LIFE CYCLE COST RISK CALCULATOR FOR GREEN HIGHWAY CRITERIA

MUHAMMAD FAIZ BIN ABD RAHMAN

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Civil Engineering)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MARCH 2023

DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother and wife, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, including researchers, academicians, and practitioners. They have contributed to my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Associate Professor Dr. Rozana Binti Zakaria, for encouragement, guidance, criticism, and friendship. I am also very thankful to my co-supervisor, Sr. Dr. Siti Mazzuana Binti Shamsuddin, for her guidance, advice, and motivation. Without their relentless continued support and interest, this thesis would not have been the same as presented here.

My gratitude is also extended to the UTM GreenPrompt Research Group. Thank you for your support and friendship shown to me throughout the experimental periods.

I would like to thank Universiti Teknologi Malaysia (UTM) as my research university and the Research Management Center (RMC) for the financial and management support provided under the Fundamental Research Grant Scheme (FRGS); R.J130000.7851.5F034.

Finally, I would like to thank my family, especially my mother, father, and lovely wife, Nur Nadhira Binti Abdul Rasid, for their unconditional support and assistance on various occasions. All your kindness will not be forgotten.

ABSTRACT

The negative perception of the high initial cost of investment in green characteristics into buildings or infrastructure projects is a stigma for project developers when adopting sustainable construction. A green project must ascertain the long-term cost benefits during the project viability stage. Life Cycle Cost (LCC) analysis is a method introduced to highlight the return of investment and cost risks that possibly encounter during the life span of the buildings or infrastructures. Besides green building, "green highway" or "green road" is among the emerging concern in sustainable construction. The establishment of Green Highway & Road (H&R) Rating Tools such as Malaysia Green Highway Index (MyGHI), offers multi-criteria of sustainable initiatives that count towards the score of the green certification of H&R. The decision to implement sustainable initiatives implementation raises questions about the cost risk of the investment. This research aims to develop Life Cycle Cost Risk Calculator (LCC-RC) for green highway criteria as a decision-making support for the green cost benefits and prediction of risk analysis. This research used the highways certified by MyGHI to identify relationships between LCC components and the green highway's measurable criteria. The subject of cost benefit and risk analysis was based on risk associated with the green criteria of Energy Efficiency (EE) only. A questionnaire survey of 65 respondents was conducted. Friedman's Test and Spearman's Correlation Coefficient Analysis were used to validate LCC component, and the correlation was used in LCC-RC. The results show the average total LCC of RM481,156 for a green highway project and its energy efficiency green criteria cost have a positive and significant relationship except for capital, maintenance, and replacement costs. Risk contingency costs have the strongest positive relationship (0.29, $p < 0.005$). The results of the calculator portray the descriptive statistical summary of the calculated LCC analysis, along with the simulation output chart. The electrical system of LED street lighting data from LED lantern manufacturer in Malaysia was selected to test the LCC-RC. The User Acceptance Test (UAT) resulted in agreement that the LCC-RC is a unique and user-friendly tool. It was also agreed that LCC-RC supports the decision-making for green H&R projects by accumulating the total LCC of green criteria investment. This research innovation is novel in terms of an alternative for reducing the negative perception of green highways. The LCC-RC also exceptionally facilitates decision-making, hence, aiding the H&R stakeholders in foreseeing the green highway cost benefits and risks evaluation.

ABSTRAK

Persepsi yang negatif daripada kos awalan yang tinggi dalam pelaburan ciri-ciri hijau ke projek-projek bangunan atau infrastruktur ialah stigma kepada pemaju dalam menerapkan pembinaan lestari. Projek hijau perlu menentukan kos faedah jangka masa panjang pada peringkat daya maju projek. Analisis Kos Kitaran Hayat (LCC) adalah kaedah yang telah diperkenalkan untuk menyerlahkan pulangan pelaburan dan risiko kos yang berkemungkinan dihadapi semasa jangka hayat bangunan atau infrastruktur. Selain bangunan hijau, "lebuhraya hijau" atau "jalanraya hijau" adalah antara keprihatinan muncul dalam pembinaan lestari. Penubuhan rating lebuhraya & jalanraya (H&R) seperti Index Lebuh raya Hijau Malaysia (MyGHI), menawarkan multi-kriteria inisiatif kelestarian yang dikira sebagai skor daripada pensijilan H&R hijau. Keputusan untuk melaksanakan inisiatif kelestarian menimbulkan persoalan tentang risiko kos kepada pelaburan. Penyelidikan ini bertujuan untuk membangun suatu kalkulator risiko LCC (LCC-RC) untuk kriteria lebuh raya hijau sebagai sokongan membuat keputusan untuk analisis kos faedah dan anggaran risiko. Penyelidikan ini telah menggunakan projek lebuhraya yang mendapat pensijilan MyGHI untuk mengenal pasti perhubungan antara komponen LCC dan kriteria ukuran daripada lebuhraya hijau. Subjek analisis faedah kos dan risiko telah berdasarkan risiko berkaitan dengan kriteria hijau daripada kecekapan tenaga (EE) sahaja. Kaji selidik telah dijalankan terhadap 65 responden. Ujian Friedman dan Analisis Pekali Korelasi Spearman telah digunakan untuk menentusahkan komponen LCC, dan korelasi tersebut telah digunakan dalam kalkulator risiko LCC. Keputusan menunjukkan purata jumlah LCC berjumlah RM481,156 daripada projek lebuhraya hijau dan kriteria EE hijau mempunyai hubung kait positif dan signifikan kecuali untuk kos kapital, penyelenggaraan, dan gantian. Kos kontingensi mempunyai hubung kait positif yang paling kuat (0.29, $p < 0.005$). Keputusan daripada kalkulator menggambarkan ringkasan statistik deskriptif yang telah dikira daripada analisa LCC bersama dengan carta output simulasi. Sistem elektrik daripada data lampu jalan LED daripada pengeluar lampu jalan LED di Malaysia telah dipilih untuk percubaan kalkulator LCC-RC. Keputusan Ujian Penerimaan Pengguna (UAT) telah menunjukkan persetujuan yang kalkulator risiko LCC adalah unik dan mesra pengguna. Persejutuan tentang LCC-RC menyokong pembuat keputusan untuk projek lebuhraya hijau dengan mengumpulkan jumlah LCC daripada pelaburan kriteria hijau. Inovasi penyelidikan ini membuktikan kebaharuan dari segi alternatif untuk mengurangkan persepsi negatif projek lebuhraya hijau dengan menggunakan kalkulator risiko LCC. Kalkulator LCC-RC ini juga menyumbang khusus untuk memudahkan pembuatan keputusan, sekali gus, membantu pemegang taruh H&R dalam meramalkan faedah kos dan penilaian risiko lebuhraya hijau.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CO2	-	Carbon Dioxide
GTMP	-	Green Technology Master Plan
LCC	-	Life Cycle Cost
LCC-RC	-	Life Cycle Cost Risk Calculator
TBL	-	Triple Bottom Line
H&R	-	Highway and Road
DSS	-	Decision-Making Support System
EE	-	Energy Efficiency
MyGHI	-	Malaysia Green Highway Index
LED	-	A light-emitting diode
PV	-	Present Value
PDF	-	Probability Distribution Function
CBA	-	Cost-Benefit Analysis
IRR	-	Internal Rate of Return
LAN	-	Local Area Network
OLAP	-	Online Analytical Processing
TBL	-	Triple Bottom Line
EIA	-	Environmental Impact Assessment
AASHTO	-	American Association of State Highway and Transportation Officials
MHA	-	Malaysian Highway Authority
ETC	-	Electric tax collection
LCM	-	life-cycle management
LCSA	-	Life cycle sustainability assessment
WLC	-	Whole-Life Costing
SEM	-	Structural Equation Modelling
VBA	-	Visual Basic For Application

LIST OF SYMBOLS

α	-	Alpha
$\bar{c}$	-	Average Covariance between Item-Pairs
$\bar{v}$	-	Average Variance
$\varkappa^2$	-	Friedman
ρ	-	Spearman coefficient

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Many green highway projects aim to improve biodiversity, improve the quality of air and water, reduce waste, together with protecting the infrastructure's natural assets. The aims are mainly to support sustainable development which in direct outcome the green projects responsive to environment and inhabitation. There is huge ambiguity while discussing the cost of green highway projects. Much research has proven that green projects require high initial costs at their initial stage of implementation. According to Taleizadeh et al. (2020), green criteria costs are incurred when green materials and the cost of green commodities are to be used. A green project in building or infrastructure creates a new approach for green technology applications in the construction industry and can impact cost escalation (J. S. Khan, 2019).

The problem of global warming and natural resource depletion has been addressed differently by various nations. Recent surveys reveal that CO2 emissions are expected to continue to develop as Malaysia's economy develops (Azlina and Mustapha, 2012; Begum et al., 2017), unless the growth paradigm "grow first, clean up later" changes to greener and sustainable routes. There is, therefore, still a significant cause of CO2 emissions for fossil fuel combustion, which is a resource-efficient route of development when considering the shift to a low carbon economy (Babatundea, et al., 2018). Equally, issues of sustainability were commonly discussed (e.g., Crane et al., 2019; Neardey et al., 2020; Zhou et al., 2018). One of the examples of green projects is the development of green highway and road (H&R) construction projects led to environmental issues such as exposure to contaminated and dangerous materials, resource depletion, habitat disturbances, noise, soil, and land. According to Ahmad et al. (2016), the operations of the H&R project have a strong environmental impact, and this situation can have a negative environmental impact, creating a sustainable problem. Furthermore, Balubaid et al. 2015 stressed that growing concerns on the scarcity of supply of non-renewable material for H&R and increasing costs of manufacturing of natural resources had encouraged designers and engineers to find an alternative solution to the above issues. Ahmad et al. 2016 also stressed the same issues by stated the transport industry consumes 30% of the worldwide electricity, consumes 25% of fossil fuels, and emits about 40% of air and greenhouse gas emissions. This industry may trigger hazardous emissions, global climate changes, disturbances to ecosystems, and the depletion of natural assets, in particular aggregates and binders, because of the increased demand in the building of pavements.

Set against the global context, it is anticipated that in future Malaysia will face a critical decrease in natural aggregates and binders if no action is taken to resolve these problems (Bujang et al., 2018). Furthermore, there is an increase in the depletion of current resources in natural pavement products that do not ensure sustainability for future generations (Azahar et al., 2016; Idham and Hainin, 2015). The primary focus when to concern in implementing sustainable development goals into highway infrastructure projects is the energy efficiency criteria. Most of the green rating tools over the globe put significant consent in energy efficiency criteria in order to response to the effects of climate change by reducing energy consumption. Likewise, energy efficiency should be carefully considered during the creation of green Highway and Road (H&R) projects. Energy efficiency in H&R projects and its operation, for instance, refers to consuming less energy by obtaining adequate electrical power and significantly reducing air pollutant emissions (Qin et al., 2014). In example the energy efficient for H&R street lighting have to provide safety and comfort which refer to clear and soft illumination with assurance of no light pollution of harmful light generation such as ultraviolet light and glare.

Mukta et al. (2020) claimed increasing the energy efficiency of public lighting systems is a primary priority for energy-conscious organisations worldwide. In the case of energy efficiency in lighting systems is sometimes undervalued by the traditional measures of reduced energy demand and lower GHG emissions, it has the potential to play a crucial role in promoting environmental sustainability, bolstering economic growth, accelerating social development, and protecting the energy system's security. Taking instance of H&R street lighting, each pole need at distance of least 2.5-3 of the lighting pole height and it is multiply with kilometres of the highway (Ramli et al., 2016). This numbers of streets lighting is more serious in urban highways and toll plaza. The cumulative number of street lighting indicates that the consumption of energy is high and improving energy efficiency has the potential to save large amounts of energy annually.

On Malaysian highways, the installation of Light-Emitting Diodes (LED) for street lighting is an example of the application of green technology. Increasing the energy efficiency of street lighting systems is frequently one of the primary initiatives that highway operators can adopt as part of their sustainable initiatives. Although the absolute amount of electricity consumed by street lighting is low, it has a significant symbolic value for energy conservation in cumulative for all urban and rural H&R in Malaysia; and for cities lighting in Malaysia. In the context of local government budget constraints, identifying energy efficiency techniques that do not require costly expenditures and are compatible with existing technology is an option (N. Das et al., 2015). Malaysia has primary agenda of energy reduction and recently launched Malaysian Green Technology Master Pelan (GTMP). GTMP is to encourage green technology projects in developing a nation, the construction of viable green H&R for future requirements is one of the critical problems being discussed (Mohd Nusa et al., 2020).

The present worldwide improvement in the harmful impacts of building on the environment is designed to promote viable growth and implement green actions (C. Kibert, 2015). Indeed, nations are moving their focus to a domestic priority for sustainable growth. Aiming to make this concept more applicable and raise awareness among those involved in green highway projects is the goal. The entire cost of various green project designs should be assessed based on the Life Cycle Cost (LCC), which involves all costs and revenues over the lifetime of the building. In order to achieve LCC of green highway projects, all elements should first be identified as the green variable or criteria cost at the LCC component stage, and the correlation between them should be established (Rahman & Zakaria, 2018). This expected outcome and ability able to assist and boost the green project Triple Bottom Line (TBL), specifically green technology example in green H&R investment area and the correlation amongst its LCC components of total green criteria cost, can be known. Besides, the LCC components variance control can be applied using correlation studies, and the total green criteria cost inferring can be improved with integrated risk and life cycle costing tools (Ilg et al., 2017). Nevertheless, the LCC value for green highway projects can be optimised, plus the LCC profile and cost library of green highway projects can be established by aligning the green criteria cost model with value engineering.

Furthermore, it is essential to remember that green project technology is presently at the most advanced stage than ever before, and as the world's supply of non-renewable resources becomes scarce and costly, green technology remains to increase its importance. Taking again the example of green H&R projects, the cost of using this infrastructure is a consequence of the accumulated total green criteria cost during the lifetime of the H&R. Initiatives reducing future cost (e.g., power efficiency, increased H&R component durability) often lead to higher investment costs (e.g., adding heat insulation, more resilient paving materials). Automatic optimisation can substitute manual variations of various design parameters and save the H&R designers a great deal of job and simultaneously lead the designers to cost-effective H&R design with excellent results (Kleppmann, 2017). Equally important, the use of computer simulation to accurately assess the performance of various H&R design criteria, where problem definition and criteria variation can take a great deal of time. If future costs are not included in the assessment, these projects are not endorsed accordingly. In particular, it is often desirable to assess the cost-effectiveness of green highway project across separate LCC component when assessing total green criteria cost. The cost can assist and analyse the trade-offs between different green criteria, such as unique energy efficiency characteristics.

1.2 Statement of the Problem

The notion of green technology innovation fosters an enticing green revolution for sustainable environmental and economic enhancement impacting developing nations (Kenis and Lievens, 2016). For instance, in recent years, the prolonged and inefficient use of most lighting services has been a top focus, particularly in densely populated and industrialised nations with relatively high electricity rates (Beccali et al., 2015). Existing lighting systems are a huge drain on a nation's energy reserves, despite the fact that their activities are insufficient. In addition, the length of daylight changes throughout the year, but traditional lighting systems are often turned on at 6 or 7 p.m. and turned off at 6 or 7 a.m., resulting in significant energy loss (Mukta et al., 2020). Also, the lights remain on throughout the night regardless of whether there are any cars or pedestrians present, squandering energy and lamp life. In this situation, building a so-called green project with carbon-neutral equipment, in one way, expected to reduce the risk of emissions from fossil fuels and greenhouse gases (Attahiru et al., 2019).

The efforts made are a significant step forward in typical green highway projects and industries. Similarly, investment in installations is long-lived and necessarily involves threats to green project for its construction longevity, operational and maintenance costs, as well as many other factors affecting the economics of installations. If the cost and time details are substantially risky, an LCC appraisal can have little benefit for consumers and policymakers. Therefore, if the LCC models can incorporate a quantitative approach for determining the risk likelihood, this kind of obstacle can be resolved. The most significant improbabilities commonly occur in the earlier stages of a project, even when investment decisions have the most significant effect. However, future cost modelling risks entail similar risks. Likewise, the uncertainties of future capital investment and LCC projections need to be calculated in the post-road or highway variable cost analysis. Therefore, risk assessments offer useful insights into situations that explicitly describe the probability density function (Oduyemi and Okoroh, 2016) and reduce the risk of loss and optimise green highway project opportunities. It is risk assessment and final monitoring that is not adequate (Suter and Norton, 2018), and formal risk assessment strategies are required to ensure that regularity and standardisation of green project measurable variables are accomplished. Most of these approaches are, however, generally tricky, complicated, and expensive, and therefore the use of these methods is exorbitant for many projects. The lack of understanding and questions regarding adequacy within the ecosystem professions was also recognised as reasons for the slow approach (H. T. Nguyen et al., 2017).

The present study does so in the context of the green highway projects by developing a life cycle cost risk calculator as a decision-making support system (DSS) model for the green criteria cost area using LCC in Malaysia. Hence, how to implement the life cycle tools in the decision-making process becomes more critical. Green highway projects should not end up being just a conventional cost. The green highway project should have carried out the cost risk. Cost risk involves performing a risk analysis of that green highway project's cost value to determine the likelihood of finishing the green project on budget as well as estimate the requisite contingency reserve needed to provide the desired amount of certainty about achieving the cost-plus reserve. The suitable contingency reserve usually differs from the reserve included in the traditional cost estimation process, which is frequently a rough estimate. An understanding of cost risk can prove important for green highway projects to lead to a better plan, as it leads to early mitigation of the investment of green criteria and allows management or other stakeholders to make an investment that has the desired level of certainty offers.

Though many products are using life cycle costing as a decision-making tool, its use is still far from being systematic, and the calculation methodologies are based on trial-and-error methods. Moreover, these products are not using life cycle costing to reach the minimum LCC. Achieving high "green ratings" also acts as a safeguard to minimise the effects of future energy price increases, the impact of which should not be underestimated. Therefore, this research concerned with identifying the relationship between the LCC component and green criteria to aid the designers and engineers and decision-makers in selecting their right green options and initiatives with cost and risks analyses.

1.3 Research Gap

Almost all green or sustainability rating tools across the world pay high attention on energy reduction. H&R projects, also public infrastructures that utilising energy on its operation and the consumption is relative to the length of the H&R. For instance, when constructing and analysing street lighting, the energy reduction via energy efficient of lighting must be considered for at least two reasons. First is the increasing awareness of global warming, which drives the quest for energy-saving strategies. The second factor is an increase in the cost of electrical energy, which compels the organisations responsible for street lighting to demonstrate the value and cost-effectiveness of their efforts. Given the range of available street lighting options, it would be beneficial to have a mechanism for more precise cost estimation. Therefore, the element of energy efficiency in H&R projects is absolute in gaining attention compared to other criteria in highway and road construction. With above reason, and in comparison, to other criteria, Energy Efficiency (EE) criteria is suitable to represent a green highway project in general.

The green highway project financial aspect provides various opportunities to be considered, and LCC is one of them. In addition, LCC would be confirmed by risk concepts, so the relationship between LCC components and LCC of total green criteria cost could be established. The form established and raised the inevitable research questions; firstly, how to correlate measurable green criteria cost and cost components of LCC. Secondly, how the calculation of green criteria incurring costs and LCC will presage the output of cost in LCC functionality. Thirdly, can the DSS framework to be utilised on LCC which at the same time designates the risk probability.

Given the rising prevalence of green criteria costs incurred for green highway projects investment, there is an essential need to establish complete information in the form of summary statistics for total green criteria cost output results in the form of LCC using cost risk analysis through probability distribution simulation. The simulation depicts a DSS insight using a virtual population of costs identical to the one being analysed, based on summary statistics such as mean cost and also costs at any percentile of the virtual population of costs.

1.4 Research Question

Bougie and Sekaran (2019) propose an inclusive strategy to address a study issue. Considering the problem statement outlined in the previous sub-section, this study tries to explore the association of LCC of green highway projects with LCC component of green criteria to help decision-makers choose their green criteria cost approaches of a project. Specifically, the research questions are formulated as follows:

1. How to correlate measurable criteria of green highway project with cost components of LCC?
2. How will the calculation of green criteria incurring costs and how LCC pointing the output of cost and risk probability?
3. Can the DSS to be utilised on LCC, which simultaneously indicates the risk probability?
4. Is there any manual of Life Cycle Cost Risk Calculation for decision-maker that associate LCC and risk probability?

1.5 Aim of the Research

This research aims to develop a Life Cycle Cost Risk Calculator (LCC-RC) by determining the correlation between the LCC of green highway projects and the LCC component of Energy Efficiency (EE) criteria costs using integrated Monte Carlo Simulation. With this aim, this study enables the following four primary research objectives to be achieved:

1. To establish the relationship of LCC components related to the green highway project criteria.
2. To correlate triangular probability distribution in the life cycle costing components and associate green criteria cost structured with risk probability.
3. To develop a calculator framework that analyse total cost for green criteria using life cycle costing integrated with risk probability calculator.
4. To develop a manual of life cycle cost risk calculator for the analysis of cost risk in green highway project.

1.6 The Scope of the Study

This study undertakes green H&R projects as case studies of green projects. Although many studies have provided evidence of evaluating green H&R and issues related to sustainability in the H&R construction industry in Malaysia, none of them has exclusively investigated the pattern, dimension, and effect of LCC application with the DSS model towards Malaysian green H&R. Thus, focus on the green H&R beneficial and understandable DSS are necessitated in the Malaysian H&R scenario.

The purpose of this study is to examine the green criteria cost for green H&R as extracted from the Energy Efficiency (EE) section of the Malaysia Green Highway Index (MyGHI) via a survey questionnaire. It is very important to note that the proposed procedure or framework can also be applied to other types of infrastructure. Therefore, the results of this study are also applicable to other infrastructure criteria and are not limited to the case studies presented in this thesis. Compared to other criteria, EE has gained attention due to its greater influence on green highway projects, as its criteria directly show the energy efficiency of the technology or methodology, especially in green rating. For example, LCC data on EE consists of planning and operating costs compared to materials such as H&R construction materials, which require a longer period for LCC data to wait for the replacement cycle of the construction material.

A preliminary pilot study was taken, whereby the EE section is used to look at the applicability of the questionnaire to determine the correlation that occurs between green highway projects LCC and LCC component of total green criteria. Next, LED streetlight criteria within the EE section in MyGHI is taken as the green criteria cost of this study. In this study, the main interest lies in creating the correlation of LCC component of total green criteria cost for LED streetlight. The reason for choosing EE criteria with its LED street lighting component is visible and available within the stages of H&R project life cycle and availability of data in representing the main element in the green H&R ecosystem. The visibility and availability of this component element has drawn attention to the availability of cost risk data and makes people easily understand and aware of the implications of rapidly changing technology, especially in the EE criteria. Even though the bitumen asphalts materials is look very visible, however, the data availability is almost impossible due to total H&R resurfacing make takes from 5-10 years cycle. The materials and the replacement with green materials is only taken at certain stretch of H&R for pilot study of the workability and strength on the materials.

Furthermore, the scope of the study also covers the type of LCC component utilise a probabilistic approach by using the Monte Carlo simulation. The correlation between life cycle costing components and associate green criteria cost is used for further risk probability analysis using an excel calculator will be developed. This study determine the LED streetlight criteria cost of risk prediction. The purpose is to incorporate risks and uncertainties in order to develop an integrated calculator that analyse LCC with a probability approach based on given input and probability distribution preferred. The input cells are based on the life cycle costing Present Value (PV) formula, and there are three (3) types of Probability Distribution Function (PDF) alternatives for Monte Carlo Simulation, which are triangular distribution to be selected. The present value formula is used in the calculator with up to a 15-year analysis period. Interest and discount rates can be chosen depending on the information available. Within deductive and exploratory research, the application of the model to a case study of LED streetlights best fits as a research strategy. This step also focuses more on the quantitative part of the problem analysis by looking at figures.

1.7 Significance of the Study

This research contributes to the growing body of knowledge of green criteria cost and LCC cost component. Even though LCC is a topic that has been researched extensively around the world but is still in its infancy stage in Malaysia. Due to that, this increases the value of the findings and is highly relevant to bridging the gap in the slow tendency literature of green criteria in linking to the critical cost components related to sustainable measures in green highway project investments. Notably, this study can make a substantial contribution to the body of knowledge in a number of ways.

In this study, Systems Theory were applied to contribute to the contemporary understanding of project management theory. This study is expected to strengthen its predictions towards adequate positioning, implementation of (where necessary) period, transformation and redefault of the construction industry structure, the industry must plan structural adjustments to guarantee the continued survival of the entire system, continually formulating new interpretations of green highway projects. Furthermore, applying this theory in this study will also contribute to improving the generalisation concerning today's thinking on H&R construction focuses on how green initiative design needs to be harmonised with local economic factors, how subsequent environmental destruction and over-use of resources can be prevented, and how sustainable development ideas can be incorporated into green highway projects.

The study is essential from a scholarly standpoint since it allows expansion of knowledge academics to reconsider the LCC, its impact on green highway project investments, and its cost risk, all relevant sources of which are extensively addressed in the literature. This empirical study helps conducted empirically and facilitates the unbiased assessment and critical interpretation of the cost components of LCC. In addition, this research compared reliable LCC outcomes from the environmental effects of the Malaysian highway construction as the case examples. The essence of the outcomes is to enable the identification of procedures and techniques that have significant adverse effects on the setting that are presently lacking in current literature.

The findings of this study may assist policymakers in properly outline measures in planning, developing and implementing the critical cost components related to sustainable measures in green highway project investments. In addition, there are social issues in terms of readiness and acceptance of green highway projects among the Malaysian construction industry, and the findings of this study may provide incentives as well as enables a regulatory mechanism that affects the rest of the strategies created to address the Malaysian green highway project problems. This could be materialised through the establishment of LCC assessment and a green highway project database (e.g., green H&R programs, tools, indicators, and design codes) that allows users to get the required information to create and maintain a green project-built environment.

This research provided a valuable application for investors to help them for a better understanding of green highway project cost benefits. K.-K. Seo, J.-H. Park et al. (2002) argued that the design of the product influences between70% and 85% of the total cost of a product. Therefore, developers are in a situation to significantly decrease the cost of the item they design by taking due account of the cost of the life cycle of design choices they make. Henceforth, this tool will be useful for designers' decision-making such as on the materials in green highway projects. In other words, this research will provide an appropriate database and repository of available green materials in the Malaysian market and will be valuable for suppliers in creating a competitive market in terms of green procurement. The result of this research may assist academics such as lecturers, PhD, Master as well as bachelor's degree candidates to carry out further research in green projects and critical cost components related to sustainable measures such as in H&R infrastructure investments and in other construction sectors in Malaysia, which could help in understanding the contribution of LCC assessment strategies to the overall growth of this sector.

1.8 Novelty of the Study

The novelty of this study brings the LCC risk calculator for green highway criteria towards the better solution of LCC of green highway projects. The research study contributes to the body of knowledge by developing new innovative integrated calculator tool of LCC incorporated with risk probability, which had not been developed before for the quick, easy and time-saving decision-making process for the green highway projects facilitators and investors. This kind of dynamic invention will attract green highway project investors by benefiting them in determining the initial and future cost of green highway projects.

However, this rigorous approach have potential to commercially available for all the stakeholders of the green highway projects industry through their industrial domain. Green highway projects investors, builders, contractor, project managers, engineers, designers, and planners will get great benefit out of this viable and easy usable dynamic tool. LCC with risk probability tool will help to prioritise the

Malaysian government's initiatives, plans and strategies developed for the sustainable built environment for 2030 (UN-SDG, 2016) and MGTP (2020). Significantly, this tool is unique innovation in green project built environment and construction industry at large.

1.9 Summary of Research Chapter

The structure of this thesis is organised in five chapters. Chapter 1 consists of the discussion on the background of the study, which is composed of the introduction, problem statement, research objectives, and questions, significance of the study, identifying the scope of research, and defining key terms. Chapter 2 summarises the current state of knowledge by addressing the relevant literature. Areas covered in this chapter include sustainable development principles and the evolution of green projects taken example of highway infrastructure development. The literature review also covers the long-term financial management in highway development, which includes the principles of long-term financial management, application of LCC in highway projects, development of the LCC models and programs, and the limitation of existing LCC studies regarding sustainability. The literature on the responses to the sustainability challenge and cost implication in highway infrastructure is also surveyed. Overall, this chapter identifies the research gap, which justifies the need for this study.

Chapter 3 describes the research methodology in detail including the research methodology; data collection methods (namely questionnaire, framework development and case example); research information; selection of participants and case projects; research instrumentation; data analysis and validation of results; and, finally, guideline formulation. Chapter 4 describes the data analysis and results of the questionnaire and semi-structured interview. Questionnaire feedback is presented, and the results tabulated in order to answer the research questions. Total green criteria cost in term of LCC components are identified, and conclusions are drawn. The data analysis and findings of the interview results illustrate the understanding of the current industry practice of long-term financial management in green H&R infrastructure.

Besides, potential issues hindering the integration of green criteria cost into LCC are identified.

Chapter 5 reviews the research objectives and development processes; and offers conclusions concerning the research outcomes based on the particular research questions, the contributions to the body of knowledge and its implications for both the research community and the highway infrastructure recommendations for future research are proposed.

1.10 Chapter Summary

In this introduction chapter, the structure of the thesis and the theme of the study have been introduced. Background of the research has been presented and the research problem described. The broad research questions which incorporate the objectives of this research have been articulated. Finally, the anticipated benefits deriving from this research, the scope of study and the inherent limitations of the research employed are elaborated. The next chapter takes a brief look into the literature to explore the nature of the development of green highway projects and the LCC, taken example of green H&R as the main focus of this research. The chapter provides the literature review related to concepts included in the research framework and hypothesis developed.

REFERENCES

Abate, F., Carratù, M., Liguori, C., and Paciello, V. (2019). A low cost smart power meter for IoT. *Measurement: Journal of the International Measurement Confederation*, *136*, 59–66. https://doi.org/10.1016/j.measurement.2018.12.069

Abd Rahman, M. F., Zakaria, R., Shamsudin, S. M., Aminudin, E., and Yousif, O. S. (2022). The Importance of Life Cycle Cost (LCC) Components for Emerging Green Costs Incurred in Green Highway Budget Preparation Decision-Making. *IOP Conference Series: Earth and Environmental Science*, *1067*(1), 012061. https://doi.org/10.1088/1755-1315/1067/1/012061

Abdelaty, A., Jeong, H. D., Dannen, B., and Todey, F. (2016). Enhancing life cycle cost analysis with a novel cost classification framework for pavement rehabilitation projects. *Construction Management and Economics*, *34*(10), 724–736. https://doi.org/10.1080/01446193.2016.1205206

Abduli, M. A., Naghib, A., Yonesi, M., and Akbari, A. (2011). Life cycle assessment (LCA) of solid waste management strategies in Tehran: landfill and composting plus landfill. *Environmental Monitoring and Assessment*, *178*(1), 487–498.

Aburamadan, R., and Trillo, C. (2020). Applying design science approach to architectural design development. *Frontiers of Architectural Research*, *9*(1), 216–235.

Adom, D., Hussein, E. K., and Agyem, J. A. (2018). Theoretical and conceptual framework: Mandatory ingredients of a quality research. *International Journal of Scientific Research*, *7*(1), 438–441.

Adzar, J. A., Zakaria, R., Aminudin, E., Rashid, M. H. S. A., Munikanan, V., Shamsudin, S. M., … Wah, C. K. (2019). Development of operation and maintenance sustainability index for penarafan hijau jabatan kerja raya (pHJKR) green road rating system. *IOP Conference Series: Materials Science and Engineering*, *527*(1). https://doi.org/10.1088/1757-899X/527/1/012058

Agrawal, P. (2018). Ethical issues in research. *Higher Education and Professional Ethics, Ed. SS Sethy. Routledge India: Roles and Responsibilities of Teachers.*

Ahammed, M. A., and Tighe, S. L. (2008). Quiet pavements: A sustainable and environmental friendly choice. In *Proceedings of the 2008 Annual Conference of the Transportation Association of Canada (TAC), Toronto, Ontario, CD-ROM.*

Ahmad, A. C., Husin, N. I., Ab Wahid, A. M., and Kamaruzzaman, S. N. (2016). Tropical Environment Elements for Green Highway Assessment. *Social and Management Research Journal*. https://doi.org/10.24191/smrj.v13i2.5276

Akmam Syed Zakaria, S., Gajendran, T., Skitmore, M., and Brewer, G. (2018). Key factors influencing the decision to adopt industrialised building systems technology in the Malaysian construction industry: an inter-project perspective. *Architectural Engineering and Design Management*, *14*(1–2), 27–45.

Akour, M., and Falah, B. (2016). Application domain and programming language readability yardsticks. In *2016 7th International Conference on Computer Science and Information Technology (CSIT)* (pp. 1–6). IEEE.

Al-Alili, A., Hwang, Y., and Radermacher, R. (2014). Review of solar thermal air conditioning technologies. *International Journal of Refrigeration*, *39*, 4–22. https://doi.org/10.1016/j.ijrefrig.2013.11.028

Alirezaei, M., Onat, N. C., Tatari, O., and Abdel-Aty, M. (2017). The climate change-road safety-economy nexus: a system dynamics approach to understanding complex interdependencies. *Systems*, *5*(1), 6.

Alyoubi, B. A. (2015). Decision support system and knowledge-based strategic management. *Procedia Computer Science*, *65*, 278–284.

Amundrud, Ø., Aven, T., and Flage, R. (2017). How the definition of security risk can be made compatible with safety definitions. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *231*(3), 286–294.

Anderson, A. J., and Vingrys, A. J. (2001). Small samples: does size matter? *Investigative Ophthalmology & Visual Science*, *42*(7), 1411–1413.

Aravind, K., and Das, A. (2007). Pavement design with central plant hot-mix recycled asphalt mixes. *Construction and Building Materials*, *21*(5), 928–936.

Assali, A., Khatib, T., and Najjar, A. (2019). Renewable energy awareness among future generation of Palestine. *Renewable Energy*, *136*, 254–263. https://doi.org/10.1016/j.renene.2019.01.007

Attahiru, Y. B., Aziz, M. M. A., Kassim, K. A., Shahid, S., Wan Abu Bakar, W. A., NSashruddin, T. F., … Ahamed, M. I. (2019). A review on green economy and development of green roads and highways using carbon neutral materials. *Renewable and Sustainable Energy Reviews*, *101*, 600–613. https://doi.org/10.1016/j.rser.2018.11.036

Aye, L., Bamford, N., Charters, B., and Robinson, J. (2000). Environmentally sustainable development: a life-cycle costing approach for a commercial office building in Melbourne, Australia. *Construction Management & Economics*, *18*(8), 927–934.

Azahar, W. N. A. W., Jaya, R. P., Hainin, M. R., Bujang, M., and Ngadi, N. (2016). Chemical modification of waste cooking oil to improve the physical and rheological properties of asphalt binder. *Construction and Building Materials*. https://doi.org/10.1016/j.conbuildmat.2016.09.032

AzariJafari, H., Yahia, A., and Amor, M. Ben. (2016). Life cycle assessment of pavements: reviewing research challenges and opportunities. *Journal of Cleaner Production*, *112*, 2187–2197.

Azlina, A. A., and Mustapha, N. H. N. (2012). Energy, Economic Growth and Pollutant Emissions Nexus: The Case of Malaysia. *Procedia - Social and Behavioral Sciences*. https://doi.org/10.1016/j.sbspro.2012.11.082

Babashamsi, P., Md Yusoff, N. I., Ceylan, H., Md Nor, N. G., and Salarzadeh Jenatabadi, H. (2016). Evaluation of pavement life cycle cost analysis: Review and analysis. *International Journal of Pavement Research and Technology*, *9*(4), 241–254. https://doi.org/10.1016/j.ijprt.2016.08.004

Babatundea, K.A., Saida, F.F., Nora, N. G. M. (2018). Reducing Carbon Dioxide

Emissions from Malaysian Power Sector: Current Issues and Future Directions. *Engineering Journal*.

Badcock, P. B., Davey, C. G., Whittle, S., Allen, N. B., and Friston, K. J. (2017). The depressed brain: an evolutionary systems theory. *Trends in Cognitive Sciences*, *21*(3), 182–194.

Balasbaneh, A. T., Marsono, A. K. Bin, and Khaleghi, S. J. (2018). Sustainability choice of different hybrid timber structure for low medium cost single-story residential building: Environmental, economic and social assessment. *Journal of Building Engineering*, *20*, 235–247.

Baldoni, E., Coderoni, S., D'Orazio, M., Di Giuseppe, E., and Esposti, R. (2019). The role of economic and policy variables in energy-efficient retrofitting assessment. A stochastic Life Cycle Costing methodology. *Energy Policy*, *129*, 1207–1219.

Balubaid, S., Bujang, M., Aifa, W. N., Seng, F. K., Rooshdi, R. R. R. M., Hamzah, N., … Ismail, H. H. (2015). Assessment Index Tool for Green Highway in Malaysia. *Jurnal Teknologi*, *77*(16), 99–104. https://doi.org/10.11113/jt.v77.6405

Bamodu, O., Osebor, F., Xia, L., Cheshmehzangi, A., and Tang, L. (2018). Indoor environment monitoring based on humidity conditions using a low-cost sensor network. In *Energy Procedia* (Vol. 145, pp. 464–471). Elsevier Ltd. https://doi.org/10.1016/j.egypro.2018.04.093

Banister, D., Crist, P., and Perkins, S. (2015). Land transport and how to unlock investment in support of "Green Growth."

Barile, S., Saviano, M., Iandolo, F., and Calabrese, M. (2014). The viable systems approach and its contribution to the analysis of sustainable business behaviors. *Systems Research and Behavioral Science*, *31*(6), 683–695.

Barrella, E., Lineburg, K., and Hurley, P. (2017). Applying a transportation rating system to advance sustainability evaluation, planning and partnerships. *International Journal of Sustainability in Higher Education*.

Barringer, H. P., and Weber, D. P. (1996). Life Cycle Cost Tutorial–Fifth International

Conference on Process Planet Reliability–Houston. *Texas–1996*.

Baum-Snow, N., Brandt, L., Henderson, J. V., Turner, M. A., and Zhang, Q. (2017). Roads, railroads, and decentralization of Chinese cities. *Review of Economics and Statistics*, *99*(3), 435–448.

Beccali, M., Bonomolo, M., Ciulla, G., Galatioto, A., and Lo Brano, V. (2015). Improvement of energy efficiency and quality of street lighting in South Italy as an action of Sustainable Energy Action Plans. The case study of Comiso (RG). *Energy*, *92*(Part 3), 394–408. https://doi.org/10.1016/j.energy.2015.05.003

Begum, R. A., Abdullah, S. M. S., and Sujahangir Kabir Sarkar, M. D. (2017). Time Series Patterns and Relationship of Energy Consumption and CO2 Emissions in Malaysia. *Asian Journal of Water, Environment and Pollution*. https://doi.org/10.3233/AJW-170014

Bentler, P. M., and Bonett, D. G. (1980). Significance Tests and Goodness of Fit in the Analysis of Covariance Structures. *Psychological Bulletin*, *88*(3), 588–606. https://doi.org/10.1037/0033-2909.88.3.588

Bentler, Peter M, and Huang, W. (2014). On components, latent variables, PLS and simple methods: Reactions to Rigdon's rethinking of PLS. *Long Range Planning*, *47*(3), 138–145.

Berglund, T., and Gericke, N. (2016). Separated and integrated perspectives on environmental, economic, and social dimensions–an investigation of student views on sustainable development. *Environmental Education Research*, *22*(8), 1115–1138.

Betts, M., and Ofori, G. (1992). Strategic planning for competitive advantage in construction. *Construction Management and Economics*, *10*(6), 511–532. https://doi.org/10.1080/01446199200000049

Bilodeau, J.-P., Cloutier, J.-P., and Doré, G. (2017). Experimental damage assessment of flexible pavements during freeze-up. *Journal of Cold Regions Engineering*, *31*(4), 4017014.

Bisinella, V., Conradsen, K., Christensen, T. H., and Astrup, T. F. (2016). A global approach for sparse representation of uncertainty in Life Cycle Assessments of waste management systems. *The International Journal of Life Cycle Assessment*, *21*(3), 378–394.

Blair, J., Czaja, R. F., and Blair, E. A. (2013). *Designing surveys: A guide to decisions and procedures*. sage publications.

Blanchard, B. S., Fabrycky, W. J., and Fabrycky, W. J. (1990). *Systems engineering and analysis* (Vol. 4). Prentice hall Englewood Cliffs, NJ.

Boardman, A. E., Greenberg, D. H., Vining, A. R., and Weimer, D. L. (2017). *Cost-benefit analysis: concepts and practice*. Cambridge University Press.

Bonci, A., Carbonari, A., Cucchiarelli, A., Messi, L., Pirani, M., and Vaccarini, M. (2019). A cyber-physical system approach for building efficiency monitoring. *Automation in Construction*, *102*(February), 68–85. https://doi.org/10.1016/j.autcon.2019.02.010

Bougie, R., and Sekaran, U. (2019). *Research methods for business: A skill building approach*. John Wiley & Sons.

Bozorg Chenani, S., Maksimainen, M., Tetri, E., Kosonen, I., and Luttinen, T. (2016). The effects of dimmable road lighting: A comparison of measured and perceived visibility. *Transportation Research Part F: Traffic Psychology and Behaviour*, *43*, 141–156. https://doi.org/10.1016/j.trf.2016.10.012

Bozorg Chenani, S., Vaaja, M. T., Kurkela, M., Kosonen, I., and Luttinen, T. (2017). Target detection distances under different road lighting intensities. *European Transport Research Review*, *9*(2). https://doi.org/10.1007/s12544-017-0234-z

Bozorg, S., Tetri, E., Kosonen, I., and Luttinen, T. (2018). The Effect of Dimmed Road Lighting and Car Headlights on Visibility in Varying Road Surface Conditions. *LEUKOS - Journal of Illuminating Engineering Society of North America*, *14*(4), 259–273. https://doi.org/10.1080/15502724.2018.1452152

Broman, G. I., and Robèrt, K.-H. (2017). A framework for strategic sustainable development. *Journal of Cleaner Production*, *140*, 17–31.

Bueno, P. C., Vassallo, J. M., and Cheung, K. (2015). Sustainability assessment of transport infrastructure projects: A review of existing tools and methods. *Transport Reviews*, *35*(5), 622–649.

Buffat, R., Schmid, L., Heeren, N., Froemelt, A., Raubal, M., and Hellweg, S. (2017). GIS-based decision support system for building retrofit. *Energy Procedia*, *122*, 403–408.

Bujang, M., Hainin, M. R., Abd Majid, M. Z., Idham Mohd Satar, M. K., and Azahar, W. N. A. W. (2018). Assessment framework for pavement material and technology elements in green highway index. *Journal of Cleaner Production*, *174*, 1240–1246. https://doi.org/10.1016/j.jclepro.2017.11.002

Cabeza, L. F., Rincón, L., Vilariño, V., Pérez, G., and Castell, A. (2014). Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: A review. *Renewable and Sustainable Energy Reviews*, *29*, 394–416.

Callistus, T., and Clinton, A. (2016). Evaluating Barriers to Effective Implementation of Project Monitoring and Evaluation in the Ghanaian Construction Industry. *Procedia Engineering*, *164*(June), 389–394. https://doi.org/10.1016/j.proeng.2016.11.635

Campbell, H. F., and Brown, R. P. C. (2003). *Benefit-cost analysis: financial and economic appraisal using spreadsheets*. Cambridge University Press.

Campbell, N., D'Arcy, B., Frost, A., Novotny, V., and Sansom, A. (2005). *Diffuse pollution*. IWA publishing.

Campisi, D., Gitto, S., and Morea, D. (2018). Economic feasibility of energy efficiency improvements in street lighting systems in Rome. *Journal of Cleaner Production*, *175*, 190–198. https://doi.org/10.1016/j.jclepro.2017.12.063

Caplehorn, P. (2012). *Whole life costing: a new approach*. Routledge.

Cengiz, M. S., and CENGIZ, Ã. (2018). Numerical Analysis of Tunnel Led Lighting

Maintenance Factor. *IIUM Engineering Journal*, *19*(2), 154–163. https://doi.org/10.31436/iiumej.v19i2.1007

Cepeda-Carrion, G., Cegarra-Navarro, J. G., and Cillo, V. (2019). Tips to use partial least squares structural equation modelling (PLS-SEM) in knowledge management. *Journal of Knowledge Management*. https://doi.org/10.1108/JKM-05-2018-0322

Chan, A. P. C., Darko, A., and Ameyaw, E. E. (2017). Strategies for Promoting Green Building Technologies Adoption in the Construction Industry—An International Study. *Sustainability*, *9*(6), 969. https://doi.org/10.3390/su9060969

Chen, E. Y. T., Ma, L., Yue, Y., Guo, B., and Liang, H. (2018). Measurement of dust sweeping force for cleaning solar panels. *Solar Energy Materials and Solar Cells*, *179*(November 2017), 247–253. https://doi.org/10.1016/j.solmat.2017.12.009

Chen, M., and He, Y. (2017). Exploration on Automated Software Requirement Document Readability Approaches.

Cheng, C. C., and Lee, D. (2014). Smart sensors enable smart air conditioning control. *Sensors (Switzerland)*, *14*(6), 11179–11203. https://doi.org/10.3390/s140611179

Chin, W. W., Marcolin, B. L., and Newsted, P. R. (2003). A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Information Systems Research*, *14*(2), 189–217.

Chua, Y. P. (2008). *Asas statistik penyelidikan: analisis data skala ordinal dan skala nominal*. McGraw-Hill (M).

Chybiński, M., Kurzawa, Z., and Polus, L. (2017). Problems with Buildings Lacking Basic Design Documentation. In *Procedia Engineering* (Vol. 195, pp. 24–31). Elsevier Ltd. https://doi.org/10.1016/j.proeng.2017.04.519

Chyung, S. Y., Kennedy, M., and Campbell, I. (2018). Evidence-Based Survey Design: The Use of Ascending or Descending Order of Likert-Type Response Options. Performance Improvement. *Wiley Online Library*, *57*(9), 9–16.

https://doi.org/10.1002/pfi.21800

Clemente, M. (2016). Decision Support System Approach for the Management of Complex Systems in Transportation and Logistics.

Coccia, M. (2018). A theory of the general causes of long waves: War, general purpose technologies, and economic change. *Technological Forecasting and Social Change*, *128*, 287–295.

Cohen-Rosenthal, E., and Musnikow, J. (2017). *Eco-industrial strategies*. Taylor & Francis.

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge.

Cole, R. J., and Sterner, E. (2000). Reconciling theory and practice of life-cycle costing. *Building Research & Information*, *28*(5–6), 368–375.

Crane, A., Matten, D., Glozer, S., and Spence, L. (2019). *Business ethics: Managing corporate citizenship and sustainability in the age of globalization*. Oxford University Press, USA.

Croasmun, J. T. (2011). *Using Likert-Type Scales in the Social Sciences*. *Journal of Adult Education* (Vol. 40). Retrieved from https://eric.ed.gov/?id=EJ961998

Cui, M., and Levinson, D. (2018). Full cost accessibility. *Journal of Transport and Land Use*, *11*(1), 661–679. https://doi.org/10.5198/jtlu.2018.1042

Damania, R., Russ, J., Wheeler, D., and Barra, A. F. (2018). The road to growth: Measuring the tradeoffs between economic growth and ecological destruction. *World Development*, *101*, 351–376.

Dandy, G., Daniell, T., Foley, B., and Warner, R. (2017). *Planning & Design of Engineering Systems*. CRC Press.

Das, H. S., Tan, C. W., Yatim, A. H. M., and Lau, K. Y. (2017). Feasibility analysis of hybrid photovoltaic/battery/fuel cell energy system for an indigenous residence in East Malaysia. *Renewable and Sustainable Energy Reviews*, *76*(March 2016), 1332–1347. https://doi.org/10.1016/j.rser.2017.01.174

Das, N., Pal, N., and Pradip, S. K. (2015). Economic cost analysis of LED over HPS flood lights for an efficient exterior lighting design using solar PV. *Building and Environment*, *89*, 380–392. https://doi.org/10.1016/j.buildenv.2015.03.005

Datta, S. (1991). Decision support for decentralised planning (DSSDP). *The Administrator*, *36*(3), 77–86.

Datta, S. (1994). Local area management and planning (LAMP) in India. *International Transactions in Operational Research*, *1*(2), 135–145.

De Courchelle, I., Guérout, T., Da Costa, G., Monteil, T., and Labit, Y. (2019). Green energy efficient scheduling management. *Simulation Modelling Practice and Theory*, *93*(May 2018), 208–232. https://doi.org/10.1016/j.simpat.2018.09.011

Denzin, N. (2017). *The research act: A theoretical introduction to sociological methods*.

Detzel, A., Krüger, M., Busch, M., Blanco-Gutiérrez, I., Varela, C., Manners, R., Zannini, E. (2021). Life cycle assessment of animal-based foods and plant-based protein-rich alternatives: an environmental perspective. *Journal of the Science of Food and Agriculture*.

Di Bucci, D., and Savadori, L. (2018). Defining the acceptable level of risk for civil protection purposes: a behavioral perspective on the decision process. *Natural Hazards*, *90*(1), 293–324.

Di Maria, A., Eyckmans, J., and Van Acker, K. (2020). Use of LCA and LCC to help decision-making between downcycling versus recycling of construction and demolition waste. In *Advances in Construction and Demolition Waste Recycling* (pp. 537–558). Elsevier.

Diaz, J., Pernia, A. M., Guerrero, J. M., Pereirinha, P. G., and Williams, A. (2016). Learning Energy Storage in Hybrid/Electric Vehicles: Erasmus Mundus Master Course in Sustainable Transportation & Electrical Power Systems. *2016 IEEE Vehicle Power and Propulsion Conference, VPPC 2016 - Proceedings*. https://doi.org/10.1109/VPPC.2016.7791719

Diewald, W. J. (2001). Requirements for Successful Technology Transfer in the Highway Industry. *Public Works Management & Policy*, *6*(1), 59–69. https://doi.org/10.1177/1087724X0161006

Dikmen, I., Birgonul, M. T., and Arikan, A. E. (2004). A critical review of risk management support tools. In *20th Annual ARCOM Conference* (Vol. 2, pp. 1145–1154). Heriot-Watt University Edinburgh, UK.

Dinçkal, Ç. (2018). Design of integral spreadsheet calculator for engineering applications. *Computer Applications in Engineering Education*, *26*(5), 1159–1172. https://doi.org/10.1002/cae.21947

Ding, G. K. C. (2008). Sustainable construction—The role of environmental assessment tools. *Journal of Environmental Management*, *86*(3), 451–464.

Dittenber, D. B., and GangaRao, H. V. S. (2012). Critical review of recent publications on use of natural composites in infrastructure. *Composites Part A: Applied Science and Manufacturing*, *43*(8), 1419–1429.

Djuretic, A., and Kostic, M. (2018). Actual energy savings when replacing high-pressure sodium with LED luminaires in street lighting. *Energy*, *157*, 367–378. https://doi.org/10.1016/j.energy.2018.05.179

Doppelt, B., and McDonough, W. (2017). *Leading change toward sustainability: A change-management guide for business, government and civil society*. Routledge.

Dornan, M. (2016). The political economy of road management reform: Papua New Guinea's national road fund. *Asia & the Pacific Policy Studies*, *3*(3), 443–457.

Dow, K., and Downing, T. E. (2016). *The atlas of climate change*. University of California Press.

Dowlatshahi, S., and Ashok, M. S. (1997). Design Optimization in Concurrent Engineering: A Team Approach. *Concurrent Engineering*, *5*(2), 145–154. https://doi.org/10.1177/1063293X9700500206

Drejer, A. (2002). Situations for innovation management: towards a contingency model. *European Journal of Innovation Management*.

Drouard, K., and Martin, J.-C. (2019). *Introduction to the RAMS Concept for Road Tunnel Operation*.

Dubey, R., Gunasekaran, A., Helo, P., Papadopoulos, T., Childe, S. J., and Sahay, B. S. (2017). Explaining the impact of reconfigurable manufacturing systems on environmental performance: The role of top management and organizational culture. *Journal of Cleaner Production*, *141*, 56–66.

Dukkanci, O., Kara, B. Y., and Bektaş, T. (2019). The green location-routing problem. *Computers & Operations Research*, *105*, 187–202.

Duman, A. C., and Güler, Ö. (2019). Techno-economic analysis of off-grid photovoltaic LED road lighting systems: A case study for northern, central and southern regions of Turkey. *Building and Environment*, *156*(April), 89–98. https://doi.org/10.1016/j.buildenv.2019.04.005

Dwaikata, L. N., and Ali, K. N. (2018). Green Buildings Life Cycle Cost Analysis and Life Cycle Budget Development : Practical Applications Reference : *Journal of Building Engineering*, *18*(March), 303–311. https://doi.org/10.1016/j.jobe.2018.03.015

Eisenman, J. (2012). China–Africa trade patterns: causes and consequences. *Journal of Contemporary China*, *21*(77), 793–810.

Emblemsva, J. (2007). Activity-based life-cycle costing in long-range planning, *6*(4), 370–390. https://doi.org/10.1108/14757700710835041

Emblemsvag, J. (2001). Activity-based life-cycle costing. *Managerial Auditing Journal*. https://doi.org/10.1108/02686900110363447

Emblemsvåg, J. (2003). *Lıfe-cycle costing: Using activity-based costing and Monte Carlo methods to manage future costs and risks*. John wiley & sons.

Epstein, M. J., Elkington, J., and Herman, B. (2018). *Making sustainability work: Best practices in managing and measuring corporate social, environmental and economic impacts*. Routledge.

Erdiwansyah, Mamat, R., Sani, M. S. M., and Sudhakar, K. (2019). Renewable energy in Southeast Asia: Policies and recommendations. *Science of the Total Environment*, *670*, 1095–1102. https://doi.org/10.1016/j.scitotenv.2019.03.273

F. Hair Jr, J., Sarstedt, M., Hopkins, L., and G. Kuppelwieser, V. (2014). Partial least squares structural equation modeling (PLS-SEM). *European Business Review*, *26*(2), 106–121. https://doi.org/10.1108/ebr-10-2013-0128

Fang, W., Ding, L., Zhong, B., Love, P. E. D., and Luo, H. (2018). Automated detection of workers and heavy equipment on construction sites: A convolutional neural network approach. *Advanced Engineering Informatics*, *37*(November 2017), 139–149. https://doi.org/10.1016/j.aei.2018.05.003

Fang, X. (2017). *Development of distress and performance models of composite pavements for pavement management*. The University of North Carolina at Charlotte.

Farrell, H., and Schneier, B. (2018). Common-knowledge attacks on democracy. *Berkman Klein Center Research Publication*, (2018–7).

Faul, F., Erdfelder, E., Buchner, A., and Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Ferry, D. J., and Flanagan, R. (1991). *Life cycle costing: a radical approach*. Construction Industry Research and Information Association London.

Fink, A. (2015). *How to conduct surveys: A step-by-step guide*. Retrieved from https://books.google.com/books?hl=en&lr=&id=Rl12CwAAQBAJ&oi=fnd&pg=PP1&dq=Fink,+A.+(2015).+How+to+conduct+surveys:+A+step-by-step+guide.+Sage+Publications.&ots=AgEe06V-4j&sig=PrQTIzF5eh-Xa5_dPL4i4Mmwo8A

Finkbeiner, M., Schau, E. M., Lehmann, A., and Traverso, M. (2010). Towards life cycle sustainability assessment. *Sustainability*, *2*(10), 3309–3322.

Fong, K. F., and Lee, C. K. (2014). Performance advancement of solar air-conditioning through integrated system design for building. *Energy*, *73*, 987–996.

https://doi.org/10.1016/j.energy.2014.06.114

Friedman, M. (1937). The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. *Journal of the American Statistical Association*, *32*(200), 675–701. https://doi.org/10.1080/01621459.1937.10503522

Frynas, J. G., and Yamahaki, C. (2016). Corporate social responsibility: Review and roadmap of theoretical perspectives. *Business Ethics: A European Review*, *25*(3), 258–285.

Fu, Y., Li, Z., Zhang, H., and Xu, P. (2015). Using Support Vector Machine to Predict Next Day Electricity Load of Public Buildings with Sub-metering Devices. *Procedia Engineering*, *121*, 1016–1022. https://doi.org/10.1016/j.proeng.2015.09.097

Fullerton, J. T., Johnson, P., Lobe, E., Myint, K. H., Aung, N. N., Moe, T., and Linn, N. A. (2016). A Rapid Assessment Tool for affirming good practice in midwifery education programming. *Midwifery*, *34*, 36–41.

Gantner, J., Fawcett, W., and Ellingham, I. (2018). Probabilistic approaches to the measurement of embodied carbon in buildings. In *Embodied Carbon in Buildings* (pp. 23–50). Springer.

Garvey, P. R., Book, S. A., and Covert, R. P. (2016). *Probability methods for cost uncertainty analysis: A systems engineering perspective*. CRC Press.

Gerbrandt, R., and Berthelot, C. (2007). Life-cycle economic evaluation of alternative road construction methods on low-volume roads. *Transportation Research Record*, *1989*(1), 61–71.

Gerdes, M., Scholz, D., and Galar, D. (2016). Effects of condition-based maintenance on costs caused by unscheduled maintenance of aircraft. *Journal of Quality in Maintenance Engineering*, *22*(4), 394–417. https://doi.org/10.1108/JQME-12-2015-0062

Ghajar, R. F., Khalife, J., and Richani, B. (2000). Design and cost analysis of an automatic meter reading system for Electricite′ du Liban. *Utilities Policy*, *9*(4), 193–205. https://doi.org/10.2316/journal.203.2012.1.203-3654

Ghertner, D. A., and Fripp, M. (2007). Trading away damage: Quantifying environmental leakage through consumption-based, life-cycle analysis. *Ecological Economics*, *63*(2–3), 563–577.

Ghisellini, P., Cialani, C., and Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32.

Giachetti, R. (2016). *Design of enterprise systems: Theory, architecture, and methods*. CRC Press.

Gliem, J. A., and Gliem, R. R. (2003). Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for Likert-type scales. Midwest Research-to-Practice Conference in Adult, Continuing, and Community.

Gnambs, T., and Kaspar, K. (2015). Disclosure of sensitive behaviors across self-administered survey modes: a meta-analysis. *Behavior Research Methods*, *47*(4), 1237–1259.

Goh, B. H., and Sun, Y. (2016). The development of life-cycle costing for buildings. *Building Research & Information*, *44*(3), 319–333.

Goh, K. C., and Yang, J. (2014a). Importance of Sustainability-Related Cost Components in Highway Infrastructure: Perspective of Stakeholders in Australia. *Journal of Infrastructure Systems*, *20*(1), 04013002. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000152

Goh, K. C., and Yang, J. (2014b). Managing cost implications for highway infrastructure sustainability. *International Journal of Environmental Science and Technology*, *11*(8), 2271–2280. https://doi.org/10.1007/s13762-014-0572-5

Goh, K., and Yang, J. (2013). Importance of Sustainability Related Cost Components in Highway Infrastructure: Perspective of Stakeholders in Australia. *Journal of Infrastructure Systems*, 130224192045000.

https://doi.org/10.1061/(ASCE)IS.1943-555X.0000152

Goh, Kai Chen, Goh, H. H., and Chong, H.-Y. (2019). Integration Model of Fuzzy AHP and Life-Cycle Cost Analysis for Evaluating Highway Infrastructure Investments. *Journal of Infrastructure Systems*, *25*(1), 04018045. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000473

Goh, Kai Chen, and Jay, Y. (2011). Managing Financial Implications for Sustainable Highway Project Delivery, 347–352.

Goudie, A. S. (2018). *Human impact on the natural environment*. John Wiley & Sons.

Grabara, J. K. (2017). The another point of view on sustainable management. *Quality-Access to Success*, *18*.

Griffiths, K., Boyle, C., and Henning, T. F. P. (2018). Beyond the certification badge—How infrastructure sustainability rating tools impact on individual, organizational, and industry practice. *Sustainability*, *10*(4), 1038.

Guinée, J. (2016). Life cycle sustainability assessment: what is it and what are its challenges? In *Taking stock of industrial ecology* (pp. 45–68). Springer, Cham.

Gupta, R., Majid, S., and Yadav, M. (2020). Design of Smart Lighting Control for the Built Environment (pp. 29–36). https://doi.org/10.1007/978-981-15-2545-2_4

Haas, R., Hudson, W. R., and Zaniewski, J. P. (1994). *Modern pavement management*.

Haas, R., and Kazmierowski, T. (1998). Implementation Experience of a new Pavement Design and Management Guide. In *FOURTH INTERNATIONAL CONFERENCE ON MANAGING PAVEMENTS, 17 TO 21 MAY 1998, DURBAN, SOUTH AFRICA. PAPERS-VOLUME 2: IMPLEMENTATION OF PAVEMENT MANAGEMENT SYSTEMS OUTPUTS*. Citeseer.

Hair, J. F. (2010). *Multivariate data analysis*. Prentice Hall.

Hair, J., Hollingsworth, C. L., Randolph, A. B., and Chong, A. Y. L. (2017). An updated and expanded assessment of PLS-SEM in information systems research. *Industrial Management and Data Systems*, *117*(3), 442–458.

https://doi.org/10.1108/IMDS-04-2016-0130

Halachmi, A., and Gianakis, G. A. (2017). Strategic Planning and Capital Budgeting: A Primer. In *Handbook of Debt Management* (pp. 207–236). Routledge.

Hall, K. T., Correa, C. E., and Simpson, A. L. (2003). Performance of flexible pavement maintenance treatments in the long-term pavement performance SPS-3 experiment. *Transportation Research Record*, *1823*(1), 47–54.

Hammersley, J. (2013). *Monte carlo methods*. Springer Science & Business Media.

Harris, F., McCaffer, R., Baldwin, A., and Edum-Fotwe, F. (2021). *Modern construction management*. John Wiley & Sons.

Harvey, P.-L. (2017). Toward a Discovery and Strategic Alignment Matrices for Socio-technical Systems' Design. In *Community Informatics Design Applied to Digital Social Systems* (pp. 279–312). Springer.

Hasan, U., Whyte, A., and Al Jassmi, H. (2019). Critical review and methodological issues in integrated life-cycle analysis on road networks. *Journal of Cleaner Production*, *206*, 541–558. https://doi.org/10.1016/j.jclepro.2018.09.148

Hassanain, M. A., Assaf, S., Al-Hammad, A. M., and Al-Nehmi, A. (2015). A multi-criteria decision making model for outsourcing maintenance services. *Facilities*, *33*(3–4), 229–244. https://doi.org/10.1108/F-01-2013-0003

Henseler, J., Hubona, G., and Ray, P. A. (2016). Using PLS path modeling in new technology research: Updated guidelines. *Industrial Management and Data Systems*, *116*(1), 2–20. https://doi.org/10.1108/IMDS-09-2015-0382

Henseler, J., Ringle, C. M., and Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, *43*(1), 115–135.

Henseler, J., and Sarstedt, M. (2013). Goodness-of-fit indices for partial least squares path modeling. *Computational Statistics*, *28*(2), 565–580.

Heralova, R. S., Hromada, E., and Johnston, H. (2014). Cost structure of the highway projects in the Czech Republic. *Procedia Engineering*, *85*, 222–230. https://doi.org/10.1016/j.proeng.2014.10.547

Hertwich, E. G. (2005). Life cycle approaches to sustainable consumption: a critical review. *Environmental Science & Technology*, *39*(13), 4673–4684.

Hill, R. C., and Bowen, P. A. (1997). Sustainable construction: principles and a framework for attainment. *Construction Management & Economics*, *15*(3), 223–239.

Hinge, A., Winston, D., Stigge, B., and Happold, B. (2006). Moving toward transparency and disclosure in the energy performance of green buildings. *AEEE Summer Study on Energy Efficiency in Buildings*.

Holl, A., and Mariotti, I. (2018). Highways and firm performance in the logistics industry. *Journal of Transport Geography*, *72*, 139–150.

Holsapple, C. W. (2008). Decisions and knowledge. In *Handbook on Decision Support Systems 1* (pp. 21–53). Springer.

Hong, J., Hong, T., Kang, H., and Lee, M. (2019). A framework for reducing dust emissions and energy consumption on construction sites. *Energy Procedia*, *158*, 5092–5096. https://doi.org/10.1016/j.egypro.2019.01.637

Howe, J., Richards, P., and Howe, J. (2019). *Rural roads and poverty alleviation*. Routledge.

Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55. https://doi.org/10.1080/10705519909540118

Hu, W., Xie, J., Chau, H. W., and Si, B. C. (2015). Evaluation of parameter uncertainties in nonlinear regression using Microsoft Excel Spreadsheet. *Environmental Systems Research*, *4*(1). https://doi.org/10.1186/s40068-015-0031-4

Hulett, D. (2016). *Integrated Cost-Schedule Risk Analysis*. Routledge. https://doi.org/10.4324/9781315589015

Hurlimann, A. C., Browne, G. R., Warren-Myers, G., and Francis, V. (2018). Barriers to climate change adaptation in the Australian construction industry–Impetus for regulatory reform. *Building and Environment*, *137*, 235–245.

Hwang, S.-N., Lee, H.-S., and Zhu, J. (2016). *Handbook of operations analytics using data envelopment analysis*. Springer.

Idham, M. K., and Hainin, M. R. (2015). The effect of incorporating reclaimed asphalt pavement on the performance of hot mix asphalt mixtures. *Jurnal Teknologi*. https://doi.org/10.11113/jt.v77.6992

Ilbeigi, M., Ghomeishi, M., and Dehghanbanadaki, A. (2020). Prediction and optimization of energy consumption in an office building using artificial neural network and a genetic algorithm. *Sustainable Cities and Society*, *61*(June), 102325. https://doi.org/10.1016/j.scs.2020.102325

Ilg, P., Scope, C., Muench, S., and Guenther, E. (2017). Uncertainty in life cycle costing for long-range infrastructure. Part I: leveling the playing field to address uncertainties. *The International Journal of Life Cycle Assessment*, *22*(2), 277–292. https://doi.org/10.1007/s11367-016-1154-1

Ilie, A., Dumitrescu, R., Girip, A., and Cublesan, V. (2017). Study on Technical and Economical Solutions for Improving Air-conditioning Efficiency in Building Sector. *Energy Procedia*, *112*, 537–544. https://doi.org/10.1016/j.egypro.2017.03.1113

Inayat, A., and Raza, M. (2019). District cooling system via renewable energy sources: A review. *Renewable and Sustainable Energy Reviews*, *107*(March 2019), 360–373. https://doi.org/10.1016/j.rser.2019.03.023

Islam, H., Jollands, M., and Setunge, S. (2015). Life cycle assessment and life cycle cost implication of residential buildings—A review. *Renewable and Sustainable Energy Reviews*, *42*, 129–140.

Ismail, M. A., Rozana, Z., Sani, B. A., Foo, K. S., Ain Naadia, M., Yazlin Salfiza, Y., … Muhd Zaimi, A. M. (2013). Fundamental Elements of Malaysia Green Highway. *Applied Mechanics and Materials*, *284–287*, 1194–1197.

https://doi.org/10.4028/www.scientific.net/AMM.284-287.1194

ISO, B. S. (2017). BS ISO 15686-5: 2017 Buildings and constructed assets. Service life planning. Life-cycle costing. BSI.

Israel, G. D. (1992). *Determining Sample Size 1 The Level Of Precision*.

Izadi, A., Nabipour, M., and Titidezh, O. (2020). Cost models and cost factors of road freight transportation: a literature review and model structure. *Fuzzy Information and Engineering*, 1–21.

Jackson, A. Y., and Mazzei, L. (2011). *Thinking with theory in qualitative research: Viewing data across multiple perspectives*. Routledge.

Jamaluddin, A., Nur 'aini, A., Adhitama, E., and Purwanto, A. (2017). Assessment of LiFePO4 Battery Performance in Stand Alone Photovoltaic Street Light System. *Procedia Engineering*, *170*, 503–508. https://doi.org/10.1016/j.proeng.2017.03.080

Jasmi, S. Z. A., Ayob, M. F., Rashid, K. A., and Rahim, F. A. M. (2018). A review on the state of cost data inputs of life cycle cost (LCC) for rigid pavement maintenance and rehabilitation in Malaysia. *Journal of Design and Built Environment*, 26–38.

Jeon, C. M., Amekudzi, A., and Guensler, R. L. (2007). Evaluating transportation system sustainability: Atlanta metropolitan region. In *Proceedings of the 2007 Annual Meeting of the Transportation Research Board–CDROM* (Vol. 1).

Jha, M. K., Ogallo, H. G., and Owolabi, O. (2014). A Quantitative Analysis of Sustainability and Green Transportation Initiatives in Highway Design and Maintenance. *Procedia - Social and Behavioral Sciences*, *111*, 1185–1194. https://doi.org/10.1016/j.sbspro.2014.01.153

Ji, S., Lee, B., and Yi, M. Y. (2021). Building life-span prediction for life cycle assessment and life cycle cost using machine learning: A big data approach. *Building and Environment*, *205*, 108267.

Jiang, Y., Li, S., Guan, B., and Zhao, G. (2015). Cost effectiveness of new roadway lighting systems. *Journal of Traffic and Transportation Engineering (English Edition)*, *2*(3), 158–166. https://doi.org/10.1016/j.jtte.2015.03.004

Jin, M., Jia, R., Das, H. P., Feng, W., and Spanos, C. (2019). Biscuit: Building intelligent system customer investment tools. *Energy Procedia*, *158*, 6152–6157. https://doi.org/10.1016/j.egypro.2019.01.495

Juntunen, E., Tetri, E., Tapaninen, O., Yrjänä, S., Kondratyev, V., Sitomaniemi, A., … Heikkinen, V. (2015). A smart LED luminaire for energy savings in pedestrian road lighting. *Lighting Research and Technology*, *47*(1), 103–115. https://doi.org/10.1177/1477153513510015

Juntunen, Eveliina, Sarjanoja, E. M., Eskeli, J., Pihlajaniemi, H., and Österlund, T. (2018). Smart and dynamic route lighting control based on movement tracking. *Building and Environment*, *142*(March), 472–483. https://doi.org/10.1016/j.buildenv.2018.06.048

K.-K. Seo, J.-H. Park, D.-S. J. and D. W., Seo, K. K., Park, J. H., Jang, D. S., and Wallace, D. (2002). Approximate Estimation of the Product Life Cycle Cost Using Artificial Neural Networks in Conceptual Design. *The International Journal of Advanced Manufacturing Technology*, *19*(14), 461–471. https://doi.org/10.1021/jo00928a014

Kaewunruen, S., Sussman, J. M., and Matsumoto, A. (2016). Grand challenges in transportation and transit systems. *Frontiers in Built Environment*, *2*, 4.

Kaming, P. F., and Marliansyah, J. (2016). Implementation of Life Cycle Costing: A Case of Hostel Building in Kediri, Eastern Jawa, Indonesia. In *Applied Mechanics and Materials* (Vol. 845, pp. 326–331). Trans Tech Publ.

Karim, H. (2011). Life-Cycle Cost Analyses for Road Barriers. *Journal of Transportation …*, (July), 830–851. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000391.

Karim, H., Ph, D., Magnusson, R., and Natanaelsson, K. (2011). Life-Cycle Cost Analyses for Road Barriers. *Journal of Transportation …*, *138*(July), 830–851. https://doi.org/10.1061/(ASCE)TE.1943-5436.0000391.

Kaur, E., Sharma, S., Verma, A., and Singh, M. (2019). An Energy Management and Recommender System for Lighting Control in Internet-of-Energy enabled Buildings. *IFAC-PapersOnLine*, *52*(4), 288–293. https://doi.org/10.1016/j.ifacol.2019.08.213

Kenis, A., and Lievens, M. (2016). Greening the economy or economizing the green project? When environmental concerns are turned into a means to save the market. *Review of Radical Political Economics*, *48*(2), 217–234.

Kerzner, H. (2017). *Project management metrics, KPIs, and dashboards: a guide to measuring and monitoring project performance*. John Wiley & Sons.

Khalil, N., Bohari, A. A. M., Shamsudin, S. M., Abd Rashid, A. F., and Husin, H. N. (2021). Key approaches of life-cycle cost in green government procurement (GGP) for green projects. *PLANNING MALAYSIA*, *19*.

Khan, J. S. (2019). AUTOMATION OF INTEGRATED SYSTEM ON MyCREST AND LIFE CYCLE.

Khan, J. S., Zakaria, R., Aminuddin, E., Abidin, N. I., Sahamir, S. R., Ahmad, R., and Abas, D. N. (2018). Web-based automation of green building rating index and life cycle cost analysis. *IOP Conference Series: Earth and Environmental Science*, *143*(1). https://doi.org/10.1088/1755-1315/143/1/012062

Khan, J. S., Zakaria, R., Aminudin, E., Abidin, N. I. A., Mahyudin, M. A., and Ahmad, R. (2019). Embedded Life Cycle Costing Elements in Green Building Rating Tool. *Civil Engineering Journal*, *5*(4), 1–9.

Khan, Z. R., James, D. G., Midega, C. A. O., and Pickett, J. A. (2008). Chemical ecology and conservation biological control. *Biological Control*, *45*(2), 210–224.

Khouja, M., Shelnutt, J. W., and Wilmot, M. (1998). The economics of air conditioning for precision manufacturing: A simulation model. *Integrated Manufacturing Systems*, *9*(3), 182–192. https://doi.org/10.1108/09576069810210475

Kibert, C. (2015). Sustainable Development and Sustainable Construction. In

Sustainable Construction - Green Building Design and Delivery.

Kibert, C. J. (2016). *Sustainable construction: green building design and delivery*. John Wiley & Sons.

Kim, C., Lee, E.-B., Harvey, J. T., Fong, A., and Lott, R. (2015). Automated Sequence Selection and Cost Calculation for Maintenance and Rehabilitation in Highway Life-Cycle Cost Analysis (LCCA). *International Journal of Transportation Science and Technology*, *4*(1), 61–76. https://doi.org/10.1260/2046-0430.4.1.61

Kivilä, J., Martinsuo, M., and Vuorinen, L. (2017). Sustainable project management through project control in infrastructure projects. *International Journal of Project Management*, *35*(6), 1167–1183.

Kleppmann, M. (2017). *Designing Data-Intensive Applications: The Big Ideas behind Reliable, Scalable, and Maintainable Systems. O'Reilly Media, Inc.*

Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of E-Collaboration (Ijec)*, *11*(4), 1–10.

Koo, C., Hong, T., Hyun, C., Park, S. H., and Seo, J. (2010). A study on the development of a cost model based on the owner's decision making at the early stages of a construction project. *International Journal of Strategic Property Management*, *14*(2), 121–137.

Korpi, E., and Ala-Risku, T. (2008). Life cycle costing: a review of published case studies. *Managerial Auditing Journal*, *23*(3), 240–261. https://doi.org/10.1108/02686900810857703

Koukias, A., and Kiritsis, D. (2015). A step-by-step approach to ensure asset performance based on technical documentation. In *IFAC-PapersOnLine* (Vol. 28, pp. 820–825). https://doi.org/10.1016/j.ifacol.2015.09.628

Kozlovska, M., Mackova, D., and Spisakova, M. (2016). Survey of Construction Management Documentation Usage in Planning and Construction of Building Project. In *Procedia Engineering* (Vol. 161, pp. 711–715). Elsevier Ltd. https://doi.org/10.1016/j.proeng.2016.08.747

Kroese, D. P., Brereton, T., Taimre, T., and Botev, Z. I. (2014). Why the Monte Carlo method is so important today. *Wiley Interdisciplinary Reviews: Computational Statistics*, *6*(6), 386–392.

Krog, L., and Sperling, K. (2019). A comprehensive framework for strategic energy planning based on Danish and international insights. *Energy Strategy Reviews*, *24*(February), 83–93. https://doi.org/10.1016/j.esr.2019.02.005

Kumar, V., and Sutherland, J. W. (2009). Development and assessment of strategies to ensure economic sustainability of the US automotive recovery infrastructure. *Resources, Conservation and Recycling*, *53*(8), 470–477.

Ladyman, J., Lambert, J., and Wiesner, K. (2013). What is a complex system? *European Journal for Philosophy of Science*, *3*(1), 33–67.

Lai, J., Yik, F., and Jones, P. (2008). Expenditure on operation and maintenance service and rental income of commercial buildings. *Facilities*, *26*(5–6), 242–265. https://doi.org/10.1108/02632770810865014

Lapets, A., and Kfoury, A. (2012). A user-friendly interface for a lightweight verification system. *Electronic Notes in Theoretical Computer Science*, *285*, 29–41.

Lee, Jay, Wu, F., Zhao, W., Ghaffari, M., Liao, L., and Siegel, D. (2014). Prognostics and health management design for rotary machinery systems—Reviews, methodology and applications. *Mechanical Systems and Signal Processing*, *42*(1–2), 314–334.

Lee, Jincheol, Edil, T. B., Asce, D. M., Benson, C. H., Asce, F., Tinjum, J. M., … Asce, M. (2013). Building Environmentally and Economically Sustainable Transportation Infrastructure : Green Highway Rating System. *Journal OfConstruction Engineering and Management*, *139*(12), 1–10. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000742.

Lehtonen, M. (2004). The environmental–social interface of sustainable development: capabilities, social capital, institutions. *Ecological Economics*, *49*(2), 199–214.

Leslie, R. P. (1998). A Simple Cost Estimation Technique for Improving the Appearance and Security of Outdoor Lighting Installations. *Building and Environment*, *33*(2–3), 79–95. https://doi.org/10.1016/S0360-1323(97)00051-6

Levinson, D., and Chang, E. (2003). A model for optimizing electronic toll collection systems. *Transportation Research Part A: Policy and Practice*, *37*(4), 293–314. https://doi.org/10.1016/S0965-8564(02)00017-4

Li, M., Gu, W., Chen, W., He, Y., Wu, Y., and Zhang, Y. (2018). Smart home : architecture, technologies and systems. *Procedia Computer Science*, *131*, 393–400. https://doi.org/10.1016/j.procs.2018.04.219

Lieberman, H., and Liu, H. (2006). Feasibility studies for programming in natural language. In *End user development* (pp. 459–473). Springer.

Lindholm, A., and Suomala, P. (2007). Learning by costing: Sharpening cost image through life cycle costing? *International Journal of Productivity and Performance Management*, *56*(8), 651–672. https://doi.org/10.1108/17410400710832985

Link, J., Waedt, K., Zid, I. Ben, and Lou, X. (2018). Current Challenges of the Joint Consideration of Functional Safety & Cyber Security, Their Interoperability and Impact on Organizations: How to Manage RAMS+ S (Reliability Availability Maintainability Safety+ Security). In *2018 12th International Conference on Reliability, Maintainability, and Safety (ICRMS)* (pp. 185–191). IEEE.

List, G. (2007). A model for life cycle evaluation of highway investments. *Structure and Infrastructure Engineering*, *3*(2), 95–101. https://doi.org/10.1080/15732470600590903

Litman, T. (2017). *Evaluating transportation equity*. Victoria Transport Policy Institute.

Liu, D., Wu, Y., Li, S., and Sun, Y. (2016). A real-time monitoring system for lift-thickness control in highway construction. *Automation in Construction*, *63*, 27–36. https://doi.org/10.1016/j.autcon.2015.12.004

Liu, Linn, Rohdin, P., and Moshfegh, B. (2016). LCC assessments and environmental impacts on the energy renovation of a multi-family building from the 1890s. *Energy and Buildings*, *133*, 823–833.

Liu, T., Lu, J., and Xie, H. (2011). Study on the appliances energy efficiency label and multi-dimensional thinking under low-carbon economic development. *Energy Procedia*, *5*, 577–580. https://doi.org/10.1016/j.egypro.2011.03.101

Lousberg, L. H., Heintz, J., and Prins, M. (2016). Sustainability in projects requires training in managing as designing. *CIB Proceedings 2015: Going North for Sustainability: Leveraging Knowledge and Innovation for Sustainable Construction and Development*, 194.

Love, P. E. D., Zhou, J., and Matthews, J. (2019). Project controls for electrical, instrumentation and control systems: Enabling role of digital system information modelling. *Automation in Construction*, *103*(March), 202–212. https://doi.org/10.1016/j.autcon.2019.03.010

Luo, H., Xiong, C., Fang, W., Love, P. E. D., Zhang, B., and Ouyang, X. (2018). Convolutional neural networks: Computer vision-based workforce activity assessment in construction. *Automation in Construction*, *94*(June), 282–289. https://doi.org/10.1016/j.autcon.2018.06.007

Macpherson, A., and Wilson, A. (2003). Enhancing SMEs' capability: opportunities in supply chain relationships? *Journal of Small Business and Enterprise Development*.

Maji, A., and Jha, M. K. (2011). A multiobjective analysis of impacted area of environmentally preserved land and alignment cost for sustainable highway infrastructure design. *Procedia-Social and Behavioral Sciences*, *20*, 966–972.

Majid, M. Z. A., and McCaffer, R. (1998). Factors of non-excusable delays that influence contractors' performance. *Journal of Management in Engineering*, *14*(3), 42–49.

Mancini, M. S., Galli, A., Niccolucci, V., Lin, D., Bastianoni, S., Wackernagel, M., and Marchettini, N. (2016). Ecological Footprint: Refining the carbon Footprint calculation. *Ecological Indicators*, *61*, 390–403. https://doi.org/10.1016/j.ecolind.2015.09.040

Manseau, A. (2019). Construction-a changing industry challenging current innovation models. In *Building Tomorrow: Innovation in Construction and Engineering* (pp. 23–42). Routledge.

Markeset, T., and Kumar, U. (2001). R&M and risk-analysis tools in product design, to reduce life-cycle cost and improve attractiveness. In *Annual Reliability and Maintainability Symposium. 2001 Proceedings. International Symposium on Product Quality and Integrity (Cat. No. 01CH37179)* (pp. 116–122). IEEE.

Markow, M. J. (2012). *Engineering economic analysis practices for highway investment* (Vol. 424). Transportation Research Board.

Markvica, K., Richter, G., and Lenz, G. (2019). Impact of urban street lighting on road users' perception of public space and mobility behavior. *Building and Environment*, *154*(March), 32–43. https://doi.org/10.1016/j.buildenv.2019.03.009

Mastrucci, A., Marvuglia, A., Leopold, U., and Benetto, E. (2017). Life Cycle Assessment of building stocks from urban to transnational scales: A review. *Renewable and Sustainable Energy Reviews*, *74*, 316–332.

McCaffer, R., and Majid, M. Z. A. (1997). Assessment of work performance of 8 maintenanceMcCaffer, R., & Majid, M. Z. A. (1997). Assessment of work performance of 8 maintenance contractors in saudi arabia. Journal of Management in Engineering, ASCE, 17(October), 1997. https://doi.org/10.1061/(ASC. *Journal of Management in Engineering, ASCE*, *17*(October), 1997. https://doi.org/10.1061/(ASCE)0742-597X(1997)13:5(91)

McDonough, R., and Calmar Telematics, L. L. C. (2009). *Universal real-time highway information system development program: final report phase II*. New York State Energy Research and Development Authority.

Mechler, R. (2016). Reviewing estimates of the economic efficiency of disaster risk management: opportunities and limitations of using risk-based cost–benefit analysis. *Natural Hazards*, *81*(3), 2121–2147. https://doi.org/10.1007/s11069-016-2170-y

Mele, C., Pels, J., and Polese, F. (2010). A brief review of systems theories and their managerial applications. *Service Science*, *2*(1–2), 126–135.

Mell, I. (2016). *Global green infrastructure: lessons for successful policy-making, investment and management*. Routledge.

Mellit, A., Tina, G. M., and Kalogirou, S. A. (2018). Fault detection and diagnosis methods for photovoltaic systems: A review. *Renewable and Sustainable Energy Reviews*, *91*(July 2017), 1–17. https://doi.org/10.1016/j.rser.2018.03.062

Mellouk, L., Ghazi, M., Aaroud, A., Boulmalf, M., Benhaddou, D., and Zine-Dine, K. (2019). Design and energy management optimization for hybrid renewable energy system- case study: Laayoune region. *Renewable Energy*, *139*(2019), 621–634. https://doi.org/10.1016/j.renene.2019.02.066

Memon, M. A., Ting, H., Cheah, J.-H., Thurasamy, R., Chuah, F., and Cham, T. H. (2020). Sample Size for Survey Research: Review and Recommendations. *Journal of Applied Structural Equation Modeling*, *4*(2), i–xx. https://doi.org/10.47263/jasem.4(2)01

Mena, Á., López, F., Framiñan, J. M., Flores, F., and Gallego, J. M. (2010). XPDRL project: Improving the project documentation quality in the Spanish architectural, engineering and construction sector. *Automation in Construction*, *19*(2), 270–282. https://doi.org/10.1016/j.autcon.2009.10.001

Mertler, C. A., Vannatta, R. A., and LaVenia, K. N. (2021). *Advanced and multivariate statistical methods: Practical application and interpretation*. Routledge.

Miemczyk, J., and Luzzini, D. (2018). Achieving triple bottom line sustainability in supply chains: The role of environmental, social and risk assessment practices. *International Journal of Operations & Production Management*.

Miles, M. B., Huberman, A. M., and Saldaña, J. (2018). *Qualitative data analysis: A methods sourcebook*. Sage publications.

Miller, T. (2018). Role of the Private Sector in the Management of Highways: A Primer on Public-Private Partnerships. *Mercatus Research Paper*.

Mirfenderesk, H., Carroll, D., Chong, E., Jafari, A., Hossain, N., van Doorn, R., and Vis, S. (2016). New generation flood forecasting and decision support system for emergency management. *Australian Journal of Emergency Management, The*, *31*(2), 31–37.

Mitropoulos, L. K., and Prevedouros, P. D. (2015). Life cycle emissions and cost model for urban light duty vehicles. *Transportation Research Part D: Transport and Environment*, *41*, 147–159.

Mohd Nusa, F. N., Mohamed Arifin, M. A., Ab Rani, N. I., Abu Bakar, A., Nazura Paimin, A., Soo Fen, F., and Abdul Rahman, S. H. (2020). Determinants of Green Highway Implementation Factors by Using Partial Least Squares. *IOP Conference Series: Earth and Environmental Science*, *498*(1). https://doi.org/10.1088/1755-1315/498/1/012013

Molenaar, K. R. (2005). Programmatic Cost Risk Analysis for Highway Megaprojects. *Journal of Construction Engineering and Management*, *131*(3), 343–353. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:3(343)

Moore, C. B., Payne, G. T., Autry, C. W., and Griffis, S. E. (2018). Project complexity and bonding social capital in network organizations. *Group & Organization Management*, *43*(6), 936–970.

Morini, E., Castellani, B., Nicolini, A., Rossi, F., and Berardi, U. (2018). Effects of aging on retro-reflective materials for building applications. *Energy and Buildings*, *179*, 121–132. https://doi.org/10.1016/j.enbuild.2018.09.013

Mosler, H.-J. (2012). A systematic approach to behavior change interventions for the water and sanitation sector in developing countries: a conceptual model, a review, and a guideline. *International Journal of Environmental Health Research*, *22*(5), 431–449.

Mostert, M., Caris, A., and Limbourg, S. (2017). Road and intermodal transport performance: the impact of operational costs and air pollution external costs.

Research in Transportation Business & Management, *23*, 75–85.

Mukta, M. Y., Rahman, M. A., Asyhari, A. T., and Alam Bhuiyan, M. Z. (2020). IoT for energy efficient green highway lighting systems: Challenges and issues. *Journal of Network and Computer Applications*, *158*(January 2019), 102575. https://doi.org/10.1016/j.jnca.2020.102575

Mulmi, A. Das. (2009). Green road approach in rural road construction for the sustainable development of Nepal. *Journal of Sustainable Development*, *2*(3), 149–165.

Nagle, T. T., and Müller, G. (2017). *The strategy and tactics of pricing: A guide to growing more profitably*. Routledge.

Namburu, S. M., Azam, M. S., Luo, J., Choi, K., and Pattipati, K. R. (2007). Data-driven modeling, fault diagnosis and optimal sensor selection for HVAC chillers. *IEEE Transactions on Automation Science and Engineering*, *4*(3), 469–473. https://doi.org/10.1109/TASE.2006.888053

Nas, T. F. (2016). *Cost-benefit analysis: Theory and application*. Lexington Books.

Navon, R. (2005). Automated project performance control of construction projects. *Automation in Construction*, *14*(4), 467–476. https://doi.org/10.1016/j.autcon.2004.09.006

Neardey, M., Aminudin, E., Chung, L. P., Zin, R. M., Zakaria, R., Che Wahid, C. M. F. H., … Noor, Z. Z. N. (2020). Simulation on Lighting Energy Consumption based on Building Information Modelling for Energy Efficiency at Highway Rest and Service Areas Malaysia. *IOP Conference Series: Materials Science and Engineering*, *943*(1). https://doi.org/10.1088/1757-899X/943/1/012062

Needy, K. L., Nachtmann, H., Roztocki, N., Warner, R. C., and Bidanda, B. (2003). Implementing activity-based costing systems in small manufacturing firms: A field study. *Engineering Management Journal*, *15*(1), 3–10.

Newell, W. H., Wentworth, J., and Sebberson, D. (2001). A theory of interdisciplinary studies. *Issues in Interdisciplinary Studies*.

Nfaoui, M., and El-Hami, K. (2018). Extracting the maximum energy from solar panels. *Energy Reports*. https://doi.org/10.1016/j.egyr.2018.05.002

Ng, K. C., Shahzad, M. W., Burhan, M., and Oh, S. J. (2019). Approaches to Energy Efficiency in Air conditioning: Innovative processes and thermodynamics. *Energy Procedia*, *158*, 1455–1460. https://doi.org/10.1016/j.egypro.2019.01.349

Nguyen, H. T., Skitmore, M., Gray, M., Zhang, X., and Olanipekun, A. O. (2017). Will green building development take off? An exploratory study of barriers to green building in Vietnam. *Resources, Conservation and Recycling*. https://doi.org/10.1016/j.resconrec.2017.08.012

Nguyen, P. A., Abbott, M., and Nguyen, T. L. T. (2019). The development and cost of renewable energy resources in Vietnam. *Utilities Policy*, *57*(January), 59–66. https://doi.org/10.1016/j.jup.2019.01.009

Nguyen, T. L. T., Gheewala, S. H., and Bonnet, S. (2008). Life cycle cost analysis of fuel ethanol produced from cassava in Thailand. *The International Journal of Life Cycle Assessment*, *13*(7), 564–573.

Niazkar, M. (2021). An Excel VBA-based educational module for bed roughness predictors. *Computer Applications in Engineering Education*, *29*(5), 1051–1060. https://doi.org/10.1002/cae.22358

Nithya, N., and Hemalatha, M. (2012). GSM based cost effective street lighting application. In *Procedia Engineering* (Vol. 30, pp. 737–741). Elsevier. https://doi.org/10.1016/j.proeng.2012.01.922

Nkwake, A. M. (2015). *Credibility, validity, and assumptions in program evaluation methodology*. Springer.

Novaes Pires Leite, G. de, Weschenfelder, F., Araújo, A. M., Villa Ochoa, Á. A., Franca Prestrelo Neto, N. da, and Kraj, A. (2019). An economic analysis of the integration between air-conditioning and solar photovoltaic systems. *Energy Conversion and Management*, *185*(November 2018), 836–849. https://doi.org/10.1016/j.enconman.2019.02.037

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., … Kok, K. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change*, *42*, 169–180.

Oad, P. K. (2016). *Innovation in the road construction sector and its benefits to the industry*. Queensland University of Technology.

Ocalir-Akunal, E. V. (2016). Decision support systems in transport planning. *Procedia Engineering*, *161*, 1119–1126.

Odeh, O. O., and Featherstone, A. M. (2004). *Reliability Of Programming Software: Comparison Of Shazam And Sas*.

Oduyemi, O., and Okoroh, M. (2016). Building performance modelling for sustainable building design. *International Journal of Sustainable Built Environment*. https://doi.org/10.1016/j.ijsbe.2016.05.004

Ogando-Martínez, A., López-Gómez, J., and Febrero-Garrido, L. (2018). Maintenance Factor Identification in Outdoor Lighting Installations Using Simulation and Optimization Techniques. *Energies*, *11*(8), 2169. https://doi.org/10.3390/en11082169

Ökmen, Ö. (2016). Risk assessment for determining best design alternative in a state-owned irrigation project in Turkey. *KSCE Journal of Civil Engineering*, *20*(1), 109–120. https://doi.org/10.1007/s12205-015-0397-x

Oliveira, R. V. (2018). Back to the future: The potential of intergenerational justice for the achievement of the Sustainable Development Goals. *Sustainability (Switzerland)*, *10*(2). https://doi.org/10.3390/su10020427

Oltean-Dumbrava, C., Watts, G., and Miah, A. (2016). Towards a more sustainable surface transport infrastructure: a case study of applying multi criteria analysis techniques to assess the sustainability of transport noise reducing devices. *Journal of Cleaner Production*, *112*, 2922–2934.

Omair, A. (2014). Sample size estimation and sampling techniques for selecting a representative sample. *Journal of Health Specialties*, *2*(4), 142.

Onat, N. C., Kucukvar, M., Tatari, O., and Egilmez, G. (2016). Integration of system dynamics approach toward deepening and broadening the life cycle sustainability assessment framework: a case for electric vehicles. *The International Journal of Lıfe Cycle Assessment*, *21*(7), 1009–1034.

Onwuegbuzie, A. J., Jiao, Q. G., and Bostick, S. L. (2004). *Library anxiety: Theory, research, and applications*. Scarecrow Press.

Osanloo, A., and Grant, C. (2016). Understanding, selecting, and integrating a theoretical framework in dissertation research: Creating the blueprint for your "house." *Administrative Issues Journal: Connecting Education, Practice, and Research*, *4*(2), 7.

Otaduy, I., and Diaz, O. (2017). User acceptance testing for Agile-developed web-based applications: Empowering customers through wikis and mind maps. *Journal of Systems and Software*, *133*, 212–229. https://doi.org/10.1016/j.jss.2017.01.002

Ozbay, K., Jawad, D., Parker, N., and Hussain, S. (2004). Life-Cycle Cost Analysis: State of the Practice Versus State of the Art. *Transportation Research Record: Journal of the Transportation Research Board*, *1864*(June 2014), 62–70. https://doi.org/10.3141/1864-09

P. M. Bentler. (1990). Comparative fit indices in structural models. *Psychological Bulletin*, *107*(2), 238–246.

Pallant, J. (2020). *SPSS survival manual: A step by step guide to data analysis using IBM SPSS*. Routledge.

Park, J., and Cai, H. (2017). WBS-based dynamic multi-dimensional BIM database for total construction as-built documentation. *Automation in Construction*, *77*, 15–23. https://doi.org/10.1016/j.autcon.2017.01.021

Parker, K. R., Chao, J. T., Ottaway, T. A., and Chang, J. (2006). A formal language selection process for introductory programming courses. *Journal of Information*

Technology Education: Research, *5*(1), 133–151.

Parrish, J., and Uren, H. V. (2017). Communicating energy efficiency to senior citizens: The influence of solar-PV and role of technology. In *Energy Procedia*. https://doi.org/10.1016/j.egypro.2017.08.025

Patil, R. A., Shabunko, V., and Ramakrishna, S. (2021). Renewable Energy and Circular Economy: Application of Life Cycle Costing to Building Integrated Solar Energy Systems in Singapore BT - An Introduction to Circular Economy. In Lerwen Liu & S. Ramakrishna (Eds.) (pp. 201–218). Singapore: Springer Singapore. https://doi.org/10.1007/978-981-15-8510-4_11

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage publications.

Pavlov, G., Maydeu-Olivares, A., and Shi, D. (2021). Using the Standardized Root Mean Squared Residual (SRMR) to Assess Exact Fit in Structural Equation Models. *Educational and Psychological Measurement*, *81*(1), 110–130. https://doi.org/10.1177/0013164420926231

Peng, B., Flager, F. L., and Wu, J. (2018). A method to optimize mobile crane and crew interactions to minimize construction cost and time. *Automation in Construction*, *95*(May), 10–19. https://doi.org/10.1016/j.autcon.2018.07.015

Pike, A. M., and Bommanayakanahalli, B. (2018). Development of a Pavement Marking Life Cycle Cost Tool. *Transportation Research Record*, *2672*(12), 148–157. https://doi.org/10.1177/0361198118758012

Portier, C. J., Tart, K. T., Carter, S. R., Dilworth, C. H., Grambsch, A. E., Gohlke, J., … Lutz, J. T. (2013). A human health perspective on climate change: a report outlining the research needs on the human health effects of climate change. *Journal of Current Issues in Globalization*, *6*(4), 621.

Postance, B., Hillier, J., Dijkstra, T., and Dixon, N. (2017). Extending natural hazard impacts: an assessment of landslide disruptions on a national road transportation network. *Environmental Research Letters*, *12*(1), 14010.

Power, D. J. (2000). Web-based and model-driven decision support systems: concepts and issues. *AMCIS 2000 Proceedings*, 387.

Pracki, P. (2011). A proposal to classify road lighting energy efficiency. *Lighting Research and Technology*, *43*(3), 271–280. https://doi.org/10.1177/1477153511407996

Pučko, Z., Šuman, N., and Rebolj, D. (2018). Automated continuous construction progress monitoring using multiple workplace real time 3D scans. *Advanced Engineering Informatics*, *38*(April), 27–40. https://doi.org/10.1016/j.aei.2018.06.001

Qin, X. C., Shao, S. G., and Shen, Y. (2014). Application of Green Lighting Technology in Highway Service – A Case Study of Mt. Lushan West Sea Tourism Highway Service. *Applied Mechanics and Materials*, *548–549*, 1815–1819. https://doi.org/10.4028/www.scientific.net/amm.548-549.1815

Rabhi, A., Bosch, J., and Elhajjaji, A. (2015). Energy management for an autonomous renewable energy system. *Energy Procedia*, *83*, 299–309. https://doi.org/10.1016/j.egypro.2015.12.184

Rafeeq, M., Afzal, A., and Rajendra, S. (2019). Remote Supervision and Control of Air Conditioning Systems in Different Modes. *Journal of The Institution of Engineers (India): Series C*, *100*(1), 175–185. https://doi.org/10.1007/s40032-017-0434-2

Rahman, F., and Zakaria, R. (2016). 2 nd IRF Asia Regional Congress & Exhibition The Needs of Life Cycle Cost Application for Malaysia Green Highway Projects The Needs of Life Cycle Cost Application for Malaysia Green Highway Projects. Kuala Lumpur: International Road Federation.

Rahman, F., and Zakaria, R. (2018). Highway and Life Cycle Costing as Decision-Making Support System Model. *Advanced Science Letters*, *24*(6), 3989–3992. https://doi.org/10.1166/asl.2018.11527

Rahman, F., Zakaria, R., and Zin, R. (2022). The Importance of Life Cycle Cost Components for Green Highway and Road Management : A Review, *1*(1), 13–

21.

Ramli, R. M., Arief, Y. Z., and Aziz, P. D. A. (2016). Application of LED technology into public road lighting in Malaysia for replacing the high pressure sodium vapour lighting. *Proceeding - 2015 International Conference on Sustainable Energy Engineering and Application: Sustainable Energy for Greater Development, ICSEEA 2015*, 76–81. https://doi.org/10.1109/ICSEEA.2015.7380749

Ramosaj, S. B. (2014). Systems theory and systems approach to leadership. *ILIRIA International Review*, *4*(1), 59–76.

Rashid, S. A., Haider, Z., Chapal Hossain, S. M., Memon, K., Panhwar, F., Mbogba, M. K., … Zhao, G. (2019). Retrofitting low-cost heating ventilation and air-conditioning systems for energy management in buildings. *Applied Energy*, 648–661. https://doi.org/10.1016/j.apenergy.2018.12.020

Rau, H., Goggins, G., and Fahy, F. (2018). From invisibility to impact: Recognising the scientific and societal relevance of interdisciplinary sustainability research. *Research Policy*, *47*(1), 266–276.

Rawool, R. A., Saini, S., Shah, A. A., Shah, T. P., and Katira, V. (2020). Design and Performance Evaluation of a Cost-Effective Radiant Cooling System (pp. 777–789). Springer, Singapore. https://doi.org/10.1007/978-981-15-4485-9_76

Razavi, R., Gharipour, A., Fleury, M., and Akpan, I. J. (2019). Occupancy detection of residential buildings using smart meter data: A large-scale study. *Energy and Buildings*, *183*, 195–208. https://doi.org/10.1016/j.enbuild.2018.11.025

Rebolj, D., Babič, N. Č., Magdič, A., Podbreznik, P., and Pšunder, M. (2008). Automated construction activity monitoring system. *Advanced Engineering Informatics*, *22*(4), 493–503. https://doi.org/10.1016/j.aei.2008.06.002

Ribeiro, I., Kaufmann, J., Schmidt, A., Peças, P., Henriques, E., and Götze, U. (2016). Fostering selection of sustainable manufacturing technologies–a case study involving product design, supply chain and life cycle performance. *Journal of Cleaner Production*, *112*, 3306–3319.

Richards, M., Boyce, P., and Fotios, S. (2009). Road lighting and energy saving. *Lighting Research and Technology*, *41*(3), 245–260. https://doi.org/10.1177/1477153509338887

Robinson, J. G. (2011). Ethical pluralism, pragmatism, and sustainability in conservation practice. *Biological Conservation*, *144*(3), 958–965.

Rose, S., Mathew, B. S., Isaac, K. P., and Abhaya, A. S. (2018). Risk based probabilistic pavement deterioration prediction models for low volume roads. *International Journal of Pavement Engineering*, *19*(1), 88–97.

Rossi, G., Iacomussi, P., Mancinelli, A., and Di Lecce, P. (2015). Adaptive systems in road lighting installations. *Light and Engineering*, *23*(4), 33–40.

Rouse, P., and Chiu, T. (2009). Towards optimal life cycle management in a road maintenance setting using DEA. *European Journal of Operational Research*, *196*(2), 672–681. https://doi.org/10.1016/j.ejor.2008.02.041

Rubinstein, A. (2008). Comments on neuroeconomics. *Economics & Philosophy*, *24*(3), 485–494.

Rubinstein, R. Y., and Kroese, D. P. (2016). *Simulation and the Monte Carlo method*. John Wiley & Sons.

Ruparathna, R., Hewage, K., and Sadiq, R. (2018). Multi-period maintenance planning for public buildings: A risk based approach for climate conscious operation. *Journal of Cleaner Production*, *170*, 1338–1353. https://doi.org/10.1016/j.jclepro.2017.09.178

Russ, N. M., Hanid, M., and Ye, K. M. (2018). Literature review on green cost premium elements of sustainable building construction. *International Journal of Technology*, *9*(8), 1715–1725. https://doi.org/10.14716/ijtech.v9i8.2762

Rybka, I., and Bondar-Nowakowska, E. (2013). Planning of the risk handling methods related to alterations to project documentation. In *Procedia Engineering* (Vol. 57, pp. 952–957). Elsevier Ltd. https://doi.org/10.1016/j.proeng.2013.04.121

Sadeli, S. (2015). *The Conceptual Model of Lıfe Cycle Costing Automation on Green*

Building Energy Efficient Criteria. Universiti Teknologi Malaysia.

Safi, M., Sundquist, H., Karoumi, R., and Racutanu, G. (2013). Development of the Swedish bridge management system by upgrading and expanding the use of LCC. *Structure and Infrastructure Engineering*, *9*(12), 1240–1250.

Saif, M. A., Zefreh, M. M., and Torok, A. (2019). Public transport accessibility: A literature review. *Periodica Polytechnica Transportation Engineering*, *47*(1), 36–43.

Salvado, F., de Almeida, N. M., and e Azevedo, A. V. (2018). Toward improved LCC-informed decisions in building management. *Built Environment Project and Asset Management*.

Sarker, B. R., and Faiz, T. I. (2017). Minimizing transportation and installation costs for turbines in offshore wind farms. *Renewable Energy*, *101*, 667–679. https://doi.org/10.1016/j.renene.2016.09.014

Sazali, H., and Firdaus, I. M. (2019). Highway infrastructure: visions & challenges in the next decades. In *IOP Conference Series: Materials Science and Engineering* (Vol. 512, p. 12047). IOP Publishing.

Schweitzer, M., and Tonn, B. (2002). Nonenergy benefits from the weatherization assistance program: A summary of findings from the recent literature. *Prepared for US Department of Energy, Oak Ridge National Laboratory, Oak Ridge, TN, USA*.

Settanni, E., Newnes, L. B., Thenent, N. E., Parry, G., and Goh, Y. M. (2014). A through-life costing methodology for use in product–service-systems. *International Journal of Production Economics*, *153*, 161–177.

Sexton, M., and Barrett, P. (2003). A literature synthesis of innovation in small construction firms: insights, ambiguities and questions. *Construction Management and Economics*, *21*(6), 613–622.

Shah, M. A. R., Rahman, A., and Chowdhury, S. H. (2017). Sustainability assessment of flood mitigation projects: An innovative decision support framework.

International Journal of Disaster Risk Reduction, *23*, 53–61.

Shah, T., Bhatt, S., Shah, R. K., and Talati, J. (2008). Groundwater governance through electricity supply management: Assessing an innovative intervention in Gujarat, western India. *Agricultural Water Management*, *95*(11), 1233–1242.

Shaoul, J., Stafford, A., and Stapleton, P. (2006). Highway Robbery? A Financial Analysis of Design, Build, Finance and Operate (DBFO) in UK Roads. *Transport Reviews*, *26*(3), 257–274. https://doi.org/10.1080/01441640500415243

Sharma, V., Haque, M. H., and Aziz, S. M. (2019). Energy cost minimization for net zero energy homes through optimal sizing of battery storage system. *Renewable Energy*, *141*(2019), 278–286. https://doi.org/10.1016/j.renene.2019.03.144

Sheldon, M. R., Fillyaw, M. J., and Thompson, W. D. (1996). The use and interpretation of the Friedman test in the analysis of ordinal-scale data in repeated measures designs. *Physiotherapy Research International*, *1*(4), 221–228.

Shuhaiber, A. H. (2021). Residents' perceptions of smart energy meters. *Expert Systems*, *38*(6), e12500.

Shuhaiber, A., and Mashal, I. (2019). Understanding users' acceptance of smart homes. *Technology in Society*. https://doi.org/10.1016/j.techsoc.2019.01.003

Shukla, A. K., Jain, S. S., Parida, M., and Srivastava, J. B. (2009). Performance of FHWA model for predicting traffic noise: A case study of Metropolitan city, Lucknow (India). *Transport*, *24*(3), 234–240.

Sidorova, A., and Isik, O. (2010). Business process research: a cross-disciplinary review. *Business Process Management Journal*.

Singh, R. K., Murty, H. R., Gupta, S. K., and Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. *Ecological Indicators*, *9*(2), 189–212.

Singh, Y. K. (2006). *Fundamental of research methodology and statistics*. New Age International.

Slaper, T. F., and Hall, T. J. (2011). The triple bottom line: What is it and how does it work. *Indiana Business Review*, *86*(1), 4–8.

Sørensen, E., and Torfing, J. (2016). *Theories of democratic network governance*. Springer.

Stazyk, E. C., Moldavanova, A., and Frederickson, H. G. (2016). Sustainability, Intergenerational Social Equity, and the Socially Responsible Organization. *Administration and Society*, *48*(6), 655–682. https://doi.org/10.1177/0095399713519094

Steen, B. (2005). Environmental costs and benefits in life cycle costing. *Management of Environmental Quality: An International Journal*.

Sterner, E. (2000). Life-cycle costing and its use in the Swedish building sector. *Building Research & Information*, *28*(5–6), 387–393.

Surahyo, M., and El-Diraby, T. E. (2009). Schema for interoperable representation of environmental and social costs in highway construction. *Journal of Construction Engineering and Management*, *135*(4), 254–266.

Suter, G. W., and Norton, S. B. (2018). Ecological risk assessment. In *Encyclopedia of Ecology*. https://doi.org/10.1016/B978-0-12-409548-9.11137-6

Szymański, P. (2017). Risk management in construction projects. In *Procedia Engineering* (Vol. 208, pp. 174–182). https://doi.org/10.1016/j.proeng.2017.11.036

Tähkämö, L., Räsänen, R. S., and Halonen, L. (2016). Life cycle cost comparison of high-pressure sodium and light-emitting diode luminaires in street lighting. *International Journal of Lıfe Cycle Assessment*, *21*(2), 137–145. https://doi.org/10.1007/s11367-015-1000-x

Tähkämö, L., Ylinen, A., Puolakka, M., and Halonen, L. (2012). Life cycle cost analysis of three renewed street lighting installations in Finland. *International Journal of Lıfe Cycle Assessment*, *17*(2), 154–164. https://doi.org/10.1007/s11367-011-0345-z

Taleizadeh, A. A., Noori-Daryan, M., and Sana, S. S. (2020). Manufacturing and selling tactics for a green supply chain under a green cost sharing and a refund agreement. *Journal of Modelling in Management*, *15*(4), 1419–1450. https://doi.org/10.1108/JM2-01-2019-0016

Tao, X., Mao, C., Xie, F., Liu, G., and Xu, P. P. (2018). Greenhouse gas emission monitoring system for manufacturing prefabricated components. *Automation in Construction*, *93*(June 2018), 361–374. https://doi.org/10.1016/j.autcon.2018.05.015

Tarne, P., Lehmann, A., and Finkbeiner, M. (2019). Introducing weights to life cycle sustainability assessment—how do decision-makers weight sustainability dimensions? *The International Journal of Life Cycle Assessment*, *24*(3), 530–542.

Teo, H. C., Lechner, A. M., Walton, G. W., Chan, F. K. S., Cheshmehzangi, A., Tan-Mullins, M., … Campos-Arceiz, A. (2019). Environmental Impacts of Infrastructure Development under the Belt and Road Initiative. *Environments*, *6*(6), 72. https://doi.org/10.3390/environments6060072

Thoft-Christensen, P., Jensen, F. M., Middleton, C. R., and Blackmore, A. (2011). Revised rules for concrete bridges. In *Safety of bridges* (pp. 175–188). Thomas Telford Publishing.

Tokody, D., and Flammini, F. (2017). The intelligent railway system theory. *International Transportation*, *69*(1), 38–40.

Triki-Lahiani, A., Bennani-Ben Abdelghani, A., and Slama-Belkhodja, I. (2018). Fault detection and monitoring systems for photovoltaic installations: A review. *Renewable and Sustainable Energy Reviews*, *82*, 2680–2692. https://doi.org/10.1016/J.RSER.2017.09.101

Tseng, P. H., Lin, D. Y., and Chien, S. (2014). Investigating the impact of highway electronic toll collection to the external cost: A case study in Taiwan. *Technological Forecasting and Social Change*, *86*, 265–272. https://doi.org/10.1016/j.techfore.2013.10.019

Ugwu, O. O., Kumaraswamy, M. M., Wong, A., and Ng, S. T. (2006). Sustainability appraisal in infrastructure projects (SUSAIP): Part 1. Development of indicators and computational methods. *Automation in Construction*, *15*(2), 239–251.

UN-SDG. (2016). United Nations Sustainable Development Agenda.

Usenko, L. N., Bogataya, I. N., Bukhov, N. V, Kuvaldina, T. B., and Pavlyuk, A. V. (2018). Formation of an integrated accounting and analytical management system for value analysis purposes.

Van Teijlingen, E., and Hundley, V. (2002). The importance of pilot studies. *Nursing Standard (through 2013)*, *16*(40), 33.

Vittorio, A., Rosolino, V., Teresa, I., Vittoria, C. M., Vincenzo, P. G., and Francesco, D. M. (2014). Automated Sensing System for Monitoring of Road Surface Quality by Mobile Devices. *Procedia - Social and Behavioral Sciences*, *111*, 242–251. https://doi.org/10.1016/j.sbspro.2014.01.057

Wang, C., Shi, J., Chen, Z., and Zha, X. (2017). Study on energy consumption of large public building based on sub-metering technology. *Procedia Engineering*, *205*, 3056–3060. https://doi.org/10.1016/j.proeng.2017.10.273

Wang, G., Bernanda, D. Y., Andry, J. F., and Fajar, A. N. (2019). Application development and testing based on iso 9126 framework. In *Journal of Physics: Conference Series* (Vol. 1235, p. 12011). IOP Publishing.

Wang, J., Yu, C., and Pan, W. (2020). Relationship between operational energy and life cycle cost performance of high-rise office buildings. *Journal of Cleaner Production*, *262*, 121300. https://doi.org/10.1016/j.jclepro.2020.121300

Wang, N. (2014). Correlation Analysis of Capital and Life Cycle Costs in Private Financial Initiative Projects. *Journal of Management in Engineering*, *30*(5). https://doi.org/10.1061/(ASCE)ME.1943-5479

Waris, M., Liew, M. S., Khamidi, M. F., and Idrus, A. (2014). Criteria for the selection of sustainable onsite construction equipment. *International Journal of Sustainable Built Environment*, *3*(1), 96–110.

Welch IV, J. (2018). The Impact of Newell's" A Theory of Interdisciplinary Studies": Reflection and Analysis. *Issues in Interdisciplinary Studies*, *36*(2), 193–211.

Wilde, W. J., Waalkes, S., and Harrison, R. (1999). *Life cycle cost analysis of Portland cement concrete pavements*. University of Texas at Austin. Center for Transportation Research.

Wood, D. J., and Logsdon, J. M. (2017). Theorising business citizenship. In *Perspectives on corporate citizenship* (pp. 83–103). Routledge.

Wu, M. S., Huang, H. H., Huang, B. J., Tang, C. W., and Cheng, C. W. (2009). Economic feasibility of solar-powered led roadway lighting. *Renewable Energy*, *34*(8), 1934–1938. https://doi.org/10.1016/j.renene.2008.12.026

Wu, X., Zhao, W., and Ma, T. (2019). Improving the impact of green construction management on the quality of highway engineering projects. *Sustainability (Switzerland)*. https://doi.org/10.3390/su11071895

Wu, Y. C., Chen, M. J., Chang, B. Sen, and Tsai, M. T. (2014). A low-cost web-based infrared remote control system for energy management of aggregated air conditioners. *Energy and Buildings*, *72*, 24–30. https://doi.org/10.1016/j.enbuild.2013.12.035

Xu, H., and Nakajima, K. (2017). Highways and industrial development in the peripheral regions of China. *Papers in Regional Science*, *96*(2), 325–356.

Y, K., Y, H., M, W., and R, C. (2019). Predicting intra-day load profiles under time-of-use tariffs using smart meter data. *Energy*, *173*, 959–970. https://doi.org/10.1016/j.energy.2019.01.037

Yang, I. T. (2005). Simulation-based estimation for correlated cost elements. *International Journal of Project Management*, *23*(4), 275–282. https://doi.org/10.1016/j.ijproman.2004.12.002

Yi, J., Ahmed, U. Z., Karkare, A., Tan, S. H., and Roychoudhury, A. (2017). A feasibility study of using automated program repair for introductory programming assignments. In *Proceedings of the 2017 11th Joint Meeting on Foundations of Software Engineering* (pp. 740–751).

Zakaria, R., Seng, F. K., Abd. Majid, M. Z., Mohamad Zin, R., Hainin, M. R., Che

Puan, O., … Moayedi, F. (2013). Energy Efficiency Criteria for Green Highways in Malaysia. *Jurnal Teknologi*, *65*(3), 91–95. https://doi.org/10.11113/jt.v65.2152

Zhang, H., Arens, E., and Pasut, W. (2011). Air temperature thresholds for indoor comfort and perceived air quality. *Building Research and Information*, *39*(2), 134–144. https://doi.org/10.1080/09613218.2011.552703

Zhang, Z., Zhang, Y., and Khan, A. (2020). A Comparison of Thermal Comfort of People from Buildings with Centralized Air-Conditioning Systems and Split Air-Conditioners. In *Environmental Science and Engineering* (pp. 1181–1190). Springer. https://doi.org/10.1007/978-981-13-9520-8_122

Zhao, B. Y., Li, Y., Wang, R. Z., Zhao, Z. G., and Taylor, R. A. (2018). A universal method for performance evaluation of solar photovoltaic air-conditioner. *Solar Energy*, *172*, 58–68. https://doi.org/10.1016/j.solener.2018.05.029

Zhao, X., Ma, C., and Gu, P. (2012). Energy Saving Methods and Results Analysis in the Hotel. *Energy Procedia*, *14*(2011), 1523–1527. https://doi.org/10.1016/j.egypro.2011.12.1127

Zhou, Z., Tang, Y., Dong, J., Chi, Y., Ni, M., Li, N., and Zhang, Y. (2018). Environmental performance evolution of municipal solid waste management by life cycle assessment in Hangzhou, China. *Journal of Environmental Management*. https://doi.org/10.1016/j.jenvman.2018.08.083

Zou, P. X. W., Zhang, G., and Wang, J.-Y. (2006). Identifying key risks in construction projects: life cycle and stakeholder perspectives. In *Pacific Rim Real Estate Society Conference*.

LIST OF PUBLICATIONS

1. Abd Rahman, M. F., Zakaria, R., Shamsudin, S. M., Aminudin, E., & Yousif, O. S. (2022, October). The Importance of Life Cycle Cost (LCC) Components for Emerging Green Costs Incurred in Green Highway Budget Preparation Decision-Making. In IOP Conference Series: Earth and Environmental Science (Vol. 1067, No. 1, p. 012061). IOP Publishing.

2. Rahman, M. F. A., Zakaria, R., & Zin, R. (2022). The Importance of Life Cycle Cost Components for Green Highway and Road Management: A Review. Journal of Advanced Research in Technology and Innovation Management, 2(1), 13-21.

3. Rahman, M. F. A., and Zakaria, R. (2020). 8th International Graduate Conference on Engineering, Science and Humanities (IGCESH 2020): The Needs Of Life Cycle Cost As Decision-Making Instrument For Emerging Green Road Project. In *IR 4.0 Towards Sustainable Development Goals: Trends and Challenges* (pp. 332–336). Johor Bahru: School of Graduate Studies, Universiti Teknologi Malaysia

4. Rahman, M. F. A., and Zakaria, R. (2018). Highway and Life Cycle Costing as Decision-Making Support System Model. Advanced Science Letters, 24(6), 3989–3992. https://doi.org/10.1166/asl.2018.11527

5. Rahman, Muhammad Faiz A, and Zakaria, R. (2016). 2 nd IRF Asia Regional Congress & Exhibition The Needs of Life Cycle Cost Application for Malaysia Green Highway Projects. Kuala Lumpur: International Road Federation.

6. Abd Rahman, M. F. B. (2011). Introduction of pack test for participative environmental monitoring and environmental education for sustainability in Malaysia. Journal of Tropical Life Science, 1(2), 60-68.