Concept Paper

Design of a Reverse Processing Network for Sub-Optimal Fruit in a Retail Store Using an Milp Model

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Design of a Reverse Processing Network for Sub-Optimal Fruit in a Retail Store Using an Milp Model

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Abstract: Modernizing the retail sector is essential to societal progress toward creating a smart city. The retail sector is crucial to the development of a smart city because of its adaptability and capacity for innovation. However, due to their perishability, supermarkets throw away a lot of fruits and vegetables. This article discusses the design of a sub-optimal process for processing sorted fruits using a reverse logistics approach, demonstrating how productivity can be increased despite constraints on processing capacity. This paper presents the results of a case study conducted in a Qatari supermarket that offers a variety of regular fruit processing techniques. In order to maximize output and cut down on waste, this project aimed to develop a reverse logistics system for imperfect fruit.

Keywords: food waste; MILP; retail; reverse logistics; sustainability

Chapter 1 Introduction

1.1. Introduction

Reverse logistics is typically used in the manufacturing sector to carry out take-back agreements, warranty fulfillment, and product guarantee transfers from the buyer to the seller. Due to the perishability and biological complexity of the products, reverse logistics in fruit retailing is challenging. However, it may be possible to reduce the internal waste of retail stores while maximizing sales and profit by using reverse processes of execution in retail stores, such as refurbishment, redistribution, disassembly, and price discounting. It is crucial to choose the proper processes for the specific fruit when designing and planning these reverse logistics processes for fruit retailing in order to reduce processing costs. To choose and create reverse logistics processes, a mixed integer linear programming-based model for cost minimization is appropriate.

1.2. Background of the Study

In every fruit and vegetable retail, the common practice of product flow is shown in Figure 2. The day-to-day activity of a retail shop starts with getting storage of fresh fruits and vegetables (FV). Then they start sorting the FV according to the grades. Usually, substandard products are thrown away. But some retailers sort the less damaged, abnormally shaped but good quality FV and initiate promotion that attracts the customer to buy those FV. The ultimate result of this promotion initiation is the reduction of potential waste. In the same way, implementing other reverse logistics decisions such as repacking, refurbishing, disassembling, and redistributing are also useful in this regard.

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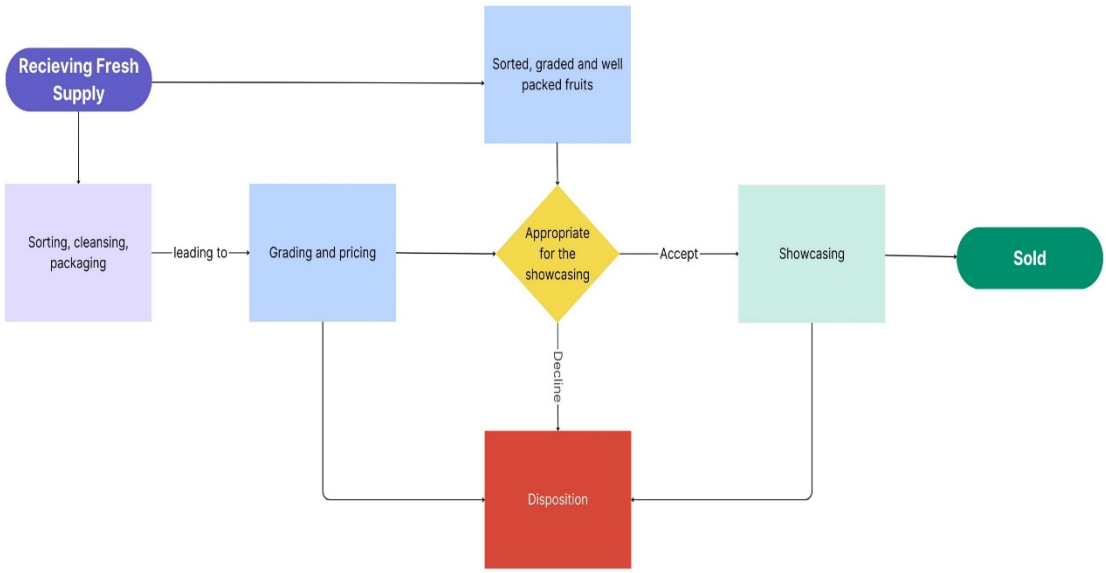

Figure 1. Traditional fruit journey in a retail store.

1.2. Problem Statement and Research Questions

Selecting reverse logistics processes according to the fruit condition criteria is suitable by using Analytical Hierarchy Process (AHP) and the Technique for order of preference by similar to ideal solution (TOPSIS) if the numeric values of corresponding parameters are fuzzy. However, the constraints-based linear programming model is required for cost optimization of the reverse logistics processes. In Figure 1 it is clear that the fuzzy AHP-TOPSIS method is applicable within the red-marked area and the constraints-based model is required if the cost constraints are available for optimization.

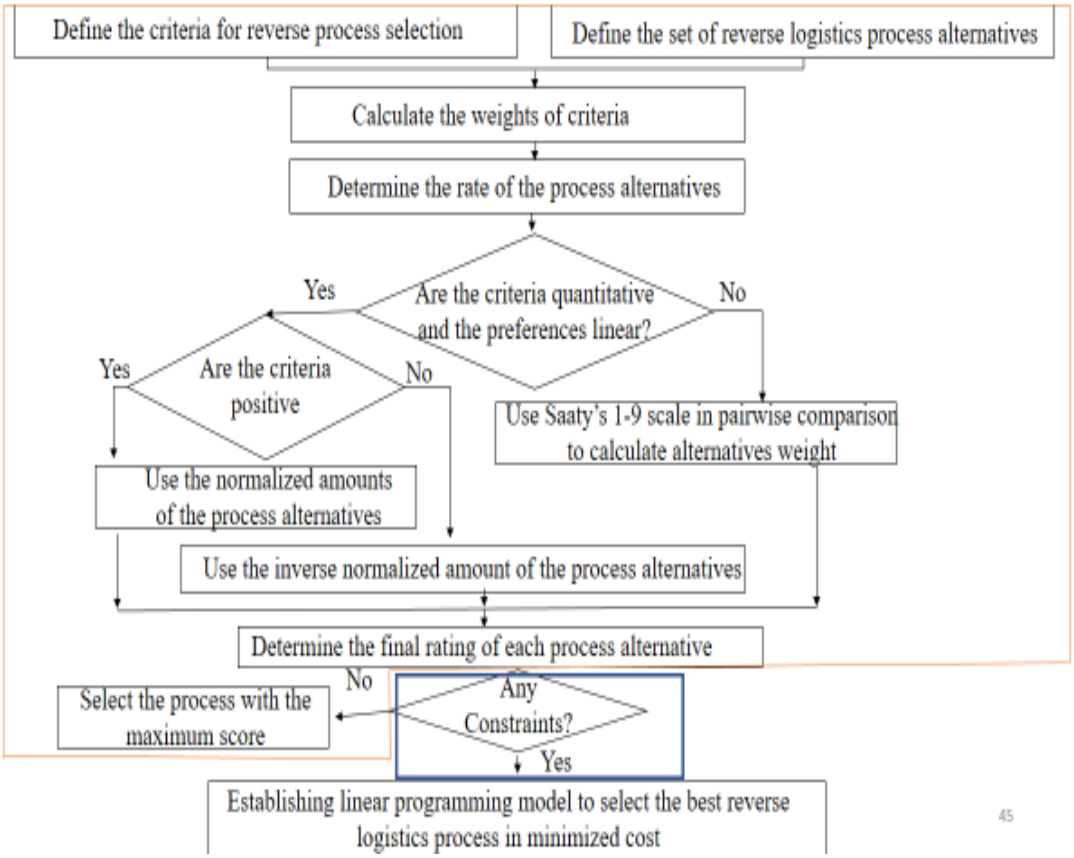

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Figure 2. Mathematical model determination process for criteria-based reverse process decision selection.

Research Questions: Followings are the research question of this study.

- How the retailer can utilize the capacity of a particular reverse logistics process for a specific fruit based on different criteria for the problem fruit?
- How the retailer can minimize the reverse logistics process cost?

Chapter 2: Literature Review

2.1. Introduction

The starts of the reverse logistics had been considered as something that is happening in the backroom and is not considered as strategic as today (Caldwell, 1999, p. 48). The popularity of reverse logistics has been increased due to environmental consciousness, achieving sustainability, operational cost minimization, and waste management.

The reverse process of fruits are not the same as the other manufacturing processes. The biological complexity makes it difficult to design a proper reverse process for a particular fruit.In this section of the study, different reverse logistics decisions appropriate for fruit retailing are discussed.

Plenty amount of Scientific design and framework of RL related to food industry are available. In this paper models related to fruits and vegetables has been synthesized. (Velychko, 2014) identified technological, logistical and marketing process and integrate them in model of forward flow of supply chain. Model useful to track the expired food by using FEFO (First Expired First Out) has been developed by (Bogataj et al., 2017) and (Spagnol et al., 2018). Distribution and packaging focused waste management model (Guillard et al., 2015),(Bortolini et al., 2018) and (Accorsi et al., 2020). (Chen et al., 2018), (Hua et al., 2018), (Feingold et al., 2019) and (Sura raksa & Shin, 2019) worked mostly on transportation and distribution model. IoT based warehouse management system to monitor the storage condition of fruits and vegetables has been developed by (Deshmukh & Bhalerao, 2018). (Morales-Plaza et al., 2020) designed the RL supported waste management model which resulted 2.57% less waste generation. For optimizing the location decisions, quantities of inventory and flow among the facilities (Jabarzadeh et al., 2020).

2.2. Reverse Logistics for Fresh Fruit Retail

Reverse logistics in the fresh fruit industry refers to the process of managing and recovering products that have been returned, overstocked, or are nearing their expiration date. The management of these products is a critical concern in the industry as they can impact the quality and profitability of the product. Several strategies are commonly used in the reverse logistics process of fresh fruit, including refurbishing, repackaging, disassembling, pricing discounts, redistribution, and disposition. In this literature review, we will examine the existing research and literature on each of these strategies.

2.2.1. Refurbishing

Refurbishing is a strategy that involves repairing and restoring products to their original state. In the fresh fruit industry, this strategy is often used to salvage damaged or bruised fruit. Kaddoura et al., (2019) investigated the life cycle evaluation and shown that extending the shelf life of fruits can be accomplished through the use of refurbishing of low-hanging fruit. According to the findings of their research, the allowed for a reduction in waste that ranged from 45 to 72 percent in the majority of the situations that were analyzed.

2.2.2. Repackaging

Repackaging involves the removal of original packaging and the placement of new packaging. This strategy is often used to improve the product's presentation and extend its shelf life. In order to cut down on the amount of fruit and vegetable that is thrown away, Perez-Mesa et al., (2021)

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developed a location model for a repackaging and redistribution network. They demonstrated that ten percent of products are sent back by customers due to relatively small flaws such as packing issues.

2.2.3. Disassembling

Disassembling involves the separation of products into their constituent parts. In the fresh fruit industry, this strategy is often used to salvage products that have been damaged or are nearing their expiration date. Seymour et al. (2013) show in their study that overripe fruit expedites the ripening process of other adjacent fruits. As a result, it is recommended to separate the problem fruit from the cart of good fruit to control the ripening process.

2.2.4. Pricing Discounts

Pricing discounts involve the reduction of the product's price to encourage its sale. In the fresh fruit industry, this strategy is often used to manage overstocked products or those nearing their expiration date. Pricing discounts are an attractive tool for retailers to sell suboptimal foods (Huang et al., 2020). It helps to increase customer preference behavior to buy.

2.2.5. Redistribution

Redistribution involves the transfer of products from one location to another. In the fresh fruit industry, this strategy is often used to manage overstocked products or to redistribute products to areas with higher demand. It is helpful to reallocate the fruit to the proper cart, where it has its appropriate value.

2.2.6. Disposition

Disposition involves the final management of products that cannot be salvaged or sold. In the fresh fruit industry, this strategy is often used to manage products that have exceeded their expiration date or are no longer fit for consumption.

Chapter 3: Methodology

3.1. Introduction

The journey of a fresh supply of fruits in a retail store is divided into two stages: the initial process and the continuous process. The block diagram of the process design is shown in Figure 3. The outcome of the initial process stage of retailing is sorting, grading, and determining the reverse logistics process and benchmarking them. The outcome of the continuous process stage of retailing consists of selecting the appropriate decision for the appropriate fruit. In short, the initial stage helps the retailer to determine the reverse logistics decisions for a batch of fruits after being observed by the retailing decision maker and the continuous stage helps the retailer to merchandise the fruit according to the condition of fruits, increasing the visibility of the fruits, continuous reverse logistics decision support system designing for the batch, and on final stage retailer get the reverse logistics process decision and optimizing the reverse logistics process cost.

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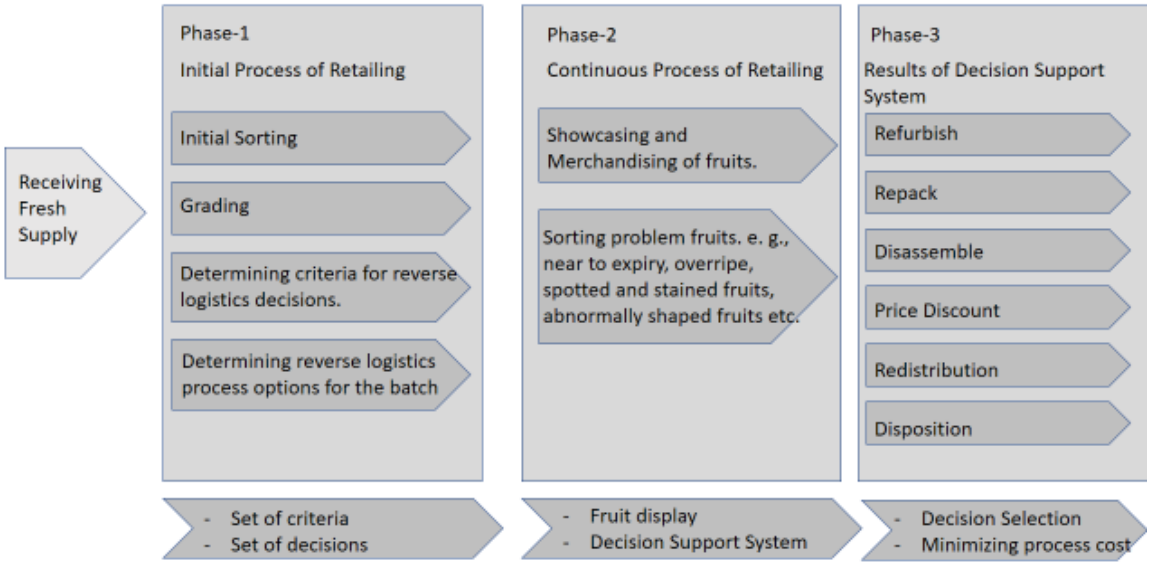

Figure 3. Block-diagram of a reverse process design in a retail store.

3.2. Case Problem Formulation

In the case study, we will consider a simple reverse supply chain network depicted in Figure 4. It includes the following elements:

- A set of reverse processes required orange with different criteria. (eg., Orange near to the expiry date, abnormally shaped, overripen, odd skinned, Cut mark on orange).
- As set of the candidate reverse processes. (eg., Jam producing, Pickle making, Fresh juice production, Salad making)
- A set of market shelves to sell the final processed fruit, with certain demands.

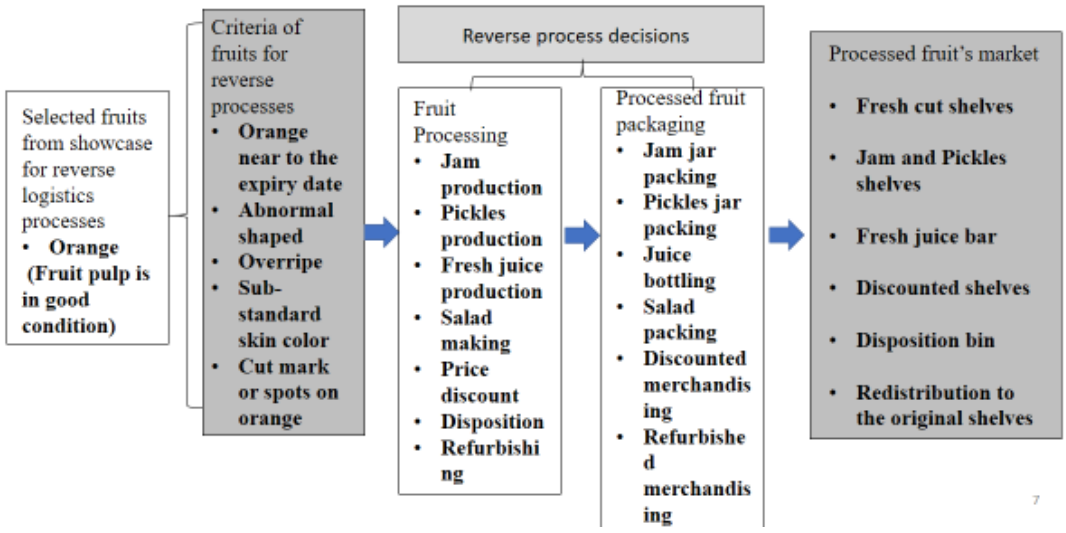

Figure 3. Reverse supply chain network in a retail store.

After installing a set of process stations, an additional amount of cost is incurred due to the additional labor, equipment, energy bill, packaging, etc. Utilizing the capacity of the selected set of reverse processes efficiently is important for the profitability of a retail store. The optimization model in this study can support the decision-making process by answering important questions such as:

- Which reverse processing option and the problem fruit category relation is most attractive from the processing capacity utilization viewpoint?
- What is the optimal combination of the cost?

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3.2. Mathematical Modeling

It's really difficult to arrange different capacities of processing according to the different varieties of fruits and their criteria. Generalized processing arrangement for all types of output demand is also can be questioned by quality control. However, minimizing the processing capacity in the existing processes and meeting the demands at the same time is an important measurement that needs to be taken by the retailer to plan fruit-specific reverse processing.

The problem is related to the classical bin box problem because a sorted group fruit criterion need to be processed in a single process at a time. The sorted fruit and their processed can not be mixed with any other processes , product or fruit.

Inputs

P; Set of processes to produce final product

I; Set of input fruit criteria

C_p; Capacity of the process $p \in P$

L_i; Available input fruit of criteria $i \in I$

Decision variable:

$X_{pi} \in \{0, 1\}$; binary variable equal to 1 if input fruit category $i \in I$ is processed in process $p \in P$ (0 otherwise)

$Y_p \in \{0, 1\}$; binary variable equal to 1 if the process $p \in P$ is used (0 otherwise)

Objective function

Min,

$$\sum_{p \in P} C_p Y_p \quad \dots\dots\dots \quad (1)$$

Minimize the capacity of the processes used.

Constraints

Subject to

$$\sum_{p \in P} X_{pi} = 1 \quad \forall\, i \in I \quad \dots\dots\dots \quad (2)$$

Inequality (2) states that each type of fruit $i \in I$ has to be processed.

$$\sum_{p \in P} L_i X_{pi} \leq C_p Y_p \quad \forall\, p \in P \quad \dots\dots\dots \quad (3)$$

Inequality (3) is related to the capacity of each process can not be exceeded.

$$X_{pi} \in \{0, 1\}\ \forall\, p \in P, \forall\, i \in I \quad \dots\dots\dots \quad (4)$$

$$Y_p \in \{0, 1\}\ \forall\, p \in P, \dots\dots\dots \quad (5)$$

(5) and (4) is related to the integrality constraints.

Chapter 4: Data Analysis and Results

4.1. Introduction

The case study has been conducted at SPAR Qatar. The SPAR licensee in Qatar, Al Wataniya International Holding, was approved in 2015. After acquiring the SPAR brand in Qatar, Al Wataniya set out to create the most efficient retail and supply chain model possible for the country. Regular fruit is used in a variety of their in-house processed products, including fresh juice, salads, jams, and pickles. This study is presented that shows how the same processes can be used as the reverse process with the already existing capacity, in addition to the regular processing activity.

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4.2. Data Collection

A number of sub-optimal and less attractive oranges have been sorted out from the retail cart before the day activity started. They are divided into the sub-optimal category such as orange near the expiry date, abnormally shaped, overripe, sub-standard skin color, and cut marks or spots on orange. And the selected reverse processes are fresh juice making, jam making, pickles making, and salad making. Tables 1 and 2 is showing the remaining capacity of the processes for a week and the available sub-optimal fruit amount according to the categories.

Table 1. Capacities of the reverse processes.

Reverse Process	Fresh juice production	Jam Production	Pickles production	Salad making
Process capacity (KG)	45	32	26	22

Table 2. Available fruits of different categories for reverse processes.

Fruit Categories	Orange near the expiry date	Abnormal shaped	Overripe	Sub-standard skin color	Cut marks or spots on fruit
Sorted Amount (KG)	42	28	10	18	16

The assumption for the analysis is as follows.

- One process can be used for a single category of fruit altogether. Then it can take another category if there is available capacity.
- Fruit can not be mixed up with other categories for quality control.
- Any category of fruit can be used on any process as the pulp condition is still good.

4.3. OPL Application

IBM OPL CPLEX has been used to analyze the data. The input code is shown below.

```
/***************
 * OPL 12.10.0.0 Model
 * Author: ThinkPad
 * Creation Date: Apr 13, 2023 at 2:24:47 PM
 ***************/
int ni = ...;          // Number of input fruit categories
range I = 1..ni;     // Set of fruit category
int np = ...;          // Number of processes
range P = 1..np;     // Set of processes
int C[P] = ...;       // Process capacities
int L[I] = ...;       // Input fruits amount

dvar boolean x[P][I];     // Is fruit i processed in process p?
dvar boolean y[P];          // Is processp used?

minimize sum ( p in P) C[p] * y[p];

subject to {
```

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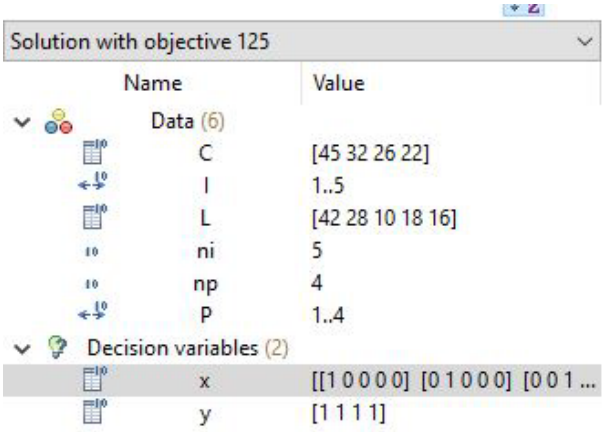
```
    forall (i in I)
      (sum (p in P) x[p][i] == 1);

    forall (p in P)(
      sum (i in I) L[i] * x[p][i] <=C[p]*y[p]);
}
```

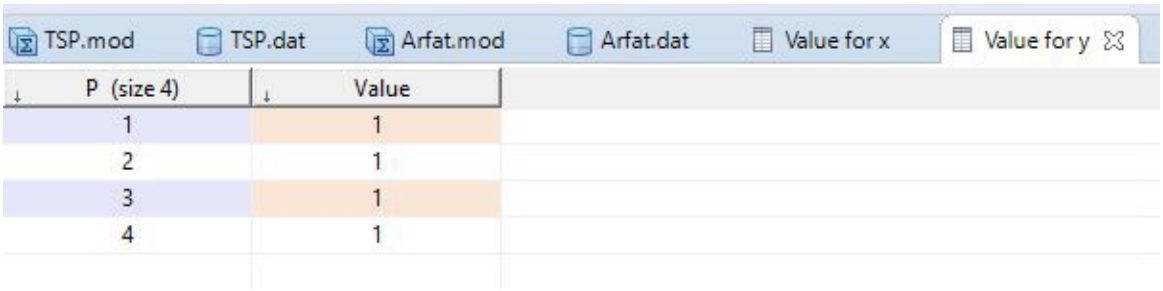
4.4. Results and Discussion

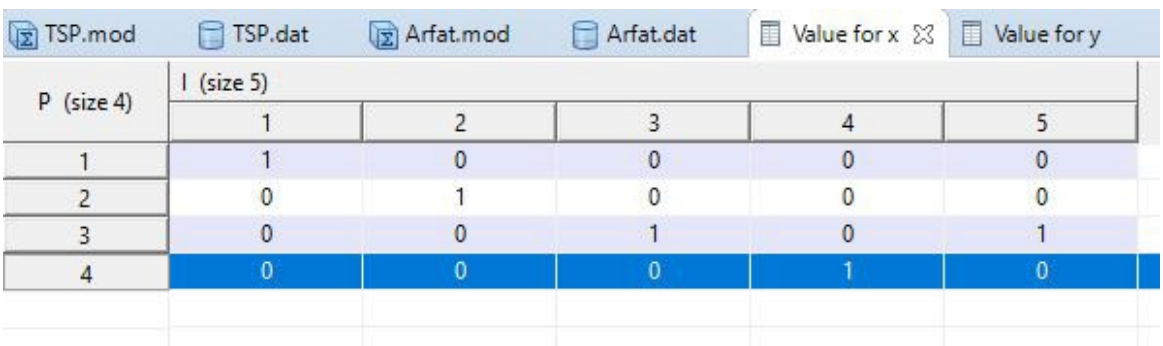
According to the findings of OPL CPLEX, all of the processes are utilized, and in order to make the most of the capabilities offered by those processes, the fruits must be selected in accordance with Table 1. Figure 1 displays a portion of the overall results obtained through OPL.

Table 3. Results.

Reverse Processes	Fruit categories to process
Fresh Juice Production	Orange near to expiry date
Jam Production	Abnormal shaped
Pickles Production	Overripe, Cutmark on fruits and vegetables
Salad Making	Sub-standard skin color







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Chapter 5: Conclusion

This study demonstrates that a maximum usage of available fruit that was sorted owing to its low attractiveness may be achieved with a minimum capacity of the procedures involved in reverse logistics. However, it has been observed that for a batch of fruits, retailers are not using all the reverse logistics processes. After observing the batch of fruits they need to do cost optimization and select of appropriate reverse logistics process for a specific batch of fruits. For example, for a batch of tomatoes without packaging, it is not required to engage repack decision plan. Scheduling the decisions according to the batch of fruits makes the problem more dynamic.

Cutting stock problem of the combinatorial optimization process can help only to get the optimized decision of resource utilization. But the journey of fresh fruits in a retail store is complex and involves multiple stages. The initial process of sorting, grading, and determining the reverse logistics process is important for ensuring that the fruits are of high quality and that waste is minimized. The continuous process of selecting appropriate decisions for each fruit, merchandising according to the condition of the fruit, increasing visibility, and designing a continuous reverse logistics decision support system is important for ensuring that the fruits are delivered efficiently and that the reverse logistics process is optimized. By paying attention to both stages, retailers can ensure that their customers receive fresh and high-quality fruits in a timely manner, while minimizing waste and reducing costs.

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