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APPLYING ACTIVITY-BASED COSTING TO OPTIMIZE PRODUCT-LEVEL PROFITABILITY IN GREENHOUSE FARMING OPERATIONS

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ABSTRACT

Vikum Sudarshan Jayasekera Jayalathge Don: Applying Activity-Based Costing to optimize Product-Level Profitability in greenhouse farming
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Greenhouse farming is a resource-intensive production environment where profitability depends heavily on energy use, workforce efforts and crop-specific cultivation needs. To support informed decision-making in such environments, firms must understand the true cost of each product, yet traditional costing systems often rely on broad averages that distort product costs and hide inefficiencies. This thesis addresses this challenge by developing a hybrid management accounting framework that combines direct costing, Activity-Based Costing (ABC), and continuous improvement principles to evaluate product-level profitability in a Nordic greenhouse enterprise.

The study follows a mono-method quantitative case study design and uses financial statements, production records, operational data and representative cost-driver estimates as primary data. Direct costing is used to trace variable inputs such as seeds, peat, packaging, and direct labour, while ABC is employed to allocate shared overheads, including heating, electricity, maintenance and administrative support, across key activities such as sowing, cultivation, harvesting and packing. Drivers were selected based on causality, measurability and data availability and quantified using a mix of numerical records and informed managerial estimates.

The results show that direct costs remain a major cost driver in greenhouse farming. ABC revealed that cultivation process absorbed the largest portion of overheads because of climate-control requirements, while harvesting and packing were also found to be resource-intensive. When combined with selling prices, these allocations highlighted clear differences in product profitability: some crops generated strong margins, while others were unprofitable and reduced cumulative profits. The whale curve illustrated this imbalance by showing that a small share of products accounted for most profits, whereas the least profitable crops eroded overall performance. A Cost-Volume-Profit (CVP) analysis for one unprofitable crop further showed a relatively high break-even point, indicating that significant efficiency improvements or pricing adjustments would be required for viability.

Overall, the hybrid model revealed cost and profitability patterns that couldn't be uncovered with traditional costing methods. It clarified where resources were consumed, which products created value, and where operational inefficiencies existed. The study concludes that greenhouse producers could strengthen long-term profitability by refining cost drivers and integrating continuous improvement tools into their costing practices. Future research could build on this work by applying time-driven ABC, incorporating environmental performance metrics, or using sensor-based operational data to further improve costing accuracy in greenhouse production.

Keywords: activity-based costing, ABC, direct costing, product level profitability analysis

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PREFACE

“Hard work beats the talent when talent doesn’t work hard.” – Kevin Durant

This thought has stayed with me throughout my studies and has guided me especially during the writing of this thesis. The journey has been filled with challenges, continuous learning, and long nights, but looking back, I am grateful for every step that brought me to this point.

I would first like to express my sincere gratitude to my supervisor, Prabhat Thakuri, who supported me from the very beginning. His flexibility, encouragement, and insightful guidance shaped the direction of this thesis and supported me through the most demanding phases of the research. I am equally thankful to associate professor Tuomas Korhonen, who entrusted me with this supervision arrangement and ensured I had the right support throughout the process.

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Tampere, 24 November 2025

Vikum Sudarshan Jayasekera Jayalathge Don

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LIST OF SYMBOLS AND ABBREVIATIONS

ABC	Activity-Based Costing
ABM	Activity Based Management
CANBUS	Controller Area Network Bus
CEA	Controlled-Environment Agriculture
CVP	Cost-Volume-Profit
EUR	Euro
GAAP	Generally Accepted Accounting Principles
IFRS	International Financial Reporting Standards
LED	Light Emitting Diode
PLP	Product Level Profitability
USD	United States Dollar

1. INTRODUCTION

1.1 Backrgound for the study

Greenhouse farming represents a modern form of controlled-environment agriculture (CEA) that enables continuous crop production under stable and optimized conditions (Nemali, 2022). By regulating key environmental factors including temperature, humidity, light and carbon-dioxide levels, greenhouses protect plants from external weather fluctuations and pests while maintaining higher yields and product quality (Nemali, 2022; Vatistas, et al., 2022). Over the past decades, greenhouse technology has evolved from simple structures to automated facilities equipped with digital systems that control climate, irrigation and nutrient delivery (Maraveas et al., 2023).

However, while greenhouse cultivation significantly enhances productivity and resource efficiency, it also involves huge financial commitments (Paris et al., 2022). Fixed costs arise from construction, insulation and automation equipment, whereas variable costs include labour, fertilizers and packaging (Wei et al., 2020). Energy alone can represent 25–30% of total operating costs, particularly in temperate regions that require continuous heating and artificial lighting throughout the year (Trépanier et al., 2025). Labor costs also account for a considerable share, since skilled workers are essential for crop monitoring and harvesting (Wei et al., 2020). Consequently, greenhouse farming is more cost and technology-dependent than openfield agriculture and therefore requires systematic cost control to maintain profitability (Paris et al., 2022).

Achieving accurate cost visibility in such environments might be challenging. Most greenhouse facilities grow multiple crops simultaneously, sharing resources such as heating, electricity and water systems (Wei et al., 2020). Traditional cost-allocation methods that distribute overheads uniformly across products often fail to reflect the true consumption of resources (Stašová, 2020). This lack of transparency can lead to incorrect pricing, unidentified inefficiencies and an unclear understanding of which crops contribute most to overall profitability (Carli & Canavari, 2013;Kaplan & Cooper, 1998; Stašová, 2020). Reliable cost information is therefore essential for product-level profitability analysis, where revenues and costs for each crop are evaluated separately to guide resource allocation, production planning and managerial decision-making (Kaplan & Cooper, 1998; Paris, et al., 2022; Stašová, 2020).

To improve cost accuracy, researchers and practitioners have increasingly applied advanced costing approaches such as direct costing and Activity-Based Costing (ABC).

Direct costing focuses on variable expenses including materials and labour, which helps to determine each product's contribution margin, thereby supporting short-term operational decisions (Bunea-Bontaş, 2013). ABC complements this by assigning indirect costs including electricty and heating, to the specific activities that generate them, based on cost drivers like square meters (m2) or heating time (Kaplan & Cooper, 1998). Empirical studies show that ABC enhances cost transparency and highlights inefficiencies within activity flows, offering a better foundation for process and performance improvements (Stašová, 2020).

Combining direct costing and ABC provides a more comprehensive view of greenhouse cost behavior. Direct costing reveals how variable costs respond to changes in production volume, while ABC clarifies how overheads are consumed across different operational activities (Bunea-Bontaş, 2013; Kaplan & Cooper, 1998). Together, these methods help managers understand where costs originate, how efficiently resources are utilized and which crops generate the highest financial returns (Carli & Canavari, 2013; Kaplan & Cooper, 1998). This understanding supports continuous improvement by enabling managers to identify costly processes, target energy or labor inefficiencies and introduce corrective measures that gradually lower unit costs and enhance profitability.

In energy-intensive environments including greenhouses, implementing an integrated cost-management framework is particularly valuable. It allows producers to balance economic and environmental goals by improving cost efficiency, supporting sustainable production practices and strengthening competitiveness in controlled-environment agriculture (Paris et al., 2022; Trépanier et al., 2025). Therefore, this study develops and applies a combined direct costing and ABC model to measure product-level profitability, identify inefficiencies and establish a foundation for continuous improvement in greenhouse operations.

1.2 Research problem and motivation

Despite major advances in automation, climate control and energy efficiency, greenhouse producers continue to face persistent challenges in understanding the true cost and profitability of their operations (Paris et al., 2022; Stašová, 2020; Wei et al., 2020). In many cases, managerial decisions are still based on aggregated or estimated cost information derived from traditional accounting systems, which often allocate indirect expenses uniformly across all crops (Stašová, 2020). Since greenhouses simultaneously produce several product varieties using shared resources including heating and lighting, this approach hides how individual products actually consume

resources (Paris et al., 2022; Wei et al., 2020). Consequently, managers may misinterpret product-level profitability, under or over price certain crops and overlook opportunities to improve production efficiency.

The problem is further increased by the dual challenge of maintaining economic viability while achieving environmental sustainability (Maraveas, et al., 2023; Paris, et al., 2022). Modern greenhouse enterprises invest heavily in automation, digital monitoring, and renewable-energy solutions to reduce waste and emissions. However, these same technologies also increase fixed costs and introduce greater cost complexity (Maraveas et al., 2023). Traditional costing methods are often too simplistic to capture these interconnections between technological investment, operational efficiency and financial outcomes (Carli & Canavari, 2013; Kaplan & Cooper, 1998; Stašová, 2020). This gap highlights the need for more precise and decision-oriented cost-analysis tools that can reflect the realities of modern greenhouse production.

This research is therefore motivated by the need to develop an accurate and practical cost-management framework tailored to greenhouse operations. The study combines direct costing and ABC to provide a comprehensive understanding of cost behaviour. Direct costing identifies variable cost components including materials and labour, and calculates contribution margins for each crop, which supports short-term decision making (Bunea-Bontaş, 2013). ABC complements this approach by tracing indirect costs including electricity and heat, to specific activities that use them, thereby improving the accuracy of overhead allocation (Kaplan & Cooper, 1998). Integrating both systems enables the measurement of total product-level profitability while revealing the underlying activities that drive cost variances and inefficiencies (Stašová, 2020).

The motivation for this case study specifically arises from the growing demand for data-driven cost visibility in Nordic greenhouse enterprises operating under high energy costs and strict sustainability goals. Through the application of the combined direct costing and ABC framework, this research aims to uncover unprofitable processes, highlight opportunities for resource optimization and support continuous improvement within greenhouse management. Ultimately, the study aims to demonstrate how enhanced cost transparency can strengthen economic sustainability, guide investment decisions and provide a model for other controlled-environment agricultural operations.

1.3 Research objectives and questions

As discussed in the preceding sections, the integration of direct costing and ABC provides a more reliable basis for cost allocation and managerial decision-making for companies (Bunea-Bontaş, 2013; Kaplan & Cooper, 1998). Direct costing clarifies short-term cost behaviour by isolating variable expenses, allowing managers to observe contribution margins and production efficiency across different crops (Bunea-Bontaş, 2013). In contrast, ABC assigns indirect and overhead costs to the activities that actually generate them, offering a clearer view of how resources are consumed in complex production environments (Kaplan & Cooper, 1998). The combined use of these systems therefore provides both financial accuracy and operational insight, which are essential for profitability evaluation and continuous improvement in greenhouse management.

The main objective of this study is to design and apply a hybrid cost management framework that integrates direct costing and ABC to evaluate product level profitability and identify opportunities for operational enhancement in greenhouse production. This objective reflects both practical need and an academic aim, which is to improve cost visibility in a real production setting and to demonstrate the analytical value of combining two complementary costing approaches in controlled environment agriculture, to drive continuous improvement through data-driven cost analysis.

Based on these objectives, the study seeks to answer the following research questions:

1. *How can a hybrid direct costing and ABC framework be effectively designed and implemented for greenhouse operations to measure total and product level costs accurately?*
2. *What do cost driver analysis provide about the structure of resource consumption and cost behaviour across different crops?*
3. *Which areas of greenhouse operations exhibit inefficiencies, and how can these be addressed through managerial or process improvements?*

By addressing these questions, the research aims to contribute to both the theoretical and practical understanding of cost management in agriculture. The findings are expected to provide a replicable model for similar enterprises seeking to align financial control with sustainability and operational efficiency.

1.4 Scope and delimations

The scope of this study is defined by its focus on the development and application of a hybrid direct costing and ABC framework to analyze product-level profitability in greenhouse farming. The research is conducted as a single case study within a Nordic greenhouse enterprise that produces multiple crops under controlled environmental conditions.

The study covers both core production and support processes directly associated with crop cultivation. It includes the identification of key resource inputs including electricity, labour, and materials, and their systematic allocation to activities and then to final products. Variable costs are separated according to direct costing principles, while indirect and overhead costs are traced through activity-level cost drivers defined under ABC approach. The analysis focuses on internal operational and financial data, including Financial statements, budgets, production records, energy usage reports and labour records, complemented by discussions with company representative.

The study's analytical scope extends to evaluating product-level profitability, identifying inefficiencies in major cost components and proposing process-level improvements. Paricular emphasis is placed on activities that significantly influence resource consumption, including energy management and cultivation practices. In addition to technical and financial evaluation, the study aims to provide the company's management with practical insights for continuous improvement, cost optimization and informed decision-making. It also seeks to demonstrate the broader relevance of hybrid costing approaches within agricultural production contexts.

However, certain delimitations apply. The research is limited to a single case company, which may restrict the generalizability of findings to other agricultural or industrial settings. The analysis does not include transportation and logistics activities, as these are managed by external service providers and fall outside the company's direct cost-control domain. Similarly, macroeconomic factors such as market pricing, consumer demand fluctuations, or market competition are not modelled quantitatively, eventhough they may indirectly influence profitability.

Furthermore, the study relies on existing operational data and representative estimates provided by company personnel where direct measurements were unavailable. These estimates were validated through email-colloboration but may still introduce minor disrepeancies in cost driver quantities. Despite these limitations, the study's structured and transparent methodology ensures that the results remain analytically consistent and

practically meaningful, offering valuable insights into cost behavior, profitability measurement, and opportunities for continuous improvement in greenhouse management.

1.5 Structure of the thesis

This thesis is structured into five chapters, each building progressively from theoretical foundations toward practical application and empirical analysis.

The first chapter introduces the topic and provides the overall background of the study. It explains the importance of effective cost management in greenhouse farming and presents the research problem, objectives, methodology overview, and study limitations. The chapter also establishes the motivation for combining direct costing and ABC as a hybrid framework for analyzing product-level profitability.

The second chapter includes the literature review, which discusses cost management practices in agriculture and manufacturing It discusses traditional costing methods, direct costing and ABC in detail, emphasizing their theoretical foundations and practical relevance to greenhouse operations. This chapter also identifies research gaps that justify the development of a hybrid cost-management framework.

The third chapter describes the research methodology, including the case company description, data collection methods and model development process. It explains how the hybrid direct costing and ABC framework was applied to allocate costs, identify cost drivers and analyze product-level profitability within greenhouse environment.

The fourth chapter presents the results of the empirical analysis It details the outcomes of the cost-allocation process, compares product-level profitability across crops and identifies inefficiencies in resource utilization. The findings are also discussed in relation to the research questions and objectives.

Finally, the fifth chapter concludes the thesis by summarizing the main findings and presenting managerial implications for greenhouse producers. It also discusses the limitations of the study and provides recommendations for future research, particularly in the fields of cost management, profitability analysis and sustainable greenhouse production.

2. THEOROTICAL BACKGROUND

2.1 Overview of Greenhouse Agriculture

Greenhouse farming represents an advanced system of controlled-environment agriculture that maintains optimal growth conditions for crops throughout the year, regardless of external climate variations (Nemali, 2022; Vatistas et al., 2022).The transparent coverings of greenhouses allow sunlight to penetrate while trapping heat inside, thereby generating a warm, humid and stable microclimate that accelerate plant growth and enhances productivity (Nemali, 2022). Such controlled environments enable the cultivation of a wide range of crops, including vegetables, fruits, flowers and herbs, while simultaneously protecting plants from adverse weather conditions, pests and diseases (Maraveas et al., 2023).

Modern greenhouses integrate physical structures with advanced climate-control technologies to regulate key environmental parameters such as light, temperature, humidity and nutrient delivery (Nemali, 2022). According to Nemali (2022) the evolution of greenhouses from small-scale facilities into commercial production systems has largely been driven by progress in structural engineering, glazing materials and environmental automation. The introduction of lightweight polyethylene films in the mid-20th century reduced construction costs considerably and expanded greenhouse adoption globally (Maraveas et al., 2023). Likewise, innovations in heating, ventilation, and artificial lighting improved productivity in moderate-climate regions (Castro et al., 2024). Region specific designs such as the venlo-type glasshouse in the Netherlands, the energy-efficient solar greenhouses in China and low-cost plastic-covered houses in Mediterranean and tropical climates illustrates how structural optimization aligns with local environmental conditions (Nemali, 2022). Collectively, these technological developments, along with the growing use of hydroponic and soilless systems, have transformed greenhouse farming into a resource-efficient production method that supports high yields, product consistency and sustainability across diverse agricultural settings (Vatistas, et al., 2022).

Modern greenhouses are characterized by their ability to maintain a semi-controlled microclimate that secures optimal plant growth despite seasonal variations or external climatic changers (Kutta & Hubbart, 2014). They rely on engineered structures equipped with technologies that regulate temperature, humidity, carbon dioxide and light intensity through automated systems of heating, ventilation, cooling and shading (Maraveas et al., 2023). This controlled environment ensures continuous, year-round crop production,

while enhancing resource usage efficiency through optimizing the use of water, fertilizers and energy (Vatistas et al., 2022). According to Nemali (2022) these systems represent highly intensive farming operations designed to sustain productivity, by keeping environmental variables optimal for crops.

However, this level of precision also demands huge capital investment in infrastructure, automation, and energy-intensive equipment, which makes greenhouse cultivation more cost and technology dependent than open field production (Paris et al., 2022). Wei et al. (2020) note that greenhouse operations incur higher fixed costs for structure, heating and lighting, while labor and overhead expenses represent a large portion of total production costs. The economic viability of such systems therefore depends on balancing high operational costs with appropriate product pricing and efficient yield management (Paris et al., 2022; Wei et al., 2020). Eventhough greenhouse systems require high investments and energy use, their ability to maintain continuous production across different seasons, achieve higher yields per unit area and supply markets with consistent product quality, makes them essential in modern agricultural production (Paris et al., 2022; Wei et al., 2020; Maraveas et al., 2023).

The performance and sustainability of greenhouse systems largely depend on the efficient management of key resource inputs such as energy, labor, seeds and fertilizers (Paris et al., 2022). Among these, energy is the dominant factor, often accounting for approximately 25–30% of total operational costs due to continuous heating, ventilation, and lighting requirements, especially in colder regions (Trépanier et al., 2025). Research indicates that implementing energy-efficient measures including LED lighting, thermal screens, improved insulation and waste-heat recovery, can reduce total energy consumption by up to 25% without lowering yields (Trépanier et al., 2025). At the same time, labor remains another significant cost component, as skilled workers are required for crop monitoring and harvesting (Wei et al., 2020).

Morever, the increasing integration of automation and digital technologies, such as precision irrigation, automated climate regulation and sensor-based monitoring, has begun to reduce these labor intensity by improving accuracy and operational consistency (Maraveas et al., 2023). Similarly, the use of high-quality seeds and fertilizers supported by fertigation and nutrient-delivery systems enables precise control of water and nutrient supply, thereby enhancing productivity while minimizing waste (Nemali, 2022). As highlighted in recent studies, balancing input costs with automation and energy-efficiency strategies allows greenhouse producers to achieve stable, year round yields

while progressing toward economically viable and sustainable controlled-environment agriculture (Maraveas et al., 2023; Paris et al., 2022).

Having that said, understanding the cost behavior is essential for evaluating the economic performance of greenhouse farming systems. As apposed to open-field cultivation, Greenhouse production involves a complex cost structure with a high proportion of fixed costs, including the construction of structures, glazing, insulation, climate-control devices and automation technologies (Al-Asadi et al., 2023). Variable costs include labor, fertilizers, seeds and water that fluctuate according to the scale of production (Wei et al., 2020). Studies have shown that energy and labor collectively account for the largest share of operating costs, while depreciation and equipment maintenance dominate fixed expenditures (Paris et al., 2022).

Al-Asadi et al. (2023) highlighted that the greenhouse cost index varies significantly across regions depending on materials, insulation and design choices, with construction costs ranging from USD 5 to 35 per square foot. This variation highlights that how design type and component selection directly influence total cost and overhead intensity. Maraveas et al. (2023) emphasized that increasing automation and renewable-energy integration can reduce recurring operating costs by improving energy efficiency and extending equipment lifespan. Overall, greenhouse farming haracterized by a high overhead intensity, because a substantial portion of total costs arises from energy consumption, equipment depreciation, and maintenance.

Despite continuous advancements in greenhouse technologies and energy-optimization strategies, cost management and profitability measurement remain major challenges in modern greenhouse operations (Maraveas et al., 2023). The dominance of fixed capital investments and high energy dependency makes it difficult to attribute costs accurately to specific production cycles or product types (Paris et al., 2022; Wei et al., 2020). As Wei et al. (2020) observed variations in labor productivity, input prices and crop yields create significant uncertainty in determining actual cost structures and profit margins. Paris et al. (2022) showed that regional disparities in electricity tariffs, energy supply and climatic conditions lead to fluctuations in operational expenses, complicating cost forecasting and profit stability.

Morever, automation and digital systems introduce new cost layers related to depreciation, maintenance and technological upgrades (Maraveas et al., 2023). The challenge extends beyond direct production costs because, as Stašová (2020) emphasized high overhead ratios in agricultural enterprises often distort cost visibility when traditional mark-up systems are used, leading to misestimated product profitability.

Her statistical comparison of conventional costing and ABC in Slovak agricultural firms revealed that ABC provides more accurate overhead allocation by identifying activity-level cost drivers, though it requires more analytical and data infrastructure investment.

In greenhouse contexts, this problem is amplified by market volatility, seasonal demand, and environmental variability, which collectively make profitability measurement less predictable (Wei et al., 2020; Vatistas et al., 2022). Moreover integrating sustainability goals such as energy efficiency adds analytical complexity since their economic benefits are difficult to express in purely financial terms (Vatistas et al., 2022). Altogether, these findings indicate that accurate profitability measurement requires reconciling economic, operational and environmental perspectives. The next subsection, therefore, examines cost management in agricultural production and discusses how frameworks such as ABC can address these challenges by linking cost behavior to strategic performance assessment.

2.2 Cost Management in Agricultural production

The history of cost accounting in agriculture goes back to the 18th century, when Arthur Young first emphasized the importance of farm record-keeping and systematic cost control (Juchau, 2002). Although agriculture represents humanity's oldest economic activity, its accounting systems evolved slowly due to limited capital, weak markets and a primary focus on domestic consumption rather than trade (Fatah & Mat-Zin, 2013). Young was among the first to identify the absence of reliable cost records that could help farmers determine the cost of crops, livestock, and farm operations, and he advocated better cost comparisons and allocation practices to guide managerial decisions in mixed farming systems (Juchau, 2002). These early efforts to promote financial awareness in agriculture laid the foundation for cost management as a key component of farm efficiency.

Over time, scholars and practitioners recognized that cost accounting systems are essential tools for managerial decision-making in farms. Modern agricultural enterprises, especially multi-product operations, require timely and accurate cost information to support pricing, performance evaluation and budgeting (Argiles & Slof, 2003; Juchau, 2002; Wijewardena & Zoysa, 1999). According to Kaplan & Cooper (1998) cost accounting systems serve three primary objectives: (1) valuing inventory and measuring the cost of goods sold, (2) providing economic feedback on process efficiency and (3) determining the cost of activities, products and customers. Within agriculture, such systems enable managers to compare field performance, allocate overheads across

crops and identify unprofitable activities, ultimately improving the utilization of land, labor and machinery (Jack & Jones, 2007).

Despite these advantages, research on cost accounting in agriculture has historically been limited (Jack & Jones, 2007). The sector was long overlooked by accounting scholars due to perceptions of low managerial experiance and limited financial capacity among farmers (Athanasios et al., 2010). However, empirical evidence shows that applying structured costing practices are indispensable to enhance farm performance (Carli & Canavari, 2013; Stašová, 2020; Kabinlapat & Sutthachai, 2017). As Slof & Argilés (2001) note, implementing cost accounting systems can strengthen management control and decision making. Similarly, Latruffe (2010) indicate that improving cost efficiency and economic performance is critical for maintaining profitability and competitiveness in modern agribusinesses.

During the 20th century, two principal cost-calculation methodologies emerged, which are Absorption (Full) Costing and Direct (Variable) Costing (Ratnatunga, 1997; Fremgen, 1964; Bunea-Bontaş, 2013). Each reflects a different managerial perspective on how fixed manufacturing overheads should be treated and how costs contribute to pricing, profitability and decision-making.

Absorption costing, also referred to as full cost accounting, is based on the principle that all production-related expenses, whether variable or fixed, should be included in the cost of a product (Drury & Tayles, 2006; Horngren et al., 2014). Under this method, the unit cost of production includes direct materials, direct labour, variable manufacturing overhead and a proportional share of fixed overhead (Bunea-Bontaş, 2013). Consequently, all manufacturing costs are treated as product costs, while selling and administrative expenses are recognized as period costs in the income statement (Bunea-Bontaş, 2013; Kaplan & Cooper, 1998). Because of its compliance with these standards, absorption costing is dominant in financial (Bunea-Bontaş, 2013). However, it is less flexible for internal management decisions, as it often hides the behavioural relationship between cost and activity levels (Bunea-Bontaş, 2013).

In agricultural settings, particularly in multi-crop farms and greenhouse systems, absorption costing can lead to distorted cost allocations when overheads such as energy, climate control, and maintenance are distributed uniformly across outputs (Kaplan & Cooper, 1991; Carli & Canavari, 2013). These overheads often vary by activity type rather than output volume, making volume-based allocations inaccurate. As Carli & Canavari (2013) and Fatah & Mat-Zin (2013) observed this issue continues in modern

agribusiness, where indirect costs frequently exceed direct costs and traditional full-cost approaches hide inefficiencies in resource-intensive processes.

As opposed, direct costing (also known as variable costing or partial costing) includes only costs that vary directly with production volume namely direct materials, direct labour and variable manufacturing overheads (Drury & Tayles, 2006). Fixed manufacturing overheads are treated as period costs, expensed in the accounting period in which they occur (Drury & Tayles, 2006; Horngren et al., 2014). Consequently, inventory values under direct costing are lower than those under absorption costing, as they exclude fixed overhead allocations (Bunea-Bontaş, 2013).

The conceptual strength of direct costing lies in its ability to support managerial decision-making, by clearly distinguishing variable and fixed cost behaviour (Drury & Tayles, 2006; Horngren et al., 2014). By focusing on contribution margin analysis, which is the difference between sales revenue and total variable costs, allows managers to evaluate product profitability, perform break-even analysis and access operational efficiency (Bunea-Bontaş, 2013; Tsui, 2011). Direct costing aligns well with internal management objectives in agriculture, offering rapid insights on the profitability of individual crops or cultivation methods. As Bunea-Bontaş (2013) explains, this approach enhances operational flexibility in planning and cost control, as it enables managers to observe how profits respond to changes in production levels, resource usage, or selling prices. However, because it excludes fixed overheads from inventory valuation, direct costing is not compliant with IFRS or GAAP for external reporting (Bunea-Bontaş, 2013). Its strength lies primarily in internal short-term decision-making rather than in financial compliance (Fremgen, 1964).

Vatter (1945) emphasize the need for more objective and systematic bases for overhead allocation than traditional methods, noting that the use of volume-related drivers could distort product costs. Kaplan & Cooper (1991) later expand this argument, demonstrating that the allocation of service and support overheads through volume measures leads to significant cost distortions. Traditional costing approaches were developed at a timeframe when the direct costs such as labour and material costs were significant part of total production costs (Carli & Canavari, 2013) However, in modern diversified enterprises where overheads account for a substantial proportion of total costs, traditional methods tend to under or overestimate indirect costs (Kaplan & Cooper, 1998; Kaplan & Cooper, 1991; Horngren et al., 2014). Furthermore, traditional costing systems fail to provide the level of accuracy and analytical depth required for operational, inventory and quality management decisions (Kaplan & Cooper, 1998). By allocating

overheads using broad, volume-based measures, they hide inefficiencies in specific activities, distort product-level cost information and provide little insight into performance variation. Consequently, managers lack reliable cost visibility to support process improvement and quality initiatives (Johnson & Kaplan, 1987; Green et al., 1991; Hendricks, 1988; Steedle, 1988).

These limitations encouraged a methodological shift toward ABC. As Jeans & Morrow (1989) note, an increasing number of firms adopted ABC to enhance competitiveness through more accurate cost information. Studies such as Lee & Kao (2001) demonstrated the feasibility of applying ABC in agricultural settings by analyzing fish-market operations in Taiwan, where ABC improved pricing accuracy and operational transparency. Similarly, Mattetti et al. (2022) integrated real-time CANBUS data into an ABC framework, highlighting how automation and precision-farming data can enhance economic insight. More recently, Ortiz-Cea et al. (2025) concluded that ABC enables organizations to trace environmental and resource costs more accurately, aligning financial management with sustainability objectives, which is a crucial consideration in modern agribusiness industry.

Overall, the development of cost management in agriculture has evolved from the basic record-keeping of Arthur Young to the data-driven precision of modern costing systems such as ABC (Juchau, 2002; Kaplan & Cooper, 1991). This evolution reflects the growing technological complexity of agricultural operations, the rising share of indirect costs, and the need for more accurate visibility of cost behaviour in competitive and sustainable production systems (Carli & Canavari, 2013; Zakić & Borović, 2013; Ortiz-Cea et al., 2025). While both absorption and direct costing provide valuable insights for cost analysis, they each posses inherent limitations when applied to complex, technology-driven agricultural environments. Absorption costing ensures financial compliance but often hides the behavioural relationship between costs and activities, whereas direct costing enhances managerial transparency but fails to account for the increasingly significant share of overhead costs (Bunea-Bontaş, 2013).

In summary, in modern greenhouse production, where automation, climate control, and energy management dominate the cost structure, traditional volume-based allocations are insufficient to capture true resource consumption (Carli & Canavari, 2013; Fatah & Mat-Zin, 2013). To address these limitations, ABC has emerged as a complementary approach that assigns overheads to the specific activities that generate them, rather than distributing them uniformly across production volumes (Kaplan & Cooper, 1998; Mattetti et al., 2022). In the context of this study, direct costing will be applied to materials and

labour, representing variable production costs, while ABC will be used to allocate production overheads such as energy and depreciation-related expenses. This integrated framework provides a more realistic representation of cost behaviour and profitability across production stages. The following subsection therefore elaborates on the principles, relevance, and application of ABC in agricultural production.

2.3 Theoretical foundations of Activity-Based Costing

The concept of ABC was first clearly defined by Kaplan & Bruns (1987), although it is said that its conceptual foundations emerged in the United States manufacturing sector during the 1970s and 1980s (Kaplan & Bruns, 1987; Kaplan & Cooper, 1998). Regradless, the approach emerged as a solution to the limitations of traditional costing systems, which failed to capture the increasing share of overhead costs and the increasing complexity of modern production environments (Kaplan & Atkinson, 1998). The Consortium for Advanced Management International played a significant role in formalizing and promoting the ABC framework through industry-based research and consultancy (Cardos & Pete, 2011). Over time, ABC evolved into an essential management accounting tool designed to improve the cost accuracy and support strategic decision-making across a wide range of industries (Dierks & Cokins, 2000; Kaplan & Cooper, 1998; Turney, 2005).

Technically, ABC provides a structured framework for quantifying the relationships among resources, activities and cost objects (Kaplan & Cooper, 1998). It operates on the basic principle that activities consume resources and cost objects such as products, services and customers, consume activities (Horngren et al., 2014). Rather than allocating overheads broadly through cost centers, ABC assigns resource costs to activities and then traces activity costs to cost objects based on their actual consumption of cost drivers (Dierks & Cokins, 2000).

According to Lanen et al. (2008), four key stages can be identified in implementing ABC.

1. Identifying activities: The process begins by mapping all major activities that consume resources within an organization, such as procurement, maintenance, production, quality control or distribution.

2. Assigning resource costs: In the second step, resources including materials, labor, and utilities are analyzed, and their respective costs are assigned to these

activities. This provides the initial link between operational processes and incurred costs.

3. Determining cost drivers: Each activity is then associated with an appropriate cost driver that best explains how and why the activity cost varies. Examples include machine hours, number of setups or inspection time.
4. Computing driver rates and allocating costs: Finally, the cost per driver unit is calculated, and costs are assigned to individual products or services according to their level of driver consumption.

Together, these steps provide a transparent flow of cost information from resources to final cost objects, enabling organizations to determine the true cost of their operations (Fisher, 2012). As noted by Al-Eidan et al. (2019) ABC helps to uncover hidden or distorted costs which are often overlooked in traditional systems and ensures that indirect costs are correctly traced. In many cases, firms initially relying on traditional costing systems have adopted ABC due to increasing competitive pressure and the need for more accurate cost data to support managerial decision-making (Altawati et al., 2018).

Unlike traditional systems that typically allocate overheads using a single pre-determined rate, ABC identifies and measures the specific activities, such as planning, production, maintenance and distribution, that actually drive overhead costs (Kaplan & Cooper, 1998). This detailed tracing produces more accurate cost estimates and helps managers identify profitable, non-profitable and breakeven products (Dierks & Cokins, 2000; Kaplan & Cooper, 1998). Moreover, by distinguishing value-adding from non-value adding activities, organizations can redirect efforts toward value-adding processes (Kaplan & Cooper, 1998). The broader application of this philosophy is known as Activity-Based Management (ABM), which supports continuous improvement, cost reduction and customer-oriented product design (Sinha et al., 2020).

Empirical studies have shown that the diversity of a company’s product portfolio is positively associated with the need for ABC adoption. According to Alcouffe et al. (2019), as firms expand their product portfolios understanding precise cost structures becomes increasingly vital for strategic planning and performance evaluation In such contexts, overhead allocation challenges increase, and ABC provides a logical, cause and effect based linkage between overheads and product outputs (Kaplan & Cooper, 1998).

Moreover, advances in digital information systems have enhanced the timeliness and accuracy of ABC data collection and analysis (Riesener et al., 2019).

The development of an ABC based cost management system requires integrating information flows across the organizational structure to ensure that resources are effectively allocated (Perevozova et al., 2019). Studies by Vetchagool et al. (2020) show that the application of ABC enhances operational performance and, consequently, financial performance, regardless of the industry that a firm operates in. Furthermore, ABC assists in identifying over-costed or under-costed products, enabling management to make corrective adjustments in pricing, production planning, and resource utilization (Altawati et al., 2018).

In recent years, agricultural enterprises have increasingly recognized the strategic importance of adopting ABC to manage costs in highly competitive and dynamic markets (Koutouzidou et al., 2015). Empirical evidence suggests that ABC improves cost accuracy, supports profitability analysis and strengthens pricing decisions within agricultural operations (Stašová, 2020). Traditional cost systems often allocate expenses at the product level without tracing them to the activities that generate them, which leads to distorted product costs. In contrast, ABC highlights cost drivers and their relationships with operational processes, offering farmers and agribusiness managers a more realistic understanding of cost behavior (Arora & Raju, 2018; Barus et al., 2019). As a result, implementing ABC in agricultural contexts contributes to cost reduction, profitability improvement and enhanced managerial decision-making (Al Hanini, 2018; Calvi, 2019). Enterprises that have applied ABC to logistics cost accounting have similarly reported better resource utilization and performance outcomes (Zhang & Li, 2018).

However, effective ABC implementation requires organizational readiness and structural adaptation. As Sorros et al. (2017) emphasize, firms must anticipate both operational and cultural changes that accompany ABC adoption. Araujo et al. (2020) found that ABC enhances administrative efficiency in agro-industrial and agro-forestry enterprises, helping them remain competitive under increasing global cost pressures. The improved cost transparency and resource allocation achieved through ABC contributes directly to higher income levels and better long-term sustainability (Gazzarin & Lips, 2018).

After reviewing these studies, it becomes clear that understanding how ABC is implemented in practice is crucial. In practical terms, this means examining the specific stages involved in applying the system, starting from identifying activities to assigning costs to final products. This approach helps to demonstrate how theoretical concepts translate into real cost-management processes within agricultural enterprises.

2.3.1 Steps in Activity-Based Costing

The implementation of ABC follows a structured procedure that converts operational resource data into accurate product-level costs (Fisher, 2012). However, before describing the detailed steps, it is useful to illustrate the fundamental structure of the ABC model (*see* Figure 1), which establishes a clear cause and effect relationship between resources, activities, and cost objects.

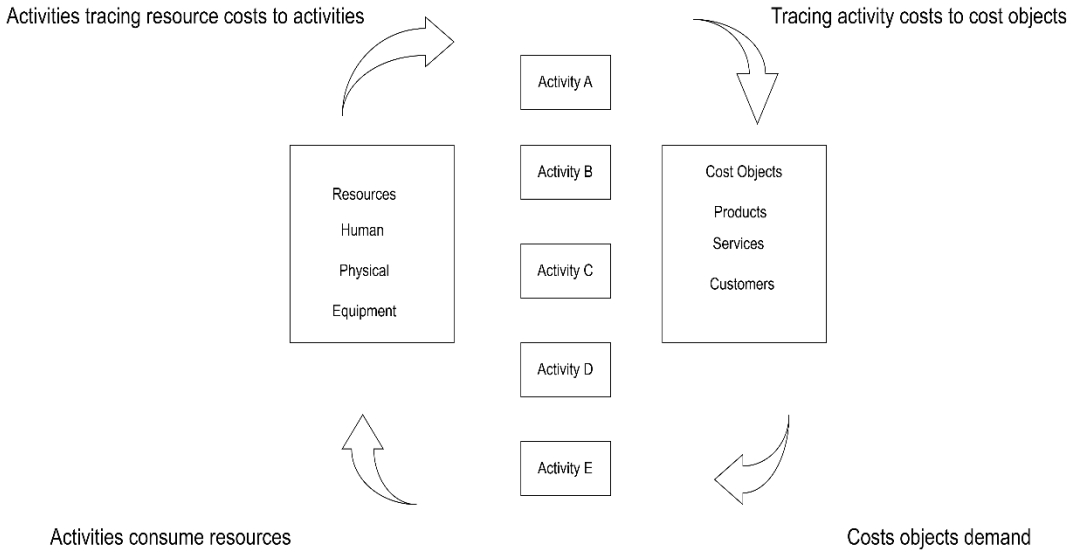

Figure 1. Concept of Activity Based Costing (ABC) method (Yazid & Zheng, 2019).

In the ABC model, as illustrated in Figure 1, resources such as human resources, physical assets and equipment form the foundation of cost occurrence. These resources are then assigned to activities (e.g ; Activity A–E) through appropriate resource drivers that capture the extent to which different operational processes consume resources. Once resource costs have been traced to activities, the next stage involves assigning these activity costs to cost objects, which may include products, services or customers. These drivers represent measurable factors like machine hours, labor hours or the number of transactions. The feedback loop shown in the the Figure 1 highlights the dynamic nature of ABC, where cost information derived from cost objects can be fed back into resource planning and process improvement. This cyclical process allows management to identify inefficiencies, eliminate non value-added activities and improve decision making related to pricing, product mix and process optimization continuosly.

While the four-stage structure in Figure 1 presents the general logic of ABC, the practical implementation in this study follows a more detailed five-stage process. This expanded version, commonly used in applied ABC research (Fisher, 2012; Lanen et al., 2008), separates the identification and quantification of resource and activity drivers into an independent step, rather than treating them implicitly inside the allocation stages. In greenhouse production systems, this distinction is especially important because heating demand, electricity usage, workforce effort and cultivated space vary substantially between crops. These variations mean that driver selection and quantification directly affects the precision of cost allocation. Therefore, the five-stage model is more suitable in this context, as it provides the level of granularity required to reflect real crop-level cost behaviour.

Building on this rationale, the implementation of ABC in this study follows the commonly used five-stage structure described in the literature. According to Fisher (2012) and Lanen et al. (2008), and recent agribusiness applications such as Kabinlapat & Sutthachai (2017) , the process of implementation of ABC typically involves five interrelated stages: identifying activities, assigning resource costs, determining both resource and activity drivers, allocating activity costs to cost objects and finally analyzing cost outcomes.

The first step involves identifying all major activities performed within the production process that consume resources and generate costs. Activities represent seperate operational activities such as procurement, machine setup, production, quality inspection and logistics. In agricultural or food-processing environments, these may include planting, cultivation, harvesting, sorting, packaging and cold storage. The activities can be identified through documentation review, direct observation and interviews with operational staff to ensure that all relevant processes are captured (Kabinlapat & Sutthachai, 2017).

Once activities are defined, the second step assigns resource costs, such as labor, energy, materials, depreciation, and utilities, to each activity. This step depends on the use of resource drivers, which measure how much of each resource an activity consumes. For example, total electricity expenses may be distributed to activities based on kilowatt-hour usage, while maintenance costs could be allocated based on the number of machine hours or maintenance calls. Resource drivers are selected using three key criteria outlined by Gary & Sorinel (2010), which are, ease of identification, direct relevance to indirect cost behavior and their ability to reflect cost variability. This

stage produces a set of resource cost pools, each representing the portion of total indirect costs consumed by a particular activity.

The third step focuses on identifying activity drivers, which define the relationship between activity costs and cost objects. While resource drivers allocate costs from resources to activities, activity drivers allocate costs from activities to products. As suggested by Kabinlapat & Sutthachai (2017), driver selection can typically selected through brainstorming sessions, interviews or data analysis, with validation by management to ensure fairness and practicality. In agricultural production, common activity drivers may include kilograms harvested, hectares cultivated or time spent in packaging. Each driver should demonstrate a clear cause and effect relationship with its associated activity cost (Fisher, 2012; Gary & Sorinel, 2010).

After establishing activity drivers, the fourth step involves calculating the driver rate by dividing the total cost of each activity by its total driver quantity. These driver rates are then used to assign activity costs to cost object based on their level of driver consumption. For example, if the “packaging” activity has a total cost of €10,000 and 5,000 kilograms of produce were packaged, the driver rate would be €2 per kilogram. Products requiring 800 kilograms of packaging effort would therefore be assigned €1,600 of packaging cost. This calculation provides a precise linkage between cost behavior and production outputs, enabling managers to identify cost-intensive processes and optimize resource utilization (Altawati et al., 2018; Sánchez et al., 2020).

The final stage involves comparing ABC-derived costs with those obtained from traditional methods to identify potential distortions. Kabinlapat & Sutthachai (2017) demonstrated that, in food-processing firms, ABC often reveals significantly different unit costs particularly for energy-intensive or multi-stage products, indicating hidden inefficiencies in conventional cost systems. By highlighting non value-added activities and inaccurate overhead allocations, ABC provides a fundamental basis for Activity-Based Management (ABM), supporting continuous improvement, pricing optimization, and performance control (Vetchagool et al., 2020).

2.3.2 Applications of ABC in Agriculture and Food Industry

Accounting and agriculture are two distinct economic disciplines that both make substantial contributions to the global economy. However, collaboration between them has historically been limited, as management accounting methods are underused in primary production, and agricultural studies often prioritise agronomic or economic models (Koutouzidou et al., 2015; Sridharan et al., 2016). Nevertheless, a growing body

of literature demonstrates that ABC enhances cost transparency and managerial decision-making in agricultural enterprises and agri-food firms. These studies range from conceptual frameworks that integrate ABC into farm management information systems to empirical case studies examining implementation feasibility and statistical analyses assessing the suitability of ABC across agriculturalal and food sectors (Carli & Canavari, 2013; Stašová, 2020; Sridharan et al., 2016).

Pockevičiūt (2008) introduced an Activity-Based Budgeting (ABB) model for a Lithuanian dairy holding, combining ABC principles with enterprise budgeting to enhance planning and control. The study emphasized that traditional budgeting systems in agriculture often fail to reveal the true sources of overhead costs or distinguish between value-adding and non-value-adding operations. By integrating ABC into budgeting, the model traced major costs such as administration, energy, and depreciation to specific activities influencing milk production. Through activity-level budgeting, managers were able to forecast costs more accurately, analyze variances between planned and actual performance and identify areas where operational efficiency could be improved. The study demonstrated that ABC-based budgeting enhances managerial insight into resource utilization and cost behavior. However, it remained limited by its static nature, manual data handling and short term forcasting.

González-Gómez & Morini (2009) developed an ABC model for cost calculation and management in multiproduct agricultural enterprises, using ornamental plant cultivation as a case study. Their work contributed a flexible and transparent framework capable of handling multiple crops, varying production methods and overlapping production cycles. The model demonstrated how to identify activities, assign cost drivers, and separate direct and indirect costs while accounting for “stay costs,” which represent the cost of occupying greenhouse space over time. However, its reliance on manual data recording limited its practicality for larger or automated systems. Furthermore, while the model provided detailed cost insights, it lacked integration with decision-support tools for performance optimization or scenario analysis. The authors treated ABC primarily as a cost measurement framework rather than a continuous managerial control system.

Korpunen et al. (2010) presented one of the most comprehensive ABC applications within the forestry sector. The model’s main strength lay in its detailed process mapping and accurate allocation of machinery, labor and energy costs across sawmilling operations. However, the model was complex and data-intensive, relying on historical parameters without accounting for downtime or process variability. Additionally, the

model was designed for large-scale industrial sawmills, limiting its adaptability to other agricultural or small-scale production settings.

Carli & Canavari (2013) developed an early conceptual model that integrates direct costing and ABC within a farm management information system framework. Their study showed that integrating accounting methods with farm data systems could enhance cost allocation accuracy and managerial control. Using interviews with farmers and prototype models developed in microsoft access, the authors designed a system that links machinery, labor and service data directly to specific crop activities. This structure provides detailed crop-level cost visibility and allows managers to perform simple “what-if” analyses. While this model was an important step toward embedding managerial accounting in agriculture, it remained largely conceptual, focusing on data architecture and reporting functions rather than on empirical validation or efficiency analysis.

Sridharan et al. (2016) provided a practical ABC applications in a small-scale agricultural setting. Their model, developed for a family-owned farm, illustrated how ABC could address farming-specific challenges such as seasonal variation, biological uncertainty and multi-year production cycles. They employed non-volume-based cost drivers related to specific tasks such as pruning, planting and watering, showing that even small farms could adopt ABC heuristically. However, their approach heavily relied on estimated activity volumes and static assumptions about operating conditions. The model did not incorporate environmental factors such as weather or temperature fluctuations that significantly change cost behavior in real production environments.

Kabinlapat & Sutthachai (2017) conducted an ABC study in Thailand’s chicken processing industry, focusing on joint products from fresh and frozen poultry production. The study’s main contribution lies in demonstrating how ABC can correct distortions in traditional absorption costing, particularly in complex food-processing systems with numerous co-products and by-products. However, The approach was labor and data intensive, requiring manual tracking of activities and extensive interviews to establish consumption rates. It depended heavily on managerial judgment to define activity and resource drivers, introducing possible subjectivity and reducing replicability. Overall, Kabinlapat & Sutthachai (2017) successfully demonstrated that ABC can improve cost allocation in joint-product agri-food systems.

Yazid & Zheng (2019) applied the ABC to a Malaysian palm oil plantation, to address inaccuracies caused by traditional cost accounting . Their model demonstrated how ABC enhances cost accuracy and profitability estimation in long-term plantation management. It highlighted that, under conventional systems, volume-driven overheads tend to distort

cost structures, whereas ABC links resources and activities directly to plantation processes such as harvesting, fertilization and milling. The model also emphasized the managerial benefits of using cost drivers to identify non-value-adding activities to improve resource allocation efficiency. However, it remained largely descriptive and conceptual, lacking empirical validation through real operational datasets, and did not extend to measuring efficiency or performance improvements.

ABC has been applied in a wide range of industries since its introduction by Kaplan & Cooper (1998). Over the years, researchers have explored its use in sectors such as manufacturing, engineering, finance, healthcare, and education, emphasizing its ability to enhance cost accuracy, performance evaluation and managerial decision-making (Carli & Canavari, 2013; Sridharan et al., 2016; Stašová, 2020; Yazid & Zheng, 2019). Despite this wide application, the degree of adoption varies considerably across industries, with agriculture and education remaining among the least represented fields (Yazid & Zheng, 2019). To visualize these differences, Yazid & Zheng (2019) reviewed one hundred peer-reviewed studies published between 2011 and 2018 to examine how ABC has been applied across major sectors. The results of their analysis are presented in Figure 2.

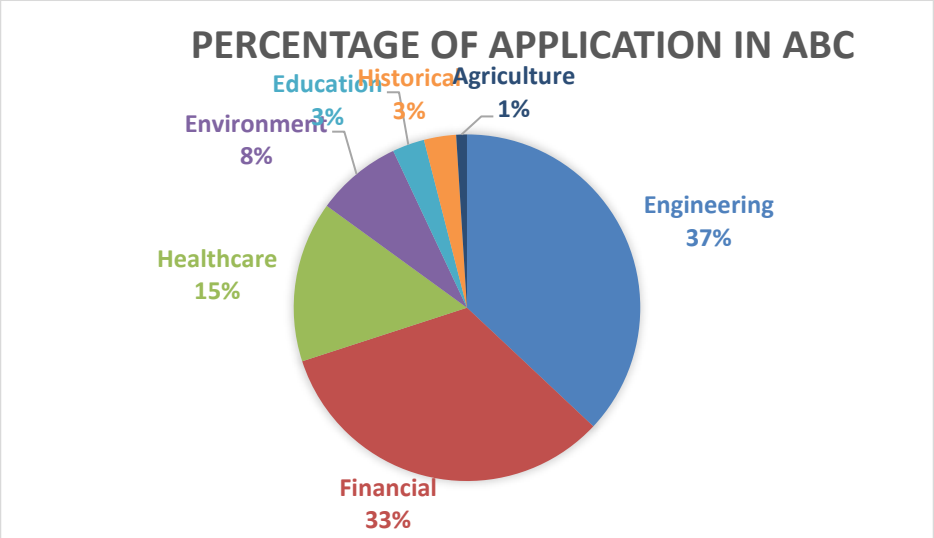

Figure 2. Usage of ABC across different industries (Yazid & Zheng, 2019).

As shown in Figure 2, ABC has been most widely applied in engineering (37%) and financial (33%) sectors, where complex operational processes and overhead-intensive activities demand precise cost allocation methods. The healthcare sector (15%) also demonstrates a relatively high level of adoption, driven by the need for transparent costing and performance measurement in hospitals. In contrast, environmental

management (8%), education (3%), and agriculture (1%) remain underrepresented in the literature. This distribution indicates that while ABC is well established in data-rich, industrial and service-oriented environments, its potential in agriculture remains largely unexplored. Expanding the adoption of ABC in agriculture and related food industries could substantially enhance cost visibility, support data-driven managerial decisions and promote greater efficiency through activity-based insights.

Taken together, these studies highlight several important themes that are directly relevant to the present research. Overall, the existing literature shows that ABC can substantially improve cost visibility and managerial understanding in agricultural settings, but many implementations still rely on estimated driver values, manually collected data and simplified assumptions about production conditions. These limitations are particularly evident in sectors such as greenhouse farming, where costs depend heavily on shared resources like heating, space, and electricity, and where traditional costing methods often fail to capture the real drivers of overhead consumption. Although previous studies have proposed integrating direct costing and ABC to improve cost accuracy, most applications remain conceptual and rarely combine both systems in a practical case setting. The low adoption of ABC in agriculture reported by Yazid & Zheng (2019) further reinforces the need for empirical studies that apply activity-based approaches in real production environments. These insights justify the methodological choices of this thesis, which develops a hybrid direct costing and ABC model to capture actual resource usage patterns and support data-driven profitability evaluation in a Nordic greenhouse context.

2.4 Integrating ABC and Product profitability in greenhouse farming

Product-level profitability (PLP) analysis is considered one of the most essential practices in management accounting, as it enables managers to identify both profitable and unprofitable products and make informed strategic decisions accordingly (Drury & Tayles, 2006). For this reason, accurate product cost and profitability information is essential, as it forms the basis for cost-conscious decisions related to pricing, resource allocation, and product mix (Drury & Tayles, 2006). As Sievänen et al. (2004) note, when cost data are inaccurate or incomplete, managers may make decisions about product mix, production volumes, or process changes without fully understanding their long-term financial implications. This challenge becomes even more significant in environments where many products share the same resources, making it difficult to see which ones genuinely contribute to business performance.

The importance of product-level profitability analysis is especially evident in multi-product or resource-intensive environments such as greenhouses, where product diversity and overhead intensity are high (Brierley, 2016). In such contexts, traditional costing systems often provide distorted cost allocations, hiding the true profitability of individual products (Drury & Tayles, 2006; Kaplan & Cooper, 1998; Sievänen et al., 2004). Kaplan & Cooper (1998) illustrate this phenomenon in their Harvard Business School "Kanthal case," which show that only a small proportion of customers generate most of the company profits, and relatedly, a minority often cause the substantial losses. This finding led to the development of the whale curve, a graphical representation of cumulative company profits plotted against products ranked by profitability (Kaplan & Atkinson, 1998; Kaplan & Cooper, 1998). To illustrate this concept as it is commonly presented in the literature, Figure 3 shows the typical shape of the whale curve.

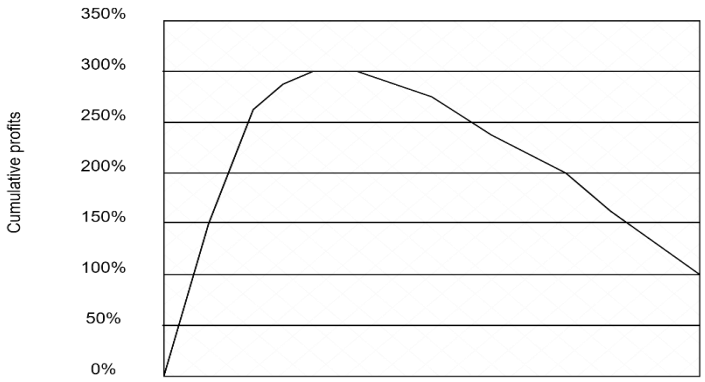

Figure 3. Whale curve of cumulative profitability (Sievänen et al., 2004).

As illustrated in Figure 3, the most profitable 20% of products often generate over 100% of total profits, while the least profitable ones reduce overall profitability. This pattern is most visible in industries with high indirect costs and broad product diversity, precisely the type of environment for which ABC systems are most suitable (Kaplan & Atkinson, 1998). Sievänen et al. (2004) demonstrated this empirically in a Finnish industrial case study, where the introduction of an ABC model revealed significant variation in product profitability. The study found that main components generated most of the profits, while customized end products often operated at a loss due to high product-sustaining costs and declining production volumes. These findings highlight how ABC enhances cost visibility by uncovering structural inefficiencies hidden within direct costing systems. It provides managers with a clearer view of resource consumption across four activity levels including unit, batch, product-sustaining and facility-sustaining.

In practice, ABC-based profitability analysis enables firms to identify unprofitable products and undertake corrective actions including process redesign, resource reallocation or discontinuation of low-value product lines (Kaplan & Cooper, 1998). However, effective profitability evaluation also depends on complementary tools that connect cost information with operational performance (Drury & Tayles, 2006). One widely used approach is Cost-Volume-Profit (CVP) analysis, which estimates how changes in production volume, unit price, or variable cost affect profit levels. According to Drury & Tayles (2006), CVP analysis helps determine contribution margins and break-even points, allowing firms to assess how sensitive profitability is to changes in operational activity. Ebe et al. (2020) similarly observed that CVP analysis is useful for evaluating product profitability and its effect on overall firm performance in manufacturing firms. The analysis involves companies to calculate contribution margin of the products by subtracting variable costs from revenues and then determing profits by deducting fixed costs from contribution margin (Choo & Tan, 2011). Through CVP analysis, companies can identify their most profitable products and can gain insights regarding their underlying cost structures that affect profitability. A visualisation CVP analysis method is presented in the Figure 4.

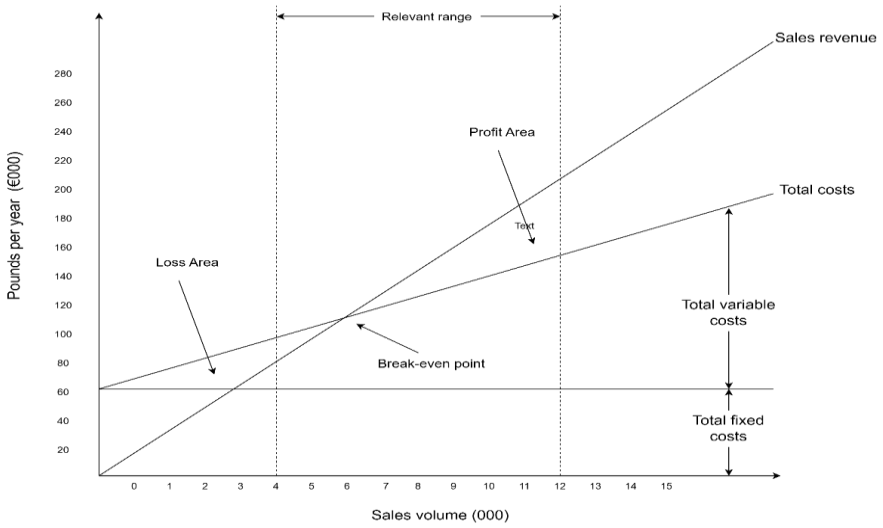

Figure 4. Break-even chart (Drury, 2021).

Figure 4 illustrates the relationship between cost, volume, and profit at different activity levels. The horizontal axis represents sales volume, while the vertical axis represents costs and revenues in monetary terms. The total cost line begins at fixed costs and increases with production volume, while the total revenue line starts at the origin and

rises proportionally with sales. The break-even point occurs where total revenue equals total cost. At this point, no profit or loss is made. To the left of the break-even point, the firm incurs a loss because costs exceed revenue. To the right, the firm earns a profit because revenue exceeds costs. The margin of safety shows how much sales can fall before the firm reaches break-even again. This type of visualization helps management assess the impact of changes in price, cost or volume on profitability. While CVP assumes linear cost behavior, ABC overcomes this limitation by identifying nonlinear cost drivers, making the two frameworks complementary (Drury & Tayles, 2006; Horngren et al., 2014; Kaplan & Cooper, 1998). Together, ABC and CVP analysis enhance profitability evaluation by combining structural cost allocation with dynamic scenario assessment. Building on this, recent developments in management accounting further emphasise how crucial accurate cost information is for understanding product-level profitability.

Drury and Tayles (2006) emphasize that accurate cost information is fundamental for profitability analysis, as product costing enables firms to measure profitability across cost objects from the product level to the business unit level. Traditional costing methods often generate distorted results, whereas ABC provides a more accurate basis for profitability measurement by tracing costs through the activities that actually consume resources.

Recent developments in management accounting continue to emphasize the importance of accurate cost information in evaluating product-level profitability. The accuracy of profitability analysis depends largely on the costing system used, as it determines how both direct and indirect costs are traced to products (Drury & Tayles, 2006; Kaplan & Cooper, 1998). ABC has consistently been shown to produce more reliable and detailed cost information than traditional costing, as it allocates overheads according to activity usage rather than arbitrary measures (Horngren et al., 2014). Empirical studies by Namazi (2016) and Öker & Adigüzel (2016), support this view, showing that activity-based systems enhance the precision of cost allocation and improve managerial understanding of profitability formation. Consequently, adopting ABC enables firms to identify inefficiencies and make more informed decisions on pricing, product design or process improvements, which are the key aspects in achieving sustainable profitability. While these insights apply broadly across industries, they are particularly relevant in agricultural and greenhouse settings, where cost behaviour is strongly shaped by environmental and operational conditions.

In agricultural and greenhouse production environments, profitability analysis must also capture the influence of environmental and operational variables on resource consumption (Drury & Tayles, 2006; Maraveas et al., 2023; Sievänen et al., 2004). Greenhouses depend heavily on controlled climate systems, including heating, lighting and irrigation, which create cost behaviour that varies by season, crop type and production stage. These characteristics make it difficult for traditional costing systems to reflect the real drivers of overhead consumption. ABC is well suited for this context because it uses measurable, crop-specific activity drivers such as area occupied, heating hours, labour effort or machine time (Maraveas et al., 2023; Sievänen et al., 2004). By integrating such operational realities into the costing model, ABC provides a more precise representation of product-level resource utilization and supports the identification of inefficiencies that reduce profitability (Drury & Tayles, 2006; Horngren et al., 2014; Kaplan & Cooper, 1998). Such integration is especially valuable in greenhouse farming, where costs are highly sensitive to environmental conditions and seasonal variability.

From a broader strategic perspective, ABC's ability to represent complexity and variability in production aligns with broader research connecting product complexity and managerial control to improved profitability (Drury & Tayles, 2006; Jelvezan et al., 2025; Kaplan & Cooper, 1998). Firms that effectively measure and manage operational complexity tend to achieve higher margins and maintain competitive advantage (Jelvezan et al., 2025; Kaplan & Cooper, 1998). By tracing costs through activities rather than broad cost centres, ABC provides a stronger analytical foundation for understanding how different workflows, technologies, and resource patterns influence financial performance. When ABC is combined with product-level profitability analysis (PLP) and complementary tools such as CVP analysis, managers gain a more complete view of cost behaviour. This helps them identify inefficiencies, redesign processes and evaluate the financial impact of operational decisions more accurately.

In greenhouse production, this integrated approach becomes especially meaningful because profitability is highly sensitive to environmental control costs. Activity-based insights can reveal opportunities to reduce energy consumption, minimise waste or improve labour efficiency, factors that matter greatly in settings where heating, lighting, and weather variation affect margins (Maraveas et al., 2023; Paris et al., 2022). Recent management accounting studies also show that combining operational data with financial indicators strengthens competitiveness and supports continuous improvement (Baxadirovna 2025; Nguyen et al., 2019). As a result, modern profitability analysis does

more than measuring cost efficiency, as it reflects how well an organisation understands and manages the underlying complexity of its production processes.

Ultimately, this accuracy is especially important in greenhouse farming, where profitability depends not only on labour and materials but also on environmental and operational factors such as climate control, irrigation, and seasonal changes (Maraveas et al., 2023; Paris et al., 2022). By using activity drivers that represent real patterns of resource use, ABC provides a more realistic picture of product-level cost behaviour. This helps managers identify inefficiencies and make better-informed decisions about pricing, crop selection, production planning and process improvement (Sievänen et al., 2004).

Taken together, ABC and profitability analysis provide a detailed and realistic view of how resources are consumed and how profits are formed across different crops. This is particularly important in greenhouse operations, where cost behaviour is shaped by shared processes and environmental requirements. Based on these ideas, the following section introduces the theoretical framework used in this study, outlining how cost information moves through inputs, activities and profitability evaluation to support managerial decision-making and continous improvement in greenhouse production systems.

2.5 Theoretical Framework of the Study

The theoretical framework of this study integrates the main principles discussed in the previous sections into a comprehensive model for analyzing cost behavior and product profitability in greenhouse farming. It demonstrates how cost information derived from both direct costing and ABC can be transformed into actionable insights that support managerial decision-making. Essentially, the framework represents the process through which operational data are converted into financial knowledge, enabling managers to detect inefficiencies, allocate resources more effectively, and improve profitability. The full structure of the framework is illustrated in Figure 5 below.

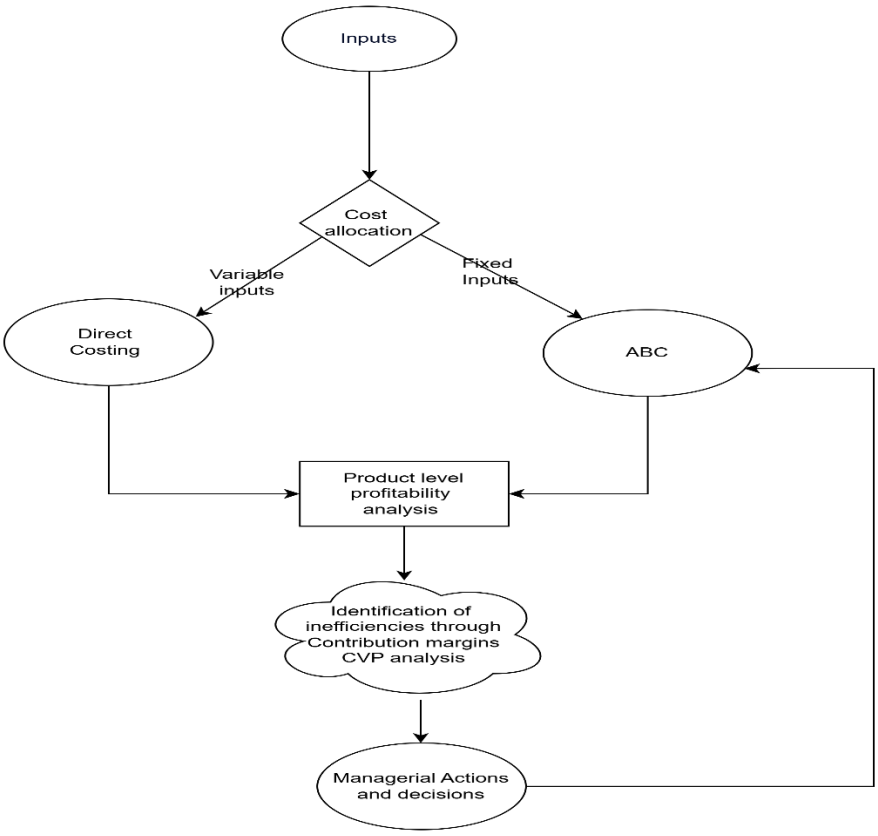

Figure 5. Theoretical framework integrating direct costing, ABC, and product profitability analysis in greenhouse farming.

The process begins with the Inputs, which represents all measurable resources used in greenhouse production. These include materials, labor and energy which together form the basis for accurate cost measurement (Horngren et al., 2014). These inputs include variable resources like seeds, fertilizers, growing media and packaging, as well as shared or support resources such as heating, maintenance and supervision. Because greenhouse production involves both variable and indirect costs, a single costing approach cannot accurately capture true behavior of total costs (Drury & Tayles, 2006; Sievänen et al., 2004).

The next element, cost allocation, functions as the important decision point within the framework. At this stage, resource costs are seperated and analyzed through two different paths. The first path applies direct costing, which traces variable costs directly associated with individual products, thereby enabling the calculation of contribution margins and short-term profitability. The second path applies ABC, which allocates indirect or overhead costs to specific operational activities such as propagation, planting,

harvesting and packaging. In this method, resource consumption is assigned through cost drivers such as labor hours, equipment time or cultivated area (Kaplan & Cooper, 1998).

Outputs from both costing paths converge at product-level profitability analysis stage, where direct and activity-based cost data are combined to evaluate each crop's financial contribution. At this point, the analysis is supported by two complementary approaches, where analytical methods such as CVP analysis work alongside visualisation tools such as the whale curve. CVP analysis helps quantify contribution margins and assess how sensitive profits are to changes in costs, prices or production volume, while the whale curve provides a graphical illustration of cumulative profitability across products (Sievänen et al., 2004). This analysis supports the identification of inefficiencies, where energy-intensive operations, underperforming product lines or capacity imbalances are detected and prioritized for corrective actions (Drury & Tayles, 2006; Kaplan & Cooper, 1998).

The final element, managerial actions and decisions represents the point where profitability insights are translated into operational strategies. Based on the information generated through direct costing, ABC, and CVP analysis, managers can implement actions such as process redesign, crop selection adjustments, energy optimization or automation investments. Linking ABC-based cost transparency with profitability analysis ensures that these interventions are data-driven and aligned with both short-term financial goals and long-term sustainability goals. Empirical research shows that integrating management accounting practices into decision making processes enhances organizational performance, adaptability, and resource efficiency (Baxadirovna, 2025).

Importantly, these managerial actions create a feedback loop that directly influences future production inputs, by adjusting energy usage, refining labor allocation or changing material requirements, which restarts the cycle of cost measurement and profitability evaluation. This iterative structure emphasizes continuous improvement and learning within the greenhouse production system.

Table 1 summarizes the theoretical framework illustrated in Figure 5, outlining how resource inputs flow through two costing systems, to generate product-level profitability insights and support managerial decisions. Each component contributes to transforming operational data into actionable financial knowledge. Ultimately, the framework highlights how continuous feedback between costing accuracy and managerial action fosters ongoing efficiency improvement and sustained profitability across production cycles.

Table 1. Summary of Theoretical Framework Integrating Direct Costing, ABC, and Product-Level Profitability Analysis.

Framework component	Function	Examples in greenhouse context
Inputs	Identify all measurable production resources forming the basis for cost determination	Seeds, fertilizers, electricity, heating, growing media
Cost allocation	Divide resources into variable and indirect categories for further analysis.	Separating heating and packaging costs between product lines.
Direct costing	Trace variable costs directly to products.	Determining fertilizer and packaging cost per herb type to assess short-term profitability
ABC	Allocate indirect and shared costs to activities based on resource drivers and then to products using activity drivers.	Allocating heating to to cultivation to products
Product-level profitability analysis	Integrate direct and activity-based cost data to measure profitability by product or crop.	Comparing profitability of salad vs. herb based on energy and labor usage.
Identification of inefficiencies	Detect low-margin or energy-intensive activities that reduce total profit.	Identifying high energy use during winter heating as a cost driver lowering margins.
Managerial actions and decisions	Translate profitability insights into operational or strategic changes.	Adjusting lighting schedules or automating irrigation to reduce cost per unit.
Feedback loop (continuous improvement)	Feed managerial outcomes back into input and costing stages to refine operations.	Results from optimized heating and automation inform the next costing cycle, reducing overheads and continuously improving efficiency.

3. METHODOLOGY

3.1 Research approach and design

This section outlines the methodological choices made in this study. According to Saunders et al. (2023) research design plays a crucial role in guiding strategic decisions regarding methodology, time frame and data collection. The selection of an appropriate research strategy depends on several factors, including the nature of the research questions, existing theoretical knowledge and the time and resources available (Saunders et al., 2023).

Saunders et al (2023) introduced the well-known “research onion” framework, which explains how research philosophies and approaches can be structured systematically. Each layer of the onion represents a deeper stage of methodological decision-making, progressing from broad philosophical choices to specific techniques. This layered structure allows researchers to follow a logical and progressive pathway toward selecting the most suitable research design for their study, which is illustrated in the following figure.

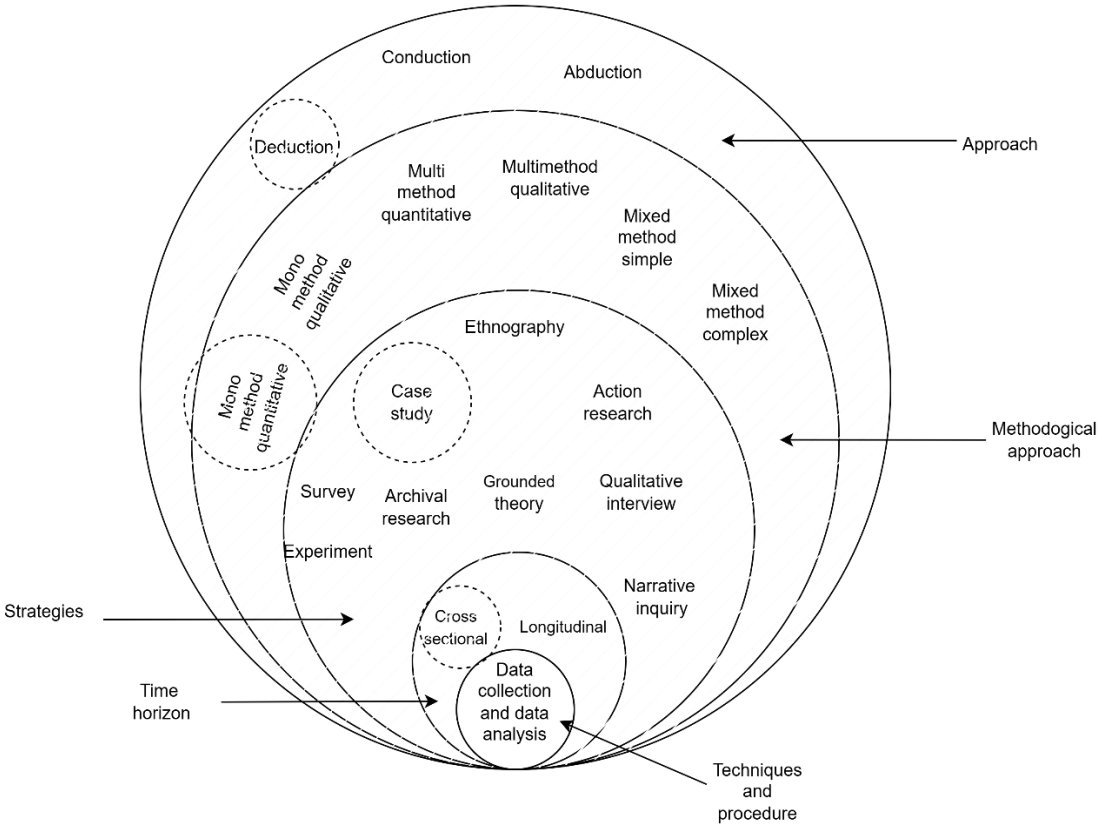

Figure 6. Research Onion (modified from Saunders, et al., 2023).

Figure 6 presents the adjusted version of the research onion used in this study, based on Saunders et al. (2009) and the circulated dotted sections of the figure highlight the elements of the onion that correspond to the design of the empirical component of this thesis.

This research follows a mono-method quantitative approach, meaning that all empirical evidence is derived from numerical and operational data. The analysis relies on cost information produced through the ABC and direct costing models, including activity cost allocations, cost driver quantities and product-level profitability results. The choice of a quantitative strategy is appropriate because the study focuses on measurable financial and operational indicators and aims to evaluate cost behaviour through objective calculations (Saunders et al., 2023).

This study adopts a deductive research approach, progressing from established theories toward empirical testing. According to Casula et al. (2021) deductive reasoning begins with theoretical concepts and evaluates their applicability through data. In this thesis, the theoretical principles of direct costing and ABC provide the foundation for constructing the hybrid cost model, which is then applied to the case company's data to examine how well these approaches explain cost behaviour in a greenhouse context. The deductive approach is well suited to quantitative studies, as it emphasizes hypothesis testing, objectivity and measurable outcome (Saunders et al., 2023).

A cross-sectional time horizon is used, as the data represent a single, well-defined operational period rather than multiple years. Even though cost allocation and continuous improvement concepts can be iterative in nature, the empirical analysis in this study examines one production period only. Cross-sectional designs are appropriate when the objective is to describe and analyse relationships within one point in time rather than observe long-term changes (Saunders et al., 2023).

The study employs a single case study strategy to analyse the cost structure of a Nordic greenhouse enterprise. Although case studies are often associated with qualitative research, Yin (2018) emphasises that quantitative case studies are equally valid when the aim is to analyse numerical performance data within a real organisational setting. This strategy allows the researcher to investigate ABC and direct costing in the specific context of controlled-environment agriculture, where cost behaviour is complex and highly dependent on environmental and operational factors. As Gustafsson (2017) notes, case studies are well suited for capturing how processes function in practice, especially when the process cannot be separated from their real-life context.

3.2 Case Selection and Context

The case company was purposefully selected to enable an in-depth examination of cost management practices and the implementation of operational efficiency initiatives to improve overall profitability, in a continuos improvement framework. As Saunders et al. (2023), case selection must ensure alignment between the research objectives and the organizational setting to allow meaningful exploration of the studied phenomena. The selected company provides a relevant context where enhancing cost visibility, eliminating process inefficiencies and improving value creation are key strategic goals. This environment offers an excellent opportunity to study how quantitative cost analysis and continuous improvement practices can together strengthen financial and operational performance

Harvest house Oy is a Nordic family-owned company recognized for its well-established brand, which ranks among the top brands in some Nordic countries in terms of revenue. The company provides consumers with clean and fresh salads and herbs throughout the year, maintaining a strong commitment to innovation. The company employs about 200 full-time professionals dedicated to the production and development of products. In 202X Harvest house Oy expanded its operations by establishing a fully controlled, multilayer cultivation, where young leaves are grown in vertical layers under LED lighting. In addition to this advanced cultivation site, the company operates a traditional greenhouse production facility, where 16 types of different products have been selling to the Nordic retail market.

The focus of this study is the main greenhouse facility, where the integrated ABC and direct costing framework is applied to assess product-level profitability and support continuous improvement. Despite its strong operational foundation, the company faced several challenges related to cost visibility and profitability measurement across 16 products sold to retail customers. Management saw the possibility to improve the understanding concerning which activities consumed the most resources, as the existing costing system relied on traditional absorption costing. In this system, overheads were allocated uniformly across all products, leading to inaccurate cost information and difficulty identifying unprofitable items. The company representative stressed that it was important to know product level profitability of the products, to know how each product contributes to the overall profit of the company.

To address these issues, the study was structured in two stages. First, ABC was implemented to trace indirect costs to specific activities based on measurable cost

drivers, thereby identifying the most resource-intensive operations. Second, direct costing was used to separate variable costs and calculate contribution margins for each of the 16 products. Combining these two methods allowed for precise measurement of total and product-level profitability, as well as the identification of cost behaviors across different activities.

The company also recognized the importance of continuous improvement as part of its long-term strategy. Production processes might occasionally experienced inefficiencies such as idle time, excess material usage or overlapping work tasks. They represented areas where better coordination and cost awareness could enhance efficiency. By linking ABC results with a continuous improvement framework, managers could prioritize critical activities where cost reductions would have the highest financial impact. This structured approach allows the organization to focus on process refinement, data-driven decision-making and sustainable profitability growth.

Given these conditions, Harvest house Oy presents an ideal setting for studying how the integration of ABC and direct costing, supported by a continuous improvement framework, can enhance cost efficiency and operational performance. The company's commitment to transparency, sustainability and performance improvement makes it a strong case for exploring how systematic cost analysis can guide managerial actions and contribute to long-term competitiveness in controlled-environment agriculture.

3.3 Data collection methods

The data collection approach adopted in this study was quantitative in nature, focusing on measurable organizational data to support the analysis of cost behavior, product profitability and operational efficiency. Quantitative research is used to test objective theories by examining the relationships among variables and analyzing numerical data, with the aim of producing generalizable insights (Saunders et al., 2023). Accordingly, this study relied primarily on numerical data drawn from the company's financial statements, budgets, and operational records, supplemented by limited, contextual inputs from field observations and process documentation to enhance interpretive accuracy. Such a mixed but quantitatively dominant approach is often recommended in applied management research to balance analytical precision with contextual understanding (Bryman, 2016). The sources provided comprehensive numerical information essential for performing ABC, direct costing and Product-Level Profitability (PLP).

The data collection process began with a field visit to the case company's greenhouse facilities, conducted to develop an initial understanding of production stages and related activities. This groundwork was essential in defining the scope of the cost analysis and ensuring that subsequent quantitative data accurately reflected operational conditions. Field observations provided insights into how resources such as labor, materials and energy were consumed across stages like sowing, cultivation, harvesting and packing. As Robson & McCartan (2016) note, such groundwork enhances the ecological validity of quantitative research by anchoring numerical models in real-world operational environments.

After the initial observations, financial and accounting data were collected from the company's internal budgeting and reporting systems. These datasets included actual and budgeted financial statements, which detailed expenditure categories such as direct labor, energy, materials and overheads. This information was critical for identifying cost types and resource pools within the ABC framework. According to Drury (2021), Implementing ABC requires a comprehensive examination of the organization's financial statements and budgetary data to accurately trace resource expenditures to activities and cost objects. In practice, this involved identifying key overheads and verifying their treatment through follow-up emails with the company representative. It clarified cost classifications and the specific activities to which expenses such as heating, maintenance or depreciation were assigned.

Subsequent to financial data collection, periodic discussions with the company representative helped to validate the selection of resource and activity drivers in the cost model. This iterative communication ensured that all selected drivers were quantifiable, logically linked to resource consumption and aligned with operational realities. The numerical quantities of each driver (e.g., labor hours, square meter-days, tray-days) were provided by the company and later used to allocate resource costs to activities and products in the ABC model. Engaging company personnel in the validation of driver selection is consistent with good ABC practice, as it ensures alignment between managerial understanding and analytical modeling (Ríos-Manríquez et al., 2014). As mentioned elsewhere, a lack of communication and participation from managers and staff is one of the main reasons why many ABC initiatives fail (Kaplan & Cooper, 1998; Ríos-Manríquez et al., 2014).

In addition, process charts and flow diagrams were obtained from the company to visualize the operational sequence and structure of activities. These documents helped identify and define the distinct cost-bearing activities involved in greenhouse production,

ensuring that the cost model captured the full range of processes influencing resource utilization.

While the study aimed to ensure accuracy and reliability through triangulated data sources, certain quantitative inputs, particularly estimates of driver quantities and resource usage, relied on the professional judgment of the company representative. This reliance on managerial estimates is common in applied cost analysis, especially when precise operational measurements are unavailable (Drury & Tayles, 2006). Therefore, the results of this study should be interpreted as representative rather than absolute, reflecting the company's best-informed assessment of activity-level cost behavior.

Overall, the combination of financial records, operational data, field observations, and company documentation formed the empirical foundation for the study's quantitative analysis. The field visit and ongoing collaboration ensured that cost relationships were correctly interpreted and aligned with practical realities. The integrated flow of these data sources is illustrated in Table 2 which depicts how financial inputs and operational drivers were combined through direct costing and to derive product-level profitability and support continuous improvement within the greenhouse production system.

Table 2. summary of the collected data sources, their types, and analytical purposes.

Data source	Type	Example variables	Purpose in analysis
Financial statements and budgets	Quantitative	Overheads, labour	Identify cost types, define resource pools, and allocate costs
Operational records (production logs, driver data)	Quantitative	Labor hours, m²-days	Determine activity and resource drivers for ABC and to execute direct costing models
Process charts and flow diagrams	Documentary (supporting)	Activity sequences, process times	Identify and structure production activities
Field visit, meetings, and email correspondence	Contextual (supporting)	Cost classification, driver validation	Ensure accurate, contextual understanding of processes and cost linkages

3.4 Data processing and model development

3.4.1 Data Processing

The raw financial, operational and process data obtained from the company were systematically cleaned, organized and standardized to ensure accuracy and consistency before proceeding to model development. The first step involved data screening, where financial entries and operational records were examined for completeness and internal consistency. During this stage, discrepancies such as missing cost items, duplicated figures and translation differences between country-specific documentation and English documentation were identified and corrected. This stage followed the principle that reliable analysis requires accurate and verifiable input data, which Robson & McCartan (2016) describe as essential for maintaining the validity of real-world research.

During this process, particular attention was required to understand and interpret accounting terminology specific to the local context, such as localized payroll or benefit related entries. These items were carefully examined to ensure they were correctly translated and classified to recognized overhead categories. This step was important for preserving the integrity of the cost mapping, as any misunderstanding or mistranslation could have led to misallocation of expenses across cost pools or incorrect classification between direct and indirect costs.

Once the initial screening was completed, data classification was performed to organize all expenditures according to their nature and traceability. Costs were grouped into categories as direct costs, production overheads, and administrative and support functions, in line with the ABC guidelines proposed by Kaplan & Cooper (1998). This classification made it possible to the identify resource cost pools and clarified which costs would flow directly to products through direct costing and which would be allocated through activities through ABC.

The next phase involved data normalization, which focused on ensuring consistency and comparability across the multiple data sources. Since the company’s financial statements and operational logs already reported figures for a complete annual production cycle, no temporal extrapolation or adjustment was necessary. Instead, normalization centered on aligning units of measurement and confirming that all cost and driver quantities corresponded to the same operational period. This verification was

conducted collaboratively with the company representative to enhance internal consistency. According to Dierks & Cokins (2000) normalization is essential to ensure that cost drivers accurately represent consistent and realistic patterns of resource consumption rather than short-term operational variations.

Following normalization, integration of data sources was carried out to consolidate the various sources into a single structured dataset. Information from financial statements, departmental budgets, process flow charts and communication records was merged using microsoft excel and word. This allowed cross-referencing of financial and operational information to verify linkages between resource expenditures, activities and products.

The final step involved verification of the compiled dataset, carried out collaboratively with the company representative. Each cost item was reviewed to confirm its correct assignment to a resource pool and corresponding activity. However, there was limited interaction with the company representative during this phase, which meant that some validation had to rely on available documentation and previously established driver estimates rather than continuous managerial feedback. This limitation was acknowledged in interpreting the results to maintain transparency regarding potential uncertainties in the final cost allocations.

3.4.2 Cost Pool Definition

After the financial data had been processed and validated, the next stage involved defining resource cost pools to establish the structure for allocation within the costing model. In the context of ABC, cost pools functions as intermediate categories that group together resources sharing similar cost behavior and functional purpose, thereby providing a more accurate representation of how resources are consumed by activities (Kaplan & Cooper, 1998). Accordingly, the company's expenditure accounts were reviewed and reorganized into internally homogeneous pools such as labor, energy, materials and supplies, maintenance, depreciation and administrative support. Each pool aggregated costs that were influenced by a common driver and subject to similar managerial control, which is essential for maintaining causal accuracy in ABC modeling (Dierks & Cokins, 2000).

The classification of these cost pools was informed by both financial documentation and operational understanding of how resources were utilized across different stages of greenhouse production. For example, Monthly production salaries were grouped as a distinct overhead category, representing fixed personnel expenses for permanent staff

involved in supervision tasks. These costs differ from direct labour, which is assigned separately under direct costing, as they remain relatively unchanged regardless of production volume. Machinery expenses included depreciation and maintenance costs of equipment used in production processes, such as packing and labelling machines. Facility costs referred to expenditures incurred in maintaining production premises, including greenhouse property maintenance, rents and lease payments. Likewise, support service salaries represented personnel costs for administrative, supervisory and other assisting functions that indirectly support the main production flow.

Each resource cost pool was then linked to a resource driver, a measurable factor that reflects how the resource cost is incurred by different activities. These drivers inlcuded, for example, % of staff time for Research and development expenses and square meters (m^2) for electricity. The selection of these drivers followed the ABC principles of causality and measurability, ensuring that each metric accurately represented the relationship between the resource and the activities it supported (Dierks & Cokins, 2000; Kaplan & Cooper, 1998).

To maintaining internal consistency, the composition of each cost pool was verified against company records, where possible, validated with the representative. However, because interaction during this phase was limited, certain allocations had to rely on informed estimates derived from existing operational data. As a result, there remains a possibility that some resource costs may have been partially misclassified between cost groups, particularly where documentation lacked sufficient detail or managerial clarification. These uncertainties were acknowledged and carefully documented to maintain transparency in the model's interpretation and to ensure that such limitations did not materially affect the overall cost-behavior analysis.

3.4.3 Driver Selection and Quantification

Once the cost pools were defined, the next step involved identifying and quantifying appropriate drivers to allocate resource and activity costs to cost objects. In ABC, cost drivers form the causal link between resources, activities and final products, ensuring that cost allocation accurately represents operational reality (Kaplan & Cooper, 1998). Accordingly, both resource drivers and activity drivers were selected based on their ability to represent measurable and traceable patterns of resource consumption (Kaplan & Cooper, 1991).

The selection process followed three main criteria, which are, causality, measurability, and data availability (Dierks & Cokins, 2000). Causality ensured that each driver

genuinely influenced the level of cost incurred; measurability required that it could be quantified reliably; and data availability determined whether the company's existing records provided sufficient detail for reliable estimation (Horngren et al., 2014; Kaplan & Cooper, 1998). For instance, electricity expenses were allocated using square meters (m^2) of greenhouse area, as electricity consumption was primarily related to the size of the cultivation zones, Similarly, machinery expenses were distributed according to the number of machines assigned to each production section, as recorded in the company's management system.

For activities directly related to production, such as planting, cultivation, harvesting and packaging, specific activity drivers were determined to reflect how each process contributed to product-level costs. Examples included number of trays seeded for sowing, square meter-days for cultivation, and labour hours for harvesting. In some cases, particularly during cultivation, a single-variable driver was insufficient to capture the real cost behavior. Therefore, hybrid drivers such as $m^2 \times$ days were used to reflect the combined influence of cultivated area and time duration on energy and labor utilization (Kaplan & Cooper, 1998).

The quantification of drivers relied primarily on information provided by the company representative, who supplied detailed estimates for both resource and activity drivers, including energy usage, labour allocation and space utilization across various production stages. Where precise numerical data were unavailable, approximate quantities were derived from operational experience and validated through researcher-representative correspondence. In several cases, driver data were provided as percentage-based allocations, indicating the estimated share of total resources consumed by each activity. These proportions were based on the representative's best professional judgment and understanding of the production process. Although quantitative records were limited, such estimates are considered acceptable in applied ABC studies when grounded in consistent logic, transparently documented, and cross-checked for internal consistency (Dierks & Cokins, 2000; Kaplan & Cooper, 1998).

Finally, all driver quantities and percentages were organized in microsoft excel, forming a structured dataset that linked resource consumption to activity outputs. This dataset served as the foundation for subsequent cost rate calculations and activity-level cost allocation, providing a transparent and replicable basis for the quantitative analysis.

3.4.4 Model Construction

After defining the cost pools and identifying the relevant drivers, the next stage involved constructing the analytical costing model. The model was developed in microsoft excel, using a stepwise structure that linked resources to activities and activities to products through the selected drivers. This approach followed the standard ABC framework proposed by Kaplan & Cooper (1998) and the applied methodology demonstrated by Kabinlapat & Sutthachai (2017).

In the excel-based model, data tables were created to record cost pool totals, corresponding driver quantities and calculated cost driver rates. The allocation of resources to activities was performed using the following proportional equation adapted from Kabinlapat & Sutthachai (2017):

$$Activity\ cost = Consumption\ rate\ \times Allocated\ resource\ cost$$

Here, the consumption rate represents the proportion of each resource consumed by an activity, calculated from the ratio of activity driver quantity to the total driver quantity within the resource pool (Kabinlapat & Sutthachai, 2017). This ensured that each activity absorbed a proportionate share of resources according to its actual intensity of use (Kaplan & Cooper, 1998). Similarly, the activity to product allocation followed the same principle, where product-level costs were obtained by multiplying the activity cost rate by the activity driver quantity consumed by each product (Kabinlapat & Sutthachai, 2017). This two-stage allocation process provided a transparent and traceable link from resources to final cost objects.

Both direct costing and ABC principles were applied concurrently within the model. Direct costs including seeds, packaging materials and product-specific labor, were traced directly to products without intermediate allocation, following standard direct costing practice. In contrast, overhead and indirect expenses were distributed through the ABC framework (Kaplan & Cooper, 1998). This hybrid approach captured both variable and fixed cost behaviors, enhancing the precision of product-level profitability analysis and enabling a more accurate understanding of cost behavior across processes (Carli & Canavari, 2013; Kaplan & Cooper, 1998).

3.5 Product-Level Profitability Analysis

The final stage of the costing model focuses on the product-level profitability analysis, which evaluates how each crop contributes to the overall financial performance of the

greenhouse. By integrating results from direct costing and ABC, this step provides a detailed understanding of the cost structure and profitability differences among crops. As Kaplan & Cooper (1998) explains, ABC improves cost accuracy by tracing overhead resources to cost objects based on their actual activity consumption, thereby providing a more realistic basis for evaluating product profitability compared to traditional costing systems.

In the first stage, direct costs including seeds, fertilizers, packaging materials and direct labor were assigned directly to each crop. These costs were identified from production logs and procurement data, obtained with the assistance of the company representative. Because these costs vary proportionally with output, they represent the variable portion of the total production cost. This approach aligns with the principle of direct costing, in which only those costs directly attributable to a product are included in its unit cost (Drury & Tayles, 2006).

The second stage incorporates activity-based costs, which represent the indirect portion of production expenses. Overheads including heating, electricity, maintenance and administrative support were first grouped into activity cost pools. These activity costs were then allocated to crops based on suitable activity drivers such as cultivated area (m²), labour hours and sales volume, reflecting the relative resource consumption of each product (Kaplan & Cooper, 1998). This ensured that each crop absorbed its fair share of overheads based on operational reality rather than on arbitrary or volume-based allocations.

Once both cost components were determined, the total cost per crop was obtained by summing the direct and activity-based allocations. The resulting cost was then compared against the corresponding selling price to determine the gross margin and gross margin percentage, using following formula:

$$Gross\ Margin\ \% = \frac{Selling\ price - Unit\ cost}{Selling\ price} \times 100\%$$

The gross margin percentage provides a relative measure of profitability, enabling comparisons between crops with different price levels and production scales (Drury & Tayles, 2006; Horngren et al., 2014). This indicator helps identify high-margin and low-margin products, thereby supporting managerial decisions regarding pricing and product mix optimization (Kaplan & Cooper, 1998).

To facilitate further comparison among crops, the cost structure of each product was expressed as a percentage of its total cost, distinguishing between direct and activity-

based components. This relative breakdown made it possible to identify cost-intensive areas and to compare how resource usage patterns differ among products (Carli & Canavari, 2013; Kaplan & Cooper, 1998). The results were summarized through comparative tables and cost composition charts, allowing a visual comparison of cost distribution and profitability variations among different crops. Such visualizations improved managerial understanding of cost behavior and highlighted potential areas for process and efficiency improvements (Cooper & Kaplan, 1991).

To complement the product-level profitability calculations, two additional tools were incorporated into the analysis. First, the whale curve was constructed to visualise the cumulative profitability contribution of each crop after ranking them from the most to the least profitable. This allowed the study to observe whether the greenhouse followed the typical profit distribution pattern identified in earlier ABC studies, where a small number of products generate most of the total profit. Second, a CVP analysis was applied to one selected crop to examine how changes in volume, costs, and selling price affect its profit and break-even point. These tools were used to to present the profitability outcomes of the costing model in a more interpretable way. Their implementation followed directly from the cost results calculated through direct costing and ABC, and the numerical outputs of both the whale curve and CVP analysis are presented in Chapter 4.

4. RESULTS

4.1 Overview of Greenhouse cost structure

This section presents the overall cost structure of the greenhouse production system and summarizes how the total costs were classified, quantified and prepared for allocation within the ABC framework. The purpose is to provide a general picture of the main cost categories and their relative significance before proceeding to detailed activity-based costing and product-level analysis.

The total production costs were divided into direct costs and overheads. Direct costs included all expenses that could be traced specifically to individual crops without the need for further allocation. The main components included seeds, paper pots, peat, fertilizers, control costs, packaging materials, direct labour and transport. Each crop consumed these resources in different proportions depending on its volume, growth cycle and handling requirements.

To determine the total direct cost for each crop, the average unit cost was first calculated and then multiplied by the total number of units produced during the analysis period. This approach provided both per-unit and total cost values, allowing for direct comparison among crops with different production scales. Table 3 summarizes the results, which illustrates the distribution of direct costs per unit (EUR/unit) and the corresponding total cost contribution of each crop (EUR).

Table 3. Direct and variable cost components per unit and total direct cost by crop.

Crop	Seeds	Paper pot	Peat	Fertilizers	Control costs	Bags	Boxes	Cells	Labour	Transport	Direct cost per unit	Number of units	Total Direct costs
Pot salad A	0.0024	0.0191	0.0155	0.0073	0.0174	0.0238	0.0415	0.0277	0.229	0.053	0.4366	426,600	186,252.21
Pot salad B	0.0693	0.0166	0.0134	0.0109	0.0022	0.0302	0.0592	0.0276	0.291	0.080	0.6006	2339880	1,405,415.05
Pot salad C	0.0564	0.0174	0.0141	0.0102	0.0101	0.0242	0.0592	0.0277	0.186	0.080	0.4847	1,498,072	726,061.13
Pot salad D	0.0669	0.0216	0.0175	0.0089	0.0005	0.0244	0.0488	0.0277	0.317	0.053	0.5860	386,844	226,696.54
Pot salad E	0.0536	0.0166	0.0134	0.0118	0.0232	0.0226	0.0592	0.0276	0.256	0.080	0.5638	2,146,848	1,210,301.64
Pot salad F	0.1139	0.0182	0.0147	0.0124	0.0155	0.0241	0.0589	0.0275	0.339	0.080	0.7036	484,440	340,844.79
Pot herb A	0.0033	0.0152	0.0123	0.0039	0.0003	0.0299	0.0432	0.0275	0.150	0.053	0.3393	2,586,006	877,324.71
Pot herb B	0.0177	0.0160	0.0130	0.0048	0.0039	0.0302	0.0400	0.0275	0.149	0.053	0.3552	1,340,250	476,041.31
Pot herb C	0.0186	0.0168	0.0136	0.0014	0.0000	0.0265	0.0569	0.0276	0.170	0.053	0.3843	735,576	282,648.63
Pot herb D	0.0152	0.0160	0.0130	0.0048	0.0039	0.0265	0.0400	0.0275	0.127	0.054	0.3279	501810	164,543.50
Pot herb E	0.0029	0.0168	0.0136	0.0047	0.0022	0.0263	0.0567	0.0276	0.127	0.053	0.3310	401,988	133,038.67
Pot herb F	0.0079	0.0154	0.0125	0.0047	0.0022	0.0221	0.0568	0.0276	0.149	0.053	0.3510	1,877,826	659,025.23
POTherb G	0.0083	0.0154	0.0125	0.0032	0.0008	0.0302	0.0566	0.0275	0.159	0.053	0.3671	1,424,694	523,010.70
Bag salad A	0.0208	0.0523	0.0423	0.0032	0.0008	0.0305	0.0611	0.0000	0.552	0.080	0.8429	96,152	81,044.39
Bag salad B	0.0628	0.0194	0.0157	0.0102	0.0101	0.0306	0.0614	0.0000	0.288	0.080	0.5780	1,210,464	699,640.49
Bag salad C	0.0209	0.0173	0.0140	0.0097	0.0052	0.0301	0.0402	0.0000	0.225	0.053	0.4155	2,950,776	1,226,144.01

As shown in Table 3, labor represented the highest cost component per unit among all crops, accounting for the largest share (51% on average) of total direct expenses. It

indicates intensive manual effort required for cultivation and harvesting activities. Shipping and transport costs (13%) formed the second-largest component and they could be directly traced to individual products based on delivery records. Seeds contributed roughly of 6% for the total direct costs, followed by bags at around 5%. Paper pots accounted for an average of 4%, while cells represented 3.5% total direct costs. Similarly, peat contributed roughly by 3% while fertilizers represented 1.4%. Among the variable inputs, control costs represented lowest share (1.25%) of the total direct costs. These figures indicated that labor and shipping costs remain the most resource-demanding elements of production, whereas cells, peat and control costs are comparatively smaller and more stable resource inputs.

On the other hand, indirect costs included resources that were shared among several crops and therefore could not be readily linked to any single product. These expenses were first grouped into overhead cost pools, such as electricity, heat, machinery expenses, and research and development expenses. Table 4 presents the summarized overhead cost pools with their corresponding total costs and driver selected, forming the basis for the subsequent ABC allocation.

Table 4. Summary of overhead groups, included overheads, selected drivers, and total costs.

Overhead category	**Included Overheads**	**Driver selected**	**Total costs (EUR)**
Factory supplies	Repair supplies, tools, work clothes (both maintenance and production)	Number of labourers	340686
External services (outsourced)	Services, repairs and maintenance, other external services, waste management services, cleaning and maintenance	% of external service time	354792
Production salaries	Production services, monthly salaries (production), repair and maintenance	Number of staff	680321
Support service salaries	salaries (admin), wages for product	Number of staff	872146

	presenters, workclothes and protective gear		
Indirect employee costs (fringe benefits)	salary supplements and compensation, holiday pay, holiday return pay, change in holiday pay, day off, sick and maternity leave, sickness and insurance compensation, benefits, mileage allowance, Pension expenses, employer contributions, Accident insurance, Unemployment insurance, Group life insurance, social insurance payment, car benefits, phone benefits	Number of staff and labourers	966564
Machinery expenses	Machinery and equipment depreciation	Number of machines	758584
Training expenses	training services	Number of staff and labourers	15300
Facility costs	Facility rents, leasing rents, property maintenance and premises, yard maintenance, land lease, depreciation of owned buildings	% of floor area	695218
Planning	Planning and production	% of staff time	115262
Research and development expenses	Development activity costs	% of staff time	3000
Electricity expenses	Electricity	% of electricity consumption	1044901
Heat and fuel expenses	Fuel inventory movement, charged propane	% of floor area	741431

	fuel and electricity, heating plant fuel purchases, peat, heating oil, co2		
Office and other supplier expenses	Mobile data chargers, computer software, software services, office supplies, printing supplies, printed materials, files access rights	Number of staff	249832
Employee welfare expenses	Social facility supplies, aid supplies, coffee supplies, occupational health and care, Leisure and hobbies, staff events, entertainment expenses	Number of staff and labourers	186166
Machine and equipment rentals	Rentals paid to machines	% of machine utilisation	32594
Advising and expert services	Expert service costs, membership fees, auditing or consultation	% of area monitored	140440
Analysis costs	Analytical costs	% of analysed area	29357

As shown in Table 4, energy (electricity and heat) represented the largest overhead cost pools, together accounting for more than 25% of the total indirect expenses. Production and support services salaries (19%) formed the next significant categories, reflecting the labour intensity of daily greenhouse operations and the continuous need for monitoring, supervision and quality control. Research and development expenses contibuted to a smaller proportion of Indirect costs (0.04%), indicating that limited resources are currently devoted to innovation with the greenhouse.

Based on these cost groupings and selected drivers, the ABC model was developed to allocate indirect costs across activities and products. This stage transformed the summarized financial data into activity-level insights, enabling a clearer understanding of how resources were consumed within different production activities. The resulting allocations formed the basis for analyzing product-level profitability in the subsequent section.

4.2 Activity based costing model results

In the next stage of the analysis, the ABC model was implemented to trace overheads from shared resources to specific activities and crops. This step made it possible to see how indirect costs, such as energy, maintenance, and administrative support, were distributed throughout the production process. The outcomes of this allocation reveal the activities that consume the most resources and show the resulting indirect costs of each product.

Table 5 summarizes how resource costs were allocated to different activities based on their consumption rates and the corresponding proportion of total overheads. The table illustrates the distribution of indirect resources across major greenhouse processes and forms the basis for calculating activity driver rates in the next stage of the analysis. The consumption rates were derived by dividing each activity's driver quantity by the total driver quantity within the resource pool, allowing the model to assign costs proportionally to actual resource use.

Table 5. Resource cost allocation to activities through consumption rate analysis (certain columns are excluded due to confidentiality).

			1	2	3	4
No	Expense Categories		Administration	Planning and setup	Sowing	Germination
1	Factory supplies	Con. Rate			0.019108	0.012739
		Alloc. Cost			6509.924	4339.949
2	External services	Con. Rate			0.15	0.05
		Alloc. Cost			53218.8	17739.6
3	Production salaries	Con. Rate	0.5	0.133333	0.033333	0.033333
		Alloc. Cost	340160.5	90709.47	22677.37	22677.37
4	Support services salaries	Con. Rate	0.5	0.133333	0.033333	0.033333
		Alloc. Cost	436073	116286.1	29071.53	29071.53
5	Indirect employee costs (frienge)	Con. Rate	0.080214	0.02139	0.02139	0.016043
		Alloc. Cost	77531.87	20675.17	20675.17	15506.37
6	Machinery expenses	Con. Rate			0.28	0.04
		Alloc. Cost			212403.5	30343.36
7	Training costs	Con. Rate	0.080214	0.02139	0.02139	0.016043
		Alloc. Cost	1227.273	327.2727	327.2727	245.4545
8	Facility costs	Con. Rate	0.05	0.05	0.1	0.1
		Alloc. Cost	34760.9	34760.9	69521.8	69521.8
9	Planning expenses	Con. Rate	0.3	0.7		
		Alloc. Cost	34578.6	80683.4		
10	Research and development expenses	Con. Rate			0.1	0.1
		Alloc. Cost			300	300
11	Electricity expenses	Con. Rate			0.05	0.03
		Alloc. Cost			52245.05	31347.03
12	Heat and fuel expenses	Con. Rate			0.05	0.05
		Alloc. Cost			37071.55	37071.55
13	Office and other supply expenses	Con. Rate	0.5	0.133333	0.033333	0.033333
		Alloc. Cost	124916	33310.93	8327.733	8327.733
14	Employee welfare expenses	Con. Rate	0.080214	0.02139	0.02139	0.016043
		Alloc. Cost	14933.1	3982.16	3982.16	2986.62
15	Machine and equipment rentals	Con. Rate			0.05	
		Alloc. Cost			1629.7	
16	Advertising and Expert services	Con. Rate	0.05	0.05	0.1	0.1
		Alloc. Cost	7022	7022	14044	14044
17	Analysis costs	Con. Rate			0.1	0.15
		Alloc. Cost			2935.7	4403.55
	Total costs		1071203	387757.4	534941.3	287925.9
	Total amount of activity driver		20408226	18651228	18651228	18651228
	Activity rate (per unit)		0.052489	0.02079	0.028681	0.015437

The results in Table 5 show that the largest share of total resource costs was allocated to cultivation, followed by harvesting and manual packing and administration activities. Apart from the administrative activities, these stages require continuous operation of electricity, environmental heat control systems and workforce effort, which explains their dominant share of total overheads. In particular, cultivation was highly resource-intensive because of heating, ventilation and lighting demands maintained throughout the production cycle. Harvesting and manual packing also consumed a considerable proportion of costs, reflecting workforce effort and equipment use during crop collection and handling. By contrast, cooling, germination and storage absorbed relatively smaller portions of total resource costs, as these activities involve shorter operational periods and lower dependence on energy systems.

The next step of the analysis examined how each crop utilized the defined activities through measurable cost drivers. The activity-product dependence matrix summarizes the relative amount of each activity consumed by individual crops. This matrix provides an overview of how resource-intensive each crop is across the main greenhouse processes and supports the subsequent allocation of activity costs to products.

Table 6. Activity-Product Dependence Matrix showing the proportion of activities consumed by each crop (certain columns are excluded due to confidentiality).

No	Activities	Pot salad A	Pot salad B	Pot salad C	Pot salad D	Pot salad E	Pot salad F	Pot herb A
1	Administration	1	1	1	1	1	1	1
2	Planning and setup	0.901941	0.917364	0.860897	1.073172	0.94244	1.04757	0.893997
3	Sowing	0.901941	0.917364	0.860897	1.073172	0.94244	1.04757	0.893997
4	Germination	0.901941	0.917364	0.860897	1.073172	0.94244	1.04757	0.893997
5	Planting	0.846021	0.882504	0.829904	1.071025	0.860448	0.716538	0.893997
6	Cultivating	0.002637	0.001909	0.002487	0.002908	0.002603	0.003846	0.000994
7	Harvesting and manual packing	0.005968	0.005968	0.005968	0.005968	0.005968	0.005968	0.003953
8	Machine packing	0.001182	0.001182	0.001182	0.001182	0.001182	0.001182	0.001182
9	Cooling	0.083333	0.125	0.125	0.166667	0.125	0.125	0.083333
10	Storage	0.125	0.1875	0.1875	0.25	0.1875	0.1875	0.125
11	Dispatching	1	1	1	1	1	1	1

The results show that dependence on core production activities varied considerably across crops. Bag salad A had the highest reliance on cultivation and planting activities due to their greater energy requirements and their longer growth cycles. In contrast, pot herb G and pot herb E showed lower dependence on these activities respectively,

reflecting shorter growing durations and reduced energy use. All crops displayed similar levels of dispatching and administrative activity, as these stages are uniform across products. The variation in activity dependence confirms that indirect resources are not consumed evenly, emphasing the suitability of the ABC model for identifying product-level cost differences.

In the final stage of the ABC model, the activity driver rates and product consumption data were combined to calculate the total indirect costs for each crop. This step provided a clear breakdown of how much each activity contributed to the overall overhead absorbed by the different products. It also helped to show how variations in activity use across crops affected the final indirect cost of production.

Table 7.Allocation of activity costs and total indirect cost per product (certain columns are excluded due to confidentiality).

Activties	Products								
	Pot salad A			Pot salad B			Pot salad C		
	Activity rate	Activity consumption	cost	Activity rate	Activity consumption	cost	Activity rate	Activity consumption	cost
Administration	0.052489	1	0.052489	0.052489	1	0.052489	0.052489	1	0.052489
Planning and setup	0.02079	0.901940928	0.01875135	0.02079	0.917363711	0.019072	0.02079	0.860896539	0.017898
Sowing	0.028681	0.901940928	0.02586857	0.028681	0.917363711	0.026311	0.028681	0.860896539	0.024691
Germination	0.015437	0.901940928	0.01392326	0.015437	0.917363711	0.014161	0.015437	0.860896539	0.01329
Planting	0.022258	0.846020591	0.01883073	0.022258	0.88250389	0.019643	0.022258	0.829904264	0.018472
Cultivating	43.07923	0.002637131	0.11360556	43.07923	0.001908645	0.082223	43.07923	0.002487197	0.107147
Harvesting and manual packing	12.3222	0.00596758	0.07353372	12.3222	0.00596758	0.073534	12.3222	0.00596758	0.073534
Machine packing	14.13473	0.001182354	0.01671225	14.13473	0.001182354	0.016712	14.13473	0.001182354	0.016712
Cooling	0.083126	0.083333333	0.00692717	0.083126	0.125	0.010391	0.083126	0.125	0.010391
Storage	0.087218	0.125	0.01090225	0.087218	0.1875	0.016353	0.087218	0.1875	0.016353
Dispatching	0.029839	1	0.029839	0.029839	1	0.029839	0.029839	1	0.029839
Total indirect cost per unit			0.38138286			0.360728			0.380816

Table 7 shows how the total indirect costs were distributed across the main crops based on their activity rates and consumption levels. The results indicate that bag salad A had the highest overall indirect cost, indicating the crop required longer cultivation periods and more heating and lighting compared to the others. In contrast, pot herb A and pot herb G had lower indirect costs because of their shorter growing cycles and lower dependency on environmental control factors. Among the activities, cultivation accounted for the largest share of costs, followed by harvesting and manual packing, which also required labour input and equipment use. Overall, the results show that most overheads in greenhouse production come from energy and labour-intensive processes.

These results represent the final output of the ABC model and provide the total indirect cost for each product. This information is used in the next part of the analysis, where the focus shifts to examining product-level profitability and how these indirect costs affect overall performance.

4.3 Product level profitability analysis

After determining the total direct and indirect costs for each crop, the next step was to assess product-level profitability. This analysis combined the direct costs, obtained through the direct costing method and the indirect costs derived from the ABC model. Together, these figures provided the full cost per product, which was then compared with the selling price to calculate the gross margin and gross margin percentage.

Table 8. Summary of total cost, selling price, and gross margin per crop.

Crop	Direct cost	Indirect cost	Total cost	Selling price	Gross margin	Gross margin %
Pot salad A	0.4365968	0.381382856	0.8179797	0.84	0.022020302	3%
Pot salad B	0.6006355	0.36072806	0.96136358	0.89	-0.071363582	-8%
Pot salad C	0.4846637	0.3808157	0.86547941	1.07	0.20452059	19%
Pot salad D	0.5860154	0.427009925	1.01302531	0.88	-0.133025309	-15%
Pot salad E	0.5637575	0.391792195	0.95554969	1.04	0.084450314	8%
Pot salad F	0.7035851	0.448931322	1.15251647	1.23	0.077483533	6%
Pot herb A	0.3392586	0.286331664	0.62559024	0.76	0.134409762	18%
Pot herb B	0.3551884	0.312562351	0.66775079	0.76	0.092249208	12%
Pot herb C	0.3842548	0.329027924	0.71328276	0.8	0.086717243	11%
Pot herb D	0.3279	0.298128146	0.62602815	0.89	0.263971854	30%
Pot herb E	0.3309518	0.37384568	0.70479753	0.89	0.185202472	21%
Pot herb F	0.3509512	0.337234105	0.68818528	0.9	0.211814725	24%
Pot herb G	0.3671039	0.297347873	0.66445175	0.9	0.235548246	26%
Bag salad A	0.8428778	0.778378258	1.62125606	1.83	0.208743939	11%
Bag salad B	0.5779936	0.4141002	0.99209383	1.21	0.217906167	18%
Bag salad C	0.4155327	0.369829386	0.78536212	0.9	0.114637883	13%

Table 8 shows clear differences in profitability across the crops. The results indicate that Bag salad A and pot salad F had the highest overall costs, reflecting their high usage of direct costs and high energy use for heating and lighting. Although these crops were cost-intensive, their higher selling prices allowed them to remain profitable. In contrast, pot salad A had much lower production costs but also smaller margins, and in some cases, the selling prices were not sufficient to fully cover total costs, making them the non-profitable products in the analysis.

The gross margin percentages show that profitability does not necessarily depend only on total cost but also on how efficiently each product converts its resource use into value. For example, although Bag salad A had the highest total cost, it still achieved a solid gross margin because of its strong market price. In contrast, products like pot salad B

showed that comparatively low-cost items can still be un-profitable if their selling prices are proportionally lower.

To examine these profitability differences more systematically, the crops were next ranked according to their total profit. A summary table was prepared showing each crop's absolute profit, its percentage share of total profit, and the cumulative percentage as the products are added in descending order of profitability. Presenting the data in this way makes it easier to see how much each crop contributes to overall profitability of the company and provides the basis for constructing the whale curve.

Table 9. Whale curve table.

Crop	profit	profit % of the total	Cumulative %
Pot herb D	0.263972	14%	14%
Pot herb G	0.235548	12%	26%
Bag salad B	0.217906	11%	37%
Pot herb F	0.211815	11%	48%
Bag salad A	0.208744	11%	59%
Pot salad C	0.204521	11%	69%
Pot herb E	0.185202	10%	79%
Pot herb A	0.13441	7%	86%
Bag salad C	0.114638	6%	92%
Pot herb B	0.092249	5%	97%
Pot herb C	0.086717	4%	101%
Pot salad E	0.08445	4%	105%
Pot salad F	0.077484	4%	109%
Pot salad A	0.02202	1%	111%
Pot salad B	-0.07136	-4%	107%
Pot salad D	-0.13303	-7%	100%

The table shows that profitability is uneven across the product range. The most profitable crops account for a disproportionately large share of total profits, as reflected in their high individual profit percentages and the rapid rise in the cumulative percentage. In contrast, crops with lower profits add very little to the cumulative total, and in some cases reduce it if they are unprofitable. When plotted as a whale curve, this cumulative pattern becomes even clearer, highlighting a small group of high-performing products and a long tail of crops that contribute less to overall profitability.

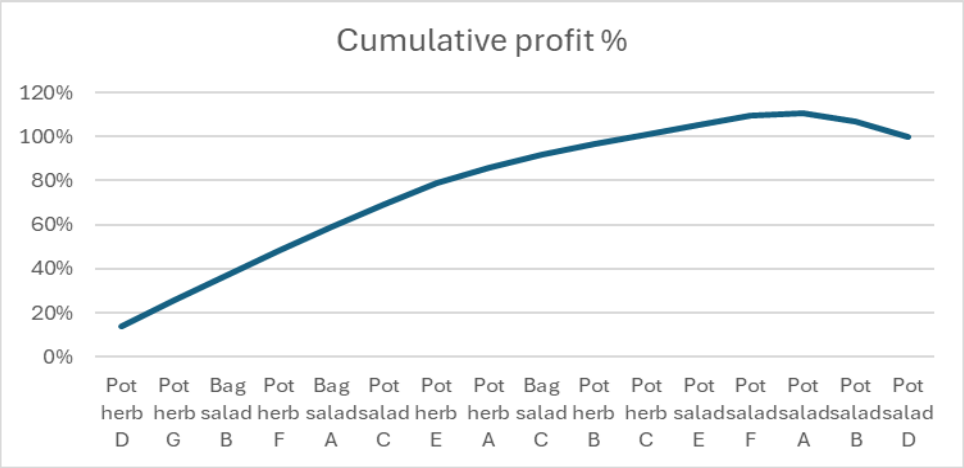

Figure 7. Whale curve graph.

The whale curve shows that profitability is concentrated in a few key crops. The sharp upward section at the beginning reflects high-performing products such as pot herb D, pot herb G, bag salad B, pot herb F, bag salad A, pot salad C, pot herb E, which together account for a substantial share of total profits. As more crops are added, the curve begins to flatten, indicating items like Pot herb A, bag salad C, pot herb C, that contribute only modestly to cumulative profitability. Toward the end of the curve, the downward slope reveals underperforming crops such as pot salad B and pot salad D, which reduce the cumulative profit due to their lower margins. This pattern demonstrates that not all crops convert resources into financial value equally and highlights the need to examine these weaker products more closely.

While the whale curve provides an overall view of how profits accumulate across the full product range, it does not show how individual crops behave as production volumes change. To examine this more closely, the next part of the analysis applies the CVP approach to pot salad B. Before constructing the CVP graph, a separate table was compiled summarizing the pot salad B's total revenue, total variable cost and the fixed-cost portion allocated through the ABC model, total cost and profit.

Table 10. Input data for CVP analysis.

Volume	Total revenue	Total variable cost	Total cost	profit	Fixed cost
0	0	0	844060.372	-844060.3719	844060.3719
100000	89000	53456.56128	897516.933	-808516.9332	844060.3719
200000	178000	106913.1226	950973.494	-772973.4945	844060.3719
300000	267000	160369.6838	1004430.06	-737430.0558	844060.3719
400000	356000	213826.2451	1057886.62	-701886.617	844060.3719
500000	445000	267282.8064	1111343.18	-666343.1783	844060.3719
600000	534000	320739.3677	1164799.74	-630799.7396	844060.3719
700000	623000	374195.929	1218256.3	-595256.3009	844060.3719
800000	712000	427652.4902	1271712.86	-559712.8622	844060.3719
900000	801000	481109.0515	1325169.42	-524169.4234	844060.3719
1000000	890000	534565.6128	1378625.98	-488625.9847	844060.3719
1100000	979000	588022.1741	1432082.55	-453082.546	844060.3719
1200000	1068000	641478.7354	1485539.11	-417539.1073	844060.3719
1300000	1157000	694935.2966	1538995.67	-381995.6686	844060.3719
1400000	1246000	748391.8579	1592452.23	-346452.2298	844060.3719
1500000	1335000	801848.4192	1645908.79	-310908.7911	844060.3719
1600000	1424000	855304.9805	1699365.35	-275365.3524	844060.3719
1700000	1513000	908761.5418	1752821.91	-239821.9137	844060.3719
1800000	1602000	962218.103	1806278.47	-204278.475	844060.3719
1900000	1691000	1015674.664	1859735.04	-168735.0362	844060.3719
2000000	1780000	1069131.226	1913191.6	-133191.5975	844060.3719
2100000	1869000	1122587.787	1966648.16	-97648.15881	844060.3719
2200000	1958000	1176044.348	2020104.72	-62104.72009	844060.3719
2300000	2047000	1229500.909	2073561.28	-26561.28137	844060.3719
2400000	2136000	1282957.471	2127017.84	8982.157353	844060.3719
2500000	2225000	1336414.032	2180474.4	44525.59607	844060.3719

The CVP table provides the key financial values needed to analyse how pot salad B behaves as production volume changes. By comparing total revenue with total variable cost, the table shows how much of the product's income is available to cover the fixed-cost portion allocated through the ABC model. Adding this fixed-cost component to the variable cost gives the total cost at each volume level, which is then compared against revenue to determine the profit or loss at that point. These figures make it possible to identify the break-even volume and evaluate whether the product can become profitable within a realistic production range. Based on these values, the following CVP graph illustrates how pot salad B's total revenue and total cost change as production volume increases.

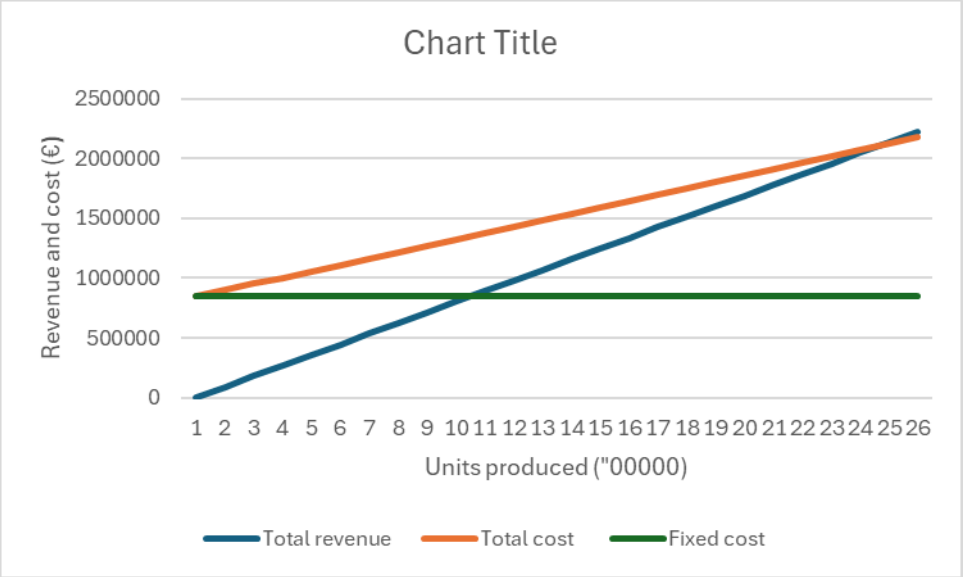

Figure 8. CVP curve for pot salad B.

The CVP graph illustrates the relationship between pot salad B's total revenue and total cost across different production volumes. The point where the two lines intersect represents the break-even level, which in this case occurs at approximately 2374729 units. At this volume, total revenue equals total cost. Below this point, the product results in a loss, while production levels above it generate a positive margin. The graph therefore demonstrates how pot salad B's profitability changes as output increases and provides a visual summary of its cost-volume relationship.

Overall, the results from the direct costing, ABC, product-level profitability calculations, and supporting visualisations such as the whale curve and CVP graph provide a detailed picture of how resources were consumed across the greenhouse production process and how these patterns translated into the total costs and profitability of each crop. The analysis revealed differences in both cost composition and activity usage among products, as well as variations in how indirect costs accumulated across stages such as sowing, cultivation, and harvesting. Together, these results establish the empirical foundation for assessing cost behaviour and profitability within the case company. In the following chapter, these findings are examined more closely to identify underlying causes, evaluate their implications for cost management, and discuss how the combined costing framework can support continuous improvement in greenhouse operations.

5. DISCUSSION AND CONCLUSION

5.1 Discussion of results

The results of this study reveal several important patterns in how costs behave within the greenhouse production system and how these patterns ultimately shape product-level profitability. One of the clearest findings was that direct costs were relatively high for nearly all crops. Seeds, peat, paper pots, packaging materials, direct labour and transportation together formed a substantial portion of total production costs. This reflects the material-intensive and hands on nature of the greenhouse processes, where each crop requires specific inputs and manual handling. Although earlier research often highlights the dominance of overheads in greenhouse cost structures (Paris et al., 2022; Wei et al., 2020), the case company showed that direct inputs remain a major cost driver. It is particularly for crops with dense planting requirements or particularly for crops that required intensive manual handling, where tasks such as harvesting and packaging took considerable labour time. In addition, shipping fees were directly traceble to the products, further contributing to the dominace of direct costs. However, the study also showed that direct costs alone did not fully explain differences in total product cost or profitability.

A clearer explanation emerged when analysing cost allocations through ABC. For instance, activities such as cultivation, harvesting and manual packing absorbed the majority of indirect resources. Cultivation showed a strong concentration of heating and electricity-related costs, which aligns with the findings of Maraveas et al. (2023), who noted that environmental control systems operate continuously during plant growth and therefore dominate overhead consumption in greenhouse farming. This observation reinforces Kaplan & Cooper's (1998) claim that overheads tend to accumulate in activities where capacity is tied up for extended durations.

Harvesting and labour packing also emerged as a relatively cost-intensive activity. This was expected, as harvesting and manual packing rely heavily on labour and repetitive handling, which are well-documented cost drivers in agricultural operations (Stašová, 2020). Crops requiring more time during harvesting and packing tended to accumulate higher production salaries and equipment usage costs.

When profitability was examined across the product portfolio, these cost behaviours became even more visible. The profitability ranking of crops showed a clear divide between high-margin and low-margin items, and even unprofitable products which even eat up cumulative profits. Some products generated strong gross margins because they

used energy and labour efficiently relative to their selling price, while others despite being popular or high-volume, reduced overall profitability due to heavy overhead absorption. This pattern closely reflects the findings of Sievänen et al. (2004), who also observed that only a small number of core products generated most of the profits, while energy-intensive or workforce-effort-intensive items reduced cumulative earnings.

The whale curve constructed in this study confirmed a similar trend. As in the classical Kanthal example by Kaplan & Atkinson (1998), a small subset of products contributed the majority of the greenhouse's total profit, while lower-performing products pushed the cumulative curve downward. This finding reinforces the importance of product mix decisions in environments characterised by high overhead intensity. The presence of unprofitable products in the case company suggests that certain crops may be using resources inefficiently relative to their revenue contribution, a challenge that Stašová (2020) also identified in Slovak agricultural enterprises.

The CVP analysis offered an additional perspective by illustrating how profitability for pot salad B, which was deemed to be an unprofitable product based on gross margin, changes at different production volumes. The break-even volume was relatively high, indicating that for the product to become profitable at reasonable sales volumes, either production efficiency would need to improve or the selling price would need to be increased. This interpretation aligns with Drury & Tayles (2006), who note that in overhead-intensive systems products often require higher output levels before covering their allocated fixed costs. The CVP results confirmed that maintaining adequate production volume is essential for covering fixed costs and sustaining profitability.

Taken together, the results show that the hybrid direct costing and ABC model offered insights that would not have been visible under traditional costing. Direct costing highlighted crop-specific input behaviour, while ABC provided a more detailed view of how overheads were consumed across different production activities. When combined, these methods produced a more accurate picture of product-level cost behaviour and profitability, supporting the arguments made by Carli & Canavari (2013) and Stašová (2020) regarding the advantages of activity-based systems in agricultural production. The findings also provide a stronger basis for identifying inefficiencies and guiding continuous improvement initiatives, which are discussed further in the next sections.

5.2 Implications for Cost Management

The findings of this study carry several implications for how cost management can be improved in greenhouse operations, particularly in environments where production relies heavily on manual work and energy-dependent growing conditions. One of the most important insights is that direct costs still play a much larger role in greenhouse farming than previous studies have suggested. While the literature often highlights overheads as the dominant cost components in greenhouse farming (Paris et al., 2022; Wei et al., 2020), the results here showed that materials, labour and transportation formed a substantial share of total costs for almost every crop. This suggests that improving cost control in material usage and labour efficiency could produce immediate benefits. For example, crops that involved time-intensive tasks, such as extended handling or repeated manual checkups, accumulated noticeably higher direct costs. This pattern suggests that better workflow planning or selective automation could reduce overall expenditure. However, any move toward automation should be evaluated carefully through proper investment appraisal methods to ensure that the expected cost savings justify the initial capital investment as well as associated recurring costs (Horngren et al., 2014).

At the same time, the ABC results demonstrated that indirect costs still have a major influence on profitability, especially through activities such as cultivation, harvesting and manual packing. The high proportion of heating and electricity allocated to cultivation means that even small changes in production schedules or growing times can have a noticeable financial impact. This is aligned with Maraveas et al. (2023), who emphasise that environmental control settings are among the strongest cost drivers in controlled-environment agriculture. For the case company, reducing unnecessary cultivation days, improving temperature regulation efficiency, or redesigning space utilisation might lower overhead absorption and improve margins particularly for slower-growing crops.

The identification of high-cost activities also provides a better guidance for capacity planning. Activities that absorbed the largest share of indirect costs, such as cultivation, harvesting and manual packing, act as bottleneck areas where resource usage should be monitored more closely. This is consistent with Kaplan & Cooper’s (1998) argument that ABC allows managers to pinpoint activities where cost behaviour does not align with operational goals. For instance, if harvesting remains highly labour-intensive for certain crops, the company may consider revisiting its handling procedures or adjusting batch sizes to balance labour time with production needs. Automation could also be considered

as a way to reduce labour time and improve cost efficiency. However, as Drury (2021) and Horngren et al. (2014) emphasize, such capital-intensive decisions should only be made after conducting proper investment appraisal to ensure that the long-term financial benefits outweigh the initial investment.

The profitability ranking and whale curve analysis offer further managerial implications. The whale curve revealed that a small number of products generated most of the total profit, while several low-margin and un-profitable crops reduced overall profitability. This pattern, which mirrors the findings of Kaplan & Atkinson (1998) and Sievänen et al. (2004), indicates that product mix optimization could be an effective cost management strategy. For unprofitable or marginal crops, managers should evaluate whether improving production efficiency is possible or whether resources would be better allocated to high-performing lines. In practice, this could mean reducing greenhouse space for crops with high indirect absorption or shifting production toward items that consistently generate strong contribution margins. However, before reducing or discontinuing these low-margin products, management also needs to consider whether such changes could affect the sales of more profitable crops, particularly in cases where customers expect a full range of crops or tend to buy certain products together.

Another implication relates to break-even behaviour. The CVP analysis demonstrated that pot salad B required a relatively high production volume to break even due to its fixed-cost burden. This highlights the importance of stable production planning and predictable demand in greenhouse operations. Where fixed costs are high, running below capacity can quickly reduce profitability. Therefore, cost management cannot be separated from operational decisions such as scheduling, capacity utilisation or target yield levels.

The findings also showed why using both direct costing and ABC together was helpful for understanding the greenhouse's cost behaviour. For the case company, direct costs were already quite high for most crops, but the ABC model revealed that overheads did not spread evenly across products. Some activities, especially cultivation and harvesting, absorbed far more shared resources than others. If only a traditional costing approach had been used, these differences would not have been visible, because all crops would have received roughly similar overhead charges. The hybrid model made it easier to see which products were genuinely expensive to produce and which ones only appeared costly because of their direct inputs. This becomes important for decision-making, because managers can now separate issues related to high material use from issues caused by activity-level inefficiencies. Earlier studies have pointed out similar benefits of

ABC in multi-product environments (Carli & Canavari, 2013; Kaplan & Cooper, 1998; Stašová, 2020), so these results support the idea that activity-based information gives a clearer and more realistic basis for improving cost control and reviewing the product mix.

Overall, the implications suggest that effective cost management in greenhouse production requires a dual focus: improving the efficiency of direct inputs and labour, while simultaneously managing overhead-intensive activities such as cultivation and harvesting. The combined costing model used in this study gives managers the information needed to pursue both goals in a systematic and data-driven manner.

5.3 Evaluation of the hybrid costing framework

The hybrid costing framework developed in this study, product-level profitability analysis, and a continuous improvement loop, proved to be a practical and analytically useful approach for examining cost behavior in greenhouse production. Its strength lies in the way each component complements the others. Direct costing clarified the variable cost structure of each crop, allowing a straightforward comparison of resource use such as seeds, packaging, peat and fertilisers. At the same time, ABC provided a more detailed picture of how indirect resources, including heating, electricity, maintenance and monthly production and support services salaries, were consumed across different activities. When combined, these two perspectives offered a more complete understanding of total cost behaviour than either method alone, which is consistent with earlier findings that hybrid costing can improve decision-making in complex production settings (Carli & Canavari, 2013; Drury & Tayles, 2006).

A major strength of the framework was its ability to reveal cost differences that would have remained invisible under traditional costing. By allocating indirect costs through resource drivers such as m², labour hours and percentage-related measures, the ABC model identified which processes absorbed the largest share of overheads. In this case, cultivation, harvesting and manual packing emerged as the most resource-intensive activities, largely due to growth durations, climate-control requirements and the high amount of manual handling. These findings are consistent with existing literature showing that greenhouse operations often face high energy and labour intensity, which distort profitability if overheads are simply averaged across crops (Paris et al., 2022; Wei et al., 2020). The hybrid model therefore allowed for more accurate distinctions between high-cost and low-cost products, which guided the profitability rankings and whale-curve interpretation.

The integration with product-level profitability analysis further strengthened the evaluative capacity of the framework. By linking cost allocations to selling prices, the model clearly identified profitable and unprofitable crops and showed how both direct and indirect cost structures shaped these outcomes. The whale curve demonstrated that only a small number of products generated most of the total profit, while others contributed very little or even reduced the cumulative margin. This pattern aligns with findings from Sievänen et al. (2004), who showed often in multi-product environments, a minority of products tend to sustain the overall profitability of the company. The CVP analysis of pot salad B provided additional insight into financial viability by specifying its break-even point under current cost conditions. Together, these tools helped connect cost behavior with economic performance in a meaningful and operationally relevant way.

Finally, the hybrid framework supports the principles of continuous improvement by offering clear visibility over where inefficiencies originate. By highlighting activities that carry high overhead burdens or contribute to low-margin products or un-profitable products, the model provides a basis for targeted improvement initiatives. For example, overhead-intensive processes, high manual labour requirements in harvesting and manual packing and ongoing low-margin or un-profitable products could be reviewed for process redesign, automation potential or adjustments in crop mix. Such alignment between costing accuracy and operational improvement also reflects broader recommendations in management accounting literature, which emphasises the importance of using cost information to support strategic and operational improvements (Drury & Tayles, 2006; Horngren et al., 2014).

Despite these strengths, the hybrid model also presents some limitations. Some driver quantities were based on percentage estimates provided by the company representative, and in cases where no records existed, broader heuristics were used to approximate resource usage. While these approaches are common and acceptable in ABC when detailed data are unavailable (Kaplan & Cooper, 1998; Ríos-Manríquez et al., 2014; Sridharan et al., 2016), they introduce some uncertainty into the precision of the allocations. A further limitation concerns the use of hybrid activity drivers. For example, in cultivation activities, a driver such as m² × days would more accurately reflect differences in crop duration, yet the model relied solely on m² because the necessary data were not available. These limitations should be considered when interpreting the results and applying them to future decision-making.

Overall, the hybrid costing framework offered an effective method for analysing cost behaviour and profitability in a greenhouse environment. The integration of direct costing, ABC, and profitability analysis methods enabled a holistic understanding of resource consumption and product performance, while the findings remain actionable for future managerial decisions, including the continuos improvement operations and resource management.

5.4 Conclusions

This study set out to build and apply a hybrid cost-management framework that combines direct costing and ABC to measure product-level profitability within a greenhouse production environment. The framework was designed to address a key challenge faced by greenhouse producers, which is the limited cost transparency provided by traditional costing systems, particularly when multiple crops share resources such as heating, electricity, labour and production space. By integrating variable cost tracing with activity-based overhead allocation, the study aimed to produce a clearer and more operationally meaningful view of cost behaviour. The conclusions are organised according to the research questions presented in Chapter 1.

R.Q 1 - How can a hybrid direct costing and ABC framework be effectively designed and implemented for greenhouse operations to measure total and product level costs accurately

As detailed in chapter 4.1 and 4.2, the hybrid framework was successfully developed using the company's financial and operational data, despite some inherent data limitations within the company. Direct costing provided clear visibility into the variable cost structure of each crop, while ABC captured the distribution of shared overheads using resource drivers and activity drivers, thereby measuring total product level costs. Although some driver quantities were estimated heuristically due to data availability limitations, the overall model remained consistent and aligned with recognised ABC practices. This demonstrates that hybrid costing is feasible and analytically useful for greenhouse producers seeking more reliable cost information.

R.Q 2 - What do cost driver analysis provide about the structure of resource consumption and cost behaviour across different crops?

As detailed in chapter 4.2, the findings show that that the majority of overhead absorption occurred during energy-intensive and labour-intensive stages, particularly cultivation and harvesting. Crops with longer growth cycles or greater handling needs naturally consumed a larger proportion of heating, electricity, and labour resources, explaining variations in indirect costs between products. These findings validate earlier observations in the literature that cost behaviour in controlled-environment agriculture is closely influenced by space utilisation, labour time, and energy requirements. Additionally, the analysis revealed that monthly production and support salaries and energy costs dominated the overhead structure, suggesting that improvements in labour allocation and energy efficiency have the strongest potential to reduce total costs.

R.Q 3 - Which areas of greenhouse operations exhibit inefficiencies, and how can these be addressed through managerial or process improvements?

As shown in Chapter 4.3, the profitability comparison revealed significant differences across crops, including the presence of low-margin and unprofitable items. The whale curve illustrated that only a few crops generated most of the total profit, while several contributed to a limited extent or negatively. The CVP analysis performed for pot salad B further clarified the break-even conditions and highlighted the sensitivity of profitability to production volume. Collectively, these results point to clear inefficiencies related to energy use, labour distribution, and product mix decisions. While the study does not recommend discontinuing low-performing crops openly, it highlights the need for further operational evaluation, such as labour rescheduling, heating optimisation, and assessing small-scale automation options. However, any such improvements should undergo proper investment appraisal to ensure they do not negatively affect high-performing product lines.

5.5 Recommendations and future research

Based on the findings of this study, several recommendations can be made to support more effective cost management and operational improvement in greenhouse production. The hybrid direct costing and ABC framework proved useful for identifying where resources are consumed and which products contribute positively or negatively to profitability. To build on these insights, greenhouse managers could consider the following actions.

First, improving labour efficiency should be a priority, since labour-related costs formed a major share of both direct and activity-based expenses. Scheduling practices, task standardisation or reallocating labour during peak workloads could help reduce unnecessary handling time. Even small adjustments in labour planning may create noticeable improvements in unit costs, especially for crops that require frequent and more manual care. Similarly, exploring low-cost automation tools may help reduce labour intensity over the long term. However, any automation proposal should be evaluated using proper investment appraisal techniques to ensure that the benefits outweigh the costs.

Second, energy management represents another important area for improvement. The study found that heating and electricity were among the largest overheads, particularly during the cultivation stage. Managers could evaluate opportunities for optimising heating schedules and improving insulation. Monitoring energy use more closely across seasons may also help identify patterns of overconsumption. Eventhough this study did not measure environmental impacts directly, reducing energy use can support both economic and sustainability goals.

Third, product mix decisions should be accessed regularly. The whale curve analysis showed that only a small number of high-margin crops contributed most of the overall profit, while others performed marginally or resulted in losses. Rather than removing low-margin products immediately, managers should first examine the reasons behind their low performance. If the issues are related to resource usage inefficiency or workflow problems, these may be addressed through operational changes. However, if certain products consistently underperform even after improvements, adjusting the product portfolio might be a good move.

At the end, this study points towards several opportunities for further research as well. For example, future studies could build on this work by applying time driven activity based costing, which relies on time equations and may offer even more precise cost estimates. Another direction would be to integrate environmental cost metrics, for example, carbon footprint or water use, to explore how financial and sustainability goals can be evaluated together. Finally, future research could use more detailed operational measurements, for example, sensor-based energy data or real-time labour tracking, to reduce reliance on estimates and further improve costing accuracy in the hybrid costing methodology.

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