INTEGRATION OF ACTIVITY-BASED COSTING AND MATERIAL FLOW COST ACCOUNTING TO REDUCE LOSSES AND IMPROVE RESOURCE ALLOCATION EFFICIENCY: AN APPLICATION IN THE PHARMACEUTICAL INDUSTRY

Farah Nadhim Shamkhi

Master's Degree in Accounting

Department of Financial and Banking Sciences,

College of Administration and Economics, Wasit University, Iraq

Abstract. The pharmaceutical industry is characterized by complex production processes, high-value materials, stringent quality requirements, and substantial resource consumption, making effective cost management and waste reduction essential for improving operational efficiency. Traditional cost accounting systems may not provide sufficient information to identify the activities responsible for resource consumption or to determine the costs associated with material losses. This study aims to develop an integrated framework combining Activity-Based Costing (ABC) and Material Flow Cost Accounting (MFCA) to reduce material losses and improve resource allocation efficiency in the pharmaceutical industry.

The study adopts an applied case study approach based on production, cost, and material-flow data from a pharmaceutical manufacturing environment. ABC is used to identify production activities, allocate resource costs, and determine activity-level costs, while MFCA is applied to quantify material inputs, positive outputs, negative outputs, and the costs associated with material losses. The two approaches are subsequently integrated to establish a relationship between resource consumption, production activities, material flows, material losses, and loss costs.

The results indicate that total material input amounted to 12,000 kg, of which 1,200 kg represented material losses, corresponding to a loss rate of 10%. The total cost of material losses was estimated at USD 21,100, with the production stage accounting for the largest share of material loss and associated costs. Under the proposed integrated approach, material losses decreased to 960 kg, while the associated loss cost decreased to USD 16,880. Resources allocated to non-value-adding activities decreased from USD 34,000 to USD 27,200, while resource allocation efficiency increased from 80% to 84%.

The findings indicate that integrating ABC and MFCA provides more comprehensive information for identifying loss-generating activities, measuring the economic consequences of material losses, and supporting more efficient resource allocation. The study contributes to cost management research by demonstrating the applicability of an integrated cost and material-flow approach to pharmaceutical manufacturing and provides a basis for reducing avoidable losses and improving resource utilization.

Keywords: Activity-Based Costing; Material Flow Cost Accounting; Material Losses; Waste Reduction; Resource Allocation Efficiency; Cost Management; Pharmaceutical Industry.

JEL Classification: M41; M11; D24; Q53

ИНТЕГРАЦИЯ КАЛЬКУЛИРОВАНИЯ ЗАТРАТ ПО ВИДАМ ДЕЯТЕЛЬНОСТИ И УЧЁТА ЗАТРАТ ПО МАТЕРИАЛЬНЫМ ПОТОКАМ ДЛЯ СОКРАЩЕНИЯ ПОТЕРЬ И ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ РАСПРЕДЕЛЕНИЯ РЕСУРСОВ (НА ПРИМЕРЕ ФАРМАЦЕВТИЧЕСКОЙ ПРОМЫШЛЕННОСТИ)

Фарах Надхим Шамхи

магистр по направлению «Бухгалтерский учёт»

Кафедра финансовых и банковских наук,

Колледж управления и экономики, Университет Васит, Ирак

Аннотация. Фармацевтическая промышленность характеризуется сложными производственными процессами, использованием дорогостоящих

материалов, строгими требованиями к качеству и значительным потреблением ресурсов, что делает эффективное управление затратами и сокращение отходов необходимыми условиями повышения операционной эффективности. Традиционные системы учёта затрат могут не предоставлять достаточной информации для выявления видов деятельности, ответственных за потребление ресурсов, или для определения затрат, связанных с потерями материалов. Цель данного исследования заключается в разработке интегрированной модели, объединяющей калькулирование затрат по видам деятельности (Activity-Based Costing, ABC) и учёт затрат по материальным потокам (Material Flow Cost Accounting, MFCA), с целью сокращения материальных потерь и повышения эффективности распределения ресурсов в фармацевтической промышленности.

В исследовании используется прикладной подход на основе анализа конкретного случая с использованием производственных данных, данных о затратах и материальных потоках в условиях фармацевтического производства. ABC применяется для выявления производственных видов деятельности, распределения затрат ресурсов и определения затрат на уровне отдельных видов деятельности, тогда как MFCA используется для количественной оценки материальных входов, положительных выходов, отрицательных выходов и затрат, связанных с материальными потерями. Впоследствии оба подхода интегрируются для установления взаимосвязи между потреблением ресурсов, производственными видами деятельности, материальными потоками, материальными потерями и затратами, связанными с этими потерями.

Результаты показывают, что общий объём материальных ресурсов на входе составил 12 000 кг, из которых 1 200 кг приходилось на материальные потери, что соответствует уровню потерь в 10%. Общая стоимость материальных потерь была оценена в 21 100 долл. США, при этом на производственную стадию приходилась наибольшая доля материальных потерь и связанных с ними затрат. При использовании предлагаемого интегрированного подхода материальные потери снизились до 960 кг, а связанные с ними затраты — до 16 880 долл. США. Объём ресурсов, направленных на виды деятельности, не создающие добавленной стоимости, сократился с 34 000 до 27 200 долл. США, тогда как эффективность распределения ресурсов увеличилась с 80% до 84%.

Полученные результаты показывают, что интеграция ABC и MFCA предоставляет более комплексную информацию для выявления видов деятельности, приводящих к возникновению потерь, оценки экономических последствий материальных потерь и поддержки более эффективного распределения ресурсов. Исследование вносит вклад в развитие исследований в области управления затратами, демонстрируя применимость интегрированного подхода к затратам и материальным потокам в фармацевтическом производстве, а также формирует основу для сокращения предотвратимых потерь и повышения эффективности использования ресурсов.

Ключевые слова: калькулирование затрат по видам деятельности; учёт затрат по материальным потокам; материальные потери; сокращение отходов; эффективность распределения ресурсов; управление затратами; фармацевтическая промышленность.

Классификация JEL: M41; M11; D24; Q53.

1. Introduction

The pharmaceutical industry is characterized by complex production processes, high-value raw materials, strict quality requirements, and substantial resource consumption. These characteristics increase the importance of effective cost management, waste reduction, and efficient resource allocation. Recent studies emphasize the need for accounting systems that provide more detailed information about resource consumption and production losses (Usul & Olgun, 2025).

Activity-Based Costing (ABC) provides a useful approach for assigning resource costs to activities and subsequently allocating activity costs to products based on appropriate cost drivers. This approach can improve the accuracy of cost information and support managerial decisions concerning resource utilization and cost reduction (Wang & Simarmata, 2024).

However, ABC primarily focuses on the cost of activities and may not provide sufficient information about the physical flow of materials and the costs associated with material losses. Material Flow Cost Accounting (MFCA) addresses this issue by tracing material flows through production processes and identifying the quantities and costs of positive and negative outputs. Recent research indicates that MFCA can improve transparency regarding material losses and support more efficient resource utilization (Al-Eqabi, 2024; Dierkes & Siepelmeyer, 2025).

Furthermore, recent evidence indicates that MFCA can contribute to reducing product costs, improving waste management, and identifying opportunities for resource efficiency (Cavalcante et al., 2025; Usul & Olgun, 2025). In the Iraqi industrial context, studies have also demonstrated the applicability of MFCA in identifying material losses and improving cost and resource management (Al-Eqabi, 2024). Of particular relevance to the present study, Mohammed Ali (2025) applied MFCA in the pharmaceutical industry and highlighted its potential role in supporting more sustainable production and improving material-flow management.

Despite these developments, there remains a need for an integrated approach that connects activity costs, resource consumption, material flows, and losses within a single analytical framework. Integrating ABC with MFCA may provide more comprehensive information about the activities responsible for excessive resource consumption and the costs associated with material losses. Such information can support management in identifying inefficient activities, reducing avoidable losses, and reallocating resources toward value-adding activities (Dierkes & Siepelmeyer, 2025; Usul & Olgun, 2025).

Accordingly, this study examines the integration of Activity-Based Costing and Material Flow Cost Accounting to reduce losses and improve resource allocation efficiency in the pharmaceutical industry. The study aims to provide an integrated accounting approach that links resources, activities, material flows, losses, and costs, thereby supporting more effective managerial decisions and improving the efficiency of resource utilization.

1.1 Significance of the Study:

The significance of this study lies in addressing the need for more comprehensive cost information in pharmaceutical manufacturing, particularly where production processes involve multiple activities and material flows. Integrating Activity-Based Costing with Material Flow Cost Accounting provides a broader perspective for analyzing production costs and material losses.

From a theoretical perspective, the study contributes to cost accounting research by bringing together activity-based cost information and material-flow information within a single framework. This integration extends the analysis beyond conventional cost measurement to consider the relationship between activities, resources, material flows, and losses.

From a practical perspective, the proposed approach can help management identify the stages of production where material losses and resource consumption are concentrated. Such information can support the evaluation of production processes and the identification of opportunities for operational improvement.

The study also has managerial significance, as the information generated by the integrated approach can support decisions concerning production planning, cost control, process improvement, and the allocation of available resources.

Finally, the study provides an applied contribution to the pharmaceutical industry by examining the feasibility of using an integrated accounting approach within a manufacturing environment characterized by complex production processes and stringent quality requirements.

1.2 Statement of the Problem

Pharmaceutical manufacturing involves multiple production activities, diverse material inputs, and strict quality requirements, which can make it difficult to accurately determine how resources are consumed and where material losses occur. Traditional cost accounting practices may aggregate costs at a level that does not clearly identify the activities responsible for excessive resource consumption or the costs associated with material losses.

Although Activity-Based Costing can provide more detailed information about the cost of production activities, it does not by itself provide sufficient information about the physical movement of materials and the losses generated throughout the production process. Conversely, material flow management techniques can identify material movements and losses but may not adequately link these losses to the costs of specific activities.

This creates a need for an integrated approach that connects activity costs with material flows and losses. Accordingly, the problem addressed by this study is the extent to which integrating Activity-Based Costing with Material Flow Cost Accounting can improve the identification and measurement of losses and provide more useful information for improving resource allocation efficiency in the pharmaceutical industry.

1.3 Measurable Research Gap

Previous studies have generally examined Activity-Based Costing and Material Flow Cost Accounting as separate approaches. Activity-Based Costing focuses primarily on assigning resource costs to activities, while Material Flow Cost Accounting focuses on tracing material flows and identifying material losses. However, limited attention has been given to quantitatively integrating activity-level cost information with material-flow losses to determine the cost of losses attributable to specific production activities.

Accordingly, the measurable research gap addressed by this study is the absence of an integrated measurement framework that simultaneously determines:

1. The cost of individual production activities using Activity-Based Costing.
2. The quantity and cost of material losses at each production stage using material flow analysis.
3. The activity-level cost of material losses by linking losses to the activities in which they occur.
4. The proportion of total resources consumed by non-value-adding activities and material losses.
5. The potential improvement in resource allocation efficiency resulting from reallocating resources from inefficient activities toward value-adding activities.

The study therefore seeks to measure the difference between the existing allocation of resources and the allocation proposed after identifying activity-level losses. This allows the research gap to be examined quantitatively through indicators such as loss quantity, loss cost, activity cost, resource utilization, and resource allocation efficiency.

The main contribution of the study is consequently not merely the application of Activity-Based Costing or material flow management separately, but the development of an integrated measurement approach that connects activities → resource consumption → material flows → losses → loss costs → resource allocation within the pharmaceutical manufacturing process.

1.4 Research Questions

The study seeks to answer the following main research question:

How can the integration of Activity-Based Costing and Material Flow Cost Accounting reduce material losses and improve resource allocation efficiency in the pharmaceutical industry?

This main question is addressed through the following sub-questions:

1. What are the major production activities and resources consumed in the pharmaceutical manufacturing process?

2. What are the quantities and costs of material losses generated at each production stage?
3. Which activities are associated with the highest levels of resource consumption and material losses?
4. How can Activity-Based Costing and material flow information be integrated to measure activity-level loss costs?
5. To what extent can the integrated approach improve resource allocation efficiency?
6. What changes in resource allocation can be identified after measuring activity-level losses?

2. Literature Review

2.1 Activity-Based Costing

2.1 Activity-Based Costing

Activity-Based Costing (ABC) is a management accounting approach that provides detailed information on the relationship between resources, activities, and cost objects. Rather than allocating indirect costs using broad volume-based measures, ABC identifies the activities that consume resources and assigns costs according to the extent to which products or other cost objects use those activities. This approach can improve cost transparency and provide more relevant information for managerial decision-making and resource allocation (Wang & Simarmata, 2024).

Recent research has continued to demonstrate the relevance of ABC in complex manufacturing environments. Wang and Simarmata (2024) developed a fuzzy activity-based costing framework that identifies and allocates resource and activity costs under conditions of uncertainty, demonstrating the potential of activity-based approaches to improve the accuracy and usefulness of cost information. Similarly, Rajan and Pillai (2025) found that ABC can improve the allocation of overhead costs by linking indirect expenditures to the resources consumed by individual activities.

The application of ABC is particularly relevant to pharmaceutical manufacturing because production processes involve multiple activities with different resource requirements and cost characteristics. Muoneke and Dandago (2024), in their study of the Nigerian pharmaceutical industry, emphasized the usefulness of ABC for improving production cost management, reducing cost distortion, and supporting more informed production and pricing decisions. In the Iraqi pharmaceutical context, Abd et al. (2024) examined Performance-Focused Activity-Based Costing (PFABC) in the State Company for Drugs Industry and Medical Appliances–Samarra and reported its relevance to cost reduction and product-quality improvement.

Accordingly, ABC provides the cost dimension of the present study by identifying production activities, determining the resources consumed by each activity, and assigning the corresponding costs to production activities. This information is subsequently linked with material-flow information to identify the economic consequences of material losses.

2.2 Material Flow Cost Accounting

Material Flow Cost Accounting (MFCA) is an environmental management accounting approach that examines the physical and monetary dimensions of material flows within production processes. Its central purpose is to make material consumption, material losses, and the associated costs more visible by tracing materials through different stages of production.

Recent studies have emphasized the ability of MFCA to quantify both material flows and the costs associated with waste and losses. Usul and Olgun (2025) describe MFCA as an approach that tracks production waste in both quantitative and monetary terms and demonstrate that it can reveal the costs associated with material losses under different cost accounting systems. Similarly, Dierkes and Siepelmeyer (2025) developed an MFCA framework that differentiates among various sources of inefficiency, including waste, rejects, rework, and recycling, thereby providing more detailed information about their economic consequences.

Empirical evidence also supports the role of MFCA in improving resource efficiency and reducing waste. Ahmed et al. (2024) applied MFCA in a corrugated-packaging manufacturing enterprise and demonstrated its usefulness in identifying negative costs and areas of inefficient resource utilization. Kurniawan et al. (2024) likewise showed that MFCA can increase transparency regarding material use and support resource-saving and waste-reduction scenarios.

The relevance of MFCA is also evident in the Iraqi industrial environment. Al-Eqabi (2024), through an applied study in a Wasit weaving and knitting factory, found that MFCA can provide information useful for waste management, cost reduction, productivity improvement, and product sustainability. Dahi and Abdullah (2024) further reported that MFCA can contribute to green productivity by reducing material and energy consumption and improving production-related outcomes.

Within the present study, MFCA provides the physical-flow dimension by measuring material inputs, positive outputs, negative outputs, and material losses at different stages of pharmaceutical production. The resulting information is then connected to activity-level costs obtained through ABC.

2.3 Material Losses and Waste Costs

Material losses represent an important source of production inefficiency because they involve resources that are consumed without generating an equivalent level of productive output. In manufacturing environments, losses may arise from processing activities, quality problems, equipment operation, material handling, packaging, rejected production, rework, or other operational conditions. Recent MFCA research emphasizes the importance of measuring such losses not only in physical quantities but also in monetary terms.

Dierkes and Siepelmeyer (2025) demonstrate that material inefficiencies may arise from several sources, including waste, rejects, reworking, and recycling, and argue that differentiated information about these factors can improve the analysis of their economic consequences. Similarly, Usul and Olgun (2025) show that MFCA can identify the costs associated with material losses and provide information that extends beyond conventional cost accounting.

The economic significance of material losses is also demonstrated by Ahmed et al. (2024), whose application of MFCA in the corrugated-packaging industry identified substantial negative costs associated with material, system, energy, and waste-management factors. Their findings indicate that identifying the sources of negative costs can provide a basis for reducing waste and improving resource utilization.

In the Iraqi industrial context, Al-Eqabi (2024) found that the information generated by MFCA can support waste management, cost reduction, and improvements in production and product sustainability. Dahi and Abdullah (2024) similarly emphasized that reducing material and energy consumption through MFCA can contribute to lower production costs and improved productivity.

For pharmaceutical manufacturing, the economic measurement of material losses is particularly relevant because losses may involve not only the direct cost of raw materials but also labor, machinery, energy, quality-control activities, packaging, and other production resources. Therefore, measuring material losses solely in physical units may not fully reflect their economic significance. The present study addresses this issue by linking material losses to the production activities in which they occur and by determining the corresponding activity-level loss costs.

2.4 Resource Allocation Efficiency

Resource allocation efficiency refers to the extent to which available production resources are directed toward activities that contribute to productive output while minimizing unnecessary or non-value-adding consumption. In manufacturing organizations, such resources may include raw materials, direct labor, machinery, energy, production capacity, quality-control resources, and packaging materials.

ABC provides information that can support resource allocation by identifying the activities that consume resources and measuring the costs associated with those activities. Wang and Simarmata (2024) demonstrated that activity-based costing can be used to identify and allocate resource and activity costs within complex production environments. Rajan and Pillai (2025) similarly emphasized the role of ABC in improving the allocation of overhead costs by linking indirect costs with the activities that generate resource consumption.

MFCA provides a complementary perspective by identifying the physical use of materials and the losses generated during production. Dahi and Abdullah (2024) found that MFCA can support green productivity through reductions in material and energy consumption. Kurniawan et al. (2024) likewise demonstrated that MFCA can improve transparency regarding resource utilization and support scenarios for resource saving and waste reduction.

The combination of these perspectives provides a broader basis for evaluating resource allocation efficiency. ABC identifies where financial resources are consumed, while MFCA identifies where material resources are consumed and lost. When these two types of information are analyzed together, management can identify activities that consume substantial resources while generating relatively low productive output.

In the pharmaceutical industry, this approach is particularly relevant because production activities are often interdependent and subject to stringent quality requirements. The findings of Muoneke and Dandago (2024) and Abd et al. (2024) further demonstrate the relevance of activity-based approaches to cost management and production performance in pharmaceutical manufacturing.

Accordingly, the present study evaluates resource allocation efficiency by examining the relationship between resources consumed by production activities, material losses, loss costs, and the proportion of resources directed toward value-adding activities.

2.5 Integration of ABC and MFCA

Activity-Based Costing and Material Flow Cost Accounting provide complementary information for analyzing production performance. ABC focuses primarily on the cost of activities and the resources consumed by those activities, whereas MFCA focuses on the physical movement of materials and the losses generated during production. The integration of these perspectives can therefore provide a more comprehensive basis for identifying production inefficiencies and evaluating their economic consequences.

Recent research provides evidence supporting the usefulness of each approach independently. Wang and Simarmata (2024) demonstrate that activity-based costing can provide detailed information for identifying and allocating resource and activity costs, while Usul and Olgun (2025) demonstrate that MFCA can quantify material losses and their associated costs within different cost accounting environments. Dierkes and Siepelmeyer (2025) further show that MFCA can provide differentiated information about various forms of material inefficiency, including waste, rejects, rework, and recycling.

The integration of ABC and MFCA is particularly relevant when material losses generate costs beyond the direct value of the materials lost. A material loss may also involve labor time, machine usage, energy consumption, quality-control activities, packaging resources, and other activity-related costs. ABC can identify the activities responsible for these resource costs, while MFCA can identify the material losses occurring within the production flow. Consequently, their integration can establish a relationship between resource consumption, production activities, material flows, material losses, and loss costs.

The practical relevance of this integrated perspective is also supported by recent studies conducted in industrial and pharmaceutical contexts. Al-Eqabi (2024) and Dahi and Abdullah (2024) demonstrate the usefulness of MFCA for improving resource efficiency and reducing waste, while Muoneke and Dandago (2024) and Abd et al. (2024) demonstrate the relevance of activity-based approaches to pharmaceutical cost management and production performance. Most importantly for the Iraqi pharmaceutical context, Mohammed Ali (2025) applied MFCA to the General Company for the Manufacture of Medicines and Medical Supplies–Samarra and demonstrated its relevance to material-loss analysis and green supply-chain management.

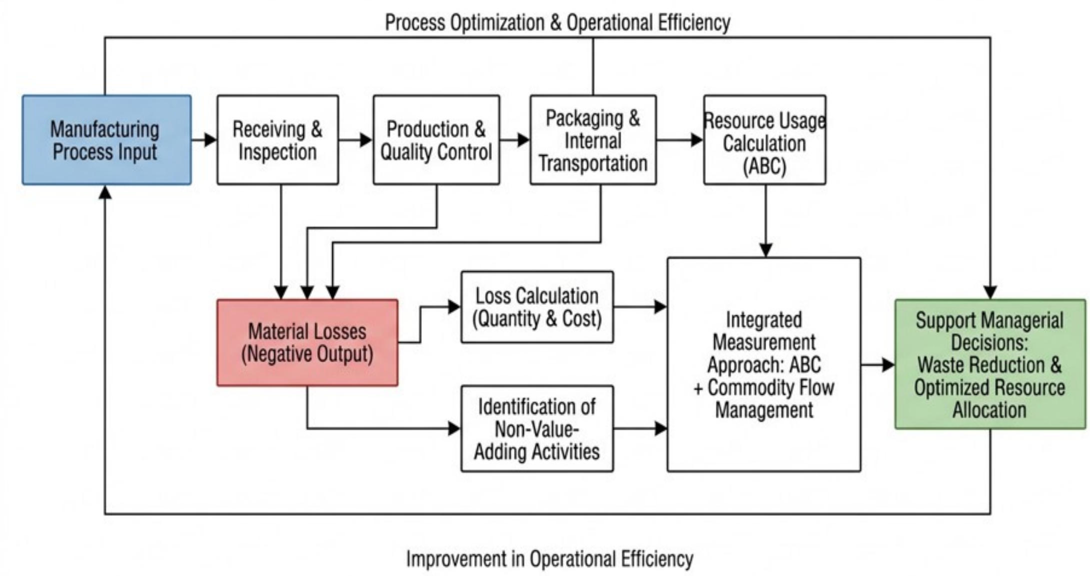
Despite these developments, the reviewed studies primarily examine ABC and MFCA independently rather than establishing a quantitative framework that directly links activity-level costs with material losses and resource allocation efficiency. The present study addresses this issue by integrating the two approaches within a single analytical framework.

The proposed relationship can be represented as follows:

Resources → Activities → Activity Costs → Material Flows → Material Losses → Loss Costs → Resource Reallocation

Under this approach, the analysis does not stop at identifying the quantity of material loss. It also determines the activities associated with the loss and the resources consumed in generating it. This provides management with more detailed information for evaluating production processes and considering alternative resource allocation decisions.

Figure 1: Conceptual Framework for the Integration of ABC and MFCA



Source: Developed by the author based on Al-Eqabi (2024); Dierkes & Siepelmeyer (2025); Mohammed Ali (2025); Usul & Olgun (2025); and Wang & Simarmata (2024).

2.6 Previous Studies

Under this approach, the analysis does not stop at identifying the quantity of material loss. It also determines the activities associated with the loss and the resources consumed in generating it. This provides management with more detailed information for evaluating production processes and considering alternative resource allocation decisions.

Previous studies have examined Activity-Based Costing (ABC) and Material Flow Cost Accounting (MFCA) as tools for improving cost measurement and resource efficiency. Wang and Simarmata (2024) demonstrated the usefulness of ABC in improving resource cost allocation, while Dierkes and Siepelmeyer (2025) showed that MFCA can identify material losses and their associated costs. Usul and Olgun (2025) further examined MFCA under different cost accounting systems and highlighted its role in identifying waste-related costs. In the pharmaceutical industry, Mohammed Ali (2025) applied MFCA to a pharmaceutical company in Samarra, Iraq, focusing on material losses and green supply-chain management.

Table 1. Comparison of Previous Studies and the Current Study

Study	Method	Context	Main Focus	Difference from Current Study
Wang & Simarmata (2024)	ABC	Manufacturing	Resource cost allocation	Does not address material losses
Dierkes & Siepelmeyer (2025)	MFCA	Manufacturing	Waste and material losses	Does not integrate ABC
Usul & Olgun (2025)	MFCA	Manufacturing	Waste costs	Does not focus on pharmaceutical production
Mohammed Ali (2025)	MFCA	Pharmaceutical industry–Iraq	Material losses and green supply chain	Does not integrate ABC
Current Study	**ABC + MFCA**	**Pharmaceutical industry**	**Loss costs and resource allocation efficiency**	**Integrates activity costs with material flows and losses**

Overall, previous studies have mainly applied ABC or MFCA separately. The current study differs by integrating both approaches to link production activities, resource consumption, material losses, and their costs, thereby providing information to support more efficient resource allocation in pharmaceutical manufacturing.

2.7 Research Gap

The review of previous studies indicates that Activity-Based Costing (ABC) and Material Flow Cost Accounting (MFCA) have mainly been applied as separate approaches. ABC provides information on resource consumption and activity costs, whereas MFCA focuses on material flows, losses, and their associated costs.

However, limited attention has been given to integrating these two approaches within a single framework, particularly in the pharmaceutical industry. Existing studies also provide limited measurement of the costs of material losses at the activity level and their relationship with resource allocation efficiency.

Therefore, the current study addresses this gap by integrating ABC with MFCA to identify material losses, determine their associated activity costs, and assess opportunities for improving resource allocation efficiency in pharmaceutical manufacturing.

3. Research Methodology

3.1 Research Design

This study adopts an applied case study design to examine the integration of Activity-Based Costing (ABC) and Material Flow Cost Accounting (MFCA) in the pharmaceutical industry. The study combines quantitative cost and material-flow data to identify material losses, determine their associated costs, and assess resource allocation efficiency.

3.2 Case Study and Data Sources

The study is conducted in a pharmaceutical manufacturing environment. Data are collected from accounting records, production reports, material consumption records, inventory records, quality-control reports, and other relevant operational documents. The data include material quantities and costs, labor, machine hours, energy consumption, production quantities, and material losses.

3.3 Identification of Production Activities

The main production activities are identified by examining the production process and the resources consumed at each stage. These activities may include material receiving, inspection, storage, production, quality control, packaging, and internal transportation.

3.4 ABC Cost Allocation Procedure

ABC is used to determine the cost of production activities based on the resources consumed by each activity. Appropriate cost drivers are identified for each activity, and activity cost-driver rates are calculated. The costs assigned to products are then determined according to their consumption of the relevant activities.

The basic calculation is:

Cost Driver Rate = Total Activity Cost ÷ Total Cost Driver Quantity

3.5 Material Flow Measurement

MFCA is used to trace the physical movement of materials through the production process. For each production stage, material inputs are compared with positive outputs and negative outputs. Negative outputs include waste, rejects, defects, and other material losses.

3.6 Measurement of Loss Costs

The cost of material losses is determined by combining the quantity of losses with their relevant material and process costs. The analysis also links these losses to the activities where they occur, allowing the study to identify the activities associated with the highest loss costs.

3.7 Integrated ABC–MFCA Model

The proposed model integrates the cost information generated by ABC with the physical-flow information generated by MFCA. The relationship can be represented as:

Resources → Activities → Activity Costs → Material Flows → Material Losses → Loss Costs → Resource Allocation

This integration enables the study to identify not only the quantity of material losses but also the activities and resources associated with those losses.

3.8 Resource Allocation Efficiency Measurement

Resource allocation efficiency is assessed by examining the proportion of resources consumed by value-adding and non-value-adding activities. The study compares the existing allocation of resources with the allocation proposed after identifying significant losses and inefficient activities.

A proposed indicator is:

Resource Allocation Efficiency = Resources Used in Value-Adding Activities ÷ Total Resources Used × 100

This indicator is used as an analytical measure within the study rather than as a universally established accounting standard.

3.9 Data Analysis and Scenario Comparison

The analysis compares the existing cost and resource allocation system with the proposed integrated ABC–MFCA approach. The comparison focuses on activity costs, material-loss quantities, loss costs, resource utilization, and resource allocation efficiency.

Two main scenarios are considered:

- **Current Scenario:** Existing cost and resource allocation practices.
- **Proposed Scenario:** Allocation based on the information generated by the integrated ABC–MFCA approach.

The results are used to identify potential opportunities for reducing material losses and improving resource allocation efficiency.

4. Results and Analysis

4.1 Production and Cost Data

The analysis is based on the production and cost data presented in Table 2. The data include production quantities, material consumption, labor, machinery, energy, quality control, packaging, and other production costs.

Table 2. Production and Cost Data

Item	**Value**
Production batches	20 batches
Planned production	200,000 units
Actual good output	188,000 units
Material input	12,000 kg
Material cost	$96,000
Direct labor cost	$42,000
Machine cost	$28,000
Energy cost	$14,000
Quality-control cost	$10,000
Packaging cost	$18,000
Other production costs	$12,000
Total production costs	**$220,000**

Interpretation: Table 2 presents the main production and cost data used in the analysis. Total production costs amount to **$220,000**.

For the ABC analysis, **$170,000** of the total production costs are allocated to the selected activity-cost pools presented in Table 3. The remaining **$50,000** are treated as common and unallocated production costs that are not assigned through the selected activity cost drivers. Accordingly, the subsequent ABC-based analysis and resource allocation calculations are based on the **$170,000 activity-cost pool**, while the total production cost remains **$220,000**.

The difference between planned production and actual good output indicates the presence of losses and non-conforming output, which are further analyzed using MFCA and linked to activity costs through ABC.

4.2 Activity Costs under ABC

Table 3. Costs Allocated to the Selected ABC Activity Pools

Activity	**Activity Cost ($)**	**Cost Driver**	**Driver Quantity**
Material receiving	8,000	Shipments	40
Material inspection	12,000	Tests	200
Storage	10,000	Storage-days	1,000
Production	82,000	Machine hours	4,000
Quality control	20,000	Tests/batches	300
Packaging	28,000	Units	200,000
Internal transportation	10,000	Material movements	500
Total costs allocated to selected ABC activity pools	**170,000**	—	—
Common and unallocated production costs	**50,000**	—	—
Total production costs	**220,000**	—	—

Note. Total production costs amount to $220,000, as reported in Table 2. For the purposes of the ABC analysis, $170,000 is allocated to the selected activity-cost pools shown above. The remaining $50,000 is treated in this study as common and unallocated production costs that are not assigned through the selected activity cost drivers. Accordingly, subsequent ABC-based resource-allocation calculations are based on the $170,000 activity-cost pool.

Interpretation: Table 3 shows the costs assigned to the main production activities. Production represents the largest activity cost, followed by packaging and quality control. This information provides a basis for identifying activities with relatively high resource consumption.

The reconciliation presented in Table 3 explains the difference between the total production costs of $220,000 reported in Table 2 and the $170,000 allocated through the selected ABC activity-cost pools. The remaining $50,000 is retained outside the activity-cost allocation base used in the subsequent ABC analysis.

4.3 Material Flow Analysis

Table 4. Material Flow Analysis

Production Stage	Input (kg)	Positive Output (kg)	Negative Output (kg)	Loss Rate
Material preparation	12,000	11,700	300	2.50%
Production	11,700	11,150	550	4.70%
Quality control	11,150	10,950	200	1.79%
Packaging	10,950	10,800	150	1.37%
Total	**12,000**	**10,800**	**1,200**	**10.00%**

Interpretation: Table 4 traces the movement of materials through the main production stages. Total material losses amount to 1,200 kg, representing 10% of total material input. The production stage records the highest quantity of material loss.

4.4 Measurement of Material Loss Costs

Table 5. Material Loss Costs by Production Stage

Production Stage	Loss (kg)	Material Cost ($)	Process Cost ($)	Total Loss Cost ($)
Material preparation	300	2,400	1,000	3,400
Production	550	4,400	7,000	11,400
Quality control	200	1,600	2,000	3,600
Packaging	150	1,200	1,500	2,700
Total	**1,200**	**9,600**	**11,500**	**21,100**

Interpretation: Table 5 converts material losses into monetary values. The total cost of material losses is $21,100. The production stage accounts for the largest share of loss costs, with $11,400, indicating that this stage requires particular attention in the resource improvement process.

4.5 Integration of ABC and MFCA

Table 6. Integrated ABC–MFCA Analysis Based on the Selected ABC Activity-Cost Pool

Activity	Activity Cost ($)	Loss Cost ($)	Loss Cost / Activity Cost
Material receiving	8,000	1,200	15.0%
Material inspection	12,000	2,000	16.7%
Storage	10,000	200	2.0%
Production	82,000	11,400	13.9%

Activity	Activity Cost ($)	Loss Cost ($)	Loss Cost / Activity Cost
Quality control	20,000	3,600	18.0%
Packaging	28,000	2,700	9.6%
Internal transportation	10,000	0	0.0%
Total	**170,000**	**21,100**	**12.4%**

Note. The activity-cost total of $170,000 corresponds to the selected ABC activity-cost pool identified in Table 3. The remaining $50,000 of total production costs is treated as common and unallocated production costs and is therefore excluded from the activity-level loss-cost ratios presented in this table.

Interpretation: Table 6 demonstrates the integration of activity cost information with material-loss information. Although production has the highest absolute activity cost, quality control records the highest ratio of loss cost to activity cost at 18%. This integration provides more detailed information than analyzing activity costs or material losses separately. The ratios are calculated using only the selected ABC activity-cost pool of $170,000.

4.6 Comparison of Current and Proposed Resource Allocation

Table 7. Comparison of Current and Proposed Scenarios

Indicator	Current Scenario	Proposed Scenario	Change
Material input (kg)	12,000	12,000	—
Material loss (kg)	1,200	960	−240 kg
Loss rate	10.0%	8.0%	−2.0 pp
Loss cost ($)	21,100	16,880	−$4,220
Resources in non-value-adding activities ($)	34,000	27,200	−$6,800
Resource allocation efficiency	80.0%	84.0%	+4.0 pp

Note. Resource allocation efficiency is calculated using the $170,000 selected ABC activity-cost pool as the denominator. The $50,000 of common and unallocated production costs is excluded from this study-specific efficiency measure.

Interpretation: Table 7 compares the current allocation of resources with the proposed allocation based on the integrated ABC–MFCA approach. The results indicate a reduction in material losses and loss costs, together with an improvement in resource allocation efficiency within the selected ABC activity-cost pool. Material losses decrease from 1,200 kg to 960 kg, while the loss cost decreases from $21,100 to $16,880. Resource allocation efficiency increases from 80.0% to 84.0%, based on the $170,000 activity-cost pool used in the ABC analysis.

4.7 Summary of Results

Table 8. Summary of Results

Measure	Current	Proposed	Change
Material loss	1,200 kg	960 kg	-240 kg
Loss cost	$21,100	$16,880	-$4,220
Non-value-adding resources	$34,000	$27,200	-$6,800
Resource allocation efficiency	80.0%	84.0%	+4.0 pp

Note. The resource allocation efficiency values are calculated relative to the $170,000 selected ABC activity-cost pool and do not use the total production cost of $220,000 as the denominator.

Interpretation: Table 8 summarizes the main results of the analysis. The integrated ABC–MFCA approach provides information that links production activities, resource consumption, material flows, and material losses. The results indicate that identifying activity-level loss costs can provide a basis for reducing avoidable losses and improving resource allocation efficiency.

5. Conclusions and Recommendations

5.1 Conclusions

This study examined the integration of Activity-Based Costing (ABC) and Material Flow Cost Accounting (MFCA) as an approach for reducing material losses and improving resource allocation efficiency in the pharmaceutical industry.

The findings indicate that ABC provides detailed information about the costs of individual production activities and the resources consumed by those activities. The analysis showed differences in resource consumption across production activities, with production, packaging, and quality control representing major areas of resource consumption. This information provides management with a clearer understanding of where production resources are being consumed.

The MFCA analysis identified material losses at different stages of the production process. Total material losses amounted to 1,200 kg from a total material input of 12,000 kg, representing a loss rate of 10%. The production stage recorded the largest material loss, indicating that this stage requires particular attention when evaluating production efficiency and opportunities for loss reduction.

The analysis also demonstrated that material losses generate costs beyond the direct cost of the lost materials. The total cost associated with material losses reached $21,100, including material and process-related costs. This confirms the importance of considering both physical material losses and their economic consequences when evaluating production efficiency.

The integration of ABC and MFCA provided a more comprehensive view of production costs and material losses. ABC identified the activities responsible for resource consumption, while MFCA identified material flows and losses. Combining the two approaches allowed activity-level information to be connected with material losses and their associated costs.

The comparison between the current and proposed resource allocation scenarios indicated that material losses could be reduced from 1,200 kg to 960 kg, while material loss costs could decrease from $21,100 to $16,880. Non-value-adding resource consumption was also reduced from $34,000 to $27,200. Based on the defined resource allocation efficiency measure and the selected ABC activity-cost pool of $170,000, efficiency increased from 80.0% to 84.0%.

The remaining $50,000 of total production costs was treated as common and unallocated production costs and was therefore excluded from the study-specific resource allocation efficiency calculation.

Accordingly, the study concludes that the integration of ABC and MFCA can provide useful managerial information for identifying inefficient activities, measuring material losses, determining loss-related costs, and supporting more informed resource allocation decisions in pharmaceutical manufacturing.

5.2 Contributions of the Study

The study provides several contributions to cost accounting and resource management.

First, it contributes theoretically by integrating two complementary accounting perspectives within a single analytical framework. ABC provides a cost and activity perspective, whereas MFCA provides a physical material-flow perspective. Their integration creates a framework that connects resources, activities, material flows, losses, and costs.

Second, the study provides a methodological contribution by proposing a sequence for measuring activity costs, material flows, material losses, loss costs, and resource allocation efficiency. This approach can provide a structured basis for analyzing production inefficiencies.

Third, the study provides a managerial contribution by demonstrating how accounting information can be used to identify activities associated with high resource consumption and material losses. Such information can support management decisions concerning process improvement, cost control, and resource allocation.

Finally, the study contributes to the applied literature on pharmaceutical manufacturing by examining an integrated cost and material-flow approach within a production environment characterized by multiple activities, material inputs, quality-control requirements, and potential material losses.

5.3 Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. Adoption of an Integrated ABC–MFCA Information Framework

Pharmaceutical manufacturing organizations should consider integrating activity-based cost information with material-flow information to obtain a more comprehensive view of production costs and material losses.

2. Regular Measurement of Material Losses

Material losses should be measured periodically at each major production stage rather than only at the aggregate production level. This can help identify changes in loss patterns and facilitate timely corrective actions.

3. Identification of Loss-Generating Activities

Management should identify the activities associated with significant material losses and investigate the operational causes of these losses. Particular attention should be directed toward production stages with relatively high loss quantities and loss costs.

4. Linking Loss Costs to Production Activities

The costs of material losses should be linked to the activities in which they occur. This can provide more accurate information for evaluating the economic consequences of inefficient processes.

5. Improving Resource Allocation

Resources should be reviewed according to their contribution to value-adding activities. Where excessive consumption is identified, management should evaluate opportunities to reallocate resources toward activities that contribute more directly to production objectives.

6. Strengthening Production and Quality Controls

Production and quality-control procedures should be continuously reviewed to identify sources of defects, rejected materials, reprocessing, and other forms of material loss. Preventive controls may reduce losses before they generate additional costs.

7. Developing Management Performance Indicators

Management should establish indicators that combine financial and physical information, such as material loss rate, loss cost, activity cost, resource utilization, and resource allocation efficiency. These indicators can support continuous performance monitoring.

8. Integrating Accounting and Production Information

Accounting departments should cooperate closely with production, inventory, quality-control, and engineering departments. Integrating information from these functions can improve the accuracy of activity costs and material-flow measurements.

9. Supporting Continuous Improvement

The results generated by ABC and MFCA should be incorporated into continuous improvement programs. Management can use the information to prioritize activities requiring process redesign, waste reduction, resource optimization, or improved operational controls.

10. Employee Training

Employees involved in accounting, production, quality control, inventory management, and process supervision should receive appropriate training in activity-based costing and material-flow analysis. This can improve the quality of data collection and facilitate implementation of the integrated approach.

5.4 Limitations of the Study

The study has several limitations that should be considered when interpreting its findings.

First, the analysis focuses on a pharmaceutical manufacturing environment, and therefore the results may not be directly generalizable to all industries with different production structures and cost characteristics.

Second, the analysis depends on the availability and accuracy of accounting, production, material consumption, and loss data. Differences in data quality may affect the accuracy of activity-cost allocation and material-flow measurements.

Third, the resource allocation efficiency indicator used in this study is an analytical measure developed for evaluating the relationship between resources assigned to value-adding activities and total resources consumed. It should therefore be interpreted as a study-specific performance measure rather than as a universally established accounting standard.

In addition, the ABC analysis is based on a selected activity-cost pool of $170,000 out of total production costs of $220,000. The remaining $50,000 is treated as common and unallocated production costs because it is not assigned through the selected activity cost drivers. Consequently, the resource allocation efficiency indicator should be interpreted in relation to the selected ABC activity-cost pool rather than total production costs.

Finally, the proposed framework focuses primarily on cost and material-flow dimensions. Other factors, such as environmental impacts, product quality, customer requirements, and operational risk, may also influence resource allocation decisions and could be incorporated into future research.

5.5 Suggestions for Future Research

Future studies could extend this research in several directions.

First, future research could apply the integrated ABC–MFCA framework to multiple pharmaceutical companies to examine whether similar patterns of material losses and resource consumption are observed across different organizations.

Second, future studies could incorporate environmental costs and carbon-related information into the integrated framework to provide a broader assessment of economic and environmental performance.

Third, researchers could combine ABC–MFCA with other management accounting techniques, such as Time-Driven Activity-Based Costing, Resource Consumption Accounting, or Target Costing, to examine whether additional information can improve resource allocation decisions.

Fourth, future research could develop digital systems for automatically collecting material-flow and activity-cost information from enterprise resource planning and production-monitoring systems.

Finally, future studies could examine the long-term effects of implementing ABC–MFCA on production costs, material efficiency, waste reduction, and organizational performance using longitudinal data.

5.6 Final Conclusion

The study concludes that integrating Activity-Based Costing with Material Flow Cost Accounting provides a useful framework for connecting financial and physical information within pharmaceutical manufacturing. ABC identifies the costs of production activities and the resources they consume, while MFCA identifies material flows, losses, and their associated costs.

The integrated approach makes it possible to trace the relationship between resources, activities, material flows, losses, and costs. This information can support management in identifying inefficient production stages, reducing avoidable material losses, controlling loss-related costs, and improving the allocation of available resources.

Therefore, the main contribution of the study is the development of an integrated analytical framework that moves beyond conventional cost measurement by linking activity-level costs with material-flow losses and resource allocation decisions. This framework can provide a practical basis for improving cost management and resource utilization in pharmaceutical manufacturing.

The resource allocation efficiency results reported in this study are based specifically on the selected ABC activity-cost pool of $170,000 and should not be interpreted as efficiency measures based on the full production cost of $220,000.

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