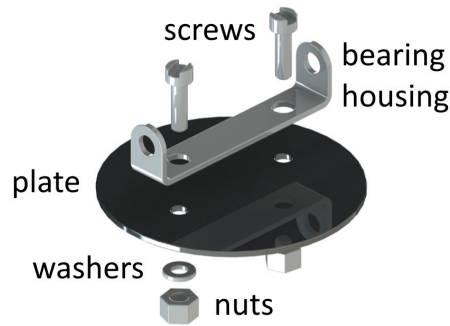


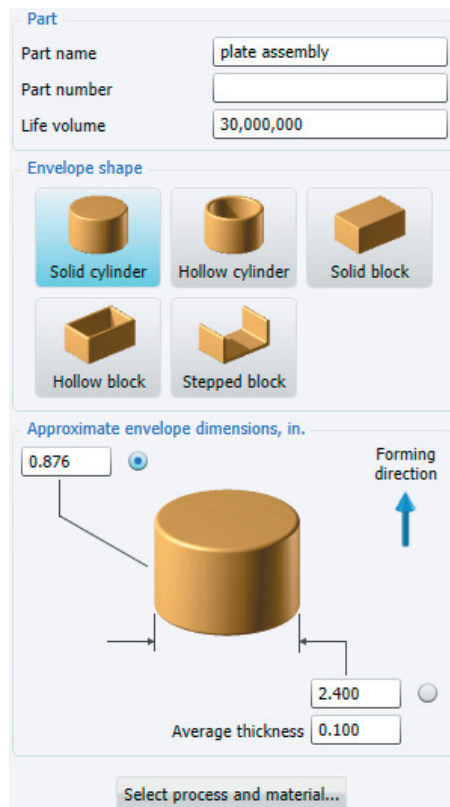
## An automatic assembly analysis

The Automatic Assembly process program allows you to estimate the cost of assembly of a product using high-speed automatic assembly machines. For comparison purposes, the program will simultaneously estimate the cost of assembling the product on a manual assembly line.



Our sample analysis is for a small plate assembly consisting of eight parts.

1. Start a new analysis and enter **plate assembly** for the Part name and a Life volume of **30,000,000**.
2. The overall shape of this assembly would be a solid cylinder and the overall dimensions are 0.876 inches for the length of the envelope parallel to the cylinder axis, 2.4 for the diameter and 0.1 for the average thickness.



3. Click *Select process and material* and select *Automatic assembly*. You are not required to select a material for this process. Click **OK** and the main Response screen will be displayed.

Note that in the left panel, in addition to the entry for the *Automatic assembly process* there is an entry entitled *Transfer system and downtime*.

Once you have entered the operations, highlighting this entry will display the results of the analysis for two types of automatic assembly machines and for a manual assembly line. As you add operations for the feeding, orienting and insertion of the various parts in the assembly and for any other operations you add, these results will be continually updated.

- Automatic assembly of plate assembly
      - Automatic assembly process**
        - Transfer system and downtime

Select the *Automatic assembly process*. In the right Responses panel you will now review the data for the overall requirements of the assembly machine and the basic costs of assembly equipment.

Basic data	
Overall plant efficiency, %	85
Equipment payback, months	36
Shifts worked per day	2
Manual assembly worker rate, \$/hr	30.00
Automatic assembly production parameters	
Assemblies per cycle	1
Desired assembly rate per minute	30
Parts causing stoppage, per thousand	2
Average down-time per stoppage, s	30.00
Technician rate, \$/hr	40.00
Transfer device cost per station	
Manual assembly, \$	2,000
Auto assembly (non-synchronous), \$	12,000
Auto assembly (synchronous), \$	10,000
Other equipment cost	
Additional buffer space (non-synch), \$	2,000
Workcarrier for auto assembly, \$	500
Workhead for auto assembly, \$	10,000
Automatic feeder and simple tooling, \$	5,000

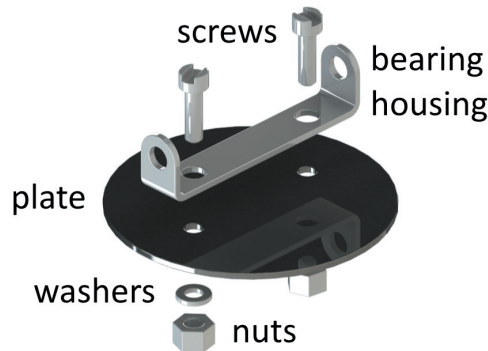
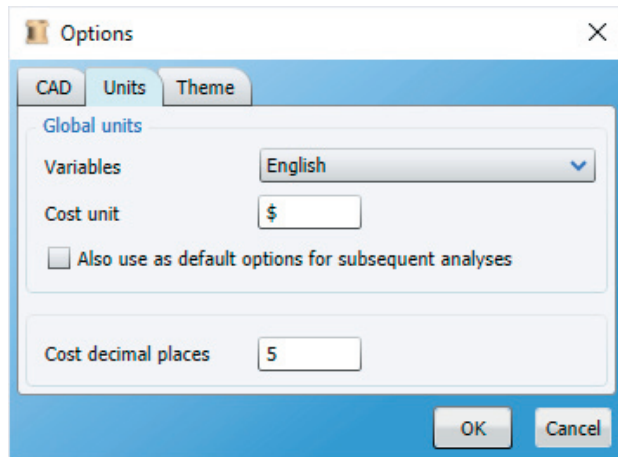
4. *Overall plant efficiency, %*: As with the other processes in Concurrent Costing, we allow you to specify an overall plant efficiency. In this case we will accept the default of **85%**. We should note, however, that this figure will not include the additional downtime, special to automatic assembly machines, where stoppages occur due to faulty parts jamming in feeders or insertion devices.
5. *Equipment payback, months*: An automatic assembly machine is generally a one-of-a-kind special-purpose machine. Consequently, when the economics of an assembly machine are considered, the calculations are usually based on an equipment payback period. For automatic assembly machines this payback period usually varies between eighteen months and three years. In our example we shall assume an equipment payback of **36** months.
6. *Shifts worked per day*: This value (1, 2 or 3) will be used, together with the payback period and the overall plant efficiency, to estimate the cost per unit time for the assembly equipment. Assume **2**-shift working for this analysis.
7. *Manual assembly worker rate, \$/hr*: This is the cost per unit time for a manual assembly line worker or for a worker performing manual assembly operations on an automatic assembly machine. Accept the default of **30** \$/hr.
8. *Assemblies per cycle*: In automatic assembly machines, assemblies are built on specially designed workcarriers. Sometimes, workcarriers are designed to hold more than one assembly. In our analysis, we will assume that only **1** assembly is delivered per machine cycle.

- 9. *Desired assembly rate per minute:* This is the rate, in assemblies per minute, for which the automatic assembly machine is to be designed. This rate together with the number of assemblies per cycle will determine the cycle time for the machine. For this example, we will enter a rate of **30** assemblies per minute. With one assembly per cycle, this will mean that the machine will cycle every two seconds and produce an assembly every two seconds when it is working.
- 10. *Parts causing stoppage and Average down-time per stoppage:* You should make every effort to obtain reasonable values for these two factors, based on your experience with similar automatic assembly equipment. In this case we will accept the defaults. This means that, on average, two parts in every thousand will be defective and will cause a machine or workstation stoppage. The average downtime per stoppage of **30** seconds represents the average length of time that it will take a machine supervisor to recognize and locate the cause of the stoppage, clear the faulty part from the feeder or workhead and restart the machine.
- 11. *Technician rate, \$/hr:* This is the cost per unit time for a technician overseeing an automatic assembly machine and correcting machine or workstation faults. We will accept the default value of **40** \$/hr.
- 12. Other responses: We will accept the defaults for the various basic equipment costs.

### Analysis of Individual Parts

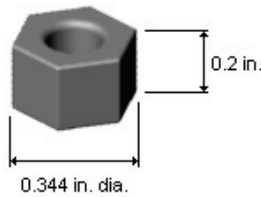
We now analyze each individual part for the cost of feeding and insertion into the assembly. During the analysis we will define whether the part is inserted and then secured later during the assembly process or whether it is inserted and secured immediately. Since the cost of automatic assembly is usually quite small, click the *Analysis* menu and select *Set units...* In the Options window that appears, set the Cost decimal places to **5**.

This program allows you to estimate the total cost of assembling your product or subassembly. However, you have the option of including the costs of the parts. For this analysis we shall only determine the cost of assembly and will not include the manufacturing costs of the individual parts.



As mentioned earlier, assembly machines are designed to transport workcarriers on which the assembly is built. These workcarriers are designed to accept and, where possible, hold the assembled parts in position. Since we name the operations in the order in which assembly proceeds, we start by inserting the two nuts into prepared recesses in the workcarrier.

## Insertion of Nuts



1. We first decide whether the basic shape of the part is rotational or non-rotational.

The envelope that would best fit a nut is cylindrical. In other words this is a rotational part. Select *Operation* from the *Insert* menu and then select *Assembly of rotational part* from within the Automatic assembly category on the list of operations. Click **Insert**. Close the Insert Operation dialog. The responses for an analysis of the nuts are now displayed.

2. Specify a part thickness or length of **0.2**, a part diameter of **0.344** and a repeat count of **2**.

Data	
Part thickness or length, in.	0.200
Part diameter, in.	0.344
Repeat count	2

3. Now we respond to questions regarding the symmetry of the part. The first questions refer to end-to-end symmetry. Since the nuts do not require end-to-end orientation and can be inserted either way up into the workcarrier and there are no features required for end-to-end orientation, click the button labeled *End to end orientation not required*.
4. Similarly, for rotational symmetry, the nuts do not require significant rotation about their axes in order to insert them into suitably designed pockets in the workcarrier. Click the button labeled *Orientation about axis not required*.
5. For the nuts, it is assumed that feeding problems do not exist and none of the boxes should therefore be checked.
6. We now address the problems of part insertion. Here we assume that an automatic pick-and-place workhead will select the parts, delivered by the feeder in the required orientation, and then place them in the workcarrier. Again, we select whether the parts are added and not secured or whether they are added and secured immediately.
 

The nuts are added to the workcarrier but they will be secured to the assembly later. Since the nuts will be retained in the recesses in the workcarrier ready for the next operation none of the boxes relating to insertion need to be checked.
7. Click the **Calculate** button. Scroll if necessary to review the results for the automatic feeding and orienting and insertion of the two nuts. First we see that the program has decided the nuts will be inserted simultaneously at one automatic station.
8. Since we have assumed that there will be one assembly built on each workcarrier and have indicated that the desired assembly rate is 30 assemblies per minute, the machine cycle rate is 30 per minute. However, because we are assembling two nuts at the same station, the desired feed rate from the automatic feeder will be 60 per minute.
9. With the data that we have provided regarding orientation and feeding of the parts, the program has estimated a maximum feed rate from one feeder of 122 parts per minute. However, the actual feed rate from the feeder will be 60 per minute because this is the desired rate. We see that the cost of feeding the parts is displayed together with the insertion operation cost. Adding these costs gives an automatic assembly cost per assembly of \$0.00136.

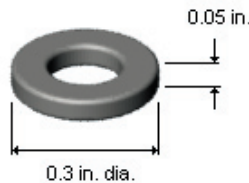
Cost results, \$	Previous	Current
Material	0.00000	0.00000
Setup	0.00000	0.00000
Process	0.00000	0.00136
Rejects		
Piece part	0.00000	0.00136
Tooling	0.00000	0.00000
Total	0.00000	0.00136
Tooling investment	0	0

10. Also displayed are the costs of the feeder and workhead. We specified a basic feeder cost of \$5,000 and since one feeder can supply parts at the required rate this will be the cost of the feeder for the nuts. However, since we are inserting two nuts at one station, a more expensive workhead costing \$20,000 would be required.

Results	
Automatic stations per entry	1
Machine cycle rate, cycles/min	30
Desired feed rate from feeder, parts/min	60
Maximum rate from one feeder, parts/min	122
Feeder cost, \$	5000
Workhead cost, \$	20000
Automatic feeding cost per assembly, \$	0.00027
Automatic insertion cost per assembly, \$	0.00109

- The program has estimated the manual assembly time and cost for inserting the nuts. These figures are not displayed but will be used in the final calculation to compare the cost of assembly using a manual assembly line. Also, as we will see later, if it is found that manual handling is less expensive than automatic handling, manual assembly would be assumed.
- In order to keep track of our analysis for this assembly we should edit the names of the entries as we add them. In this case we should edit *Assembly of rotational part* to **insertion of nuts**.
- It would be a good idea to name and save our analysis at this stage. Select *Save* from the *File* menu. We will give the analysis the name **plate assembly tutorial**.

**Insertion of Washers**



- With the entry *insertion of nuts* highlighted, add another operation for the *Assembly of a rotational part*.
- The part thickness or length is **0.05**, the part diameter is **0.3** and the repeat count for the washers is **2**.

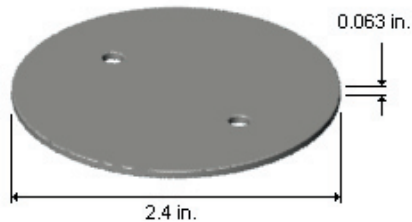
Data	
Part thickness or length, in.	0.050
Part diameter, in.	0.300
Repeat count	2

- Like the nuts, the washers do not require orienting end-to-end (can be placed in the workcarrier either end up) and do not require orienting about their axes. Also, there would be no feeding problems. The washers would be added but not secured and there would be no insertion problems.
- Click **Calculate** to view the results. We see that the results are almost identical to those for the nuts except that we could obtain a slightly higher feed rate from the feeder.

Results	
Automatic stations per entry	1
Machine cycle rate, cycles/min	30
Desired feed rate from feeder, parts/min	60
Maximum rate from one feeder, parts/min	140
Feeder cost, \$	5000
Workhead cost, \$	20000
Automatic feeding cost per assembly, \$	0.00027
Automatic insertion cost per assembly, \$	0.00109

- Change the entry to read **insertion of washers**.

### Insertion of Plate




- With the *insertion of washers* entry highlighted, add a library operation for a rotational part.
- The part thickness or length is **0.063**, the part diameter is **2.4** and the repeat count is **1**.
- The part can be placed in the workcarrier either end up so end-to-end orientation is not required.
- The part must be placed in the workcarrier so that the two holes, which will eventually accept the screws, are located above the washers and nuts. These two holes are the features that determine the orientation of the plate about its axis. However, they cannot be seen in the outer shape of the silhouette of the part, so in the *Rotational symmetry* group click the last button which is labeled *Asymmetry too small or cannot be seen*.

We can assume there are no additional feeding problems for the plate but we should indicate that, once the part has been inserted and properly oriented in the workcarrier, it will require holding down and was not easy to align and position. Check these boxes in the *Insertion* group.

- Click **Calculate** and see that a warning is presented stating that automatic feeding is not practical and manual assembly is assumed. The plate will require 5 manual stations to maintain a machine cycle rate of 30 per minute (a cycle time of 2 seconds) because the estimated manual assembly time is 8.56 seconds. Also, we note that the cost for this entry will be \$0.07133 which is significantly higher than the costs we saw for automatic assembly of the nuts and washers.

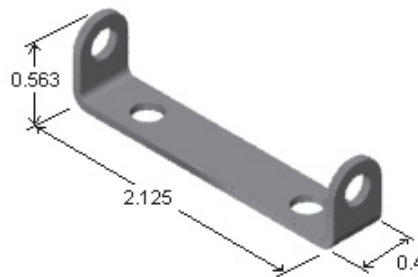
Results

 Automatic feeding not practical  
manual assembly assumed

Manual stations per entry	5
Machine cycle rate, cycles/min	30
Manual handling time per part, s	2.06
Manual insertion time per part, s	6.50
Manual assembly time per assembly, s	8.56
Manual assembly cost per assembly, \$	0.07133

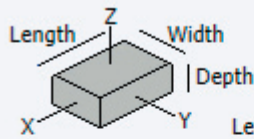
- Edit the entry to **manual insertion of plate**.

### Insertion of Bearing housing



- With the entry *manual insertion of plate* selected, add an operation for *Assembly of non-rotational part*.
- Enter the dimensions of the rectangular envelope that will enclose the part. It is important to realize that the part envelope length must be larger than the part envelope width which in turn, must be larger than the part envelope depth. Thus, we enter **2.125** for the length, **0.563** for the width and **0.4** for the depth. The repeat count is **1**.
- Referring to the picture in the Data group we also need to recognize that the X-axis of the part is parallel to its length, the Y-axis is parallel to its width and the Z-axis is parallel to its depth. We must now consider 180 degree rotation of the part about each of these axes in turn. We note that the Y-axis is the only axis for which the part repeats its orientation after rotation of 180 degrees. We check the box for the **Y-axis**.

**Data**



Length >= Width >= Depth

Part envelope length, in.

Part envelope width, in.

Part envelope depth, in.

Repeat count

**Part has 180 deg. symmetry**

when rotated about the X-axis ?

when rotated about the Y-axis ?

when rotated about the Z-axis ?

- We now view the part along each of its axes. When the part is viewed in the X direction, we see symmetrical projections and click the button labeled as such for the X direction. For the Y direction, accept the default of *No main feature defines asymmetry*. A groove can be viewed in the Z direction so we click the button labeled *Symmetrical grooves or steps* for that direction.
- We assume the bearing housing presents no additional feeding problems and that it is added but not secured. However, when it is added to the assembly it must be carefully positioned because there are no features to assist in alignment and positioning and it will require holding down until the screws are inserted. Check the two checkboxes appropriate for these difficulties and then click **Calculate** to view the results.

**Insertion**

Insertion type

Insertion motion non linear

Insertion not from above

Holding down required

Part not easy to align and position

Resistance to insertion

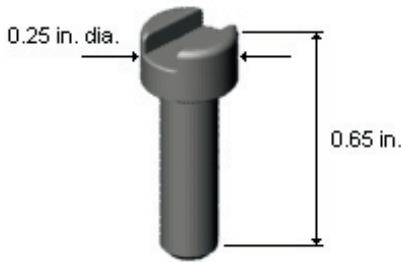
**Results**

Automatic stations per entry	1
Machine cycle rate, cycles/min	30
Desired feed rate from feeder, parts/min	30
Maximum rate from one feeder, parts/min	11
Feeder cost, \$	13281
Workhead cost, \$	20000
Automatic feeding cost per assembly, \$	0.00072
Automatic insertion cost per assembly, \$	0.00109

- Edit the name of the entry to **insertion of bearing housing**.



### Insertion of Screws



1. With *insertion of bearing housing* selected, add an operation for the assembly of a rotational part.
2. The part thickness or length is **0.65** and the part diameter is **0.25** and the repeat count is **2**.
3. The screws require end-to-end orientation but can be fed suspended by their heads in a slot. We click the button labeled *Part can be fed in slot* in the End-to-end symmetry group.
4. The screws do not require orientation about their axes because the automatic screw drivers will locate the slot in a screw head.
5. There are no additional feeding problems but we must select *Part secured immediately* for the insertion type. An additional drop down appears for the Securing method and we select *Screw fastening*. There is no pilot point on these screws or any other features to facilitate alignment and positioning so we check the box *Part not easy to align and position*.
6. After clicking **Calculate** we can see that a single feeder can feed these parts at a rate of 83 per minute but, because the parts are not easy to align and position and two workheads are required, the cost of equipment is fairly high.
7. Name the entry **insert and fasten screws**.

### Results

1. Click the entry *transfer system and downtime* to view the results of the analysis.

We note that an automatic assembly machine will have four automatic stations and five manual assembly stations giving a total number of stations of nine. We have not added stations for inspection or packing, etc.

Automatic assembly machines	
Automatic assembly stations	4
Manual assembly stations	5
Other stations, inspection, packing, etc.	0

For a synchronous assembly machine, the total equipment cost is approximately \$219,000 with a significant downtime due to faulty parts of over 17%. This gives us an actual assembly rate of just over 21 per minute due to overall plant efficiency and the downtime due to faulty parts. This figure is about two thirds of the desired assembly rate of 30 per minute and it would take about six years to complete the production of 30 million assemblies at a total assembly cost for each assembly of \$0.22485. We should realize that this cost is rather high due to the fact that we required 5 manual assembly stations for the insertion of the plate.

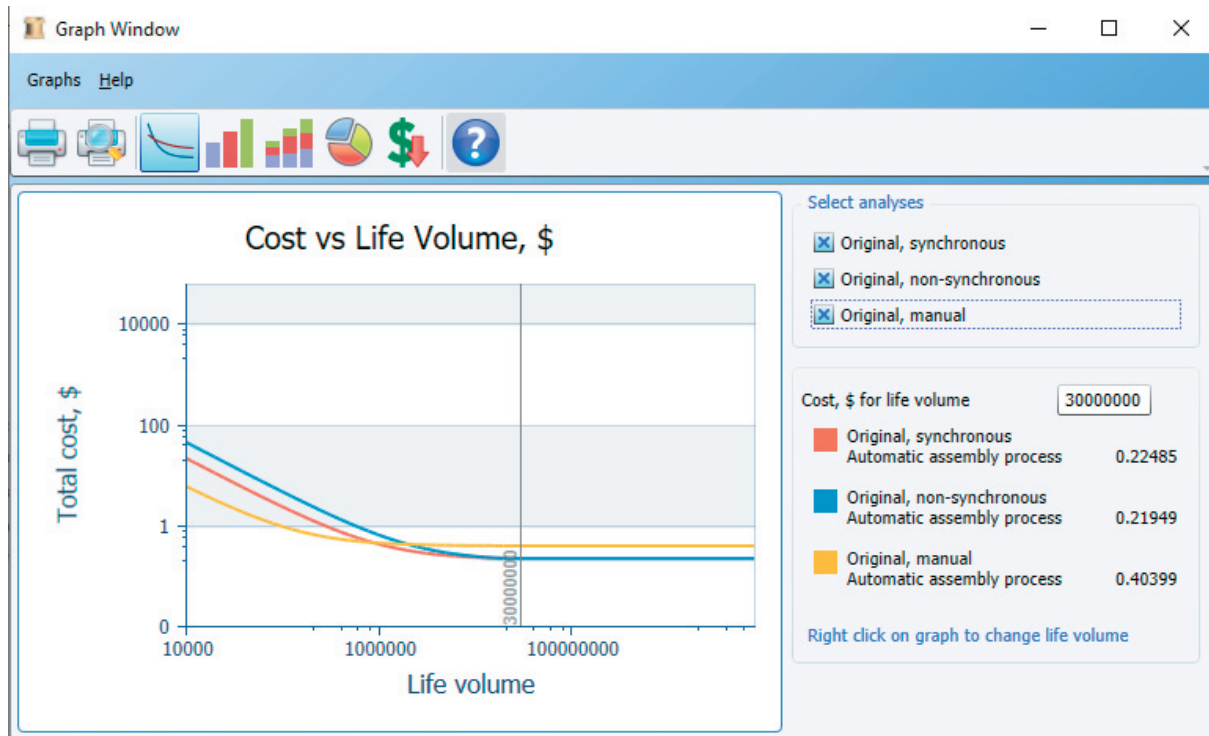
Synchronous assembly machine	
Cost of transfer device, \$	94,500
Total equipment cost, \$	218,781
Down time due to faulty parts, %	17.36
Average assembly rate, assy/min	21.07
Production time for life volume, years	5.93
Total assembly cost per assembly, \$	0.22485
Non-synchronous assembly machine	
Cost of transfer device, \$	321,750
Total equipment cost, \$	446,031
Down time due to faulty parts, %	9.50
Average assembly rate, assy/min	23.08
Production time for life volume, years	5.42
Total assembly cost per assembly, \$	0.21949

For the non-synchronous assembly machine the equipment cost is over twice that for the synchronous machine. However, since the down time due to faulty parts is less and the average assembly rate is higher, the assembly cost per assembly is slightly less than that for the synchronous machine.

For a manual assembly line, the average assembly rate is the highest and is only less than the desired assembly rate due to the overall plant efficiency. The assembly cost per assembly is almost twice that for the non-synchronous assembly machine.

Manual assembly line	
Manual stations	29
Total equipment cost, \$	58,000
Average assembly rate, assy/min	25.50
Production time for life volume, years	4.90
Total assembly cost per assembly, \$	0.40399

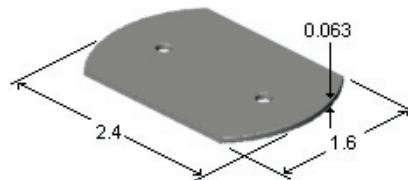
- Highlight the entry for the *Automatic assembly process*. Note that the total cost corresponds to the least of the three options, namely the non-synchronous assembly machine. The program has selected the optimum assembly system.
- Select *Cost vs. Life Volume* from the Results menu to view this graph. Select all three assembly systems to compare.



We see that manual assembly would be preferred for life volumes up to almost 850 thousand and that a synchronous machine, because of its lower investment, would be preferred for volumes up to 12 and a half million. Close the Cost vs. Life Volume graph window.

## Redesign of the plate

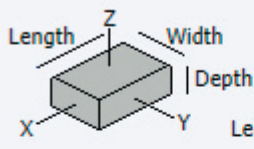
It is clear from this analysis that careful attention should be given to the design of the plate because it required manual assembly, adding considerably to the cost of assembly.



1. Copy the current analysis to a new tab. Right-click the Original analysis tab and select *Copy* from the pop-up menu that appears. Right-click the *Original* analysis tab again and select *Paste* from the pop-up menu. Rename the tab *New design*.
2. Highlight the entry *manual insertion of plate* and add a new operation for the assembly of a non-rotational part.
3. We see on the redesign that the edges of the plate have been cropped to correspond to the position of the holes. This new design corresponds more closely to the definition of a non-rotational part whose orientation is defined solely by its dimensions. Enter **2.4** for the length, **1.6** for the width and **0.063** for the depth.
4. Note that the part now has 180 degree symmetry when rotated about any of its axes. Click each of the three boxes.

Since there are no features defining the orientation of the part, and since the part will be located properly when it is placed in the workcarrier, no other boxes need be checked.

**Data**



Axes of non-rotational part envelope  
 $Length \geq Width \geq Depth$

Part envelope length, in.

Part envelope width, in.

Part envelope depth, in.

Repeat count

Part has 180 deg. symmetry

when rotated about the X-axis ?

when rotated about the Y-axis ?

when rotated about the Z-axis ?

5. Click **Calculate** and observe that the part is now automatically fed, oriented and inserted and the automatic assembly cost is minimal.
6. We can now name the entry **insertion of redesigned plate** and delete the entry *manual insertion of plate*.
7. Click **Calculate** and highlight *Transfer system and downtime*. We now see that the automatic assembly machine would have five automatic stations and no manual assembly stations. We should also note that the assembly cost per assembly for a synchronous assembly machine is less than one tenth of the previous estimate and much less than the cost of manual assembly. Also, the graph of Cost vs. Life Volume shows automatic assembly is now economic for life volumes as low as 410,000.