Accurate estimate of the cost of an AS/R System could be obtained by summing the costs of:

- the storage rack, \( \left( \frac{\text{# of unit loads, cubic size of the unit load, weight of the unit load, height of the rack}}{\text{height of the AS/R system, weight of the AS/R machine, type of loading}} \right) \)
- the S/R machine, and \((\text{height, cost per square foot equipment})\)
- the building used to house the AS/R System. \((\text{height, cost per square foot building})\)

Let:

\(x = \text{depth of the unit load (in)}\)
\(y = \text{width of the unit load (in)}\)
\(z = \text{height of the unit load (in)}\)

\[V = \text{volume of unit load in cubic feet} = \frac{xyz}{1728}\]

\(W = \text{weight of the unit load in pounds}\)

\(W = \text{Width of the aisle of AS/R storage in inches}\)

\(L = \text{Length of an aisle of AS/R storage in inches}\)

\(H = \text{Height of an aisle of AS/R storage in inches}\)

\(n = \text{number of tiers or levels of storage}\)

\(m = \text{number of columns of storage per aisle side}\)
\( q = \) number of storage aisles

\( BH = \) Building height

\( BW = \) Building width

\( BL = \) Building length

\( a = \) allowance, measured in feet

\( \alpha = \) parameter for computing rack cost, \((\$)\)

\( \nu = \) weight parameter for computing S/R rack cost, \((\$)\)

\( \beta = \) height parameter for computing S/R rack cost, \((\$)\)

\( \phi = \) control parameter for computing S/R rack cost, \((\$)\)

\( S = \) cost per square foot to construct a 25-ft.-tall building.

\( CF = \) conversion factor for converting cost per sq. ft. to construct a 25-ft.-tall building to the cost per sq. ft. to construct a building height, \( BH \).

The dimensions of a storage aisle:

- 3-ft.-6-in. \((3(x + 6''))\) (with in-rack sprinklers)
- 3-ft.-4-in. \((3(x + 4''))\) (without in-rack sprinklers)

\[ W = \begin{cases} 3(x + 6') \\ 3(x + 4') \end{cases} \]

\[ L = m(y + 8') \]

\[ H = n(2 + 10') \]
The dimensions of the building:

\[
\begin{align*}
B + H &= 48 + 48 \text{ m} \\
BW &= aW + 24 \text{ m} \\
BL &= L + a
\end{align*}
\]

\[\gamma = \begin{cases} 
12.5 + 0.45y \\
28.5 + 0.45y
\end{cases}
\text{(without transfer car)}
\]

\[24 \leq y \leq 54 \text{ mds.}\]

Example:

Suppose A3/RS 13 to be designed for 40" x 48" (depth x width) cut loads that are 48" tall.

There are to be 8 aisles.

Each aisle is 12 loads high and 80 loads long.

With sprinklers and no transfer car.

The minimum dimensions of the building:

\[
\begin{align*}
BA &= 12(48+10) + \frac{48}{12} = 62 \text{ ft}, \\
BW &= 8(3)(40+6) + 24 = 94 \text{ ft}, \\
BL &= 80(48+8) + 12.5\text{ ft} + 0.45(48) = 407.43 \text{ ft}.
\end{align*}
\]
A building of at least 62 ft tall, 84 ft wide, and 407.43 ft long will be required.

**Rack Cost Calculation:**

\[ CR0 = \left[ 0.8248y + 0.025w + 0.0004424w \right. \\
\left. -(w^2/82,500,000) + 0.23328n - 0.00476 n^2 \right] \]

**Example:**

Suppose a storage rack is to be provided to accommodate 10,000 unit loads, weighing 2500 pounds and having a dimension of 42" x 48" x 46.5". Suppose the rack will support 10 unit loads vertically (10 tiers of storage). If \( x = 30 \), what will be the cost of the rack?

\( x = 42", \ y = 48", \ z = 46.5", \ w = 2500 \text{ lb}, \ n = 10 \)

\( x = 30 \), \( y = \frac{42 \times 48 \times 46.5}{1728} = 54.25 \text{ ft}^3 \)

\[ CR0 = 30 \left[ 0.8248y + 0.025w + 0.0004424w \right. \\
\left. -(w^2/82,500,000) + 0.23328n - 0.00476 n^2 \right] \\
= 155.04 \text{ per rack opening} \]
S/R Machine Cost Calculation

\[ CSR = A + B + C \] (The cost per S/R machine)

<table>
<thead>
<tr>
<th>H</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>H &lt; 35'</td>
<td>1</td>
</tr>
<tr>
<td>35' ≤ H &lt; 50'</td>
<td>2</td>
</tr>
<tr>
<td>50' ≤ H &lt; 75'</td>
<td>3</td>
</tr>
<tr>
<td>75' ≤ H &lt; 110'</td>
<td>4</td>
</tr>
<tr>
<td>H ≥ 110'</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>W</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>W &lt; 1000 lb</td>
<td>1</td>
</tr>
<tr>
<td>1000 ≤ W &lt; 3500</td>
<td>2</td>
</tr>
<tr>
<td>3500 ≤ W &lt; 6500</td>
<td>3</td>
</tr>
<tr>
<td>W ≥ 6500</td>
<td>4</td>
</tr>
</tbody>
</table>

Control logic

<table>
<thead>
<tr>
<th>C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>manual</td>
</tr>
<tr>
<td>2</td>
<td>onboard</td>
</tr>
<tr>
<td>3</td>
<td>end-of-aisle</td>
</tr>
<tr>
<td>4</td>
<td>control console</td>
</tr>
</tbody>
</table>

Example: Suppose six S/R machines to be used to lift 2000 lb loads to a height of 55 ft and control console is to be used to control the S/R machine.
Based on current market prices, \( \beta = \phi = y = $25,000 \) \( \text{per machine} \)

\( H = 55 \text{ ft}, \ w = 2500 \text{ lb} \)

\[ CSR = 3 \beta + 2 \gamma + 4 \phi = 5 \times (25,000) = $225,000 \text{ per machine} \]

**Building Cost Calculation:**

\[ BC = (3w)(BL)(CF) \]

<table>
<thead>
<tr>
<th>BF</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>25'</td>
<td>1.00</td>
</tr>
<tr>
<td>40'</td>
<td>1.25</td>
</tr>
<tr>
<td>55'</td>
<td>1.50</td>
</tr>
<tr>
<td>70'</td>
<td>1.80</td>
</tr>
<tr>
<td>85'</td>
<td>2.50</td>
</tr>
</tbody>
</table>

**Example:**

Suppose a 60 ft-tall building is to be used to house an AS/RS system. Assuming it costs $30/ft^2 to construct a 25 in-tall building. Suppose the footprint of the building is 150 ft x 440 ft. What will be the cost of the building?

By interpolation, CF is obtained to be 1.633.

\[ BC = 150 \times (440)(1.633) \times 30 = $3,234,000 \]
Example 3

Suppose storage space of $1,540,000\text{ft}^3$ must be provided.

A 55 ft tall building will yield a footprint of $28,000\text{ft}^2$.

$$BC = 1.5(28,000) \cdot 5 = 42,000 \text{ S}.$$ 

If a 25 ft tall building is built, $61,600\text{ft}^2$ of footprint is required.

$$BC = 1.0(61,600) \cdot 8 = 61,600 \text{ S}.$$ 

If 70 ft tall building,

$$BC = 41,800 \text{ S}$$

If 85 ft tall building,

$$BC = 45,284 \text{ S}$$

$\leq$ minimum cost obtained at a height of 70 ft.