WORKERS ASSIGNMENT FOR SELECTED ASSEMBLY LINE

EMJAY INTERNATIONAL (PVT) LTD – PANVILA BRANCH

GROUP 07 | MAT 3991

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GROUP 07

Register Numbers	Members Names
1. S19809	Kasun Dhanushka
2. S19832	Malith Mewanga
3. S19836	Thilina Sasanka
4. S19845	Hiruni Rathnaweera
5. S19847	Chamuditha Rowel
6. S19850	Thilini Sadarenu
7. S19869	Dineth Ashen

ABSTRACT

Sri Lanka's apparel and textile manufacturing industry is the most significant contributor to Sri Lanka's economy. Over the years, Sri Lankan apparel Industries have earned a powerful reputation worldwide for the reliable manufacturing of high-quality apparel trusted by famous global fashion brands. Apparel manufacturers contribute prominently to the country's Gross Domestic Product and experience some deficiencies. The efficiency problem in the production lines, one of the plant's sections, is discussed here. The incompatible allocation of workers to each line operation is identified as one of the major causes of this gap. In finding the optimal allocation, the best-negotiated approach is developed using a mathematical model, and the solution is derived by using a modified assignment problem. In determining the solution, a modified Hungarian algorithm was applied using Python and Microsoft Excel.

01. INTRODUCTION

01.1 Introduction to Company

Emjay International (PVT) Ltd is a leading company in Sri Lanka which manufactures and exports readymade garments worldwide. This Leading Company is a dynamic and innovative company committed to excellence in its field. Since its inception, Emjay Penguin has been dedicated to delivering high-quality products and services, becoming a trusted name in the industry. They mostly make Loungewear, Underwear, Active Wear, and Thermal Wear.

The headquarters is in Colombo. The sub-branches of the company are situated mainly in Karandagolla, Pallethalawinna, Teldeniya, and Panvila. Penguin Sportswear was started in 1990 and in 1995 the company was expanded by improving the production facilities and acquiring the Panvila factory. Then it was extended to Emjay International in 2005 founded by Emjay Internationals. Then In 2007, the company was expanded by improving its production facilities by acquiring the Teldeniya Factory.

At Emjay Penguin, they prioritize sustainability, efficiency, and customer satisfaction. Their team of skilled professionals works diligently to ensure that their offerings meet the highest standards of quality and reliability. They continuously invest in cutting-edge technology and sustainable practices to stay ahead in a competitive market, reflecting their commitment to environmental stewardship and corporate responsibility.

The factory selected for our research is in the Panvila Kandy district. Currently, 1200 employees are working in that plant. Panvila plant mainly focuses on stitching and embroidery of clothes which are mainly men's underwear and sports wears.

- Address: 9P88+27C, Panvila
- Contact number: 0814 484 500
- Workers
    - Machine operators -1000
    - Others -260

01.1.1 Vision

- We CREATE value in our business
- We make every attempt to INNOVATE our products and services
- We strive to EXCEL with our people and processes
- With the aspiration to DELIGHT our customers in every way

01.1.2 Mission

- A great place to work that achieves operational excellence while ensuring a high degree of social and environmental responsibility.

01.2 Product Portfolio

1. Essentials: Ladies
2. Underwear: Men
3. Loungewear: Men
4. Active Wear
5. Thermal wear



01.2.1 Major customers

1. HUGO BOSS
2. TESCO
3. MARK & SPENCER
4. HELLY HENSEN
5. GEORGE
6. OLD NAVY
7. GAP
8. BHS
9. H & M
10. DEESEL
11. BURTON
12. CRAG HOPPERS
13. MERRELL

01.3 Production Process

01.3.1 Departments (Production Process)

1. Storing Section
2. Inspection Area (Color, Material checking)
3. Cutting Section
4. Quality Assurance Department (overall procedure)
5. Sewing Department
6. Finished goods warehouse

1. Storing Section

- The amount of fabric required from the main branch.
- The fabrics are stored separately based on different criteria.
- Fabric loosening is done as per the request of the cutting department.
- It is mandatory to store the fabric loosely for at least two days.

2. Inspection Area

● To examine the fabric, sewing, button, thread, zipper, garments measurement, color and so on according to specification or desired standard is called inspection.

● The aim of inspections is to reduce the time and cost by identifying the faults or defects in every step of garments making.
Inspection process

- Identify the defects or faults
- Knock the appropriate person
- Identify the reasons of defects or faults
- Remove the defects or fault

3. Cutting Section

- **Cutting Section Setup**

The cutting section consists of four tables, each equipped with two cutting machines, making a total of eight machines.

- **Fabric Marking and Cutting**

The fabrics are marked optimally to ensure minimal waste and precise cutting. Workers manually operate the cutting machines to execute the cutting tasks.

- **Cut Numbering and Tagging**

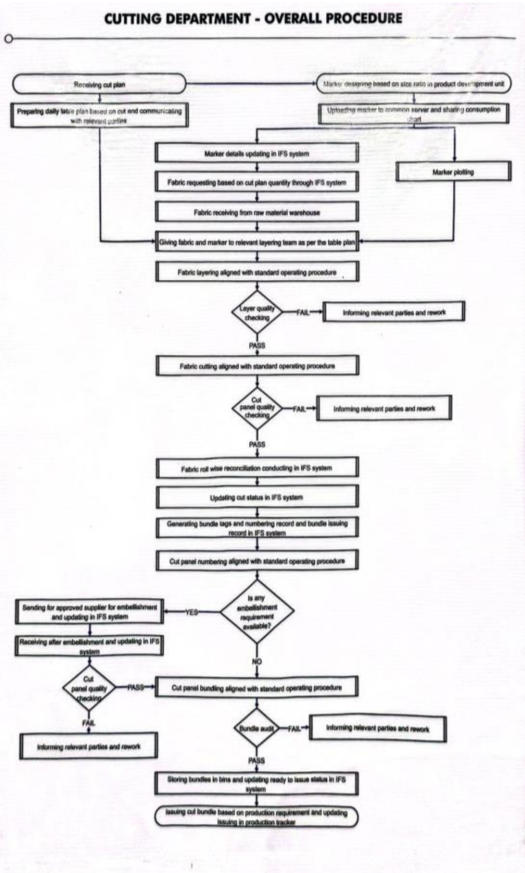
Each cut is assigned a unique number and tagged appropriately to ensure traceability and organization.

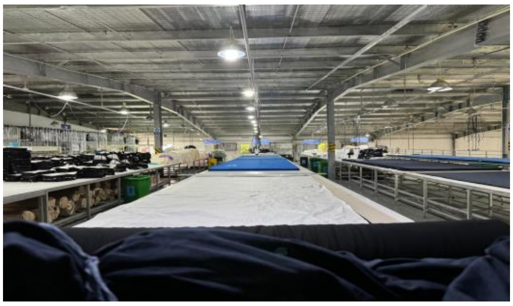
- **Weekly Cutting Plan**

The fabrics are cut according to the weekly cutting plan, with the production cut scheduled for Friday.

- **Production Issue Date**

The relevant quantities of cut fabrics are issued to the designated production lines on the following Monday.



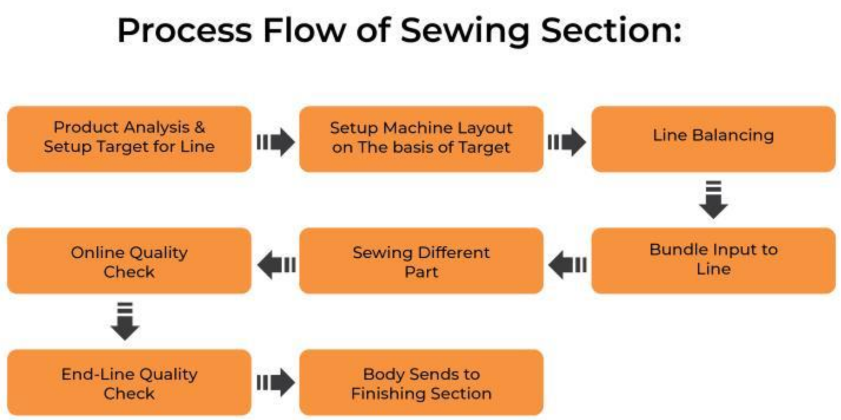


4. Quality Assurance Department - Overall Procedure

1. Sewing size set aligned with standard procedure
2. Evaluating size set and bulk approval
3. Cutting quality process aligned with standard procedure
4. Quality control orders/ Presetting quality process aligned with standard procedure (If there is any QCO/Presetting quality verification requirement)
5. Feeding bulk production aligned with standard procedure
6. First fifty inspections aligned with standard procedure
7. Inline quality (TLS-Traffic Light System) process aligned with standard procedure
8. Label process within the production teams aligned with standard procedure
9. Needle process within the production teams aligned with standard procedure
10. In-Station Quality (ISQ) process within the production teams aligned with standard procedure
11. End-line quality process aligned with standard procedure
12. End-line inspection (by internal NQC) aligned with standard procedure
13. Pre-final inspection aligned with standard procedure
14. Final inspection aligned with standard procedure

5. Sewing Department

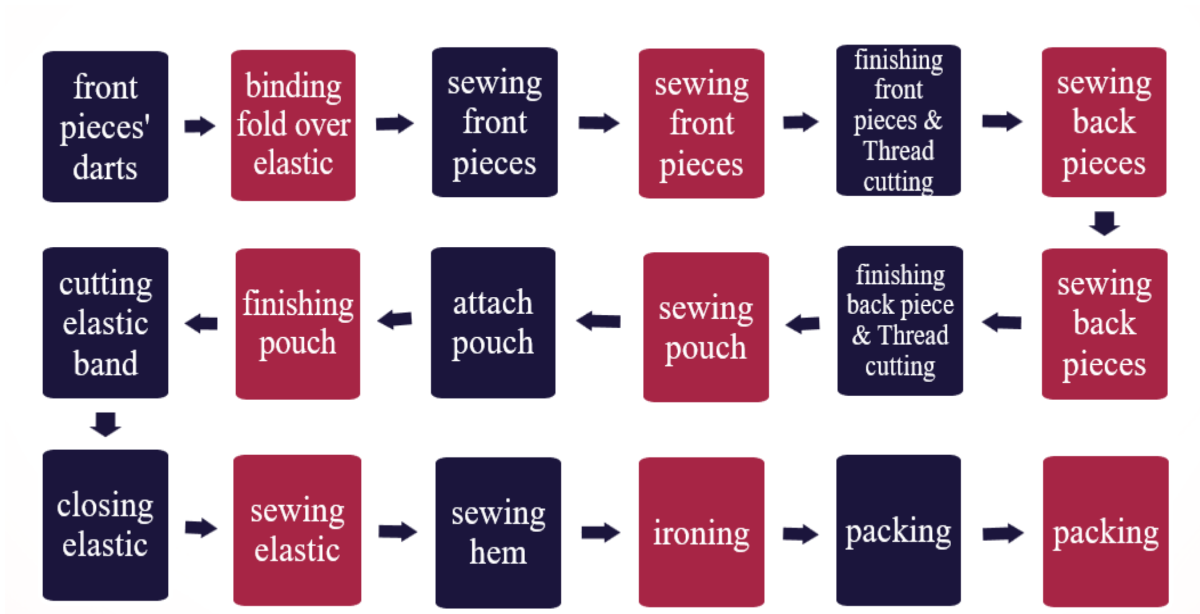
- The sewing process is the attachment of different parts of the cut pieces.
- Process flow of sewing section:



- **Sewing Defects** :

    - Needle damage
    - Skip stitches
    - Thread breakages
    - Broken stitches
    - Open seam
    - Un-cut threads
    - Shade variation
    - Seam puckering
    - Uneven/ Wrong stitch density
    - Pleated seam

01.3.2 Assemble Line



01.4 Problems Identified

During our company visit we saw that they have a good planning procedure for overall production, since this is a large-scale company.

Any how we identified some of the problems in this company.

1.Storage problems

Sometimes, company faces to some storage problems. To complete the orders, firstly they should order the fabrics and other requirements and store them. And also, before moving the fabrics to the cutting department, the fabrics should be loosed at least 2 days. So, to continue these processes, the company should have enough storage facilities. But, during our company visit, one of the main problems we identified that they don't have enough storage facilities. At this situation, they store the excess fabrics in their other branches like Karadagolla and Teldeniya. So, the company must bear some of the extra transportation cost.

2.Defects generating in sewing

We identified some of the fabric defects. That means, some of the final products have horizontal lines that runs from side to side and shade variation, dirt or stains, misprinting, holes, Needle lines and broken and some of the fabric defects that the company faces in the production process.

These fabric defects directly affect to the company profit since they reject the all the defected items. As a solution, the company sell these defected items at a lower cost to reduce the value loss and, they maintain the machines properly.

3.Machine Downtime

Apart from that machine downtime is one of the main problems that the company always faces. Specially, these machine downtimes directly cause the production stoppage and. It is a margin problem to delay the orders. When delaying the orders. The company must face some of the increasing cost to finish the order within a short time of period. As a solution, the company is maintaining a collection of machines that properly work. So, when happen a machine failure it can be used one of the machines that properly work. Until broken machine is repaired.

4.Cover the targets before deadlines

As well as sometimes the company is struggling to cover the orders before deadlines. Mainly this happens when the company has many orders. As a solution, the employees must work more than an hour. For that, the company must pay money for overtime work.

Because of that, we are going to introduce a proper solution to overcome this problem assigning a worker. That means our solution will help to cover the targets before deadlines. As the advantages of our approach, Mainly We can show that the company cost is reduced since the company does not want to pay for overtime work. And our solution that has been introduced to overcome this problem is cost free.

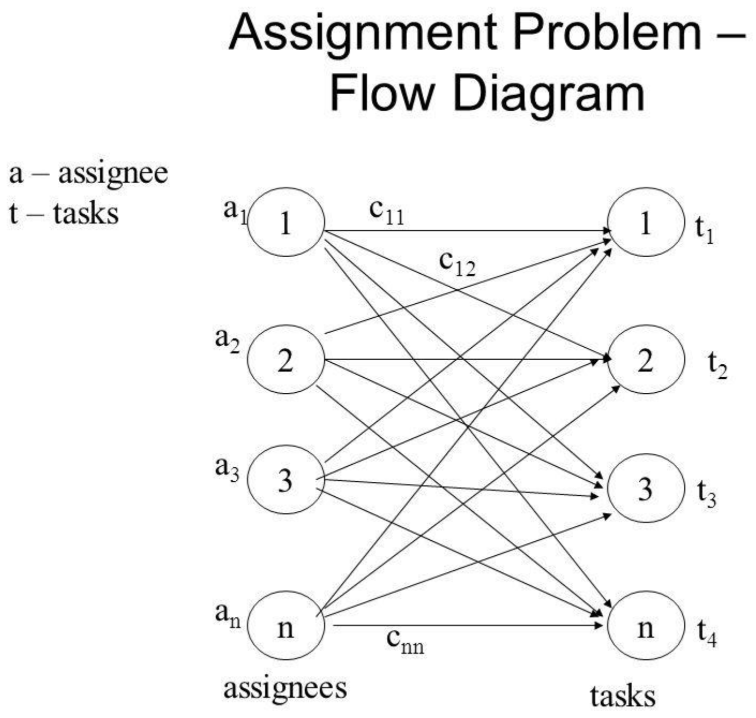
02. METHODOLOGY

02.1 Definition of Assignment Problem

Assignment problem is a type of optimization problem that seeks to find optimal solution for assigning task to a set of resources in a way that minimizes the total cost or maximizes the total profit.

The assignment problem can be solved using 4 methods.
- The complete enumeration method
- The simplex method
- The transportation method
- The Hungarian method

Our goal is to find a perfect matching of tasks to resources that optimizes the objective function using Hungarian method.



02.2 Hungarian method

The Hungarian method (also known as the Hungarian algorithm or Kuhn-Munkres algorithm) is an optimization algorithm used to solve the assignment problem.

The assignment problem involves assigning n workers to n tasks in such a way that the total cost (or total time, distance, or any other metric) is minimized (or maximized, in some cases). The Hungarian method provides an efficient way to find the optimal assignment in polynomial time.

02.2.1 Steps of Hungarian Method

- Step 1 : For the balanced assignment problem , Identify the minimum element in each row and subtract it from each element of that row.
- Step 2 : Identify the minimum element in each column and subtract it from each element of that column.
- Step 3 : Draw the least possible number of horizontal and vertical lines to cover all the zeros. If the number of lines equals the order of the cost matrix, then go to step 5; otherwise, go to step 4.
- Step 4 : Identify the smallest element among the uncovered elements left after drawing the horizontal and vertical lines in step 3. Subtract this element from all the uncovered elements and add the same element to the elements lying at the intersections of the horizontal and vertical lines. Then go to step 3.
- Step 5 : For each row or column with a single zero, box that zero as an assigned cell. For every zero that becomes assigned, cross out all other zeros in the same column or row. If for a row or a column, there are two or more zeros then choose one cell arbitrarily for assignment. The process is to be continued until every zero is either assigned with box or crossed out. Cells having a box indicate optimal assignment. In case a zero cell is chosen arbitrarily then there may be alternate optimal solution.

03. DATA, MATHEMATICAL MODELS AND SOLUTIONS

03.1 Data Collection

- Collected skill scores for each worker (0-2 scale).
- Noted worker availability.
- Mapped tasks to required skill levels.
- Skill variation across workers.

03.1.1 Skill Score

In the textile industry, skill score typically refers to a metric or measure used to evaluate the efficiency, productivity, and proficiency of workers or machines in various production processes. It helps to assess the quality and accuracy of work performed during operations.

Key factors in skill score:
Productivity: Output per unit of time (e.g., meters of fabric per hour).
Quality: Defect rate or error percentage.
Efficiency: Time taken versus standard time required.
Adaptability: Ability to work with diverse designs or materials.
Consistency: Uniform performance over a given period.

Establish a Scoring System:
Develop a scoring mechanism, usually on a percentage or point-based scale.
For example:

Productivity: 40 points
Quality: 30 points
Efficiency: 20 points
Adaptability: 10 points
Total: 100 points

For instance:

Productivity: 32/40
Quality: 28/30
Efficiency: 18/20
Adaptability: 8/10
Total Skill Score = 86/100

03.1.2 Company data set

Skill scores of the workers based on their efficiency and quality of the complete work as follows.

ID number	Front pieces darts	binding fold over elastic	sewing front pieces	sewing front pieces	Finishing front pieces & Thread cutting	Sewing back pieces(1)	cutting elastic band	Finishing pouch	Attach pouch	sewing pouch	Finishing back piece & Thread cutting	Sewing back pieces(2)	closing elastic	Sewing elastic	Sewing hem	ironing	packing(1)	packing(2)
E1118	1.19	0.95	1.85	1.85	0	0	1.83	1.76	1.19	1.23	0	1.57	1.63	1.28	0.86	0.89	1.56	0.63
E1246	0	1.84	0	0	1.16	0.77	1.19	0	0.76	1.4	1.59	1.09	0.68	1.15	1.09	1.95	1.68	1.75
E1156	1.58	1.68	0	0	0.8	1.69	0	0.74	0.81	1.6	1.38	1.43	0	1.14	1.72	1.18	1.95	0
E1143	1.59	0	0	0	1.49	1.58	0.85	0.74	0	0	0	0.64	1.06	1.01	0	0	1.42	1.55
E1179	0	1.86	1.18	1.18	0.74	1.51	0.73	0	1.58	0	0.55	0	0.73	0.83	1.89	0.74	0.81	0.46
E1099	0	1.08	0	0	1.87	1.46	1.42	1.43	0.74	1.11	1.37	1.55	0.68	0	1.51	1.02	1.62	0
E1233	0.69	0	0.63	0.63	0.77	0.44	0.7	0.99	0	1.85	0.62	0	0.53	0	0	1.27	1.69	1.38
E0999	0.94	1.56	1.38	1.38	0	1.83	0.51	1.85	1.95	1.81	1.89	1.94	1.72	1.29	1.75	0	1.16	1.27
E1567	0.48	1.55	0.3	0.3	1.36	0.33	1.12	0	0	0	1.09	1.58	1.94	0	1.94	1.92	0.69	1.24
E1589	1.22	1.86	1.28	1.28	1.28	0	1.53	0	1.27	1.24	0.81	1.92	1.12	1.29	1.65	0	0.3	0
E2004	1.74	0.85	0	0	1.32	0.89	0	0.94	0.92	1.19	0.75	1.84	0.53	0	0.84	1.49	0	0
E2014	0	0.84	1.8	1.8	0	0.85	0.77	1.79	1.38	0.9	1.72	0.91	0.11	1.18	1.07	1.84	1	1.94
E1887	1.91	1.68	1.77	1.77	1.89	0	1.31	0.6	1.73	0.59	0	0.7	1.14	0.63	1.08	0	1.71	0
E1934	0.9	0	0.56	0.56	1.31	0.93	1.81	0	1.57	0.43	0.4	1.42	0.97	1.5	0.72	1.88	0.59	1.67
E1857	0.97	0.75	0.97	0.97	0.75	0.55	0.99	0	0	0	0.43	0.16	1.51	0	1.76	0	0.72	0.82
E1469	0	0	0	0	0	1.76	1.71	1.72	1.53	1.02	1.91	1.37	1.07	0.69	0.64	1.02	0.67	1.05
E2069	1.6	1	0	0	0	1.08	1.94	0	1.6	0	1.89	0	1.16	1.57	0	1.32	0	0.63
E2071	1.94	0	1.46	1.46	0.54	0	0	0.79	0.89	0.5	1.7	0.55	1.7	1.49	1.23	0.85	1.07	1.05
E2007	0	1.06	0.94	0.94	0.74	1.48	0	1.56	0.8	1.58	1.26	1.34	0	1.04	1.1	1.2	1.25	1.48
E1578	0	0	1.5	1.5	0	1.35	1.41	1.86	1.29	0.93	1.44	1.88	1.62	1.75	1.91	1.48	0.66	1.2

Workers assignments before using the Hungarian method as follows.

ID number	Front pieces darts	binding fold over elastic	sewing front pieces	sewing front pieces	Finishing front pieces & Thread cutting	Sewing back pieces	cutting elastic band	Finishing pouch	Attach pouch	sewing pouch	Finishing back piece & Thread cutting	Sewing back pieces	closing elastic	Sewing elastic	Sewing hem	ironing	packing	packing
E1118	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
E1246	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E1156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
E1143	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
E1179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
E1099	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
E1233	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
E0999	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E1567	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
E589	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
E2004	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
E1887	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
E1934	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
E1857	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E1469	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
E2069	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
E2071	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
E2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E1578	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

03.2 Mathematical Model

03.2.1 Assumptions

- Skill score is a fixed number.
- All tasks are equally importance.
- One worker can do at most 2 tasks.
- Additional of 2 workers.
- Workers are fixed for the given line.
- If the workers are less than 18, presented workers must be assigned for a task.

03.2.2 MATHEMATICAL MODEL

Case 01 – No. workers ≥ No. of tasks

Let x_{ij} be the number of units assign i^{th} worker to j^{th} task

Max z = $\sum_{i=1}^{m} \sum_{j=1}^{n} Sij\ xij$

Subject to

$\sum_{i=1}^{m} x_{ij} \leq 1$ for i = 1,2,………,n,..,m

$\sum_{j=1}^{n} x_{ij} = 1$ for j = 1,2,………,n

$$x_{ij} = \begin{cases} 1 & ; \text{if assigning } i^{th} \text{ worker to } j^{th} \text{ task} \\ 0 & ; \text{if not assigning} \end{cases}$$

Case 02 – No. workers < No. of tasks

Let x_{ij} be the number of units assign i^{th} worker to j^{th} task

Max z = $\sum_{i=1}^{m} \sum_{j=1}^{n} Sij\ xij$

Subject to

$\sum_{i=1}^{m} x_{ij} \leq 2$ for i = 1,2,………,n,..,m

$\sum_{j=1}^{n} x_{ij} = 1$ for j = 1,2,………,n

$\sum_{i=1}^{m} (\sum_{j=1}^{n} x_{ij} = 2)$ = No. absents - 2

$$x_{ij} = \begin{cases} 1 & ;\text{ if assigning } i^{th} \text{ worker to } j^{th} \text{ task} \\ 0 & ;\text{ if not assigning} \end{cases}$$

03.2.3 MODEL SOLUTION SOFTWARES

Excel

Python

Model-solving software refers to tools and platforms designed to address optimization problems by finding the best solutions under given constraints. These tools help solve mathematical models efficiently, whether they involve resource allocation, scheduling, routing, or decision-making in various fields like logistics, manufacturing, or data analysis.

For the assignment problem specifically, Python and Excel are excellent tools:

Python: Python offers powerful libraries such as PuLP, ORTools, and Pyomo for solving optimization problems. These libraries allow you to define variables, constraints, and objective functions programmatically, making them highly flexible and scalable for complex problems.

Excel: Excel's Solver add-in is a user-friendly tool for optimization. It’s suitable for smaller problems where constraints and objectives can be easily formulated in a spreadsheet. It provides a visual interface, making it accessible for those with minimal programming experience.

Combining both tools can be advantageous. You can use Excel for data preparation and visualization while leveraging Python for more computationally intensive tasks, like solving large-scale assignment problems efficiently.

03.3 Solutions

03.3.1. Solutions for secondary dataset

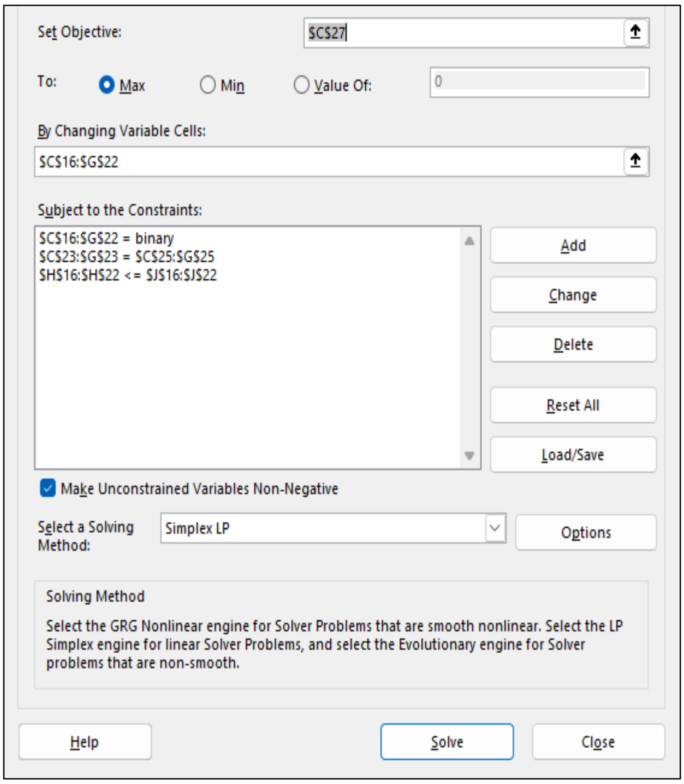
Visual representation of excel using secondary dataset

We can solve assignment problems using excel software. But there are some limitations in excel. We can solve only up to 200 variables using excel. Since there are more than 200 variables in our application, we have taken a secondary dataset to show that we can solve assignment problems using excel. And also, we have verified that our created python code is correct using this secondary dataset.

Secondary Dataset

	Task 0	Task 1	Task 2	Task 3	Task 4
EMP001	1.25	0	1.65	0	0.66
EMP002	0.82	0	0	1.5	0.99
EMP003	0	1.98	0	1.45	0
EMP004	1.39	1.4	0	0.9	0
EMP005	1.3	0	0.69	0	0
EMP006	1.56	1.33	0	1.9	1.96
EMP007	0	0.79	1.4	0	0.86

		Tasks							
		T0	T1	T2	T3	T4	Row Sum		
Employees	Emp1	0	0	1	0	0	1	<=	1
	Emp2	0	0	0	1	0	1	<=	1
	Emp3	0	1	0	0	0	1	<=	1
	Emp4	1	0	0	0	0	1	<=	1
	Emp5	0	0	0	0	0	0	<=	1
	Emp6	0	0	0	0	1	1	<=	1
	Emp7	0	0	0	0	0	0	<=	1
	Column Sum	1	1	1	1	1			
		=	=	=	=	=			
		1	1	1	1	1			
	Objective Function	8.48							



Solve using python

```
Are there any absent employees? (yes/no): no

Skill Score Dataset (Worker ID and Skill Scores for each task):
  Worker ID  Task 0  Task 1  Task 2  Task 3  Task 4
0    EMP001    1.25    0.00    1.65    0.00    0.66
1    EMP002    0.82    0.00    0.00    1.50    0.99
2    EMP003    0.00    1.98    0.00    1.45    0.00
3    EMP004    1.39    1.40    0.00    0.90    0.00
4    EMP005    1.30    0.00    0.69    0.00    0.00
5    EMP006    1.56    1.33    0.00    1.90    1.96
6    EMP007    0.00    0.79    1.40    0.00    0.86

Worker Task Assignments and Skill Scores:
  Worker ID    Task  Skill Score
0    EMP001  Task 2         1.65
1    EMP002  Task 3         1.50
2    EMP003  Task 1         1.98
3    EMP004  Task 0         1.39
4    EMP006  Task 4         1.96

Total Maximized Skill Score: 8.48
```

Python Code Implementation

Import packages

```
import openpyxl
import pandas as pd
import numpy as np
from scipy.optimize import linear_sum_assignment
from heapq import heappush, heappop
```

- **`import openpyxl`**
  - This library is used for reading, writing, and modifying Excel files (`.xlsx`) in Python.
  - It allows you to work with Excel spreadsheets, manipulate cells, and save changes.
- **`import pandas as pd`**
  - `pandas` is a powerful data analysis library.
  - It is commonly used for handling and analyzing structured data like tables (DataFrames).
  - `pd` is the alias, making it easier to reference the library in the code.
- **`import numpy as np`**
  - `numpy` is a library for numerical computations.
  - It provides support for arrays, matrices, and various mathematical functions.
  - `np` is the alias, simplifying usage in the code.
- **`from scipy.optimize import linear_sum_assignment`**
  - This function is part of the `scipy` library's `optimize` module and is used to solve the assignment problem using the Hungarian algorithm.
  - It helps find the optimal assignment of tasks to workers by minimizing costs or maximizing efficiency.
- **`from heapq import heappush, heappop`**
  - `heapq` is a library for implementing a priority queue using a heap.
  - `heappush`: Adds an element to the heap while maintaining the heap property.
  - `heappop`: Removes and returns the smallest element from the heap.
  - This is useful for tasks like scheduling or finding the next smallest element in a priority queue.

Worker Class

The Worker class is a blueprint for representing employees. It contains the following components:

- **Attributes:**
  id: A unique identifier for each worker.
  tasks: A list to store tasks assigned to the worker.

- **Methods:**
  __init__: Initializes a worker instance with a unique ID and an empty task list.
  assign_task: Appends a task index to the worker's task list.
  can_take_more_tasks: Returns a boolean indicating if the worker can take more tasks (max 2 tasks).
  __str__: Provides a string representation of the worker and their assigned tasks.

```python
class Worker:
    def __init__(self, id):
        self.id = id
        self.tasks = []

    def assign_task(self, task_index):
        self.tasks.append(task_index)

    def can_take_more_tasks(self):
        return len(self.tasks) < 2

    def __str__(self):
        return f"Worker {self.id}: Tasks {self.tasks}"
```

Skill Score Data Loading

The function **load_skill_scores_from_excel** reads a dataset from an Excel file. It processes the data into a structured format using pandas and returns a DataFrame with workers as rows and tasks as columns. Key aspects include:
Handling invalid or missing files.
Extracting worker IDs and task names from the dataset.

```python
def load_skill_scores_from_excel(file_path):
    workbook = openpyxl.load_workbook(file_path)
    sheet = workbook.active
    task_names = [cell.value for cell in sheet[1]][1:]
    workers_data = []
    for row in sheet.iter_rows(min_row=2, values_only=True):
        worker_id = row[0]
        skill_scores = list(row[1:])
        workers_data.append([worker_id] + skill_scores)
    df = pd.DataFrame(workers_data, columns=['Worker ID'] + task_names)
    return df
```

Task Assignment Logic

The core of the program lies in the **maximize_skill_score_with_consecutive** function. It addresses two scenarios:

1. **More Workers Than Tasks:**
- Uses the Hungarian algorithm (via **scipy.optimize.linear_sum_assignment**) to assign tasks optimally.
- Converts the skill score matrix into a cost matrix by negating values and solves for the highest skill score.

2. **Fewer Workers Than Tasks:**
- Implements a custom greedy algorithm where workers can take up to 2 tasks.
- Iteratively assigns the highest-scoring task to eligible workers until all tasks are assigned.

```python
# Task Assignment with Constraints for fewer workers than tasks
def maximize_skill_score_with_constraints(skill_matrix, num_tasks, absent_count):
    num_workers = skill_matrix.shape[0]
    max_multiple_tasks_workers = absent_count -2 # Strictly less than the number of absent employees
    workers_with_multiple_tasks = 0

    task_heap = []
    for i in range(num_workers):
        for j in range(num_tasks):
            if skill_matrix[i, j] > 0:
                heappush(task_heap, (-skill_matrix[i, j], i, j))

    assignments = []
    total_skill_score = 0
    workers = [Worker(i) for i in range(num_workers)]
    assigned_tasks = set()

    while len(assigned_tasks) < num_tasks:
        if task_heap:
            neg_score, worker_id, task_id = heappop(task_heap)
            score = -neg_score

            if task_id in assigned_tasks or score == 0:
                continue
```

```python
# More Workers or Equal Case
def hungarian_task_assignment(skill_matrix, num_tasks):

    num_workers = skill_matrix.shape[0]
    cost_matrix = skill_matrix * -1
    row_ind, col_ind = linear_sum_assignment(cost_matrix)

    assignments = [(row, col) for row, col in zip(row_ind, col_ind)]
    total_skill_score = skill_matrix[row_ind, col_ind].sum()

    return assignments, total_skill_score
```

```python
            max_tasks = 2 if (len(workers[worker_id].tasks) == 0 and workers_with_multiple_tasks < max_multiple_tasks_workers) else 1
            if workers[worker_id].can_take_more_tasks(max_tasks):

                workers[worker_id].assign_task(task_id, score)
                assigned_tasks.add(task_id)
                total_skill_score += score
                assignments.append((worker_id, task_id))


                if len(workers[worker_id].tasks) == 2:
                    workers_with_multiple_tasks += 1
        else:

            for worker_id in range(num_workers):
                for task_id in range(num_tasks):
                    if task_id not in assigned_tasks and skill_matrix[worker_id, task_id] > 0:
                        workers[worker_id].assign_task(task_id, skill_matrix[worker_id, task_id])
                        assigned_tasks.add(task_id)
                        total_skill_score += skill_matrix[worker_id, task_id]
                        assignments.append((worker_id, task_id))
                        break

    return assignments, total_skill_score
```

Main Task Assignment Workflow

The **workers_assignment_problem_with_consecutive** function orchestrates the task assignment process. Its key steps are:

- **Input Validation:** Prompts the user for absentee information and validates the IDs of absent employees.
- **Skill Matrix Preparation:** Converts the filtered dataset into a numerical matrix for processing.
- **Task Assignment Execution:** Calls **maximize_skill_score_with_consecutive** to compute the optimal assignments and the total skill score.
- **Output Presentation:** Displays task assignments and their corresponding skill scores in a tabular format.

```python
# Main function to read data, apply the algorithm, and print results
def workers_assignment_problem_with_constraints(file_path):

    absent_employees_input = input("Are there any absent employees? (yes/no): ").strip().lower()
    absent_employees = []
    if absent_employees_input == "yes":
        absent_employees = input("Enter the absent employee IDs (comma-separated): ").strip().split(",")
        absent_employees = [emp.strip() for emp in absent_employees]
    df = load_skill_scores_from_excel(file_path)


    if absent_employees:
        df = df[~df['Worker ID'].isin(absent_employees)]

    skill_matrix = df.drop(columns=['Worker ID']).values
    num_tasks = skill_matrix.shape[1]
    num_workers = skill_matrix.shape[0]

    if num_workers >= num_tasks:
        assignments, total_skill_score = hungarian_task_assignment(skill_matrix, num_tasks)
    else:
        assignments, total_skill_score = maximize_skill_score_with_constraints(
            skill_matrix, num_tasks, len(absent_employees)
        )
```

```python
    # Output: Print the Worker Task Assignments with corresponding skill scores
    print("\nWorker Task Assignments and Skill Scores:")
    worker_task_info = []
    for worker_id, task_id in assignments:
        worker_real_id = df.iloc[worker_id]['Worker ID']
        task_name = df.columns[task_id + 1]  # Skip 'Worker ID' column
        skill_score = df.iloc[worker_id, task_id + 1]
        worker_task_info.append([worker_real_id, task_name, skill_score])

    # Create a DataFrame for better table visualization
    assignments_df = pd.DataFrame(worker_task_info, columns=['Worker ID', 'Task', 'Skill Score'])
    print(assignments_df)

    # Output: Print the total maximized skill score
    print(f"\nTotal Maximized Skill Score: {total_skill_score}")

# Example usage
file_path = 'smalldataset.xlsx'
workers_assignment_problem_with_constraints(file_path)
```

03.3.2. Solutions for company dataset

Case : No Absences

Condition: Number of workers ≥ Number of tasks

Summary:

This case assumes no worker absences, allowing for all tasks to be optimally assigned to available workers based on their skill scores. The primary objective was to maximize the total skill score for task assignment while ensuring each worker is assigned only one task.

```
Are there any absent employees? (yes/no): no

Worker Task Assignments and Skill Scores:

   Worker ID                                 Task  Skill Score
0      E1118                  sewing front pieces         1.85
1      E1246                              ironing         1.95
2      E1156                           packing(1)         1.95
3      E1143                 Sewing back pieces(1)        1.58
4      E1179                           Sewing hem         1.89
5      E1099  Finishing front pieces & Thread cutting     1.87
6      E1233                          sewing pouch         1.85
7      E0999                          Attach pouch         1.95
8      E1567                       closing elastic         1.94
9      E1589                binding fold over elastic      1.86
10     E2004                 Sewing back pieces(2)         1.84
11     E2014                            packing(2)         1.94
12     E1887                   sewing front pieces         1.77
13     E1934                        Sewing elastic         1.50
14     E1469   Finishing back piece & Thread cutting      1.91
15     E2069                  cutting elastic band         1.94
16     E2071                    Front pieces darts         1.94
17     E1578                       Finishing pouch         1.86

Total Maximized Skill Score: 33.39
```

Observations:

All workers were successfully assigned tasks with no absences.
The assignment strategy achieved a maximized total skill score by considering the highest available scores for each task.
Tasks were assigned ensuring optimal efficiency and balance across workers.

Case: 1 Worker Absent

Condition: One worker (E1118) is unavailable, requiring a reassignment of tasks to maximize the total skill score.

Summary:

In this case, one worker (E1118) is absent. Tasks were reassigned to ensure all tasks were covered, and the total skill score was optimized based on the remaining workforce.

```
Are there any absent employees? (yes/no): yes
Enter the IDs of absent employees (comma-separated): E1118

Worker Task Assignments and Skill Scores:

   Worker ID                                   Task  Skill Score
0      E1246                             packing(2)         1.75
1      E1156                             packing(1)         1.95
2      E1143                  Sewing back pieces(1)         1.58
3      E1179                             Sewing hem         1.89
4      E1099  Finishing front pieces & Thread cutting       1.87
5      E1233                            sewing pouch        1.85
6      E0999                            Attach pouch        1.95
7      E1567                         closing elastic        1.94
8      E1589                 binding fold over elastic      1.86
9      E2004                  Sewing back pieces(2)         1.84
10     E2014                     sewing front pieces        1.80
11     E1887                     sewing front pieces        1.77
12     E1934                                 ironing        1.88
13     E1469   Finishing back piece & Thread cutting        1.91
14     E2069                     cutting elastic band       1.94
15     E2071                      Front pieces darts        1.94
16     E2007                         Finishing pouch        1.56
17     E1578                          Sewing elastic        1.75

Total Maximized Skill Score: 33.03
```

Observations:

Worker E1118's absence required task reassignment.
Despite the absence, all tasks were covered, and the total skill score of 33.03 is near-optimal compared to the no-absence scenario.
The reassignment ensured minimal disruption to efficiency while maintaining high skill scores.

Case: No. of Workers < No. of Tasks

Condition: Multiple workers absent (E0999, E1567, E2071, E1246), leading to fewer workers than tasks. Task assignments had to accommodate the shortage while aiming for the highest total skill score.

Summary:

This scenario involved a worker shortage due to the absence of four workers (E0999, E1567, E2071 and E1246). To address the imbalance, tasks were reassigned to available workers, with priority given to maximizing the total skill score.

```
Are there any absent employees? (yes/no): yes
Enter the absent employee IDs (comma-separated): E0999,E1567,E2071,E1246

Worker Task Assignments and Skill Scores:
   Worker ID                                     Task  Skill Score
0       E1156                               packing(1)         1.95
1       E2014                               packing(2)         1.94
2       E2069                      cutting elastic band         1.94
3       E1589                     Sewing back pieces(2)         1.92
4       E1887                        Front pieces darts         1.91
5       E1469    Finishing back piece & Thread cutting         1.91
6       E1578                               Sewing hem         1.91
7       E1934                                  ironing         1.88
8       E1099  Finishing front pieces & Thread cutting         1.87
9       E1179                 binding fold over elastic         1.86
10      E1118                       sewing front pieces         1.85
11      E1233                              sewing pouch         1.85
12      E1143                     Sewing back pieces(1)         1.58
13      E2007                          Finishing pouch         1.56
14      E1857                          closing elastic         1.51
15      E2004                              Attach pouch         0.92
16      E1118                       sewing front pieces         1.85
17      E1156                           Sewing elastic         1.14

Total Maximized Skill Score: 31.35000000000001
```

Observations:

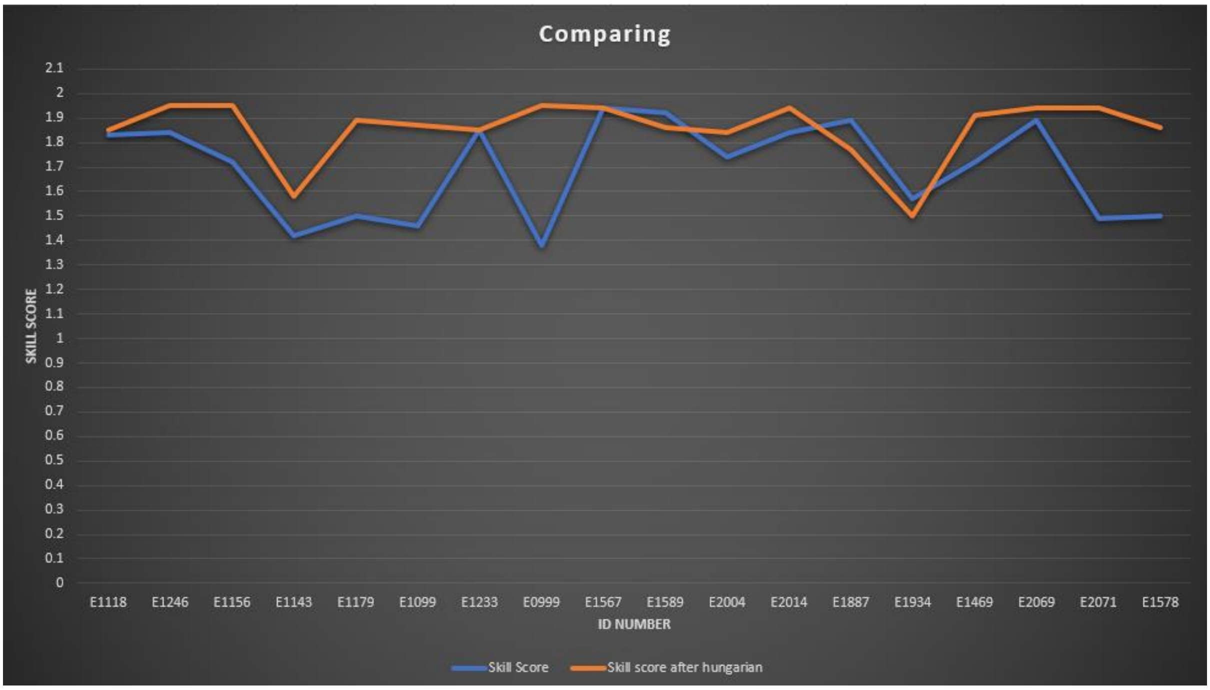
The absence of four workers reduced the workforce, necessitating reassignment of tasks.
Some workers were assigned multiple tasks due to the shortage, which may slightly impact efficiency in practical settings.
The reassignment strategy achieved a total skill score of 31.35, which is a reasonable outcome given the worker shortage.
Priority was given to tasks with higher skill scores to maintain optimal output.

03.4 Comparison

We have shown that there is a difference of total skill score between company assignment and assignment of Hungarian method. Total skill score of company assignment is 30.5 and the total skill score of assignment using Hungarian method is 33.39. So, we have maximized the total skill score.

EMPLOEE ID	COMPANY'S ASSIGNMENT	OUR ASSIGNMENT
E1118	1.83	1.85
E1246	1.84	1.95
E1156	1.72	1.95
E1143	1.42	1.58
E1179	1.5	1.89
E1099	1.46	1.87
E1233	1.85	1.85
E0999	1.38	1.95
E1567	1.94	1.94
E1589	1.92	1.86
E2004	1.74	1.84
E2014	1.84	1.94
E1887	1.89	1.77
E1934	1.57	1.5
E1469	1.72	1.91
E2069	1.89	1.94
E2071	1.49	1.94
E1578	1.5	1.86
Total Skill Score	**30.5**	**33.39**

Graphical Representation



This is the graphical representation of workers assignment before and after using the Hungarian method. Clearly, we can see that the line represented the skill score of company workers assignment is in below the line represented the skill score of Hungarian method.

04. BENEFITS OF THE MODEL & DIFFICULTIES FACED

Benefits for the Factory

Enhanced Productivity:
By aligning tasks with the skills of workers, the factory experiences a notable improvement in production efficiency. Workers are able to perform tasks they are most suited for, reducing errors and increasing output.

Better Use of Skilled Labor:
The model ensures that workers' skills are utilized to their full potential. This strategic deployment of skilled labor minimizes underutilization and allows for effective task management.

Reduction in Production Time:
Efficient task allocation reduces the time required to complete production cycles. Tasks are distributed in a way that minimizes idle time and maximizes workflow continuity.

Cost Reduction:
By optimizing task assignments and reducing inefficiencies, the factory achieves lower production costs. This is particularly beneficial in competitive markets where cost control is critical for profitability.

Benefits for Workers

Tasks Aligned with Skills:
Workers are assigned tasks that match their specific skill sets. This not only increases their efficiency but also enhances job satisfaction, as they are more confident and comfortable performing tasks they excel at.

Fair Workload Distribution:
The model ensures an equitable distribution of tasks among workers. By balancing workloads, the model helps prevent overburdening specific individuals and promotes a healthier work environment.

Difficulties Faced

- Data collection challenges.
- Complex constraints.
- Model design.
- Computational complexity.
- Difficult to implement in Excel.

05. CONCLUSION AND SUGGESTIONS

Conclusion

The worker assignment model developed for Panvila Emjay Garment Factory represents a significant step forward in operational efficiency and workforce management. This model leverages advanced optimization techniques to assign tasks based on worker skill sets and availability, ensuring that tasks are completed efficiently even in the event of worker absences.

Key improvements observed include:

A marked increase in productivity due to the alignment of tasks with individual strengths.

Reduced downtime and enhanced workflow continuity, minimizing delays caused by absences.

A more balanced and fair distribution of workloads, promoting a positive work environment.

Substantial cost savings achieved through reduced waste and optimized labor use.

By mitigating the challenges associated with worker absences and inefficiencies, the factory has set a benchmark in using modern optimization methods to streamline operations. The model not only supports the factory's immediate goals but also lays a robust foundation for sustainable growth and adaptability in the competitive garment industry.

Suggestions

Based on If the workers are assigned according to the Hungarian method as recommended, the target order can be reached within the deadline. It is better if they update the efficiency of the workers (grade points) after the completion of each order.

These are the conclusion and suggestions that could be arrived at from the performed analyses, and the recommendation provided in this section have a significant effect on the increase of sales if they are implemented properly.

Timeline

Task	Month									
	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan
Finding a place to continue the project	■									
Visited Emjay international pvt(ltd)		■								
Selected the project topic and identified the problem		■	■							
Meeting 1			■							
Data preparation			■	■						
Online meeting				■						
Analyse the skill scores and identify trends or patterns.					■					
Design the model using hungarian method					■					
Meeting 2						■				
Mid presentation						■				
Implement the algorithom in python						■	■			
Test the model with using sample data in excel and python							■			
Validate the results with actual factory scenarioes							■	■	■	
Prepare the final presentation and final report									■	■
Meeting 3										■
Final presentation										■

06. REFERENCES

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