Lessons from implementing sustainable practices on public sector university projects

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Abstract:

The purpose of lessons learned is to capture any insights gained during a project that can be usefully applied on future projects. This research captured lessons learned from public sector university capital projects which adopted sustainability goals. The target population is institutional owners with multiple facilities in their portfolios, developed over time. The focus of this specific investigation is Virginia Tech and Georgia Tech. A case study based approach was utilized on appropriate candidate projects to determine how the project team implemented the sustainable practices. This involved a study of how participating organizations initially adopt sustainable principles and what lessons are learned from those initial attempts for use on future projects by the institutional owner. The case studies investigated whether there were any unanticipated consequences and recommendations from project stakeholders for future projects of a similar nature. The case studies conducted on the buildings at Virginia Tech captured the lessons learned from how Virginia Tech has implemented sustainable practices on its early projects. These are then compared with similar case studies performed at Georgia Tech. This helps in relating the practices followed in the two universities for implementing sustainability and provides information for other universities adopting sustainable construction practices.

Introduction and Background:

It is almost axiomatic in the field of construction that a project may be regarded as 'successful' if the project is completed on time, within budget, without any reportable accidents, to the specifications and to overall client satisfaction. Institutional owners are becoming increasingly interested in implementing the sustainable practices in an effort to reduce the use of natural resources, energy consumption, and emission of greenhouse gases and other pollutants. An institutional owner can be defined as an entity which has a large stake in a large capital portfolio of facilities. Universities are considered as institutional owners.

Various policies have been made by state and federal governments. For instance in Virginia, according to the Executive Order 48, all state agencies and institutions constructing state-owned facilities over 5,000 gross square feet in size, and renovations of such buildings valued at 50% of the assessed building value, shall be designed and constructed consistent with the energy performance standards at least as stringent as Leadership in Energy and Environmental Design (LEED) or Environmental Protection Agency (EPA) Energy Star rating (Commonwealth of Virginia, 2007). Similarly, various federal government organizations like the U.S. Army, U.S. Navy, U.S. Air force, and U.S. General Services Administration, made their commitments to implement sustainable practices (Flanders et al. 2001) As a result of such policies, all the state universities are required to implement the sustainable practices in their construction. According to the statistics provided by the Green Building Resource Center (GBRC) shown in Table 1, buildings are one of the major sectors that consume vast amounts of energy and emit harmful gases.

Table 1: Statistics of the energy consumption and emissions of buildings in U.S. (Source: GBRC 2011)

• 36% of total energy use
• 65% of electricity consumption
• 30% of greenhouse gas emissions
• 30% of raw materials use
• 30% of waste output (equal to 136 million tons annually)
• 12% of potable water consumption

It is essential to reduce energy consumption and the negative impacts displayed in Table 1, and progress towards more sustainable buildings. Sustainable design prevents pollution from the start and calls for systems thinking, which acknowledges the connections between the economy, the environment and social responsibility (U.S. EPA 2009). However, there is a growing body of examples that show us potential unanticipated consequences and poor performance of the sustainable practices implemented during construction. Many green products which help in sustainable practice implementation have been developed in the past five years, though these products have minimal on-site testing or performance verification (Odom and Scott 2008).

Lessons learned can be identified as "knowledge gained from experience, successful or otherwise, for the purpose of improving future performance" (CII 2007). Lessons learned can be seen as a part of an organization's knowledge management system and can help in performing future construction more efficiently. Universities are committed to implement sustainability plans. As explained, it is necessary for universities to identify the unanticipated consequences of implementing sustainable practices, and understand the importance of the lessons they learn. This would help them in future construction by minimizing the risks and costs involved in the maintenance.

Owing to the recent evolution of sustainability practices, the concept of building commissioning may not be completely effective in avoiding mistakes. The current approach to building commissioning, including LEED Enhanced Commissioning version Energy and Atmosphere (EA), is unlikely to prevent moisture and similar building failures in many climates, such as low rainfall, moderate temperatures all year round, and minimal humidity levels (Odom and Scott 2008).

The traditional practices to reduce the risk in buildings do not exceed industry guidelines on mechanically introduced outside air. Green buildings, on the other hand, reward the introduction of more outside air than current industry standards, which can lead to indoor humidity problems and mold growth (Odom et al. 2009). Green roofs could become hazardous during drought conditions. Schools having green roofs are facing an increased risk due to these conditions. The actual green roofs must include means of irrigation which helps in preventing risks (Perico 2008).

These examples illustrate potential problems involved in following sustainable practices, and also experiencing unanticipated consequences that can lead to major issues like the lawsuit filed against the USGBC. Henry Gifford, the owner of Gifford Fuel Saving, has filed a class action lawsuit in federal court against the U.S. Green Building Council and its founders, claiming that USGBC is misleading the consumers by moving consumers away from proven energy saving techniques and harming the environment (Zemtsteff 2010).

Various studies have been performed in the industry to identify lessons learned in implementing sustainable practices. According to studies made by the National Renewable Energy Laboratory (NREL) on six high performance buildings, they realized the studied building's performance is less than expected, the design teams were optimistic about the behavior of the occupants, occupants loads are much higher than anticipated during the design process, buildings are consuming more energy and generating less energy than expected, buildings temperatures are not set back as much as anticipated, and insulation values are often inflated when designing the building (Torcellini et al. 2004; Torcellini et al. 2006). Case studies were performed by NREL also on the new applications of photovoltaics in buildings (Hayter et al. 2002). In both cases NREL identified the problems involved with the current sustainable practices, and analyzed and provided recommendations for better performance of the buildings. Currently for universities, there are no such findings to help them to avoid the unanticipated consequences of implementing sustainable practices. Research exists that helps universities in understanding potential sustainable practices, but it does not explain the unanticipated consequences.

Methodology:

After reviewing a point of departure study conducted at Georgia Tech (Pearce et al. 2005) a questionnaire was created. A university architect was interviewed to identify Virginia Tech facilities that meet the criteria of having one or more of the following attributes:

- LEED Certified Project
- Project with sustainable goals but not LEED certified
- Project with funding for the building in the form of material donations
- Project with significant funding from corporate donors
- Project with technically advanced features

In these criteria, the first two are identified based on the requirement that buildings follow sustainable practices, and the next two because the donors might have an influence in the design phase of the building and this might have unanticipated consequences.

After identifying appropriate buildings, project managers involved during construction, and facilities personnel maintaining the buildings were identified and requested to participate in the research study. Two methodological approaches were used in acquiring the data necessary to answer this research. The first method took place in the format of a survey distributed in print or electronic form to project managers and campus architect of Virginia Tech after requesting their participation in this study. Survey questions were tailored specifically to match the building and the type of sustainable practices implemented and lessons learned during construction (See Attachment A).

The second approach for this research involved a personal interview with university architects as well as other project managers willing to participate. Site visits were scheduled during the interviews in order for the researcher to observe various construction processes underway at that time. These two methods were helpful in acquiring the data in an effective manner. Since the target population was busy professionals with other responsibilities two parallel approaches to data collection were chosen so we can collect the data from them according to their convenience. After collecting data at Virginia Tech and extracting lessons, the lessons were compared with the results of Pearce et al. study at Georgia Tech to draw conclusions about issues of concern.

Research:

As a state university, Virginia Tech has made a public commitment to reduce its environmental impact by following sustainable practices and using resources efficiently. As part of the Virginia Tech Climate Action Commitment and Sustainability Plan (VTCAC & SP), Virginia Tech is aiming to reduce the carbon footprint. Virginia Tech is geared to pursue LEED Silver or better for all new buildings and major renovations (VT 2009). Similarly, Georgia Tech has an initiative called Green Buzz and has modified its master plan to implement several sustainable practices. Hence, the focus on lessons learned in implementing sustainable practices during the construction would help future construction avoid the same mistakes.

As per the above mentioned criteria, this study included the following buildings at Virginia Tech.

Case Studies:

1. **Bishop Favrao Hall (BFH)**

Bishop-Favrao Hall (Figure 1), which serves the facility needs for the Department of Building Construction and the Myers-Lawson School of Construction, was completed in 2008. It has four floors, occupying a space of 31,651 square feet. The building has classroom space on first and second floors, faculty offices and seminar rooms on the third and fourth floors, and administrative offices on the fourth floor. It also has a workshop on the first floor.

Bishop Favrao Hall was conceived as a new facility that would facilitate the transformation of a well-established construction curriculum into one of the nation's leading construction programs was observed by the then department head, when Mr. Richard Bishop, alumni from the building construction department, approached to offer donations for the creation of construction laboratory (Ku and Ooi 2008). Construction planning for Bishop Favrao Hall began in fall 2006 with an estimated project cost of nine million dollars. Owing to the financial constraints from the proposal stage, the building was not LEED certified, although it was built confirming to those standards as closely as possible.

Figure 1: Bishop Favrao hall (Source: Naveen Sadhu)

The building itself was designed to be a teaching tool to help students in their learning. The mechanical, electrical, plumbing, fire protection, and electrical systems that are usually hidden behind walls and ceiling panels in other buildings are exposed and labeled. This helps students to clearly see the systems they are studying and assist them in learning and understanding the concepts in construction.

2. Henderson Hall and Theater 101

Renovated in 2009, Henderson Hall (Figure 2) houses the School of Performing Arts and Cinema and the School of Visual Arts, home to various music, theater, and arts programs. It has a space of 15,455 square feet distributed in three floors. This space includes computer and design labs, a lighting lab, critique and seminar rooms, scene and design model shops, a costume shop, an editing studio, a digital fabrication studio, and practice rooms for music situated in different floors.

This building has undergone changes many times since initial construction. It was expanded initially in 1902 and converted into an infirmary, with further changes in 1929 and 1951. It was later converted into offices for student affairs and placement services in 1998 after the infirmary was relocated. It was renovated again between 2007-09 to serve various music, theatre, and arts programs. It first served as the home for college presidents and was used by the president, Mr. Charles Landon Carter Minor when it was built in 1876.

Figure 2: Henderson Hall (Source: Naveen Sadhu)

Theatre 101 was constructed adjacent to Henderson Hall during its renovation in 2007-09. This building has 8,479 square feet distributed in two floors. It is home to the Department of Theatre Arts and Cinema since it opened in October 2009. Theatre 101 is an academic building with a high-tech black box performance space. It contains a large performance space with high-end computer-controlled systems and rehearsal space on the second floor.

Henderson Hall and Theatre 101 are the university's first LEED-certified buildings. Many sustainable practices were introduced during the renovation and construction of the buildings. The materials removed from Henderson hall during the renovation were recycled and reused in the construction of Theatre 101.

3. Institute for Critical Technology and Applied Sciences (ICTAS-II)

Construction of the ICTAS-II building (Figure 3) began in April 2009. It was the first major research building completed by Virginia Tech after its resolution of 'Climate Action Commitment and Sustainability Plan'. It has a total space of 42,190 square feet distributed on three floors. This building contains engineering-led research labs, offices, and workspaces. The institute supports and promotes cutting edge research at the intersection of engineering, science, and medicine. Thus, this building includes state-of-the-art research facilities with highly specialized research laboratories, which will support multi-disciplinary research areas including bio-nanotechnology, bio-materials, communications technology, and sensor technology. This building was open for occupancy in early 2011 and is expected to obtain a LEED silver certification.

Figure 3: ICTAS – II (Source: Naveen Sadhu)

The cost of this project was $35 million. This project incorporated various sustainable practices such as the use of fluorescent lights and efficient glass which allows more natural light in the office spaces thus lowering energy usage. The project also minimized the material usage by reducing the number of walls wherever possible. The pavement at the entrance is porous, allowing water to penetrate into the ground. All the labs and office spaces have occupancy sensors that help to reduce energy usage, when the place is not occupied. This project has reduced the heat island effect on the whole since the location of the building was initially a parking lot.

4. The Inn at Virginia Tech

Virginia Tech's new alumni and conference center facility is composed of three different facilities — an alumni center, a conference center, and a hotel. The building totals 193,000 square feet of space of which 29,000 square feet supports the Holzman Alumni Center; 75,000 square feet serves as the Skelton Conference Center; and The Inn at Virginia Tech (Figure 4) utilizes the remaining 89,000 square feet. The facility was occupied in June 2005.

The Skelton Conference Center houses a banquet hall that seats up to 700 people in addition to a pre-function space. There are also two 20-seat private dining salons, a 60-seat restaurant, and a café. More than 5,000 people can be accommodated in the indoor function area and outside terrace spaces. The Inn is made up of 147 guest rooms, six executive suites, ten conference rooms and a fitness and wellness facility. It also provides a demonstration kitchen and classroom for use by Virginia Tech's Department of Hospitality and Tourism Management.

Figure 4: The Inn at Virginia Tech (Source: Naveen Sadhu)

The following are the buildings that are considered as comparison case studies at Georgia Tech.

5. Food Processing Technology Building

The Food Processing Technology Building, (Figure 5) which officially opened in May 2005, is a world-class center for collaborative food processing technology development, academic research, and public interaction. Food Processing Technology Division researchers are focused on automation, information technology, food safety, worker safety, and environmental technology.

The building's high bay research area is a 4,370-square-foot space with a 34-foot ceiling, a three-ton overhead crane, a 16-foot x 24-foot climate control chamber, a modeling shop, and access via both a loading dock and semi-tractor trailer drive-in door. The building also contains specialized labs to support environmental analysis studies, optics research, software development, and electronic fabrication and troubleshooting. Funding for the building was provided through a mixture of state, private, and industrial dollars.

The building serves as headquarters for the Food Processing Technology Division of the Georgia Tech Research Institute, the nonprofit applied research arm of Georgia Tech. The division is a unique research unit focused on new technology developments for processing efficiency and operational enhancement in the food processing and poultry industries. It conducts significant research under two major programs: the Agricultural Technology Research Program (ATRP) and Georgia's Traditional Industries Program for Food Processing, which is managed through the Food Processing Advisory Council (FoodPAC) (Pearce et al. 2005).

Figure 5: FOODPAC Building – exterior and lobby view (Source: Pearce et al. 2005)

6. Sustainable Education Building (SEB)

Opened in 1998, the Lamar Allen Sustainable Education Building (SEB) (Figure 6) has a space of 30,000 square feet and is intended to serve as a living laboratory for the education, research, and application of sustainable technologies. SEB was built with special focus on sustainability principles, adhering to many of the ideas that are now taught inside Georgia Tech classrooms. SEB was constructed using some of the most up-to-date sustainable materials in Georgia, that are produced in a more environmentally sound way and will last longer. From its networking capabilities to the concrete selection, and in the design aspects, the building was built through donations from about 40 businesses and individuals. The four million dollar facility has a multimedia theater, research labs, computer centers and faculty offices for the School of Civil and Environmental Engineering (Hughes 2004).

Figure 6: SEB (Source: Pearce et al. 2005)

The building is named after Mr. O. Lamar Allen. Mr. Allen was the visionary who conceived the idea of SEB to educate future engineers to better understand the relationship between economic development, technology, and the environment. Mr. Allen had the vision of creating a building at Georgia Tech where the areas of environmentally conscious design could come together with manufacturing and sustainable technologies.

7. College of Management Building

The College of Management Building (Figure 7), completed in 2003, was the first officially LEED Certified facility on the Georgia Tech campus. Certified as LEED Silver, this facility is part of the award-winning Tech Square redevelopment of central Midtown in Atlanta. The four-story building serves as the new home for the College of Management and also houses the Institute for Sustainable Technology and Development, the Environmentally Conscious Design & Manufacturing Program, and the Barnes & Noble store at Georgia Tech bookstore.

Figure 7: College of Management Building (Source: Pearce et al. 2005)

The project incorporates many environmentally friendly features that serve as a model for future sustainable construction on the Georgia Tech campus. For instance, the outdoor and indoor water conservation technologies reduce water use by more than 50% and include low-flow toilets and fixtures, graywater trap recharge systems, and drip irrigation systems. The computerized Energy Management and Control System optimizes energy use and increases energy efficiency by 16.5%. The high efficiency filters, low-emitting paints and furniture as well as the carbon-dioxide monitor alert system maintain high indoor air quality. Using recycled building materials and recycling consumer waste also contribute to the building's sustainability.

8. Georgia Tech Aquatic Center

The Georgia Tech Aquatic Center (Figure 8) was constructed as a swimming and diving venue for the 1996 Summer Olympic Games in Atlanta. It features 3/4 of an acre of photovoltaic (PV) panels and a solar hot water heating system to pre-heat pool water. This facility was selected as a case study for evaluation since it is an actively-sensored living laboratory in which sustainable building technologies are used for research and education as well as serving their functions as components of an actively used campus facility. At the time of its construction, it was the largest building-integrated photovoltaic array in the world, although it has since been superseded by a larger system in Bonn, Germany.

Funding for the $5.2 million photovoltaic system came from Georgia Tech, Georgia Power Co. and the U.S. Department of Energy. During its first year of operation, the PV array operated close to its design efficiency, but produced less power than expected overall due to several environmental factors. The PV array on the Aquatic Center functions as a living laboratory for the University Center of Excellence in Photovoltaic Research and Education (UCEP) housed in Georgia Tech's School of

Electrical and Computer Engineering. It is equipped with a data acquisition system that is linked in real time to the Center's web site, providing live and historical performance data to anyone who is interested worldwide.

Figure 8: Georgia Tech Aquatic Center (Source: Pearce et al. 2005)

Results:

Interviews and surveys were used to collect information about unintended consequences of these projects which serve as a basis for lessons learned. The lessons learned are divided into various categories depending on the system type to which they apply. The combined lessons that are learned from case studies performed at Virginia Tech and Georgia Tech are as follows.

Roofs

1. The type of roof that needs to be installed depends on the location of the project. LEED gives a credit for using a white roof as they are considered to be an energy-efficient roofing option due to their high albedo. This is because a light colored roof absorbs less heat. But at Virginia Tech white roofs became brittle due to inappropriate design standards for the cold weather climate and cracked when the maintenance personnel tried to work on it. Thus white roofs are no longer favored on Virginia Tech buildings.
2. It has been observed that the surface of a black roof (Figure 9) can experience a temperature increase much higher than white roof under the heat of the full sun. Given that Virginia Tech is located in a

cold region, a black roof is more appropriate since the black roof captures the heat and provides more insulation.

3. In order to account for the aforementioned cold weather conditions, Virginia Tech started using Ethylene Propylene Diene Monomer (EPDM) roofs that help in heat recovery and thus help in conserving energy. Virginia Tech also recognized that the Polyvinyl Chloride (PVC) roofs are not recyclable whereas the EPDM roofs are. Hence, Virginia Tech has taken the initiative of recycling EPDM roofs and got a LEED credit for it on one project.

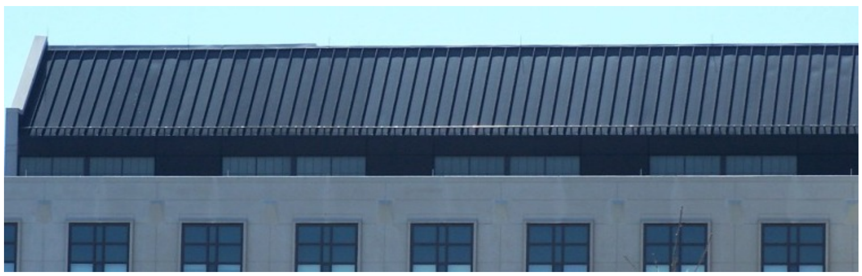

Figure 9: Black roof at ICTAS-II (Source: Naveen Sadhu)

Ceilings

1. An open ceiling (Figure 10), helps in the reduction of usage of materials. It also helps to identify any leakages (Figure 11) in the pipes with exact location, thus enabling the maintenance personnel to perform quick maintenance.

Figure 10: Open ceiling showing utility pipes (Source: Naveen Sadhu)

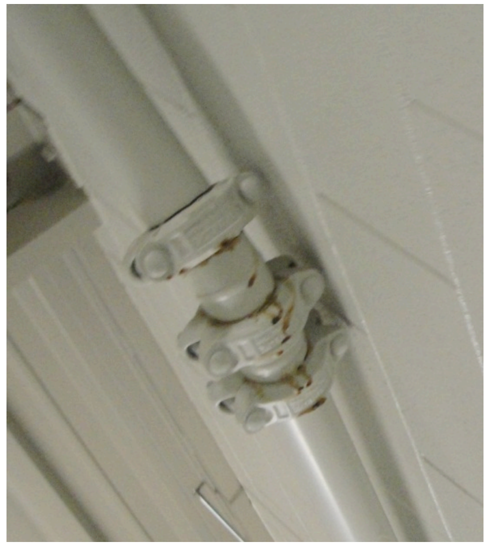

Figure 11: Leakages in utility pipes (Source: Naveen Sadhu)

2. Exposing the utilities that are installed in the building allows construction students see what they are studying and there by assisting them in learning. Thus, buildings with this feature are also acting as a laboratory for the students.
3. VT personnel observed that it is hard to maintain the utilities when they are built one above the other in the ceiling (Figure 12). Hence, it is advised to stack the pipes one above the other on the side walls rather than on ceiling so that they can add more utility pipes can be added easily in future if necessary and will also be convenient for maintenance.

Figure 12: Utility systems arrangement in the ceiling (Source: Naveen Sadhu)

Carpets

1. It is easy to install and maintain carpet tiles than carpet rolls. Unlike the carpet rolls where the entire carpet on the flooring needs to be removed, which is expensive, carpet tiles can be conveniently and less expensively removed if there is a maintenance issue (Figure 13).

Figure 13: Removal of a carpet tile for maintenance (Source: Naveen Sadhu)

2. In one of the case studies an issue has been identified where conventional adhesive backing on the carpets was not used to achieve a LEED credit for Indoor Air Quality. The carpet was installed on the wooden floor. This created problems for the maintenance personnel since the carpet did not properly bond and slips from the floor.
3. Virginia Tech and Georgia Tech both have an initiative of using carpet tiles having recycled content.

Windows

1. More windows in buildings helps in allowing more natural light into the building, thus reducing the usage of artificial light during the daytime and conserving energy.
2. Due to large glass windows, the occupants with space closer to windows suffered from excessive natural lighting (glare) while occupants in the center of the floor suffered from low natural lighting. Hence, the occupants using center of the floor have to use artificial light (Figure 14).

Figure 14: Uneven distribution of light (Source: Naveen Sadhu)

3. In one project, glare was later taken into consideration and blinds were installed on the windows which prevented the natural lighting from entering into the building and subsequently led to the usage of more artificial light (Figure 15).

Figure 15: Using artificial light (Source: Naveen Sadhu)

4. There is also an issue of uneven distribution of light when blinds in some rooms are closed and in some rooms are open (Figure 16).

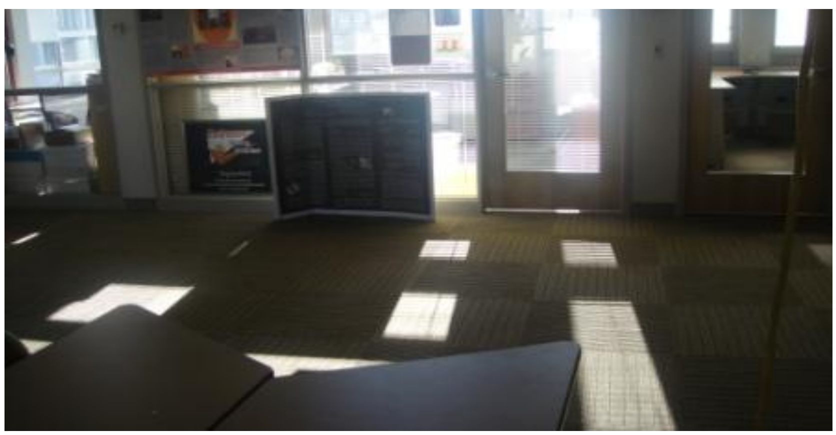

Figure 16: Uneven distribution of light (Source: Naveen Sadhu)

5. Having more windows on a building can lead to poor performing building envelopes, resulting and resulting in extreme temperature when the HVAC is turned off (Figure 17).

Figure 17: Excessive windows (Source: Naveen Sadhu)

Restrooms

1. Use of automated flush valves and low flow automated faucets in the restrooms helps to reduce the usage of water and improve energy efficiency (Figure 18).

Figure 18: Low flow automated Faucets (Source: Naveen Sadhu)

2. In one case study, the rechargeable capacitors in the flush valves did not work, and it led to replacement of all flush valves with in the first year of their installation. This issue was due to the usage of the first generation of automated flush valves from a vendor. This was a costly issue for the maintenance during the replacement (Figure 19). As a result, the university prefers to use flush valves with a proven track record at the university.

Figure 19: Flush valve (Source: Naveen Sadhu)

3. The traps in one building's restrooms are primed using gray water from lavatory sinks by a small line attached to the sink drain. These lines tend to get clogged with soap residue under low use conditions, leading the traps to dry out and sewer gases to be released. Under higher use conditions, they perform as intended. The university now considers likely use patterns when designing similar systems.

Lights

1. Light-emitting diode (LED) (Figure 20) lights tend to consume less energy when compared to the High Intensity Discharge (HID) (Figure 21) lights and produce same amount of illumination. But it is observed that some of the LED lights that have been used in one project's parking lot are actually consuming more energy than HID lights.
2. The LED fixtures that were needed for a pole to obtain light levels and distribution desired were more than the number of HID lights required. Thus even though each LED fixture may consume less energy, so many were required that the energy consumption for this lot with LED fixtures uses more energy than a comparable lot lit with HID fixtures.

Figure 20: LED lighting in the parking garage (Source: Naveen Sadhu)

Figure 21: HID lighting in the parking garage (Source: Naveen Sadhu)

3. It is observed that the fluorescent lights (Figures 22 and 23) are more energy efficient and durable and hence, are being used in the new construction projects at Virginia Tech.

Figure 22: Fluorescent light (Source: Naveen Sadhu)

Figure 23: Fluorescent light (Source: Naveen Sadhu)

Sensors

1. Occupancy sensors are being used to reduce the energy use as they help in switching the lights off when the room is unoccupied.
2. Occupancy sensors (Figure 24) controlling lights in rooms such as labs, office spaces, supply closets and copy rooms are programmed to remain turned on for a period of time after the people leave.
3. Despite the fact that light switches can still be controlled by occupants, many occupants became accustomed to the idea that "the sensor will turn the light off for me" and no longer use the manual light switches. This can lead lights in the building to stay on for longer durations and increase the usage of energy.

Figure 24: Occupancy sensor (Source: Naveen Sadhu)

Thermal comfort

1. There has been an issue at Virginia Tech with maintaining the anticipated temperature in buildings. It is observed that some of the reasons are having large number of windows around the building, and varying levels of insulation in the building.
2. It is difficult to maintain the same temperatures in different rooms due to the presence of the standalone control system (Figure 25) for temperature setbacks. These control systems help in regulating the temperature of the entire building instead of each individual room which can lead to occupant discomfort.

Figure 25: Control system (Source: Naveen Sadhu)

Further issues

1. Despite the fact that high efficiency systems are being used in the construction of some buildings, they often do not get replaced with the same type of product, at the end of their service lives, meaning that the system does not perform as intended. This is reflective of a larger disconnect between standard maintenance practices/policies and the effective incorporation of innovative sustainability technologies.
2. Value engineering affects the projects as it can lead to many design changes in the original design, which may some time lead to issues where the system does not perform as intended.
3. It can be more expensive to both install and maintain green technologies than conventional, familiar systems.
4. Some green materials such as low Volatile Organic Compounds (VOC) paints are not perceived to be as durable as the regular paints.

Summary:

In summary, the research methodology comprised a literature review of unanticipated consequences of sustainability practices, personal interviews with campus architects and subsequent identification of case studies. This was followed by collecting data from project managers and facilities personnel through interviews/surveys. The data obtained was analyzed and can be summarized in Tables 2 and 3.

Table 2: Systems that performed as intended

Buildings / Observed Practices	BFH	HH	The Inn	ICTAS-II	FPTB	SEB	Coll. Mgt. building	GT Aquatic center
Black roof installation		X	X	X				
Open ceilings	X	X		X		X		X
Use of Carpet tiles	X	X		X		X	X	
Use of Low flow automated faucets	X	X		X		X	X	X
Use of Fluorescent lights	X	X		X	X		X	

See Attachment B

Table 2 shows the systems that performed as intended. Black roof installation is only limited to Virginia Tech. This is a significant factor because Virginia Tech installed these systems even though they did not win any LEED credit for using this system. At the same time, other systems such as low flow automated faucets, and fluorescent lights helped the universities in reducing their energy consumption and improving efficiency.

Table 3: Systems that did not perform as intended

Issues \ Buildings	BFH	HH	The Inn	ICTAS-II	FPTB	SEB	Coll. Mgt. building	GT Aquatic center	Other Buildings
White roof issues									Virginia Tech Library
Lack of adhesive backing leading to maintenance issues		X							
Issues with Windows	X					X			
Issues with first generation rechargeable capacitors		X							
Graywater issues in rest rooms							X		
Occupancy sensors issues		X		X	X		X		
Use of LED lights									VT Parking lot
Thermal discomfort	X	X		X		X			
Issues with replacement of same technology					X	X		X	
Value Engineering	X	X			X	X			

Table 3 shows the systems that did not perform as intended. Some non performing examples were building specific such as the failure of the first generation flush valves at Henderson Hall, Virginia Tech., or the graywater system at College of Management building, Georgia Tech. Even though these failures are unique they are important to consider because they might lead to an expensive maintenance. Non-performance systems such as occupancy sensors, thermal discomfort and value engineering should be addressed as they are common in both universities. "Other buildings" column in Table 3 is the buildings not involved in the research.

Future Research:

This research is limited to insights obtained by interviewing owner's representatives (Project Managers) during construction and the facilities personnel responsible for building maintenance. Since many of these buildings were recently constructed/ occupied, post occupancy evaluation has not been conducted through interviews/surveys with the building occupants. Research on post occupancy experiences might identify additional information about the issues faced by building occupants due to the sustainable practices employed. The current study is also a potential point of departure for future research by examining the extent to which subsequent projects at both universities will employ present findings. At the time of research, it was observed that the maintenance personnel provided more insights, than design and construction personnel as they are responsible for building maintenance.

The current research findings are being submitted to university architects of both campuses to enable early adoption of such practices in future projects and avoid repeating mistakes. In addition, there is scope for this research to be published as a journal paper to assist project managers interested in adopting sustainability practices in project management.

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Appendix

Attachment A

The following was the IRB survey that was submitted to the project managers during the surveys.

Re: Lessons Learned by the Analysis of Green Capital Projects at Virginia Tech

Dear Mr. / Mrs. XXXXX,

I am Naveen a graduate student currently pursuing my Masters in Construction Management. I am writing to invite your participation in a survey to identify lessons learned during the capital project delivery process at Virginia Tech. The focus of this study is specifically on green projects or projects with unusual funding mechanisms. As you may know, Virginia Tech has embraced a goal to reduce its carbon footprint, and an important part of reaching that goal will be to increase the sustainability of new facilities being constructed on campus.

As a project manager for one or more projects with green attributes on campus, we'd like to obtain your input about what went well on those projects and what you'd wish could be done differently on future projects. The results of our study will be useful not only to Virginia Tech in future capital projects, but also to other project managers at similar universities around the U.S. In fact, this study parallels a similar study conducted recently at Georgia Tech, and we hope to be able to compare and contrast the lessons learned between the two institutions as part of our analysis.

Specifically, we'd like to ask you about the innovative or green features of your project, what it was like to deliver a project with those features, and what you'd recommend on future projects that attempt to incorporate those features. If you are able to find the time in your schedule, we would also like to do a walk-through of the building and take photographs of the features you discuss. Finally, we would be happy to follow up with other information you can suggest, such as commissioning reports, discussions with subcontractors, or other measures that can help us gain insight into Virginia Tech's experiences with green product innovations.

Mr. Bruce Ferguson has recommended that we contact you via email to obtain your input to the study, so we are attaching a questionnaire that you can complete at your convenience and return via email to me at (nbsadhu@vt.edu; 540-553-6058). If you are willing to provide a walk-through of the facility so that we can take photographs of the building, please indicate as such on the survey when you respond. If you would prefer to reply to the questions in an interview rather than via email, please let us know and we'll be happy to interview you instead.

Thanks in advance for your help! Please feel free to contact either me or my faculty supervisor, Dr. Annie Pearce in the Department of Building Construction (apearce@vt.edu; 540-818-7732) if you have any questions about this survey or the larger study of which it is a part.

Project Name: XXXXXX

Note: the pages following this sheet contain a form that provides spaces for your answers to the second question below.

1) What were the most notable **innovative or green** features incorporated on this project? Please include any innovative or green construction **practices** used in addition to technologies or features of the building itself.

2) For each identified feature, please respond to the following questions (see following pages):
    a. What was the feature or practice?
    b. Who was involved?
    c. What was the benefit or reason for incorporating the feature or practice?
    d. Were there any unusual requirements or experiences involved with its delivery? Did it affect project schedule or cost?
    e. Have there been any unusual outcomes as a result of its incorporation in the project?
    f. Do you have any advice for future projects regarding this innovation?

g. Can you recommend any additional sources of information about Tech's experience with this feature or practice?

3) For the project overall:

   a. In hindsight, what, if anything, do you wish had been done differently to make the project more successful?

   b. What would you recommend to a project manager undertaking a similar project in the future?

   c. How have you changed your practices or opinions as a result of working on this project?

d. Can you recommend anyone else we should contact to learn more about this project and lessons learned from it?

Thank you for your contribution to this study! Please see the following pages for space to answer questions about each innovation mentioned earlier.

<table>
<tr><td>Innovative Technology or Practice:</td><td>Who was involved?</td><td>Benefits/Reasons for Using Innovation:</td></tr>
<tr><td colspan="3">Unusual requirements during project delivery/impacts to schedule/cost:</td></tr>
<tr><td colspan="3">Unusual or unanticipated outcomes:</td></tr>
<tr><td colspan="2">Advice for others:</td><td>Additional sources of information:</td></tr>
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Innovative Technology or Practice:	Who was involved?	Benefits/Reasons for Using Innovation:
Unusual requirements during project delivery/impacts to schedule/cost:		
Unusual or unanticipated outcomes:		
Advice for others:		Additional sources of information:

Innovative Technology or Practice:	Who was involved?	Benefits/Reasons for Using Innovation:
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Attachment B

BFH: Bishop Favrao Hall

HH: Henderson Hall and Black box Theater

ICTAS-II: Institute of Critical Technology and Applied Sciences

FPTB: Food Processing Technology Building

SEB: Sustainable Education Building

Coll. Mgt. Building: College of Management Building.

GT Aquatic center: Georgia Tech Aquatic Center