

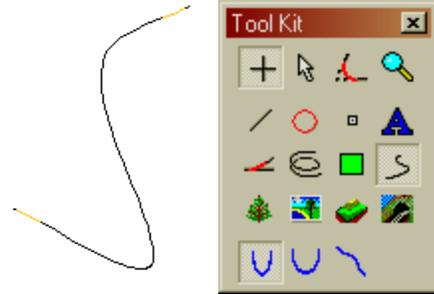
1. Splines

There are three kinds of splines available in 3rd PlanIt: Cubic, Rounded and MA (Minimum Acceleration). The first two splines use geometry defined entirely within the spline, and thus cannot have their entry or exit aligned to existing objects. MA splines are specifically designed for track planning, allowing the direction of endpoints to be aligned to other objects. All of the splines assume the curvature at each end is zero, so you can reasonably align tangent (straight) track or lines to splines.

1.1 Cubic Splines

The cubic spline is what you may have come across in other drawing programs, a smooth curve that connects three or more points. Although a cubic spline may have two points, it ends up as a straight line.

To draw a cubic spline, or any other spline, first select the kind of spline you prefer from the ToolKit. Point to the location for the spline to begin, then click the left mouse button. As you move the mouse, a line will be drawn from the first point to your cursor's location.

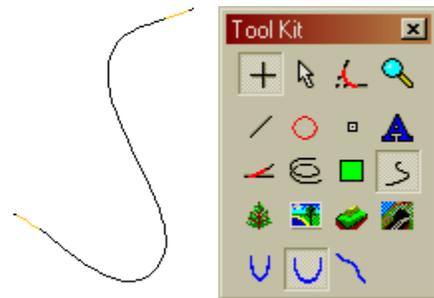


At the location you want the second point, click the left mouse button again. Now, as you drag the mouse, the spline curve will begin to show. You may point to a third location and click the left mouse button again. Continue this procedure until you get to the last point of the curve, and then double-click the left mouse button.

1.2 Rounded Splines

These splines are, as the name implies, more rounded than the cubic spline. They are more suited for track planning, as the sharp bends present in cubic spirals are rounded.

The example at the right was not drawn; it was made from the example above. Using the object's Properties dialog, the spline was changed from cubic to rounded. You can see the difference between the two examples. If you wish, you can align objects to the spline's endpoints. These should generally be straight lines, as splines end with zero curvature.



It's worth noting that the ends of cubic and rounded splines have a bit a "reverse curvature". This is the nature of these curves, which are not particularly suited for trackwork.

1.3 MA Splines

Minimum acceleration splines – MA splines – have been specifically designed for track planning. Their endpoints can be aligned to existing objects. In addition, their curvature is designed to provide the least horizontal acceleration through the curve given the start and end directions. Finally, MA splines can be straightened, letting you design complex track with multiple curves in one spline.

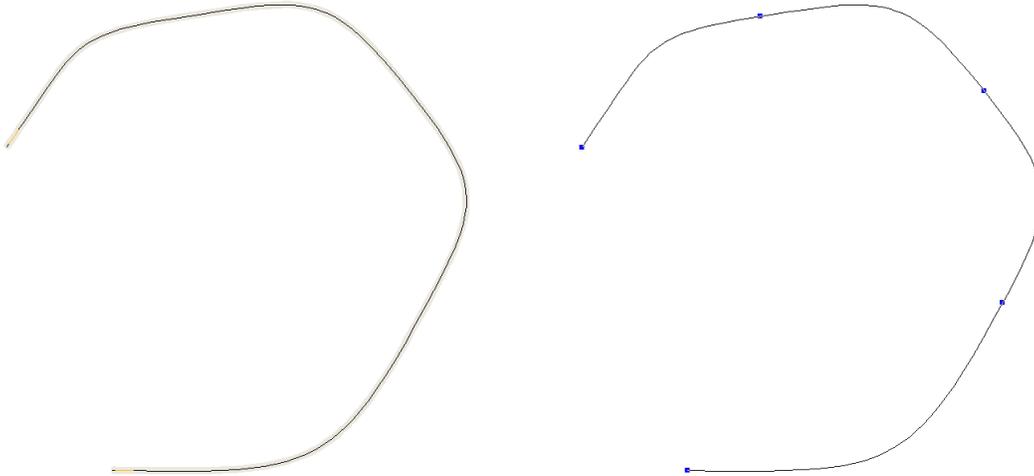
In the example below, we see a reversing loop that might appear on a peninsula in our layout. The curve has been defined by five points, as can be seen more clearly on the right.

MA splines minimize horizontal acceleration, as measured over the whole curve. Because of this, moving one vertex will result in changes throughout the curve, especially between the vertex being moved and its neighbors.



1.4 Straightened MA Splines

With MA splines, you can design track with several curves, controlling the position and radius of curves by the location of the spline vertices, along with the straightening percentage. To serve as an example, the same MA spline used in the previous section was used here.



You can turn on straightening either from the spline's property page, or by clicking on **Straighten** in the Object Data Window. In either case, you can also set the straightening percentage. In this example, a 80% straightening was chosen.

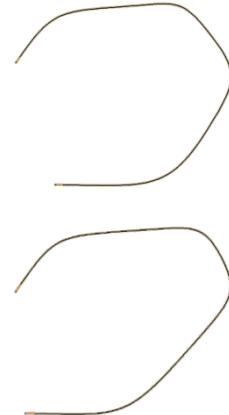
1.4.1.1 Editing Blocks of Track

One of the great benefits of MA splines is the ability to edit areas of track as a whole. You can make such changes while editing the spline. To enter object editing mode, double-click on the spline. Each vertex will have a blue handle that you can move independently – or as part of a group. To move one vertex, point at its handle, press and hold the left mouse button, then move it around. Release the mouse button when you're done.

To move a group of vertices, double-click the spline using the Select Tool to edit its vertices. Then “rubber-band” a number of vertex handles. When you move any one of them, all of them will move together. The example on the right was made by moving the three vertices in the upper-right of the spline. to the right. The result is still an orderly, useful track segment that is a bit wider than before.

In the next step of this example, the lower two vertices were moved to the left. The minimum radius is about 27” again, with two broad curves and two more narrow curves.

This large change in track geometry was accomplished in just a few simple operations. All the curves are smoothed by cubic easements and flow into each other as part of a balanced whole. It's easy to try a wide range of layout options in a short time using MA splines, with elegant results.

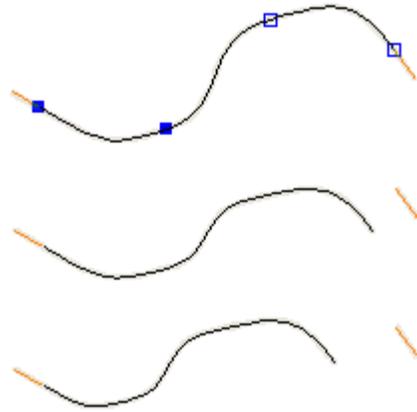


1.4.1.2 S-Curves with MA Splines

This example shows an S-Curve embedded within an MA spline, as well as editing blocks of track. To help visualize the changes between the drawings, an orange line was added to each end of the spline. Both lines stay in their original positions as changes are made.

The first edit moved the upper-right two vertices a bit lower and to the left. Compare the end of the spline to the end of the line to which it was adjacent. After that, three of the four vertices were moved to the left as a block, shortening the lower-left track.

While you are editing an MA spline, if the radius becomes too small at some point, the spline will become first orange, then red where the radius is under the minimum. You can also see the changing radius in the Object Data Window as you edit.

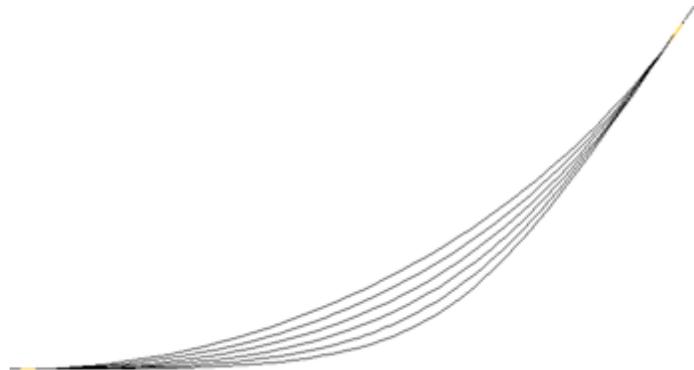


1.4.1.3 Transitions between Straight Lines

You can use MA splines as transition track between two straight lines (tangent track). If you want to transition between one or more curved segments, you are better off using Quintic Easements, as shown in the SoftTrak chapter.

In the image on the right, you can see the range of straightening available to MA splines, ranging from 0% to 100%, every 20%. The radii of the curves vary from just over 12" to about 33".

By adjusting the straightening value, you can achieve the working radius you want. Adding a point mid-spline will generally not achieve the same results, unless you turn straightening off.



2. Quintic Easements

3rd PlanIt offers a design capability previously available only to full scale high-speed railroads. Quintic Easements have their roots in CAD software, based on mathematics not available until recently: quintic splines. Unlike cubic splines available in many drawing programs, splines based on a quintic equation allow the curvature at each endpoint to be specified. Quintic Easements can be visualized as transition curves that change curvatures in all three dimensions simultaneously.

2.1 Background

To better understand the role of the quintic in railroading, we can look into the role of the transition curve in general. If you'd like to simply use them, feel free to skip to the next section.

Before CAD design systems were available, both regular curves and transition curves (easements) were determined by "stationing". Surveying points, or stations, are located every 100ft along the track (in the United States). If one was laying out a curve of constant radius, at each station the surveyor would set out an angle of a few degrees, using the same angle at each station.

To transition that curve to a tangent (straight) track, the surveyor would subtract a small value from the angle at each station, until the angle between stations reached zero. This natural measuring process resulted in a curve that is represented by a cubic spiral. "Cubic" means that the distance from the tangent increases as the cube of the distance along the curve.

Quintic transition curves find their power in CAD systems by exploiting the mathematics of equations using the distance along the curve raised to the fifth power, rather than the third. What is special to us is that a quintic equation can calculate a curve with specified curvatures at each end. Traditional cubic splines must approach zero curvature at each end – which renders them ineffective for connecting curved track to tangent track or to another curve.

What new design capabilities are available with Quintic Easements? There are three major benefits. The first is the shape of the curve. It is very close to the same curve as a cubic easement, but it is optimized to provide a better transfer of lateral acceleration when entering or leaving a curve. This difference is critical to the operation of high-speed trains, as momentum is proportional to velocity – and curves must change the momentum of a train. The second benefit is that the quintic curve operates in three dimensions, not just two. It can just as easily transition vertical grades as horizontal grades. One or both ends may have curvature, as well. Finally, it allows connection between two curves in situations that are difficult or impossible to accomplish with traditional easements, such as curves whose center of radius is concentric or closely spaced.

2.2 Vertical easements

If a track at one grade meets track at another grade, the simplistic solution appears at the right. The difference in grade between the flat segment on the left and the 10% grade to the right is made more noticeable here by the use of terrain underneath the track. One never sees track like this in the real world, as there would be a huge bump changing from one grade to another. The track designer must provide transition track to smoothly change grades.



3rd PlanIt offers a connect tool to quickly add vertical easements to your design. Select the “Connect Quintic Easement” tool, shown at the right. This tool operates in much the same manner as Connect With Easements, and other Connect tools. The transition track is made by clicking first on the left track segment (press and release the left mouse button).

Next, point your cursor to the center of the right track segment. Press and hold the left mouse button, then move the mouse to adjust the length of the vertical easement. When you think the transition track looks reasonable, release the left mouse button to complete the connection.



Your track should look like the image on the right when you view it in 3D. You can see that the track now smoothly curves from the 10% grade on the right into the flat track on the left. The abrupt change in grade is still visible in the terrain below the track.



The image on the right was made after conforming the terrain to the new vertical easement and placing a short train on it. The train looks natural despite the huge change in grade, with each car’s angle a bit more than the one in front of it. This not only looks better, but makes reliable operation possible.



Building vertical easements is easy. They are created naturally by gradual flexing of the track and roadbed, be it wood or foam. 3rd PlanIt gives you valuable reference points at each end of the curve, which can be transferred to your layout as you build it.

2.3 Vertical easements with a fixed radius

The Connect Tool also lets you create a vertical easement with a fixed radius. This provides regularity in your design and building. Select the tool “Connect vertical easement, fixed radius” as shown at the right.

Using the tool is much the same as using the adjustable radius version discussed above. There is no need to adjust the curve using the left mouse button, though. The length of the transition curve is set to achieve the fixed radius. You can set the value of the fixed radius by pressing the button with the lock and blue check mark.



2.4 Complex vertical easements

In the Background section of this chapter, it was noted that quintic equations allow us to specify curvature at both ends. This fact brings great flexibility to quintics, allowing track designs not possible otherwise. As an example, a tangent track with no grade is butted against a curve that has a 10% grade.

You can see the abrupt change in grade in the left image. On the right, a transition curve has replaced a few inches of both sections of track. The track transitions not only as a vertical easement, it smoothly connects the curve and the tangent while smoothing the change in grade. This design would be extremely difficult to achieve without quintic transition track.



2.5 Editing Quintic Easements

Quintic Easements may be simply edited, bringing new speed and flexibility to track design. Starting from the example above, each primary track segment was shortened using the double-click edit feature. A gap appears between the primary tracks and the Quintic Easement, shown at the right.



Note the yellow tips of the Quintic Easements. These tips indicate a powerful new editing feature – flexible track that maintains smooth curvature from end to end. Before completing the broken trackwork, take time to experiment with the Quintics. Choose the Select Tool and point your cursor to the left end of the Quintic, at the yellow tip.



As you move the tip, the whole track flexes from end to end. The curvature of the other end is maintained until you adjust it by its tip.

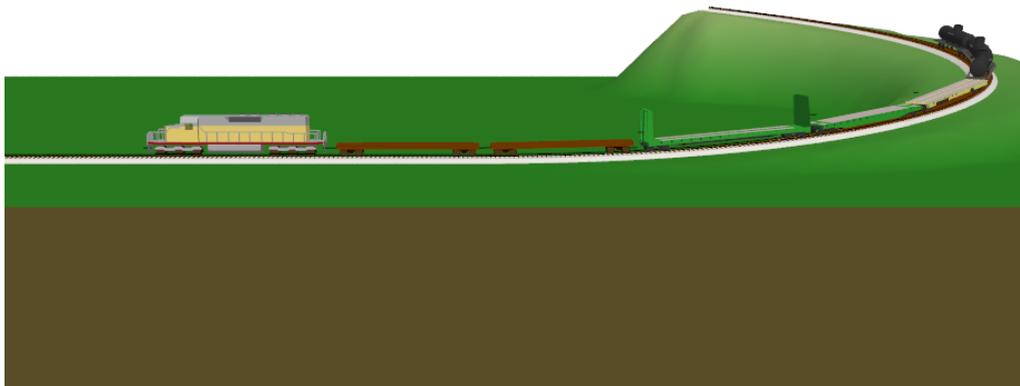


As shown above left, the left tip of the Quintic was dragged to the tangent track. When the tip hovers over the end of the tangent track, the tangent is highlighted in confirmation. At that point, the left mouse button is released and the Quintic is aligned to the tangent track.

To move a Quintic Easement, point your cursor near the center of the track segment. When it highlights, press and hold the left mouse button, then drag the Quintic elsewhere. If you double-click the Quintic Easement, you can move the editing handles without changing the curvature.

Note that there is a bit of an S-curve in the track on the left. An S-curve is not good track design in general. However, given the curvature and location of the Quintic's right end, the path with the least acceleration is accomplished as shown. You need to be aware of this when designing with Quintic, and avoid unwanted S-curves by using good geometry. When the right tip of the Quintic is connected to the constant radius curve, the Quintic is adjusted for its new location and the curvatures in play. This longer easement allows a graceful transition from curve to tangent, absorbing the change in grade along the way.

After adding a train and swapping to 3D by pressing the Tab key, you can see the graceful results.



It's worth considering this connection in detail. The 10% grade of the curved track has been transitioned smoothly to a tangent track with no grade, while at the same time transitioning from curve to tangent. This kind of track planning power lets you design complex track in very little time.

2.6 Connecting with Quintic Easements

If you use easements in your designs, using quintic easements is much the same. In fact, the program computes the quintic curves with the same routines used for cubic easements. Quintic easements replace cubic easements as the final step.

This implies that you can replace any cubic easements in an existing design with quintic easements. That's quite true. You'll find two versions of the tool, providing variable and fixed radius connections. The Toolkit shown at the right has the variable radius version checked; the fixed radius version lays to its right.

This example begins with two segments of tangent track at a shallow angle to each other. The "Connect Quintic Easement" tool is used in the same manner as the "Connect with Easements" tool, optionally with a fixed radius curve.



While it is only evident in this illustration by their colored tips, the easements are quintic. You use the same procedures found elsewhere in the program to design with modern geometry. By printing your design 1:1, you can build your layout to the exact specifications you designed.

2.7 Connecting with a Single Quintic Easement

When connecting obtuse angles of 135 degrees or more, you might prefer having the connection made with a single Quintic Easement. This provides a very smooth curve, with lateral acceleration distributed evenly throughout the transition.

Although a quintic transition curve does not follow track design standards prior to the 21st century, this kind of transition is currently used on prototype high-speed rails on shallow curves. You might also find it useful in designs of an earlier era, where it can provide more attractive flow or let you achieve complex yard designs.

This example begins with two segments of tangent track at a shallow angle to each other. If the lines to be connected form an angle less than 135 degrees, a traditional easement-curve-easement will be automatically be produced, not a single easement.



2.8 S-curves with Quintic Easements

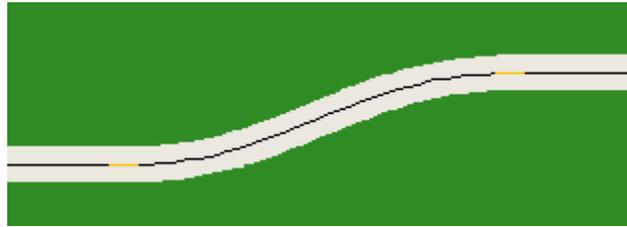
You might be wondering – if the quintic transition curve can have an S-curve, can it be used to solve an S-curve situation intentionally? The answer is definitely "Yes". A new tool is available to connect existing endpoints with Quintic Easements, as shown on the right.

Shown at the right is an arbitrary misalignment of track to serve as an example.



After selecting the “Connect Quintic Easement, between ends” tool, click on the end of the left track, then the end of the right track. A new piece of track is laid out between the ends, without repositioning the ends.

Even this artificial design situation is resolved smoothly with the quintic transition track. It would not only be difficult and time-consuming to perform a similar design with curves, easements and tangent track. It would not be possible to minimize the transitions as effectively, nor provide reliable operation in a small area. You will be able to make more compact and interesting designs by carefully using this new curve.



2.9 Connecting two circles

You will occasionally run into a situation where you wish to connect two curves that form overlapping circles, as in the example at the right. These nearly concentric circles are of 24” (on the left) and 36” radius (on the right). It would be nearly impossible to connect these curves using traditional design tools. However, the Quintic Easement makes it easy and customizable.



Start by slicing each curve at places that appear to provide reasonable transition opportunities, such as shown below on the left.



Use the “Connect Quintic Easement, between ends” tool to produce a very smooth curve that gradually eases one radius into the other. The transition curve that resulted is not a unique solution to the overall problem, though. Let’s try the same situation, with a slightly different end for the left curve.



You can decide which curve is preferable to your eye. Both will provide reliable and smooth operation when you build your layout. Use good judgment, though – you can also take things to an extreme.



If you consider the image above left, it does not appear that a smooth connection can result. It can’t, but the quintic will try its best to smooth the complex connection. The new track looks like it is in the mountains, but if the radii are large enough, it will operate reliably. The curvature from the left track is bled off as the S-curve begins, and curvature to the right track is worked in near that end. It is the best available solution to the complex (or inappropriate) starting geometry.

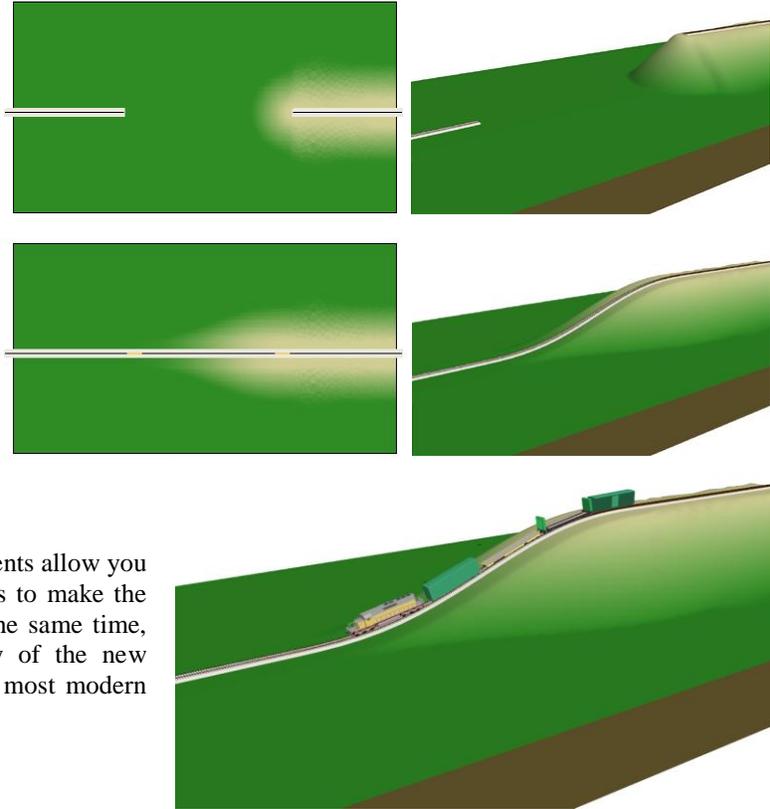
2.10 Understanding the vertical component

This example will help you understand the capabilities of the Quintic Easement. We start with a contrived design to make the nature of the curve more visible.

The track at the left has no grade and is at 0" elevation. The right track is at 10" elevation with no grade. The terrain makes this quite evident.

After using the "Connect Quintic Easement, between ends" tool and conforming the mesh to the track, a smooth roller-coaster track appears between the two original tracks.

3rd PlanIt's unique Quintic Easements allow you to create flowing, complex designs to make the best use of your layout area. At the same time, you will enjoy the subtle beauty of the new curve, knowing you are using the most modern design methods available.



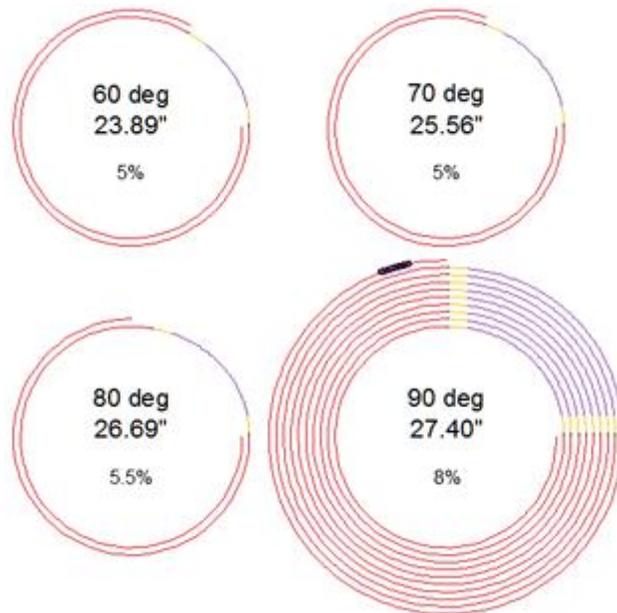
2.11 Concentric Circles

A particularly difficult problem can be connecting two concentric circles. This most commonly arises when one is designing a dual-track helix, crossing from the inner to the outer helix.

At the right are two concentric circles. The radius of the inner circle is 30", and outer circle has a radius of 32". There are an infinite number of paths by which you can connect the two. It's up to you to choose the curve that will operate reliably with your equipment, and has a smooth flow throughout the curve.

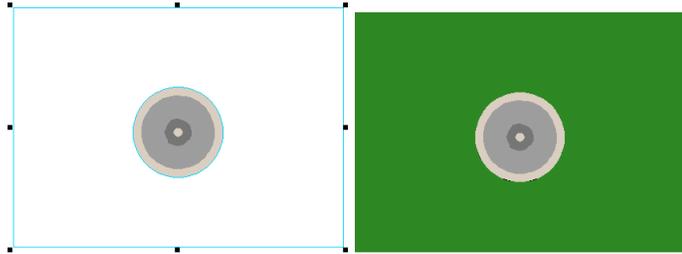
Four examples are shown, with the transition length varying from 60 to 90 degrees of arc. The 60 degree example has a clear bulge at the bottom of the arc; the 70 degree is fairly good, and the 80 and 90 degree curves are both quite usable. The minimum radius in the curve is shown, and comes very near the 30" radius of the inner circle despite the bending required.

These smooth curves were accomplished using the **Straighten** feature of Quintic Easements. In most cases, you will only use Straightening with MA splines, not Quintic Easements. However, in some cases such as this, it comes in very handy to adjust the location of the smallest radius.



3. Holes in Meshes

If you'd like to have a turntable or an access hole in your mesh, or even more than one, it's easy to do. If you have a contour line left from designing the turntable choose it. If not, you can draw a new Freehand Contour Line, and snap it to the perimeter vertices of the turntable.



Draw another contour line for the outline of the mesh. Select both contour lines, then use **Edit / Transform / Change to Mesh** to create a mesh similar to the one on the right. You can embed as many polygons as you wish, for example, to create windows in the side of a piece of rolling stock.

