Journal of Engineering Research and Applied Science
Available at www.journaleras.com
Volume 15 (1), June 2026, pp 31-38
ISSN 2147-3471 © 2026

Cost Effective Hybridge Models for Allocating Industrial Machine Maintenance Budget in a Dynamic Economy

Olasoji Rasak Olagunju[1], Basil Olufemi Akinnuli[2,*]

[1]Mechanical Engineering, Federal University of Technology Akure, Nigeria
[2]Industrial and Production Engineering, Federal University of Technology Akure, Nigeria

Accepted 12 April 2026

Abstract

In today's fast-paced and competitive business landscape, understanding the cost of failure has become increasingly crucial. The cost of failure refers to the financial and non-financial consequences that arise from unsuccessful projects, initiatives, or processes. It encompasses not only the direct monetary losses but also the indirect impacts on reputation, customer satisfaction, and employee morale. Prevention is better than cure. Avoiding cost of failure occurrence is better than proffering solution after its ill effect. This is purely medicine after death. This study found this as gap in literature that needs the attention of economic researcher. Hence the development cost effective models capable of allotting available budget optimally for its effective usage. By this, failed projects that often results in wasted resources, such as time, labor, and materials as well as failed projects that demoralize employees, leading to decreased productivity and increased turnover rates will be under control from onset. Cost effectiveness models are analytical tools that help businesses compare the costs and benefits of different alternatives and make informed decisions. This study identified the required strategic decisions, with their attributes and their models adopted from literature for the required logics to these models. The computer algorithms was developed as well as the software model using a JAVA scripts for its implementation for decision making. Performance index of each machine were: Winnowing machine (WM is 0.324); Milling Machine (MM is 0.327); While that of Liquor Press Machine (LPM was 0.349). The company available maintenance budget (AB) for the three machines in 2025 was Eighteen Million, Six hundred and forty five Thousands (**18,645,000)** Naira. Using the performance index of each machine to predict what should be allocated to each of this machine in 2025 maintenance activities; Winnowing Machine Allocation Budget (AB_{wm}), **6,040,980** Naira; Milling Machine Allocation Budget (AB_{mm}), **6,096,915** Naira. While that of Liquor Press Machine Allocation Budget (AB_{lpm}), **6,507,105** Naira. This model is very simple and easy to use. It will find its application in small, medium and large scale industries.

Keywords: *Budget allocation, strategic decision, cost effective models, mathematics logic.*

1. Introduction

According to Prof. Harrod, "Economic dynamics is the study of an economy in which rates of output are changing." In the real world, economic variables like population, capital, techniques of production, fashions, habits, etc. do not change at a constant rate. The rate of change is different at different times [1], [2] and [3].

Recently the concept of dynamics has been applied to the economy as a whole, Prof. Clark has pointed out the following features of a dynamic economy: In a dynamic economy, population grows; Quantity of capital grows; Modes of production improve; Industrial institutions undergo changes. Inefficient organizations are replaced by efficient organizations. Habits of the people, fashions and customs change, as wants of the people increase. It be can concluded by saying that dynamic economics relates to a dynamic economy where uncertainty and expectations play their part [4], [5], [6] and [7].

Dynamic economics is becoming more and more popular since 1925. Though the principles advocated by Clark and Aftalian were dynamic in nature yet their main purpose was to explain the business fluctuations. After 1925, dynamic economics became popular not only in business fluctuations but also in the determination of income and growth models [8], [9] and [10].

*Corresponding author: ifembola@yahoo.com, olasoji.olagunju@yahoo.com
Phone : +2348034659522, +2348033101655

This economic dynamism has impacts on economics factors either positively or negatively which lead to economic performance decision uncertainty [11, 12, 13, 14].

In the realm of evaluation, a cost-effective models plays a crucial role in assessing the efficiency and value of various interventions, programs, or projects. It provides a systematic framework for analyzing the costs incurred and the outcomes achieved, allowing decision-makers to make informed choices based on evidence and data [15], [16] and [17].

From a broader perspective, a cost-effectiveness model serves as a quantitative tool that compares the costs and benefits of different alternatives. It helps evaluate the efficiency of resource allocation and aids in determining the most cost-effective approach to achieve desired outcomes [18],[19],[20],and [2]. By incorporating various perspectives and considering multiple factors, such as financial implications, societal impact, and long-term sustainability, a cost-effectiveness model provides a comprehensive evaluation of interventions. Such as, Comprehensive Analysis, Outcome Evaluation, Resource Allocation, Comparative Assessment, and Policy Development [22], [23] and [24].

A cost-effectiveness model is a valuable tool for evaluation, enabling a comprehensive analysis of costs and outcomes, facilitating resource allocation decisions, supporting comparative assessments, and informing policy development [25], [26], [27] and [28]. By incorporating various perspectives and providing evidence-based insights, it empowers decision-makers to make informed choices that maximize the efficiency and impact of interventions [29], [30] and [31].

The main types of cost-effectiveness models are: Decision Tree Models; Markov Models, Micro-simulation Models [32], [33], [34] and [35]. One of the most important decisions in conducting a cost-effectiveness analysis is choosing the appropriate type of model to represent the intervention and its outcomes. [36], [37] and [38].

2. Methodology

2.1. Cost Effective Index Development

The attributes for consideration for the strategic decision are machine productivity index, and price recovery index.

2.1.1. Machine Productivity Index (MPI).

American productivity Center (APC) has suggested a general approach to the measurement of factor productivity [20]. The APC model is a plant level productivity measure obtained by combining the data from various factors. The formula used in this model is as follows.

$$\left[\ell\right]_f = \frac{\alpha_0/\beta_0}{\alpha_i/\alpha_i} = \frac{\sum Q_2P_1/\sum Q_1P_1}{\sum I_RC_1/\sum I_1C_1} \quad (1)$$

Where; α_0 is Current Output Quantities, β_0 is Based Output Quantities, α_i is Current Input Quantities and β_i is Based Input Quantities.

2.1.2. Price Recovery Index (PRI) $[\psi]$

In a period of inflation, another index is found to be useful and this is known as Price Recovery Index (PRI).

This index is expressed as:

$$\left[\psi\right] = \frac{\sum Q_2P_2/\sum Q_2P_1}{\sum I_2C_2/\sum I_2C_1} \quad (2)$$

The index shows the extent to which the firm has succeeded in absorbing cost increases to combat inflation.

2.1.3. Cost Effectiveness Index (W_c)

A cost effectiveness index reflects how costs for the current period compare with the cost relationship established for the base period. Cost effectiveness is measured by the capacity of a business firm to produce a commodity at lower cost or by its success in achieving cost reduction through improved efficiency of operations or more effective utilization of its existing resources.

$$\text{Cost Effective Index} = \frac{\text{Productivity for Current Period}}{\text{Productivity for the base Period}}$$

$$W_c = \frac{\sum Q_2P_2/\sum Q_1P_1}{\sum I_2C_2/\sum I_1C_1} \quad (3)$$

It is to be noted that cost effectiveness index is product of factor productivity index and price recovery index.

$$W_c = \left[P\right]_f \times \left[\psi\right] \quad (4)$$

2.2. Mathematics Logic for the Cost Effectiveness Computation

In putting the collected data in Tables 1 into the adopted mathematic models that's equations 1,2,3 and 4 cost effective results in table 2 was gotten.

Models Application

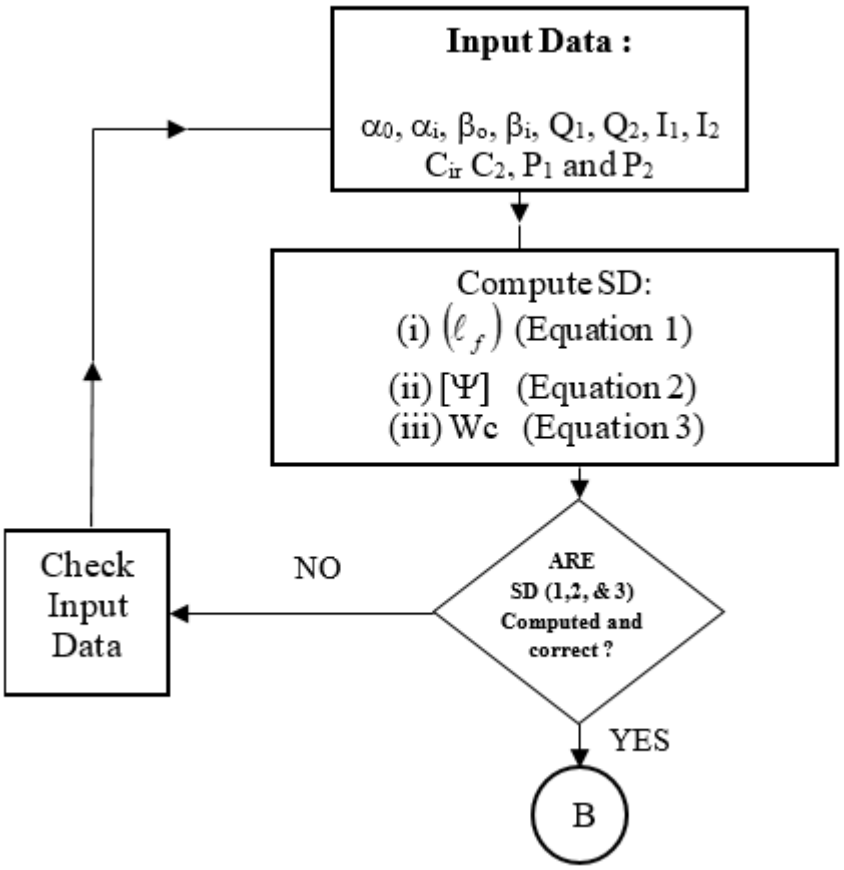

Figure 1. Logic for the Cost Effectiveness Computation

Table 1 Average Data Cost Effective Index CEI 2015 – 2018

S/N	Input: Parameter Cost Effective Index (CEI)	Winnowing Machine (WM)	Milling Machine (MM)	Liquor Press Machine (LPM)
1.	Q_2: Cocoa Nibs Current Output (kg)	414,000	410,457	381,500
2.	Q_1: Cocoa Nibs Base Output (kg)	396,000	390,500	389,820
3.	I_2: Cocoa Beans Current Input (kg)	416,000	415,420	375,260
4.	I_1: Cocoa Beans Base input (kg)	400,000	390,625	373,700
S/N	**Cost and Price (Millions of Naira)**			
5.	C_1 (Base Input Cost).	120	131	133
6.	C_2 (Current Output Cost).	140	144	139
7.	P_1 (Base input Price).	1,000	1,500	1,6
8.	P_2 (Current Output Price).	1,250	1,720	1,880

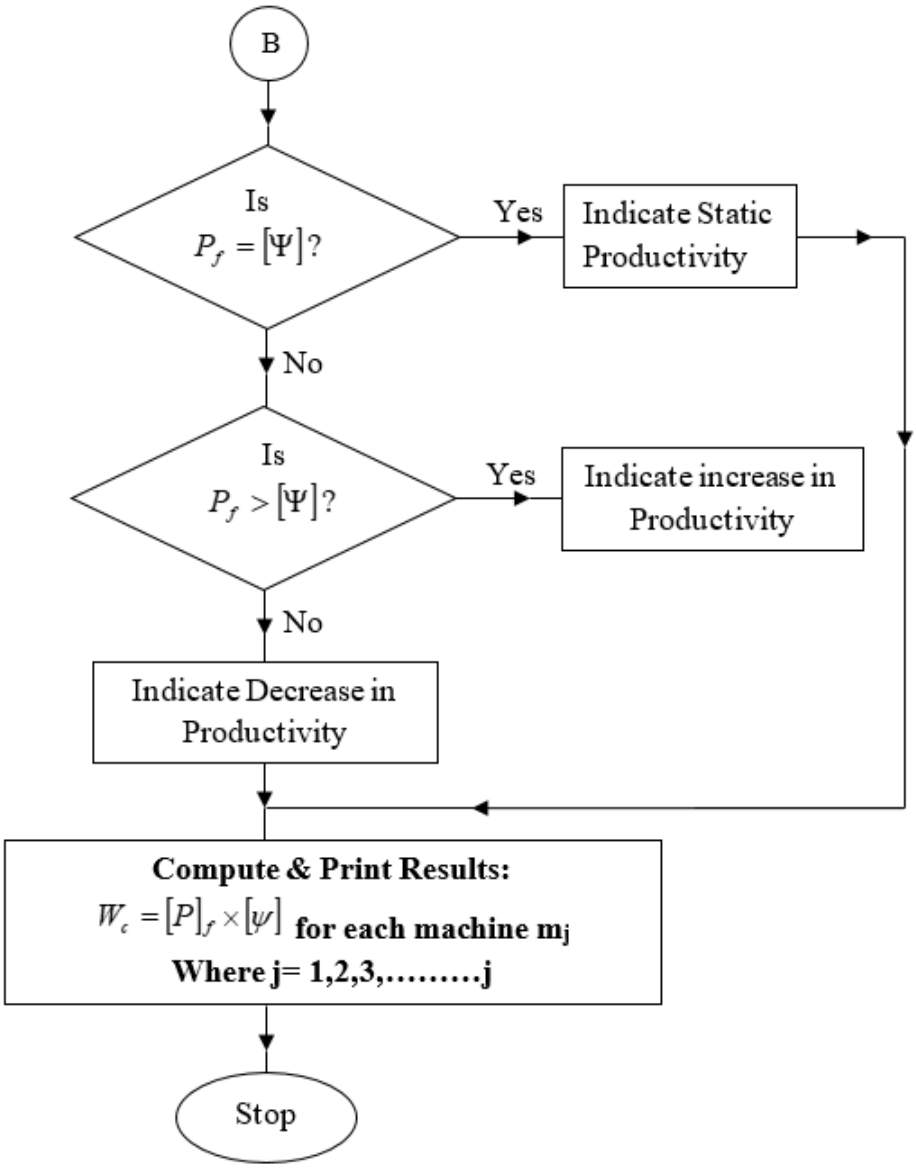

Figure 2. Logic for the Cost Effectiveness Computation

Table 2: Selected machines and their average yearly cost effectiveness for ten years were generated.

MACHINE	AVERAGE YEARLY COST EFFECTIVE INDICES FOR TEN YEARS.										FINAL
Winnowing Machine	0.99	1.09	0.80	0.78	0.97	1.14	1.02	1.11	0.81	0.96	0.967
Milling machine	1.07	0.89	1.2	0.95	0.87	0.99	0.79	1.04	1.13	0.81	0.974
Liqour Press Machine	1.1	0.94	0.87	1.34	0.99	0.88	0.88	1.27	1.07	1.13	1.04
YEAR / SUM	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2.981**

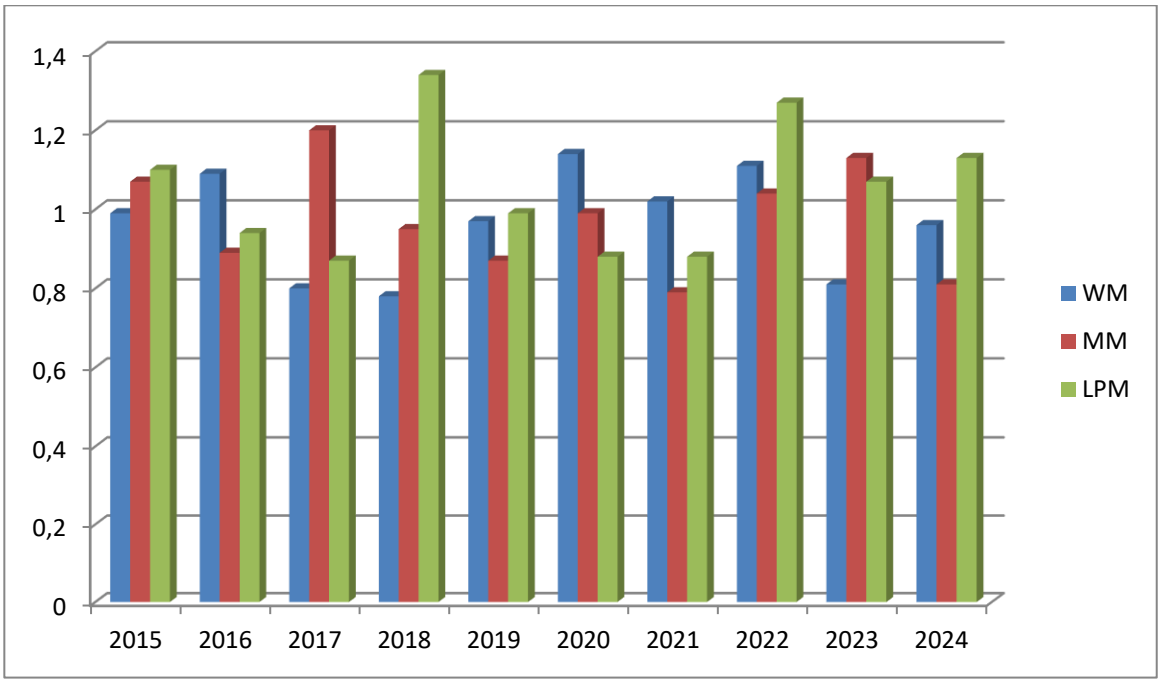

Figure 3. Average yearly cost effectiveness for ten years of the machines

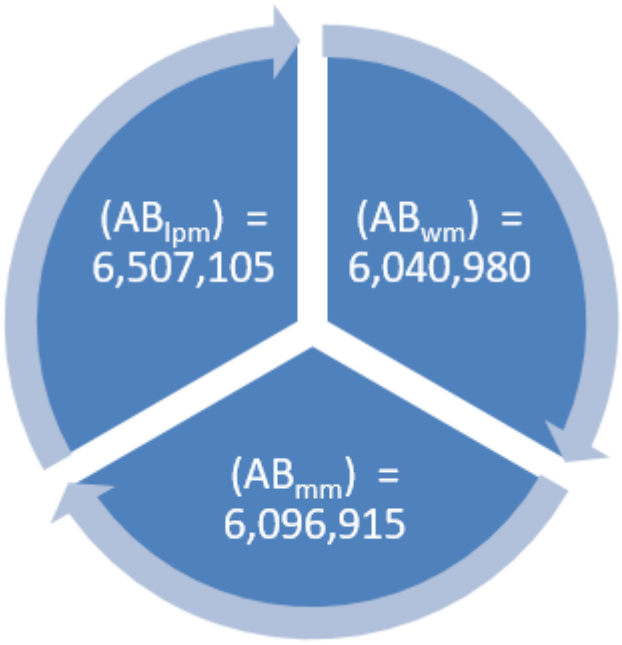

Figure 4. Available budget allocation for the three machines

Fractional value of any available budget for the three machines = Sum/Each Machine Final Average.

$$FV = S/M_{fj} \quad (5)$$

$$\text{WinnowingMachine}: \quad FV_{wm} = S/M_{wm} \quad (5a)$$

$$\text{Milling Machine}: \quad FV_{mm} = S/M_{mm} \quad (5b)$$

$$\text{Liquor Press Machine}: FV_{lpm} = S/M_{lpm} \quad (5c)$$

$FV_{wm} = 0.324$; $FV_{mm} = 0.327$; and $FV_{lpm} = 0.349$

Available Budget (AB) for the Three Machines 2025 was **18,645,000** Naira.

In order to run each of this machine out of the available budget, (AB_{mj})

Winnowing Machine Allocation Budget (AB_{wm})

(AB_{wm}) = FV_{wm} (AB).= 0.324(18,645000) = **6,040,980** Naira.

Milling Machine Allocation Budget (AB_{mm})

(AB_{mm}) = FV_{mm} (AB).= 0.327(18,645000) = **6,096,915** Naira.

Liquor Press Machine Allocation Budget (AB_{lpm})

(AB_{lpm}) = FV_{lpm} (AB).= .349(18,645000) = **6,507,105** Naira.

3. Results

The strategic decision for this study were machine productivity index, and price recovery index. And their attributes were identified as Current Output Quantities, Based Output Quantities, Current Input Quantities and Based Input Quantities. The mathematics models used were as stated in equations 1 to 4 while the logic is as shown in figures 1 and 2 respectively.

Case study of three Cocoa processing machines were considered putting into consideration their past maintenance cost effective index for periods of ten years were as shown in figure 3. Performance index of each machine were: Winnowing machine (WM is 0.324); Milling Machine (MM is 0.327); While that of Liquor Press Machine (LPM was 0.349).

The company available maintenance budget (AB) for the Three Machines in 2025 was Eighteen Million, Six hundred and forty five Thousands (**18,645,000)** Naira. Using the performance index of each machine to predict what should be allocated to each of this machine in 2025 maintenance activities; Winnowing Machine Allocation Budget (AB_{wm}), **6,040,980** Naira; Milling Machine Allocation Budget (AB_{mm}), **6,096,915** Naira. While that of Liquor Press Machine Allocation Budget (AB_{lpm}), **6,507,105** Naira. These were expressed with pie chart in figure 4.

4. Conclusions

The objectives of this study which were to identified the strategic decisions and their attributes for cost effective models development were made known, the logic was successfully developed. Application of this logic using JAVA scripts makes it more easy to use and time saving. The software results were validated with the manual computed results. It was found 100% efficient and is of high saving cost compared with the foreign product capable of doing same job. This model is very simple and easy to use. It will find its application in small, medium and large scale industries.

References

[1] Quade E S. A (1971). History of Cost-Effectiveness. Santa Monica, California: RAND Corporation; 1971:1–22. [Google Scholar]

[2]. Boardman, A.E., Greenberg, D.H., Vining, A.R., and Weimer, D.L.(2011). "Chapter 18: Cost-effectiveness analysis and cost-utility analysis". In Cost-Benefit Analysis Concepts and Practice, Fourth Edition. Upper Saddle River, N.J.: Prentice Hall. (Open in a new window)Google Scholar

[3]. Gray AM, Clarke PM, Wolstenholme JL.(2010). Applied Methods of Cost-effectiveness Analysis in Healthcare. First ed. United States of America: Oxford University Press; 2010. [Google Scholar]

[4]. Brown, E.D., and Tanner, J.C. (2019). Integrating Value for Money and Impact Evaluations: Issues, Institutions, and Opportunities. Policy Research Working Paper 9041. World Bank. Ac Availableat: https://documents1.worldbank.org/curated/en/862091571145787913/pdf/Integrating-Value-for-Money-and-Impact-Evaluations-Issues-Institutions-and-Opportunities.pdf(open in a new window) (Open in a new window)Google Scholar

[5]. Bhula, R., M. Mahoney, and K. Murphy. (2020). "Conducting Cost-effectiveness Analysis [Set of Online Resources]." Available at: https://www.povertyactionlab.org/resource/conducting-cost-effectiveness-analysis-cea(open in a new window) (Open in a new window)Google Scholar

[6]. Cameron, D. B., A. Mishra, and A. N. Brown. (2015). "The Growth of Impact Evaluation for International Development: How Much Have We Learned?" *Journal of Development Effectiveness* 8 (1), 1-21. (Open in a new window)Web of Science ®(Open in a new window)Google Scholar

[7]. Tan SS, Rutten FF, van Ineveld BM, (2009). Comparing methodologies for the cost estimation of hospital services. Eur J Health Econ. 2009;10:39–45. [DOI] [PubMed] [Google Scholar]

[8]. Capturing Cost Data.(2019). "Strategic Impact Evaluation Fund (SIEF) at the World Bank and the International Rescue Committee (IRC)." Accessed March 25, 2021. Available at: https://pubdocs.worldbank.org/en/994671553617734574/Capturing-Cost-Data-190314.pdf(open in a new window) (Open in a new window)Google Scholar

[9]. Hummel N, Debray TPA, Didden EM, (2017). Methodological guidance, recommendations and illustrative case studies for (network) meta-analysis

and modelling to predict real-world effectiveness using individual participant and/or aggregate data. Brussels: Innovative Medicines Initiative;2017
[10]. Dhaliwal, I., E. Duflo, R. Glennerstser, and C. Tulloch.(2013). "Comparative Cost-Effectiveness Analysis to Inform Policy in Developing Countries: A General Framework with Applications for Education." In *Education Policy in Developing Countries*, edited by P. Glewwe. Chicago: University of Chicago Press 285–338. (Open in a new window)Google Scholar
[11]. Vermeer M, Kievit W, Kuper HH, (2013). Treating to the target of remission in early rheumatoid arthritis is cost-effective: results of the DREAM registry. BMC Musculoskelet Disord. 2013;14:350.
[12]. Drummond, M. F., M. J. Sculpher, K. L. Claxton, G. L. Stoddart, and G. W. Torrance. (2015). *Methods for the Economic Evaluation of Health Care Programmes*. Fourth ed. Oxford: Oxford University Press.(Open in a new window)Google Scholar
[13]. Gold MR, Siege JE, Russell LB, Weinstein MC.(2015. Cost-effectiveness in health and medicinex.Availableat: https://www.oxfordscholarship.com/view/10.1093/acprof:oso/9780190492939.001.0001/acprof-9780190492939
[14]. Evans, D., and A. Popova.(2014). "Cost-Effectiveness Measurement in Development: Accounting for Local Costs and Noisy Impacts (English)." Policy Research working paper; no. WPS 7027 Washington, D.C.: World Bank Group. Accessed March 25, 2021. Available at: http://documents.worldbank.org/curated/en/969291468340210399/Cost-effectiveness-measurement-in-development-accounting-for-local-costs-and-noisy-impacts(open in a new window) (Open in a new window)Google Scholar
[15].Michaud TL, Abraham J, Jalal H, (2015). Cost-effectiveness of a statewide campaign to promote aspirin use for primary prevention of cardiovascular disease. J Am Heart Assoc. 2015;4:e002321.
[16]. Filmer, D., H. Rogers, N. Angrist, and S. Sabarwal.(2020). "Learning-adjusted Years of Schooling (LAYS): Defining a New Macro Measure of Education." *Economics of Education Review* 77: 101971. doi:10.1016/j.econedurev.2020.101971. (Open in a new window)Web of Science ®(Open in a new window)Google Scholar
[17]. Simoens S.(2010). Health economic assessment: cost-effectiveness thresholds and other decision criteria. Int J Environ Res Public Health. 2010;7:1835–40. [DOI] [PMC free article] [PubMed] [Google Scholar]
[18]. Fleming, F. (2013). "Evaluation Methods for Assessing Value for Money." Better Evaluation. Accessed March 25, 2021. Available at: https://www.betterevaluation.org/sites/default/files/Evaluating%20methods%20for%20assessing%20VfM%20-%20Farida%20Fleming.pdf(open in a new window) (Open in a new window)Google Scholar
[19]. Gomez GB, Dowdy DW, Bastos ML, et al. Cost and cost-effectiveness of tuberculosis treatment shortening: a model-based analysis. BMC Infect Dis. 2016;16:726.
[20]. Goodman, C. S. (2014). "Health Technology Assessment 101: Economic Analysis Methods." National Information Center on Health Services Research and Health Care Technology (NICHSR). Accessed March 25, 2021. Available at: https://www.nlm.nih.gov/nichsr/hta101/ta10107.html(open in a new window) (Open in a new window)Google Scholar
[21]. Griffiths, U. K., R. Legood, and C. Pitt. (2016). "Comparison of Economic Evaluation Methods across Low-income, Middle-income, and High-income Countries: What are the Differences and Why?" *Health Economics* 25 (Supplement 1): 29–41. doi:10.1002/hec.3312.(Open in a new window)PubMed (Open in a new window)Web of Science ®(Open in a new window)Google Scholar
[22]. Uyl-de Groot CA, van Rooijen EM, Punt CJA, (2018). . Real-world cost-effectiveness of cetuximab in the third-line treatment of metastatic colorectal cancer based on patient chart review in the Netherlands. Health Econ Rev. 2018;8:13.
[23]. Levin, H. M.(1975). "Cost-effectiveness Analysis in Evaluation Research." In *Handbook of Evaluation Research*, Vol. 2. Chap. 5, edited by M. Guttentag, and E. L. Struening. Washington, D.C.: Sage 346–368 . (Open in a new window)Google Scholar
[24]. Drummond MF, Sculpher MJ, Claxton K, Stoddart GL, Torrance GW (2006).. Methods for the Economic Evaluation of Health Care Programmes, 3rd ed. Thrid ed. New York: OUP Oxford; 2006:464. [Google Scholar]
[25]. Levin, H. M., P. J. McEwan, C. Belfield, A. B. Bowden, and R. Shand.(2018). *Economic Evaluation in Education: Cost-effectiveness and Benefit-cost Analysis*. Third ed. Washington, D.C.: Sage. (Open in a new window)Google Scholar
[26]. Manca A, Hawkins N, Sculpher MJ (2005). Estimating mean QALYs in trial-based cost-effectiveness analysis: the importance of controlling for baseline utility. Health Econ. 2005;14:487–96. [DOI] [PubMed] [Google Scholar]
[27]. McEwan, P. J. (2011). "Cost-Effectiveness Analysis of Education and Health Interventions in Developing Countries." Office of Strategic Planning and Development Effectiveness, Inter-American

Development Bank. Accessed March 25, 2021. Available at: https://publications.iadb.org/publications/english/document/Cost-Effectiveness-Analysis-of-Education-and-Health-Interventions-in-Developing-Countries.pdf(open in a new window) (Open in a new window)Google Scholar

[28]. Stevens A, Milne R, Burls A.(2003). Health technology assessment: history and demand. J Public Health Med. 2003;25:98–101. [DOI] [PubMed] [Google Scholar]

[29]. McIntosh, C., and A. Zeitlin (2020). "Using Household Grants to Benchmark the Cost Effectiveness of a USAID Workforce Readiness Program." ArXiv e-print. USAID, 2 September 2020. https://arxiv.org/pdf/2009.01749.pdf(open in a new window) (Open in a new window)Google Scholar

[30]. Brandao SMG, Rezende PC, Brunner-La Rocca HP, 2018). Comparative cost-effectiveness of surgery, angioplasty, or medical therapy in patients with multivessel coronary artery disease: MASS II trial. Cost Eff Resour Alloc. 2018;16:55. [DOI] [PMC free article] [PubMed] [Google Scholar]

[31]. Sen, A. K. (2000). "The Discipline of Cost-benefit Analysis." *Journal of Legal Studies* 29 (S2): 931–952. doi:10.1086/468100.(Open in a new window)Web of Science ®(Open in a new window)Google Scholar

[32]. United State Environmental Protection Agency (EPA)(2014).. Guidelines for preparing economic analyses. Wahington, D.C.: EPA; 2014. Available at: https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses. [Google Scholar]

[33]. Standards for the Economic Evaluation of Educational and Social Programs.(2021). "Cost Analysis Standards Project, American Institutes for Research." Accessed March 25, 2021. Available at: https://www.air.org/sites/default/files/Standards-for-the-Economic-Evaluation-of-Educational-and-Social-Programs-CASP-May-2021.pdf. Google Scholar

[34]. Cho J-H, Jang HM, Jung H-Y, (2018). A real-world cost-effectiveness analysis of sevelamer versus calcium acetate in Korean dialysis patients. Clin Ther. 2018;40:123–134

[35]. Sullivan, S. D., J. A. Mauskopf, F. Augustovski, J. J. Caro, K. M. Lee, M. Minchin, E. Orlewska, P. Penna, J.-M. Rodriguez Barrios, and W.-Y. Shau. (2014). "Budget Impact Analysis-Principles of Good Practice: Report of the ISPOR 2012 Budget Impact Analysis Good Practice II Task Force. Value in Health." Volume 17, Issue 1, January–February 2014, Pages 5-14.

[36]. Walls, E. C. Tulloch, and C. H.-V. Keuren. (2020). "Cost Analysis Guidance for USAID-Funded Education Activities, Second edition." Washington, DC: United States Agency for International Development. Available at: https://www.edu-links.org/resources/usaid-cost-measurement(open in a new window).

[37].Teng M, Zhao YJ, Khoo AL (2018). Cost-effectiveness analysis of biodegradable polymer versus durable polymer drug-eluting stents incorporating real-world evidence. Cardiovasc Ther. 2018;36:e12442.

[38]. Wilkinson, T., M. J. Sculpher, K. Claxton, P. Revill, A. Briggs, J. A. Cairns, Y. T(2016) . "The International Decision Support Initiative Reference Case for Economic Evaluation: An Aid to Thought." *Value in Health* 19 (8): 921–928. doi:10.1016/j.jval.2016.04.015.