The IISE Body of Knowledge Governing Board presents:

IISE BoK Applications in Economic Analysis, System Design and Information Engineering

Mayra Méndez-Piñero, Ph.D.

**Engineering economic analysis** for the implementation of investment projects in the public sector

Ben Amaba, PhD, PE, CPIM®, LEED® AP

**ISE is the profession of the future:** Orchestrating the physical, mathematical, and social sciences for the digital future
IISE BoK Applications in Economic Analysis, System Design and Information Engineering

Webinar Speakers

Mayra Méndez-Piñero, Ph.D.
Professor
Department of Industrial Engineering
University of Puerto Rico-Mayagüez

Ben Amaba, PhD, PE, CPIM®, LEED® AP
Global Chief Technology Officer
IBM
Agenda

- **IISE BoK Overview**

- **Engineering economic analysis** for the implementation of investment projects in the public sector

- Q&A

- **ISE is the profession of the future:** Orchestrating the physical, mathematical, and social sciences for the digital future

- Q&A
ISE Body of Knowledge Overview

Visit the IISE BoK Website at: https://www.iise.org/details.aspx?id=43631
IISE BoK Applications in Economic Analysis, System Design and Information Engineering

Applications

1. Work Design & Measurement
2. Operations Research & Analysis
3. Engineering Economic Analysis
4. Facilities Engineering & Energy Management
5. Quality & Reliability Engineering
6. Ergonomics & Human Factors
7. Operations Engineering & Management
8. Supply Chain Management
10. Safety
11. Information Engineering
12. Design & Manufacturing Engineering
13. Product Design & Development
14. System Design & Engineering
Engineering Economic Analysis for the Implementation of Investment Projects in the Public Sector

September 16, 2021

Based on Project done by IE undergraduate students Perlängelys Pérez and Mariela Maldonado

Presented by: Mayra I. Méndez Piñero, Ph.D.
Construction Projects

- Essential for a country’s economic development
- Important to follow procedures for implementations and investments

Planning Process

- Proper and solid planning process for every project is needed
- Designed for present and future needs of communities and their users
Issues
- Hard to complete on time
- Lack of maintenance
- Decrease in useful life
- Recurring inspections
- Higher repair costs

Challenges
- Economic crisis
- Atmospheric and natural phenomenon
Purpose

Project Investments
Understand decisions made to support project implementations

Economic Analysis Tool
Develop an analysis tool to evaluate current and future construction projects
Methodology

- Project Selection
- Benefit-Cost Analysis
- Cost & Benefits Measurement
- Marginal Analysis
Projects’ selection

Maunabo
Naranjito
San Juan
01 Cable Stayed Bridge

02 Ecosystem Restoration
03 Maunabo Tunnels

04 Urbain Train
Cable Stayed Bridge in Naranjito
Maunabo Tunnels
Urban Train in San Juan
### Estimating Costs

<table>
<thead>
<tr>
<th><strong>Interest rate</strong></th>
<th>Considering government uses loans for capital investment projects</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Useful life</strong></td>
<td>To understand the number of years it was estimated to be valuable</td>
</tr>
<tr>
<td><strong>Maintenance costs</strong></td>
<td>To understand the additional expenses throughout the years</td>
</tr>
<tr>
<td><strong>Food consumption</strong></td>
<td>To forecast profits for local restaurants and food markets based on income from food consumption</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Gasoline</strong></td>
<td>To forecast economic savings for the users based on the differences in distance traveled</td>
</tr>
</tbody>
</table>
Food Consumption in Local Businesses

Census of Puerto Rico 2000 & 2010
- Labor force: employed and unemployed population

Socioeconomic Indicators
- Per capita income of the residents

Local newspaper “El Vocero”
- % of food consumption per person reduced by 35% from 13.8 to 8.97
Quantifying Benefits

Economic Savings in Gasoline

Google Maps Application
To compare previous and current routes

2010 DACO Report
To obtain the statistical cost of regular gasoline

Gasoline consumption
Distance traveled and tank capacity of Toyota Corolla

DACO: Department of Consumer Affairs
(Spanish: Departamento de Asuntos al Consumidor)
Economic Savings in Gasoline

2010 DTOP Report

Motor vehicles registered to obtain general savings

User Savings

• 30% - people without a car
  • 30% - unemployed (no need for transportation)

Train Passengers

Effect in local businesses based on users

DTOP: Department of Transportation and Public Works
(Spanish: Departamento de Transportación y Obras Públicas)
Equivalencies

\[
\text{PW}_{\text{costs}} = I + A \left( \frac{P}{A}, i, n \right)
\]

\[
\text{FW}_{\text{costs}} = I \left( \frac{F}{P}, i, n \right) + A \left( \frac{F}{A}, i, n \right)
\]

\[
\text{AW}_{\text{costs}} = I \left( \frac{A}{P}, i, n \right) + A
\]

\[
\text{PW}_{\text{benefits}} = IB + A \left( \frac{P}{A}, i, n \right)
\]

\[
\text{FW}_{\text{benefits}} = IB \left( \frac{F}{P}, i, n \right) + A \left( \frac{F}{A}, i, n \right)
\]

\[
\text{AW}_{\text{benefits}} = IB \left( \frac{A}{P}, i, n \right) + A
\]

\[I=\text{initial investment}\]
\[IB=\text{initial benefits}\]
\[A=\text{annuity}\]
\[i=\text{interest rate}\]
\[n=\text{useful life}\]

\[P/A, F/P \text{ and } A/P - \text{obtained from Compound Interest Tables}\]
Benefit-Cost Ratio (BCR)

\[
\text{Benefit} - \text{Cost Ratio} = \frac{\text{Equivalent Benefits}}{\text{Equivalent Costs}}
\]

Decision criteria:

- BCR ≥ 1.0, investment recommended
- BCR < 1.0, investment not recommended
Ecosystem Restoration

Five project alternatives

Equal benefits

Lowest costs alternative
Formulas

01 \[ PW_{\text{costs}} = I + A \left( \frac{P}{A}, i, n \right) \]

02 Compare each of the cost conversions to determine the lowest amount

\( I = \) initial investment  
\( A = \) annuity  
\( i = \) interest rate  
\( n = \) useful life  
\( P/A \) was obtained from the Compound Interest Tables
Results
<table>
<thead>
<tr>
<th>Project</th>
<th>Ratio</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Stayed Bridge</td>
<td>$\text{Ratio} &gt; 1$</td>
<td>Investment recommended</td>
</tr>
<tr>
<td>Maunabo Tunnels</td>
<td>$\text{Ratio} &lt; 1$</td>
<td>Investment not recommended</td>
</tr>
<tr>
<td>Urban Train</td>
<td>$\text{Ratio} &lt; 1$</td>
<td>Investment not recommended</td>
</tr>
</tbody>
</table>
Ecosystem Restoration

Lowest cost conversions

Investment recommended
VBA in Excel
Decision Making
Maximize user benefits
Measure maintenance costs
Improve planning
Welcome to the Engineering Economics Analysis Tool! This was developed by Mariela Maldonado-Toledo and Perlangeys Pérez-Torres, students from the University of Puerto Rico, Mayagüez Campus from the Industrial Engineering Department.

The purpose of this analysis tool is to facilitate economic decision making in the development of construction projects within the public sector.
# How to use the tool

## Tool Steps

1. Click the *Project Information* button and fill out the general project information for project documentation.
2. Select your analysis of interest (*Benefit-Cost Analysis* or *Marginal Cost Analysis*) by clicking their corresponding button.
3. Fill the required information in the *Project Data* section.
4. Click the *CALCULATE* button to obtain all cost results.

## Additional Features

- To erase all the data entered, click the *CLEAR DATA* button.
- Return to the Menu at anytime by clicking the *BACK TO MENU* button.
- Click the *VIEW DASHBOARD* button to view graphs for the corresponding analysis.
- From the Dashboard, click the *BACK TO ANALYSIS* button to return to the previous analysis sheet.
## Estimating Benefits

Here are some tips on how to estimate user benefits for a construction project in the public sector according to the project type:

<table>
<thead>
<tr>
<th>Project</th>
<th>Sector</th>
<th>Tips</th>
</tr>
</thead>
</table>
| Bridge  | Public  | - Consider the total population in the location, workforce, employed, and car owners to get a quantity of inhabitants that will be transiting in the area.  
- Identify local businesses that would be impacted by the accessibility. |
| Tunnel  | Public  | - Explore adjoin cities’ populations to obtain potential visitors from nearby.  
- Research inhabitant salaries and percentage of food consumption, groceries, purchases etc. to estimate local business owners profits. |
| Rail Train | Public | - Compare project with alternative routes’ time reduction and lengths to estimate gasoline savings.  
- Investigate tourists an recreational uses that bring profits to the city. |
| Road    | Public  | - Study profits for gasoline station owners per consumer. |
# Economic Analysis Tool

## Project Information

<table>
<thead>
<tr>
<th>Project Title</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Type</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>Project Manager</td>
<td></td>
</tr>
<tr>
<td>Purpose</td>
<td></td>
</tr>
<tr>
<td>Start Date</td>
<td></td>
</tr>
<tr>
<td>End Date</td>
<td></td>
</tr>
</tbody>
</table>

[BACK TO MENU]

[CLEAR DATA]

![Project Information](image.png)
Acknowledgements

This Engineering Economics Analysis Tool could not be completed without the help of some colleagues and professors in the Engineering and Construction area. We would like to express our special thanks to our mentor Dr. Mayra Méndez Piñero who gave us the opportunity to do this wonderful project about Economic Analysis and apply what we have learned in the classroom. For the research made, we would like to also thank the following people: Dr. Antonio González Quevedo, Dr. Héctor Carlo, Comité Pro-Desarrollo de Maunabo, Engineer José Serrano, Puerto Rico Highways and Transportation Authority, Francisco Maldonado Ph. D, Sylvia I Rodríguez, Stephen Álvarez, Luis López Sierra, Engineer Marilyn Rodríguez Díaz, Luis Molina, Maritza Green, Ramón “Chito” Arroyo and Rafael Díaz for providing us with great insight about the different projects to work on. Thank you and we hope the Analysis Tool helps in the decision to other projects.

Sincerely,
Mariela & Perlangeys
### Benefit-Cost Analysis

#### Project Data
- Total project cost
- O&M/R&R costs type
- O&M/R&R amount
- Interest rate (%)
- Project useful life (yr)
- Benefits type
- Benefit amount

#### Resulting Equivalent Costs
- Present Worth
- Annual Worth
- Future Worth

#### Resulting Equivalent Benefits
- Present Worth
- Annual Worth
- Future Worth

#### Benefit-Cost Ratio
- Present Worth
- Annual Worth
- Future Worth

#### Recommendations
B.C. Dashboard
Marginal Analysis

**Economic Analysis Tool**

**Marginal Analysis**

<table>
<thead>
<tr>
<th>Project Alternatives</th>
<th>Total Project Cost</th>
<th>OMRR&amp;R Costs</th>
<th>Interest rate (%)</th>
<th>Useful Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>#</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Present Worth Analysis**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>PW of Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Marginal Analysis**

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Annuity</th>
<th>Comparison</th>
<th>Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recommendations**

Remember to fill every cell for each alternative.

**Back to Menu**

**Clear Data**

**View Dashboard**

**Calculate**
M.A. Dashboard
Conclusions

Project Information
- Not always accessible to users

Project Investments
- Not always based on analysis

Project Maintenance
- Poor.
- Useful life decrease
Acknowledgements

Dr. Antonio González Quevedo
Urban Train Project Manager

Puerto Rico Highway and Transportation Authority (PRHTA)

Cable Stayed Bridge Image: https://www.elnuevodia.com/noticias/locales/notas/el-dtop-cerrara-el-puente-atirantado-de-naranjito-por-seis-meses/


Maunabo Tunnels Image: https://www.carolina787.com/bl/tu

Urban Train Image: https://www.municipiodebayamon.com/tren-urbano-regresa-su-horario-regular/
Emails:
mayra.mendez@upr.edu
perlangelys.perez@upr.edu
mariela.maldonado1@upr.edu
The Profession of the Future.

Orchestrating the physical, mathematical and social sciences for the Digital Future.

Ben Amaba, PhD, PE, CPIM®, LEED® AP
Chief Technology Officer
IBM Automation, Data Analytics and Machine Learning
Data Science and the Art of Persuasion

Organizations struggle to communicate the insights in all the information they’ve amassed. Here’s why, and how to fix it. by Scott Berinato

From the Magazine (January-February 2019)

Data Scientist: The Sexiest Job of the 21st Century

Meet the people who can coax treasure out of messy, unstructured data. by Thomas H. Davenport and D.J. Patil

From the Magazine (October 2012)
Who is solving major challenges with Data?
Software FACTORIES, Data WAREHOUSES, Agile FLOW

US News and World Report – March 2020
The following jobs are projected to be great ones to target in the current economic climate:
• Logistician
• Cost Estimator
• **Industrial Engineer**
• Actuary
• Statistician
• Information Security Analyst

- Chemical companies can incur $2,000 per hour in wasted material inputs. Up to $15,000 an hour.
- Drilling platforms can produce 200,000 barrels of oil each day, which breaks down to roughly 8,300 barrels per hour. With oil prices hovering around $60 per barrel, just one hour offline translates to $500,000.
- Furnaces for heat treatment when the power went out, cost $60,000 for a 20-minute power outage.
- A mining machine down for 24 hours justifies a brand-new replacement between $1 million and $1.5 million, which outweighs the cost of not producing.
ISE professionals and techniques are crucial.
ISEs are broad and deep – T-shaped.
The world needs interdisciplinary and integrated knowledge-based solutions

There are 11 bachelor’s degree programs that allow most graduates to recoup the money spent on their diploma in five years or less, the report notes. Seven engineering majors dominate the list, including petroleum, aerospace and industrial engineering. Institute of Industrial and Systems Engineers, National Society of Professional Engineers

These college majors have the best return on investment, according to a new report
cnbc.com • 4 min read

“Need I-shaped, T-shaped, π-shaped people…”
Slide by Jean Paul Jacob
Information to Knowledge drives Economic Development

Harvard Business Review
Analysts estimate that the companies in the Fortune 500 lose a combined $31.5 billion per year because their employees fail to effectively share knowledge.

According to IDC®, an average enterprise can have as many as 900 different applications and only 29 percent are integrated.

According to McKinsey® and IDC, knowledge workers spend 19 and 30 percent of their time respectively searching for knowledge.

Much of the content sits in PowerPoint® decks but unfortunately, search engines, such as Google and Bing®, cannot search the content inside the deck. – Keeeb

According to IDC, 20 percent of a knowledge worker’s time is spent building assets that already exist.

Over the next decade, AI won’t replace managers, but managers who use AI will replace those who don’t.” Harvard Business Review
Data represents huge opportunity for ISE’s

More Humans in the Loop

Technology is outpacing our policy and implementation

Protecting users and user data

Systems are becoming increasingly complex

The New Industrial Engineering: Information Technology and Business Process Redesign

Those aspiring to improve the way work is done must begin to apply the capabilities of information technology to redesign business processes. Business process design and information technology are natural partners, yet industrial engineers have never fully exploited their relationship. The authors argue, in fact, that it has barely been exploited at all. But the organizations that have used IT to redesign boundary-crossing, customer-driven processes have benefited enormously. This article explains why.

Thomas H. Davenport and James E. Short • July 15, 1990
Business degrees are losing favor among both data scientists and predictive analytics professionals. Regarding that last point, the study noted that math and statistics degrees were gaining favor among predictive analytics professionals, while in the data science space, there was an increase in engineering degrees. The study authors suggest this “may be due to candidates opting to strengthen their quantitative credentials for greater career opportunities over the more general MBA track.” - Burtch Works
Drs. Joseph M. Juran and W. Edwards Deming who stress that the vast majority (85 to 94 percent) of the time, the answer is found in the processes in place.

They are not up to the task of handling all the variations that exist in today's business climate, and as a result, customer expectations are not met.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Description</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Business Problem (Question) Framing</td>
<td>15%</td>
</tr>
<tr>
<td>II</td>
<td>Analytics Problem Framing</td>
<td>17%</td>
</tr>
<tr>
<td>III</td>
<td>Data</td>
<td>22%</td>
</tr>
<tr>
<td>IV</td>
<td>Methodology (Approach) Selection</td>
<td>15%</td>
</tr>
<tr>
<td>V</td>
<td>Model Building</td>
<td>16%</td>
</tr>
<tr>
<td>VI</td>
<td>Deployment</td>
<td>9%</td>
</tr>
<tr>
<td>VII</td>
<td>Life Cycle Management</td>
<td>6%</td>
</tr>
</tbody>
</table>

“"If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions.”

– Albert Einstein
Commonly used ISE techniques & outputs

Domain I – Business Problem and Question Framing
- Requirements Engineering
- Process Maps or Value Stream Analysis Project Charter
- Key performance indicators
- Critical Success Factors
- Objective Key Results.
- Source, Input, Process, Output, Consume (SIPOC) flow diagrams
- Voice of the Customers in feedback, questionnaires, or surveys
- Stakeholder Analysis
- Kano Analysis or Feasibility Maps

Domain II – Analytics and Problem Framing
- Value Stream Mapping
- Scatter Plots, R and R2 analysis to check for correlations
- Check Sheets or Check Lists
- Hypothesis Testing
- Histograms
- Run charts
- Process Capability
- Measurement System Analysis
- Cause and effect, Ishikawa diagrams (fishbone/herringbone)
- Pareto Chart
- “ANOVA” Analysis of Variance
- “MANOVA” Multivariate Analysis of Variance"
- Critical Path Method
- Performance Evaluation Review Techniques
- Decision Tree Analysis
- DOE - Design of experiments (DOE, DOX, or experimental design)
- Use case, sequence diagrams, & class diagrams for software.
- Net-Benefit, benefit-cost ratio, return on investment, or ROI, NPV, IRR, MIRR, cash flow
Operations Analysis

The abundance and growth of machine data, which can include anything from IT machines to sensors and meters and GPS devices, is another major driver of big data solutions. In its raw format, many organizations are unable to leverage machine data. Yet disregarding this data means that organizations are making business decisions based only on a subset of available information. Leveraging machine data and combining it with existing enterprise data enables a new generation of applications that are able to analyze and gain insight from large volumes of multi-structured machine data—which in turn improves business results.

**WHAT DO YOU NEED TO SUCCEED?**

- **Capture a Complete View**
  Access large volumes of machine, operational and transactional data and combine with other enterprise data.

- **Get the Context**
  Overcome complexities to perform advanced analysis and provide context across different data sets.

- **Get Insights From Analytics**
  Release intelligence trapped in your data, allowing agile interpretation and action.

**THE RESULTS**

- **Empower the C-Suite**
  Reassure decision makers that they are acting with full knowledge & understanding of all available data.

- **Improve Reliability**
  Perform root cause analysis on data to more easily identify and preempt system failures, keeping customers happy.

- **Speed Operations**
  Help departments proactively minimize the problems and bottlenecks that stymie the flow of operations.

- **Monitor & React**
  Visualize streaming data to monitor the end-to-end infrastructure and deliver real-time alerts.

Learn more at IBM.com/BigData
Silicon Valley and Agile are Ruining Engineering

Silicon Valley and Agile are Ruining Engineering (AND decimating industries and harming people for no reason)

The scientific nomenclature = The Silicon Valley Agile Holiday Inn Express Syndrome

First, “Agile” bottoms up approaches can be just fine or even the best option. That is where the folks doing the work do not work form someone else, are selling their own product, determine their own schedule, costs, scope etc, and the systems are not complex, or safety related.

Now to the issue at hand. There is a disease infecting the world. It has migrated into governments and even NASA. This disease is the Silicon Valley Agile Holiday Inn Express Syndrome.

(For those unaware of the Holiday Inn Express part —
https://www.youtube.com/watch?v=eHCTaUFxpP8&list=PL_zvTUNG--HJ2fPCph1_SeaxAatPngsMVP)
Machine Learning and Artificial Intelligence should be an outcome of robust systems and software engineering

"our civilization runs on software"

-- Bjarne Stroustrup

Yet the art of creating it continues to be a dark mystery. Never in history have we depended so completely on a product that so few know how to make well.

“Just because you can lay a brick doesn't mean you can build a pyramid to endure the test of time.”

(Amaba, 2021)
ISE Professional engineering skills are desired in the world. Plan to be a professional moving forward in the world of data

- How does failure in $S_n$ affect $S_1$?
- Can security vulnerability in $S_n$ affect $S_1$?
- Who is responsible?
- Orchestrating: The physical, mathematical and social sciences.

Legend:
Licensed Engineer (P.E.)
Unlicensed Engineer

Professional Engineers Earn More

![Graph showing earnings comparison between professional and non-professional engineers over years since baccalaureate.](chart.png)
“AI is no longer Science Fiction, but Science Fact” - Dr. Marios Savvides

“Today I will do what others won’t, So tomorrow I can do what others can’t.”
– Jerry Rice
Where to find more information:

Body of Knowledge

Performance Excellence Webinars

Conferences
https://www.iise.org/Details/?id=370

Training Center
https://www.iise.org/TrainingCenter/

Professional Engineering Exam Review
https://www.iise.org/TrainingCenter/CourseDetail/?EventCode=PEI

“Today I will do what others won’t, So tomorrow I can do what others can’t.”  
– Jerry Rice
Thank you!

Visit the IISE BoK Website at: https://www.iise.org/details.aspx?id=43631