

Article

Improving Resource Utilization Efficiency through Cost Accounting Information

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Abstract: This study examines the role of cost accounting information in supporting resource utilization efficiency and managerial decision-making. It emphasizes that a reduction in reported expenditure does not necessarily indicate improved operational efficiency, as changes in production volume, input prices, or the timing of expenditures may influence financial results. The study conceptualizes cost accounting information as a combination of measured resource quantities, monetary valuations, attribution to processes and outputs, and explanations of deviations. It further distinguishes information availability, information quality, managerial use, and realized outcomes in assessing the contribution of accounting information to resource decisions. Material Flow Cost Accounting (MFCA) is considered as a useful approach for identifying material losses and making resource consumption more visible. The analysis highlights the importance of examining physical resource flows before interpreting their economic significance and demonstrates that reliable cost information can support managerial decisions when it is connected to operational processes, decision authority, implementation costs, and potential quality risks.

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1. Introduction

Resource utilization efficiency concerns the relationship between the resources consumed and the conforming output obtained. A reduction in reported expenditure does not, by itself, demonstrate an improvement in this relationship. Expenditure may fall because production declines, input prices decrease, or spending is deferred. Conversely, physical efficiency may improve while expenditure remains unchanged because labor and equipment commitments cannot immediately be adjusted. These distinctions define the problem examined in this article: how can cost accounting information support resource decisions without confusing changes in accounting values with changes in operational performance?

The International Federation of Accountants distinguishes costing for external reporting from costing for internal analysis and decision support, emphasizing the operational relationships behind monetary information. [1] For the present study, accounting records therefore need to support an explanation of resource consumption while remaining reconcilable with the underlying transactions. The relevant issue is the suitability of information for a managerial decision, rather than replacing financial accounting with an unrelated system.

For this study, cost accounting information comprises measured resource quantities, their monetary valuations, attribution to processes and outputs, and explanations of deviations. The IMA conceptual framework similarly connects internal cost models to operational resource relationships and decision requirements. [2] The proposed analysis distinguishes information availability, information quality, managerial use, and realized outcomes. An accurate report may not change operations when its recipient lacks decision authority or an actionable alternative. An identified opportunity may also remain unattractive after implementation costs and quality risks are considered.

Material flow cost accounting (MFCA) provides a foundation for examining losses. Schmidt and Nakajima explain how assigning costs to products and residual material flows makes resource losses more visible than examining disposal charges alone. [3] The implication developed here is to investigate where quantities are consumed before interpreting the economic significance of an apparent inefficiency. Visibility identifies a question for management; it does not establish an avoidable payment or a realized saving.

Evidence of benefits also requires qualification. Walz and Guenther synthesize 73 MFCA case studies and explicitly caution that limited evidence constrains interpretation of the predominantly positive reported effects. [4] This article therefore does not infer a transferable savings rate from published applications. Its numerical example is a transparent analytical illustration, not a new company case study or an estimate of an industry-wide effect.

The connection between operational and accounting information is also a modeling problem. Sonnenberg and vom Brocke propose using event records to represent economic resource flows and connect process states with accounting information. [5] This article uses that idea as a conceptual bridge, without assuming that an enterprise system already provides complete or accurate resource data. The decision record must preserve the event, resource, unit, period, and valuation rule behind a reported amount.

The research question is: how, and under what informational and organizational conditions, can cost accounting information support improvements in resource utilization efficiency? The objective is to develop a transparent analytical framework connecting resource measurement, output-adjusted comparison, managerial intervention, and benefit verification. The framework is intended for manufacturing processes in which materials, energy, labor time, and capacity commitments can be distinguished. No claim is made about a particular country's enterprises, since no enterprise-level dataset was analyzed in this study.

The contribution is a decision-support framework separating the detection of resource inefficiency from verification of its economic consequences. It distinguishes lower physical consumption, capacity released for other uses, and reduced expenditure or additional contribution. A hypothetical numerical demonstration tests the internal consistency of these distinctions. The proposed approach also treats additional costing detail as a decision requiring justification: Cokins links higher costing maturity to an assessment of incremental informational benefits and implementation effort. [6] The article consequently develops an evaluation protocol and testable propositions rather than claiming a measured treatment effect.

The selected literature addresses complementary questions: how resource demand can be represented, whether accounting information improves performance through operational action, and how losses and recovery activities should be distinguished. These questions require different types of evidence. A costing model can clarify the calculation of resource consumption without proving that managers will use its output. An empirical association can identify a relevant relationship without establishing that every implementation will generate the same outcome. The review therefore separates modeling contributions from evidence about organizational use.

Time-driven activity-based costing is relevant when time meaningfully represents resource demand. Cokins describes the use of time-based standards and emphasizes a supply-based denominator when identifying unused capacity. [7] Here, the practical implication is to distinguish capacity supplied from capacity consumed. A reduction in processing time can then be recognized without presuming that the corresponding payroll or equipment commitment immediately falls. Materials and energy retain their own measurement units rather than being forced into a time-based model.

The valuation of released time is a capacity measure, not an automatic cash benefit. The IMA framework distinguishes avoidability from divisibility and explains that reduced resource requirements generate avoidable costs only when the supplied resources can actually be adjusted. [8] For the proposed framework, released capacity may be redeployed, used to avoid future overtime, retained as operational flexibility, or left unused. Each alternative needs its own evidence and relevant time horizon. A time saving should not be counted simultaneously as both eliminated capacity and capacity used to earn additional contribution.

Organizational coordination is a separate requirement. Nakajima, Kimura, and Wagner distinguish losses addressable within production from losses requiring changes in design, technology, purchasing, or supplier relationships. [9] This distinction suggests a conditional managerial mechanism rather than a direct link from costing-system adoption to performance. In the proposed protocol, the place where a loss is measured and the place where its cause can be changed are recorded separately. Installing software or circulating a report is insufficient evidence that either the operational problem or its economic consequences have been resolved.

This article translates that insight into an explicit intervention record. The proposed unit of managerial analysis is not simply a cost report or a software installation. It is a documented sequence in which information identifies an actionable issue, an authorized manager approves a response, the response changes operations, and comparable measurements assess the outcome. Recording only system adoption would omit most of this sequence. Recording only a favorable cost movement would leave its relationship to the intervention uncertain.

Dierkes and Siepelmeyer develop MFCA by distinguishing waste and rejects, which increase material demand, from reworking and recycling, which can reduce demand. Their analysis separates company, quantity-center, and product-unit perspectives. [10] This supports keeping the origin of a loss distinct from subsequent recovery activity. Recovering material can reduce new inputs while consuming additional energy and processing time. A favorable material indicator therefore cannot, by itself, settle the overall assessment. Saleable by-products should also be distinguished from avoidable waste according to their function and economic treatment.

Reliable analysis requires a physical basis. Schmidt and Nakajima emphasize process-level mass balances and measured input, output, loss, and energy data before monetary valuation. [11] In the present framework, quantities are reconciled first and valued second. The resulting classification should distinguish normal conversion losses, abnormal losses, rework, recoverable residues, and saleable secondary output where relevant. These categories are proposed analytical safeguards, not observations from a new enterprise sample. An unexplained mass-balance difference remains an unresolved measurement issue rather than being silently assigned to a favorable efficiency category.

The reviewed approaches support a narrower problem than whether advanced costing is generally beneficial. They supply complementary ideas concerning resource models, operational information, and organizational coordination. Sonnenberg and vom Brocke propose a process accounting model using event records to connect process-aware and accounting information systems; they also identify a need for further evaluation in practical settings. [12] The synthesis developed here is a verifiable decision process built

on a common output basis, explicit resource commitments, and separate physical, capacity, and monetary outcomes. It integrates established ideas for practical evaluation rather than claiming to invent a new costing technique.

2. Methods

Research design and evidence selection

The study combines a targeted literature-based conceptual analysis with a deterministic numerical illustration. Eight publications were retained for their relevance to managerial costing, resource measurement, capacity analysis, organizational coordination, information integration, or evidence quality. The revised manuscript contains 22 page-specific citation notes, including repeated references to different arguments within the same works. Publisher texts, professional guidance, institutional copies, and author-posted manuscripts were consulted. Published pagination is used where available; the cited author-manuscript versions are identified explicitly in the source notes.

Source selection was purposive rather than exhaustive. Searches and source checks during preparation of this revision used combinations of cost accounting information, resource efficiency, material flow cost accounting, managerial costing, and process accounting, followed by title-specific retrieval. No systematic-review screening count, pooled effect estimate, or claim of complete coverage is made. Walz and Guenther identify publication and reporting limitations in case-study evidence; their discussion informs the caution applied here. [13] A source was used to support the proposition actually examined, not as proof that the proposed framework has already been validated.

The analytical procedure involved distinguishing the information inputs, managerial mechanisms, and outcomes addressed by the selected sources; identifying points where these categories could be confused; and deriving a common decision protocol. The numerical illustration was then constructed to test the accounting consistency of that protocol. Its input values are hypothetical assumptions. No enterprise records, interviews, surveys, or administrative datasets were collected, and no inferential statistical analysis was conducted.

Measurement boundary and analytical rules

The proposed application boundary is a specified production process observed over comparable reporting periods. IFAC emphasizes operational input–output relationships and fit-for-purpose managerial information. [14] In this study, output means units meeting an unchanged specification. Consumption is measured separately in kilograms, kilowatt-hours, and working hours. Material issues must be distinguished from purchases and adjusted for relevant inventory movements. Product types, quality requirements, process routes, and rework treatment remain identifiable. Missing readings are recorded as missing rather than converted to zero consumption.

For resource j , the output-adjusted reference requirement in period t is defined as:

$$Q(\text{ref}, j, t) = \sum_i [a(i, j, 0) \times y(i, t)] \quad (1)$$

Here, $a(i, j, 0)$ is the documented reference consumption of resource j per conforming unit of product i , and $y(i, t)$ is the actual conforming output of that product. The reference coefficient is held constant during the comparison. It is a benchmark, not proof of technical optimality. Separate coefficients are required where product specifications or production routes differ materially. Changes to the reference require version control and should not retrospectively erase an unfavorable deviation.

For resources valued at a comparable unit price, the difference between reference-valued requirements and actual resource cost is decomposed as:

$$\Delta C(j, t) = [Q(\text{ref}, j, t) - Q(\text{act}, j, t)] \times p(j, 0) + Q(\text{act}, j, t) \times [p(j, 0) - p(j, t)] \quad (2)$$

The first component values the resource-quantity difference at the reference price; the second captures the price difference at actual consumption. Positive values are favorable under this convention. Their sum reconciles exactly to reference cost minus actual cost. This identity is not a causal estimator. It does not establish why quantities changed, and it is not applied indiscriminately to committed salaries, depreciation, or other costs lacking the assumed quantity–price relationship.

For a committed time-based resource pool, a separate descriptive capacity rate is used:

$$k = \text{Committed resource-pool cost} / \text{Practical capacity hours} \quad (3)$$

Practical capacity is documented independently of actual utilization. Cokins discusses output-flexed comparisons and supply-based capacity denominators. [15] Equation (3) uses the stated practical capacity of this example as a descriptive convention, not a universal allocation rule. Multiplying the resulting rate by released hours values available capacity; it does not establish avoidable expenditure. Economic benefit is assessed separately from documented payment changes or incremental contribution, less implementation, recurring operation, and adverse-effect costs. A resource cannot generate two mutually incompatible benefits in the same period.

Internal consistency and interpretation

The illustration holds conforming output, product mix, input prices, quality, and practical capacity constant. Calculations compare the assumed baseline and intervention conditions and include a reduced-benefit sensitivity case. Formula results were checked for unit consistency and arithmetic reconciliation. These checks establish that the example behaves as specified; they do not validate the framework against actual operations. Application to an enterprise would additionally require source-document reconciliation, engineering review of the reference coefficients, and a design capable of distinguishing the intervention from concurrent changes.

3. Results and Discussion

A decision framework linking information to action

The first result is a proposed five-stage decision framework: resource-consumption data; cost accounting information; variance and loss analysis; managerial intervention; and outcome verification. Its physical-to-monetary sequence is consistent with the MFCA logic described by Schmidt and Nakajima. [16] Figure 1 organizes the article's own decision protocol, rather than depicting a validated causal model. Each stage requires distinct evidence: a reading supports a quantity, a justified reference supports a comparison, an authorization identifies responsibility, and subsequent operational and accounting records support an outcome claim.



Figure 1. Proposed cost-information-to-decision framework. Source: author's synthesis. The illustrated outcomes are evaluation categories, not guaranteed improvements; verification may establish a zero or negative economic effect.

The framework starts with the decision to be supported. For example, an investigation of excessive material consumption requires a product or batch identifier, measured input and output quantities, the applicable specification, and a classification of residual flows. An investigation of labor-time use additionally requires a distinction between processing, setup, rework, and available capacity. Collection is therefore limited to information capable of changing a specified decision. Table 1 summarizes the proposed core indicators without combining unlike resources into an arbitrary index.

Table 1. Proposed indicators and interpretation controls.

Indicator	Measurement basis	Interpretation control
Material intensity	kg consumed / conforming units	Compare consistent product specifications; adjust relevant inventory movements.
Energy intensity	kWh consumed / conforming units	Retain product mix, process conditions, and the treatment of shared energy loads.
Labor-time intensity	Productive hours / conforming units	Define included activities; separate released time from payroll changes.
Capacity utilization	Productive hours / practical hours × 100	Interpret with processing efficiency; unused capacity is not automatically waste.
Verified benefit	period Documented economic benefit less implementation and related costs	Use a stated period, evidence status, and a reconciliation excluding double counting.

Source: Author's proposed measurement specification. Physical indicators are assessed separately, not aggregated across incompatible units.

The proposed control rule is that a favorable result on one indicator does not automatically override an unfavorable result on another. Reduced material consumption accompanied by higher rework energy requires joint evaluation. A lower labor-hour

requirement with unchanged payroll is a capacity outcome. A lower purchase price with unchanged quantities is a procurement outcome. Separating these categories provides managers with a more precise explanation of what improved and what remains to be realized economically.

Responsibility must follow the ability to change the underlying cause. Nakajima, Kimura, and Wagner explain why some material losses require cooperation beyond production, including other internal functions or suppliers. [17] The proposed intervention record consequently separates the location where a loss is recognized from the authority required to address it. A process owner can be responsible for reliable measurement without possessing the authority to redesign a purchased input or alter a customer specification.

For example, a production department may record a material loss that originates in a purchasing specification or product design. Assigning the entire performance burden to that department would not establish an effective corrective mechanism. The proposed intervention record therefore identifies the process affected, the suspected cause, the responsible decision maker, the supporting evidence, the approved action, and the verification period. Cross-functional review is required where the cause and decision authority lie in different units. This is an implementation recommendation derived from the synthesis, not a description of an intervention already undertaken.

Hypothetical demonstration: efficiency and capacity can move differently

The second result is an internally reconciled illustration of the distinction between physical improvement and expenditure reduction. All values in Table 2 are deliberately hypothetical. Both conditions concern one monthly period with 10,000 conforming units of the same product and unchanged quality. Material consumption is assumed to fall from 6,500 to 6,200 kilograms, energy consumption from 12,000 to 11,000 kilowatt-hours, and required productive labor time from 2,000 to 1,900 hours. Monthly committed payroll and practical labor capacity are unchanged.

Table 2. Hypothetical monthly assumptions: no enterprise observations.

Measure (unit)	Reference	Intervention	Difference
Conforming output (units)	10,000	10,000	0
Material consumption (kg)	6,500	6,200	-300
Energy consumption (kWh)	12,000	11,000	-1,000
Productive labor time (hours)	2,000	1,900	-100
Committed payroll (c.u.)	10,000	10,000	0
Practical labor capacity (hours)	2,200	2,200	0

Source: Author-constructed assumptions. Difference = intervention minus reference. c.u. denotes hypothetical currency units; all quantities concern the same monthly output and quality.

At constant output, the assumed material intensity decreases from 0.650 to 0.620 kilograms per unit, a 4.62% reduction. Energy intensity decreases from 1.200 to 1.100 kilowatt-hours per unit, an 8.33% reduction. Productive labor time decreases from 0.200 to 0.190 hours per unit, a 5.00% reduction. These percentages describe only the constructed scenario. They are neither observed enterprise outcomes nor forecasts for a particular manufacturing industry.

Figure 2 presents each resource intensity as an index, with its own reference value equal to 100. The intervention indices are 95.38 for materials, 91.67 for energy, and 95.00 for labor time. These are independent within-resource comparisons, not components of a composite score. The chart also prints the original physical units. Decorative depth does not encode a third variable; the front-face heights, common zero baseline, and direct labels determine the comparison.

Assume a material price of 4.00 currency units per kilogram and a variable energy tariff of 0.12 currency units per kilowatt-hour, unchanged between conditions. Equation (2) then produces favorable quantity components of 1,200 and 120 currency units, respectively, with zero price components. The combined resource-cost reduction is 1,320 currency units. To interpret this amount as a cash-outflow reduction within the month requires the additional assumptions that purchases and payment timing adjust accordingly, inventories are unchanged, and no minimum-purchase or tariff commitment prevents the reduction.

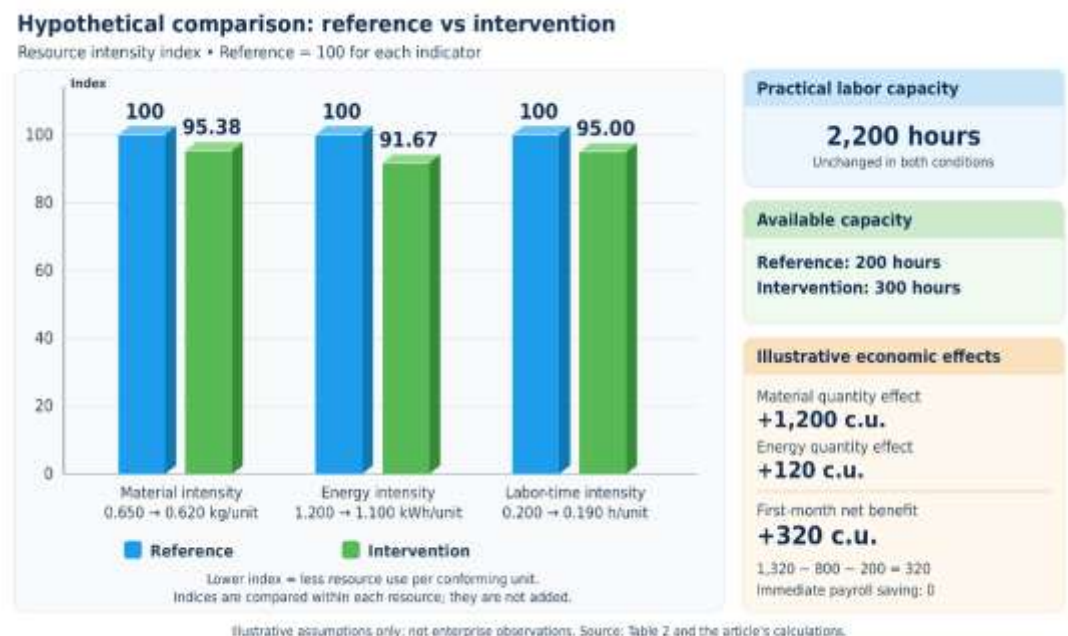


Figure 2. Hypothetical resource-intensity comparison and economic reconciliation.
Source: Table 2 and author calculations. Reference = 100 separately for each resource; original physical units are shown below the bars. All values are illustrative.

Labor illustrates a different result. The unchanged payroll of 10,000 currency units divided by 2,200 practical capacity hours gives a descriptive rate of approximately 4.545 currency units per hour. The 100 released hours therefore have an attributed capacity value of approximately 454.55 currency units, but payroll falls by zero. This distinction is consistent with the IMA framework's treatment of resource avoidability. [18] Adding 454.55 to the 1,320 resource-cost reduction as if both were immediate expenditure savings would overstate the monetary outcome.

Required productive time as a share of practical capacity falls from 90.91% to 86.36%, while labor hours per conforming unit improve. The available balance increases from 200 to 300 hours. Under the assumptions, lower capacity utilization is thus compatible with higher processing efficiency. The management question becomes whether the additional time can support profitable output, replace overtime, improve resilience, or justify a later adjustment to resource commitments. An unqualified objective of maximizing utilization would misread this improvement.

The first-month illustration also includes an assumed implementation outlay of 800 currency units and a recurring operating outlay of 200. Under the stated cash-conversion assumptions, the net first-month benefit is $1,320 - 800 - 200 = 320$ currency units. In a

sensitivity case where only half of both assumed consumption reductions is achieved, the gross benefit becomes 660 and the net result becomes -340. This sensitivity calculation shows that identifying resource differences is insufficient for determining the attractiveness of an intervention.

The first-month break-even realization is $1,000 / 1,320 = 75.76\%$ of the assumed gross benefit, provided both consumption effects scale proportionately and implementation and operating outlays remain unchanged. This is a calculated threshold within the illustration, not an estimated probability of success. Quality deterioration, additional maintenance, or delayed cash conversion would raise the effective threshold. A pilot should therefore record adverse effects and timing rather than approve an intervention solely because its unadjusted gross saving is positive.

Benefit verification and the strength of evidence

The third result is a proposed benefit-classification rule. An identified opportunity is recorded separately from an implemented action; an implemented action is distinguished from a measured resource change; and a measured change is distinguished from a verified economic benefit. This classification prevents estimated, implemented, and realized amounts from being aggregated into one savings figure. The relevant period and the assumptions governing each stage must accompany the amount reported.

The evidence warning in Walz and Guenther's case-study analysis supports separating reported improvements from substantiated effects: positive case descriptions and incomplete reporting do not establish a universally applicable performance effect. [19] The classification proposed here consequently distinguishes an opportunity, an approved action, a measured physical change, and a verified economic benefit. Each claim carries its period, measurement basis, responsible reviewer, and evidence status. The framework does not replace independent confirmation of the event being reported.

For enterprise use, benefit verification should begin with the same output and resource definitions used in the diagnosis. Finance should reconcile relevant resource-cost movements, while production and engineering should confirm the physical mechanism and any changes in quality or process conditions. A material saving requires a defensible link between lower consumption and the economic amount claimed. A labor benefit requires evidence of reduced payments, avoided additional expenditure, or realized incremental contribution from a documented alternative use of time.

Where several projects affect the same process, their benefits require a common reconciliation to prevent duplication. For instance, a reduction in rework might already be included in lower material and energy consumption; adding a separate, fully allocated rework-cost saving would count some resources again. Similarly, expenditure reduction through eliminating capacity and contribution gained by using that same capacity cannot both be claimed for the same hours. The proposed register records resource quantities and economic consequences separately before consolidating project benefits.

Verification should also consider adverse effects and boundary shifts. A saving within one department may be offset by inspection, maintenance, or handling costs elsewhere. Reduced in-process time may be accompanied by higher rejection rates or delayed deliveries. The proposed review therefore retains quality and service constraints and checks effects outside the immediate cost center. These safeguards define the evidence required for a credible claim; they do not imply that such adverse effects occurred in the hypothetical example.

Implementation proportionality and analytical propositions

Implementation should be proportionate to the decision problem. Cokins argues that movement toward more elaborate costing should be justified by the incremental value of its information relative to the additional effort required. [20] In the present proposal, the information system is itself an investment consuming staff time, measurement capacity,

and maintenance resources. A simpler controlled model is preferable when additional detail would not change the selected action or improve the credibility of benefit verification.

The proposed starting point is a bounded pilot covering one material process and a small number of recurring decisions. The pilot should establish whether quantities can be reconciled, whether deviations change managerial choices, and whether outcome verification is feasible. Only then should additional products, processes, or automated data interfaces be incorporated. Software selection follows the required data structure and control responsibilities; no particular enterprise system is necessary for the conceptual framework to function.

A practical minimum record contains a period and process identifier, product specification, resource quantity and unit, reference requirement, valuation basis, intervention identifier, decision owner, and verification status. Sonnenberg and vom Brocke's event-based integration provides a conceptual basis for relating operational events to accounting information. [21] The minimum record proposed here can be maintained in a controlled spreadsheet or an integrated system; neither implementation has been tested in this study. Access controls, documented corrections, and retained versions of assumptions are required so that later reviewers can reconstruct how each reported amount was calculated.

Three analytical propositions follow. First, cost information should be more likely to produce operational change when deviations are linked to a specific decision and an accountable decision maker. Second, the conversion of physical improvement into near-term expenditure reduction depends on the adjustability of the relevant resource commitment. Third, the decision value of additional costing detail should be assessed against both its collection cost and its capacity to alter the choice among feasible actions. These propositions remain untested and define an agenda for subsequent empirical investigation.

A future evaluation could compare similar production lines over several periods, recording both intervention timing and concurrent changes. Repeated observations would allow examination of whether changes persist and whether seasonal demand, maintenance, input quality, or product mix provide alternative explanations. Where a credible comparison group is available, a suitable quasi-experimental design could strengthen inference, subject to its assumptions. A simple before-and-after comparison should be described as descriptive evidence when those assumptions cannot be established.

Limitations and scope of application

The framework has three principal limitations. Its literature base is selective, and page references for two publications follow identified author-manuscript versions. Its quantitative component consists of assumptions rather than enterprise observations. Its managerial mechanism has not been evaluated through implementation. Consequently, neither an average effect size nor an industry-wide effectiveness claim can be supported. Numerical reconciliation establishes consistency of the example, not external validity, causal attribution, or the feasibility of changing an actual resource commitment.

Further adaptation is required for joint production, complex recycling loops, variable quality, and interdependent resources. Dierkes and Siepelmeyer show that material-based allocation can diverge from operational cost drivers and discuss alternatives and information costs. [22] The simple reference in Equation (1) may also be inadequate when batch size, routing, or nonlinear operating conditions dominate resource requirements. Monetary efficiency remains distinct from environmental performance: this illustration does not calculate emissions, water stress, or lifecycle effects, and those outcomes require their own indicators and boundaries.

4. Conclusion

Cost accounting information can support resource utilization decisions when it connects measured consumption with comparable output, identifies an actionable deviation, and enables verification of the consequences of the managerial response. The central implication of the proposed framework is that better visibility, lower physical consumption, released capacity, and monetary benefit must be distinguished throughout the decision process. Treating them as interchangeable would weaken both performance evaluation and investment appraisal.

The hypothetical demonstration clarifies why these distinctions matter. At constant output, lower labor-time requirements improve processing efficiency while reducing the share of available capacity used, and unchanged payroll generates no immediate labor expenditure saving. Material and energy improvements produce a monetary benefit only under explicit valuation and cash-conversion assumptions. Implementation and recurring costs can materially change the conclusion, as shown by the reduced-benefit scenario.

The article's contribution is therefore a transparent structure for evaluating the path from resource information to verified outcomes, rather than an empirically established savings estimate. Its practical recommendation is to begin with a bounded decision problem, preserve the distinction between quantities and monetary values, assign responsibility for action, and reconcile claimed benefits with operational and accounting evidence. Enterprise-level testing is required to determine the framework's usability, implementation cost, and performance consequences under actual manufacturing conditions.

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