Designing Perpetual Sustainability Improvement Programs for Built Infrastructures

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Abstract

The impacts on energy generation and use on sustainability, increasing energy demand, and declining natural resources have made energy improvements a top priority for many organizations. But adequate financing for sustainability improvement projects for built infrastructures is not available. The Paid-From-Savings approach can leverage savings to pay for energy improvements. Although well established and adopted by many organizations, an incomplete understanding of the dynamics of these revolving fund programs hinders their effective and efficient use. In the current work the Harvard Green Campus Initiative and a Texas A&M University sustainability improvement programs were used to develop a dynamic model of a revolving sustainability fund. The validated model is used to test the effectiveness of three project planning strategies and two financing alternatives. Results indicate that with adequate funding it was most advantageous to proceed with all projects as quickly as possible and that with insufficient initial funding the best strategy depended upon the program objectives (e.g. earliest completion, largest fund, minimum negative fund balance). Contributions to sustainability and system dynamics modeling and future research opportunities are discussed.

Keywords: Sustainability, Financing, Project Scheduling, System Dynamics, University Fund

Introduction

Limited resources and increasing human activities that damage the environmental, social, and economic well-being of societies require the development of sustainable infrastructures and practices. The undesirable impacts of the exploration, production, and use of fossil fuels make energy conservation a major component of improving sustainability. Built infrastructure is critical to energy sustainability improvements. In 2008, the building sector (e.g. single and multi-family residential buildings and commercial buildings) consumed 40% of primary energy and

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nearly 70 percent of all U.S. electricity consumption and was responsible for 40 percent of total U.S. greenhouse gas emissions (Chapter1. Building Sector; Hendricks, Goldstein, Detchon, & Shickman, 2009). Consequently, reducing energy consumption in built infrastructure can provide both operational savings for the owners and improve the environment by improving air and water quality. The current work investigates an innovative approach to improving the sustainability of buildings and other built infrastructures.

Many new building construction projects are incorporating improved sustainability features. Programs such as the Leadership in Energy and Environmental Design (LEED) in the United States (An Introduction to LEED, 2011) have established standards for such work. However, improving the sustainability of infrastructures built prior to such standardizations is also critical to improved overall sustainability efforts. This is due to the long lifespan of most built infrastructures which creates a stock of existing buildings that far exceeds the rate of new construction. According to Department of Energy's Annual Energy Outlook, only about 2 percent of new floor space is added to the commercial building stock each year (Energy Information Administration, 2010). This results in large negative environmental impacts, such as the production of 35% of the carbon emissions in the North America (Cascadia Region Green Building Council, 2011). Improved energy use in existing buildings can drastically reduce the negative impacts on the environment and occupants. As will be shown, some sustainability improvements can also improve the economic viability of the facilities.

However, improving the energy efficiency and therefore sustainability of existing built infrastructure is difficult. For example, owners and tenants of rented building spaces may not share incentives to improve the facility if the tenants are directly responsible for utility costs. Decision makers may be unaware of the quantifiable benefits and opportunities from improved building energy systems. Funds for improvements may be, or appear to be, unavailable or payback periods too long compared to other uses of limited funds (BASF The Chemical Company, 2009). The financial barriers are particularly challenging and the focus of the current work.

Public agency policies have been used to address the financial challenges of improving the sustainability of existing built infrastructure, including energy performance. At the federal level the National Energy Policy Act of 2005 and Emergency Economic Stabilization Act of 2008, and the American Recovery Reinvestment Act of 2009 have had major impacts on green building. These policies provided tax incentives or grants for constructing new facilities that exceed the current energy standard or for renovating existing facilities that exceed the ASHRAE 90.1 standard (Tax Incentives Assistance Project, 2012).

However, despite the general information and recommendations available in the literature, the operational design, funding, and management of projects sustainability improvement projects for built infrastructure remain unclear. The current work investigates the features of paid-from-savings concept by using systems dynamic. The concept is illustrated through a case study project. The next section describes the specific problem that is investigated. This is followed by a brief description of the research methodology and then a description of the case study and how data was collected. A description of the model structure is followed by validation and calibration information. We then describe how the model was used to investigate the two research questions and the results. Finally, conclusions are drawn concerning the contributions of the work and potential future work.

Problem Description

Project planning and financing are two critical aspects of sustainability improvement projects. Project planning includes flexibility and creative thinking. For example, one of challenges of energy retrofit projects is the phasing of the project around existing equipment locations, occupants and hours of operations. A recent energy improvement project for a federal courthouse required relocating occupants to reduce disrupting the facility activities. Due to the sensitivity of the documents in the facility work could only proceed in the evening from 6pm to 4am. This affected the labor cost and required detailed planning prior to engaging in the improvement activities (Kumar, 2011).

Project financing is a second critical aspect of sustainability improvement projects for existing infrastructure. Financial metrics are a common standard for evaluating project performance. Organizations typically assess projects based on net present value and benefit cost ratios. Different project financing structures can create different returns on investment. Given that most owner lack the full amount of investment capital to self-invest in the energy improvement projects, project planners and managers are faced with tough decisions when evaluating alternative financing methods. Several financing structures are available. For example, the US Department of Energy has partnered with Rebuild America to encourage energy efficiency enhancement in built infrastructures. A publication by Rebuild America, “The Energy Smart Guide to Campus Cost Savings” helps organizations achieve energy savings goals by identifying energy savings opportunities, possible solutions and by suggesting various methods of financing (National Renewable Energy Laboratory (NREL), 2003). The guide proposes several options for financing energy improvement projects including internal financing, debt financing, tax-exempt lease, energy performance contracting. Table 1 summarizes these financing options.

Table 1- Financing Options for Energy Projects (U.S. Environmental Protection Agency, 2010)

	Internal Funds	Debts (Bonds)	Tax-Exempt Leases	Energy Performance Contracts
Interest Rates	If applicable, flexible and left to the discretion of the institution	Lowest tax-exempt rate	Low tax-exempt rate	Can be taxable or tax-exempt
Financing Term	If applicable, flexible and left to the discretion of the institution	May be 20 years or more	Up to 10 years is common and up to 12-15 years is possible for large projects	Typically up to 10 years, but may be as long as 15 years
Other Costs	N/A	Underwriting, legal opinion, insurance, etc.	None	May have to pay engineering costs if contract not executed
Approval Process	Internal	May have to be approved by voters via referendum	Internal approvals needed. Simple attorney letter required	RFP usually required; internal approvals needed
Approval Time	Current bud-get period	May be lengthy – process may take over a year	Generally within one week	Generally within 1-2 weeks once the award is made
Funding Flexibility	Varies by institution	Very difficult to go above the dollar ceiling	Can set up a master lease, which allows you to draw down funds as needed	Relatively flexible. An underlying municipal lease is often used
Budget Used	Either	Capital	Operating	Operating
Greatest Benefit	Direct access if included in budget	Low interest rate because it is a general obligation of the public entity	Allows you to buy capital equipment using operating dollars	Provides performance guarantees that help approval process
Greatest Hurdle	Never seems to be enough money available for projects	Very time consuming and energy project not always a priority	Identifying the project to be financed	Identifying the project to be financed, selecting the energy service provider

Many types of sustainability improvement to existing built infrastructure can generate cost savings. This is particularly true of energy conservation projects. Private industry has used this benefit to respond to the need for financing sustainability improvement projects. For example, engaging in a Energy Performance Contract (EPC) with Energy Service Companies (ESCOs) reduce the need for upfront capital by owners and provide the cost and expertise needed to efficiently manage energy performance improvements. ESCOs are large energy service providers with the capability to audit, design, install, manage and arrange the financing for the project. Energy performance contract (EPC) projects may be financed by ESCOs or third-party financial institutions. When ESCOs arrange the financing the savings are usually shared between the host facilities and the ESCO. ESPCs allow Federal agencies to accomplish energy savings projects without up-front capital costs and without special Congressional appropriations. In FY2006, the total investment in Energy Savings Performance Contracts by various federal agencies (including the DOE Super-ESPC program, Army, Navy, and Air Force) was $321 million (ICF International, 2007). Although this model has been around since the early 1970s, it wasn't until the mid-1980s that companies began to recognize the realized savings from these endeavors.

There are many types of third-party financing options that are available (tax-exempt lease purchase, state or local government leasing, state or local government bonds, revolving loan, power purchase agreement).

A revolving loan is a type of third-party financing vehicle that is available and is the focus of this study. A revolving loan fund is a loan established for a specific purpose in which interest and principal payments are used to issue new loans with the same purpose (Barlow & Putman, 2009). Revolving fund strategies for financing sustainability improvements are sometimes called Paid-From-Savings strategies because the reduced costs of the (successful) improvements are used to pay back the load and fund future improvements. Typically, when the host facility obtains the loan from a third-party, the ESCOs guarantee a minimum energy cost savings. If at any time during the contract the verified energy cost savings produced by facilities improvements are less than the guaranteed amount, the ESCO is required to pay the difference.

Several universities use revolving funds in combination with energy performance contracts (ESPC) to leverage savings to pay for energy improvements in existing buildings. If designed properly and operated efficiently revolving funds can create perpetual, self-funding, sustainability improvement programs. As an example, 32 institutions including Harvard, Stanford, Arizona State universities are committed to invest $65 million in green revolving funds through a program called $1 Billion Green Challenge (Billion Dollar Green Challenge). However, due to their relatively large initial capital investments and intensity of resources to manage projects, revolving loan fund may not be a feasible solution for all campuses.

The dynamic aspects of revolving fund sustainability programs can determine their success or failure. Meeting financial obligations and providing adequate funds for future projects require careful planning of cash flows and investments, as well as predictions of cost savings, from sustainability improvement. Expensive sustainability improvement projects or those with low Benefit-Cost ratios may severely limit improvements. Inadequate total savings can greatly delay future improvements and threaten repaying initial funding sources. The misallocation of savings among stakeholders or aggressive loan repayment requirements can have similar effects.

Despite the availability of general guidance and success stories, planners of revolving fund sustainability programs have little program planning advice as it relates to the sustainability fund. The guidelines published by USGBC and Rebuild America do not provide a transparent structure that allows quantitatively comparing programmatic design alternatives. Therefore, to improve the understanding of revolving fund sustainability programs, this study seeks to answer the following questions:

- What is the impact of project scheduling on the performance of sustainability fund?
- What is the impact of financing structure on the performance of sustainability fund?

Both of these questions will help decision makers to develop improved sustainability programs for existing infrastructure.

Methodology

Systems dynamics was used to model a sustainability fund and the planning of its associated sustainability improvement projects. In particular, this research focused on how the performance of a sustainability fund evolved in response to different management strategies and under different financing structures. In the past, system dynamics has been successfully applied to a variety of project management issues, including failures in project fast track implementation (Ford & Sterman, 1998) poor schedule performance (Abdel-Hamid, 1988) and the impacts of changes (Rodrigues & Williams, 1997; Cooper, 1980) and concealing rework requirements (Ford & Sterman, 2003)on project performance. System dynamics has also been applied to various financial issues. Therefore, the method can be useful for the current investigation.

The traditional system dynamics modeling method was applied (Sterman, 2000). This study focused on impacts of project scheduling and financing structure on project performance, where performance was measured by the size of the sustainability fund. To address project scheduling three different project sequencing scenarios were investigated. These scenarios prioritized projects based on the amount of saving, benefit-cost ratio and the size of the projects. Project financing was investigated to determine the impact of the initial investment in the sustainability funds on program performance.

The Case Study Sustainability Improvement Program

Facility Improvements

The model was partially formulated and calibrated with data used from an energy conservation project which Texas A&M University implemented in the beginning of 2011. The overall improvement effort consisted of two loans (aka two phases); one for $10 million to upgrade 17 existing facilities and second for $5.1 million to upgrade seven additional facilities. This study investigated the 17 facilities that were part of the Phase I improvements. The case study program included improving five parking garages and 13 teaching and research facilities. The TAMU Utilities Energy Management department (UEM) led the effort, which primarily improved the HVAC and building automation systems and increased lighting efficiencies across campus. The improvement work began and was completed within the calendar year 2011.

The project included improving over 4 million square feet of space. Parking garages had the largest areas ranging from 200,000 square feet to approximately 1 million square feet. The 13 teaching and research facilities were much smaller, generally less than 200,000 square feet. The majority of work included building-automation system (BAS) upgrades and parking garage lighting retrofit. BAS optimization includes better control of HVAC equipment in buildings. For example, occupancy sensors were installed and tied to equipment controllers to minimize air flow during unoccupied periods. Installation of occupancy sensors allowed eliminating conditioning and lighting spaces when unoccupied. Building reset and setback schedules were implemented to further reduce unnecessary energy consumption. Building setback schedules refers to setting appropriate temperature set points for heating and cooling during different times (daytime/nighttime) based on occupancy (occupied/unoccupied) to maximize occupant comfort while minimizing heating and cooling energy costs. Lighting retrofits included replacing inefficient lamps with high efficient, energy saving lamps. Parking garage improvement included lighting retrofits, whereas the 13 teaching and research facilities had a combination of various improvements. For the 13 teaching and research facilities; the most improvements tied occupancy sensors or shut the heating, ventilation, and air conditioning (HVAC) off during unoccupied periods. The second most practiced improvement was resetting the supply static pressure for variable air volume (VAV) system and providing or converting air handling units (AHUs), exhaust fans and zones to direct digital controls.

Funding for the project was provided by Texas State Energy Conservation Office (SECO) under the federal American Recovery and Reinvestment Act (State Energy Conservation Office, 2010) to Texas A&M University (TAMU) at 2% annual interest rate. Texas A&M University engaged in a guarantee performance contract with Siemens, a large energy service company (ESCO), to carry out the work (SiemensIndustryUS, 2011). The term of the Contract was 10 years. The guaranteed savings included an aggregate verified savings for the 17 facilities each year over the entire term of the Contract

Baseline consumption was measured with data from complete building energy use records for 2009. This baseline consumption was the reference for comparing the actual consumption during the Performance Guarantee Period to determine the Actual Realized Savings. Three types of commodities were identified to determine the total utility consumptions; electricity, chilled water, and heating hot water. Electricity was measured in kilowatt hour (kWh). Chilled water and heating hot water were measured in Million British Thermal Unit (MMBTU). Total annual baseline consumption was determined by converting the kWh's to MMBTU's ($1^{kWh} = 0.0034^{MMBTU}$).

The predicted annual savings were obtained from the Utility Assessment Report that was prepared by Siemens for TAMU. The report summarized the annual savings for each individual building. Parking garages were predicted to have the most savings ranging from almost 30% to as much as 50% in savings. Twelve of the thirteen research facilities were predicted to have an annual saving between 10-30% from the baseline consumption. The Zachry Engineering Center had the lowest predicted annual savings of 5%. The total predicted cost savings per year was estimated to be $1,126,099. Of the total predicted savings, total utility savings was $1,080,604 and operational savings was $45,495.[5] The total guaranteed savings for ten years was $1,126,099 ($1,080,640 energy and $45,495 operations) per year. This table was also used to verify if the assumptions for the yearly loan payment were reasonable. The guaranteed savings

[5] Predicted operational savings was estimated at 4.21% of the predicted utility savings

was more than the (modeler estimated) calculated yearly payment of $1,114,859.84. Including the $20,000 of measurement and verification cost the total expense equaled $1,134,859.84.

Model Structure

Conceptual Model

Harvard University is a good example of an academic institution that utilized the paid-from-savings concept. Harvard created a Green Campus Loan Fund (GCLF) (Like, 2009). GCLF at Harvard alleviates the need to find up-front capital costs for projects that result in improving the environment. The conceptual model structure for the current work is similar to the existing paid-from-savings program at Harvard. A recent publication by Harvard University titled "Green Campuses: The Road from Little Victories to Systemic Transformation", reported on the progress the University has made in energy improvements around the campus. A diagram in this report is a suitable representation of a conceptual model of the paid-from-savings philosophy as presented by USGBC (Figure 1).

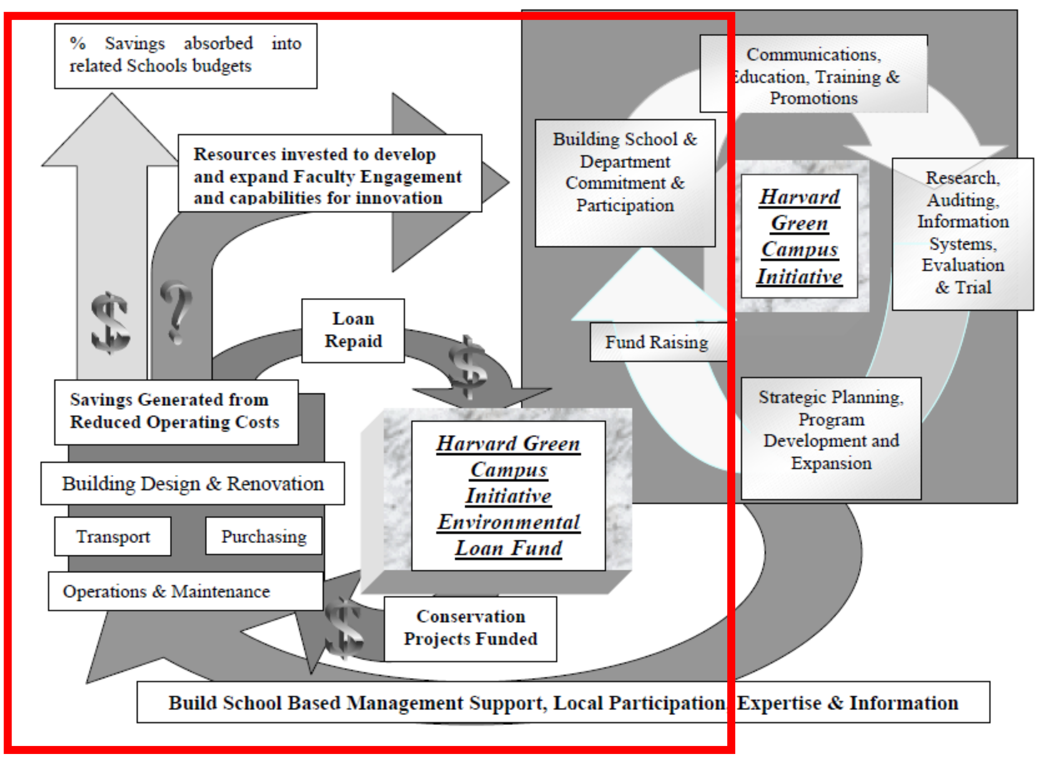

Figure 1- The Harvard Green Campus Initiative (Sharp, 2002)

The conceptual model is based on the Harvard University sustainability program. As seen in Figure 2, external funds accumulate slowly in the sustainability fund. When it reaches the required amount to improve a building, the building is improved, decreasing the remaining funds available for improvements. The resulting reduction in energy usage creates income to the fund. These interactions create the reinforcing feedback loop that sustains and eventually grows the

Sustainability Fund. The drivers and constants on this loop determine the monetary success of the Fund. Collecting those incomes from energy reduction and transferring it to the sustainability saving also provide funds to repay external funders or other stakeholders.

Formal Model Structure

The conceptual model was expanded to reflect the sustainability improvement program for seventeen different Texas A&M University campus buildings with diverse characteristics (e.g. energy usage, improvement cost and so on) as shown in Figure 2. The model was created in Vensim® DSS software and uses arraying function to handle several buildings and improvement data recorded in a Microsoft® Excel file.

The three primary stocks are the Sustainability Fund, Investment, and Savings. In the initial stage the only input to the Sustainability Fund stock is the external fund. With the flow of external fund, the funds start to grow and accumulate in the Sustainability Fund stock. When the Sustainability Fund stock reaches adequate funding to improve the first project on the list, the funds are taken out of the Sustainability Fund stock and expended to improve the first project. The same step is repeated until all of the projects on the list are completed. The model uses the project start dates to trigger improvements of each building. By implementing the improvements the amount of energy buildings consume decreases. This decrease in consumption generates cost savings. Ultimately, these cost savings transfer back into the Sustainability Fund account. The savings and external fund provide funding to the Sustainability Fund for future projects until all buildings are improved.

After all improvements are implemented, energy usage is reduced by a certain percentage from the reference case. This percentage varies based on improvement type. The difference in energy usage between before and after the improvement is the energy savings generated by implementing the improvements to the buildings.

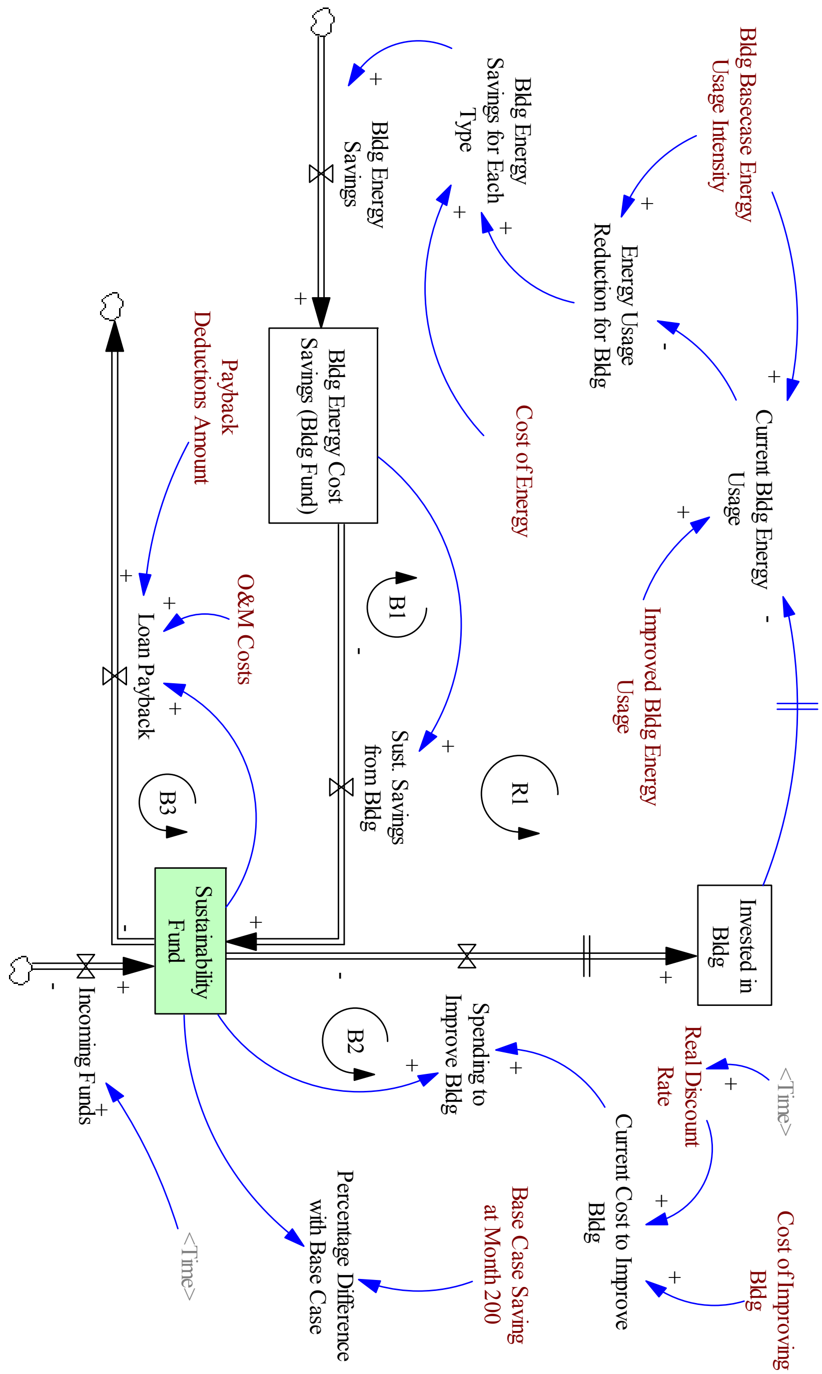

Figure 2- Formal Model Structure

Loop Descriptions

R1: When “Spending to improve Bldg” allows a building to get improved, the money moves out from the “Sustainability Fund” into “Invested in Bldg” indicating that building got improved. The “Current Bldg Energy Usage” is reduced after the building is improved, which directly results in increasing “Energy Usage Reduction for Bldg”. The increase in energy usage reduction causes “Bldg Energy Savings” to increase for each type of energy and also the total “Bldg Energy Savings” for all the energy usages. These savings result in more “Bldg Energy Cost Savings (Bldg Fund)” and finally more savings in the original “Sustainability Fund”. This creates feedback loop R1.

B1: The “Bldg Energy Cost Savings (Bldg Fund)” along with the “Owner vs. Sust. Savings ratio” will calculate the value for “Sust. Savings from Bldg” which is the amount of money needed to be taken out from “Bldg Energy Cost Savings (Bldg Fund)” and put in to “Sustainability Fund”.

B2: If there is sufficient amount of budget available in “Sustainability Fund”, then “Spending to Improve Bldg” will deduct that much from the “Sustainability Fund”.

B3: Similar to B2, when there is enough available money in “Sustainability Fund”, “Loan Payback” will take that much out from it and payback the loan.

Significant specific data was available about the structure of the TAMU case study. Therefore these structures were also incorporated into the formal model, including loan repayment, baseline energy use levels, predicted energy and cost savings, utility rates assumed for contracting, and guaranteed savings. This allowed improved model calibration and validation.

Data Collection and Calibration

Data about the case study was collected from TAMU utility records for individual buildings, the TAMU / Siemens contract, the project’s Utility Assessment Report, and meetings with representatives of the owner, ESCO, and improvement contractors. Descriptions of important specific data sources and their uses in the formal model are available from the authors.

Model Validation

Structure Assessment

The model structure closely resembles the Harvard Green Campus Initiative Environmental Loan fund structure and is consistent with the case study information. The Harvard Green Campus Initiative Environmental Loan Fund provides the necessary capital to invest (Conservation Projects Funded) in various aspects of reducing energy cost by not only reducing energy consumption in buildings through better operation and maintenance practice but also in transportation and purchasing (Savings Generated from Reduced Operating Costs). The savings generated from implementing the energy conservation projects (Savings Generated from

Reduced Operating Costs) were then applied to three different areas. Part of the savings was designed to repay the loan (Loan Repaid) and another portion to initiate Harvard's Green Campus Initiative (Resources invested to develop and expand Faculty Engagement and capability for innovation) and finally some share was absorbed into the school budget for other sustainability related purposes (% Savings absorbed into Related School budgets).

In the case study model, the Sustainability Fund represented the account that is used to provide the necessary capital for energy improvements around campus. Texas A&M University received $10 million in an account to improve campus facilities around campus by contracting with SECO. This account was defined as the Sustainability Fund. At Harvard University this was defined as Harvard Green Campus Initiative Environmental Loan Fund. In contrast to Harvard University, the research intent was to model the effect of reducing energy consumption in built infrastructure and not necessarily in transportation and purchasing. Hence, the funds were designed to invest in built infrastructure and no other areas.[6] The funds were expended to reduce energy consumption in multiple buildings on Texas A&M University campus. The flow of this fund was defined as Spending to Improve Buildings. At Harvard University it was defined as Conservation Projects Funded.

As energy projects were fulfilled, the cost of servicing the building altered. By applying the estimated reduction in energy consumption, appropriate utility rate, and the projected reduction in operating and maintenance cost the model represented the adjustment in cost by Building Energy Cost Savings. Harvard University called this Savings Generated from Reduced Operating Costs.

With the savings, Harvard University repaid the loan (Loan Repaid), supported other green campus initiatives and shared the savings with the school. The savings generated by implementing the projects was primarily collected back in the Sustainability Fund for the purpose of repaying the loan.

The model structure extends and deviates from the structure of Harvard University's program to better represent the TAMU project. Specifically, the Harvard diagram (Figure 1) does not depict the initial funding source for the Harvard Green Campus Initiative Environmental Loan Fund. Based on the Contract with SECO and Energy Service Company (ESCO), the case study model represented an external funding source by adding a flow defined as Incoming Funds. Other Universities such as Whitman College and Macalester College received a portion of their sustainability funding from surplus budget and student government. As in the case study circumstances, 100% of the funding came from SECO resulting in adding external funding source as a necessary element of the model.

[6]Similar concepts were found in Macalester College which created a Clean Energy Revolving Fund.

Table 2- Model Structure Assessment

Model Component	External Support	Case Study Data
External Fund	***Whitman College*** (WA) – Budget from building maintenance and from year-end surplus ***Macalester College*** (MN) – College's Student Government	Incoming Funds*
Fund	***Macalester College*** (MN) – Clean Energy Revolving Fund ***Harvard University*** (MA) – Green Campus Initiative Environmental Loan Fund	Sustainability Funds
Invested in Building	***Harvard University's*** (MA) - Conservation Projects Funded	Spending to Improve Buildings
Generated Savings	***Harvard University's*** (MA) – Savings Generated from Reduced Operating Costs	Building Energy Cost Savings
Shared Savings	***Harvard University's*** (MA) - % Savings absorbed into related Schools budget, Resources invested to develop and expand Faculty Engagement and capability for innovation	N/A**
Payback	***Harvard University's*** (MA) – Loan Repaid	Payback

* Extension from the Harvard's Green Campus Initiative model
**Deviation from the Harvard's Green Campus Initiative model

Some sustainability funds are designed to share savings. However, repaying the initial loan was the primary purpose of the TAMU project. This is reflected in the TAMU / Siemens contract, which does not include shared savings. Therefore, the base case model, which was built to represent the contract conditions, does not include shared savings.[7] This simplification also expedites the repayment of the loan.

[7] If shared savings are included in the base case model the Sustainability Fund temporarily has negative values, implying that the fund would have to borrow additional funds to make loan payments.

Typical Behavior Mode

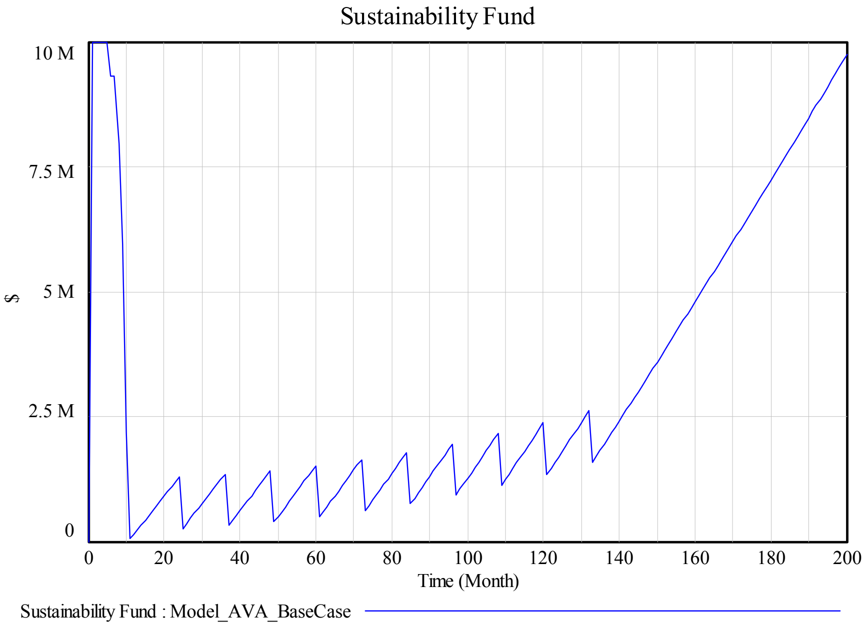

Figure 3- Model Behavior, Sustainability Fund

Figure 3 shows that at month one, a lump sum of $10M is received from an external source raising the capital in the sustainability fund to $10M in total. Then, considering the actual start dates for the projects, the first set of projects get improved at month six followed by rest of the buildings on the list. Due to contract requirement, within one year, all of the buildings improvements are completed therefore the entire budget ($10M) spent. The balance in the sustainability fund never reaches zero at month twelve since there are energy usage reductions (savings) immediately following the building improvements which starts from month seven. After month twelve, savings start to accumulate in the sustainability fund from all the building improvements. On the first guaranteed date, 12 months after the last improvement and 24 months after the project initiates, loan payments are deducted on a yearly basis (i.e. month 24, 36, etc.). After last payment, the savings would continue to grow in the sustainability fund.

Behavior Validation

The model was initially calibrated to reflect the TAMU / Siemens contract to check the validity of the model. Although utility rates are expected to rise over time and projects are traditionally assessed based on monetary values at a single point in time by discounting cash flows, neither were included in the contract conditions. Therefore, the initial calibration of the base case model did not include these factors. The simulated behavior of the Sustainability Fund (Figure 4, lower, blue line) reflects reasonable behavior. In the first month the receipt of the entire loan principal increases the sustainability fund and the available budget in this fund rose to $10M. Then, using the actual project start dates, the projects began in month six and improvements at all seventeen buildings had been started within the next five months. As required by the contract, all the buildings improvements are finished by at month eleven, emptying the sustainability fund. The fund actually did not go to zero since there are some energy usage reductions due to the completion of some improvements before the improvement deadline, causing some savings to flow into the sustainability fund. After month eleven savings are collected in the fund from all the buildings and the loan payments are paid out yearly (i.e. month 24, 36, etc.) (Trevin & SECO, 2011; U.S. Department of Energy Office of Energy Efficiency and Renewable Energy State Energy Program, 2009). This constant accumulation of savings and periodic loan payments create the “saw tooth” pattern in the fund balance. After the last loan payment (month 132) savings steadily increase in the sustainability fund.

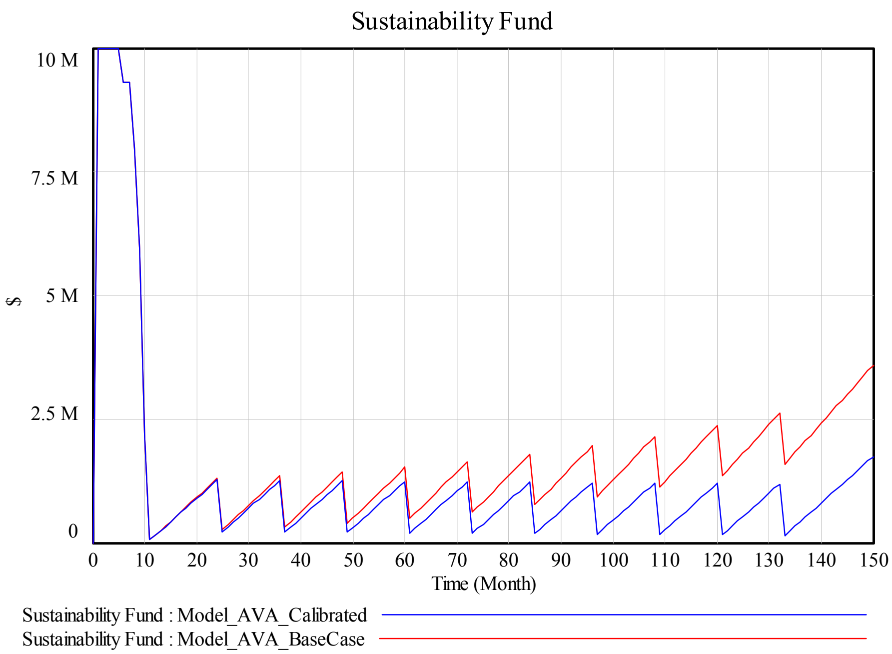

Figure 4- Sustainability Fund, comparing base case and calibrated model

Texas A&M University generates a significant portion of its own power and therefore can control the utility costs charged to its facilities better than if market utility prices were paid. However, given that market utility rates do fluctuate, and that TAMU does purchase some utilities from market sources, and sustainability fund projects for other owners may depend on market-priced utilities, the calibrated base case model was re-calibrated assuming increasing utility costs. The resulting behavior was used for model validation. The sustainability program should generate more savings with increasing utility prices than constant ones and therefore the fund balance should grow faster. Figure 4 (upper red line) shows the fund balance for this hypothetical and reasonable case and suggests that the model creates reasonable behavior for the same reasons as in the actual system.

Extreme conditions' testing was also performed to validate the model's ability to generate reasonable behavior over a wide range of exogenous values. These tests support the usefulness of the model. Based on the structure and behavior tests described above the model is considered to be adequate for the investigation of the impacts of project planning and financing on revolving sustainability funds.

Model Use

To test project planning policies and financial structures the model was calibrated with the realistic conditions of increased utility (2%/year) and construction prices (5%/year) and values measured in constant dollars (Figure 4 upper red line). This version of the model is hereafter referred to as the base case. The sustainability fund was allowed to go negative as long as it becomes positive again in less than a year. To cover the expenses when the account goes negative, it was assumed that the program borrows money from other sources within the university, by paying an extra 2% administration fee. Performance was measured with the fund balance at month 200 (after loan repayment) and compared to the base case.

Three prioritization policies were identified to address the issue of project planning for sustainability fund management.

- **Decreasing order of total savings:** buildings are improved based on the amount of predicted savings. The building with most amount of predicted saving would be started first. Then the building with second highest amount of predicted saving and so on until the improvement funds have been exhausted.
- **Decreasing Benefit-Cost ratio:** Buildings are ordered based on the ratio of the savings they are generating to their cost of improvement (B-C ratio). First the building with highest B-C ratio would be improved and then the one with second highest B-C ratio, etc. until the improvement funds have been exhausted. This is a more traditional method of prioritizing projects in this type of investment. Benefit-Cost ratio is particularly applicable in private sector with limited funds, where the program managers want to gain the largest possible savings for the limited amount of capital.
- **Increasing cost of improvement:** buildings are improved based on their improvement cost in a way that the one with smallest cost is improved first, etc. until improvement funds are exhausted. The motivation for project managers to choose this scenario could be to show progress by reporting the largest number of buildings improved in a reporting period. Another possibility may be fairness in improving multiple buildings for multiple stakeholders. As an example, several academic divisions and supporting offices co-exist in university settings. The program manager may be obligated to equally satisfy the various divisions and department heads by improving in smaller projects but more frequently.

Each of the three scenarios were simulated under two finance conditions; 1) the required budget ($10 million) is available at the beginning of the program, and 2) Half of the required budget ($5 million) is available at the beginning of the program. Both financing scenarios can complete all of the planned improvements even though they utilize different initial loans because the program generates savings that, in the case of the lower initial loan, can be used to fund the remaining projects. Like the full fund scenarios, the loan with less initial funding ($5 million) would be repaid in 10 equal yearly loan payments starting on the guaranteed date (24 months after the project initiates). These yearly loan payments equaled $577,495. To fulfill the loan obligation, the sustainability fund could temporarily go negative and borrow money in order to pay back the loan. In such circumstances, the necessary funding would be borrowed from an external source at a 2% interest rate.

Simulation Results

Fully Funded ($10 Million) Case

The $10 Million case represented adequate funding to proceed with improving all of the buildings in the first year. When buildings are improved based on the decreasing order of benefit-cost ratio the Sustainability Fund at month 200 held $10,083,389 (3.548% over base case). By prioritizing based on the amount of savings, buildings were all improved within the first year and the Sustainability Fund at the end of month 200 held $10,129,838 (4.025% over base case). When buildings were improved based on the increasing order of their construction costs the amount of savings at the end of month 200 is $9,847,845 (1.130% over the base case). Figure 5 shows the graphs of three cases comparing to the basecase.

The sequence of the projects impacts the performance of the sustainability fund. All of the scenarios showed an increase of 1-4% on savings in the sustainability fund at month 200 compared to the base case. When 100% of the upfront capital available, it was most beneficial to proceed with the projects that had the largest predicted savings regardless of the project cost followed by largest benefit-cost ratio and then smallest projects (in terms of cost).

Given that the program may not necessarily have all of the funding available and the project list can grow, the next set of analysis included studying the impact of project scheduling with budget constraints.

Table 3- Results of Fully Funded Scenario Tests

	Base Case	Benefit-Cost Ratio	Amount of Savings	Improvement Cost
Sustainability Fund ($)	9,737,849	10,083,389	10,129,838	9,847,845
Improvement Compare to the base case	0.000%	3.548%	4.025%	1.130%

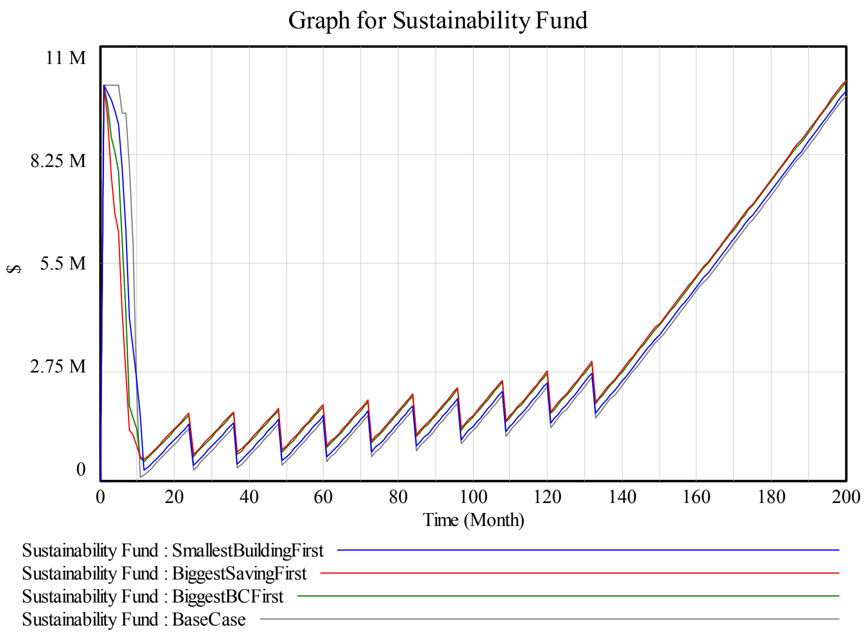

Figure 5- Sustainability Fund for Different Scenarios (Full Fund)

Limited Fund ($5 Million) Case

The $5 Million case represented circumstances in which inadequate funding was available to proceed with improving all of the buildings in the first year. Buildings were assumed to be eligible for improvements only when adequate funding was available (i.e. addition loans would not be used to accelerate improvements). Therefore some improvements are delayed until savings accumulate (see Figure 6. Notice the change in vertical scale from Figure 5.). Improvement costs increase during the delays. A historical cost index from a widely used industry source of construction data (RS Means, 2010) was used to estimate cost increases.

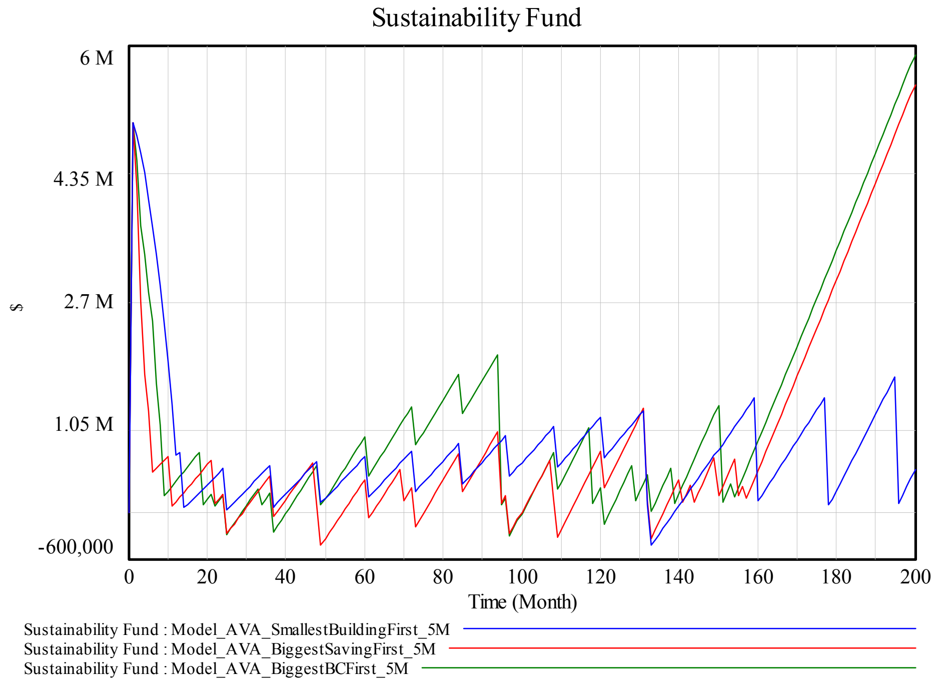

Figure 6- Sustainability Fund for Different Scenarios (Half Fund)

When improvements were prioritized based on decreasing predicted savings, 6 out of 17 buildings were improved within the first year. In this case, the next building improved after 11 months. It took a total of 156 months to improve all of the buildings. The sustainability fund had a negative balance eight times. The total duration of the negative balance was for 28 months. The largest negative balance was at month 49 for -$416,035. The net amount in sustainability fund at the end of month 200 for this scenario was $5,487,030.

When improvements were prioritized based on decreasing benefit cost ratio, 8 out of 17 buildings were improved within the first year. The next building improved after 10 months. It took a total of 153 months to improve all of the buildings. The sustainability fund had a negative balance four times. The total duration of the negative balance was for 14 months. The largest negative balance was at month 97 for -$308,246.60. The net amount in sustainability fund at the end of month 200 for this scenario was $5,869,223.50.

When improvements were prioritized based on increasing construction costs, 11 out of 17 buildings were improved within the first year. The next building improved after 2 months and one building did not get improved within 200 months. The 16th building was improved in month 195. The sustainability fund had a negative balance one time. The total duration of the negative balance was for 6 months. The largest negative balance was at month 133 for -$424,516.60. The net amount in sustainability fund at the end of month 200 for this scenario was $548,497.90.

A summary of all of these three cases is shown in Table 4.

Table 4- $5M Case Results Summary

	Benefit-Cost Ratio	Amount of Savings	Improvement Cost
Sustainability Fund ($) at month 200	$5,869,223.5	$5,487,030	$548,497.9
Last improved building on month	153	156	Last building didn't get improved within 200 months
Largest negative balance ($)	-308,246.6	-416,035	-424,516.6
Total duration on negative balance	14 months	28 months	6 months
No. of improved buildings in first year	8	6	11
No. of times getting negative	4	8	1

When only half of the required capital was available, it was most advantageous to improve the buildings that had the highest benefit cost ratio. Simply comparing the sustainability fund balance at month 200, it indicated that this scenario would lead to the highest savings. However, this was assuming that it was possible to borrow when the account temporarily goes negative.

Conclusions

Although the base case represented a positive net present value, by testing multiple scenarios this research was able to conclude that with adequate amount of funding, it was most advantageous to proceed with all of the projects as quickly as possible. Knowing this, the project manager can plan ahead before funding is received to stage all of the 17 buildings concurrently. A possible approach would be to have multiple crews or contractors to work on the project simultaneously to improve all of the buildings as quickly as possible. If this strategy is not possible, the next best approach would be to work on the projects that have the highest savings regardless of cost with projects distributed more over the summer months when the buildings are less occupied. This is expected since benefits are reaped faster following this sequence and the cost would be irrelevant as adequate funding is available. Undertaking the largest benefit-cost ratio first followed closely and led to the third highest savings

Because the interest rate on the loan for the case study was attractive, it was advantageous to borrow the maximum amount of capital and to improve additional buildings as quickly as possible. However many sustainability improvement programs may not have this advantage. With inadequate funding (half that required to complete all buildings) only a few projects were improved the first year. It was most beneficial to proceed with the projects that had the highest benefit cost ratio. This scenario had the greatest savings in the sustainability fund at month 200. As savings accumulated in the sustainability account, three different strategies improved projects at various time points. To improve the most buildings in the first year the best strategy is increasing cost, followed by decreasing Benefit-Cost ratio, and then decreasing savings. To improve all the building earliest the best strategy is decreasing Benefit-Cost ratio, followed by decreasing savings and then increasing cost. To minimize the negative balance the best strategy is decreasing benefit-cost ratio, followed by decreasing savings and then increasing cost. To maximize the size of the fund the best strategy is decreasing Benefit-Cost ratio, followed closely by decreasing savings, with increasing cost have only about 10% of the final balance at the other two strategies. This indicates that the best strategy depends on the objectives of the program managers.

The results are limited by the scope of the modeling and analysis. Wider applicability of results can be gained by testing the model structure and results with different sustainability improvement programs. Additional insights can be developed through more model analysis and developing program planning and financial strategies based on the results of those analyses. Future work can expand and improve this work by addressing these issues and investigating additional sustainability improvement program planning and financing issues, such as differences in stakeholder perspectives and the impacts of loan interest rates on program performance and strategy. This could include studying whether it was necessary to borrow the maximum qualified amount of loan and whether it was financially sound to improve all the projects on the list given different rate structures. This could answer when the project owner should not invest in improving the buildings and which combination of loan structure would lead to greater savings in the sustainability fund account. However, the project managers may be forced to improve all the buildings on the list. In that case, the project manager may be more interested in the least amount of funding (i.e. seed money) that is required to improve all of the buildings given different constraints.

The current work contributes to both system dynamics and sustainability. The model expands the application of system dynamics into a new aspect (program and fund management) of a critical domain (sustainability). This research illustrated the dynamics of project scheduling and overall impact on performance of sustainability improvement funds over time with model structures that can be used to further explore the dynamics of sustainability. One specific example is that this study provides an insight into the level of impact different project scheduling techniques have on the performance by comparing them to the base case scenario. The work also expands the modeling and analysis of sustainability, thereby improving the understanding of why sustainability programs fail or succeed. On specific example is the insight of how different loan structures can influence monetary project performance. These contributions are meaningful for organizations as they are striving to be better stewards of the environment and as they are constantly faced with limited budget and alternatives to making project management decisions.

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