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# A Proposed Menu Engineering-Based Business Intelligence Design Using K-Means Algorithm

**Jonathan Shinray Fang[1*], Dwi Hosanna Bangkalang[2]**
Universitas Kristen Satya Wacana, Indonesia
Email: 682020134@student.uksw.edu
*Correspondence

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**ABSTRACT**

Business continuity is greatly influenced by the menu, especially in the culinary industry. Micro, Small, and Medium Enterprises (MSMEs) account for 64.1 million units or around 99% of all businesses in Indonesia. For many years, MSME has been using menu analyses to keep its menu optimized. However, this is not enough since 50% of MSMEs are failing in their first 5 years due to poor decision-making as a result of a lack of knowledge. Based on that problem, there is a necessity for menu analysis and tools to assist in decision-making, also called Business Intelligence. The method used consists of three stages: data collection, business intelligence design, as well as analysis and results. The BI design focuses on menu engineering using the K-Means algorithm to divide menu items into four unique clusters according to Kasavana-Smith's menu engineering concept. After validating its findings with the Davies-Boudlin Index evaluation, it concludes that a four-cluster solution is most optimal among other value-cluster. This study aims to assist business owners in making better decisions, and it may be used as a reference for business owners by providing suggestions based on the menu review analysis.

## Introduction

The menu is one of the things that determines the continuity of a business, especially in the culinary business. (de Riandra & Islam, 2021) A well-crafted menu can provide large profits for the company and better product information to customers. The rapid business competition makes menu optimization necessary to maintain company suitability, considering that most aspects of the industry have a risk of going out of business by almost 50% in the first 5 years (Zebua et al., 2023). One of the main causes of business failure is menu incompatibility. Hence, the performance of menu requirements must be carried out to maintain business continuity (Sutaguna et al., 2023).

Micro, Small, and Medium Enterprises (MSME) are the type of company that mostly runs in Indonesia. Based on data from the Ministry of Cooperative and Small Medium Enterprises (SME), the number of MSMEs in Indonesia has reached 64.1 million

units, or around 99 percent of the total number of business actors in this country (MM, 2007). For many years, MSME has conducted menu analyses as part of its operations to keep its menu optimized and according to customer needs. Nowadays, POS systems are used as cashier systems by the majority of MSMEs (Bahwita, 2022). It can compile sales information and generate a sales report based on transactions. However, the majority of MSMEs that neglected to conduct strategic planning or menu analysis typically fail as a result of a lack of knowledge leading to poor decision-making (FADLY, 2022).

Without loss of generality, better menu analysis output can be achieved when there is more data provided as input. While the POS System can access historical transaction data, the MSME can use it to gain a more precise menu analysis to increase profitability and customer satisfaction (Laeliyah, 2017). But even though MSME has previously adopted the POS System to provide more data in menu analysis, it cannot ensure MSME's survival. There are still certain issues with operations and business. If the business owner is not skilled enough or doesn't even have the employee to process and analyze the data, the MSME is likely to make poor decisions and, worse, it will fail (Haryadi, Rojali, & Fauzan, 2021). All of the effort put into digitalization with the POS system will be in vain if it continues in this manner—it will only appear to be a fancy receipt. All of that comes to the needs of BI, the BI will help businesses in menu analysis by interpreting the transaction data, so it will come in handy for SME. Also considering the Point of Sales (POS) system adaptation in MSME, it is very wise to build a system while still making it an option to be integrated with the POS system (Sumarto, 2023).

One of the most used menu analysis techniques in the business is Kasavana-Smith's menu engineering. It is a special technique that is known to be able to see the performance comparison of items on the menu. By knowing the performance of the menu, it is possible to estimate future sales and make decisions based on marketing strategies. As introduced by Kasavana and Smith, this technique grouped items on the menu in four quadrants formed in a 2x2 matrix: Star, Plowhorse, Puzzle, and Dog. The 2x2 matrix of menu engineering can be seen in Fig. 1


**Fig. 1. Menu Engineering Matrix**

The analysis of menu engineering focuses on two elements: menu mix analysis and item contribution margin. The menu mix represents each menu item's popularity level, and the contribution margin represents the difference between the selling price of the menu and the cost of goods.

One of the latest research projects conducted by Atmaja et al. aimed to assist the management of Swell Bar & Restaurant in evaluating menus by analyzing the relationship between the level of popularity and profitability of each menu item. The research used saturated sampling with 50 menu items. The research recommends using regular analysis to enhance revenue and improve the menu by minimalizing the number of those two categories.

Another menu engineering research that Attwood. et al. conducted regarding price-based decoys in menu engineering to promote menu items by marking up the prices. The result is that the decoy didn't significantly influence customer choice. Also, the study highlights that further research is needed to determine which attributes, such as taste, portion size, or signature ingredients, are effective in promoting menu items.

Based on the current problems, a BI must exist to support business owners in menu engineering. The purpose of using the K-Means approach in menu engineering clustering is to improve efficiency by speeding up and automating the process. Besides the data visualization, menu review should also be included in the BI to assist business owners by making suggestions on menu items. Where this decision is based on current data or at a certain period. The analysis is based on market trend data to increase company sales and income. So, it is not only based on individual assumptions and hunches.

This research aims to propose a software design like BI that can provide insight into menu sales and can be integrated with the POS system. Implementing BI for menu engineering will help business actors, especially SMEs, to make better decisions for a better chance of survivability in today's highly competitive business world and experience an increase in sales.

## Research Methods

This study uses the dataset from a POS system in an SME. The development steps that are used in this study are described in Fig. 2.

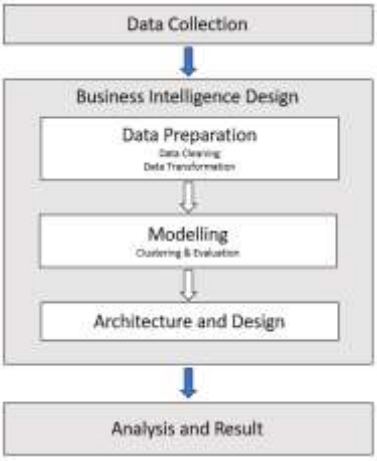


**Fig. 2. Development Step**

### Data Collection

MSMEs, or in Indonesia, Usaha Mikro Kecil dan Menengah (UMKM), are businesses owned by individuals, households, or business entities with assets and a yearly turnover below Rp 10 billion.[19] While the income generated from this kind of business is relatively small, it's not surprising that most MSMEs run from their own homes.[20] Businesses that are categorized as MSMEs can be anything from food carts to service businesses. MSME itself has a massive impact on the Indonesian national economy. Therefore, MSME is divided into three types: microenterprise, small enterprise, and medium enterprise.

The POS system is a modern cash register system commonly used in business to complete sales transactions. There are many third-party software programs nowadays. MSME is mostly the one using it since it is affordable with a low budget, and it comes with a subscription, so business owners don't have to worry about its maintenance.[21]

The dataset used in this design came from sales data from one of the MSMEs in Indonesia in the period January–December 2023. As shown in Table 1, the dataset had 118 menu items and 29,779 transaction data. It's important to know the variables that are in the POS system's report of sales data.

## Results and Discussion

### Business Intelligence Design

This section explains the design of the proposed BI regarding the menu engineering-focused BI, the unified model diagram for this BI, the system architecture that will construct this BI, and the mockup for visualization of the BI.

Menu engineering is a special technique that is known to be able to see the performance comparison of items on the menu[5]. The menu engineering model was first introduced by Kasavana and Smith. There are four categories determined by menu popularity and contribution margin.[22] The formula used to classify a menu can be seen below.

**To calculate the Contribution Margin (CM)**

$$CM = Item\ Price - Food\ Cost \quad (1)$$

**To calculate menu popularity or Menu Mix (MM)**

$$MM\% = \frac{number\ of\ item\ sold}{total\ number\ of\ items\ sold} \times 100\% \quad (2)$$

The data has to be transformed into a suitable table using the menu engineering approach by calculating CM and MM%. Referring to formula (1) to calculate CM, this table needs the difference between the Harga Jual and Harga Pokok variables. Referring to formula (2) to calculate MM%, this table needs to count the Jumlah based on the Kode Barang variable divided by the total of the Jumlah variable times 100%. The output table is shown in Table 2, where this study adds ID as an alias to Kode Barang.

**Table 2**
**The Dataset Post-Data Aggregation Using Menu Engineering Approach**

| ID | Kode Barang | CM | MM% |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 1 | 8991914101056 | 2251.507 | 4.20% |
| 2 | 00086 | 955.690 | 3.99% |
| 3 | 8886008101053 | 1638.358 | 3.06% |
| 4 | 000071 | 1720.189 | 2.71% |
| 5 | 8886008101091 | 1977.574 | 2.60% |
| … | … | … | … |

**Modelling**

One of the suggestions in the earlier research paper is to make menu engineering segmentation using an algorithm. For a brief explanation, the dataset was first standardized using Z-Score Normalization, then using the K-Means unsupervised algorithm to label the data for the next classifying process in the K Nearest Neighbor supervised algorithm.

Modelling

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The formula for Z-Score normalization to standardize the dataset in this study is seen in formula (3).

$xb = (xa - \bar{x})/\sigma$ (3)

Where:

xb = new value
xa = old value
$\bar{x}$ = average
σ = standard deviation

To calculate K-Means, the first step is deciding how many n clusters are needed. In this study, where Kasanava menu engineering is applied, it is clear that four clusters are needed. For the initial cluster centroids, this study will take four IDs. Then calculate the distance between objects with the initial centroids, there are several methods to calculate this, in this study uses Euclidean distance, as seen in formula (4).

$d = \sqrt{(〖(x\_2 - x\_1)〗^2 + 〖(y\_2 - y\_1)〗^2)}$ (4)

Then, to complete it, this manual computation will have different centroids and measure it all along again until there's no change in the output. The final output table is shown in Table 3.

**Table 3**
**K-Means Labelled Dataset**

| ID | CM | MM% | Label |
|---|---|---|---|
| 1 | 2251.507 | 4.20% | 3 |
| 2 | 955.690 | 3.99% | 2 |
| 3 | 1638.358 | 3.06% | 0 |
| 4 | 1720.189 | 2.71% | 3 |
| 5 | 1977.574 | 2.60% | 3 |
| … | … | … | … |

To evaluate the K-means model, it applies the Davies-Bouldin Index (DBI). DBI is a method to evaluate cluster performances by examining the maximum distance between clusters and, at the same time, decreasing the distance between cluster members.[23] The main concept of DBI is that clusters are more optimal the cluster formed when they have a smaller score.[24] A positive DBI value that is close to zero is considered more favorable. The performance results of the initial cluster and the DBI score are shown in Table 4.

**Table 4**
**Davies-Bouldin Index**

| n-cluster | DBI score |
|---|---|
| 2 | 5.676 |
| 3 | 3.474 |
| 4 | 1.093 |
| 5 | 2.436 |
| 6 | 13.649 |

In Table 4, it seems that among the others, the 4 clusters have the lowest DBI score, so it can be concluded that the 4 clusters either have a high degree of similarity or produce a low variance within their cluster. In the beginning, the scope of this study was to design a menu engineering BI. According to Kasavana-Smith's method, menu engineering only has four categories. By evaluating using DBI, the difference between each n-cluster is shown based on the score, and it seems the best k is still obtained by using four clusters.

Table 5 displays the result from the K-Means cluster, with each cluster detailed by cluster count, CM detail, and MM% detail.

**Table 5**
**K-Means Cluster Detail**

| Cluster | CM | | | MM% | | | Count |
|---|---|---|---|---|---|---|---|
| | Average | Min | Max | Average | Min | Max | |
| 0 | 1038.559 | 303.1579 | 1645.161 | 0.005617 | 0.003151 | 0.013809 | 54 |
| 1 | 5083.305 | 3747.7 | 6798.942 | 0.009324 | 0.003336 | 0.021779 | 6 |
| 2 | 1651.488 | 930.6122 | 2409.355 | 0.024694 | 0.016867 | 0.042014 | 14 |
| 3 | 2178.274 | 1557.93 | 3449.682 | 0.006705 | 0.003182 | 0.013933 | 44 |

Based on Table 5, this study has generated a category label for each cluster in menu engineering; the star category is judged by the highest maximum CM times MM%, the dog category by the lowest CM times MM%, and the other two categories are judged by compare, where the higher CM becomes the puzzle and the other is plowhorse. The results are presented in Table 6.

**Table 6**
**K-Means Cluster Categories**

| Cluster | Categories | Total Count |
|---|---|---|
| 0 | Dog | 54 |
| 1 | Star | 6 |
| 2 | Plowhorse | 14 |
| 3 | Puzzle | 44 |

**Menu Effectiveness Review**

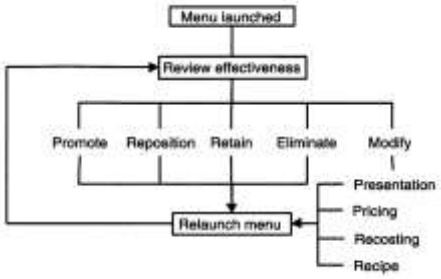


**Fig 7 shows a menu effectiveness review framework**

This review is necessary to determine the changes necessary to improve menu items. As proposed by Jones, P., & Mifli, M., the activities in this framework comprise promotion, repositioning, retention, eliminating, and modification. However, the focus of this study is modifying activity which involving evaluate the presentation, pricing, re-costing, and recipe.[25] Many researchers agree that menu prices have a significant influence on clients' purchasing decisions.

Based on this review framework, the suggestion can be concluded into this study four categories:

**Table 7**
**Menu Effectiveness Recommendation**

| Category | ID | Recommendations |
|---|---|---|
| Star | 55, 56, 61, 65, 68, 69, 70, 76, 78, 79, 80, 81, 83, 84, 85 | a. Maintain the performance of the restaurant.(Jones & Mifll, 2001)<br>b. Maintain the appropriate recipe standards for menu quality, quantities, and appearance.(Tom & Annaraud, 2017)<br>c. Periodically raise selling prices while accounting for rising demand from customers and rivals' prices.(Setiyawati & Hosanna, 2020)<br>d. Keep an eye on rising menu raw material costs and make necessary adjustments to menu selling prices.(Setiyawati & Hosanna, 2020) |
| Plowhorse | 1, 2, 3, 4, 5, 6, 7, 8, 62, 63, 64, 66, 67, 71, 72, 73, 74, 75, 77, 82 | a. Maintain the appropriate recipe standards for menu quality, quantities, and appearance.(Tom & Annaraud, 2017)<br>b. Examining methods of cost reduction,(Tom & Annaraud, 2017) such as keeping an eye on the amount of ingredients ordered, optimizing processing effectiveness, and streamlining presentation while preserving food quality and presentational appeal.<br>c. Gradually raise food costs while keeping an eye on rising demand from customers and rivals' prices.(Setiyawati & Hosanna, 2020) |

| | | |
|---|---|---|
| Puzzle | 57, 58, 59, 60, 87, 88, 89, 90, 92, 93, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 108, 109, 110, 111, 112, 113, 115, 116, 117, 118 | a. To attract clients, offering deals on food delivery services and/or advertising the menu on social media<br>b. Putting the menu in a prominent location, either on the menu display screen,(Tom & Annaraud, 2017) or having the waiter deliver it to customers when they place food or drink orders to increase its popularity<br>c. Give the menu a new, more appealing name.<br>d. Review costing, and the next action that can be made is to lower the food's selling price by considering the state of profit margins, the cost of goods supplied, and the prices that competitors are charging<br>e. Take into account removing the menu |
| Dog | 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 86, 91, 94, 107, 114 | a. Cost reduction to larger the profit<br>b. Increase price to larger the profit<br>c. Promote to gain more popularity<br>d. Eliminate the menu (Tom & Annaraud, 2017); this policy serves as a substitute for cutting significant business costs when it can't be pushed to other categories<br>e. Give the menu a new, more appealing name.<br>f. Put together a menu package from this cluster with very popular foods and/or beverages from other clusters.(Adiatma, Andriatna, & Sudono, 2014) |

For example, this study will use one of the dog category members in this menu, ID 14, who goes by the name Indomie Kuah Cakalang. By using this suggestion based on the menu effectiveness review framework, this study recommends whether to increase the price or remove the menu, as the cost cannot be reduced and will have no significant impact on promotion.

**Architecture and Design**

At this stage, the author describes how a system works by modeling the system using the Unified Modeling Language (UML), which is the industry standard for designing, visualizing, and documenting a system, this helps the author to describe and design software systems. The type of Unified Modeling Language (UML) used is a Use Case Diagram, which is a diagram that describes functional requirements or activities in a system and actors that are connected, and an Activity Diagram, which is a diagram that describes the workflow or activities of a system.

**Use Case Diagram**

This Use Case diagram illustrates the concept of functional requirements analysis, in which some activities and actors are interconnected in the system.

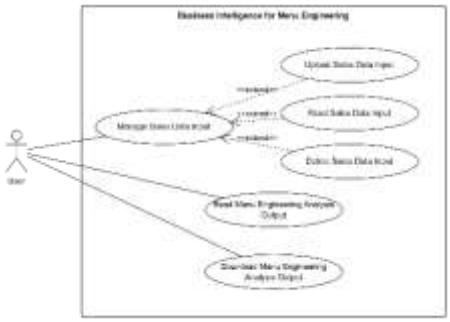

**Fig. 4. Use Case Diagram**

Fig. 4 explains that in this system there is only one actor, namely the user and use cases, which are activities that can be operated by users in this BI.

**Activity Diagram**

This activity diagram describes the concept of data flow or activity from the system as shown in Fig.6.

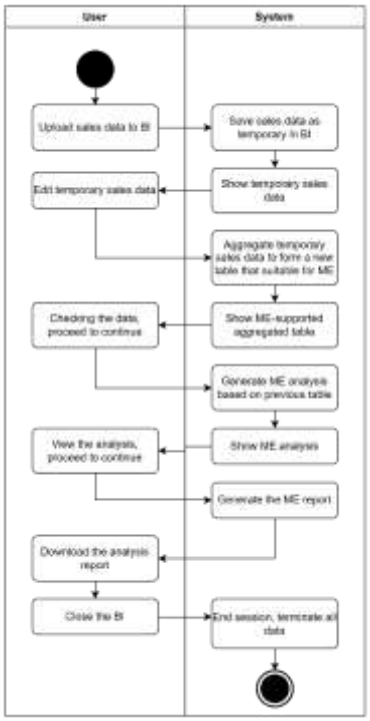


**Fig. 5. Activity Diagram**

Fig. 5 explains the flow of generating menu engineering analysis. From the beginning, when the user uploaded the sales data, the system kept it as a temporary data frame. By aggregating the initial data to make a new dataset that applies to the rule of menu engineering, it can be used to process the knowledge discovery by using the menu engineering formulas. That resulted in a report that explains the insight from the sales data.

**System Architecture**

The system architecture here focuses on creating website-based BI so that the picture adapts to the development of the website, which is divided into two, namely the front end where users interact, and the back end where all the computing and analysis takes place.

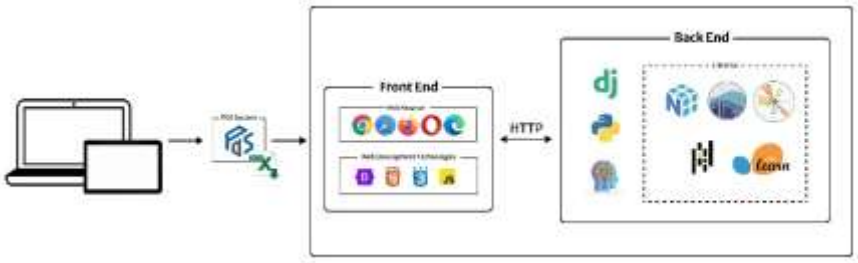


**Fig. 6. System Architecture**

As shown in Fig.7, from the far right, there are recommended devices in the form of tablets and laptops with landscape orientation. Refers to the postal system. This postal system will generate user sales reports so that later users can enter data files on this BI website. Continue is the final font. Where there is a browser, the technology used is a bootstrap framework and programming language in the form of HyperText Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript (JS). And for the backend, it uses technology in the form of the Django framework and the Python programming language, along with libraries that support BI computing.

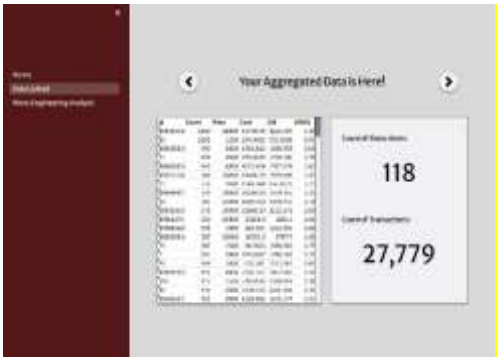


**Fig. 8. Aggregate Data Page Design**

In Fig. 8, there is a display of the results of data aggregation that has been carried out on the previous dataset, producing new variables that are by the formula of menu engineering. On this page, the user also gets a brief explanation regarding their data, like the count of menu items and the count of transactions.

**Fig. 9. K-Means Menu Clustered and Detail Page Design**

In Fig. 9, this is the display of the menu-engineered categories, and when the next button is clicked, it will show the user the details and the recommendations on each menu. When hovering over one of the dots, it will tell the user the menu ID.

**Fig. 10. K-Means Menu Clustered Category Recommendations**

Fig. 10 shows a detailed menu of cluster categories with the recommendations for each cluster category. This design also tells the ID of each menu in the category.

## Conclusion

The goal of menu engineering with a website approach in business intelligence design is to assist micro, small, and medium business owners in managing their companies. The efficacy and efficiency of the K-Means method have been shown to grow with its implementation. The average similarity has been assessed using the Davies-Bouldin Index, and the results of this study indicate that the four clusters are the most optimal, since it is in line with menu engineering that employs four categories. It is intended that by offering helpful development suggestions and insights, businesses would be able to thrive in this cutthroat environment. Adding the services required for business management to business intelligence is the next action that may be taken. Suggestions for

further research include adding business intelligence features that are useful in the engineering menu analysis process, as well as simply considering adding algorithms to carry out analysis for more efficient results.

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