Creating Team Competency for Idea Generation and Implementation of Energy Efficient Innovation in Buildings*

การสร้างสมรรถภาพของทีมงานในการสร้างและใช้แนวคิดเพื่อนวัตกรรมอนุรักษ์พลังงานในอาคาร

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Abstract

This paper reports the initial findings of an ongoing study that aims to identify the mechanisms that foster technical innovation in the building industry, specifically energy efficient innovations. Building practice is a complex and collective endeavor, which involves a large number of different parties (knowledge experts, manufacturers, and suppliers), specialized design, and a variety of types of contracts. These collaborative efforts, however, do not necessarily produce a technologically innovative building due to other forces such as economics, preferences, and constructability. Nonetheless, it is clear that some buildings are more innovative while others maintain the traditional conventions. The investigation finds that team competency or 'relational competence' of team members to achieve Energy Efficient Innovation (EEI) in buildings depends largely on the commitment of project participants and their collaborative climate, which, in turn, is a function of five interrelated factors: Green alliance and criteria formulation; value-based relationship; feedback cycle; green driver and leadership; and the prospect of future collaboration.

บทคัดย่อ

บทความนี้เป็นการรายงานขั้นต้นถึงกลไกที่สนับสนุนนวัตกรรมทางเทคนิคในอุตสาหกรรมการก่อสร้าง โดยเฉพาะอย่างยิ่งนวัตกรรมการอนุรักษ์พลังงาน การปฏิบัติวิชาชีพทางสถาปัตยกรรมเป็นการทำงานร่วมกันที่ซับซ้อนของบุคลากรหลายกลุ่ม ได้แก่ กลุ่มต่าง ๆ ที่เกี่ยวข้องกับการผลิตและจำหน่ายวัสดุก่อสร้าง กลุ่มผู้เชี่ยวชาญในการออกแบบด้านต่าง ๆ และกลุ่มผู้รับเหมาต่าง ๆ อย่างไรก็ตาม การทำงานร่วมกันเหล่านี้ไม่ได้หมายความว่าจะสามารถร่วมมือกันสร้างนวัตกรรมทางเทคโนโลยีของอาคารเสมอไป เนื่องจากมีสาเหตุประกอบอื่น ๆ เข้ามาเกี่ยวข้อง เช่น เงื่อนไขทางเศรษฐกิจ ความชอบส่วนตัว และความยากง่ายในการก่อสร้างเป็นต้น

* This article has originally been posted on the Boston Society of Architect, Committee on the Environment (COTE) website. It has been re-edited by the authors for this publication.

เห็นได้ชัดว่าอาคารบางหลังมีลักษณะของนวัตกรรม ในขณะที่อาคารอีกหลายหลังยังใช้เทคโนโลยีการก่อสร้างแบบปัจจุบัน การศึกษาพบว่า สมรรถภาพของทีมงานหรือสมรรถภาพที่สัมพันธ์กันของบุคลากรภายในทีมงานเพื่อให้เกิดนวัตกรรมการอนุรักษ์พลังงานในอาคารขึ้นอยู่กับความทุ่มเทให้กับโครงการของผู้ร่วมงาน และบรรยากาศการทำงานร่วมกัน ซึ่งเป็นผลจากปัจจัยที่เกี่ยวข้อง 5 ประการ ได้แก่ ความร่วมมือในสถาปัตยกรรมสีเขียวและการตั้งกฎเกณฑ์ ความสัมพันธ์ของทีมงานแบบที่มีความสำนึกร่วมกัน วงจรของการให้ข้อคิดเห็น ผู้ผลักดันสถาปัตยกรรมสีเขียวและความเป็นผู้นำ และความคาดหวังของการทำงานร่วมกันในอนาคต

Keywords (คำสำคัญ)

Innovation (นวัตกรรม)
Energy Efficiency (ประสิทธิภาพการใช้พลังงาน)
Relational Competence (สมรรถภาพที่สัมพันธ์กัน)
Sustainability (ความยั่งยืน)
Collaboration (การทำงานร่วมกัน)

Introduction

Team members of most successful architectural projects have attributed their achievement to 'having great chemistry among the participants (and) the ability to work well together.' This paper will discuss the characteristics of design teams that have this 'chemistry,' not only for generating new ideas, but also for overcoming resistance to change, embracing unconventional solutions, and being able to bring such innovations to fruition. As building projects today become increasingly complex, a greater number of participants are included in the design, coordination, and construction of a building—providing more opportunities for new ideas. However, as the number of participants increases, working effectively as a team becomes a critical issue.

This study examines the 'relationships' between project participants (rather than characteristics of individual members of design teams[1]) that create the 'extra mile' attitude found in seven building projects where eight energy efficient innovations (EEI) have been successfully integrated into the final construction. Detailed data about each participant and their backgrounds are relevant, but examining their working relationships is arguably far more important for evaluating the effectiveness of a team as a whole.

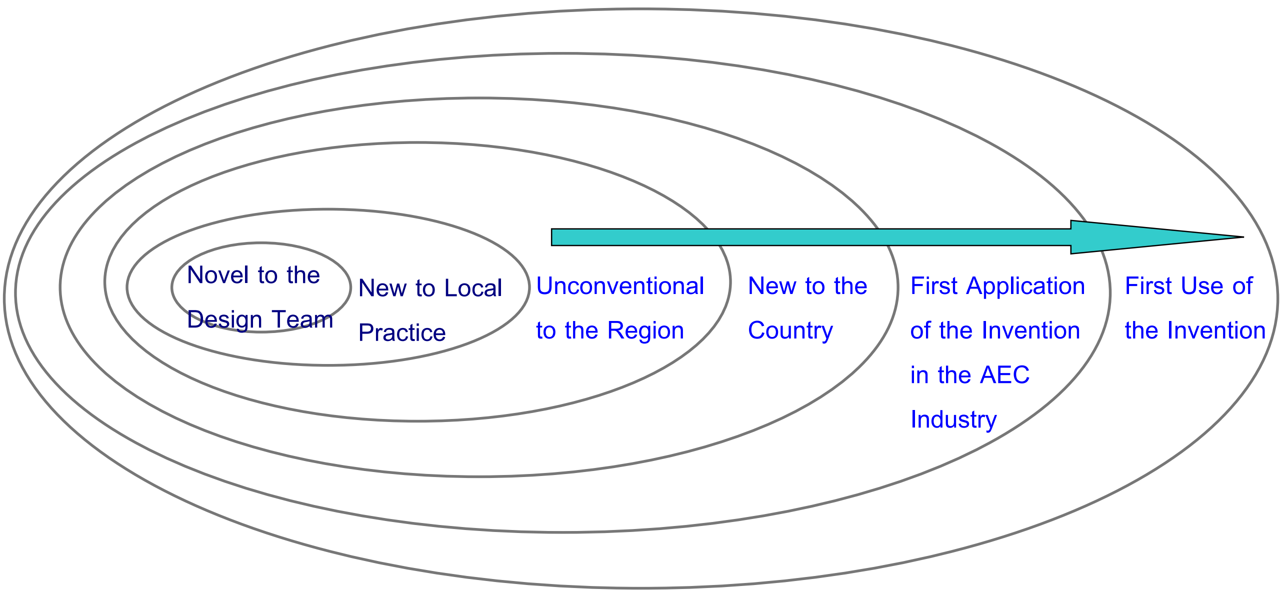

Figure 1 Levels of innovation

[1] The term 'design team' is used because it is essential to acknowledge that the design of buildings is not the sole responsibility of the architect, but is the result of a collaboration among many participants: architects, engineers, fabricators, and manufacturers.

Research Methodology

Seven projects completed between 1994-2000 in Europe and North America were selected for this investigation. These projects were chosen if they feature EEI that were, at the minimum, new to the region in which they were implemented. Innovations that were first introduced in a country or new to the global architectural industry or the first application ever were considered. Innovations that were novel only to a design team or to local practice were not included in the study (see Figure 1).

Since the objective of this research is to identify the practices that led to unconventional energy efficient solutions, these projects were not limited by types of technology (passive, active, etc.), building types (commercial, residential, institutional, etc.), climates, or locations but by their level of technological innovation. The seven case studies and respective innovations are listed and described in Figure 2.

The interview research method was used to build the case studies because it was the most efficient means to gather information, simultaneously confirm hypotheses, and gain immediate feedback. A total of 35 face-to-face individual or paired interviews were conducted with architects, mechanical engineers, testing engineers, and clients (or their representatives) and, in some cases, with structural engineers, if relevant. At least three persons from each project were interviewed to clarify and validate information. The interview questions were loose, but aimed to record the practices associated with each innovation and its implementation process. The questions were organized into four sections. The first group of questions focused on the general nature and origin of the environmental aspect of the project. The second focused on the composition of the design team. The third focused on the source and development process of the innovation itself, trying to identify the peculiarities, the compromises, and the management techniques during the implementation process. The last group of questions focused on the knowledge gain, benefits, and restrictions relating to technology transfer. However, as research proceeded, the questions were continually modified and adjusted to incorporate new findings and/or repeating patterns. The interviews conducted for the first few cases were used to gauge the comprehensiveness of the interview questions; therefore, they have not been included in the final set of case studies and analysis. Follow-up questions were asked during the interviews as well as through e-mails and phone calls after interviews were completed. All interviews were taped and transcribed. The repeating patterns and factors were mapped and tabulated. The factors that appear in most or in all of the cases were kept while those that were only specific to a single or a few cases were not included. Based on the analyses of the data gathered from the teams, the interrelated factors were developed.

Figure 2 Descriptions of case studies

Project	Location	Innovation	Description of Innovation
Design Center 	Linz, Austria (1994)	Light Metrics (Lichtraster)	A 16mm light grid system sandwiched between large glazed panels which allows natural light to enter the exhibition hall below while excluding solar heat gain due to direct sunlight. Through the maximum exploitation of natural daylight and prevention of solar radiation, the building is able to conserve thermal and electrical energy.
Telus Headquarters 	Vancouver B.C., Canada (2000)	Triple-Glazing Double-Skin Façade	Two-layer façade systems enclosing buildings to help stabilize the temperature fluctuation and minimize excessive heat loss or heat gain through building perimeters— therefore minimizes the use of the mechanical system for heating, ventilating and conditioning the interior volume.
Contact Theatre 	Manchester, UK (1999)	Ventilated Chimney for Performance Auditorium	A series of stack chimneys with H-shape extract-termination was designed to passively cool the interior of the theatre auditorium. This solution has to mitigate the conflict between acoustics and temperature control.
Coventry Library 	Coventry, UK (2000)	Ventilated Chimney for Large Floor Plate	A series of stack chimneys with aluminum extruded extract-termination was used to passively condition a deep floor plan building (which typically served by artificial light and mechanical control systems).
The New Parliamentary Building (Portcullis House) 	London, UK (1999)	Dynamic Building Façade	Dynamic Building façade is a combination of air supply shaft and window systems. Windows become an integral part of the mechanical system of this building. These specialized windows consist of 3 parts: an outer leaf of double-glazed insulating glass; a cavity for air movement and a shading device is located inside of this membrane; with a simple inner pane of glass placed to the inside of these elements. A light shelf separates the lower two thirds of the window from the upper third. Air is drawn into the cavity through gaps in the inner glass at the bottom of either segment of the window.
Four Times Square 	NYC, USA (1999)	Fuel Cells	An energy-producing technology that utilizes hydrogen as its fuel source to produce electricity without combustion. Their by-products are heat and water.
		Building Integrated Photovoltaic (BIPV)	An energy-producing device, specifically designed for integration in building façades. Its application on a vertical surface is, however, less than optimal since photovoltaic modules produce electricity when it is exposed to light and therefore should be oriented towards the sun.
Lindål Housing Project 	Götenborg, Sweden (2001)	Nordic building without heating system	Nordic homes that exclude mechanical heating systems relying instead on heat generated by human activities and lighting system with typical light weight wood construction with heavy insulation and tight construction details to reduce leakage and infiltration.

Relational Competency

The usefulness of a relationship in an architectural endeavor has to be evaluated in the context of developing the proficiency to achieve innovations and the relationship's contribution to the successful completion of those innovations. Josef Frischer [1] has defined the relational aspects of competency development as the ability to develop work relationships with other individuals that lead to effective action. Using Frischer's definition, characteristics of design teams that enable the implementation of innovative energy efficient technology—the teams' *relational competence*—are described. Relational competence is achieved when work relationships increase the team's capacity and tendency to pursue the unfamiliar and take effective actions through team collaboration.

The relational competence of a building team is particularly difficult to achieve because building projects involve design and construction processes, which are necessarily multidisciplinary. Teams typically comprise of specialized design, knowledge experts, contracting and supply firms, each of which has its own goals and agenda, which are not always aligned. Its members are usually not fully committed to the benefits of coordinating design and do not necessarily share a common organizational goal [2]. Clients also have several concerns related to building performance and financial limitations. Clients typically have a fixed budget; any challenge to the prescribed allocation of expenditures often meets with disapproval. There is also a long-term commitment implied by the investment in energy efficient design. The study concludes that the competency of the teams that attempt to integrate EEI into an architectural project depends largely on the commitment of project participants (i.e., team members and building owners) and the collaborative climate they create, which is a function of five interrelated variables:

(1) Green Alliance and Criteria Formulation
(2) Value-based Relationship
(3) Feedback Cycle
(4) Green Driver and Leadership
(5) Prospect of Future Collaboration

(1) Green Alliance and Criteria Formulation

Buildings that involve green innovations cannot be based solely on contractual and legal arrangements because they primarily serve as preventive devices when failures or conflicts arise and do not inspire participants to advance beyond their prescribed routines. Successful working relationships in environmentally conscious projects go beyond performance provision or the legal aspect [3]. The notion of green alliance and criteria formulation is a two-step process. It is not merely for establishing mutual understanding of the environmental issues and reaching common ground, but it is also a procedure that creates a sense of *ownership* in the team's energy efficient design approach. Minimizing the environmental impacts is the most important goal that must first be established for a team that strives toward EEI. In fact, all of the teams in the case study strove to establish a green goal in their first meeting. The Four Times Square project was initiated with a 2-day retreat mandated by the client, the Durst

Organization. The intention of the retreat was to get individual participants to familiarize themselves with each other (outside the project setting). Through a partnering process each participant expressed his/her goals for the project and explained why. The discussion helped formulate agreements and expectations, which led to the shift of focus from financial benefits to include education, quality, reputation, aesthetic, and environmental concerns. In the Telus Headquarters project, educating participants about environmental concerns was achieved through a slide presentation and discussion of green buildings. Though the slide presentation detracted from the tight project schedule, it explained the reasons for pursuing environmentally friendly design and created a common level of understanding and expectation from the start.

The study, however, further reveals that the process of criteria formulation is especially critical to the team's collaboration and commitment to creating energy efficient projects (see Figure 3). This is because energy efficiency can be accomplished by several strategies: passive, active, mechanical, building enclosure, etc. The process of formulating specific energy efficient design criteria and strategy through discussions with team members does not only generates ideas but also creates a sense of control, ownership, and interpersonal bonding among participants. To each participant, pursuing the strategy formulated as a team becomes both a team and personal venture that each is willing to contribute to, manage, and claim as his/her own. "Ownership is established if participants feel that the eventual design approach emerges from their contribution," states Blair McCarry, mechanical engineer for Telus Headquarters. One of the key techniques in formulating a project's criteria and strategy includes recording and circulating ideas and agreements (both formal or informal) to all members for endorsement; each participant signs the document even if it seems ad hoc (i.e., on handwritten papers). Such efforts are important in developing and maintaining commitment among team members and clarifying each member's role and expectations.

Figure 3 summarizes the design goals, the corresponding strategies, and their associated formulation methods. Aligning diverse ideology and expectations to the environmental ideology of the team leader is vital because not all projects have environmentally conscious clients (even projects that have successfully included EEI). Few clients require environmental responsibility from designers; few designers themselves are well-informed about environmental topics. In cases like Telus Headquarters and the Contact Theatre, the EEIs were implemented despite the initial lack of or minimal environmental concern from clients. Both teams succeeded because they were able to create designs that successfully wove environmental concerns into the owners' objectives. Specifically, these passive design strategies were implemented using a limited budget that had been allocated for the projects and the need to reduce the operating and maintenance expenses. The Contact Theatre was thus built at a cost comparable to a standard theatre; yet it incorporated an energy efficient feature to minimize expenses in operation and maintenance.

Figure 3 Description of green alliance and formulation process

Project	Owner's Objective	Designers' Design Goal and Strategy	Green Alliance Process	Strategy and Criteria Formulation Technique
Design Center in Linz	Revitalize local industry, Environmentally sound design, Aesthetics	Environmentally responsive design. Glass building enclosure for natural day-lighting but heat gain must be eliminated to minimize the cooling load, thus reducing energy consumption	**Implicitly understood** by team members since Herzog + Partners are leading designers in green design	The aim for glass structure was proposed by the designer but any specific technology was unknown. **Intense brainstorming meetings** were led by a recognized leader (Herzog + Partners). **Private meetings** were held if trade-secrets needed to be shared.
New Parliamentary Building (Portcullis House)	Good environmental conditions for occupants, Long-term performance (Building life of 200 years), Aesthetics	Environmentally responsive design through combining active and passive systems. Building structure, window design and the mechanical system were integrated into the building's climate control.	**Architect and engineers led the environmental discussion** with other consultants and secured two **grants for energy studies**.	**Highly interactive Brainstorming session** between architects and mechanical engineers. Since two **grants for energy studies** had been secured, it was a logical step to pursue energy efficient design.
Four Times Square	Setting a new standard for environmentally responsible design in commercial buildings.	Environmentally responsible design through energy production, aiming toward self-sufficiency/reducing energy consumption and environmental impacts.	Clients and architect led a **retreat** and hired a specialist to conduct a **formal partnering process** to discuss teamwork and team vision for environmental conscious design.	Environmentally friendly philosophy and related issues were **discussed during brainstorming sessions that resulted in written document** about different environmental design options. **Brainstorming was constant throughout the project.** Clients were enthusiastic and participated in all design meetings and discussions.
Lindål Housing Project	Environmentally responsible design, Retaining traditional aesthetics (not green aesthetics) Demonstration, Low cost	Environmentally responsible design by eliminating mechanical heating to be completely passive and minimize mechanical problems	Designer had secured a grant for energy analysis and post occupancy studies. He took the developer on a **trip to visit green buildings** throughout Europe. (education)	Energy studies were used to demonstrate the efficacy of the design to other team members. **Participants were included in the research activities.**

Figure 3 (Continued)

Project	Owner's Objective	Designers' Design Goal and Strategy	Green Alliance Process	Strategy and Criteria Formulation Technique
Telus Office Headquarters	Seismic upgrade, Low cost, Modern Aesthetics	Environmentally responsive design through redesigning the building envelop (double-skin façade) to minimize energy loss and modernize corporate identity	Both the designer and the mechanical engineering consultant were well respected for their commitment to environmental design. Slide presentation of green projects was used to initiate the project. (education)	Brainstorming sessions were held since no specific strategy was established. Different options were discussed in terms of pro/con in relations to aesthetics, building performance and construction cost. The conclusion was clearly derived based on these specific criteria.
Contact Theatre	Minimize operating and maintenance cost	Environmentally responsive design by passively conditioned building through stack-effect, thus, minimizing operation and maintenance cost.	The team was assembled through a design competition. Hence, the goal was clear to all participants. A presentation session was also held with the client to discuss the benefits of natural ventilation strategy	Ventilated chimneys were proposed by the designer because of his familiarity with this approach. The configuration of the design was not clear, but a close collaboration with a physicist, an accoustician, airflow specialists, and mechanical and structural engineers was constant.
Coventry Library	Minimize operating and maintenance cost, Environmentally responsible design, Flexibility	Environmentally responsive design by passively conditioned building through stack-effect, thus, minimizing operation and maintenance cost. This building can also set an example for naturally ventilated design for deep plan structure.	The team was assembled through design competition after completing a feasibility study for the client. Hence, the goal was clear to all participants including the client regarding the benefits of natural ventilation strategy	Mechanical engineering consultant approached the architect because of his ventilated chimney design. The client required the structure to be flexible (large open floor plan), a close collaboration with a physicist, an accoustician, airflow specialists, and mechanical and structural engineers was constant.

As indicated in Figure 3, the green pursuit was established either explicitly by the discussions about environmental concerns or implicitly by the involvement of green leaders and drivers. It was deemed important that the 'shared goal' of minimizing environmental impact be understood at a very early stage of design. This is a prerequisite to continuing development of EEI. With the exception of those teams led by a recognized 'green designer' (e.g., Thomas Herzog), all other teams were guided toward environmental goals by the emerging green leaders and drivers within their teams. The green leader is the catalyst and is critical to establishing each team's green alliance.

On the contrary, innovative energy efficient strategies need to be formed by all members of the design team. It is a vital step for team's commitment building. None of the green leaders presented design solutions to the other participants. Rather, the green leaders presented the team with specific design problems to work on. During strategy and criteria formulation, brainstorming sessions were used during which contributions from participants were encouraged, tolerated, and never ridiculed. Participants moved about the room and/or consulted in smaller groups (of 2-3 people) in preparation to share their thought with the larger groups. Recognition of free and focused thinking states allowed participants to move easily between them [4]. This formulation tactic helped develop a sense of ownership necessary to both personal and team commitment to the chosen energy efficient strategy. Through such a process, the chosen strategies were the result of a combined effort of the project participants.

(2) Value-based Relationship

To what are the participants of these projects committed? Green alliance is important to team's direction and expectations, but it still focuses on individuals' commitment to such a mission. To achieve energy efficient design, particularly when participants are not familiar with the technicalities and processes associated with the innovation, 'partnerships' among participants need to be established. What sort of partnership or relationship establishes a strong commitment to EEI? Different types of relationships naturally have different effects on the way participants work together. Based on the study, the relationships can be categorized into three types: (1) Shared-skills, (2) Shared-knowledge, and (3) Shared-values.

Shared-skills, or an assembly-line approach to design, is task-focused. It is the collaborative effort to apply each individual's basic knowledge and skills towards a given product or project. The parties involved are distant from one another. Participants' experiences and values are not revealed. How a task is accomplished is not in focus; only the finished product counts. This is a typical way buildings have been designed and constructed where architects provide copies of nearly complete design drawings to structural engineers, mechanical engineers, and other consulting engineers. The structural engineer adds only the building's structural systems and the associated calculations and/or details to the drawings. Mechanical engineers proceed similarly after receiving their own set of drawings, and so on. Input from one professional to another is rare and not expected. If there is a conflict in the drawings, each consultant typically resolves the problem directly with the designer—with minimal or no participation from other consultants. The combined drawings are then put together by the architects, submitted for a building permit, or sent out to bid or for proposals from contractors. Finally, a contractor is chosen and the construction begins. These working relationships separate roles clearly, and the focus of the cooperation is not on shared ideas among the participants but rather on the pre-determined assignments. For the most part, the process is sequential.

This sequential process is not conducive to energy efficient architecture. Energy efficient design involves 'a dynamic performance' of building climate control. Hence, the design has to accommodate the changing number of occupants and their activities to reach the level of desired comfort. The conventional practice of sequentially separated tasks between architects, mechanical engineers, and other consultants assumes that architects will do the right design prior to the necessary engineering works that follow.

Shared-knowledge is the sharing of personal experiences and information, both relating to the project at hand and the participants' other works. Hence, individuals bring more dimensions of themselves into their collaboration. As such, there are more opportunities to transfer tacit knowledge through sharing of stories, ideas, and hands-on skills. This is particularly important for the construction industry knowledge is often tacit and cannot be expressed easily with words or shared through plans and specifications. For example, master masons know the amount of water needed for a certain consistency of a mortar mix, but they would have a very difficult time conveying this information abstractly in words to their apprentices. Typically the master continues his working routine while being observed by the apprentices. In such a work relationship, it is also noticeable that communication is more frequent among team participants. Team meetings are more common (more than the typical once a week), random, and informal. Various participants often share suggestions.

During these meetings, various professionals and participants often share pertinent suggestions or devise solutions seen in other contexts and projects or used in their previous experiences, which may not have otherwise been raised. For example, it was difficult to find a manufacturer who could make prototypes for the Linz Design Center's Light metrics. The design team initially approached Siemens, a large manufacturer of light fixtures and other automation systems, for prototype fabrication. But Siemens offered specialized solutions on a limited basis and charged high prices. Though an initial prototype was made by a division of Siemens, it was unsatisfactory. The unlikely source of information regarding a local manufacturer of plastic, BENEDAR, came from one of the owner representatives responsible for budget control. This information was available only because project participants were committed to the solution and involved in the thinking and development process. Everyone worked together as a unit, collaborating concurrently rather than sequentially.

The concurrent process facilitates the integrated collaboration of knowledge experts which is required for energy efficient architecture. Solutions to efficient buildings typically involve balance of multiple components and use of specialized trades in addition to the usual mechanical consultants in the project. For passive solar design, such as the Telus Headquarters' double skin façade, the British New Parliament's dynamic façade, and Conventry Library's and Contact Theatre's ventilated chimneys, understanding building thermal performance, building structure, and acoustics was necessary. The invention of Linz Design Center's Light metrics would not have been possible without a continual collaboration with the lighting research and consulting firm of Bartenbach Lichtlabor.

Lastly and most importantly, the readiness to share both skills and knowledge hinges on the ability of individuals to share values. ***Shared-values*** occur when participants' convictions and beliefs are being expressed to other members and form a part of their decision-making process. The relationship embodies personal convictions regardless of the activities members are involved in. In the shared value work environment, an individual is more integrated in the collaborative relationship. This relationship is apparent in energy efficient innovative projects because such innovation is, in fact, not driven entirely by the economic force or quantifiable attributes. EEIs in these cases were primarily driven by personal ethical commitments to environmental concerns. None of the seven building projects were motivated by a sudden increase in energy price, tax or any other financial incentives, building codes, nor support from environmental agencies or legislation. The motivation was personal commitment to the green cause, which diffused throughout the team. All of the energy efficient innovations are found in projects in which the participants are active in raising environmental concerns and awareness. "We didn't know if we were going to do anything innovative or use anything unconventional; we were just trying to put together all the (incremental) things we have done that were environmentally correct over the years and we wanted to make it work—that was our whole attitude," says Bruce Fowle, an architect of Four Times Square. His client, however, intended to set a new standard or example for environmentally responsible design in the commercial building industry. Similarly, Alan Short, the architect for the Coventry Library and Contact Theatre, notes, "Even though I am interested in making naturally conditioned buildings, the motivation for such energy efficient approach is to deliver buildings that minimize environmental impacts."

For successful EEIs, an emphasis on environmental concerns—green value—is needed. It becomes a catalyst for the project. This is important for several reasons: (1) during the development of unconventional energy efficient solutions, many components and suggestions are often not practical—in terms of economy, constructability and aesthetics; (2) since environmentally responsible objectives are value driven, their cost and benefit cannot be easily quantified or explicitly demonstrated to project participants, particularly to the clients; and (3) innovation always involves unfamiliar conditions that naturally increase the risk of failure; therefore, innovative technologies in buildings are often deemed unnecessary by designers and clients. Hence, it is a prerequisite that in order to achieve EEI, both the team members and the building owners must have a consensus and committed attitude to or place the highest value on being environmentally responsible [5, 6]. Personal value must be involved so that a higher tolerance can be established. In this research, EEI became a vehicle for achieving such environmentally responsible buildings.

For instance, the team members of Four Times Square project: Douglas Durst and Johnathan Durst (owner), Robert Fox and Bruce Fowle (architect) and Dan Tishman (construction manager) brought with them to the project their personal commitment to minimize the impacts on the environment. The Durst Organization, under the leadership of Douglas Durst, has consistently upgraded several of their office towers in mid-town Manhattan to be more energy efficient. He himself also owns and operates an organic farm in upstate New York as does Dan Tishman of Tishman Construction. Both Bob Fox and Bruce Fowle, and their families, have been consistently participating in the Audubon Society and enjoy outdoor activities such as hiking and camping. Clearly, environmental awareness is part of their personal conduct. Such value must be shared among project participants if successful implementation of EEI is to occur in today's building industry—because these shared values provide a solid foundation to individual commitment to pursue unconventional energy efficient strategies.

(3) Feedback Cycle

At the most fundamental level, feedback in the architectural design process leads to new ideas, new understanding, and revision of forms, action, and strategies. Feedback also serves another purpose, particularly in EEI projects—that is to induce the team's commitment and collaborative climate.

The effective team feedback in the EEI projects generally avoids assessing any proposed strategies in terms of good—or bad ideas but rather in terms of their appropriateness to a specific context and always specifies reasons. Such an approach to assessment essentially involves making suggestions explicit (typically with energy calculation and sketches of system configuration), synthesizing parts into a whole (e.g., combining mechanical systems with building structure), and, most importantly, committing to improve the chosen energy efficient design strategies. The aim of the cycle is that the combined iterative communication and contextual restrictions will reduce the inevitable design conflicts, improve and facilitate ideas, and create enthusiasm among team members to their decided approach.

The effort by design teams to achieve EEI has been bound by standardized processes or conventional practices. Particularly on small projects, engineering consultants are typically not involved or not compensated for their early involvement in the process. Such sequentially segmented tasks have resulted in limited collaboration, thus minimizing feedback and revisions. In energy efficiency design, different components must work in concert. The conventional practice does not support complex design integration or mediate performance uncertainty associated with novel solutions in the energy efficient design. The conventional segregation of tasks in design practice, in fact, lengthens the feedback cycle and, consequently, hinders EEI from being implemented.

For example, the size and locations of air inlets and outlets for the Contact Theatre and the Coventry Library must be calculated in concert with building functions, dimensions and volumes in order for exhaust air to circulate naturally through the multiple ventilated chimneys without obstructing the intended use of space—e.g., continuous ventilated chimneys cannot be used on the fourth floor of the Coventry Library because there is an insufficient stack pressure and thus a different set of openings was added, instead of increasing the height of the stacks, which would have been very costly. Building height and volume could not be shaped by Alan Short (architect) in isolation from chimney height and locations calculated by Richard Quincey (mechanical engineer) and Kevin Lomas (airflow specialist). Had they not worked with expedient feedback or not collaborated concurrently (as opposed to sequentially), the ventilated chimney solution would not have been possible. Likewise, the British New Parliamentary Building' window and façade systems could not be resolved solely by Bill Dunster (architect) without the calculation and simulation by John Berry (mechanical engineer) because the façade of the building controls individual offices' air intake and is interconnected to the building's service and HVAC systems.

The reason for having continual feedback in EEI endeavors is two-fold: to illustrate commitment to collaboration and to increase the frequency of opportunities where innovative ideas can arise, particularly at an initial stage of design when a specific energy efficient strategy must be defined. In the successful cases of EEI implementations, all design teams exchanged feedback quickly, often within 24 hours after the questions had been put forth or within a week when specific analysis was required for decision making. Not only are rapid 'team feedback' cycles important, rapid 'client feedback' cycles help solidify the team's commitment and foster a collaborative climate. Typically, in public or large projects (comparable to our case studies), client representatives are present at each meeting to gather relevant information for the clients' organizations. It is rare for the representatives to have the authority to make immediate decisions. In Four Times Square, the client representatives present at each meeting were the executives. Therefore, decisions were often made during the same meeting or shortly after. The decision regarding the number of fuel cells to be incorporated into the structure changed many times—from 8, to 4, to 6 and in the end, 2 were incorporated into the fourth floor of the building. Each time the number of fuel cells was questioned, an analysis was done immediately and results were presented during the same meeting or shortly after. Based on the analysis, the client then quickly made a decision. In the cases where client representatives were not executives such as in the Telus Headquarters project, the client representative, Doug Green, was active in selling the idea and strategy to his executives by presenting and defending the idea fostered by the design team. This 'link' between designers and decision-makers must exist and actively support the team's goal. Such participants' personal commitment to the team's green objective and the sense of group responsibility resulted in courteous and expeditious feedback.

(4) Green Driver and Leadership

By the mere fact that participants of an architectural project come from various organizations of different expertise, a team leader cannot be easily appointed, especially when innovative and synergetic efforts are desired. The members of a design team are tied together only by bonds of interest, not through any central authority [7]. The roles of leader and subordinates are not explicitly assigned. As such, the design approach often becomes equivocal and, as a result, typically falls back to conventional, non-innovative approaches. This study reveals that the leadership role of successful teams for the implementation of EEI emerges from a specific cluster of project participants who share certain traits. Their conviction is to minimize negative environmental impacts rather than to provide the buildings with energy efficiency or unique technologies. These groups of participants are vital because they play the key role in selling the environmental concepts and strategies to decision-makers (e.g. clients, management, etc.), help keep other team members informed about the environmental strategies, and take the responsibility to maintain interest of team members in environmental issues. In other words, they are the *green drivers*.

Green drivers, however, are not necessarily team leaders. The two roles are closely related but mutually exclusive. Effective leaders of successful projects emerge through the implicit understanding and acceptance by project participants. Typically, these leaders are characterized by their basic understanding of different related fields of building physics and their commitment to coordinating the team while balancing the risks associated with the development of innovations (e.g., risk of failure, risk of exceeding the budget, etc.). For a design team to succeed in the implementation of EEI, a cluster of green drivers must exist and the leadership role of the team must be assumed by at least one of the green drivers in the team. In effect, they become the project's *green leader*. Under such leadership, the collaborative efforts and continual commitment to environmental design strategies, i.e., EEI can be ensured.

Figure 4 shows that each green leader also filled the environmental advocacy role of a green driver, even in design teams with multiple leaders. Green leaders are absolutely critical members of the design team for the success of EEIs. The study found that the green leaders have certain leading styles and attributes.

Figure 4 Summary of projects' green leaders and drivers

Project / Innovation	**Green Leader** / Team Leader	**Green Driver**
Design Center Linz Light metrics	Han Jörg Schrade (Architect)	Han Jörg Schrade and Thomas Herzog (Architect), Dr. Franz Dobusch (Mayor of The City of Linz), Mathias Bloos (Mechanical and Service Engineer)
Contact Theatre, Coventry Library Ventilated Chimneys	Alan Short (Architect)	Alan Short (Architect), Kevin Lomas (Air flow analyst), Max Fordham (Mechanical Engineer), Richard Quincy (Mechanical Engineer)
Four Times Square Fuel cells, BIPV	Douglas and Johnathan Durst (Owner), Bob Fox and Bruce Fowle (Architects), Dan Tishman (Construction Manager)	Douglas and Johnathan Durst (Owner), Bob Fox and Bruce Fowle (Architects), Dan Tishman (Construction Manager), Pamela Lippe (Green Coordinator), Mel Rufini (Project Director)
New Parliamentary Building Dynamic Building Façade	John Pringle (Architect), John Berry (Mechanical Engineer)	John Pringle (Architect), Bill Dunster (Architect), John Berry (Mechanical Engineer), Chris Twinn (Building Services Engineer)
Telus Headquarters Double-skin Façade	Peter Busby (Architect), Blair McCarry (Mechanical Engineer)	Peter Busby (Architect), Blair McCarry (Mechanical Engineer), Steve Palmier (Proj. Mngr), Doug Green (Owner representative), Gwen Graham (Contractor)

Three distinct styles of leadership found in EEI projects are (1) Facilitative, (2) Authoritative, and (3) Guardian. ***Facilitative leadership*** is characterized by the leaders' encouragement of group discussions and group decisions in choices of design and activities. He/she allows all suggestions to be expressed without denigrating the contributors. As Hans Jörg Schrade states, "There are no ideas that are too stupid to share. Each idea needs to be discussed." The organizational structure is horizontal or organic where there is a greater degree of lateral connection and higher degree of sharing [8]. Evidence was found in the design teams of Linz Design Center, Four Times Square, Coventry Library, and Telus Headquarters. Participants were encouraged to explore, debate, and listen to everyone else. Electricians could comment on the HVAC systems even if it was in the realm of the mechanical and services engineers. The logic behind these cross-field suggestions and critiques was that each individual had previously worked on other projects, where they had seen what had been accomplished. "You have to be open enough and realize that the consultants who are in totally unrelated fields can give the best idea," says Blair McCarry (Keen Engineering). This leadership style fosters both new ideas and team commitment through sharing of knowledge and recognizing individual's contribution.

Authoritative leadership is characterized by a hierarchical order among team members similar to the master-apprentice relationship. This is uncommon in design teams since it comprises multiple and specialized organizations; hence, a single person cannot possess such absolute authority. In building design, especially energy efficient buildings, no one has the expertise to make final calls on all knowledge domains. Having said that, there is a *star* within each design team who is recognized by the other members as a leader and allowed certain authority to make decisions that resolve conflicting ideas. This is an important quality. While the leaders were not contractual or assigned, they arose from mutual acceptance of other members and were recognized as the decision-maker and negotiator for the team. For example, the acoustician and mechanical engineers of the Contact Theatre could not resolve the design conflict on the treatment of interior surfaces in the concert hall. Mechanical engineers needed the exposed concrete to take advantage of its thermal capacity to passively condition the building, but such a strategy was in direct conflict with the acoustic quality of the auditorium—requiring much softer surfaces for sound absorbency. Alan Short, the project architect who conceptualized this design, had to make the final determination to prioritize thermal performance over the acoustical one since the ultimate objective was to provide the Contact Theatre Company with a city icon that would minimize its operating and maintenance costs.

Guardian leadership is characterized by the absence of involvement in the decision-making process by the leader—they become the projects' fiduciaries. In the case of an owner as a guardian, the design teams have complete freedom to pursue contingent green strategies. The guardians set the 'green' tone and may give information but refrain from participating in work and/or checking, evaluating, and commenting on work progress (except when asked). In many respects, this guardian style of leadership can be equated to non-leadership. This is often found in most architectural endeavors where project participants are required to meet code or fulfill prescribed guidelines and specifications. Building owners usually assume this role since they are typically unfamiliar with green strategies and the rules of the trade—their primary monitoring is largely of financial and budget control. For example, the New Parliamentary Building committee comprised of a number of high-ranking officials who were interested in the notion of environmentally sound building but refrained from the work duties directly. However, their presence automatically awoke expectations, which helped to build up localized green leaders (e.g., John Berry, Chris Twinn, and Bill Dunster. Such guardian's support for environmental design was crucial to the implementation of the highly integrated Dynamic Façade system.

However, a guardian can also be intimately involved as an overseer but not involved in decision-making activities in the design. In effect, they become projects' legitimizers who fasten all participating groups together on a day-to-day basis to ensure that the teams' environmental design strategies are being followed. In Four Times Square, Pamela Lippe, Earth Day New York, was specifically hired by the Durst Organization to keep a constant eye on the entire process to make sure that the decisions made by different groups were implemented according to the environmental agenda. Even though Lippe did not make design decisions, she became the project's conduit for all decisions; essentially, she became a quality controller for green strategies.

Figure 5 Descriptions of leadership styles and characteristics of each green leader

Green Leader	Leadership Style	Characteristic
Han Jörg Schrade (Architect)	Facilitative—with recognized authority combined with Guardian support from owner	Clear authority in decision making based on input of other participants, *Coordinate* with all fields, directly involve in solving the technical details
Alan Short (Architect)	Facilitative—with recognized authority and combined with Guardian support from owner	Clear approach (Passive design), Coordinate consensus toward final decision, *Coordinate* with all fields, directly involve in solving the technical details
Douglas and Johnathan Durst (Owner)	Facilitative—with clear decision making power Guardian—set the tone for green design	Clear objective and authority but rely on inputs from consultants and Construction Manager, Engage in problem solving
Bob Fox and Bruce Fowle (Architects)	Facilitative with strong and engaging support from the owner	Clear objective (Green)—balance ideas—focus on architectural design, Engage in problem solving
Dan Tishman (Construction Manager)	Facilitative with participating organizations Authoritative within Tishman Construction	Clear authority in decision making based on budget. Provide direction for subordinates in Tishman organization itself
John Pringle (Architect)	Facilitative with Guardian support from client	Clear objective (Green)—balance ideas—focus on architectural design, Engage in problem solving
John Berry (Mechanical Engineer)	Facilitative—with recognized authority on technical issues	Accept input and suggestions to create a viable innovative composition; directly involve in solving the technical details
Peter Busby (Architect)	Facilitative—shared decision making capacity with the mechanical consultant	Clear objective (Green), Coordinate consensus toward final decision, *Coordinate* with all fields, Engage in problem solving
Blair McCarry (Mechanical Engineer)	Facilitative—with recognized authority on technical issues but closely shared decision making with the architect	Clear objective (Green), balance different ideas given by all participants; directly involve in solving the technical details

It is not surprising that this investigation highlights the facilitative leading style that supports the idea and implementation of EEI where the leaders engage in all problem-solving activities rather than command the delivery of the innovations. It is, however, also important that the green leaders retain certain authorities to mitigate conflicting ideas, which often occur in energy efficient design. This is crucial because good ideas with conflicting goals inevitably arise during discussions. In each of the design teams examined, the green leaders were implicitly recognized as the default arbitrator. Also, their effectiveness as leaders involved owners and the upper management of designer's organizations who acted as guardians supporting the environmentally responsible concept. In addition, green leaders identified in this study also assumed the role of green drivers who might or might not have been projects' coordinators—as in the case of Four Time Square where Lippe was hired to be the project's green coordinator. Both roles (green leader and green coordinator) must exist if EEI is to occur. Frequently, the architects assume these roles.

(5) Prospect of Future Collaboration

Because of the nature of the building industry for which design teams are only allied temporarily, it is difficult for a group of multiple organizations to collaborate, particularly when uncustomary/ unconventional design strategies are involved. In short-term collaborations or the ones with a definite termination period, participants seldom contribute their latest ideas and inventions with other members of their projects. This is crucial, especially with EEI where many ideas and trade secrets must be shared. In such a scenario, the sources of solutions must be compensated adequately for their contributions. Unfortunately, such rewards are seldom offered in the building industry—at least financially. Due to the ephemeral alliance of participants, each member would aim to maximize their benefits from the project by exploiting the innovative efforts of others whilst minimizing their own risk and uncertainty associated with innovation by retreating to the more conventional solutions. An incentive for team commitment and collaboration is the prospect that participants in an endeavor might meet again. This possibility means that the choices made today not only determine the outcome of this action but can also influence the selection of team participants in later projects. For instance, for many competition projects Alan Short participated in, where the engineering and construction teams were not pre-determined by the client, he frequently invited or convinced the clients to hire Max Fordham & Associates. Max Fordham also reciprocated with Short & Associates. This has led to a long-standing relationship between the two organizations for almost twenty years. In other words, if there is no future to influence, the participants will have little incentive to cooperate since they cannot anticipate an implicit business relationship from other participants. As long as the participants are not sure when the last interaction between them will take place, cooperation can emerge.

The study reveals that most EEIs were achieved by participants who had histories of working with each other or were familiar with each other. The possibility of further collaboration influences the tolerance and performance of team members. Such behavior is not emotional but rather logical, especially in an industry where names and reputations determine future jobs. The motivation to establish relationships is the desire to grow intellectually, professionally and financially. Figure 6 summarizes the working history of the core members who have contributed directly to the development of the EEI in the case studies.

Figure 6 Summary of the core members' working history

Project / Innovation	Core Participant	Number of Years working with each other	Number of Projects working with each other
Design Centre Linz	Thomas Herzog and Partners (architect) and Prof. Phil Jones (Design Flow Solution)	> 10	3
	Thomas Herzog and Partners (architect) and Christian Bartenbach (Lighting designer)	3-5	2
Contact Theatre, Coventry Library	Alan Short and Associates (Architect) and Max Fordham (Mechanical Engineer)	> 15	> 5
	Alan Short and Associates (Architect) and Kevin Lomas (Air flow analyst)	> 10	> 5
Four Times Square	Fox & Fowle Architects and Durst Coporation (Owner)	> 5	3
	Tishman Construction (Construction Manager) and Durst Corporation (Owner)	> 15	> 5
New Parliamentary Building	Michael Hopkins and Partners (Architect) and Ove Arup & Partners (Mechanical and Service Engineer)	> 10	> 5
Telus Headquarters	Peter Busby Associate (Architect) and Keen Engineering (Mechanical Engineer)	5-10	4

Also, by working with other professionals that they had coordinated with before, these design teams were able to improve their chances of successfully completing their energy efficient strategy for three primary reasons. The green alliance and criteria formulation process is facilitated by the relationship that has already been developed. The team members were already aware of each other's general professional and personal style and aims. It was easier therefore to gauge and meet each member's level of expectation. Second, this head start in relationship development reduces the amount of time needed to cultivate a stronger working relationship among the team members. From this perspective, networking within the team is facilitated. Individuals who were unfamiliar with each other were easily introduced by mutual relations and so on. Besides, EEIs involved incremental developments of the similar strategies in which participants may have already begun the development of energy efficient technology. Finally, the third reason is that the perceived risk of implementing EEI is reduced. Familiarity with specific approach and trust in other individuals reduce fears of failure or impossibility.

Summary

Relational competence is the compatibility of work relationships. It is the ability of a group to effectively leverage the collaborative efforts of several individuals, not only to generate innovative ideas but also to be able to transform the ideas into final products.

The study reveals that EEI can be generated and implemented by the participants who repeatedly work with each other if relational competency is achieved. In each of the cases, the degree of relational competence hinged upon several conditions (see Figure 7). First, the members within the group must not simply strive for a common objective for green design but be able to create a sense of ownership to the design approaches (ones that are formulated by the participants). Next, the value-based conviction that aims to minimize the environmental impacts appears to be vital to the perseverance of the teams' commitment and collaborative effort to EEI. The participants need to share not only their specialized skills with each other but also their knowledge and personal values relating to this larger environmental concern. Particularly in the projects that involve innovations, the responsiveness of each participant to provide expedient feedback will not only allow various thoughts to emerge but also strengthen teams' commitment and collaborative environment. Such prompt feedback can be achieved if the design process is concurrent and integrated rather than sequential and segmented.

The degree of relational competence also hinges upon the manner with which the group is led. In each case study, at least one individual whose concern centers on environmental stability must adopt the role of green leader. They assumed the responsibility and risks to coordinate and mitigate conflicts arising from the variances between specialized fields and maintained interest of team members in the environmental design strategies—as in EEIs. Each used different leading techniques, but each green leader demonstrated a facilitative leadership while maintaining certain decision-making influence when conflicts occurred. This hybrid style fostered an interactive and productive environment with minimal conflicts. Lastly, and most unexpectedly, the EEIs in this study have not all been generated by teams of recognized experts in energy efficient design. The design teams in this study were comprised of the professionals who were familiar with each other. To put it briefly, if participants have a sufficiently large chance to work together again, the commitment to innovative ideas and collaborative efforts are all the more likely. This is especially true since energy efficient design is typically developed incrementally through on-going collaborations. These aspects all contributed to the enhancement of 'relational competence' toward idea generation and implementation of unconventional energy efficient solutions.

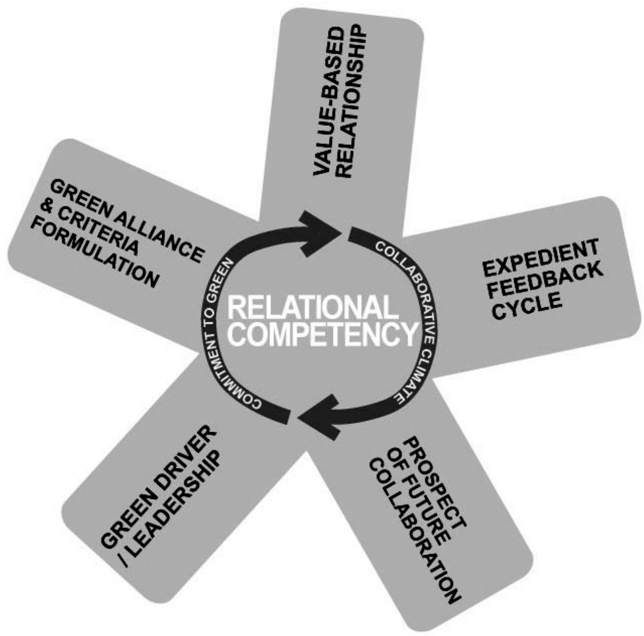

Figure 7 Relational competency for EEI

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