Analysis of Product Life Cycle Performance Strategies: MOORA Method

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Abstract.

Product Life Cycle Management (PLM) is the process of managing the entire life cycle of a product, from its conception through design and manufacturing to service and disposal. In order to validate the product life cycle classification ranking method, the Multi-Objective Optimization by Ratio Analysis (MOORA) method was applied. This method allowed us to analyze which stages of PLM were the most relevant, based on a ranking scale, and which ones showed different results in terms of the importance of various criteria. This demonstrated the significance of each item within each phase of PLM, which can vary depending on specific factors to be considered by the organization. Thus, the combination of the traditional PLM concept and the application of the MOORA method enables organizations to understand the dynamics of their products more comprehensively, making strategic decisions more effective, based on various criteria and specific goals. The results revealed that the PLM phase leading the final ranking was the introduction phase. This finding validates the applicability of the method, allowing for the identification of growth and financial return criteria as highlights. Study limitations may arise from market dynamics, the definition of weights for decision criteria, which are independent and may vary from one organization to another, and the ability of PLM to accurately predict a product's performance over time. The study's contribution and originality lie in the integration of PLM management and the MOORA method, which together allow for the rapid, standardized, and precise classification of criteria. Although the greatest challenges are market complexity and fierce competition, organizations can overcome obstacles and stand out uniquely in their product management strategies by applying them to other problem contexts. This can be achieved by conducting new comparisons and evaluations, using different parameters and significant criteria, as well as experimenting with other Multiple-Criteria Decision-Making (MCDM) methods.

Keywords: Multi-Criteria Methods; MOORA; PLM Ranking.

1 Introduction

Product Lifecycle Management (PLM) is an essential framework in product management, providing a comprehensive view of product development, launch, and market withdrawal. This approach enables organizations to assess the performance of their products at various stages, thereby making informed strategic decisions to optimize resources and meet long-term market demands [1].

Furthermore, the increasing complexity of strategic decisions in the modern business environment necessitates more advanced approaches. Multi-criteria methods, such as Multi-Objective Optimization on the basis of Ratio Analysis (MOORA), play a crucial role, enabling organizations to consider multiple criteria and objectives simultaneously, leading to more informed and precise decision-making. These methods are valuable in analyzing alternatives in complex situations and have applications in various fields, from investment selection to resource management [2].

In the contemporary dynamics of markets, strategic product management plays a fundamental role in the success of organizations. PLM is a widely adopted approach for analyzing a product's trajectory. However, the complexity of strategic decisions involving PLM requires a careful evaluation of various factors.

In this context, this paper presents an innovative analysis that combines the concept of PLM with the multi-criteria method MOORA, aiming to provide a more comprehensive and accurate view of product life cycle management. The study validates the method of ranking the stages of PLM using MOORA, highlighting the most relevant stages and the importance of specific criteria in each phase.

Its practical application in the context of banana growers in the southern region of Brazil demonstrates the versatility of the MOORA method in decision-making across different domains. This unique approach not only enhances PLM management but also offers valuable insights for a specific agricultural sector, underscoring the ability of MOORA to adapt to various challenges and needs.

In this paper, we will explore the combination of these concepts and their practical application, revealing the significance of this innovative approach to strategic product management in diverse contexts.

2 Literature Review

PLM (Product Lifecycle Management) is a concept that describes the various phases a product goes through from its launch to its decline or discontinuation. These phases are typically represented in a graph that illustrates the evolution of sales and profits over time.

PLM management involves various engineering, business, and management activities related to a product throughout its lifecycle—from the inception of an intangible concept to the disposal of a finished product [3; 4]. Previously, nine data collection stages were assigned to PLM: product concept, design, raw material procurement, manufacturing, transportation, sales utilization, after-sales service, recycling/disposal [5; 6]. Today, in simpler and more streamlined terms, the PLM stages are Introduction, Growth, Maturity, and Decline. In some cases, Development is also considered as a phase preceding Introduction [7]. Alternatively, PLM can be classified into four stages: raw material, manufacturing, usage, and recycling [8].

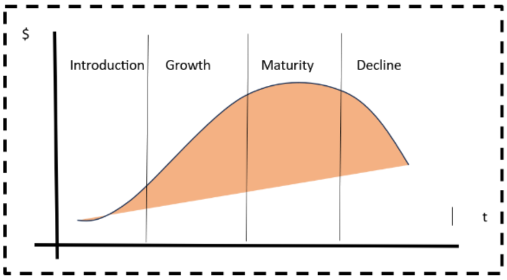

Figure 1: Product Life Cycle
Source: The authors (2023)

PLM also aims to measure the product's impacts at all stages of the life cycle, considering its relative importance in specific pre-selected indicators [9; 10]. It contributes to obtaining a market-oriented view of the product, facilitating marketing efforts, and meeting the interests of producers [11].

The introduction phase marks the market launch, where companies heavily invest in R&D and marketing strategies to build awareness and capture consumer attention. The Introduction aims to meet a list of requirements through the analysis of customer needs, market dynamics, and competition, which are crucial for the subsequent stages of product development [12]. As the product gains popularity and acceptance, it enters the Growth phase, characterized by a rapid increase in sales and significant expansion of the customer base. Profits start to grow, and competition often intensifies as new competitors try to capitalize on the product's success.

Therefore, Growth is where the product takes on a solid commercial form for mass production. This is the time to work towards increasing market share, always aiming for leadership [13]. Over time, the initial excitement diminishes, and the product reaches Maturity. Sales growth slows down, and competition becomes fierce. Companies seek innovations, improvements, or differentiations to maintain consumer interest and prolong this phase as much as possible. Marketing strategies are essential to maintain market share and maximize profits while preparing for the next phase.

At this point, it's time to put the strategy into action, as the goal is to improve process efficiency, increase quality, and stand out against competitors and in the market [14; **Error! Reference source not found.**; 15]. Sales peak, prices fall, and market saturation occurs [17]. Unfortunately, all products eventually face the inevitable - the Decline phase. Changes in consumer preferences, technological advances, or the arrival of more innovative competing products can lead to a decline in sales.

Companies face tough decisions: continue supporting the product, cut costs, or discontinue it. Some strategies include product diversification or seeking new markets, but ultimately, withdrawing the product from the market may be unavoidable [14]. Sales decline, obsolescence occurs, and changes in consumer preferences. Companies may choose to discontinue the product or reduce costs to extend its lifespan.

Therefore, at each stage of PLM, managers face unique challenges and require adaptive strategies. For example, accounting for the environmental implications of the entire supply chain for goods and services throughout their lifecycle, from "cradle to grave" [18]. Additionally, PLM is indirectly concerned with the origins of resources and materials, as provenance can influence outcomes, and competitive advantages seek to consider reuse, remanufacturing, and recycling, which are prerequisites for more sustainable business actions [19; 20; 21].

A profound understanding of this cycle is essential for making informed decisions about investments, marketing, and product development. And companies can optimize their performance and ensure a lasting presence in the constantly evolving market.

Furthermore, the breadth of PLM ensures that most structures are specifically tailored to a particular application scenario, thus supporting evolution, data changes, and leading business activities towards a certain flexibility [6; 22; 23].

From this perspective, PLM helps companies consider the survival of their business and, most importantly, their product, from birth to death. Moreover, it contributes to a more accurate assessment of environmental effects that impact each stage of the cycle [6; 11; 24].

To allow for process optimization and integration, as well as cost reduction: PLM (Product Lifecycle Management) is capable of managing data related to a product and all internal and external factors involved in the development of this product [25].

In each phase of the life cycle, resource allocation, adequate information, and improvements in quality can effectively address product quality and various cost issues [26]. In Product Lifecycle Management (PLM), it is useful to promote the growth of related fields and provide effective technical support for companies to save costs and enhance efficiency [27]. In a dynamic business environment, companies that can anticipate and proactively adapt to changes will be better positioned to thrive and remain competitive.

Regarding Multicriteria Decision Methods (MDM), they play a crucial role in solving complex problems where multiple criteria must be considered for decision-making. The primary goal of MDM methods is to evaluate and rank existing alternatives based on a predefined set of criteria [16; 28]. The selection of a suitable MDM method adapted to the specific decision-making problem is a crucial step in this process [15; 29]. Therefore, the Multicriteria Decision Aid for Ranking of Alternatives (MOORA) method was chosen, which is a robust and widely used approach in this context.

3. Methods, Application, and Results

The database used for the search was Scopus, which is a peer-reviewed reference database for bibliometric studies of research publications in the fields of science, engineering, arts, social sciences, medicine, technology, and humanities. The search utilized the keywords "PLM" and "Product life cycle" over the past 5 years, resulting in 25 documents after applying filters.

The research methodology employed in this study involved applied research and a combination of qualitative and quantitative approaches, along with a survey of multivariate case studies. The survey was conducted among 247 banana growers in Santa Catarina, with 110 responses obtained. The questionnaire consisted of 20 questions, designed based on each stage of the PLM. The research was divided into seven phases: i) Conceptual Model Structuring, involving theorization and data collection, ii) Presentation of the state-of-the-art survey through systematic review and bibliometric study, iii) Development of the conceptual model, iv) Formulation of hypotheses and objectives, v) Application of the model, vi) Evaluation of the applied conceptual model, vii) Results obtained.

The MOORA method (Multi-Objective Optimization on the basis of Ratio Analysis) was employed, designed for complex decision processes and optimization of multiple objectives [27]. It consists of two steps, with the first starting with a matrix of responses from different alternatives regarding different objectives.

$$\begin{bmatrix} x_{11} & \cdots & x_{1i} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots & \iddots & \vdots \\ x_{j1} & \cdots & x_{ji} & \cdots & x_{jn} \\ \vdots & \iddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mi} & \cdots & x_{mn} \end{bmatrix}$$

Where: xij is the response of alternative j to objective or attribute i; i = 1,2,...,n - is the number of objectives or attributes; j = 1,2,...,m - is the number of alternatives.

The second step is the normalization of the matrix:

$$x_{ij}^{\cdot}=\frac{x_{ij}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2}}$$

Where: xij is the response of alternative j in objective i; j=1,2,…,m; m is the number of alternatives; i=1,2,…,n; n is the number of objectives; xij is a normalized dimensionless number for alternative j in objective i. Dimensionless numbers, without a specific unit of measurement, are obtained, for example, through deduction, multiplication, or division. The normalized responses of alternatives to objectives belong to the interval [0; 1]. However, sometimes the interval can be [–1; 1]. For optimization, these responses are added in case of maximization and subtracted in case of minimization:

$$y_j^{\cdot} = \sum_{i=1}^{i=g} N\ x_{ij}^{\cdot} - \sum_{i=g+1}^{i=n} N\ x_{ij}^{\cdot}$$

Where: i = 1, 2, ..., g – with the aim of maximizing; i = g+1, g+2, ..., n – with the aim of minimizing; yj - the normalized evaluation of alternative j in relation to all objectives.

3 Results

Applying the MOORA method, the model was constructed through data collection via a questionnaire (measured on the Likert scale). The classification of the scale for the Product Life Cycle (PLC) phases was established as follows: 1. Very low; 2. Low; 3. Moderate; 4. High; 5. Very high. Additionally, interviews were conducted with the support of local leadership and alliances with individuals and groups interested in the research and its potential outcomes. Relevant questions regarding the PLC, comprising five (5) questions for each phase, were included.

The assessment of the applied conceptual model was analyzed using econometric models, incorporating correlations and validation clusterizations within the PLC. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were utilized in this analysis. The obtained results demonstrated how data were integrated across different themes and business models, providing insights into respondent profiles, including Occupation, Educational Level, Membership Duration in the Association of Banana Growers of São João do Itaperiú - ASBASJI, Age, and Annual Revenue.

The conceptual multiconstruct involving the phases of the PLC, namely introduction, growth, maturity, and decline, is presented in Figure 1.

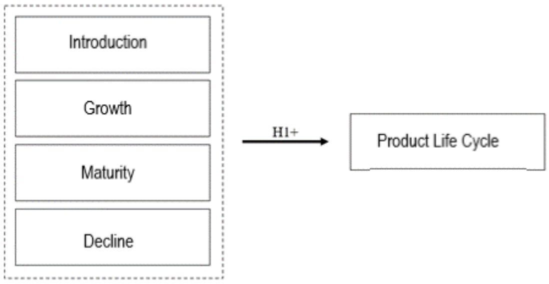

Figure 2: Preliminary Conceptual Multiconstruct of Research

To build the multi-construct, the research presented the following hypothesis (H1): The PLC and its stages have a positive association, leading the company to have a better product life cycle. In the application of the MOORA Method, the methodological processes were divided into 3 stages, as described below:

Step 1: Decision matrix for the criteria

Alt	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
A1	3	4	4	1	4	4	4	4	4	4	2	4	4	4	2	4	4	4	4	1
A2	5	5	5	1	3	5	5	5	3	2	2	2	4	3	2	4	2	3	5	1
A3	5	4	3	1	1	4	4	4	4	4	2	3	5	4	5	4	5	4	5	3
A4	4	5	5	3	4	4	4	4	3	3	3	4	3	3	4	3	3	4	4	3
A5	2	4	2	1	1	1	1	1	1	1	1	2	2	1	1	3	1	1	4	2
A6	5	5	4	3	3	3	4	3	4	4	3	4	5	4	4	3	4	4	5	4
A7	4	4	4	3	4	4	3	4	5	4	4	5	5	4	4	4	4	4	4	3
A8	5	5	5	1	4	5	4	1	1	5	5	5	5	3	5	5	5	1	1	1
A9	5	5	5	1	5	3	5	5	1	5	5	5	3	4	4	3	3	2	5	3
A10	3	5	5	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	1
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A110	3	4	3	3	3	3	3	3	2	3	3	3	3	3	2	3	2	3	5	3

Table 1: Simplified decision matrix

To improve visualization, only a percentage of the table has been displayed, and the full table will be made available upon request via email to the authors.

Table 1 presents the responses of the 110 banana farmers who participated in the survey.

Alt	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20
A1	0,0710	0,0885	0,0972	0,0430	0,1134	0,1013	0,0976	0,1013	0,1181	0,0978	0,0541	0,0958	0,0947	0,1014	0,0492	0,1029	0,1060	0,1057	0,0880	0,0321
A2	0,1183	0,1107	0,1215	0,0430	0,0851	0,1266	0,1221	0,1266	0,0885	0,0489	0,0541	0,0479	0,0947	0,0761	0,0492	0,1029	0,0530	0,0793	0,1100	0,0321
A3	0,1183	0,0885	0,0729	0,0430	0,0284	0,1013	0,0976	0,1013	0,1181	0,0978	0,0541	0,0718	0,1184	0,1014	0,1230	0,1029	0,1325	0,1057	0,1100	0,0963
A4	0,0946	0,1107	0,1215	0,1289	0,1134	0,1013	0,0976	0,1013	0,0885	0,0734	0,0811	0,0958	0,0710	0,0761	0,0984	0,0772	0,0795	0,1057	0,0880	0,0963
A5	0,0473	0,0885	0,0486	0,0430	0,0284	0,0253	0,0244	0,0253	0,0295	0,0245	0,0270	0,0479	0,0474	0,0254	0,0246	0,0772	0,0265	0,0264	0,0880	0,0642
A6	0,1183	0,1107	0,0972	0,1289	0,0851	0,0760	0,0976	0,0760	0,1181	0,0978	0,0811	0,0958	0,1184	0,1014	0,0984	0,0772	0,1060	0,1057	0,1100	0,1284
A7	0,0946	0,0885	0,0972	0,1289	0,1134	0,1013	0,0732	0,1013	0,1476	0,0978	0,1081	0,1197	0,1184	0,1014	0,0984	0,1029	0,1060	0,1057	0,0880	0,0963
A8	0,1183	0,1107	0,1215	0,0430	0,1134	0,1266	0,0976	0,0253	0,0295	0,1223	0,1351	0,1197	0,1184	0,0761	0,1230	0,1287	0,1325	0,0264	0,0220	0,0321
A9	0,1183	0,1107	0,1215	0,0430	0,1418	0,0760	0,1221	0,1266	0,0295	0,1223	0,1351	0,1197	0,0710	0,1014	0,0984	0,0772	0,0795	0,0529	0,1100	0,0963
A10	0,0710	0,1107	0,1215	0,0430	0,1418	0,1266	0,1221	0,1266	0,1476	0,1223	0,1351	0,1197	0,1184	0,1268	0,1230	0,1287	0,1325	0,1321	0,0220	0,0321
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
A110	0,0710	0,0885	0,0729	0,1289	0,0851	0,0760	0,0732	0,0760	0,0590	0,0734	0,0811	0,0718	0,0710	0,0761	0,0492	0,0772	0,0530	0,0793	0,1100	0,0963

Table 2: Normalized Decision Matrix

After presenting the matrix, it is necessary to normalize it, for which Equation 1 was used. The data shown in Table 2 will be used to rank the alternatives for both the PLC.

Ranked alternatives through the MOORA technique

MOORA						
Introduction	Ranking	C2	C1	C3	C5	C4
	Criterion	1	2	5	16	19
Growth	Ranking	C7	C6	C10	C8	C9
	Criterion	6	7	10	13	20
Maturity	Ranking	C14	C13	C12	C15	C11
	Criterion	4	8	9	14	17
Decline	Ranking	C19	C16	C17	C18	C20
	Criterion	3	11	12	15	18

Table 3: Ranking of Criteria

Finally, the alternatives were ranked, with ordering done in descending order, meaning from the highest index to the lowest, as our criteria are for optimization.

4. Discussions

The results of applying the MOORA method to analyze PLC performance strategies indicated that the introduction phase led the final ranking. This finding suggests that this phase is critical and deserves special attention during the product life cycle management process. The insights obtained emphasize the importance of comprehensively considering each phase of the PLC for making effective strategic decisions.

Using the Scopus database as a research source, only three articles were identified that addressed the application of multicriteria methods, specifically MOORA, in different contexts related to the PLC. One of the articles was presented at a conference, while the other two were published in scientific journals in the English language. These studies provided valuable insights into the application and contribution of the MOORA method in various contexts, highlighting its versatility and utility in diverse areas.

One study focused on the selection of third-party logistics service providers, using an integrated approach of multiple criteria decision-making methods, including MOORA. Its contribution provides an efficient method for selecting logistics service providers [1]. Another study concentrated on analyzing selected issues in green supply chain management using ANP and MOORA. Its contribution was to provide a framework for analyzing specific issues in green supply chain management [2]. Some authors explored decision-making in robust and flexible production systems by applying the MOORA method. Their contribution was to provide an approach for decision-making in complex production problems [6; **Error! Reference source not found.**].

This study holds practical implications by providing a methodology based on MOORA to analyze and prioritize performance strategies throughout the product life cycle. Organizations can employ this approach to gain a better understanding of their product dynamics, facilitating strategic decision-making based on varied criteria and specific objectives. This can lead to more effective product life cycle management, resulting in more competitive and sustainable products. Furthermore, the application of MOORA can be extended to other contexts and sectors, offering an objective and standardized approach for multicriteria analysis in various management areas.

4 Final Considerations

This study aimed to analyze the product life cycle of banana growers in the State of Santa Catarina in the year 2022. Initially, descriptive statistics were applied to characterize the research sample. Subsequently, correlation methods were employed, considering both dependent and independent variables that collaborate to support PLM (Product Lifecycle Management) businesses. The data sources supported these conceptual PLM models, highlighting the tools and methods each business model uses for product development. Each business is unique, and its product development model is an expression of that uniqueness. Furthermore, it is understood that the integration between the product development process and market performance significantly contributes to their survival and market performance [31].

To conclude, rankings on the subject were established using the Multicriteria Decision-Making method MOORA. The findings of this study indicate that the Introduction stage of PLM holds greater relevance compared to others in the entire process, focusing on best practices in production/cultivation and process efficiency. This discovery validates the method's applicability, allowing the identification of market performance criteria that concentrate on lead time (improvements from start to finish of production) and market maintenance. Additionally, through the MOORA-generated ranking, it was observed that some business models have similar positions in the ranking, while others occupied different positions in the two rankings.

The study's limitations stem from its exclusive focus on banana grower business models in 2023, which constrains the generalizability of the results. However, these limitations do not invalidate the research findings. To address these limitations and enhance future studies, it is recommended to increase the sample size, diversify the group of businesses studied, extend the analysis period, update the indicators and criteria used, and consider integrating advanced methodologies such as Machine Learning, Artificial Intelligence, and Neural Networks [32][33][34][35]. These enhancements can provide more comprehensive insights and contribute significantly to the field. Additionally, future research could further refine the methodology by defining weights and their application in each phase of the Life Cycle Performance Analysis. Comparative studies with other multi-criteria decision-making methods like SAW and TOPSIS could offer valuable insights into their respective strengths and weaknesses. Moreover, when using a scale of 1 to 5 for performance evaluation, normalization may not be necessary. A weighted average could be a more suitable approach, ensuring robust results and avoiding reverse ranking outcomes. This streamlined approach could improve the accuracy and efficiency of future analyses [36][37][38][39].

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