Analysis:** (Bridge Site- Chapter 1)

**Intent:** Guarantee creating a compatible bridge with its surroundings.

**Requirements:** a full study of bridge site history, architectural character and any historical facilities revealing in this study the bridge's relationship with such surroundings. This study contains any factors affecting the bridge's structure, architecture or sustainability.
AP11: **Relationship between Bridge and Road Networks:** (Bridge Site-Chapter 4)

**Intent:** To coordinate the interchanges between bridge and the surrounding roads network to avoid traffic jam which affects the bridge's functional success.

**Requirements:** A full study of road network hierarchy from/to the bridge, also studying road width, from and to the bridge to determine the bridge width to guarantee the best function for both and to avoid traffic jam. In case of pedestrian or vehicle bridges, a report which illustrate the relationship between bridge entrances, stairs, bridge structure, etc.. And the surrounding roads should be submitted for approval.

AP12: **Site Natural Delimiters:** (Bridge Site- Chapter 4)

**Intent:** To insure the best harmony between newly constructed bridge and the surrounding natural delimiters.

**Requirements:** Well understanding the site natural delimiters (rivers, seas, land farms, etc..) and the bridge design according to such delimiters (dimensions, construction materials and methods, foundations, shape and form and sustainability).

AP13: **Site Constructed Delimiters:** (Bridge Site- Chapter 4)

**Intent:** To insure the best synchronization between newly constructed bridge and surrounding constructed delimiters.

**Requirements:** well studying the constructed delimiters such as current bridges, buildings tunnels, etc.. And the design criteria to best accommodate these delimiters.

AP14: **Context Sensitive Design and Solutions:** (Bridge Site- Chapter 4)

**Intent:** Reaching to the best traffic solutions and the best function achievement

**Requirements:** An approach of context sensitive design and solution plans. These plans are to be designed, discussed and approved by the bridge design team.

AP15: **Historical Sites/Bridge Treatment:** (Bridge Site- Chapter 4)

**Intent:** To preserve the historical site/ bridge and to consider new bridge as an addition to these historical sites/bridges.

**Requirements:** An integrated plan to demonstrate the relationship between new bridges and historical or existing bridge or any other historical sites/facilities and the precautions taken to preserve these historical sites/facilities.

AP16: **Bridge Surroundings Character:** (Bridge Site- Chapter 4)

**Intent:** Creating a compatible visual image of the bridge and its surroundings

**requirements:** when designing a bridge in a site with architectural character or local character, a plan to demonstrate the relationship between bridges and this local/ architecture character is be submitted for approval.

AP17: **Expected Bridge Effect on the Curtilage:** (Bridge Site- Chapter 4)

**Intent:** guarantee the best relationship of the bridge and the surrounding curtilage

**Requirements:** The expected problems from constructing a new bridge on an existing Curtilage as (crowdedness, informal usage of area under or around the bridge, bad effects on surrounding buildings, etc...) to be well studied and proposing solutions to such problems for approval.
**AP18: Construction Materials Selection:** (Bridge Structure- Chapter 5)

**Intent:** To save material resources and achieve value engineering and to achieve the best aesthetical and functional considerations.

**Requirements:** A full study of the selected construction material. This study should include the following: Value engineering study, operation and maintenance plan, material specs safety reports, and aesthetical treatment of these materials.

**AP19: Structure Systems Selection:** (Bridge Structure- Chapter 5)

**Intent:** Selecting a structure system which best achieve safety and cost requirements within the architectural and sustainable design framework.

**Requirements:** Different structure systems alternatives should be proposed for the final selection of the structure system accomplished by the approval explanation for this selected system.

**AP20: Construction Methods Selection:** (Bridge Structure- Chapter 5)

**Intent:** Selecting a construction method which optimum achieve safety and cost requirements within the architectural and sustainable design framework

**Requirements:** A comprehensive study of the effect of the selected construction method on bridge architecture, sustainability, site, quality and time schedule should be prepared by bridge design team to be submitted for approval.

Note: To achieve these three prerequisites AP 18 to AP20, A study should be done and revised by the design team, containing the bridge site plans, site pictures, site history from local competent authorities and a survey filled by bridge surrounding residents should be submitted for approval.

**AP21: Bridge Parts Architectural Integration:** (Bridge Parts- Chapter 6)

**Intent:** To guarantee the integration between bridge parts.

**Requirements:** An integrated report defining the bridge structure and nonstructural parts selection, properties and the integration between these parts to reach to the best architecture for the bridge. This report should contain all bridge drawings, and all bridge parts specifications.

**AP22: Bridge Aesthetical Considerations:** (Bridge Aesthetics- Chapter 7)

**Intent:** Designing a bridge which follow aesthetical considerations.

**Requirements:** An integrated report showing the aesthetic design, qualities, visual design elements, visual characteristics, creativity considerations and the integration between these aesthetical considerations to ensure best bridge shape, form and aesthetics.

**AP23: Bridge Fundamentals of Aesthetical Design and Aesthetical Qualities:** (Bridge Aesthetics- Chapter 7)

**Intent:** Submit the applied aesthetical design/qualities to guarantee the best bridge shape and form

**Requirements:** Achievement of aesthetical qualities (proportion, rhythm, order, harmony, balance, contrast, scale, unity, illusion, simplicity and consistency) should be checked. Also the integrity between these qualities should be presented and demonstrated.
AP24: Aesthetical Design Objectives: (Bridge Aesthetics- Chapter 7)
\textbf{Intent:} Decide the aesthetical design objectives and goals to guarantee best bridge shape and form.
\textbf{Requirements:} The applied aesthetical design objectives and goals (functional clarity, scale and proportion, simplicity and continuity, order and balance, site/ environmental integration, refining the form, bridge architecture character, shade and shadow, fulfillment the purpose, reflections, symmetry and asymmetry) should be decided as of design stage and to be tracked through the bridge's design, construction and maintenance stages.

AP25: Bridge Visual Design Elements: (Bridge Aesthetics- Chapter 7)
\textbf{Intent:} Selection of the most appropriate visual design elements for the bridge
\textbf{Requirements:} A study of visual design elements selection reasons (color, concrete quality, texture and patterns, brick, stone and other nonstructural materials and finishes, ornamentations) according to the bridge site, history, surroundings, design goals, etc.. Should be provided.

AP26: Bridge Aesthetical considerations integration: (Bridge Aesthetics- Chapter 7)
\textbf{Intent:} To guarantee the integration between all bridge aesthetical considerations and quality to achieve the best architectural design for the bridge.
\textbf{Requirements:} An integrated report showing all bridge aesthetical considerations and qualities and the integration between them to reach to the best architecture for the bridge. This report should contain all bridge drawings.

Note: To achieve the prerequisites from AP22 to AP25, All bridge drawings attached to the elaborated report which demonstrate the selected aesthetical qualities and how these qualities achieve the previously defined aesthetical design objectives and the aesthetical design goals.

AP27: Bridge Curtilage Development Report: (Bridge Curtilage- Chapter 9)
\textbf{Intent:} Bridge development and deterioration observation
\textbf{Requirement:} A monthly report describing (bridge parts required to be maintained, bridge aesthetics, infringements on bridge curtilage, Infringements on surrounding lands or any other natural or constructed delimiters, etc..) should be submitted, Also solutions for any problem should be proposed and procedures to solve that problem should be taken.

AP28: Synchronizing with the Surroundings (Bridge Curtilage- Chapter 9)
\textbf{Intent:} Newly constructed bridge should be part of the whole site image as a beautiful addition.
\textbf{Requirements:} A full study showing the relationship between the bridge design and the surroundings (Natural and constructed delimiters, context, etc...). This study should highlight the bridge value to the surrounding context and how the designer well use the surrounding site.
Appendix B: Sustainability Evaluation Prerequisites

**PR1: Environmental Review Process** Greenroads

**Intent:** Evaluate impacts of bridge projects through an informed decision making process.

**Requirements:** Perform and document a comprehensive environmental review of the bridge project. This review should clearly and concisely document:
1. Project name and location.
2. Names and contact information of key players in the decision making process, including (but not limited to): the owner agency, agency representatives Responsible for completing the environmental review process, other stakeholders, and relevant professionals involved.
3. Intent and purpose of the bridge project.
4. Descriptions of potential environmental, economic and social impacts of the Intended bridge project.
5. Detailed descriptions of the extent of the significance of these impacts with respect To the decision making process and feasible performance expectations.
6. Description of the public involvement opportunity in the environmental review process; document this opportunity and the results of input in the final decisions.
7. Any jurisdictional requirements for more detailed environmental review documents such as environmental impact statements (EIS) or environmental assessments (EA)to determine the significance of environmental impacts.
8. Description of the final environmental decisions made. Table A-1

<table>
<thead>
<tr>
<th>Topics Addressed by an Environmental Review Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthen materials</td>
</tr>
</tbody>
</table>

**Reference:**

**PR2: Lifecycle Cost Analysis** Greenroads

**Intent:** Determine the lifecycle cost for the bridge project to aid in decision making.

**Requirements:** Perform a life cycle cost analysis (LCCA) of the bridge project. LCCA must contain at least agency costs and work zone user costs. LCCA can be performed with manual calculations or by using recommended software, do one or more of the following to determine input values for software:
- Justify the use of any default inputs
- Use historical data as representative values where available
- Use engineering estimates
- Use values recommended for select software where noted at main prerequisite in Greenroads reference guide

**Reference:**
**PR3: Lifecycle Inventory**  Greenroads  
**Intent:** Incorporate energy and emissions information into the decision making process for pavement design alternatives.  
**Requirements:** Complete a lifecycle inventory for the final pavement design alternative for the project using the software tool Road print, created by Dr. YenYu Lin at the University of Washington, or approved equivalent software. Report only results for total energy use and global warming potential (GWP) (in carbon dioxide equivalent emissions, CO2e) for the final pavement design alternative.  
**Reference:**  

**PR4: Quality Control Plan**  Greenroads  
**Intent:** Have a process in place to monitor and improve construction quality.  
**Requirements:** The prime contractor shall establish, implement, and maintain a formal construction Quality Control Plan (QCP). The QCP must follow local regulations and address the following quality control elements:  
1. Key quality control personnel, their responsibilities and their qualifications (resumes, certifications, etc.).  
2. Procedures used to control quality during construction including (as a minimum):  
   a. Items to be monitored (including pavement mix designs)  
   b. Testing to be done (including testing standards and frequency)  
   c. When corrective action is required (action limits)  
   d. Procedures to implement corrective action  
   e. Procedures to modify QCP if ineffective or when modifications are necessary  
**Reference:**  

**PR5: Noise Mitigation Plan**  Greenroads  
**Intent:** Reduce or eliminate annoyance or disturbance to surrounding neighborhoods and environments from road construction noise.  
**Requirements:** Establish, implement, and maintain a formal Noise Mitigation Plan (NMP) during construction for the prime contractor.  
**Reference:**  

**Intent:** To reduce construction and demolition waste disposed of in landfills and
Incineration facilities by recovering, reusing, and recycling materials. Also create an accounting and management plan for road construction waste materials.

**Requirements:** Develop and implement a construction and demolition waste management plan and Establish, implement and maintain a formal construction and demolition waste management plan (CWMP) during bridge construction. The CWMP should be included in the project contract documents.

**Reference:**
4. (2015), LEED version 4 for building design and construction, p 87

**PR7: Pollution Prevention Plan / Construction Activity Pollution Prevention Greenroads / LEED**

**Intent:** Reduce pollution and associated effects from construction activities by controlling soil erosion, waterway sedimentation, and airborne dust.

**Requirements:** Create and implement a comprehensive Storm water Pollution Prevention Plan (SWPPP) or Temporary Erosion and Sedimentation Control (TESC) plan that conforms to the requirements of the current Environmental Protection Agency (EPA) Construction General Permit OR the local or state Construction General areas that manage their own permitting plan, whichever is more stringent. The SWPPP/TESC must address water quality control and dust control activities used during construction of the bridge project.

**Reference:**
7. "LEED version 4 for building design and construction"- Reference guide- USGBC- USA- 2013- p 31

**PR8: Low Impact Development Greenroads**

**Intent:** Use low impact development (LID) storm water management solutions where appropriate to better mimic pre development hydrological conditions.

**Requirements:** Determine the feasibility of LID best management practices (BMPs) for storm water management in the right of way (ROW). Complete a basic LID hydrologic evaluation according to the steps outlined in the original prerequisite at Greenroads reference guide.

**Reference:**

**PR9: Pavement Management System Greenroads**

**Intent:** Make roadway capital assets last longer and perform better by preserving and maintaining them.
Requirements: Have asset management systems in effect that include the pavement and critical structural features on a project, Asset management system(s) must serve the project and include, at minimum, these activities:
1. Measure conditions of pavement structure and bridge structures at least once every two years.
2. Possess documented decision criteria for timing preservation actions.
3. Record when preservation efforts occur.
Example: A local pavement management system could be followed or any other PMS like, Street Saver or (MTC) for use by local governments.

Reference:

PR10: Site Maintenance Plan  Greenroads
Intent: Maintain environmental quality and aesthetics of the bridge project during use.
Requirements: Have and implement a comprehensive ongoing site maintenance plan that addresses (at a minimum) responsible parties/organizations, standards, schedule, methods to be used and funding source(s) for the following items (listed by major topics):
- Bridge maintenance
- Pavement patching, repair and crack sealing and Shoulder/sidewalk maintenance
- Storm water system cleaning and repair
- Roadside vegetation
- Safety device maintenance and repair
- Traffic signal maintenance and repair
- Bridge lighting maintenance and repair
- Intelligent transportation system maintenance and repair
- Pavement sweeping, cleaning and Litter control and Trash collection

Reference:
2. http://www.wsdot.wa.gov/Maintenance/Accountability

PR11: Educational Outreach  Greenroads
Intent: Increase public, agency and stakeholder awareness of roadway sustainability activities.
Requirements: Incorporate a comprehensive public educational outreach program into the operational phase of the project. A minimum of three out of the following eight educational elements, to be installed within the project limits or within the purview of the lead agency, must be completed to meet the intent of this project requirement:
1. Install and maintain a permanent project oriented signage program along the bridge right of way. During construction registered projects may use temporary signs to display factual information about the certification level being pursued.
2. Install and maintain at least one off road, permanent point of interest kiosk that displays the certification level pursued, project information, and the certification level actually achieved.
3. Provide a publicly available and maintained informational project website with capacity for submitting feedback and comments.
4. Develop an agency and/or stakeholder guide, specification, or policy that incorporates or otherwise clearly references and reflects the ideals and intents of the developed rating system.
5. Institute an internal agency continuing professional education and training program related to develop rating system.
6. Perform at least two presentations about the project for primary and secondary schools.
7. Perform one professional technical presentation.
8. Document the project experience using (conduct a detailed case study for the bridge project and spread it in national and universities libraries).

Reference:

PR12: Increasing Bridge Durability Researcher

Intent: increase the usage of the bridge and make maximum benefit from bridges investments.

Requirements: The new bridge is designed and is being built with a design life target of 100 years. Designing for a very long service life has considerable economic and community benefits and is a means of maximizing the return on community investment in infrastructure. Delaying replacement and minimizing maintenance costs and the disruption caused by maintenance activities is an aim of asset owners. Designing for such a long service life can represent sustainable structural engineering without significant cost premium. The durability design process for extended life requires the specific analysis of the environmental conditions in which the structure is placed, the strategic use of a range of materials and an understanding of the means by which they deteriorate and the rate of that deterioration.

Reference:

PR13: Fundamental Commissioning and Verification LEED

Intent: To support the design, construction, and eventual operation of a project that meets the owner's project requirements for energy, water and durability.

Requirements: Commissioning Process Scope Complete the following commissioning (Cx) process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies, in accordance with ASHRAE Guideline 0:2005, as they relate to energy, water and durability. Requirements for exterior enclosures are limited to inclusion in the owner's project requirements (OPR) and basis of design (BOD), as well as the review of the OPR, BOD and project design. NIBS Guideline 3: 2012 for Exterior Enclosures provides additional guidance or any other equivalent local code.

Reference:
1. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p.30
2. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p 64:65
PR14: Minimum Energy Performance LEED

**Intent:** To reduce the environmental and economic harms of excessive energy use by achieving a minimum level of energy efficiency for the bridge.

**Requirements:** Whole Bridge Energy Simulation Demonstrate an improvement of 5% for new construction bridge, compared with the baseline bridge performance rating. Calculate the baseline bridge performance according to ANSI/ASHRAE/IESNA Standard 90.1–2010, Appendix G, with errata (or a USGBC-approved equivalent standard for projects outside the U.S.), using a simulation model of any similar bridge.

**Reference:**

PR15: Bridge Level Energy Metering LEED

**Intent:** To support energy management and identify opportunities for additional energy savings by tracking bridge level energy use.

**Requirements:** Install new or use existing bridge level energy meters, or sub meters that can be aggregated to provide bridge level data representing total bridge energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass, etc). Utility-owned meters capable of aggregating bridge-level resource use are acceptable.

Whole-project energy usage data for a five year usage period should be calculated and traced every month to compare the difference between actual and expected consumption.

**Reference:**

PR16: Efficient Water Use Researcher

**Intent:** The objective is to efficiently use water during bridge construction and incorporate water efficiency and conservation in equipment washing. It entails a considerable reduction in potable water use and employs on site resources in order to lessen the municipal water supply demand.

**Requirements:** Consider using gray water in making ready mix concrete(Standard test method for water ASTM, 2009, Consult Section 911 of the 2012 MDOT Standard Specifications for the standard limits the amount of total solids, total organic content and alkalinity of non-potable water that can be used in concrete mix designs or any other equivalent local standard.

OR Other means to decrease the water usage could be using recycled water in truck washing, Slump adjustment Aggregate sprinklers.

**Reference:**

PR17: Outdoor Water Use Reduction LEED

**Intent:** To reduce outdoor water consumption.

**Requirements:** Reduce outdoor water use through one of the following options. No vegetated surfaces, such as permeable or impermeable pavement, should be excluded from the landscape area calculations.
Appendices: Score card prerequisites and credits explanations

Option 1. No Irrigation Required: Show that the landscape does not require a permanent irrigation system beyond a maximum two years establishment period.

OR Option 2. Reduced Irrigation: Reduce the project’s landscape water requirement by at least 30% from the calculated baseline for the site’s peak watering month. Reductions must be achieved through plant species selection and irrigation system efficiency, as calculated by the Environmental Protection Agency (EPA) Water Sense Water Budget Tool.

Reference:

PR18: Bridge Level Water Metering LEED

Intent: To support water management and identify opportunities for additional water savings by tracking water consumption.

Requirements: Install permanent water meters that measure the total potable water use for the bridge and associated grounds. Meter data must be compiled into monthly and annual summaries; meter readings can be manual or automated. Whole project water usage data for a five years usage period should be calculated and traced every month to compare the difference between actual and expected consumption.

Reference:

Appendix C: Architectural Evaluation Credits

Category 1: Bridge Function (BF)

AC1: Bridge Movement and Constancy (Chapter 3)

Intent: Taking the best decision for bridge movement or constancy.

Requirements: Deciding bridge movement or constancy according to social, economic, functional and aesthetical advantages and disadvantages.

AC2: Creating a Global Bridge (Chapter 3)

Intent: To upgrade bridge from local standards to global standards

Retirements: If there is any extra more strength global regulations or considerations which are not stipulated in existing local codes, the designer follows these considerations to upgrade the bridge design from local to global level. These regulations/considerations could be (functional, safety, aesthetical, etc...) considerations that should be submitted to score credit points.

Category 2: Bridge Site (BS)

AC3: Site Investigation: (Chapter 4)

Intent: Best selection of bridge site.

Requirements: Well investigate the unique sites to approach more useful functions from the bridge and to use the scenic views to achieve more financial resources and passenger pleasure. A report containing the site investigation should be submitted to score such credits points.
AC4: A Living Bridge Plan: (Chapter 4)
Intent: Preserve and investigate natural views such as rivers, seas, open spaces, etc..
Requirements: An integrated plan to well exploit the river front, sea front bridges or any bridge with view to protect these bridges from informal usage and to create a landmark for tourism promotion.

AC5: Bridge Viability for Expansion: (Chapter 3)
Intent: Designing a bridge which assimilates future growth to increase bridge durability and minimize the need for new bridges.
Requirements: A study showing considerations for future expansions and the proposed solutions to achieve such expansions.

AC6: Bridge as a Whole Aesthetical Design: (Chapter 4)
Intent: Design a bridge to enhance the visual image
Requirements: Study the value added by the bridge to the surrounding site as a newly added entity. Also any unique aesthetical consideration taken by the design team to suit the nature of the site should be presented and submitted.

Category 3: Bridge Structure (BST)

AC7: The Influence of Site/Context/Concept on Bridge Structure Systems Selection. (Chapter 5)
Intent: Measuring the success of the selected structure system.
Requirements: An evaluation of the selected structure system should be done after bridge operation, usage and maintenance (with reference to the original prerequisite) to record the advantages of the selected structure system and to solve the problems of selection also to avoid these disadvantages in future projects.

AC8: The Influence of Site/Context/Concept on Bridge Construction Materials Selection. (Chapter 5)
Intent: Measuring the success of the selected construction materials
Requirements: An evaluation of aesthetical construction materials should be done after bridge operation, usage and maintenance (with reference to the original prerequisite) to record the advantages of material selection, solve the problems of selection also to avoid these disadvantages in future projects.

AC9: The Influence of Site/Context/Concept on Bridge Construction Methods Selection. (Chapter 5)
Intent: Measuring the success of the selected construction methods.
Requirements: An evaluation of selected construction methods should be done after bridge operation, usage and maintenance (with reference to the original prerequisite) to record the advantages of the selected construction methods, to solve the problems of selection and to avoid these disadvantages in future projects.

Category 4: Bridge Parts (BP)

AC10: Superstructure Types Selection: (Chapter 6)
Intent: the best superstructure type selection to achieve safety, architectural and sustainability goals within budget.
Requirements: Design team should provide reasons, benefits and advantages of the selected superstructure, compared to other proposed superstructures alternatives.
AC11: Superstructure Parts Aesthetical Considerations: (Chapter 6)
Intent: Showing the integration between superstructure parts to each other and to other bridges parts.
Requirements: Aesthetical considerations for each of superstructure parts and the relation with the other parts (girder elevations and cross section, bearing, abutment bearing and drainage) should be provided by the bridge design team and to be submitted for approval.

AC12: Substructure Types Selection: (Chapter 6)
Intent: the best substructure type selection to achieve safety, architectural and sustainability goals within budget.
Requirements: Design team should provide reasons, benefits and advantage of the selected substructure compared to other proposed substructure alternatives.

AC13: Substructure Parts Aesthetical Considerations: (Chapter 6)
Intent: Showing the integration between substructure parts to each other and to other bridges parts.
Requirements: Aesthetical considerations for each of the substructure parts and the relation with the other parts (Piers "families, height, shape, form, parts, protection", bridge seats, abutments "height, placement, landscaping, shapes, materials", retaining walls, parapets) should be provided by the bridge design team to be submitted for approval.

AC14: Non Structural Parts Aesthetical Considerations: (Chapter 6)
Intent: Showing the integration between nonstructural parts to each other and to other bridges parts.
Requirements: Aesthetical considerations for each of nonstructural parts and the relation with the other parts (railings, safety screens, protective fencing, noise walls, signings, advertisements, landscaping, slope protection, lighting "roadway and accent, bridge miscellaneous details) should be provided by the bridge design team to be submitted for approval.

AC15: Whole Bridge Structure Integrity (Chapter 5)
Intent: Bridge whole structure selection to guarantee a good architecture
Requirements: whole structure parts shape and form selection to guarantee a good architecture (bridge layout, skewed structure, viaduct structure, structure depth) should be studied Also the relationship and interchanges between the new bridge and other surrounding bridges are to be shown.

Category 5: Bridge Aesthetics (BA)

AC16: Bridge Architectural Development (Chapter 1)
Intent: Designing an updated bridge which is in line with the state of the architectural technologies.
Requirements: A study showing all the updated design technologies and techniques, computer programs, construction materials and techniques, global architectural directions, etc... Used in bridge design and construction.

AC17: Following an Architectural School (Chapter 1)
Intent: Creating a bridge which adopts a specific architectural school.
Requirements: selecting the targeted architectural school and providing the reason for choosing this school, its aspects, its relationship with the bridge surrounding's architectural character and the reflection of adopting this architectural school for bridge architecture and the whole site image.

AC18: Bridge Fundamentals of Aesthetical Design and Aesthetical Qualities: (Bridge aesthetics- Chapter 7)
Intent: Check the applied aesthetical design/qualities to guarantee the best bridge shape and form
Requirements: Achievement and integration of aesthetical qualities (proportion, rhythm, order, harmony, balance, contrast, scale, unity, illusion, simplicity and consistency) should be checked/verified.
Scoring criteria: As much as achieved qualities as more as obtained points. Therefore an integrated study of the achieved qualities should be developed and discussed by bridge design team to decide the best weighting for the credit.

Category 6: Bridge Curtilage (BC)

AC19: Influence of Bridges on Cities Visual Image (Chapter 9)
Intent: Developing bridges which improve the city's visual image.
Requirements: Take decisions which facilitate the city's visual image improvement, to be provided and discussed by the design team. Answer the question of how the new bridge is considered an addition to the city's visual image.

AC20: The Space around the Bridge (Chapter 9)
Intent: Observe and use the space around the bridge.
Requirement: An integrated plan by bridge design team to manipulate the space around the bridge to improve its architecture. Also the problems of adding further functions by the community to the bridge affecting badly the original functions of the same must be discussed and proposed for solving.

AC21: The Area under the Bridge (Chapter 9)
Intent: Observe/use space under the bridge
Requirement: An integrated plan by bridge design team to exploit the area under the bridge to improve its architecture. Also the problems of adding further functions by the community to the bridge affecting badly the original functions of the same must be discussed and proposed for solving.

AC22: Bridges Maintenance from Architectural Perspective. (Chapter 9)
Intent: Maintain bridge aesthetics and functions and supervise all maintenance work of bridge to avoid bad effects of periodical structure maintenance on bridge architecture (functions, colors, ornaments, shape, form, etc...).
Requirements: periodical maintenance should be executed under an architect supervision to maintain bridge aesthetics, shape and form

Appendix D: Sustainability Evaluation Credits

Category 1: Location and Transportation (LT)

1:1: Site Selection
Site selection plays a vital role towards sustainability. Preference should be given to...
already develop sites, as further environmental damage is limited due to lesser
construction activities. Selecting the site wisely preserves natural habitats and avoids
encroachment of sites on water bodies and agricultural lands.

**CR1: Site Selection** Researcher

**Intent:** The objective of this criterion is to select sites that do not have impacts on the
environment due to the location.

**Requirements:** Try to avoid sites, which are identified as habitats of any species on the
federal or state threatened endangered lists. The criteria can be found in Appendix D of
EPA’s construction general permit or any other local equivalent code. Also avoid
building on agriculture lands if the bridge location must be on an agriculture land,
another land must be replaced in same state with same area, quality and quantity.
Reconstructing a bridge at the same location of the bridge being replaced, rather than
relocating it and having more environmental impacts at a new location might be
consideration for points.

**Reference:**
1. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design, Construction and Maintenance" - Phd Thesis-

**CR2: Historical Site Improvement:** Researcher

**Intent:** This section encourages preserving and conserving sites and structures of any
historical significance. The main purpose is to avoid any potential harm or damages to
historic sites and/or structures. The objective of this credit is to avoid development on
historic sites and reduce the socio-cultural environmental impact from the location of a
bridge on a site.

**Requirements:** Provide documentation showing the project team does not demolish any
historical bridge as defined in Egyptian ministry of tourism, If the bridge structure is
built on a historic site, improvements should be made to the facilities and/or access to
the site.

An example: Fom-Elkhalig bridge: Cairo, the
government destroyed part of Magra-Eloyon fence to
cross the metro and the bridge which considered a bad
eexample should be avoided to achieve historic site
improvement credit. Figure (A-1)

**Reference:**
1. Hunt Lauren R: "Development of a rating system for sustainable bridge"- Master
thesis- Civil and Environmental Engineering- Massachusetts institute of technology-
USA- 2005- p 16.
2. Kasim Armagan Korkmaz: "Implementation of Sustainability in Bridge Design,
Construction and Maintenance" - Phd Thesis- School of Planning, Design and
Construction- Michigan State University- 2012- p 42.
4. www.almasyryalyoum.com/

**CR3: Surrounding Density and Diverse Uses** LEED

**Intent:** To conserve land and protect farmland and wildlife habitat by encouraging
Development in areas with existing infrastructure. To promote walk ability, and
transportation efficiency and reduce vehicle distance traveled. To improve public health
by encouraging daily physical activity.

**Requirements:** Locate new bridge in previously developed areas to avoid long distance
which makes cars consume more energy, also to avoid insert new infrastructure and
utilities to non-developed areas and to limit urban sprawl

**Reference:**
CR4: Footing Pier Location  
**Researcher**

**Intent:** Avoid placing footing and piers in waterways and reduce the environmental impact from the location of a bridge on site. Also avoid affecting on fish and wildlife during bridge maintenance.

**Requirements:** Try to avoid placing footings and piers in water bodies to minimize environmental impacts. Consider choosing sites where the crossing distance is minimum.

In scenarios where bridges traverse a road, try to avoid placing footings within 50 feet of any water body such as seas, lakes, rivers, and streams that could support aquatic life, recreational or industrial use, consistent with the terminology of the clean water act. Also, with bridges over water, avoid constructing or developing sites within 100 feet of wetlands as defined in Appendix M of construction general permit of the Environmental Protection Agency (EPA) (EPA, 2011).

Try to build more durable bridge which need minimum maintenance, Also schedule maintenance to minimum time spent and minimum effect on sensitive environments.

**Reference:**

CR5: Brown Field Redevelopment (High Priority Sites)  
**Researcher / LEED**

Sites that have been abandoned due to contamination from previous activities are called as Brownfield sites. They can be redeveloped or reused once cleaned up. Redeveloping Brownfield sites may avoid environmental and health problems and reduce pressure on undeveloped lands.

**Intent:** The objective of this credit is to rehabilitate contaminated sites and to reduce pressure on undeveloped land and to encourage project location in areas with development constraints and promote the health of the surrounding area.

**Requirements:**
- **Option 1. Historic District:** Locate the project on an infill location in a historic district.
- **Option 2. Brownfield Remediation:** Locate on a Brownfield where soil or groundwater contamination has been identified, and where the local, state, or national authority (whichever has jurisdiction) requires its remediation. Perform remediation to the satisfaction of that authority.

**Reference:**

**Standard/Resource:**

CR6: Sensitive Land Protection  
**LEED**

**Intent:** To avoid the development of environmentally sensitive lands and reduce the environmental impact from the location of a building on a site.
Appendices: Score card prerequisites and credits explanations

Requirements: Locate the development footprint on land that has been previously developed or that does not meet the following criteria for sensitive land: Prime farmland. Prime farmland or important lands which as defined by local codes. Floodplains. A flood hazard area shown on a legally adopted flood hazard map or otherwise legally designated by the local jurisdiction or the state. Habitat. Land identified as habitat for the following (species listed as threatened or endangered by local codes, within 30 meters from water bodies and 15 meters of wetlands)

Reference:
4. Fws.gov/endangered
5. Natureserve.org
6. Msc.fema.gov

CR7: LEED For Neighborhood LEED

Intent: To avoid development on inappropriate sites. To reduce vehicle distance traveled. To enhance livability and improve human health by encouraging daily physical activity.

Requirements: Locate the project within the boundary of a development certified under LEED for Neighborhood or Certified Project under the LEED v4 rating system).

Reference:

CR8: Context Sensitive Solution Greenroads

Intent: Deliver projects that synthesize transportation requirements and community values through effective decision making and thoughtful design.

Requirements: Design the project according to the principles of Context Sensitive Solutions (CSS).

Fill out the submission form from the CSS National Dialog website for project design And construction. The form can be found here: http://www.cssnationaldialog.org/documents/design.pdf.

OR Create a short white paper (narrative) document describing the following:
1. The purpose and need for the project.
2. The planning horizon and proposed timeline or schedule for project completion.
3. A list or organizational chart of the management structure for the project: this includes, project planners, design professionals, consultants, agency leads, and other stakeholders involved.
4. The elements of the decision making process used.
5. The local and regional context and issues surrounding the project, other federal Context and issues, and applicable jurisdictional regulations and policies.
6. The public involvement process for CSD and results of this process.
7. The transportation modes considered and results of this consideration.
8. The visual and aesthetic components of the project.
9. The plan for long term ongoing monitoring during operations (if any).
10. The final alternatives and design elements chosen for implementation (a summary is sufficient).

Note: This credit must be earned in order to earn credits CR: Traffic Emissions Reduction, CR: Pedestrian Access, CR: Bicycle Access, and CR Transit Access.
Context Sensitive Solutions (also Context Sensitive Design; CSD) Figure (A-2) and Table (A-2).

**Figure A-2: Interurban Trail Bicycle and Pedestrian Bridge over SR 99 road: USA**

**Table A-2: Comparison of a conventional design process to a Context Sensitive design process.**

| Create a lasting value for the community and Use agency resources effectively |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maintain environmental harmony | Address community and social issues | Address aesthetic treatments and enhancements | Utilize full range of design choices | Document project decisions | Track and meet all commitments | Use full range of communication strategies | Achieve consensus on purpose and need | Address alternatives and all modes | Consider a safe facility for users and community | Use interdisciplinary teams | Involve stakeholders | Seek broad-based public involvement |

Reference:


**CR9: Scenic View** Greenroads

**Intent:** to enjoy the view from the bridge

**Requirements:** Provide at least one access from the project to a designated area for vehicles to exit the traffic stream, stop and experience scenic, natural or recreational features along the roadway. These areas may be scenic viewpoints or overlooks, welcome centers, tourist activities or information centers or recreation areas.
CR10: Safety Audit: Greenroads

**Intent:** Improve roadway safety through review by an independent audit team.

**Requirements:** Conduct a road safety audit (RSA) on the project roadway in accordance with local codes, regulations and procedures set forth in FHWA’s Road Safety Audit Guidelines. There are three general phases of a project during which a RSA may be conducted.

1. Preconstruction phase RSA. Performed before construction begins. Recommended Changes are generally less costly and result in less delay.
2. Construction phase RSA. Performed during preparation construction. They allow the roadway to be viewed as built and offer a last chance to assess safety before it is opened to the public.
3. Post construction phase RSA. Performed on existing roads to identify road safety issues for different road users.

**Reference:**

CR11: Cultural Outreach Greenroads

**Intent:** Promote cultural awareness, community connectivity and art.

**Requirements:** Any part of the project or any item within 10 miles of the project boundary is either:
- Listed in the Egyptian ministry of tourism as a historical or cultural place.
- And install informational infrastructure (e.g., viewpoint, kiosk, sign, or other small scale installation for visitors detailing historical, cultural, or archeological significance) to explain the site or direct roadway users to the site. An existing installation meets this informational infrastructure portion of the requirement.
- OR Dedicate a minimum of 1% of the total project budget (not to exceed $200,000) to art or community culture installations along the roadway right of way (ROW). Figure (A-3)

**Reference:**

**Figure A-3: Cultural Outreach**
1-2- Encourage Environmental Friendly Transportation Solution
(Traffic Efficiency)

CR12: Bicycle Lane: LEED: Researcher

Intent: To promote bicycling and transportation efficiency and reduce vehicle distance
Traveled. To improve public health by encouraging utilitarian and recreational physical
Activity.

Requirements: a) Develop plans to include bicycle pathways
b) Appoint a bicycle coordinator in order to promote the maximum use of no motorized
modes of transportation. Figure (A-4)

Bike lane Amsterdam streets

The green bike lane on Market Street approaching 10th Street. Photo: Bryan
Goebel

Helsinki Bike/Pedestrian lane

Fahy Bridge to get pedestrian lane next to unsafe sidewalks:

north of Union Square on 17th Street is a new protected contra flow bike lane and
pedestrian lane

Cycle and pedestrian signage

How the safety cross for pedestrian cuts cycle, roadway and pedestrian lanes at Amsterdam

situation was not very safe: at peak times, large numbers of pedestrians are attempting to
cross the street so the cyclist don't have enough time and space to slow down

This situation isn't safe also because the cyclists looks down to speed bumps and
didn't concentrate on the pedestrian so This could be
done by increasing the space between the bike lane and the road, so people can focus on
each obstacle separately

The New Broadway: More Pedestrian Space, Redesigned Bike Lane

Figure A-4: Bicycle and Walk able leans
CR13: Walk Able Lane "pedestrian Lanes" LEED: Researcher: Greenroads

Intent: The objective of this credit is to promote the use of alternative transportation through walking, thus minimizing pollution and energy demand.

Requirements:

a) Develop plans to include sidewalks pathways.
b) Appoint a pedestrian coordinator in order to promote the maximum use of no motorized modes of transportation.
c) Provide safe pedestrian pathways during the replacement or rehabilitation phase of the bridge.
d) Provide a safe walk able access to cross large bridges Figure (A-4)

CR14: Green Vehicles and HOV Lane "LEED: Researcher: Greenroads

Intent: To promote use of alternative transportation through High occupancy vehicles HOVs, green vehicles to reduce pollution.

Requirements:

Provide one or more travel lanes in each direction of traffic to be used exclusively by at least one of the following HOVs: 2 or more person carpools, Green vehicle, Liquid, Gas or battery vehicles. as exclusive HOV lanes. Identify sources of additional funding(Tele transit agency, regional agencies, Advertisings and tollbooth). Also to encourage people to use this credit, the fees of crossing the bridge(in case of tollbooth) may be reduced.

A green car: or Access HOV lane sticker should be on green cars to be checked by traffic policemen or may be smart sticker attached to satellite.

Note: a project may be added to bridge like a electrical train or a monorail, this may add exemplary performance points per cost and environmental effect. Figure (A-5)
Appendices: Score card prerequisites and credits explanations


California Extend HOV Lane  
Green car sticker: California state  
California state HOV lane:

High Occupancy Vehicle (HOV) Lanes, Ontario.

Figure A-5: Green Vehicles and HOV Lane

CR15: Transit Lane (Access to Quality Transit)  
LEED: Researcher: Greenroads

Intent: To encourage development in locations shown to have multimodal transportation choices or otherwise reduced motor vehicle use, thereby reducing greenhouse gas emissions, air pollution, and other environmental and public health harms associated with motor vehicle use.

Requirements: Provide one or more travel lanes in each direction of traffic to be used exclusively by Transit buses or any other transportation. Figure (A-6)

Reference:

Ottawa Transit way examples

Figure A-6: Transit Lane (Access to Quality Transit)
CR16: Lane Adaptability  Researcher  
**Description:** Bridges should be designed considering future traffic conditions. The increased traffic can increase the load on a bridge, which may deteriorate the bridge if it is not designed for carrying additional traffic, possibly resulting in additional maintenance activities. Therefore, a framework should be made to allow for additional future lanes in should any unforeseen conditions arise.  
**Intent:** To provide a framework that allows for additional lanes should there be any unforeseen conditions.  
**Requirements:** a) Design the bridge so that two or more lanes can be added without strengthening the **substructure**. Develop preliminary construction plans for the addition of lanes in the future. b) Design the structural elements so that they can bear additional loads created by the additional lanes. Therefore, consider using high performance materials, additional materials, or high strength materials in the design.  
**Reference:**

CR17: Tollbooth Transponders on Bridge Entrance  Researcher  
**Intent:** to provide extra financial resources for bridge to promote sustainability but in the same time to reduce the impact from cars stopped at toll booth stations.  
**Requirements:** Tollbooths idea to be enhanced but with a technology by electronic transponder payment system (like EZ pass electronic system). Figure (A-7)  
**Reference:**

The conventional Toll booth  
Old and New Cairo: Alexandria road toll booth  

E:Zpass System idea and E:Zpass devise fixed to car glass  

**Figure A-7: Tollbooth Transponders on Bridge Entrance**  

CR18: Sponsors, Advertisements and Signs:  Researcher  
**Intent:** to provide extra financial resources for bridge to promote sustainability and to reduce the bad effect on environment.
**Requirement:** Sponsor a Bridge provides civic minded companies an opportunity to enhance bridge by "sponsoring" segments of Bridge. Companies who utilize this program pay a fee to (Sponsor: a Bridge) or Adopt a bridge Litter Removal Service of This will allow for the sponsor to place corporate logos, colors and other identifiable messages, Arches for advertisements. Additionally, sponsor funded maintenance for the bridge, this will enhance the beauty of the bridge and its sustainability.

**Reference:**
1. [https://www.massdot.state.ma](https://www.massdot.state.ma)

**CR19: Traffic Emission Reduction** Researcher

**Intent:** Reduce operational mobile source emissions to improve air quality and human health.

**Requirements:** Use the EPA MOVES2010 software to compute the total greenhouse gas emissions and criteria pollutant emissions reduced by the tolling or pricing program compared to the non-priced alternative for the length of the project.

Emissions modeling will require establishing a baseline case. This should consist of the length of the project without congestion pricing and should use the same assumptions that are made in the congestion pricing case. Congestion pricing schemes reduce the number of vehicles on a roadway by charging money for use during peak periods, therefore reducing fuel use and total emissions. Congestion pricing need not apply to all lanes of a roadway. **Example:** Congestion Pricing in Puget Sound – Traffic Choices Study In 2002 Seattle, USA, These results included:

- All trips (tours per week) decreased 7%
- Vehicle miles traveled (miles per week) decreased 12%
- Drive time (minutes of driving per week) decreased 8%
- Tour segments (segments of tours per week) decreased 6%
- Miles driven on tolled roads (tolled miles per week) decreased 13%.

**Reference:**
2. [http://www.psrc.org/transportation/traffic](http://www.psrc.org/transportation/traffic)

**CR20: Intelligent Transportation System** Greenroads

**Intent:** Meet economic and social needs and improve mobility without adding capacity, or improve the efficiency of transportation systems.

**Requirements:** Include intelligent transportation system (ITS) applications listed in the Federal Highway Administration’s (FHWA) Research and Innovative Technology Administration (RITA) Office of Intelligent Transportation Systems Applications Overview portion of their ITS website The intelligent transportation include (Adaptive Signal Control, Advanced Signal Systems, Variable Speed Limits, Bicycle and Pedestrian, Special Events, Good traffic control and infrastructure, HOV Facilities, Ramp Rollover, Curve Speed Warning, Downhill Speed Warning, Overweight/Over width Warning, Highway Rail Crossing Warning Systems, Intersection Collision Warning, Pedestrian Safety, Bicycle Warning, Animal Warning etc..)

**Reference:**
## Category 2: Sustainable Sites and Construction Activities (SC)

### 2-1: Sustainable Sites

**CR 21: Site Assessment** LEED

**Intent:** To assess site conditions before design to evaluate sustainable options and inform related decisions about site design.

**Requirements:** Complete and document a site survey or assessment that includes the following information:

- Topography. Contour mapping, unique topographic features, slope stability risks.
- Hydrology. Flood hazard areas, delineated wetlands, lakes, streams, shorelines, rainwater collection and reuse opportunities, initial water storage capacity of the site.
- Climate. Solar exposure, heat island effect potential, seasonal sun angles, prevailing winds, monthly precipitation and temperature ranges.
- Vegetation. Primary vegetation types, Greenfield area, significant tree mapping, threatened or endangered species, unique habitat, and invasive plant species.
- Soils. Natural Resources Conservation Service soils delineation.
- Human use. Views, adjacent transportation infrastructure, adjacent properties, construction materials with existing recycle or reuse potential.
- Human health effects. Proximity of vulnerable populations, adjacent physical activity opportunities, proximity to major sources of air pollution.

The survey or assessment should demonstrate the relationships between the site features and topics listed above and how these features influenced the project design; give the reasons for not addressing any of those topics. All these topics should be connected to local standards.

**Reference:**


### CR 22: Site Development (Protect and Restore): Habitat Restoration

LEED and Greenroads

**Intent:** To conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.

**Requirements:** Preserve and protect from all development and construction activity 40% of the Greenfield area on the site (if such areas exist), and restore more area by 5% beyond what is required, this area may be in or out site or provide equivalent financial support.

**Egyptian example:** Abo kerdan bird after creating Cairo Ring road and building on Maryotia Green areas and filling Tereet El-Mariotya, Abo kerdan bird is eating from rubbish.

**Reference:**


### CR 23: Site Recycling Plan

**Greenroads**

**Intent:** Minimize the amount of construction related waste destined for landfill and promote environmental stewardship through good housekeeping practices at the work site.

XXVIII
**Requirement:** Establish, implement, and maintain a formal Site Recycling Plan as part of the Construction and Demolition Waste Management Plan (CWMP) during construction. The Site Recycling Plan must clearly describe the plan for implementing, communicating, monitoring and maintaining appropriate recycling and diversion practices on site.

**Reference:**

**CR 24: Open Space LEED**

**Intent:** To create exterior open space that encourages interaction with the environment, social interaction, passive recreation, and physical activities specially living bridges or bridges with scenic views.

**Requirements:** Provide outdoor space greater than or equal to 30% of the total bridge area (. A minimum of 25% of that outdoor space must be vegetated (turf grass does not count as vegetation) or have overhead vegetated canopy. The outdoor space must be physically accessible and be one or more of the following:

- A pedestrian oriented paving or turf area with physical site elements that accommodate outdoor social activities;
- A garden space with a diversity of vegetation types and species that provide opportunities for year round visual interest;
- A garden space dedicated to community gardens or urban food production;
- Preserved or created habitat that meets the criteria of SS Credit Site Development.

**Reference:**

**CR 25: Heat Island Reduction LEED**

**Heat islands are** temperature differences between developed and undeveloped areas. The heat island effect is created when developed areas have higher temperatures than Surrounding rural areas. An urban heat island effect is caused by sunlight heating up dark colored surfaces such as roads and rooftops. Urban heat islands effects can also be created by narrowed streets and tall buildings reducing the air flow through the city, as well as vehicle exhaust. Huge quantities of heat are generated in buildings that have dark rooftops and absorb heat rather than reflect it. Outside, we all know how much hotter a blacktop parking lot is than a grassy field.

**Intent:** To minimize effects on microclimates and human and wildlife habitats by reducing heat islands.

**Requirements:** Non roof and Roof (covered pedestrian bridges) meet the criteria mentioned at LEED reference guide.

**Cool Pavements:** Conventional paving materials can reach peak summertime temperatures of 120– 150°F (48–67°C). This extra heat is transferred to the air and results in additional evaporation of rainwater after periods of rain. Pavements that are more reflective – those with a higher SRI – can be installed to alleviate the negative properties of lower SRI materials such as black asphalt.

**References:**
1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 201539:40.
CR 26: Light Pollution Reduction LEED

Prevent Light Pollution: Light pollution is excessive or intrusive artificial light. Light pollution obscures the stars in the night sky for city dwellers, interferes with astronomical observatories, and, like any other form of pollution, disrupts ecosystems and has adverse health effects such as sleep disorder. Light pollution can be divided into two main types: 1) annoying light that intrudes on an otherwise natural or low-light setting and 2) excessive light (generally indoors) that leads to discomfort and adverse health effects.

Intent: To increase night sky access, improve nighttime visibility, and reduce the consequences of development for wildlife and people. The project uses fixtures that provide downward lighting to enhance safety and save energy while retaining the natural beauty of the night sky.

Requirements: Meet up light and light trespass requirements, using either the backlight up glare (BUG) method (Option 1) or the calculation method (Option 2). Projects may use different options for up light and light trespass. Meet these requirements for all exterior luminaries located inside the project boundary as demonstrated at LEED reference guide (LZ0, LZ1, LZ2, LZ3 and LZ4) LZ for Lighting Zone. Figure (A-8)

References:
1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p41:44.

Figure A-8: Types of external luminaries light pollution

2:2: Sustainable Construction Activities.

CR 27: Quality Management System Greenroads

Intent: Improve construction quality .

Requirement: using a contractor that has a formal quality management process.

Reference:

CR 28: Fossil Fuel Reduction Greenroads

Intent: Reduce the overall consumption of fossil fuels by non-road construction equipment.
Requirements: Reduce the fossil fuel requirements of non-road construction equipment by using bio fuel or bio fuel blends as a replacement for fossil fuel. Reduce the fossil fuel requirements of the non-road construction equipment fleet by 15% to 25% through the use of bio fuel or bio fuel blends as a replacement for fossil fuel.

Reference:

CR 29: Non road Equipment Emission Reduction  Greenroads – Researcher  
Non road engines are all internal combustion engines except motor vehicle (highway) engines, stationary engines (or engines that remain at one location for more than 12 months), engines used solely for competition, or engines used in aircraft. The non-road Standards cover mobile non road diesel engines of all sizes used in a wide range of construction, agricultural and industrial equipmentl. So, non-road equipment is used in construction and not on roads like cars, buses, etc.

Intent: Reduce air emissions from non-road construction equipment.

Requirements: At least 50% to 75% of the non-road construction equipment fleet operating hours for the project are accomplished on equipment with installed emission reduction exhaust retrofits and add on fuel efficiency technologies that achieve the EPA Tier 4 emission standard.

References:
2. The EPA describes several diesel engine emission reduction effort case studies at: http://www.epa.gov/diesel/construction/casestudies.htm

CR 30: Contractor Warranty  Greenroads

Intent: Incorporate construction quality into the public low bid process through the use of warranties.

Requirements: The project construction contract shall include, as a minimum, a 3 year warranty for constructed portions of the pavement structure to include surfacing (e.g., hot mix asphalt, Portland cement concrete, etc.) as well as any underlying layers (e.g., granular base material).

References:
3. National Research Council, Washington, D.C. Available at

CR 31: Accelerated Bridge Construction Techniques  Researcher

Accelerated construction is used to achieve the construction of structures in the shortest possible time while decreasing delays and traffic disruption. It is not just building structures rapidly, but also entails a variety of techniques, processes, and technologies to achieve the desired result of reducing congestion due to construction, while improving quality.

Intent: The objective is to reduce the construction time of the project thereby reducing environmental and traffic mobility impacts.
**CR 32: Construction and Demolition Waste Management**  
**LEED Researcher**

**Intent:** To reduce construction and demolition waste disposed of in landfills and incineration facilities by recovering, reusing, and recycling materials.

**Requirements:** Recycle and/or salvage nonhazardous construction and demolition materials. Calculations can be by weight or volume but must be consistent throughout. Exclude excavated soil, land clearing debris, and alternative daily cover (ADC). Include wood waste converted to fuel (bio fuel) in the calculations; other types of waste to energy are not considered diversion for this credit.

However, for projects that cannot meet credit requirements using reuse and recycling methods, waste to energy systems may be considered waste diversion if the European Commission Waste Framework Directive 2008/98/EC and Waste Incineration Directive 2000/76/EC are followed and Waste To Energy facilities meet applicable European Committee for Standardization (CEN) EN 303 standards (Or any other equivalent local standards).

**Reference:**

**CR 33: Soil Erosion and Sedimentation Control Plan**  
**Researcher**

**Erosion** is a process or combination of processes in which the earth materials are loosened or transported by natural agents such as wind or water. Soil is a valuable resource for plant growth and maintains biodiversity. Loss of soil may lead to water quality issues and inhibits biodiversity. Sedimentation is the deposit of soil particles or other pollutants in storm sewers or adjacent water resources. It affects the flow capacity of the stream channels and increases turbidity levels. Turbidity reduces sunlight penetration in water, which reduces photosynthesis and in turn affects aquatic vegetation and decreases oxygen levels. Air borne dust generation is another major environmental problem and could lead to many human health problems. Construction activities may result in air borne contaminants, including dust, mists, smoke, and fumes. This may lead to widespread lung diseases such as pneumoconiosis

**Intent:** The objective of this credit is to reduce pollution from soil erosion, which may be due to wind or water, sedimentation, and dust, and particulate matter generation during construction activities.

**Requirements:**

a) Develop a comprehensive erosion and sedimentation control (ESC) plan prior to earth activities. Show ESC requirements in specifications, drawings, and cost estimates for bridge projects.

b) Apply ESC practices to prevent excessive on site damage.

c) Develop a schedule and implement inspection and maintenance program.

d) Follow the Best Management Practices (BMP’s) mentioned in Principles of Runoff Control for Roads, Highways, and Bridges Erosion, Sediment and Runoff Control for
Appendices: Score card prerequisites and credits explanations

Roads and Highways and the Environmental Protection Agency (EPA) to control the addition of pollutants to coastal waters and erosion and runoff control for bridges.

Reference:

Other references to help bridge design team to achieve credit
10. HAWK.HUGH (2003), NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM, NCHRP REPORT 483, Bridge Life:Cycle Cost Analysis, Research Sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration, TRANSPORTATION RESEARCH BOARD WASHINGTON, D.C- USA

Category 3: Material, Resources and Pavement Technologies (MRPT)

3:1: Material and Resources.

CR 34: Life Cycle Cost Analysis Researcher

Life cycle cost analysis is an important technique that assists transportation agencies in making investment decisions. It is a set of economic principles and computational procedures for comparing initial and future costs to arrive at the most economical strategy for ensuring that a bridge provides the services for which it was intended.

Intent: To estimate the overall costs of project alternatives and to select the design that ensures the facility will provide the lowest overall cost of ownership consistent with its quality and function.

Requirements: Perform the calculations for the life cycle cost analysis of a bridge project. It is encouraged to compare various design alternatives.

References:
3. Hawk.hugh: National cooperative highway research program, nchrp report 483, Bridge Life:Cycle Cost Analysis, Research Sponsored by the American Association of State Highway and Transportation Officials in cooperation with the Federal Highway Administration, transportation research board Washington, D.C- 2003- USA

CR 35: Life Cycle Assessment (Bridge Life Cycle Impact Reduction)

LEED: Greedroads–Researcher

Intent: To encourage adaptive reuse, optimize the environmental performance of products and materials.

Requirements: Demonstrate reduced environmental effects during initial project decision making by reusing existing bridges resources or demonstrating a reduction in materials use through life cycle assessment. Achieve one of the following options.

Option 1: Historic Bridge Reuse
Option 2: Renovation of Abandoned or Blighted Bridge

XXXIII
Appendices: Score card prerequisites and credits explanations

Option 3. Bridge and Material Reuse
Option 4. Whole Bridge Life Cycle Assessment. Figure (A-9)

Figure A-9: The framework for Life Cycle Assessment

Reference:
5. ISO 14044: iso.org/

Bridge Product Disclosure and Optimization Credits

Intent: To encourage the use of products and materials for which life cycle information is available and that have environmentally, economically, and socially preferable life cycle impacts. and have been extracted or sourced in a responsible manner.

CR 36: Bridge Product Disclosure and Optimization: Environmental Product Declarations and Certified Wood

Option 1: Environmental Product Declaration (EPD)
Use at least 20 different permanently installed products sourced from at least five different manufacturers that meet one of the disclosure criteria (ISO, EPD products or USGBC approved environmental products).

Option 2: Use at least 50 % by cost environmental products as mentioned at same credit in LEED reference guide.

Reference:

XXXIV
CR 37: Bridge Product Disclosure and Optimization: Sourcing of Raw Material LEED

Requirements: Use at least 20 different permanently installed products from at least five different manufacturers that have publicly released a report from their raw material suppliers which include raw material supplier extraction locations, a commitment to long term ecologically responsible land use, a commitment to reducing environmental harms from extraction and/or manufacturing processes, and a commitment to meeting applicable standards or programs voluntarily that address responsible sourcing criteria.

Reference:

CR 38: Bridge Product Disclosure and Optimization: Material Ingredients: LEED

Requirements: Option 1. Material Ingredient Reporting
Use at least 20 different permanently installed products from at least five different manufacturers that use any of the mentioned programs at same credit on LEED reference guide to demonstrate the chemical inventory of the product to at least 0.1% (1000 ppm).

Option 2. Material Ingredient Optimization: Use products that document their material ingredient optimization using the paths below for at least 25%, by cost, of the total value of permanently installed products in the project.

GreenScreen v1.2 Benchmark, Cradle to Cradle certified or Cradle to Cradle Certified.

Reference:

CR 39: Earth Work Balance Greenroads

Intent: Reduce need for transport of earthen materials by balancing cut and fill quantities.

Requirements: Minimize earthwork cut (excavation) and fill (embankment) volumes such that the percent difference between cut and fill is less than or equal to 10% of the average total volume of material moved. For purposes of this credit, use the method and definitions detailed in Chapter 8 at Greenroads reference guide (Earthwork) of the Road Design Manual from the South Dakota Department of Transportation (SDDOT), or equivalent, to compute cut and fill volumes.

Include miscellaneous additional cut and fill such as outlet ditches and muck excavations (see definitions in Chapter 8 of the Manual) and account for moisture and density as well as shrink and swell. Balance cut and fill material volumes:

\[
\frac{(A + C) - (B + D)}{\frac{1}{2}(A + C + B + D)} \times 100\% \leq 10\%
\]

References:
CR 40: Recycled Materials

**Pre consumer material** is material from industry scraps that was diverted from the waste stream and used for other purposes. Examples include sawdust, wood shavings, wood chips, and print overruns. Excluded are materials that are reincorporated into the same manufacturing process that generated it. An example of what would not qualify is scraps of metal saved from a cutting process that are melted down and returned to the same manufacturing process. When the material is incorporated into a new product it is called pre consumer content. The percentage of recycled material in the new product. **An example** is a newspaper made with 25% pre consumer content.

**Post-consumer material** is a waste type produced by the end consumer of a material stream; that is, where the waste producing use did not involve the production of another product. Examples include construction and demolition debris, yard waste, and materials from curbside recycling programs (aluminum cans, newspapers, plastic bottles, milk jugs) The percentage indicates the percentage of postconsumer material included in the product. For example a plastic bottle with 50% postconsumer content.

**Durable Goods**: Durable goods are not specifically defined or addressed by LEED, but ultimately using more durable materials will reduce future demand. If a particular carpet lasts longer it means the building owner will not have to tear the carpet out and replace it frequently.

**Intent**: Reduce lifecycle impacts from extraction and production of virgin materials.

**Requirements**: Use recycled materials as a substitute for virgin materials. The fraction of recycled materials used can be calculated using one of four options below:
1. Consider only the pavement binder materials.
2. Consider only the hot mix asphalt (HMA) or Portland cement concrete (PCC) pavement materials.
3. Consider all pavement materials including granular base layers.
4. Consider all project materials.

Use Equation to compute the average recycled content (ARC) that will be achieved by the pavement section or by the binders:

\[
ARC (\%) = \frac{\sum r_n}{\sum W_n} \times 100\%
\]

- \(r_n\) is the total weight of recycled materials for that individual material or assembly
- \(W_n\) is the total weight of each individual material or assembly
- \(n\) represents the number of materials used in the pavement section

**References**:

CR 41: Regional Materials

**Intent**: To increase demands for materials and products that are extracted and
manufactured within the region, thereby supporting the use if indigenous resources and reducing the environmental impacts resulting from the transportation

Requirements: Make an itemized list of all materials, parts, components and products intended for permanent installation on the project including weights, total costs, shipping costs, and location of purchase and/or source of these materials.

Option 1. Choose local materials and product suppliers.
Compute the total cost of all materials, parts, components and products used for project construction including all shipping and transport costs based on the project bid list. Compute the percentage of this total cost that has been paid to materials suppliers, processors, distributors and producers within a 50 mile radius of the geographic center of the project. Points are awarded according to percentage, minimum percentage is 75%.

Option 2. Minimize travel distance for project construction materials.
Disaggregate each material, part, component or product into its “basic materials” by weight and express as a percentage of the sum of these weights. Compute the cumulative front haul distance traveled for each basic material from point of origin to the final endpoint on the project. Note this distance includes all intermediary points, such as assembly or distribution, between the original source and the final placement on the project. Report the total distance in terms of total freight miles (road, air, rail or barge) traveled for each basic material. Show that at least 95% of these basic materials by weight have traveled less than the 500 miles.

References:

CR 42: Reduction in Quantity of Materials Researcher

Intent: The objective is to reduce the amount of material, used in the construction of bridges by using innovative civil engineering techniques.

Requirements: This credit can be achieved by either employing structural techniques such as supplementing the cement, recycling good quality steel members, or high strength materials. It may also incorporate materials that can be replaced by recycled content. Calculations can be done by weight or volume but must be consistent throughout.

Reduction in material (25%) = (Total reduction in quantity of material)/(Total quantity of all material used without employing strategies) X 100

References:

CR 43: Material Reuse (Salvaged Materials) Researcher

Reused materials do not become waste, so they don’t end up in landfills. Reusing materials can also be considered a way of reducing waste; however, reused materials have their own strategies Potential ideas for using salvaged materials include: Salvaged brick used for walkways, Salvaged wood for flooring, cabinets, desks, design features, Salvaged tiles, etc.
**Intent:** The objective is to reuse the demolished bridge materials in road construction to reduce demand for virgin materials and reduce waste; thereby lessening impacts associated with the extraction and processing of virgin resources.

**Requirement:** Integrate salvaged or demolished material in the construction of roadways. Layout comprehensive plans and strategies to make use of demolished material in base, sub base, sub grade, embankment fills, and foundation stabilization. The reused materials should be from 5% to 10% from total materials by cost and should follow AAHSTO 2009 standard.

**References:**

**CR 44: Corrosion Resistant Steel Reinforcement** Researcher

**Intent:** To prevent bridge reinforcement from corrosion by penetration of chloride, thus preventing the bridge from early deterioration and extending the service life of the bridge.

**Requirements:**
- a) Consider using corrosion resistant reinforcing steel such as epoxy coated reinforcement, stainless steel reinforcement, and stainless steel clad reinforcement.
- b) The stainless steel industry share of CO2 emissions could be around 12% of global emissions. Stainless steel contributes greatly towards sustainability and it leaves a reduced carbon footprint.

**Scoring Criteria:**
- Minimum Points will be awarded if epoxy coated reinforcement is used on the project and maximum points will be awarded for both stainless steel reinforcement and epoxy coated reinforcement.

**References:**

**CR 45: Cement Replacement (Supplement Cementations Material)** Researcher

**Intent:** Reduce the CO2 emission created by cement production.

**Requirements:** Replace a minimum of 20% by weight of Portland cement to be used with byproduct cementations material such as fly ash, silica fume or Ground granulated blast furnace Slag (GGBFS).

**Reference:**

**3:2: Paving Credits.**

**CR 46: Paving Emission Reduction** Greenroads

**Intent:** Improve human health by reducing worker exposure to asphalt fumes.
Appendices: Score card prerequisites and credits explanations

**Requirement:** Place at least 90% of the hot mix asphalt (HMA) on the project using a paver that is certified to have met National Institute for Occupational Safety and Health (NIOSH) emission guidelines as set forth in Engineering Control Guidelines for Hot Mix Asphalt Pavers, Part 1: New Highway Class Pavers (Department of Health and Human Services (NIOSH) Publication No. 97 105, April 1997 printing). Using this equation:

\[
\frac{\text{Total HMA Pavement Placed by NIOSH Pavers}}{\text{Total HMA Pavement on Project}} \times 100\% \geq 90\% \\
\]

**References:**

**CR 47: Pavement Reuse** Greenroads

**Intent:** Reuse existing pavement and structural materials.

**Requirements:** Reuse at a minimum 50% of existing pavement materials or structural Elements for minimum points and for maximum points reuse 90% of existing pavement materials. The materials considered in volume calculations can include but are not limited to hot mix asphalt (HMA), Portland cement concrete (PCC), unbound granular base material, stabilized base material, reinforced concrete, structural steel, and timber. In general, pavement materials will be easier to calculate by volume while structural materials should be calculated in terms of weight, unless material volumes are adjusted for density.

This credit IS appropriate for:
- Pavement rehabilitation actions that place new material over the existing pavement structure such as hot mix asphalt (HMA) overlays, PCC overlays (either bonded or unbounded) and pavement surface treatments.
- In place reprocessing operations (even though some are referred to as “recycling”) such as hot in place recycling, cold in place recycling, full depth reclamation, Portland cement concrete (PCC) crack and seat.
- Repurposing of existing material for other purposes in the same project. The material must not leave the project boundary to be considered. If it does leave the project boundary it may still be considered in the recycled Materials credit.

**References:**

**CR 48: Long-Life pavement** Greenroads

**Intent:** Minimize life cycle costs by promoting design of long lasting pavement structures.

**Requirement:** Design at least 75% of the total new or reconstructed pavement surface area for regularly trafficked lanes of pavement to meet long life pavement design criteria.

**References:**
CR 49: Permeable Pavement  Greenroads

**Intent:** Improve flow control and quality of storm water runoff through use of permeable pavement technologies.

**Requirements:** Use a permeable (porous) pavement or pavers to control and treat at least 50% of the 90th percentile average annual rainfall event post construction runoff volume to 25 mg/L concentration of total suspended solids (TSS) or less.

**Note:** Low impact development (LID) storm water controls must be considered in the scope and budget of the project for this credit to be applicable AND permeable pavement must be considered a feasible design best management practice within the storm water management plan. This means that the feasibility study completed for PR Low Impact Development must clearly show that permeable pavement (of any type) is appropriate for application on the project. Figure (A-10)

![Permeable Pavement](image)

**Figure A-10: Permeable Pavement**

**References:**

CR 50: Warm Mix Asphalt  Greenroads

**Intent:** Reduce fossil fuel use at the hot mix asphalt plant, decrease emissions at the plant, and decrease worker exposure to emissions during placement

**Requirements:** Reduce the mixing temperature of hot mix asphalt by a minimum of 50°F from that recommended as the mixing temperature by the asphalt binder supplier. Mixing temperature shall be measured as the temperature of the mixture as it exits the mixing drum. This reduced temperature mix must comprise a minimum of 50% of the total project pavement (hot mix asphalt or Portland cement concrete) by weight.

**References:**
2. More information on that I:90 in Vantage, WA project can be found here:http://www.wsdot.wa.gov/Projects/I90/WGeorgePaving/

CR 51: Cool Pavement  Greenroads

**Intent:** Reduce contribution to localized increased air temperatures due to pavement Reflectance and minimize storm water runoff temperatures in order to reduce heat island effect.

**Requirements:** Use a pavement surface with a minimum albedo of 0.3 (measured using ASTM E 903) for a minimum of 50% of the total project pavement surfacing by area.

**OR** Use a porous pavement or pavers for a minimum of 50% of the total project pavement surfacing by area. In either case, the surfaces intended for use by vehicles (e.g., roads, parking lots) must all be included in the calculation. Other surfaces (e.g.,

XL
sidewalks) may be included if desired. A combination of materials may be used to meet the 50% area requirement.

**Reference:**

**CR 52: Quiet Pavement** Greenroads

**Intent:** Improve human health by reducing tire pavement noise. Figure (A-12)

**Requirements:** Design at least 75% of the total new or reconstructed pavement surface area for regularly trafficked lanes of pavement where the speed limit meets or exceeds 30 miles per hour (mph) with a surface course that produces tire pavement noise levels or listed on original credit at greenroads reference guide which describes test vehicle speed parameters and the points corresponding to the level of noise reduction achieved.

Tire pavement noise can either be measured from the side of the road as a vehicle passes by or from a point or by an appliance attached to car tires. OBSI measurement device

**Figure A-11: Pavement Surface Noise Measurement**

**References:**
2. The AASHTO Center for Environmental Excellence has many guidelines and resources for addressing NEPA compliance, including a guidebook for SAFETEA LU Environmental Review Processes. http://environment.transportation.org/center/products programs/practitioners handbooks.aspx

**CR 53: Pavement Performance Tracking** Greenroads

**Intent:** Allow for more thorough performance tracking by integrating construction quality and pavement performance data.

**Requirements:** Use a process that allows construction quality measurements and long term pavement performance measurements to be spatially located and correlated to one another. This implies four requirements:
1. Construction quality measurements must be spatially located such that the location of the quality measurement is known to within 25 ft of the actual location where the material or process that was measured is actually located.
2. Pavement condition measurements must be taken at least every 2 years and must be spatially located to a specific portion of roadway or location within the roadway.
3. An operational system, computer based or otherwise that is capable of storing construction quality measurements, pavement condition measurements and their spatial locations.
4. The designated system must be demonstrated in operation, be capable of updates and have written plans for its maintenance in perpetuity.

**References:**
Category 4: Energy and Atmosphere (EA)

CR 54: Enhanced Commissioning LEED

Intent: To further support the design, construction, and eventual operation of a project that meets the owner’s project requirements for energy, water and durability.

Requirements: Implement, or have in place a contract to implement, the following commissioning process activities in addition to those required under Prerequisite Fundamental Commissioning and Verification.

Commissioning Authority: The CxA must have documented commissioning process experience on at least two bridge projects with a similar scope of work. The experience must extend from early design phase through at least 10 months of occupancy; The CxA may be a qualified employee of the owner, an independent consultant, or a disinterested subcontractor of the design team.

Enhanced and Monitoring Based Commissioning: Develop monitoring based procedures and identify points to be measured and evaluated to assess performance of energy and water consuming systems. Include the procedures and measurement points in the commissioning plan.

References

CR 55: Optimize Energy Performance LEED

Intent: To achieve increasing levels of energy performance beyond the prerequisite standard to reduce environmental and economic harms associated with excessive energy use.

Requirements: Establish an energy performance target no later than the schematic design phase. The target must be established as kBtu per square foot/year (kW per square meter year) of source energy use.

Whole: Bridge Energy Simulation Analyze efficiency measures during the design process and account for the results in design decision making. Use energy simulation of efficiency opportunities, past energy simulation analyses for similar bridges, or published data (e.g., Advanced Energy Design Guides) from analyses for similar bridges. Points are given according to percentage of improvement in energy as shown at original credit on LEED reference guide.

References
4. ASHRAE 50% Advanced Energy Design Guides: ashrae.org

CR 56: Advanced Energy Metering LEED

Intent: To support energy management and identify opportunities for additional energy savings by tracking bridge level and system level energy use.

Requirements: Install advanced energy metering for the following:

- All whole: bridge energy sources used by the bridge; and any individual energy end uses that represent 10% or more of the total annual consumption of the bridge.
- The advanced energy metering must have the following characteristics.
- Meters must be permanently installed, record at intervals of one hour or less, and transmit data to a remote location.

References
• Electricity meters must record both consumption and demand. Whole: bridge
  electricity meters should record the power factor, if appropriate.
• The data collection system must use a local area network, bridge automation system,
  wireless network, or comparable communication infrastructure.
• The system must be capable of storing all meter data for at least 36 months.
• The data must be remotely accessible.

References
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013-
p413:420

CR 57: Renewable Energy Production LEED

Intent: To reduce the environmental and economic harms associated with fossil fuel
energy by increasing self-supply of renewable energy.

Requirements: Use renewable energy systems to offset building energy costs. Calculate the percentage of renewable energy with the following equation:

\[
\text{% renewable energy} = \frac{\text{Equivalent cost of usable energy produced by the renewable energy system}}{\text{Total building annual energy cost}}
\]

The use of solar gardens or community renewable energy systems is allowed if both of the following requirements are met.
• The project owns the system or has signed a lease agreement for a period of at least 10
  years.
• The system is located with the same utility service area as the facility claiming the use.
• Credit is based on the percentage of ownership or percentage of use assigned in the
  lease agreement. Points are awarded according percentage of renewable energy (1%,
  5% and 10%)

Eligible Renewable Energy Systems Allowable sources for renewable energy include the following:
  • Photovoltaic
  • Solar thermal
  • Wind
  • Befoul (in some cases)
  • Low:impact hydroelectricity
  • Wave and tidal energy
  • Geothermal energy (in some cases)

References
2. -----: “LEED Reference Guide for building Design and construction V4”- Accredited Professional (AP) - USGBC-USA- 2013-
p429:440.
3. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 159.
  School of Planning, Design and Construction- Michigan State University- 2012-p 61
6. Commercial Building Energy Consumption Survey (CBECS): eia.gov/consumption/commercial
  forms.pdf

CR 58: Green Power and Carbon Offset LEED

Intent: To encourage the reduction of greenhouse gas emissions through
The use of grid source, renewable energy technologies and carbon mitigation projects.

Requirements: for a minimum of five years, to be delivered at least annually. The
contract must specify the provision of at least 50%( minimum points) or
100%(maximum points) of the project’s energy from green power, carbon offsets, or
renewable energy certificates (RECs).
Green power and RECs must be Green-e Energy certified or the equivalent. For U.S. projects, the offsets must be from greenhouse gas emissions reduction projects within the U.S. Determine the percentage of green power or offsets based on the quantity of energy consumed, not the cost.

References
1. -----: “LEED version 4 for building design and construction”- Reference guide- USGBC- USA- 2015- p82.
8. epa.gov/cleanenergy/energy-resources/egrid/index.html

CR 59: Environmental Management System Greenroads

Intent: Improve environmental stewardship by using a contractor that has a formal environmental management process.

Requirements: The prime contractor, design builder or construction management firm shall have a documented environmental management system (EMS) for the entire company or at least the portion(s) of the company participating in the project. The EMS must be in place for the duration of project construction. As a minimum, the EMS and its documentation shall meet the requirements of International Standards Organization (ISO) 14001:2004.

Reference:

CR 60: Energy Efficiency Greenroads

Intent: Reduce lifetime energy consumption of lighting systems for roadways.

Requirements: Install lighting systems with luminaries that meet or exceed the 2009 Energy Star standard for roadway lighting and are compliant with all safety requirements applicable to the roadway project. Points are awarded based on the fraction of total luminaries installed on the project with energy efficient fixtures that are 2009 Energy Star compliant in the following manner: 20% minimum points and 100% maximum points. Figure (A-12)

Figure A-12: Renewable energy luminaries at ring road/Cairo-Alexandria desert road

Reference:
Category 5: Water Efficiency (WE)

CR 61: Runoff Flow Control  Greenroads

Intent: Mimic predevelopment hydrological conditions in the right of way (ROW) and minimize offsite storm water controls.

Requirements: 1. Develop a storm water management plan for the site using storm water best management practices (BMPs) for flow control. Explicitly state the goals of this plan and how performance will be measured.
2. Use low impact development (LID) BMPs to the maximum extent feasible as determined in Project Requirement PR 8 by a licensed professional.
3. Compute the 90th percentile average annual rainfall event values for the following Predevelopment and post construction conditions
4. Provide BMPs for storm water flow control. List the types, manufacturers, total volumes and flow rates controlled by BMPs within the ROW or outside of the ROW.

Points are awarded based on type of alignment, location of BMPs and level of control achieved. For more calculations refer to original credit at Greenroads reference guide p135:152. Figure (A-13)

Reference:
4:www.masralarabia.com/ /g989/g910/g1012/g951/g1006/g947
5:https://i.ytimg.com/vi/ujI5BPesoSk/hqdefault.jpg

CR 62: Runoff Quality  Greenroads: LEED

Intent: Improve water quality of storm water runoff leaving the roadway Right of Way (ROW)

Requirements: To achieve this credit, previous credit must be achieved then Provide treatment for a desired percentage of the total computed runoff volume, points could be earned according to treated volume of storm water to all volume of storm water(minimum 80%: maximum 90%) Figure (A-14)

Reference:

CR 63: Storm water Cost Analysis  Researcher, Greenroads

Intent: Determine lifecycle costs and savings associated with low impact development techniques and best management practices for stormwater utilities.


Use a financial approach (strictly monetary costs and benefits) for the LCCA. Evaluate design alternatives based on the goals of the storm water management plan.
Set up a spreadsheet to compute costs based on budget inputs.

XLV
Use estimated costs for LID Bmp Consider avoided costs of storm water treatment at off site locations, or avoided permitting costs.

Include several different methods and alternatives in the evaluation of the storm water System when performing the LCCA. Investigate both structural and non-structural Controls, including conventional controls such as detention or infiltration

Reference:
3: BMPs available from the BMP Database (BMPDB) available at: http://www.bmpdatabase.org

Washington. permeable pavement bikelanes -permeable sidewalk- A bioswale with flow control weirs.USA

Examples of bad storm water control Alexandria: October 2015
Permeable asphalt to absorb 4000 liters of rain water

The High Point subdivision in the West Seattle neighborhood of Seattle, Washington: The grassy area (left) is actually turf placed over a large infiltration basin. A bioswale (center) is featured, and still in early growth. Alsoand the street (right) are paved with permeable concrete.

Figure A-13: Runoff Flow Control
**CR 64: Site Vegetation (Water Use Reduction)**  

Greenroads, *LEED*  

**Intent:** Promote sustainable site vegetation that does not require irrigation. To reduce outdoor water consumption.  

**Requirements:** Site vegetation shall be subject to the following requirements in order to receive the points listed:  

1. **1 point:** Use noninvasive plant species only.  
2. **1 point:** Do not use water (no irrigation) after the plant establishment period.  
3. **1 point:** Use native plant species only.  

"Site vegetation" is defined as all vegetation associated with a particular roadway project and shall include all vegetation within the roadway’s right of way. This can include roadside vegetation, decorative planting (e.g., planter boxes or potted plants in urban areas) and vegetation contained in storm water facilities (e.g., bio swales and rain gardens).  

The following items must be performed to ensure that a plant species is considered “noninvasive”:  

1. Consult existing local (e.g. city, county, state, park service) vegetation policy and procedure that is applicable to the roadway project and is specifically formulated to prevent the use of invasive plant species and noxious weeds.  
2. Use local and/or regional lists to identify invasive plant species.  
3. Comply with local and/or national noxious weed laws.  

“No water use" means that the site vegetation will not require any irrigation after the plant establishment period. The “plant establishment period" shall be stated in the project specifications. Typical plant establishment periods are 1-3 years. This requirement means that vegetation requiring irrigation such as seasonal planter boxes cannot receive the associated point even if it is fully comprised of noninvasive or native species. “Native plant species “are plants native to the EPA Level III ecoregion that contains the roadway project site or known to naturally occur within 200 miles of the roadway construction site. Figure (A-15)  

**Reference:**  

2. ------: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- p 114:120.  
CR 65: Ecological Connectivity  Greenroads

**Intent:** Provide or improve wildlife access and mobility across roadway facility boundaries and reduce vehicle wildlife collisions and related accidents.

**Requirements:** Complete a site specific wildlife assessment for the roadway project. Report the resulting impacts that the roadway has on surrounding major ecosystems, identifying all non-human life that is impacted by the roadway facility according to the best scientific knowledge available for the ecosystem. Both point scenarios below require approval of the project ecologist.

And complete one of the two of the following options:

**Option A Existing Alignments only**
Replace in kind, retrofit, or upgrade any and all existing culverts and wildlife fencing structures deemed structurally deficient, damaged, obsolete, insufficiently sized, or otherwise inadequate.

**Or option B New and Existing Alignments**
Install new dedicated wildlife crossing structures and protective fencing (if needed) as recommended by the wildlife assessment. In addition, existing alignments must also replace in kind, retrofit, or upgrade all existing culverts and fencing structures deemed structurally deficient, damaged, obsolete, insufficiently sized, or otherwise inadequate.

**Reference:**

CR 66: Water Use Tracking (Water Metering)  Greenroads: LEED

**Intent:** Generate project level information about construction water use. And To support water management and identify opportunities for additional water savings by tracking water consumption.

**Requirements:** Install permanent water meters for bridge water consumption (irrigation, cleaning, operation, maintenance, etc...)

XLVII
Category 6: Bridge Maintenance (BM)

A majority of the bridges built around the 1960’s and 1970’s need significant repair and maintenance actions. Lead and chromate based paints and coatings removal may have significant impacts on the environment, workers, and public. This section outlines the requirements of inspection technologies, bridge painting, cleaning, deck drainage, in order to reduce associated environmental impacts.

CR 67: Efficient Inspection Technologies

Researcher

Intent: To use efficient inspection technologies and processes for proper maintenance action decisions, thus enhancing the service life and reducing associated environmental impacts.

Requirements:  

a) Follow Recommended Framework for a Bridge Inspection QA/QC Program of National Bridge Inspection Standards, FHWA. The framework describes the quality control and quality assurance procedures for accuracy and consistency in the bridge inspections. The framework outlines documentation of QA/QC program, Quality Assurance (QA) procedures, and Quality control (QC) procedures.  

b) Use of specialized bridge equipment such as under bridge inspection vehicles, mobile inspection platforms, nondestructive evaluation equipment, and data collection and analysis equipment for efficient data collection and to allow workers to maneuver safely into position, allowing for hands on inspection and maintenance work. The office of bridge technology, FHWA, outlines a policy regarding the use of federal aid funds, specifically highway bridge replacement and rehabilitation programs (HBRRP) funds for the purchase or rent of specialized inspection equipment. Federal HBRRP funds may also be used for the installation of permanent features that facilitate inspection activities on highway bridges as defined in 23 CFR 650.305. Such features as handrails, anchor points for a horizontal lifeline, and catwalks would be a few examples. In addition to HBRRP funds, National Highway System, Surface Transportation Program, and State Planning and Research funds may be used for the development, establishment, and implementation of bridge management systems and associated data collection activities or Any other local equivalent standard could be used.

References:  

5:MDOT Bridge Inspection Manuals: http://www.michigan.gov/mdot/0,1607,7-151:9625 24768 24773::,00.html  
6:http://www.hbrc.edu.eg/: /g997/g910/g988/g947/g1019/g909 /g1005 /g751/g910/g1000/g914/g991/g909 /g938/g1004/g972/g996/g991/g909 /g938/g1004/g972/g996/g991/g909

CR 68: Bridge Painting and Coating

Researcher

Intent: To prevent bridge components from deterioration due to corrosion thus increasing the life expectancy of bridges and also protect workers and the environment from paint related byproducts. Paint should be used to slow corrosion cause by moisture, air, and oxidizing chemicals.

Requirements:  

a) Utilize best practices to protect workers and the environment during lead paint removal and remove lead from existing structures; replace with zinc:rich type
4 systems
b) Consider applying coating to the structural steel or reinforcement i.e., consider following these standards.

Reference:
3. http://www.hbrc.edu.eg/: /g938/g1004/g972/g996/g991/g909/g1010/g996/g1321/g984/g991/g909/g922/g1321/g932/g914/g991/g997/g910/g988/g947/g1019/g909/g1005/g751/g910/g1000/g914/g991/g909/g1005

Standards/Resources:
4. Clean Air Act Amendments
5. Society for Protective Coatings (SACE)
6. National Association of Corrosion Engineers (NACE)
7. GS11 Green Seal Environmental Standard for Paints and Coatings or Any other local equivalent standard.

CR 69: Corrosion Resistant Steel Reinforcement (Credit): Research

Intent: To prevent bridge reinforcement from corrosion by penetration of chloride, thus preventing the bridge from early deterioration and extending the service life of the bridge.

Requirements: a) Consider using corrosion resistant reinforcing steel such as epoxy coated reinforcement, stainless steel reinforcement, and stainless steel clad reinforcement.

b) The stainless steel industry share of CO2 emissions could be around 12% of global emissions. Stainless steel contributes greatly towards sustainability and it leaves a reduced carbon footprint

References:

Standards/Resources:
1. Performance of epoxy coated rebar in bridge decks volume 60: No. 2, FHWA
2. Stainless steel reinforcement, MDOT bridge design manual section 7.04
3. Epoxy coated rebar bridge decks; expected service life, MDOT bridge design manual section
5. ASTM A1035 (low carbon, chromium) – MMFX2
7. Stainless steel clad bars conforming to AASHTO MP13M Any other local equivalent standard.

CR 70: Corrosion Control Materials Researcher

This criterion will address corrosion control materials that can be used during rehabilitation and maintenance of bridges.

Intent: To prevent or minimize the corrosion of bridge elements due to the penetration of chloride based deicers. This minimizes early deterioration of the structure. Each recommended method would either result in an increased amount of time between maintenance cycles or extend the bridge’s service life.

Requirements: a) Consider using galvanic anodes in all concrete patches that extend below the top layer of reinforcement. Only galvanic anodes listed on MDOT’s QPL can be used.

b) Consider using Carbon Fiber Reinforced Polymer (CFRP) wrap. This increases the strength, is lightweight and provides additional corrosion resistance.

References:

Standards/Resources:
CR 71: Bridge Cleaning  Researcher

**Intent:** To clean components of bridges vulnerable to dirt, bird drop, accumulation, etc. thus increasing the longevity of the bridge components and lessening future maintenance requirements.

**Requirements:** Bridge components subjected to dirt, bird drop accumulation, etc., should be cleaned periodically by using hand tools, air blasting, or preferably water jetting.

**References:**

**Standards/Resources:**
2. Part 7.1.3, Bridge Cleaning, Chapter 7, Bridge Maintenance, Center for Environmental Excellence by AASHTO American Association of State and Transportation Officials.

CR 72: Bridge Deck Drainage  Researcher

**Intent:** To avoid impacts on the deck structure and reinforcing bars due to inefficient drainage.

**Requirements:**

a) Gutter flow from roadways should be intercepted before it reaches a bridge;
b) Avoid zero gradients and sag vertical curves on bridges;
c) Larger grates and inlet structures can be used onto the subsequent roadway sections to collect runoff from bridge decks immediately (AASHTO, 2009).

**References:**

CR 73: Bridge Deck Joints and Deck Joint Seals  Researcher

**Intent:** To minimize or eliminate poorly maintained bridge deck joints and seals thus maintaining the service life of the bridge

**Requirements:** Consider:

a) Eliminating bridge deck joints (when possible) or moving joints off bridge with the use of sleeper slabs.
b) If possible, discontinue the use of compression seals in new construction, replacement, and rehabilitation. Replace existing compression seals and block out style joints in those locations where expansion or rotation is needed with strip seal style expansion devices.
c) Establish a routine maintenance procedure to maintain joints.

**References:**

**Category 7: Innovation and Custom Credits**

**ICC1: LEED AP**  LEED

**Intent:** To encourage the team integration required by a LEED project and to streamline
the application and certification process.

**Requirements:** At least one principal participant of the project team must be a LEED accredited professional (AP) and appropriate qualifications for the project.

**Reference:**

**ICC2: Innovation (Custom Credits) Greenroads: LEED**

**Intent:** To encourage projects to achieve exceptional or innovative performance.

**Requirements:** Project teams can use any combination of innovation, pilot, and exemplary performance strategies.

**Option 1. Innovation (1 point)**
Achieve significant, measurable environmental performance according to a strategy that is subject to the developed rating system. Identify the following.

- The intent of the proposed innovation credit.
- The proposed compliance requirements.
- The proposed submittals to demonstrate compliance.
- The design approach or strategies used to meet the requirements.

**Option 2. Pilot (1 point)**
Achieve one pilot credit from USGBC’s LEED Pilot Credit Library.

**Reference:**

**ICC3: Environmental Training Greenroads**

**Intent:** Provide construction personnel with the required information to identify the environmental issues and the best practice methods to minimize environmental impacts.

**Requirements:** Provide an environmental training plan that is customized to the project, including:
1. List of the types of project personnel to be trained. This may be a list by job type or by employer without containing actual employee names.
2. Description of types, goals and objectives of training to be given.
3. A process to track training efforts, including dates, means (e.g., online, classroom, field training), topics, the identification of those participating in training, and attendance numbers.
4. A process to measure training effectiveness such as self-assessment, pretest and Posttest, and productivity measurement.

**References:**

**ICC4: Building under the Bridge:** Researcher

**Intent:** Design a sustainable certified building under the bridge.

**Requirements:** In case of constructing a building under the bridge, this building should follow all prerequisites of LEED BD+C rating system and achieve minimum credits that make it LEED certified building.

**ICC5: Bridge Rentable Spaces:** Researcher

**Intent:** Maximize usage of spaces under and around the bridge and provide extra
funding resources.

**Requirements**: Create more rentable spaces under and around the bridge and use the renting money in bridge development and maintenance. These areas may be rented as car parking, shops, bus stops, open markets, etc..

**ICC6: Governmental Monitoring Rules of the Bridge's surface**: 
Researcher

**Intent**: Bridge architecture and sustainability success observation.

**Requirements**: Conduct a monthly inspection to monitor break of any governmental rules in connection to the bridge as (Street vendors, bridge different usages as pedestrians on vehicle bridges, etc...).

**ICC7: Governmental Rules Monitoring of the Bridge's surrounding areas**: 
Researcher

**Intent**: Bridge surroundings architecture and sustainability success observation.

**Requirements**: Conduct a monthly inspection to monitor break of any governmental rules related to the bridge's surrounding areas as (illegal buildings around the bridge such as the Ring Road indiscriminate land use, illegal usage of area the under the bridge, etc...).

**ICC8: Regional Priority** LEED

These Regional priority credits encourage the project teams to focus on their local environmental priorities.

USGBC established a process that identifies six RP credits for every location and every rating system within chapter or country boundaries. Participants were asked to determine which environmental issues were most salient in their chapter area or country. The ultimate goal of RP credits is to enhance the ability of project teams to address critical environmental issues across the country and around the world.

**Intent**: To provide an incentive for the achievement of credits that address geographically specific environmental, social equity, and public health priorities.

**Requirements**: Earn up to four of the six Regional Priority credits. These credits have been identified by the USGBC regional.

Reference:
3. -----: “LEED Principles and Green Associate Study Guide”- Green Building Education Services- USGBC -USA- 2014- 220.

**ICC9: Architectural Creativity** Researcher

**Intent**: To encourage designing a creative and unique bridge which is considered as a landmark.

**Requirements**: Developing any creative architectural technologies, solutions which are not mentioned at any credit or designing a landmark bridge which represents its neighborhood, city or country.

**ICC10: Structural Innovative Solutions**: Researcher

**Intent**: To encourage structural creativity.

**Requirements**: Innovate any new structure technique, solution, system, the construction material, construction method, etc... Or modify an existing one to achieve same safety requirements in shorter time with less cost.
مستخلص البحث

تؤثر الكباري على التشكيل العام للمدينة كما أنها تؤثر اجتماعياً وثقافياً في المجتمع. أيضاً بالإضافة إلى الوظائف الأساسية للكباري، فإن لها وظائف أخرى مكشفة والتي تعرف عن تطور المجتمع أو تخلفه. أيضاً الكثير من الكباري تعتبر من العلامات البصرية التي تميز المدن وتثير حب الحضارات.

يمكن تلخيص المشكلة البحثية كالآتي: إن معظم الكباري المصرية تواجه مشاكل جمالية ووظيفية وقصور في الإستدامة (البيئية والاقتصادية والاجتماعية). أيضاً لوحظ استيعاب المعماري من عملية تصميم وإنشاء وتشغيل الكباري المصرية وتقوم مهارات تصميم وإنشاء وتشغيل الكباري بالكامل إلى المهندس الإنشائي الذي يتم فقط بسلامة الكوبيري وتكفله دون النظر إلى نجاح الكوبيري في أداء وظائفه الأساسية والمكتسبة وأيضاً بعض النظر عن جماليات الكوبيري أو استدامة البيئية والاقتصادية والاجتماعية.

إن الهدف الأساسي من الدراسة البحثية هو استخراج نظام مسودة للمعادي الكباري في مصر. حيث يستخدم هذا النظام المستخرج كدليل إرشادي لفريق عمل الكباري لاختيارة هذه المشاريع وتجنب حدوثها في الكوبيري المستقبلية في كل من تصميم وتنفيذ وتشغيل الكباري. وذلك لأن إنشاء الكباري يستهلك أكبر قدر من جهود الموقع واستخدام المواد ويؤثر بشكل كبير على تشكيل المدينة.

لذا سيقوم هذا النظام بتقييم عمارة الكباري (تقييم الكباري ووظيفياً وجميلياً) وأيضاً تقييم الاستدامة البيئية والاقتصادية والاجتماعية للكباري.
المتاح الرسمي للبحث

تعتبر الكبائر واحدة من أهم المنتجات التي تؤثر على شكل الشارع المصري. معظم الكبائر المصرية تواجه مشاكل اجتماعية واقتصادية واقتصادية، وتمتد في القدم في الاستخدام الاجتماعي. يجب من خلال ذلك أن تجنبcomposition النموذج الكبائر، الذي تكون فيه عملية التصميم. للوصول إلى هذا الهدف سيتم تطوير نظام مستدام للتقييم.

الجزء الأول: الدراسة النظرية

الفصل الأول: التطور التاريخي الكبائي عالمياً وفنياً وإنشاً

تناولت الدراسة في هذا البحث التطورات الأساسية لكبائي. وتاريخ الكبائي عالمياً وتاريخ الكبائي في مصر وعمل مقارنة بين تطور الكبائي في مصر وتطورها في العالم.

وقد تم تحديد علاقة الكبائي بالإنتاج والمدارس المعمارية عبر التاريخ وعمرها. مثبط الترابط بين التطور المعماري للكبائي وبين الإنتاج المعماري العالمي وذلك من خلال اتخاذ نماذج من الكبائي المميز في كل فترة.

وفي نهاية الفصل، استخلاص مجموعة من الإشراطات والنقاط التي ستتم تجميعها في نظام التقييم والمتعلقة.

الفصل الثاني: الكبائي المستدام

تهدف الدراسة في هذا الفصل إلى تطبيق التطور في مفاهيم الاستدامة من المفاهيم العامة للاستدامة إلى استدامة الكبائي. وذلك من خلال التحول بكل من التغيرات المستدامة ومبادئ الاستدامة والعناصر المستدامة والمعايير المستدامة.

وستتحقق إستدامة الكبائي، تحدياً كلاً من الترابين بين الإنشاء والإستاندة والمدينة المعدنية.

وفي نهاية الفصل، استخلاص بعض النتائج: ما هو الهدف من القيام بتعميم تصميم الكبائي؟ وماهي المنهجية المتبعة لتحديد مبادئ الاستدامة في الكبائي؟

الجزء الثاني: الدراسة التحليلية

نظام تقييم الكبائي مستدام

يتكون هذا الجزء من فحص: الكبائي الأول يتكون من ستة أنواع وأدوات عملية تصميم وإنشاء الكبائي، أما الشق الثاني فيتكون من فحص ونتائج عملية تصميم وإنشاء الكبائي وبحث عنها.

أولاً: العوامل المؤثرة في خلاصة الكبائي خلال مرحلة التصميم والتنفيذ.

الفصل الثالث: أنواع الكبائي المختلفة وعمارة الكبائي

يدخل المصمم عند استدامة في بداية عملية تصميم الكبائي منها: ما هو الهدف من إنشاء الكبائي؟ ما هي وظيفة الكبائي الأساسية؟ هل الكبائي يستخدم للاستدامة أم السيناريو أم العقارات؟.

ساتيم التناول في هذا الفصل مفصلة للوظائف المختلفة الكبائي، وأيضًا أنواع الكبائي تبدأ لقابلية الحركة والكابين الذي يكون متصلًا بمكان متحرك، والمعروض للبعض من أنواع الكبائي.

وفي نهاية الفصل، استخلاص بعض النتائج خاصة بوضع ووظيفة الكبائي للتقدير من نجاحها والتي ستتم إضافتها لنظام التقييم.

الفصل الرابع: العلاقة بين الكبائي ومحددات الموقع

السؤال الثاني المطرح باستدامة المصمم خلال عملية تصميم الكبائي هو، إن سيكون موقع الكبائي؟

وقد تتأثر علاج الكبائي تأثيرًا كبيرًا، بوسيلة فتح أو تعديل الكبائي في التصميم. وتحت عن تصميم الكبائي على أحد الطرق السريعة التي يكون متصلًا تماماً عن تصميم الكبائي في أحد المناطق الفريدة.

إنه يمكن أن يكون وفقًا لتصنيف في هذا الفصل مساحة الكبائي للمعالي الكبائي محل التصميم. أيضاً العلاقة بين الكبائي الجديد وبين المحددات المبنية والشبكة المعمارية المحيته الكبائي معلقة التصميم أيضاً العلاقة بين الكبائي الجديد وبين
ktorbi أخير قائم أو أوثى أو مرتبط أو منشأ أثرية.

أيضاً نظير التأثير القوي على شكل الكباري والجسر النبيل في مصباح، إذاً سيمد فيدراسة الكباري الحية "الكبري

المملة على الأفاس" من خلال دراسة تأثير مصرية وفقاً للتاريخ بأخير شريف

أيضاً سيشمل الفصل دراسة التصميم الجمالي الكباري، كل تابع للموقع والانعكاص الممارسة الكباري وتقلاب الكباري

مع غيرة من الكباري ثم يتم استرجاع مجموعة من الإشاعات والانتقادات الخاصة بموقع الكباري وليستة العمرية

والتي سيتم إضافتها إلى نظام التقدم.

الفصل الخامس: إنبعاث الاعتقادات الإنشائية للكبري على الشكل والتكوين.

إن الاعتقادات الإنشائية الكباري من نظام إنشائي ومواد البنية يعد من الأمور ذات شكل الكباري وكوينين. إذاً

سيتم دراسة أثر الكباري في تنوع الإشاعات المختلفة للكباري ومواد البنية المختلفة المستخدمة في الكباري على شكل

النظام الكباري وكوينين. أضفي سماد دراسة أثر الكباري في الأمور المحورية وفقاً للتاريخ نحو المعلومة

لكباري وطرق الانتقاء المختلفة على إختيار التصميم الإنشائي ومواد الإنشاء من نظرة عمليات ومن ثم التأثير على

شكل الكباري وكوينين وعمارة.

في نهاية الفصل سيتم استنتاج مجموعة من الإشاعات والانتقادات التي تضمن إختيار أفضل نظم المواد الإنشائية

من وجهة نظر معمارية مستدامة.

الفصل السادس: علاقة الأجزاء المختلفة للكبري بالشكل والتكوين.

بعد تحديد النظام الإنشائي ومواد البنية المستخدمة تحول الكباري إلى مجموعة معمارية ذات شكل وكوينين، بحيث

تكتسب هذه المجموعة من الأجزاء والتفاصيل إضافة إنشائية وتغير إنشائي.

سيتم تأويل أثر إختيار هذه التفاصيل الإنشائية (جسم الكباري والأعمدة والكرات.) في الأجزاء الغير إنشائية

(الأوامر، وأطواق البذور والأعمدة.) على شكل النطاق الكباري.

في نهاية الفصل سيتم استخلاص مجموعة من الإشاعات والانتقادات التي تساعدهنا على إختيار أفضل أشكال أجزاء

وتواصل الكباري الإنشائية والغير إنشائية لضمان الحصول على أفضل تصميم معماري للكبري.

الفصل السابع: تأثير الاعتقادات الجمالية والإبداعية على التصميم المعماري للكبري.

تناولت الدراسة في هذا الفصل أصوات التصميم الجمالي والقيم الجمالية (مثل النسب والإيقاع والروابط.)

وأضف الإلهام الجمالي المرجعية إلى تصميم الكباري ونظرية الفصول والكورنس، (أخ.) أيضاً تم دراسة العمود المؤثر على تميز الكباري مثل الأوان ومواد النهش والزخارف، (أخ.) أيضاً استقبال

المشاكلة للكبري، والذي يختلف عن تصميم آخر وممن مشاهد آخر.

إن الإيقاع في تصميم الكباري من أهم العناصر المؤثرة على تطور الكباري والتي تم دراستها من خلال تعريف الابتكار

وفي نهاية الفصل سيتم استخلاص مجموعة من الإشاعات والانتقادات التي تضمن أفضل الاعتقادات الجمالية والإبداعية

للكباري والتي تضاف إلى نظام التقدم.

الفصل الثامن: العملية التصميمية للكبري المستخدمة فيها.

هناك أثبات تدريجي رائع على تأثير الكباري المستخدمة فيها في تصميم الكباري التقليدي والكبري المستخدمة في ضوء

كلا من فريق التصميم والعملية التصميمية، حيث استعرض التحتويات المختلفة في تصميم الكباري وموضوعات الأطراف

المشاركة في عملية تصميم الكباري وتفوقها من المثال إلى فريق التصاميم إلى فريق التحليل وعمارة كلا من

هؤلاء الأفراد بيضه إلى دراسته وتأثيره على الشكل النهائى للكبري.

من أهم أسباب تأثير الكباري المستخدمة في محاكاة النمط العام تصميم الكباري هو استبدال المهندس

العمليات تعليم الكباري وتفوق المهندس الإنشائي لقيام عملية التصميمية وتفوق الكباري بالكامل.

سبيت دراسة أثر الكباري والرسائل المعمارية في صناعة الكباري مصرياً وعالمياً، كما سبيت استعراض

مجموعة من الكباري التي صممت بواسطة أشهر المهندسين العالميين. أيضاً سبيت دراسة كفاءة عمل كابر في ناجح

معماريًا ومستدامًا بإجمالية من الناحية المعمارية وتقنية الكباري التقليدية.
في نهاية الفصل يتم استعراض مجموعة من الاشترارات والنقاط لتقييم العملية التصميمية وتمتوضح أهمية دور المعماري والتي تضمن نظام التقييم.

ثانيا: التعامل المؤثر على عمارة الكبائي خلال مرحلة التشغيل والاستخدام
الفصل التاسع: التأثير بين الكبائي ومحيي اقتصاد المباني في مرحلة التشغيل والاستخدام
ينتقل هذا الفصل لدراسة تأثير الكبائي بعد الإنتاج على المجتمع المحيط وعلى البيئة المعمارية حيث تأثير الكبائي على الظروف المحيطة واستخدامات الأراضي المحيطة وأيضًا الاشتراكات المختلفة للمنطقة تحت الكبائي كفرع عام. أيضاً تأثير الكبائي في توسيع الساحة المعمارية وتثبيتها أما بالأعمال أو بالأمل على الفضاء المعماري. ومن ثم إظهار الضوء على بعض استخدامات الفراشات المحيطية بالكبائي وفراغاته تحت الكبائي في مصر ليتضح هذه المشاكل في الكبائي المستقبلي.

سيتم إعداد مجموعة من الاشترارات والنقاط المستخدمة في توقع استخدامات المحيط العقاري للكبائي وتجنباً أو التعامل معها.

الجزء الثالث: الدراسة الاستقرائية
تطوير نظام مصري لتقييم إستدامة الكبائي

الهدف من هذا الجزء هو تطوير نظام تقييم استدامة الكبائي المصري، للوصول لهذا الهدف تم دراسة المحاولات السابقة لدراسة استدامة الكبائي وريادة تحسين أو تحسين استدامة الكبائي في العالم، وهو نظراً تقييم الاستدامة العالمية لأكثر نظام التقييم المستدام عالمياً تقييم الاستدامة العالمي (Greenroads).

وتضمُّ هذا الجزء المحارات: الفصل الحادي عشر، يدرس الفصل الحادي عشر، يدرس الفصل الحادي عشر، يدرس الفصل الحادي عشر,

الفصل العاشر: مفاهيم التقييم المستدام

في هذا الفصل يتم دراسة مفاهيم التقييم المستدام من خلال مقدمة عن نظام تقييم الاستدامة البيئية حيث تقييم العمل المحلي والاجتماعي والاستدامة البيئية والأعمال بمعايير التقييم المستدام. ومع ذلك، يتم تدريس الفصل الحادي عشر وفقاً لنظام التقييم المستدام والثابت (LEED BD+C) للنظام المباني بطلاب (Greenroads).

الفصل الحادي عشر: تطوير نظام مصري لتقييم استدامة الكبائي

الفصل الحادي عشر: تطوير نظام مصري لتقييم استدامة الكبائي

الفصل الثاني عشر: الخاتمة والتوصيات

يشمل هذا الفصل النتائج العامة للبحث والتوصيات التي تم إستخلاصها ويتجهى بأقتراحات الباحث لمجالات بحثية مماثلة.

الملاحظات
وفيما سيم يتم شرح الهدف الخاص بالآداب والنقاط المثوبين في نظام التقييم المعماري والذي تم استجوابهم من خلال البحث وأيضًا سيم يتم شرح كل من الاشترارات والنقاط لاستخدام نظام تقييم الاستدامة والذي تم أيضًا وضع منهجية التقييم وتجميع النقاط لتسير (LEED BD+C and Greenroads).

استخدام نظام التقييم في الكبائي المستقبلي.
ملخص ذوثمانية أسطر

تحتوي معظم الكباري المصرية على مشاكل وظيفية وجمالية بالإضافة إلى قصور في الاستدامة البيئية والاقتصادية والاجتماعية. تحتاج هذه المشاكل إلى الدراسة المتقدمة لتجنب حدوثها في الكباري الجديدة قبل عملية التصميم. كذلك لوحظ استبعاد المعماري من عمليات تصميم وبناء وتشغيل الكباري المصرية وتم تتفويض مهمات تصميم وبناء وتشغيل الكباري بالكامل إلى المهندس الإنشائي الذي لا يهمه إلا بسلامة الكباري وتقليله دون النظر إلى نجاح الكباري في أداء وظائفها الأساسية والمكتسبة وأيضًا بعض النظر عن جمالية الكباري أواستدامتها البيئية والاقتصادية والاجتماعية. لذا فإن الهدف من هذه الدراسة هو تطوير نظام مصري مستدام لتقنيه الكباري الجديدة معماريًا. يهدف هذا النظام إلى عمل دليل إرشادي لفريق عمل الكباري لتقنيه المشاكل السابق ذكرها في كلا من عمليات التصميم والتنفيذ والتثبيت للكباري الجديدة قبل عملية التصميم.
نظام مستدام للتقييم المعماري للكباري في مصر

إعداد

م.د/ محمد أسامة سيد احمد
رسالة مقدمة إلى كلية الهندسة المطرية - جامعة حلوان
جزء من متطلبات الحصول على درجة الماجستير في الهندسة المعمارية

إشراف

أ.م.د/ سحر مرسي محمد
استاذ مساعد الهندسة المعمارية
كلية الهندسة المطرية - جامعة حلوان

د/ عماد كامل فهيم
مدير بقسم الهندسة المعمارية
كلية الهندسة المطرية - جامعة حلوان

القاهرة: 2016