Rehabilitation as a Strategy to Increase the Sustainability of the Built Environment

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Abstract: As the costs of new construction skyrocket, more and more attention is being paid to rehabilitation of existing structures as a cost-effective and otherwise attractive strategy for meeting human needs for built facilities. Rehabilitation is a catch-all term which encompasses many meanings, but in the context of this paper we take it to mean the strengthening, changing, or improvement of existing facilities such that those facilities meet current performance requirements necessary for their intended use. We show that rehabilitation of existing structures should be a central strategy for creating a sustainable environment that meets human needs while maintaining the natural environment in a healthy and useful state. Three rehabilitation case studies are reviewed in terms of their sustainability, and conclusions are drawn which provide guidelines for sustainable rehabilitation projects.

What is Sustainability?

Sustainability as a concept is probably most widely known in relation to sustainable development, a term defined by the United Nations World Council on Environment and Development as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" (WCED 1987). Sustainability as a general term can be defined as a *system state* in which changes to the system are constrained so as to maintain the stability of the system into the foreseeable future (Pearce 1995). As such, sustainability is meaningful only from the perspective of systems, comprised of related entities which interact with one another to serve some purpose. Sustainability exists within a system *context*, and the properties and assumptions of that context are essential to determining the contribution of any element within the system to the sustainability of the system as a whole (DuBose 1994). To assign a level of sustainability to one element of a system without reference to its natural and man-made contexts is meaningless.

Sustainability With Respect to Built Facilities

In the creation or rehabilitation of built facilities, there are many opportunities to improve how design and construction are currently done to make them more sustainable. In addition to the traditional criteria of cost, time, and quality, three general objectives should shape the implementation of sustainable design and construction. These objectives are:

- Accomodating human needs and aspirations
- Avoiding negative environmental impacts
- Minimizing consumption of matter and energy

In the following subsections, we consider each of these three objectives of sustainability with respect to built facilities, and show how they relate to the overall objective of achieving global sustainability by improving the fabric of the built environment.

Accommodating Human Needs and Aspirations

The first objective of sustainable construction is accommodating human needs and aspirations. This objective has always, either directly or indirectly, been the fundamental reason to undertake construction projects in the first place. Buildings meet our basic needs for shelter, warmth, and security, and serve as shells for the activities which meet our needs for food, water, and social contacts. The built environment serves as the foundation for nearly all human activity, and as such is an essential component for the task of accommodating human needs and aspirations. Economic activities are sheltered by the built

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environment, and a significant component of economic activity in both developed and undeveloped countries is the building construction industry. Thus, the built environment is inextricably tied to sustainability since it is essential for accommodating human needs.

Avoiding Negative Environmental Impacts

Second, causing minimal negative environmental impacts (as well as maximizing positive impacts) is an important objective of sustainability since the environment consists of ecosystems whose ongoing health is essential for human survival on Earth (Goodland 1992). Sustainability of the human race requires that ecosystems be protected and preserved in a reasonable state of health by maintaining biodiversity, adequate habitat, and continued generation of natural resources by the environment.

Built facilities impact the natural environment in many ways. Given their large scope and long life cycles, built facilities have particularly significant and long-lasting effects on the environment as a whole. Ensuring that built facilities avoid negative environmental impacts over their life cycle is an essential objective for ensuring that the natural and human environments remain healthy, and thus is an important objective for achieving sustainability.

Minimizing Consumption of Matter and Energy

The third objective of sustainability with respect to the built environment is minimizing the consumption of matter and energy. By subjecting materials and energy to consumption processes in our human activities, we decrease their potential utility to current and future generations. We also impact the natural environment by taking materials and energy from to to be used in facility construction, since the environment is the ultimate source of all resources used for creating those facilities. Therefore, consuming as little matter and energy as possible, or "doing more with less," is a fundamental objective of sustainability.

How can Rehabilitation Contribute to Sustainability?

Given the three basic objectives of sustainability with respect to built facilities, along with the traditional considerations of cost, time, and quality, how can rehabilitation of existing structures help to work toward a state of sustainability for human built systems? In the following subsections, the contributions of rehabilitation as a strategy for meeting human needs within the built environment are presented as they relate to sustainability.

Minimizing Consumption of Matter and Energy

Minimizing the consumption of matter and energy over the life-cycle of built facilities is one of the primary advantages of rehabilitation. By extending the useful service life of buildings or infrastructure, rehabilitation avoids most of the consumption of matter and energy associated with construction of new facilities. Whether by repairing damaged facilities or renovating them to serve new purposes, rehabilitating existing structures is a practice which contributes to sustainability by reusing existing materials and avoiding much of the energy consumption used for new construction.

Reusing Existing Materials

By reusing most of the materials which already exist in a facility, rehabilitation prevents the consumption of huge amounts of matter and energy which would otherwise be required to process, transport, and install new materials in a replacement facility. Since the expenditures of matter and energy which have already occurred to build the facility cannot be undone, the most sustainable alternative in creating a facility to meet human needs is generally to rehabilitate an existing facility. Building materials in general have a relatively large embodied energy, defined as the total energy expended for harvesting, transporting, processing, packaging, and installing the material. Compared to creating a new facility "from scratch" or even recycling materials from one demolished facility into a new one, rehabilitation avoids much of the energy expenditure and material waste which generally occurs in constructing new facilities.

Avoiding Additional Energy Consumption

As noted in the previous section, huge amounts of energy consumption are associated with constructing built facilities: as embodied energy in the component materials, by the equipment used to construct the facility, as well as in the operation and maintenance of the facility. When rehabilitation of an existing structure is selected instead of new construction, much of this energy consumption is avoided. By reusing existing materials and avoiding the energy expenditure associated with demolition and new construction, rehabilitation is a sustainable strategy because it reduces the overall consumption of matter and energy within human built systems.

On occasion, however, the energy efficiency properties of existing structures are inferior to new materials. For example, new thermal window assemblies usually surpass by far the thermal energy efficiency of the single-pane windows often found in existing structures. In cases like this, rehabilitation of the facility should include removal of the old, inefficient fixtures and replacement with newer, more efficient ones to avoid larger energy consumption during operation of the facility. Life cycle energy analysis is one technique which can be used to assess the tradeoffs associated with replacement of building fixtures.

Avoiding Negative Environmental Impacts

Avoiding negative environmental impacts, along with encouraging positive impacts, is a second major objective of sustainability with respect to built facilities. Negative impacts of built facilities range from displacement of natural ecosystems on building sites, to over-harvesting of natural resources from ecosystems, to generating vast amounts of waste as a result of constructing, operating, and demolishing facilities. By reusing existing sites and reducing the amount of waste generated as a result of the facility life cycle, rehabilitation contributes to sustainability by helping to avoid negative environmental impacts.

Reusing Existing Sites

One of the most fundamental ways in which rehabilitation avoids negative environmental impacts and promotes positive environmental action is by reusing existing buildings and the sites on which they stand. The sites of such facilities have *already* been impacted by human changes, and making further changes to the site is not likely to impact the natural environment as much as building a new facility at a greenfield site. Reusing an existing site avoids much of the destruction of natural habitat, soil erosion, and generation of fugitive emissions such as runoff, noise, and dust which typically impact the natural environment in greenfield construction. In addition, many rehabilitation projects include plans for environmental rehabilitation of the surrounding site and landscaping, creating the potential for positive environmental impacts as a result of the project.

Reducing Construction and Demolition Waste

Along with the other benefits of reusing existing materials, rehabilitation has the added benefit of reducing the amounts of material waste typically generated by new construction. As much as 10% of the waste received by municipal solid waste landfills is generated by construction and demolition of built facilities (von Stein 1993). By rehabilitating existing structures, this waste generation is largely avoided. Materials *already used* to build the facility are kept as part of the structure, rather than reduced to demolition waste if the structure were demolished and replaced. The quantity of new materials added to the rehabilitated structure is much smaller than that which would be necessary to build a replacement structure, and thus the amount of residual waste associated with installing these new materials is much smaller. By reducing the amount of waste from construction projects, rehabilitation of existing structures contributes significantly to the sustainability of the built environment.

Accommodating Human Needs and Aspirations

The third objective of sustainability for the built environment is accommodating human needs and aspirations. Rehabilitation of existing structures contributes to this objective in various ways, including meeting new performance requirements for existing facilities, preserving the architectural history of older facilities, and contributing to the revival of urban areas.

Meeting Performance Requirements

One of the most basic reasons for engaging in a rehabilitation project is to bring older facilities up to current performance requirements, either due to new codes to which the facility must adhere, or to adapt the structure for new intended uses which have different performance requirements. By rehabilitating a structure to meet new performance requirements, we enable the structure to meet the human needs or aspirations which created those requirements. Thus, rehabilitation enables human needs to be met without the necessity of creating new facilities.

Preserving Architectural History

Preserving architectural history is important because older facilities subject to rehabilitation often contain valuable architectural assets which are not present in newer facilities. Old buildings were often constructed with goals other than economic and structural optimization in mind, and thus have valuable architectural attributes which would never be built in replacement facilities due to economic constraints. Such features include cohesion with the surrounding architectural fabric of the community, solidity of construction which imparts feelings of solidness and security to users, and historically important details such as stone carvings, wrought iron ornamentation, and stained glass windows, which make the facility aesthetically attractive.

By preserving these qualities and attributes in rehabilitation, the often infeasible cost of replicating them in new facilities is avoided. In newer construction where cost is often the overriding decision criteria, such features are either replicated as facades using inferior materials, or omitted altogether. Such replication reduces the *authenticity* of the structure, rendering it of intrinsically lesser value than the original structure which might have been rehabilitated. Careful planning of rehabilitation projects often enables these attributes to be preserved at far lower costs than replacement, and preserves the facility within the architectural fabric of the community in which it exists.

Reviving Urban Areas

Urban blight is often a problem in major cities, particularly in the areas where facilities with potential for rehabilitation are sited. When rehabilitation of those facilities is selected as an alternative to replacement at a different site, the surrounding community benefits from the renewal of the facility. Not only is the site of the facility itself rehabilitated and increased in beauty, but also the project can serve as an impetus to encourage further rehabilitation in the area. Bringing commercial or residential activity to an old neighborhood stimulates the economy of the area, which may cause future economic activity to flourish. Spin-off effects from urban rehabilitation include reduced new development in suburban areas with all the associated negative environmental impacts, and a reduction in transportation requirements for users of the new facilities due to proximity to urban amenities. All these benefits are evidence that rehabilitation can contribute to sustainability by helping to meet human needs and aspirations.

Cost, Time, and Quality

Cost, time and quality are the traditional criteria of design and construction, and have guided project decision making more strongly over the past century than ever before. In the following subsections, we discuss how rehabilitation surpasses new construction in terms of sustainability by creating economic advantages for owners and communities, saving time needed for new construction, and maintaining traditional quality standards.

Creating Economic Advantage

In addition to the economic benefits of urban renewal, rehabilitation of existing facilities often provides an economic advantage to owners of these facilities. Rehabilitation projects often cost far less than new, replacement construction due to their reuse of existing material and energy components. Rehabilitation of existing facilities eliminates the need for much of the sitework needed for greenfield construction, and thus saves money for prospective developers. Finally, rehabilitated projects are often more attractive to prospective tenants, due to their historical qualities, proximity to urban amenities, and unique architectural attributes (Heintz & Wosser 1994).

Saving Time Needed for New Construction

Rehabilitating old facilities often saves significant amounts of time compared to that required for replacement construction. Due to the reuse of part or all of the existing structure and sitework, time requirements are often significantly reduced to bring the facility up to meet performance standards. Sometimes, however, rehabilitation adds to the design and construction time needed to finish the project. Unfamiliarity with older materials, the necessity of detailed structural evaluation and planning, or the need to work around users of the facilities are potential pitfalls of rehabilitation projects which can add to the overall time needed to complete the project. In many cases, however, the net benefits resulting from choosing rehabilitation over new construction offset any additional time requirements.

Maintaining Traditional Quality Standards

The quality standards used in traditional construction often surpass the standards dictated today by economic optimization. Particularly with older structures, the component materials are often of a higher quality that is not even available on the current market. By rehabilitating these older, higher quality structures instead of building replacements according to current standards, we can take advantage of the lower labor and material costs and higher quality standards enjoyed by our ancestors, rather than throwing their work into a landfill.

In all these ways, rehabilitation is a superior alternative to new construction in terms of sustainability. In the following parts of the paper, several case studies are used to illustrate the sustainable aspects of rehabilitation projects.

Case Studies

In this section of the paper, three case studies are presented from the literature to illustrate several of the aspects of sustainability which must be considered in planning and implementing rehabilitation projects. In particular, the idea of sustainability as a criteria for decision making serves as a framework for analyzing the decisions made for each of these projects, and conclusions are drawn as to how each of the projects might have been made more sustainable by using sustainability as a primary decision criteria.

Second Stichtse Bridge, The Netherlands

In this case study developed by Reij et al. (1994), the authors attempt to assess whether or not using high-strength concrete for an enlargement of an existing box girder bridge is more sustainable than using lightweight or normal-weight concrete. They base their discussion of sustainability on the National Environmental Policy Plan of the Netherlands, which identifies three basic principles of environmentally-conscious design: integrated life cycle management, energy conservation, and quality improvement. As such, they assume that sustainability is equivalent to environmental friendliness plus quality in the built facility. They state that while sustainable development is a complex concept which incorporates many criteria, so far it has been neglected in design which typically is focused only on economics and performance aspects of the facility. In so doing, they automatically exclude these elements from their definition of sustainability, which we have shown to be integral components.

As the paper continues, the authors begin to equate sustainability to “environmentally friendly design”, and they limit their analysis of environmental friendliness to the energy content of the materials used for construction. While they point out that often economic design goes well with environmentally friendly design, since minimizing materials and making each member perform optimally results in using less material and lower costs, they fail to consider the larger perspective of sustainability. In optimizing a design from a structural viewpoint, inherent assumptions have to be made about the intended service life of the structure. The service life is often selected arbitrarily, balanced against the amount of economic resources which can currently be budgeted for the construction of the facility. Thus, economic criteria still remain paramount for decision making, and all subsequent decisions function within these initial economic constraints. While designs developed within this paradigm may still turn out to be optimal, the possibility exists that a more sustainable alternative might have been developed if other criteria had been primary considerations.

The authors note that aesthetic constraints were used to determine the bridge design, which causes a positive contribution to the human satisfaction component of sustainability. They also note that due to the properties of high-strength concrete, bridge joints can be placed at greater spacings, significantly reducing construction time. However, at the end of the paper, the authors conclude that no significant distinctions can be drawn from their embodied energy analysis of the various concrete alternatives, reinforcing the idea that isolated analysis of one component of sustainability is generally insufficient for making decisions and is unreflective of the sustainability of the design itself. Had the authors included a comparison of the economic costs or environmental impacts of the three alternatives, we might be able to draw a clearer picture of the relative sustainability of each alternative.

50 Green Street, San Francisco

In this case study written by Heintz and Wosser (1994), we find a more well-rounded consideration of the sustainability of a rehabilitation project, even though sustainability itself is mentioned nowhere in the article. The authors present a description of the rehabilitation of this unreinforced masonry structure in San Francisco, undertaken to improve the seismic strength of the facility to comply with updated building codes. The rehabilitation was undertaken while the building remained occupied, and planning for the project included sensitivity to the architectural features of the building as well as the owner's cost, time, tenant disruption, and appearance constraints.

While no specific analysis was undertaken of the impacts to the environment of this project, we can assume that the impacts were relatively small since the project site remained relatively undisturbed and new materials added to the structure were minimal. Particular care was taken not to disturb the human environment within the facility, since avoiding tenant disruption was a major objective in the project implementation. Attention was paid in the selection of new materials to avoid damaging the architectural and historical integrity of the facility while ensuring that it met the required performance standards. For example, the project utilized CenterCore strengthening of the masonry walls, which resulted in zero architectural impact due to its invisibility from the interior and exterior of the building.

By carefully considering impacts to the human environment and architectural integrity of the building context, making use of all the materials already in use in the facility and adding only a small quantity of new materials, and meeting the fundamental requirements of cost, time, and performance of this rehabilitation project, the planners achieved a high degree of sustainability. This case study is an excellent example of how rehabilitation as a strategy can greatly contribute to the sustainability of the built environment, without necessarily even considering it as a specific objective of planning and design.

Golden Gate Bridge, San Francisco

In this analysis of the planning of the Golden Gate Bridge retrofit by Seim (1994), the author emphasizes the importance of architectural criteria along with performance and other criteria in achieving a rehabilitation plan which preserves the historical and architectural heritage of the structure. While no specific mention is made of sustainability, the author incorporates in the discussion of the rehabilitation plan factors such as architectural and historical integrity, technical performance, maintaining service during construction, and restoration of as much as possible of the original materials in the rehabilitated structure. Aside from the obvious lack of consideration for the environmental impacts of the rehabilitation itself, this case again illustrates that it is possible to achieve sustainability in the planning of a rehabilitation project without explicitly saying so.

Since no discussion of the actual implementation of the project is given, it is impossible to assess the degree of negative environmental impact resulting from the construction and rehabilitation processes. However, since one of the explicit goals of the project was to reuse as many of the existing materials as possible, the impacts associated with using new materials will probably be minimal. From an economic perspective, rehabilitating the structure was estimated to cost only 10 to 15% of the total replacement cost, dramatically illustrating the economic advantages often inherent in rehabilitation. Careful attention was given to the architectural heritage and context of the structure in developing the rehabilitation plan, helping to assure that satisfaction of the human needs met by the bridge would be maintained. Additionally, strict requirements were set to ensure that the bridge would remain in service throughout the rehabilitation, which would have been impossible if replacement of the structure had been chosen. Thus, this rehabilitation project illustrates the dramatic advantages of rehabilitation over replacement construction, in terms of nearly all the issues of sustainability.

Conclusions

In conclusion, we have shown throughout this paper that rehabilitation of existing structures is nearly always superior to new or replacement construction in terms of the various aspects of sustainability and sustainable development. Rehabilitated projects provide many advantages, including maintenance of historical and architectural integrity, revitalizing urban areas, and avoiding negative environmental impacts and unnecessary consumption of materials and energy. In planning a sustainable rehabilitation project, it is necessary to consider the surrounding context of the project, potential impacts to the human and natural environment, and economic viability compared to other alternatives. Sustainability as a decision criterion encompasses all of these considerations, and can serve as a governing objective for all project decision making which will help to ensure the survival of the earth and its inhabitants into the foreseeable future.

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