Part I

Given:

- Prismatic part

- Four different types of tools are to be used to make features V1 through V13

- Three different types of fixtures are to be used to for features V1 through V13

Determine

(1) Set up an elementary machining feature - machining feature (machinable volume) incidence matrix.

(2) Assign tools and fixtures to the machining features.

Also given:

- The maximum number of tools and fixtures to be selected

  3 tools and 3 fixtures

- The cost vector of machining features

  Cost Vector \( [c_j] = [4, 3, 1, 1, 1, 1, 2, 3, 2, 1, 1, 1, 1] \)
(3) Formulate a model for the selection of machining features that minimize the total cost of removing all machining features, the total number of tools and fixtures.

\[
\text{MIN } 4X_1 + 3X_2 + X_3 + X_4 + X_5 + X_6 + 2X_7 + 3X_8 + 2X_9 + X_{10} + X_{11} + X_2 + X_3 + X_4 + Z_1 + Z_2 + Z_3
\]

**SUBJECT TO**

\[
\begin{align*}
X_1 + X_{10} &\geq 1 \\
X_1 + X_9 &\geq 1 \\
X_1 + X_3 &\geq 1 \\
X_1 + X_2 &\geq 1 \\
X_2 + X_{13} &\geq 1 \\
X_5 &\geq 1 \\
X_2 + X_8 &\geq 1 \\
X_8 + X_{11} &\geq 1
\end{align*}
\]

\[
\begin{align*}
V_1 &= \{v_8\} \\
V_10 &= \{v_1\} \\
V_9 &= \{v_2, v_{11}\} \\
V_7 &= \{v_{10}, v_{12}\} \\
V_6 &= \{v_9\} \\
V_5 &= \{v_6\} \\
V_3 &= \{v_3\} \\
V_2 &= \{v_4, v_5, v_7\}
\end{align*}
\]

From the incidence matrix:

<table>
<thead>
<tr>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
<th>V7</th>
<th>V8</th>
<th>V9</th>
<th>V10</th>
<th>V11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(4) Solve the model with LINDO.

**Solution**

The features selected: V2, V3, V5, V6, V7, V9, V10, V11 using tools 2, 3 and 4

From the incidence matrix:

\[
\begin{align*}
V_2 &= \{v_4, v_5, v_7\} \\
V_3 &= \{v_3\} \\
V_5 &= \{v_6\} \\
V_6 &= \{v_9\} \\
V_7 &= \{v_{10}, v_{12}\} \\
V_9 &= \{v_2, v_{11}\} \\
V_10 &= \{v_1\} \\
V_11 &= \{v_8\}
\end{align*}
\]

**Process plan that minimizes the number of fixture changeovers:**

\[
\{(V_7, t_3, f_1), (V_2, t_2, f_1), (V_5, t_4, f_2), (V_6, t_4, f_2), (V_3, t_3, f_2), (V_{10}, t_3, f_2), (V_{11}, t_3, f_2), (V_9, t_2, f_3)\}
\]

**Part II**

Sequence the machining features with the topological ordering algorithm so that the total number setups (fixture changes) is minimized.

Assume that the part surface that is not being machined serves as a tolerance base.

**Precedences**

- V2 \(\rightarrow\) V5 \(\rightarrow\) V6 \(\rightarrow\) V7 \(\rightarrow\) V10 \(\rightarrow\) V11
- V7 \(\rightarrow\) V6 \(\rightarrow\) V5

**Feasible Process Plan:** {V9, V3, V10, V11, V7, V2, V5, V6}