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LEVERAGING PLANNING STRATEGIES FOR PRIORITIZING THE MOST VIABLE PROJECTS TO MAXIMIZE INVESTMENT RETURNS

Mutua John Wambua[1], Nyakito Edward Alolo[2], Nickson Kiprotich Kimais[3]
[1]Maasai Mara University,20500-861, Kenya; https://orcid.org/0009-0002-9317-8301
[2]Maasai Mara University,20500-861, Kenya; https://orcid.org/0009-0001-9992-6211
[3]University of Bradford, Faculty of Management, Law & Social Sciences BD7 1DP;
https://orcid.org/0000-0001-6702-1437

ABSTRACT

Maximizing investment returns and overall project benefits through strategic project prioritization was crucial in programs aimed at enhancing the sustainability of building infrastructures. This necessity became particularly evident when implementing a revolving-fund approach, utilizing savings from initial projects for subsequent improvements. The success of such an approach heavily relied on the meticulous prioritization of projects. However, project prioritization during the planning phase was complicated due to competing performance metrics and resource constraints. This study evaluated the impact of various project prioritization strategies on the performance of sustainability programs employing a revolving-fund model. The research utilized system dynamics modeling, a novel decision analysis tool that captured the complex interactions within sustainability improvement programs. The methodology was developed and calibrated using a case study of a campus sustainability improvement program at Texas A&M University. The study employed five common project prioritization strategies and assessed their effects on program performance metrics – such as investment returns, energy savings, and environmental impact – across varying levels of initial investment. Findings from the Texas A&M University case study suggested that prioritizing projects based on a decreasing benefit/cost ratio proved to be the most effective strategy. This research underscored the significance of system dynamics modeling in helping sustainability program managers make informed decisions, thereby facilitating financially and environmentally successful program implementations focused on maximizing investment returns.

KEY TERMS*: Project Prioritization, Sustainability Programs, Revolving-Fund Model, System Dynamics Modeling, Investment Returns, Case Study*

1.0 INTRODUCTION

Maximizing investment returns and overall project benefits through strategic project prioritization is crucial in programs aimed at enhancing the sustainability of building infrastructures. Recent studies highlight significant challenges in the construction industry, with nationwide projects often exceeding budgets by at least 16%, resulting in notable cost overruns (Smith et al., 2020). Additionally, nine out of ten projects experience cost overruns, with an average overrun of 28% (Jones et al., 2019). These figures emphasize the critical need for meticulous project prioritization to mitigate financial risks and maximize returns. Prioritization strategies are essential to address various challenges faced by construction projects, including budget overruns, schedule delays, and resource mismanagement. Effective prioritization is necessary to optimize project execution, ensuring the efficient use of resources and minimizing costs, thus contributing to the overall success of sustainability initiatives in infrastructure development.

In the United States, the residential and commercial sectors are responsible for about 40% of the nation's total energy consumption. Addressing energy use in these sectors through sustainability improvement programs offers immediate financial savings while contributing to a healthier environment for the public. However, retrofitting existing infrastructure to meet modern energy standards is complex and challenging. The intricacies of retrofitting projects involve careful consideration of several factors, including cost-effectiveness, environmental impact, and long-term sustainability goals (Syal et al., 2013). These challenges underscore the importance of effective planning and prioritization strategies in sustainability programs. Strategic decision-making is required to ensure that energy efficiency improvements deliver meaningful results, both financially and environmentally, while overcoming obstacles such as high upfront costs, project complexity, and varying resource availability in infrastructure projects.

The urgency of upgrading infrastructure to meet sustainability goals is compounded by the prevalence of cost overruns and inefficiencies in construction projects. Large-scale projects often take 20% longer to complete than originally planned, and their budgets can exceed projections by up to 80% (McKinsey & Company, 2019). Additionally, rising construction material costs, which increased by 10% in 2019, add further pressure to project budgets, highlighting the need for efficient resource utilization (Ferguson et al., 2019). In such an environment, effective project prioritization becomes paramount. By implementing well-defined prioritization methodologies, project managers can identify and address potential risks early in the project lifecycle. This proactive approach minimizes the likelihood of cost overruns, delays, and inefficiencies, ultimately optimizing the return on investment and ensuring that projects are delivered within budget and on schedule.

In response to these challenges, sustainability programs have increasingly adopted innovative financing mechanisms such as the revolving-fund approach. This model, popularized by initiatives like the U.S. Department of Energy's Better Buildings Challenge, utilizes savings from reduced operating costs to fund future improvements (DoE, 2018). The revolving-fund approach has been successfully adopted by over 80 higher-education institutions in the U.S., contributing to investments exceeding 118 million dollars (AASHE, 2016). This financing solution offers a sustainable method to continuously fund infrastructure improvements while maximizing long-term investment returns. By reinvesting savings into subsequent projects, the revolving fund model helps ensure the sustainability of energy efficiency initiatives, allowing for ongoing improvements that contribute to both financial and environmental goals. This model has proven effective in enabling institutions to maintain energy-efficient facilities and reduce their carbon footprint over time.

Despite the success of revolving funds, there remains a gap in research on strategies to maximize the performance of energy retrofits in building portfolios, posing a challenge to effective implementation. Project managers often face the dilemma of balancing the need for early financial returns with the objective of optimizing long-term building performance, frequently operating under resource constraints and uncertain funding scenarios (Hiller et al., 2011). Additionally, poor communication and inefficiencies in the construction industry contribute to project failures and productivity losses, further complicating project management (PMI, 2019). These issues underscore the need for a more comprehensive and systematic approach to project prioritization in sustainability programs. Through rigorous analysis and the implementation of effective prioritization strategies, program managers can enhance the efficiency of sustainability projects, improve investment returns, and ensure that both financial and environmental objectives are achieved, leading to more sustainable infrastructure outcomes.

2.0 LITERATURE REVIEW

2.1 Empirical Review

Empirical studies on project prioritization and sustainability have consistently highlighted the importance of systematic planning to optimize resource use and investment returns. A prominent example is the work by Smith et al. (2020), which highlighted the critical challenge of budget overruns in large-scale construction projects, with over 90% of projects exceeding initial budget projections. This indicates a significant need for more rigorous project prioritization strategies to mitigate financial risks and maximize returns. Additionally, Jones et al. (2019) found that 28% of projects exceed their budgets on average, underscoring the financial risks of inefficient project management. To mitigate such risks, several scholars have proposed prioritization techniques that optimize both short-term and long-term outcomes in sustainability projects. For instance, Hiller et al. (2011) noted that the revolving fund approach, where initial project savings are reinvested into subsequent projects, enhances the sustainability of programs by providing a continuous funding source. This model, which has been adopted by several U.S. institutions, fosters long-term energy savings and resource efficiency, demonstrating the financial viability of sustainability programs when properly prioritized.

Furthermore, prioritizing projects based on their potential for immediate returns, such as the benefit-to-cost (B/C) ratio, has been shown to lead to significantly higher net present value (NPV) and overall savings. Syal et al. (2013) demonstrated that focusing on high-B/C projects in the early phases of a program can maximize returns, while also minimizing environmental impacts. This empirical evidence reinforces the importance of balancing financial, environmental, and social factors when prioritizing projects within sustainability programs. A similar approach was adopted by Zietsman et al. (2011), who used the NPV method to analyze energy efficiency retrofits and found that prioritizing energy-saving projects yielded superior economic returns, with a significant reduction in operating costs.

However, despite these advancements, empirical research has identified several challenges in implementing effective prioritization in real-world scenarios. According to Gottsche et al. (2016), many sustainability programs still face barriers such as fragmented data, limited resources, and competing objectives that hinder the accurate assessment of potential returns. McKinsey & Company (2019) further reported that large-scale projects often suffer from schedule delays and cost overruns due to the lack of a coherent prioritization framework. This points to the gap in current research: while many studies focus on optimizing single performance metrics like cost savings or energy efficiency, there remains insufficient focus on how multiple, often competing, performance metrics (such as cost, time, and environmental impact) can be prioritized simultaneously, especially in sustainability programs with limited funding and resources.

Moreover, few empirical studies have employed advanced modeling techniques, such as system dynamics, to analyze the long-term impacts of project prioritization decisions in sustainability programs. While empirical work has shown that prioritization based on short-term benefits, like immediate energy savings, can yield high returns (Gottsche et al., 2016), it has not sufficiently explored how these benefits accumulate over time or interact with long-term sustainability goals. This study addressesd this gap by using system dynamics modeling to assess various project prioritization strategies and their impact on program performance over a 30-year lifecycle. The novelty of this approach lies in its ability to simulate the dynamic interactions between different performance metrics and help managers make more informed, long-term decisions. This study also bridged the gap in understanding how different project sequencing strategies—such as prioritizing by benefit-to-cost ratio (B/C), total savings, or improvement costs—affect both short-term and long-term outcomes. Thus, this research aimed to fill the existing empirical gap by evaluating how system dynamics can guide more effective project prioritization strategies in sustainability programs, especially those using a revolving-fund model.

2.2 Theoretical Review

The theoretical framework underpinning this study was grounded in System Dynamics Theory, introduced by Forrester (1961). System Dynamics (SD) is a modeling methodology that provides insights into complex systems through feedback loops, accumulation of information, and time delays, emphasizing how different variables interact within a system. The theory suggests that systems, such as sustainability improvement programs, operate through interconnected feedback loops where changes in one part of the system can produce cascading effects on other parts. The SD approach is particularly useful in analyzing long-term and dynamic behaviors of systems, providing a holistic view of how decisions in one phase can influence subsequent stages of a project, thus enabling decision-makers to predict outcomes and make informed choices. Numerous studies have supported the applicability of System Dynamics Theory in project management, particularly in sustainability and infrastructure projects. For instance, Sterman (2000) demonstrated how SD models can effectively simulate the effects of various strategies on environmental sustainability, showing that such models could improve decision-making by visualizing the impacts of different actions over time. Similarly, Ford and Sterman (2003) applied SD to analyze energy efficiency programs, illustrating that systems thinking could optimize resource use and enhance the effectiveness of sustainability programs. These studies confirm that SD can capture the complexity and dynamic nature of sustainability programs, making it a valuable tool for prioritizing projects and assessing their long-term effects on investment returns and environmental outcomes.

However, not all studies have embraced the use of System Dynamics Theory in project prioritization and sustainability programs. Critics such as Jones (2003) argue that SD models, while offering insightful analyses, often oversimplify complex real-world systems by focusing too much on feedback loops without sufficiently addressing the inherent uncertainties and external variables that can significantly influence system behavior. Furthermore, Lane and Jackson (1995) cautioned that SD models can become too reliant on assumptions, potentially leading to inaccurate predictions if not rigorously tested and validated in real-world settings. These criticisms highlight limitations in the application of SD models, especially when dealing with dynamic, unpredictable systems such as construction projects, where external factors like market fluctuations and regulatory changes may not be fully captured.

Despite these criticisms, System Dynamics Theory was particularly relevant to this study due to its ability to address the gap in current literature regarding the long-term impacts of project prioritization decisions. This study builded on the insights of Sterman (2000) and Ford and Sterman (2003) by applying SD to evaluate various project sequencing strategies within a revolving-fund model for sustainability programs. By integrating feedback loops and considering the long-term effects of initial project decisions on subsequent phases, this study aligned with Forrester's (1961) vision of using SD to simulate the effects of different strategies on system performance. The ability to model the dynamic interactions between various project prioritization criteria—such as cost, savings, and environmental impact—over the entire lifecycle of a program makes SD the ideal theoretical approach for this research. Thus, System Dynamics Theory plays a crucial role in helping program managers make informed decisions about project sequencing and investment prioritization, leading to enhanced financial and environmental outcomes.

3.0 METHODOLOGY

3.1 Introduction

This section discusses the research approach that was used to analyze sustainability project sequencing. The general method for solving sequencing problems is defined, the applicability of the system dynamics model is explained, and the specific design of the model is described in detail. To enhance the focus on project prioritization within sustainability improvement programs and maximize project returns, the methodology underwent refinement to prioritize project sequencing strategies comprehensively. The approach to project sequencing, being inherently a scheduling problem, was approached with meticulous attention to optimizing the order of activities to attain maximal benefits. A spectrum of methods for determining the optimum sequence of activities was explored, broadly classified into three major classes: exact solutions, approximations, and heuristic algorithms (Shakhlevich, 2004). While exact solutions offer precision, they often demand extensive resources. On the other hand, approximation methods strike a balance between accuracy and complexity, whereas heuristic algorithms, while not ensuring absolute accuracy, are prized for their capacity to swiftly provide effective solutions, especially in scenarios where precise data may be lacking (Morton et al. 1995; Glover and Laguna 1998).

System dynamics modeling emerged as a pivotal tool in the arsenal, employed to evaluate project prioritization within sustainability improvement programs comprehensively. Renowned for its efficacy in analyzing complex systems, system dynamics was harnessed to simulate the intricate interactions within the causal structure of the program, encompassing various project sequences and their ramifications on program performance (Flood and Jackson 1991; Lane and Jackson 1995). By seamlessly integrating feedback loops and the accumulations of materials, personnel, and information, system dynamics models afford a holistic representation of program dynamics, rendering them ideally suited for assessing the effects of project sequencing on sustainability improvement program performance (Forrester 1961; Sterman 2000).

A case study approach formed the bedrock of the research endeavor, with a specific focus on a sustainability improvement program enacted at Texas A&M University (TAMU) serving as the linchpin for analysis and validation. This program, meticulously tailored to enhance energy efficiency within existing facilities, furnished invaluable data for calibrating and validating the system dynamics model (Siemens and TAMU 2011). Through a cyclical process of action, involving a systematic review of existing conditions, prioritization of improvement initiatives, and periodic evaluation of program performance, project prioritization emerged as a linchpin in realizing anticipated savings (Gottsche et al. 2016). Leveraging insights gleaned from the TAMU program, the research set out to scrutinize the impact of project prioritization on program outcomes while endeavoring to unearth strategies aimed at optimizing project returns.

At the structural core of the system dynamics model lay a revolving fund framework, wherein the costs associated with initial improvement projects were defrayed through loans procured from the fund, with subsequent savings channeled towards repaying said loans, thereby engendering a reinforcing feedback loop (Like 2009). By meticulously simulating the ebbs and flows of monetary assets within the program, the model afforded nuanced insights into how project prioritization exerted influence on program dynamics and performance. Rigorous testing and calibration protocols were meticulously adhered to, ensuring that the model's fidelity vis-a-vis the real-world system was upheld, thereby vouchsafing its reliability for analyzing the impacts of project prioritization on sustainability improvement program outcomes (Sterman 2000).

3.2 Model Structure

The conceptual basis of the system dynamics model was the revolving fund structure (Like 2009). In this structure, the costs of initial improvement projects are covered by taking out loans from the revolving fund. As a result of those improvement projects, the system uses less energy and generates savings, which are then used to repay the loan back into the revolving fund. The system dynamics model was developed to simulate the accumulations and flows of money and the causal feedback that drive program behaviour and performance (Figure 1). This general conceptual model was extended to simulate the specific TAMU sustainability improvement program, specifying the 17 TAMU buildings and their particular characteristics (energy usage, improvement cost, etc.) (Kim et al. 2012). The model was developed in Vensim^{VR} DSS software and used an arraying function to reflect facility and project data that was stored in a Microsoft Excel file.

The three main stocks in the system dynamics model are the Sustainability Fund, Savings, and Investment. External funds, as well as the monetary savings of the program, gradually pool in the Sustainability Fund over time. When the available Sustainability Fund reaches the amount needed to start the next project (the next building's improvement), as determined by the sequencing strategy, the model triggers the project's start and removes funds equal to the defined project budget from the Sustainability Fund (loop B2 in Figure 1). As a result of implementing the projects, the amount of energy and operating expenditure decreases in a manner defined by the guaranteed contract, resulting in savings that are added back into the Sustainability Fund (loop B1 in Figure 1). Loan payments are also processed by removing them from the Sustainability Fund (loop B3 in Figure 1).

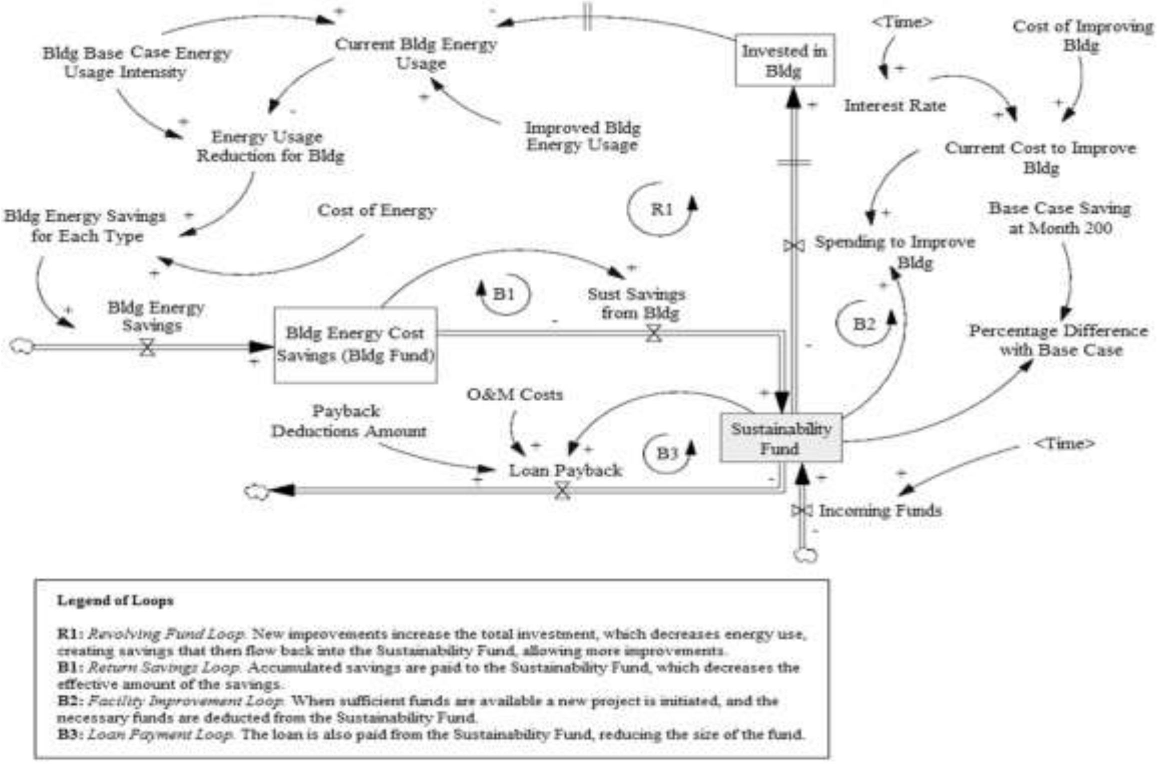
Taken all together, these interactions create the Revolving Fund Loop (R1 in Figure 1), a reinforcing feedback loop that maintains the Sustainability Fund and then eventually increases it after all of the projects have been completed. A more detailed description of this model structure (Faghihi et al.2015).

3.3 Model Testing and Calibration

Standard model-testing methods for system dynamics (Sterman 2000) were applied to validate the model, including a comparison of the model structure to actual system structures, verifying unit consistency, testing behavior under extreme conditions, and comparison of model behavior to known or expected system behavior. Partial model testing was also used to develop confidence in the model's fidelity with the system being modelled. For example, the major reinforcing loop of investment in energy efficiency and generating savings (R1) was isolated from the rest of the model, so that it could be tested and calibrated independently.

The model was calibrated to the TAMU case study using data from the project's Utility Assessment Report, Texas A&M University utility records for each building, the details of the contract between TAMU and Siemens, and informal discussions with representatives of the involved parties. The behaviour of the calibrated model was used to further validate its applicability. After the model was tested and calibrated to the case study conditions, a few adjustments were made so that the calibration would be more realistic for a wide range of sustainability programs.

These changes included the addition of increases in utility prices (assumed to be 2% per year). A negative Sustainability Fund was allowed in the model as long as it subsequently became positive again within one fiscal year. The researchers assumed that in such a case the owners would borrow funds to cover these temporary deficits, paying an additional 2% interest per year on the extra funds. This version of the model is hereafter referred to as the "base case". More details about the model are available from the authors upon request.



Legend of Loops

R1: *Revolving Fund Loop.* New improvements increase the total investment, which decreases energy use, creating savings that then flow back into the Sustainability Fund, allowing more improvements.
B1: *Return Savings Loop.* Accumulated savings are paid to the Sustainability Fund, which decreases the effective amount of the savings.
B2: *Facility Improvement Loop.* When sufficient funds are available a new project is initiated, and the necessary funds are deducted from the Sustainability Fund.
B3: *Loan Payment Loop.* The loan is also paid from the Sustainability Fund, reducing the size of the fund.

Figure 1. The conceptual system dynamics model of revolving-fund sustainability improvement programs.

3.4 Simulation Design

The most applicable heuristic strategies for sequencing projects in sustainability programs were evaluated using the system dynamics model. First, two heuristics were set as benchmarks for comparative purposes (H1 and H2). Then an exhaustive list of heuristic scheduling rules from the literature (Panwalkar and Iskander 1977) was carefully examined to select the approaches that are most applicable for use in sustainability improvement programs. Several heuristic Strategies were identified based on Panwalker's approaches, focusing on maximizing project returns through efficient project prioritization. These strategies encompassed a range of criteria; each aimed at optimizing the sequencing of sustainability improvement projects within the program. Benchmark Heuristic 1 (H1), for instance, treated projects as a hypothetical set of homogenous entities, assuming equal costs and savings across the board, thereby establishing a baseline for comparison. This strategy, termed "H1: Homogenous Projects," laid the foundation for evaluating other prioritization strategies (Panwalker, 2018). Building on this baseline, Benchmark Heuristic 2 (H2) mirrored the sequence in which projects were actually implemented during the real-world program under investigation, providing a tangible reference point derived from empirical data. Termed "H2: Case Study," this strategy leveraged insights gleaned from practical experience to inform project prioritization within the simulated context (Panwalker, 2018).

Heuristic 3 (H3) introduced a risk-management perspective, prioritizing projects based on decreasing improvement cost. This approach stemmed from the rationale that delaying high-cost projects could elevate the risk of implementation hurdles and external uncertainties. By prioritizing costly projects, program managers aimed to mitigate potential risks associated with deferred initiatives, aligning with the strategy termed "H3: Decreasing Cost" (Panwalker, 2018). Similarly, Heuristic 4 (H4) focused on maximizing the first-year benefit to cost ratio (B/C), prioritizing projects based on their potential for immediate returns relative to implementation costs. This strategy, labeled "H4: Decreasing B/C," emphasized projects that promised the highest immediate benefits compared to their upfront costs, thereby optimizing short-term performance within the program (Panwalker, 2018).In contrast, Heuristic 5 (H5) shifted the focus to total estimated savings, disregarding implementation costs to prioritize projects with the greatest energy-saving potential. Termed "H5: Decreasing Savings," this strategy underscored the importance of long-term sustainability gains, aiming to maximize overall energy efficiency and environmental impact over the program's lifecycle (Panwalker, 2018).

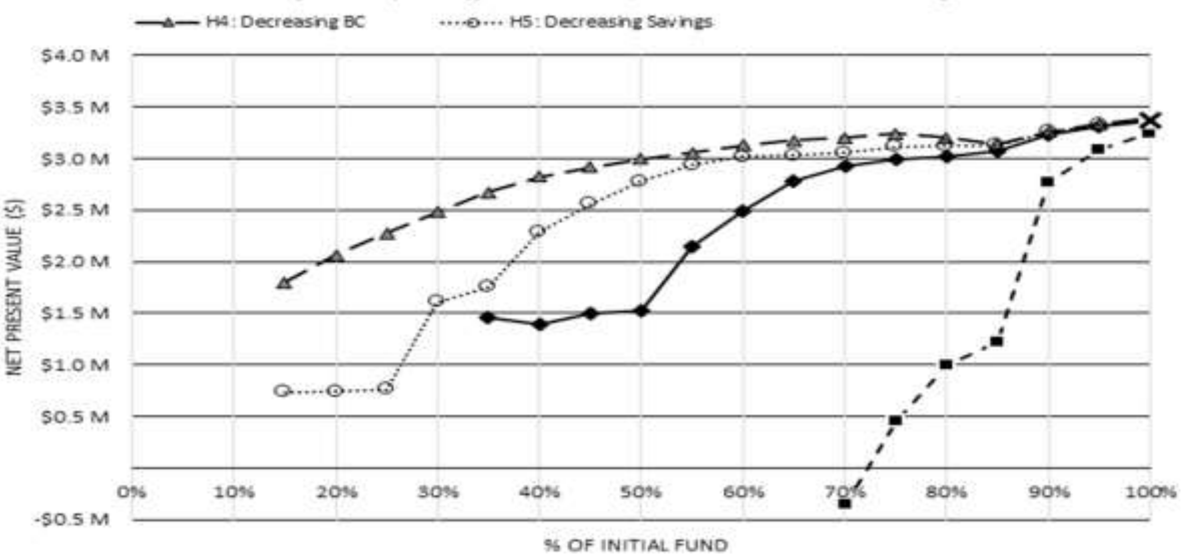


Figure 2 Total monetary value (NPV) using different project sequencing strategies at different levels of initial funding.

The selection of these heuristic strategies involved a rigorous winnowing process, which included scenario development and simulation analyses to assess their applicability and performance within the sustainability program context. Strategies deemed unsuitable, such as prioritizing projects with the lowest first-year B/C or minimal savings, were eliminated to ensure alignment with the program's overarching goal of maximizing revolving fund returns (Panwalker, 2018).

Evaluation of the tested heuristic strategies encompassed a comprehensive assessment of program performance measures over a 30-year lifecycle. Adopting a systematic approach, these performance measures were derived from Texas A&M University's Sustainability Master Plan, aligning with the program's specific objectives and sustainability goals. By establishing precise performance metrics, the evaluation process aimed to gauge progress toward achieving sustainability targets and optimizing program outcomes (TAMU Office of Sustainability, 2018; Zietsman et al., 2011). Among these goals, only two were directly related to the sustainability improvement program that was examined in the case study:
Goal 1: Achieve a 50% reduction in greenhouse gas emissions per weighted campus user by 2030; achieve net-zero emissions by 2050.

Goal 2: Deliver the lowest life-cycle-cost construction to build, operate, maintain, and decommission high-performing facilities.

In evaluating the progression towards meeting the outlined sustainability goals, the researchers embarked on identifying specific objectives and corresponding performance measures. One primary objective centered on the program's environmental performance, quantified through the per-unit cost of carbon footprint reduction. This measure holds significance as it aligns with widely accepted environmental assessment practices, utilizing carbon footprint as a key metric (Matthews et al., 2008). To compute this performance indicator, the total cost of program improvements was divided by the aggregate decrease in energy consumption over the program's lifecycle, relative to pre-improvement levels. Drawing from established models, the reduction in carbon dioxide emissions per unit of energy saved was determined, with each kilowatt-hour of electricity and million British Thermal Units (MMBTU) of natural gas yielding specific reductions (U.S. Environmental Protection Agency, 2016b).

Meanwhile, the second performance measure delved into the economic efficiency aspect of the program, directly tied to Goal 2 of the sustainability initiative. Assessing the financial benefits accruing to the university constituted a key focus, with various economic analysis methods available for such evaluations. Notably, methods grounded in the concept of the time value of money hold prominence, encompassing metrics like net present value (NPV), internal rate of return (IRR), benefit-cost ratio (B/C), and discounted payback period (Park, 2013). While a comprehensive comparison of these methods lies beyond the paper's scope, NPV emerged as the preferred approach for its widespread utilization in energy retrofit projects (DeCanio, 1998; Morrissey & Horne, 2011). Calculating NPV relied on fundamental engineering economics principles, assuming a 5% interest rate to capture market dynamics and inflation effects (Park, 2013).

Beyond environmental and economic considerations, the researchers introduced a third performance measure pertaining to temporal efficiency. This measure, reflecting the total duration of the program's implementation phase in months, held intrinsic value, with shorter durations deemed favorable. University administrations typically harbor concerns regarding construction project timelines, aiming for swift completion to minimize disruptions and preserve campus aesthetics (Jackson, 2010). The temporal performance measure, thus, resonated with the imperative of expediting program implementation while mitigating adverse impacts on campus operations and student experiences.

4.0 RESULTS AND DISCUSSION

Utilizing the system dynamics model, the researchers conducted simulations for each project sequencing heuristic, covering a spectrum of initial funding levels ranging from 15% to 100% of the total program costs, in 5% increments. The performance of the sustainability program was evaluated across environmental, economic, and temporal dimensions, and the results were visualized through plotted graphs spanning the range of initial funding levels (Figures 2–4). In these graphs, each line represents the performance trajectory of a specific project sequencing strategy with respect to a particular performance measure. However, Strategy H2, reflecting the actual case study conducted at TAMU, is depicted differently. Instead of a line, Strategy H2 is represented by a single "X" on the graphs. This distinction arises from the nature of the TAMU case study, where all improvements were fully funded at the program's outset. The sequencing of improvement projects for Strategies H2 to H5 is outlined in Table 1. Notably, Strategy H1, based on homogeneous projects, is omitted from the table as projects under this heuristic are unaffected by sequencing strategy. Strategy H2 mirrors the original case study, wherein projects were grouped into four categories, each group being implemented concurrently. Meanwhile, Strategies H3 to H5 prioritize projects based on distinct criteria, namely decreasing improvement cost, decreasing benefit-to-cost ratio (B/C), and decreasing estimated savings, respectively.

In Strategy H3, projects are sequenced in descending order of improvement cost, reflecting a risk management perspective aimed at mitigating potential challenges associated with delayed projects. This approach acknowledges the inherent uncertainties in program execution and aims to address them by prioritizing higher-cost projects, which may carry higher risks if postponed. Conversely, Strategy H4 prioritizes projects based on decreasing first-year B/C ratio, emphasizing immediate returns over long-term benefits. Projects with the highest first-year B/C ratios are executed first, aiming to maximize initial program gains relative to implementation costs. Similarly, Strategy H5 focuses on sequencing projects in order of decreasing estimated savings, without consideration for relative implementation costs. This approach underscores the importance of achieving maximum energy savings potential, aligning with the overarching goal of enhancing program effectiveness and sustainability outcomes. The selection of these heuristic strategies was informed by their relevance to real-world sustainability programs and their potential to optimize program performance under varying funding scenarios. Through these simulations and analyses, the researchers aimed to identify the most effective project sequencing strategy for maximizing program returns and achieving sustainability goals. By comparing the performance of different strategies across multiple dimensions, the study sought to provide valuable insights for program managers and stakeholders tasked with decision-making in sustainability improvement initiatives.

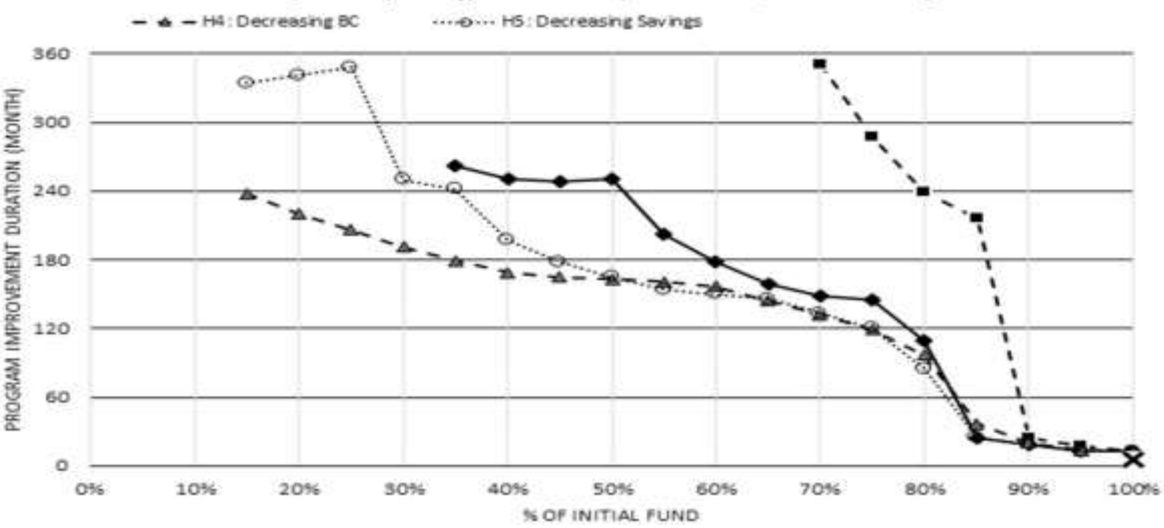


Figure 3. Total program duration using different project sequencing strategies at different levels of initial funding.

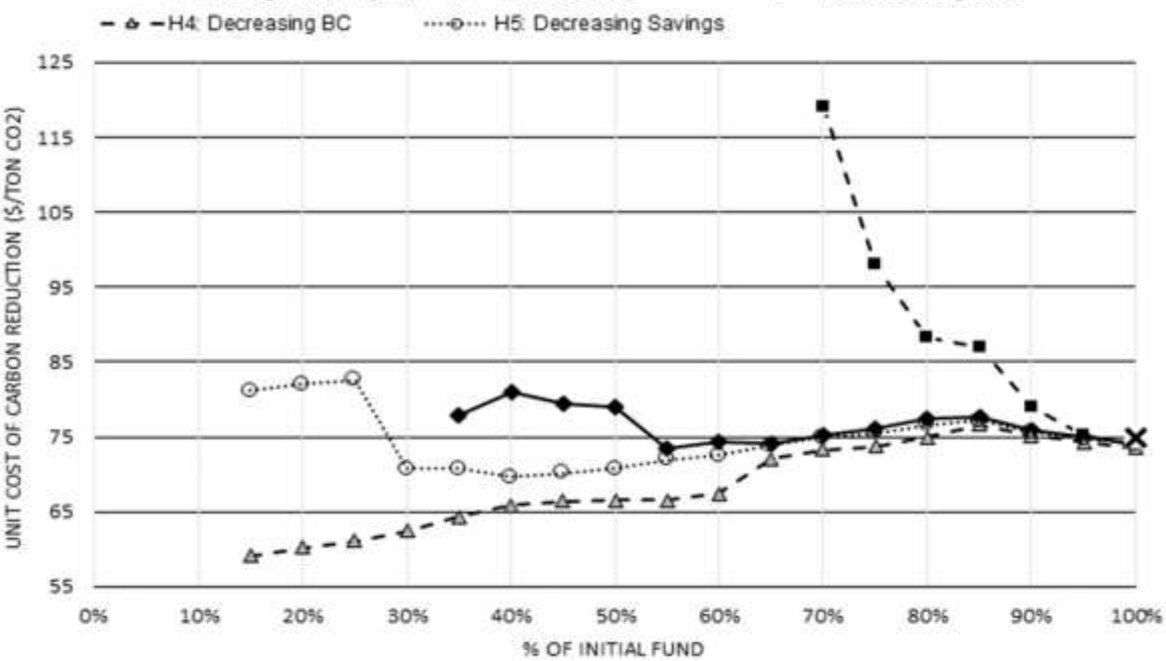


Figure 4. Per-unit cost of carbon footprint reduction using different project sequencing strategies at different levels of funding.

A number of important observations for the planning of revolving-fund sustainability improvement programs can be made on the basis of these results. First, performance varied widely across the sequencing heuristics, and this was true for all three of the performance dimensions. Comparing the three nonhomogeneous heuristics (H3, H4 and H5) with 50% initial funding, the program net present value varied up to 100% ($3.0M vs. $1.5M). The schedule performance varied up to 36% (160 months vs. 250 months), and the environmental performance varied up to 25% ($60/ton CO_2 vs. $80/ton CO_2).

Table 1. Sequence of improvement projects for H2–H5.

	Heuristic			
Building ID	H2	H3	H4	H5
1501	1	2	1	1
1507	3	1	8	2
378	4	7	2	6
388	2	6	3	5
1559	3	4	4	3
1194	1	5	5	4
469	1	11	6	9
379	3	10	7	8
392	2	8	9	10
463	3	9	10	11
518	3	3	11	7
1508	3	12	12	12

Performance variations are much larger than those produced by many other program performance improvements means. This demonstrates that project sequencing is an important, high-leverage factor in sustainability improvement programs using a revolving fund approach and that such decisions should be made with care based on a good understanding of the program's feedback structure.

Second, the financial returns and schedule performance generally improved for all strategies as initial funding levels increased. The reason for this is that regardless of the project sequencing strategy chosen, partial funding will delay the start of some projects and thereby delay the capture of their benefits. In contrast, the environmental performance of the various strategies was generally worse when initial funding was higher (i.e. the cost per unit of carbon reduction was higher with greater initial funding, in all but the baseline homogenous project sequence, H1). This is because programs with more initial funding do not exploit the maximum cost savings that can be obtained from the revolving fund financing approach. A third general observation is that all of the competitive strategies (H3, H4 and H5) performed about the same in all three performance dimensions if at least 60% of the total improvement costs are provided as initial funding. This suggests that the program performance is fairly insensitive to the differences among these three sequencing variations when the initial funding level equals or exceeds 60% of the total improvement costs.

Fourth, it is evident from the analysis that all competitive strategies (H3, H4, and H5) outperformed the Homogenous Projects strategy (H1) across all three performance dimensions. Notably, Strategy H1 resulted in a negative Net Present Value (NPV) when initial investment constituted less than 75% of the total improvement costs. This suboptimal performance of H1 can be attributed to its failure to capitalize on the diversity of project characteristics. By assuming uniformity among projects, H1 overlooks the potential benefits of prioritizing more impactful projects and subsequently reinvesting those gains into less effective ones. Consequently, the performance curves of H1 exhibit smoother trends compared to other strategies across all performance dimensions. Fifth, a significant inflection point in the performance curves occurs at approximately 85% initial funding, indicating a meaningful shortage of funds. Below this threshold (90% in the case study program), the lack of funds begins to impede project initiation. Consequently, multiple improvement projects are deferred as program managers await the necessary funding generated from energy savings in previously upgraded buildings.

Sixth, the analysis reveals that, with few exceptions, the Decreasing Benefit-to-Cost (B/C) strategy consistently outperformed other strategies across all three performance dimensions. Following this, the Decreasing Savings strategy exhibited the next best performance, followed by the Decreasing Cost strategy, with the Homogenous strategy trailing behind. These findings underscore the importance of considering both benefits and costs in decision-making processes, as strategies that incorporate both factors tend to yield superior outcomes compared to those that focus solely on either benefits or costs. Thus, prioritizing sustainability projects based on their anticipated benefits (savings) appears to be more effective than prioritizing based solely on costs. Seventh, the effectiveness of strategies diverges more prominently as the initial funding level decreases, evident from the widening gaps between performance curves towards the lower end of the funding spectrum. This trend holds true across all three performance dimensions. At lower initial funding levels, any inefficiencies in prioritization strategies are exacerbated, as they impose a more significant drag on future funding accumulation. Consequently, poor prioritization combined with limited starting funds leads to a "slow-programs-become-slower" phenomenon.

This divergence becomes particularly pronounced at very low initial funding levels, with the effectiveness gap between strategies widening considerably. For instance, the disparity in schedule performance between the Decreasing B/C and Decreasing Savings strategies exceeds 40% at an initial funding level of 25% of the total improvement costs. At a further reduced initial funding level of 15%, the effectiveness gap between these two strategies surpasses 100%.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This study has critically evaluated various project prioritization strategies within sustainability improvement programs utilizing a revolving-fund model, emphasizing the complexity of balancing competing performance metrics and resource constraints. The findings highlight that prioritizing projects based on a decreasing benefit-to-cost ratio (B/C) proves to be the most effective strategy for maximizing program returns. The research also underscores the significance of innovative financing mechanisms, such as revolving funds, which facilitate continuous investment in sustainability initiatives. Through the use of system dynamics modeling, the study provides valuable insights into how different project sequencing strategies impact program performance across varying initial investment levels. These findings offer practical guidance for program managers and stakeholders, helping them make informed decisions to optimize both investment returns and environmental sustainability goals, contributing to a more sustainable future.

5.2 Recommendations

Based on the research findings, several recommendations are proposed to enhance the success of project prioritization in sustainability improvement programs. Firstly, it is crucial to establish clear project prioritization frameworks that integrate financial, environmental, and temporal performance metrics to optimize resource allocation. Secondly, policymakers and industry leaders should encourage the use of system dynamics modeling in program planning to enhance decision-making and anticipate the long-term impacts of project sequencing strategies. Thirdly, expanding the use of revolving-fund models could provide a sustainable source of financing for energy-efficient projects, ensuring that savings from initial projects are reinvested into future improvements. Finally, further research is needed to explore the scalability of these strategies in different sectors and geographic regions to determine the broader applicability of the findings.

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