LEGO® 9V TRAIN TRACK GEOMETRY

by Donát Raáb

Brickshelf – member of MLVK and Kockajáték Klub

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1. Getting started

What's the point?

We can ask, what's the point to keep rules of track geoemtry? Of course, if we play alone at home, place our train tracks on the floor, we don't really need geometry rules, our non-standard layouts can be connected as a loop with a little stressing of the connections between tracks. But there are some cases when we simply can't ignore geoemtry rules. If we don't play alone, we have to design standard connections, so people in the same LUG (or even people from different LUGs) can connect their layouts, regardless how many of the LUG members attend that event. Standard connections allows to put together a great layout differently on different events. If we play alone but decided to put baseplates and track ballast under our tracks we need geoemtry rules as well. Keeping geometry rules and those techniques we present in this document your tracks will end up always at the end of the baseplates (or near to them), so assembling and dismantling your ballasted layout will become much easier. Keeping standards will allow you to build modular ballast, which enables easy additions to your layout without rebuilding existing parts.

Standard track pieces

Five different track pieces were produced in the 9V-era (*Fig. 1)*.

- **Straight:** 16 studs long, straight track segment. The sleepers underneath are 8 studs wide.
- **Curve:** In midlane its length is 16 studs, with 8 studs wide sleepers underneath. Each curved track segment turn 22.5 degrees, four of them makes a 90 degrees turn, sixteen of them is needed for a full loop.
- **Point - left:** In straight direction its length is 32 studs and allows trains to change track into left direction. The sideways curve can be made parallel with straight track using one curved track after point. Note, that the lenght of curve and lenght of the sideways curve of a point is not the same, however both allows a 22.5 degrees turn.
- **Point - right:** See above, with opposite direction.
- **Crossing:** It is a 90 degrees crossing of two straight track segments. We do not recommand to use these in your layouts since the crossing part damages plastic train wheels under heavier trains quite quickly.

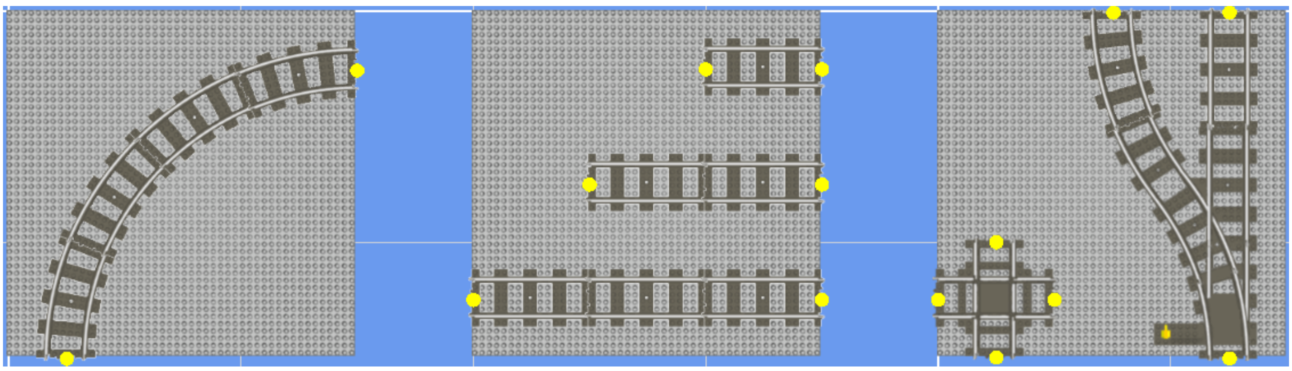

Fig 1: *9V tracks. On the left there are four curved segments placed together. The 90 degrees turn can be put on one single big baseplate. In the middle there are straight tracks built from 1,2 ans 3 straight segments. On the right there is a single crossing and a left point. There is one curve and one straight connected to the upper ends of the point. The point with additional curve to make tracks parallel fits on a big baseplate. Note that you should always start your track on the edge of baseplate and sleepers should be placed 4, 20 or 36 studs from the edge of baseplate parallel with your track. The standard distance between the center line of two parallel tracks should be 16 or 32 studs (and any distance divideable with 16 studs), which means 8 (24, 40...) studs between sleepers of parallel tracks.*

2. Basic Rules

Tracks should be always started from the edge of baseplates, and their sleepers should be 4 studs away from the edge of baseplate parallel with track. Since the straight segment is 16 studs long and we prefer to use baseplates with edge lenght divideable by 16 studs, the track segment connections should be always be on baseplate edge. If the baseplate is wider than 16 studs, we can place additional parallel tracks, 8 studs should be left between two tracks' sleepers (and 16 studs between center lines of tracks). For example, if we have a normal 32×32 baseplate, its edge will be divided the following:
→ 4 studs empty – 8 studs track's edge – 8 studs empty – 8 studs track's edge – 4 stud empty.
If we put more similar baseplates next to each other, there will be 2×4=8 studs next to each other left empty, and parallel tracks will have standard distance between each other. parallel tracks can be connected as shown in *Fig. 1*.

Curves doesn't mean any problem until we use four of them together. Four of curved track segments result in a 90 degrees turn, which fits nicely to a large baseplate (curved track will end on baseplate edge and 4 studs away from the edge parallel with the track). *Fig. 2* shows a simple layout using only the basic rules.

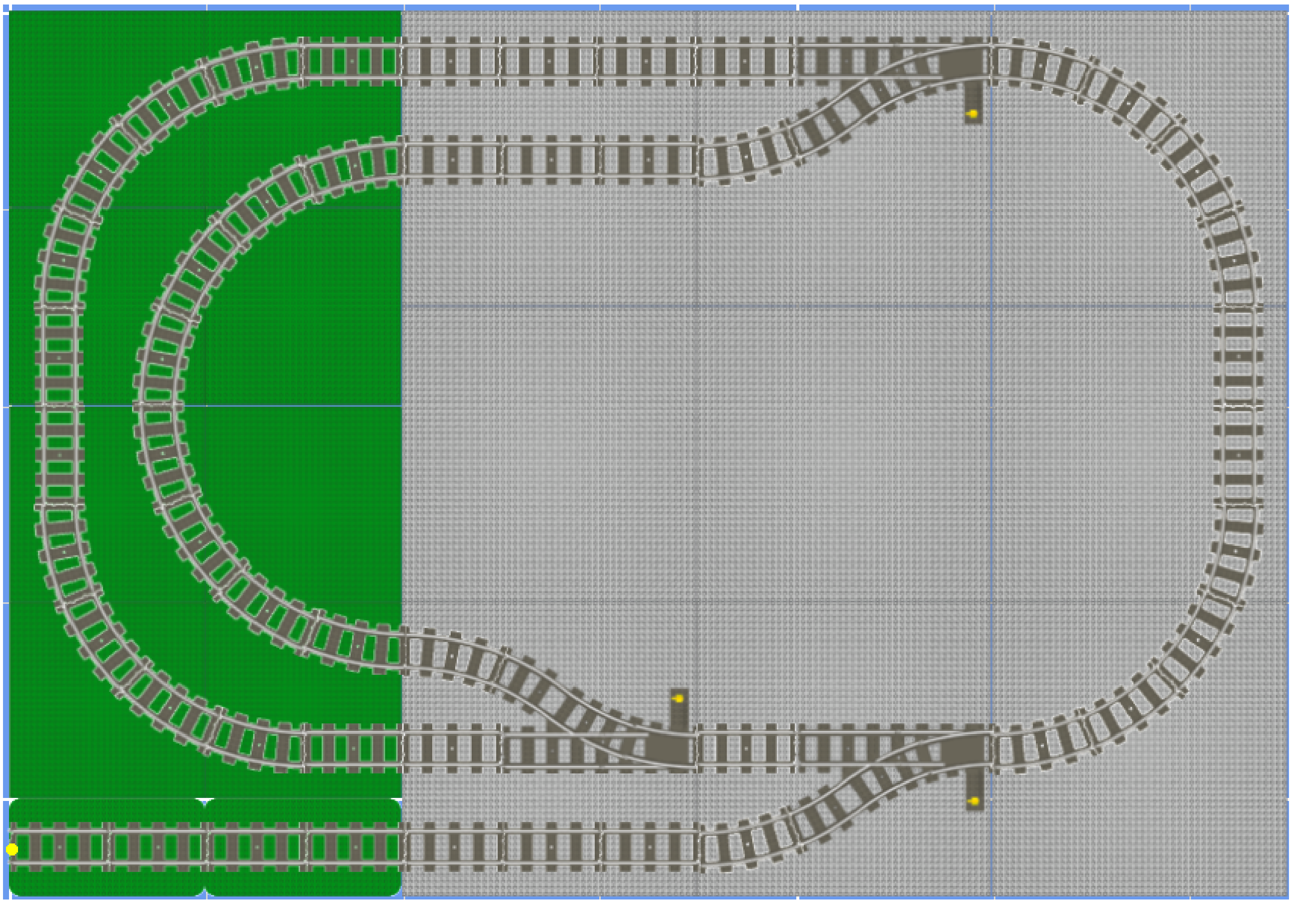

Fig. 2: *Simple layout with dead-end.*

3. Beyond basic rules

Fortunately we don't have to use only 90 degrees turns and points give much more fun than strictly built parallel tracks. We can design quite difficult geometries using the pieces shown in section 1.

„Long” radius curves

Unfortunately we won't have curves with larger radius, but we can build smoother turns for our trains placing one straight track between two curves (*Fig. 3*). It is also possible to put more straights between curves, but make sure you put the same amount of them after every curve. Regardless how many straights you used, the curve after 90 degrees turn will end on baseplate edge.

Less „S-curves”

Two curves next to each other with opposite direction can be replaced with one straight track segment (at 22.5 degrees), see *Fig. 4*. Using this technique we can spare some space on our layout and eliminate unnecessary turns (which can slow down trains with long cars).

Delta tracks

We can build and simplify delta tracks with the replacement technique described above sparing 32 studs in lenght and 16 studs in perpendicular direction. *(Fig. 5)*.

Building delta tracks (or loops returning to itselves) will result in short circuit without insulation. A single small sheet of paper inserted between track connections will be enough as insulation. I recommend to cover the metal part of the track at least 6 studs long (the axle distance of a 9V train motor) by the insulation to make sure the train motor won't create itself the short circuit.

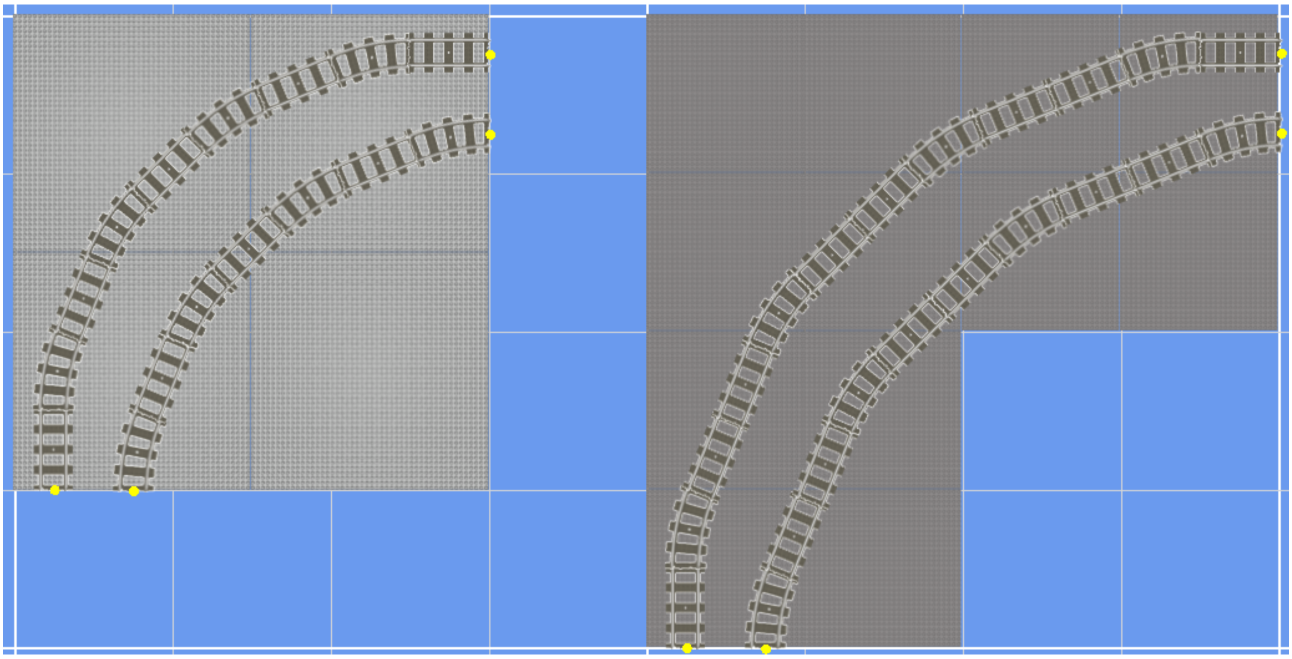

Fig. 3: *„Long” radius curves built with standard curved and straight track pieces. Image on left shows a curve with one straight segment put between curved pieces, right image shows a curve built inserting two straight segments between curved segments.*

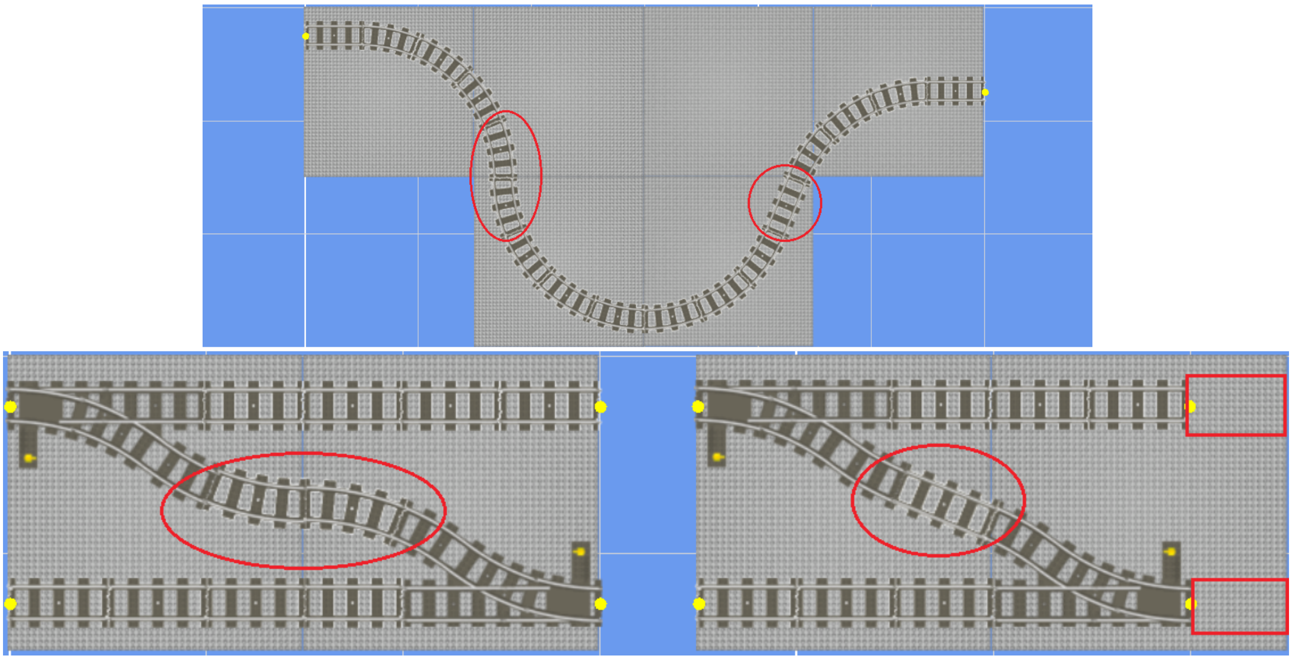

Fig. 4: *Replacing opposite direction curves with straight track segments at 22.5 degrees. Image above shows how we can spare space and unnecessary turns for our trains, image below shows simplified connection between two parallel tracks.*

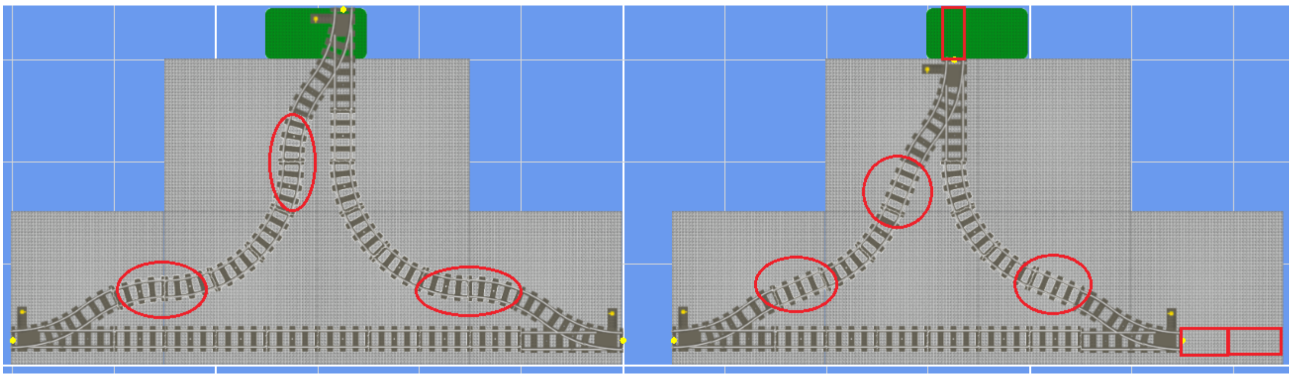

Fig. 5: *Building delta track (left) and simplified delta track using the replacing method.*

22.5 degrees diagonal

Above layouts – however they used the replacing technique to simplify curves – never get rid of 90 degrees turns, in the end, the track resulted in a direction parallel with the edge of the baseplates. Let's make a try to build tracks running not parallel with baseplates' edges. Our tracks can close 0, 22.5, 45, 67.5 and 90 degrees with the edges of baseplates. 22.5 and 67.5 degrees are the same case, 0 and 90 degrees are parallel with baseplates' edges so take a look at 22.5 for first. As we can see on *Fig. 3.* if we put straights between curves (regardless how many until we put the same amount of straight between each curves) we can have a long section running at 22.5 degrees. But this is only the extrapolation of „long” radius curves, so we should look around for other solution. To make tracks running at 22.5 degrees and fitting geometry we need triangles with side lengths of Pythagorean triples (or near to it). *Fig. 6* shows the 5,13,14 triple, which is near to a Pythagorean one ($5^2 + 13^2 = 13.92^2$).

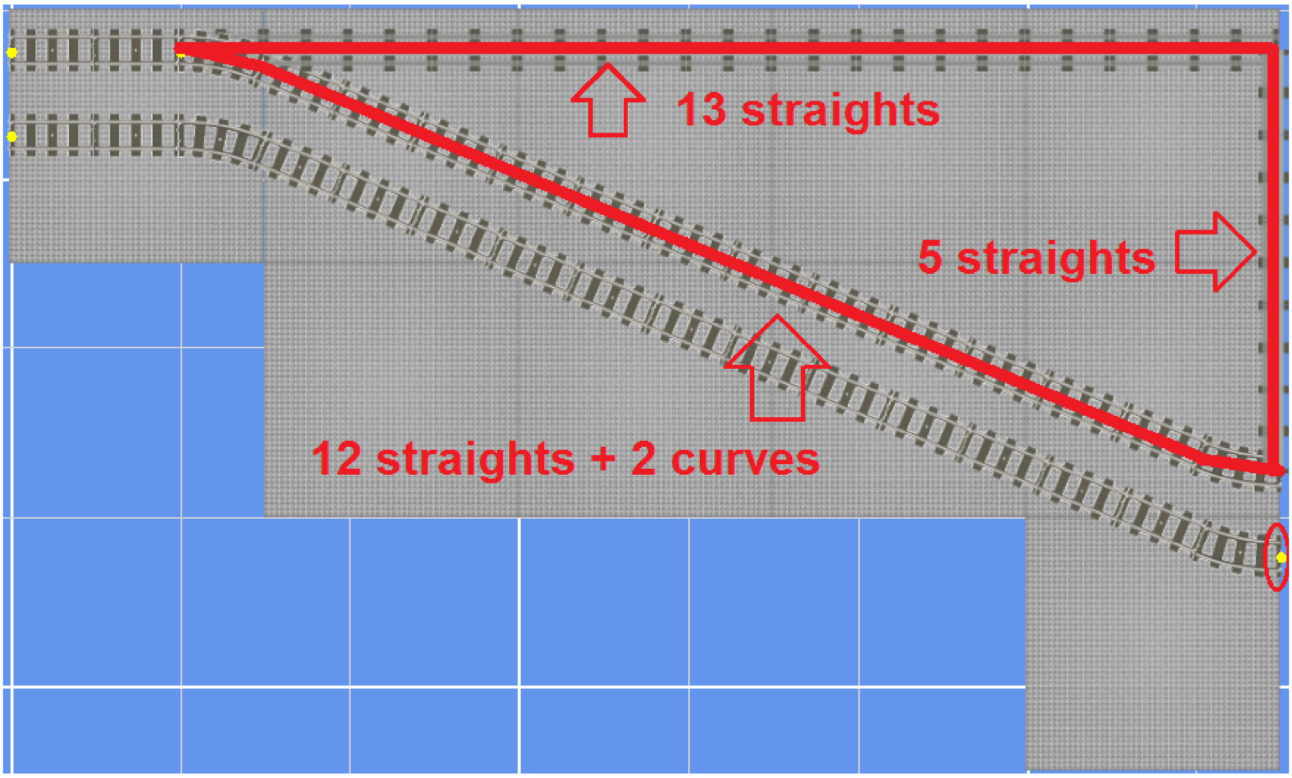

Fig. 6: *22.5 degrees diagonal with almost standard track ending. Since track connections are not that rigid, we can fix the track ends at standard position.*

We can also turn to a perpendiclar direction to the original (*Fig. 7*)

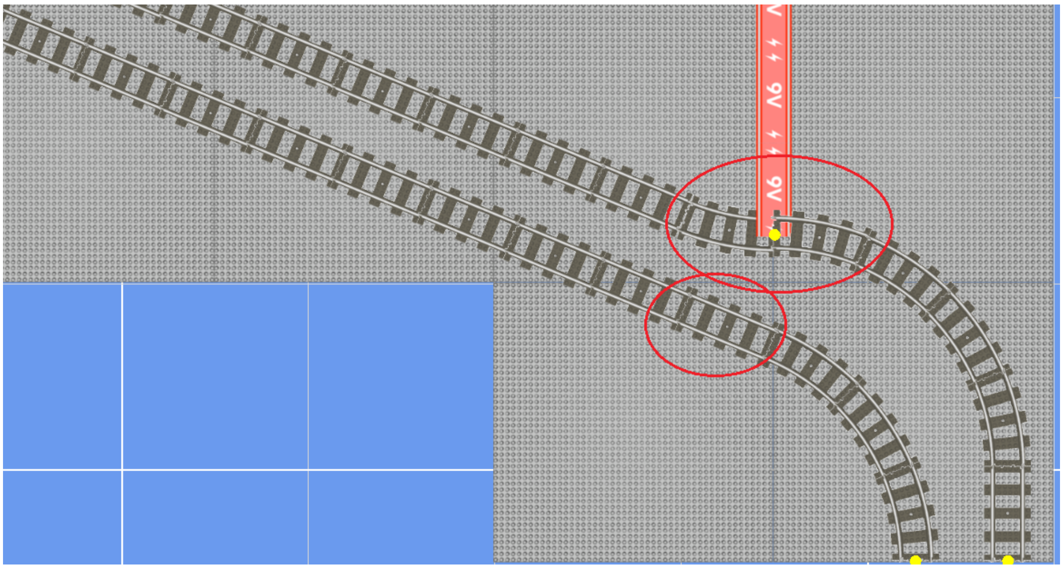

Fig. 7: *22.5 degrees diagonal ended with a direction perpendicular to the starting direction. To prove the offset of 16 studs between parallel tracks we should replace one straight track segments in 22.5 degrees with two curves in opposite direction.*

45 degrees diagonal

Unfortunately we can't count on Pythagorean triples when building 45 degrees diagonals, since there are no square numbers doubled being a square number as well. A straight track segment placed at 45 degrees „runs" cos(45) = sin(45) = 0,7071 straight track segment distance. We need a whole number multiplied with 0,7071 giving a whole number also. 10 is a nice choice, but 17 is even better. Take a look at *Fig. 8*.

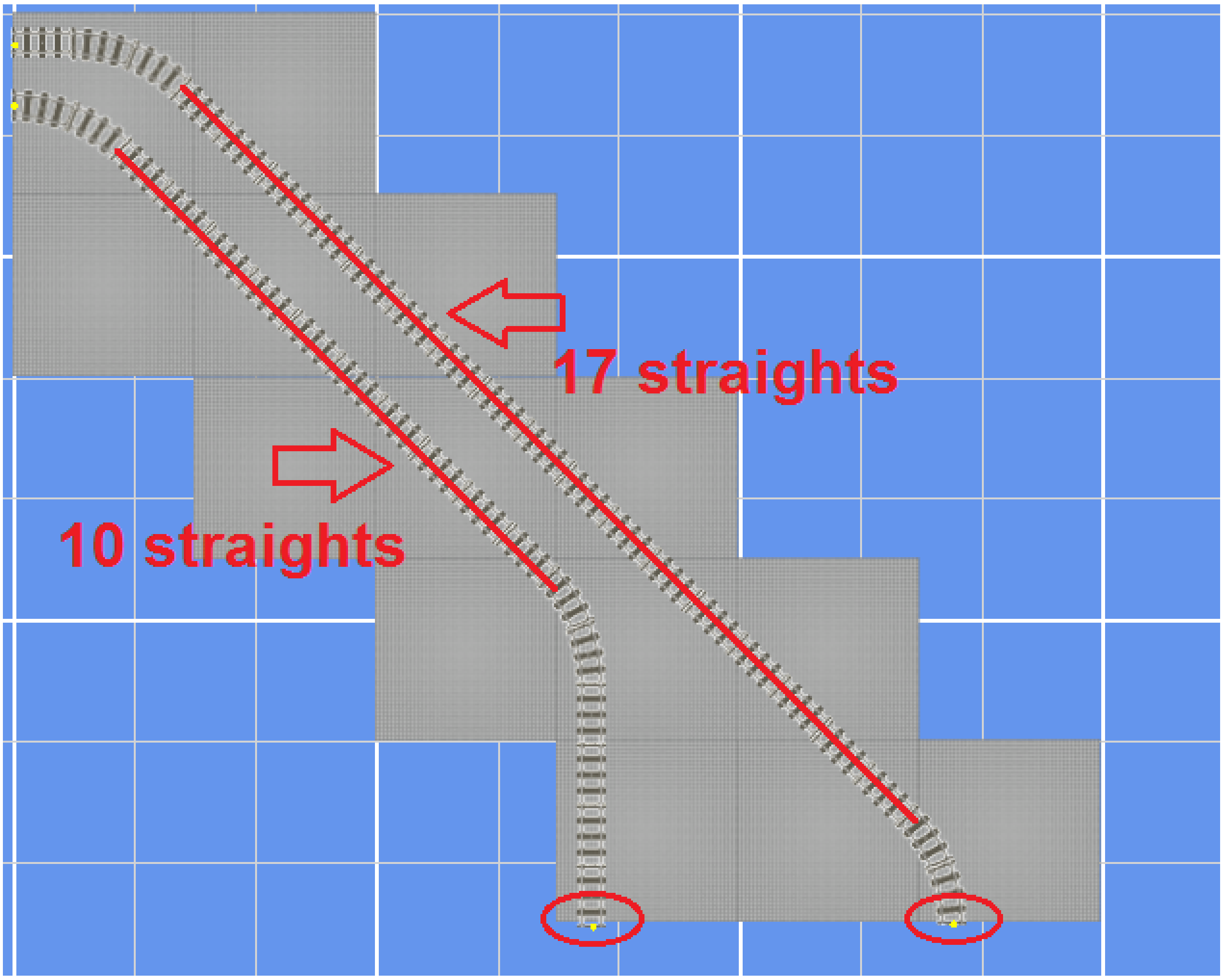

Fig. 8: *45 degrees diagonal with almost standard endings. The version with 10 diagonal straight segments result in less fitting, and the sleepers of the track start 5 studs from baseplate edge, but thanks to loose connections between tracks we can fix it at standard position. The version containing 17 straights fits much better.*

Using some of the techniques mentioned above we can build a more complicated layout (*Fig. 9*) than shown on *Fig. 2*.

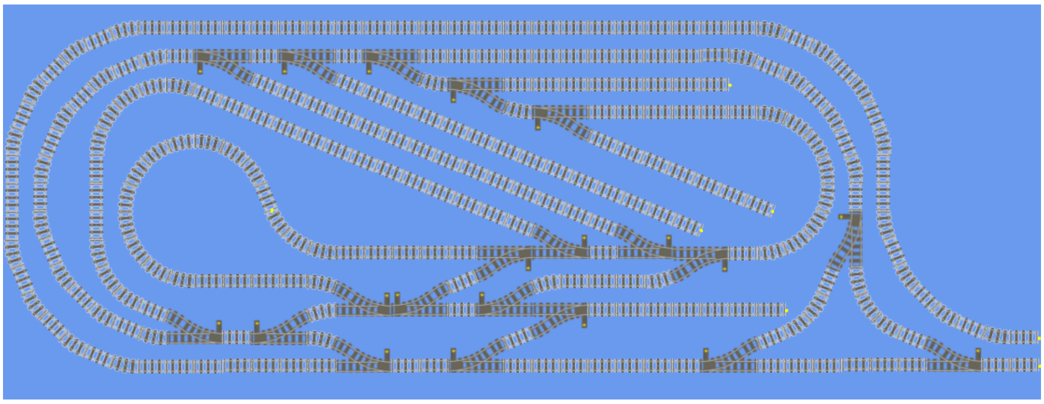

Fig. 9: *Some techniques on a more complicated layout. Trains can go around only on „long" radius curves, they can change direction on loops and delta track, and we can store trains on diagonal tracks. Make sure you make insulations between tracks in loops and delta tracks to avoid short circuits.*

4. Station geometries

The five different track segments allow as some station geometries, but keeping only the basic rules will result in simple and sometimes not autenthic station geometries. Station builders can experience lots of trouble when creating stations with two or more through lines, especially by building connection between these lines. If we build a railway terminus, we don't have to take care how our tracks end – since train tracks go nowhere but end at our station, they don't have to be in line or have standard distance between themselves (*Fig. 10*).

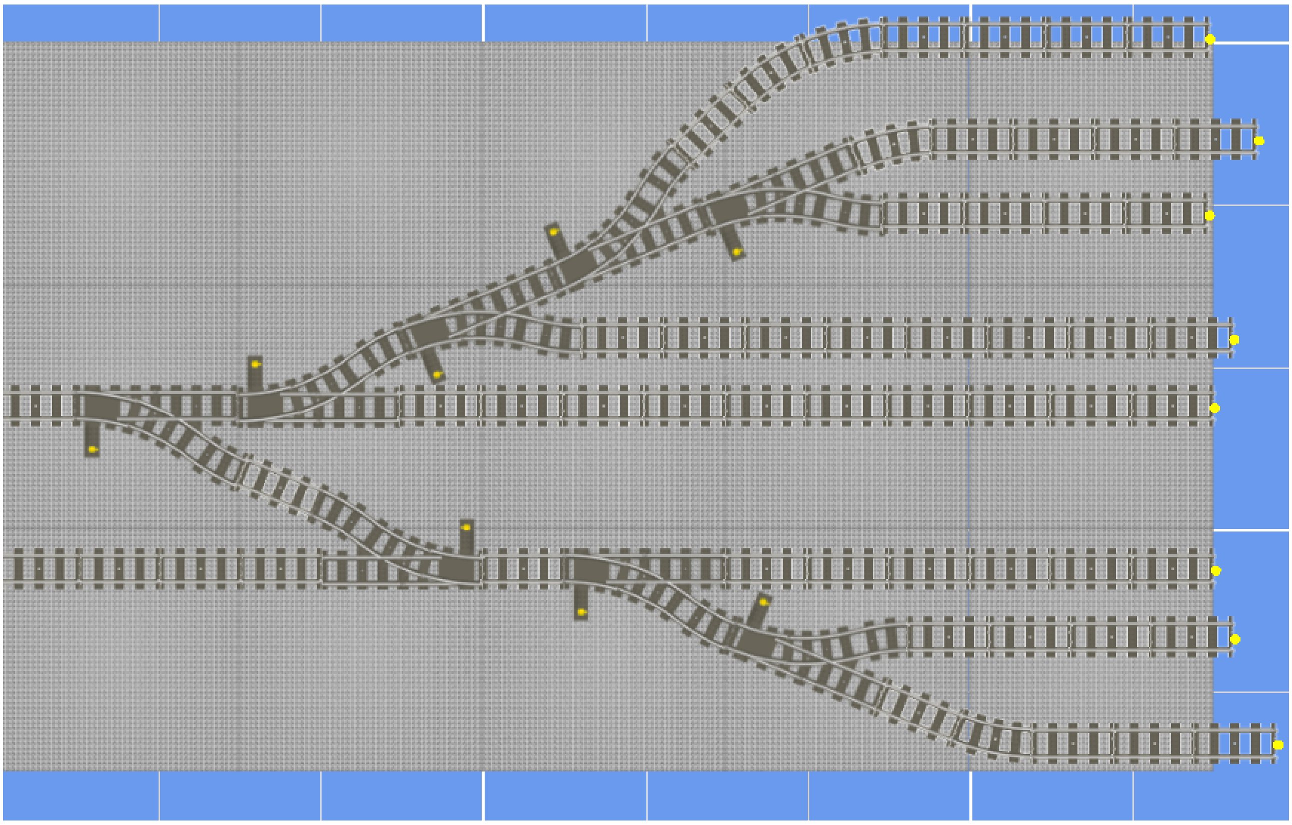

Fig. 10: *Railway terminus with two tracks leading to the station.*

If our station has through lines, we have to care about proper lining up to have a standard connection to other LUG-members' sections. Keep in mind: offset between parallel track should be divideable by 16 studs and track ends should line up with baseplates' edges. But what we do between the ends of our section – well, it is not necessary to always fit to geometry rules.

Simple station

For first take a look at *Fig. 11*. It shows a very simple train station using only basic rules. There are 8 studs between the parallel tracks – if you run 8W trains, it means 6 studs wide paltforms, which is sometimes simply not enough when we try to replicate a real station with bricks. This simple station fits perfectly for a rural area's station or to store freight trains, but not a good decision when we model mainline stations.

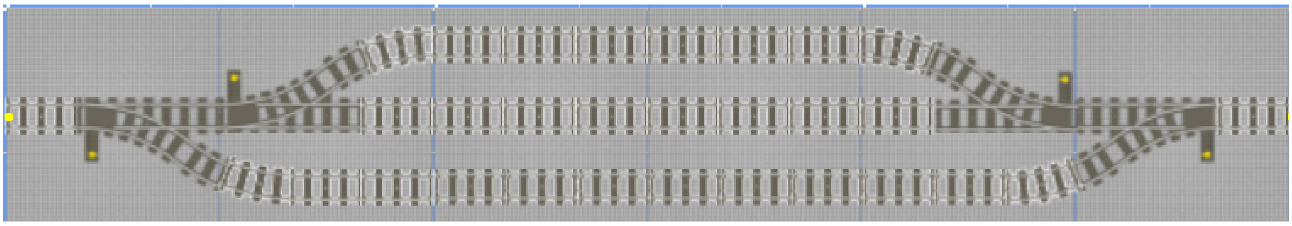

Fig. 11: *Simple station.*

Simple station with wider platforms

Try to create wider space for platforms, but still using the five electrified track pieces and simple geometry rules (*Fig. 12*). We succesfully increased the distance between sleepers to 24 studs (22 wide platform for 8W trains), but those four dead ends and the consumption of 8 expensive points for a three-track station is not a pretty solution.

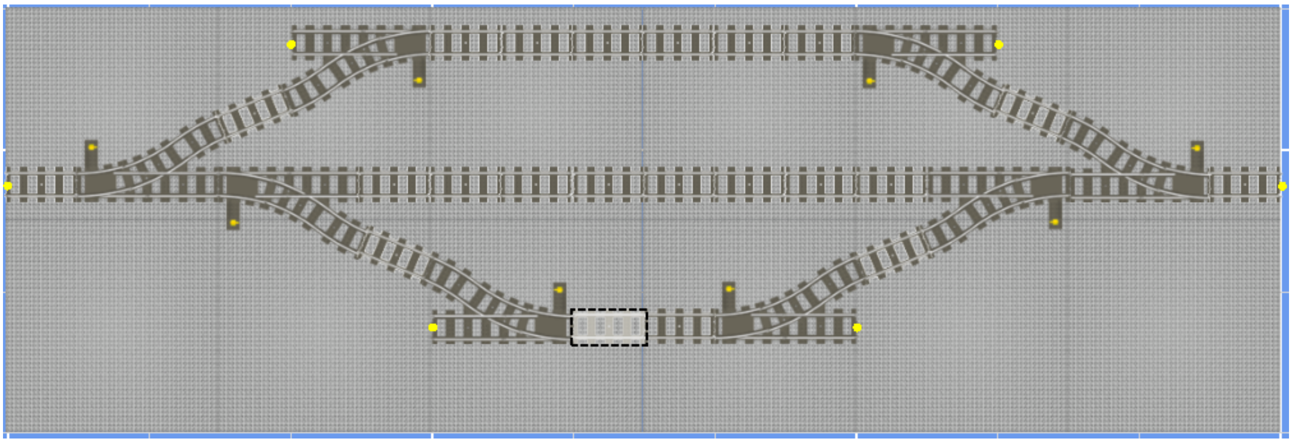

Fig. 12: *Simple station with wide platforms.*

Unfortunately with these two arrangements we reached the limits of basic geometry (and using electrified tracks only), so add one more track piece to our inventory: the 4 studs long, 8 studs wide non-electrified flexible track from power function trains era. This flexible track segment has a pivot point in the middle which allows us to set the radius of our curves, but this track segment's power is not this option, but it's length, which is quarter part of a standard straight track. This track segment is perfect to fit gaps!

9V stations with PF-flexible track segment

And where do we have any gaps? Above we said, there should be a curved track segment placed after the point to make tracks parallel, let's try placing a straight after the curve at 22.5 degrees, and place a curve only after the straight. A straight closing 22.5 degrees with the straight direction of the point results in „shortening” in the direction parallel with the straight part of the point – this shortening is one stud after each straight placed at 22.5 degrees. Placing tracks like this will result in non-standard distance between parallel tracks and parallel tracks will not end in line anymore. But what can we do with this?

Take a look at *Fig. 13*!

We present two different geoemtries on that figure. At the upper part we added one straight track after each point, at bottom part we added two straights. After we place curves next to straight at 22.5 degrees the studs of curves won't perfectly fit on the studs of baseplate – but with little stressing of the loose connections we can make them to fit. Above there are 13 studs between sleepers, allowing 11 studs wide platform for 8W trains, below there are 19 studs between sleepers to build 17 studs wide platforms for 8W trains. Above there is a gap with 2 studs length (2×1 studs from shortening), below it is 4 studs (2×2 studs). It is hard to fill the 2 studs long gap (but not impossible with a headlight brick and 1×1 plates and tiles), but easy to fill the 4 studs long one with one flexible track segment.

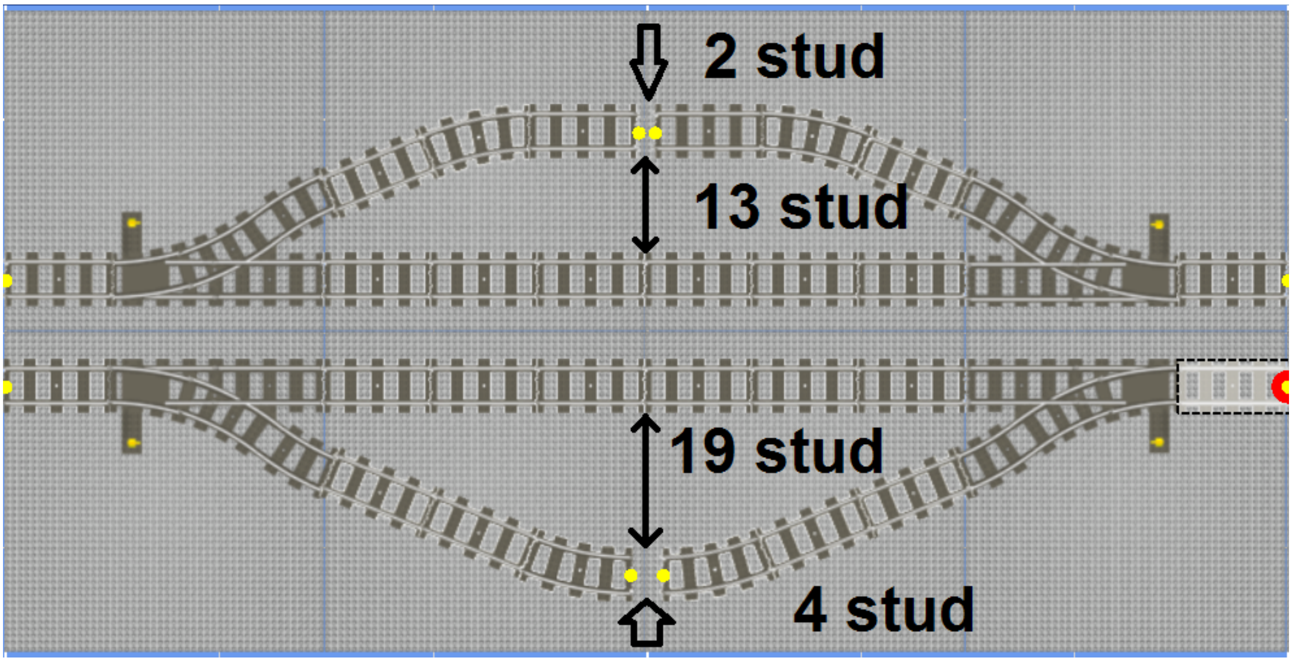

Fig. 13: *Placing straights after points and dimensions of such geometries.*

The two straights after the point can be replaced with the curve-straight-curve technique (*Fig. 14*). There are lot of stations, where parallel tracks are quite close to each other and the distance between them is only increased where the platforms are placed. We can build these arrangements quite easy based on the usage of flexible track.

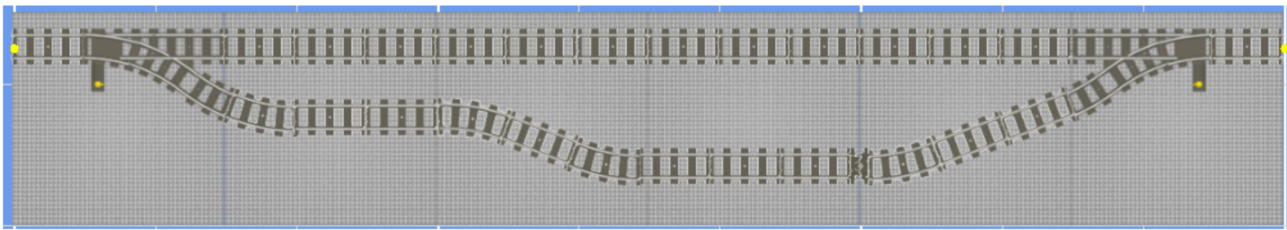
Fig. 14: *Decreasing distance between parallel tracks where there are no platforms placed.*

But how can we run our 9V based engines on flexible track?

Short answer: we can't. Long answer: The axle distance of a 9V train motor is 6 studs so there will be at least one pair of wheels picking up current from the track. If the track with flexible segment is powered from both directions (part of a loop or there are two power supplies placed on the same speed regulator), it shouldn't be a problem to run trains on these station geometries.

Station geoemtries with two through lines

On many LEGO-layouts, there are two parallel track running, and two trains can run in different directions on them. If we want to put our train to the other track, we need connections between these tracks. Connections are mostly built on those stations, which have two through lines. Unfortunately this is the hardest task to perform with LEGO-tracks, since there is no point making easy connection between to parallel tracks. We need compromises or other geometry tricks, or (for non-purists!) cutting 9V points for ideal connections. What can we do (*Fig. 15*)?

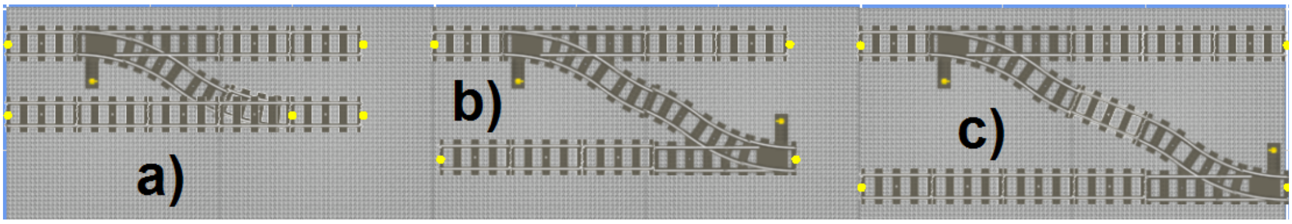

Fig. 15: *Image a) shows what we really want. Unfortunately without cutting points there is no such connection (except the crossover part from PF-train era, but it is not electrified and has limited possibilities). Image b) is totally a wrong decision, connecting those points directly will result in no line-up and non-standard distance of parallel tracks. Image c) shows a solution using only simple geometry rules, but through lines are often closer to each other. It could be a nice solution, when our main platform is between these through lines.*

The best solution is image c) from *Fig. 15*, but train tracks run often with 16 studs offset, not with 32 studs. We should find some tricks to make them run closer to each other on open lines (*Fig. 16*).

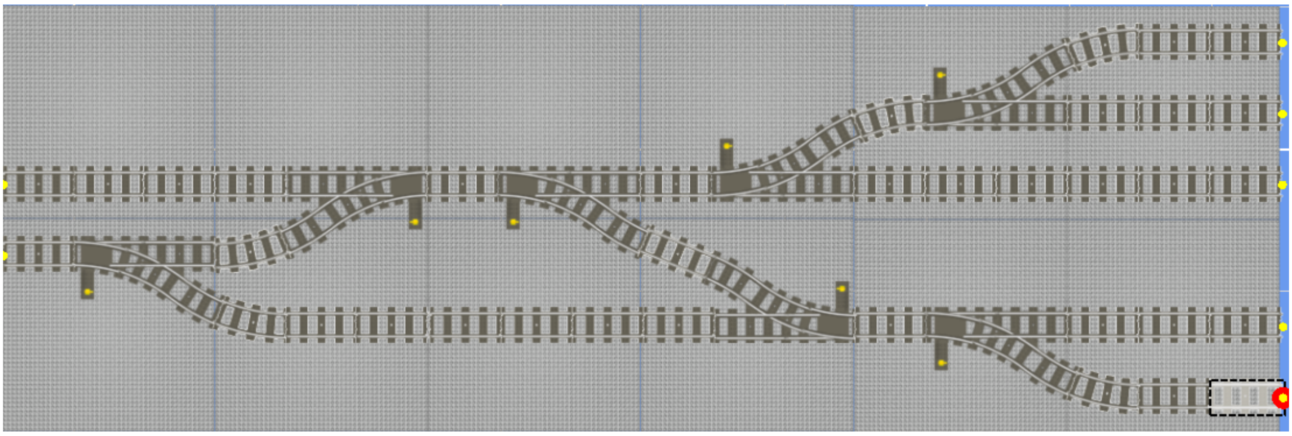

Fig. 16: *Station with 5 tracks and 2 through lines. The open line part has 16 studs offset between parallel tracks. Our trains can reach every tracks from every open line tracks, but the points consume lots of space and one of the through lines has curves built in.*

The geometry shown in *Fig. 16* is maybe the best solution we can make with stations having two through lines and keeping simple geometry rules.

Cutting points

Builders cut quite often two pieces of points with same direction to get a simple connection between parallel tracks (*Fig. 17*). Cutting off a little from both points' curved part will result in smooth and nice connection.

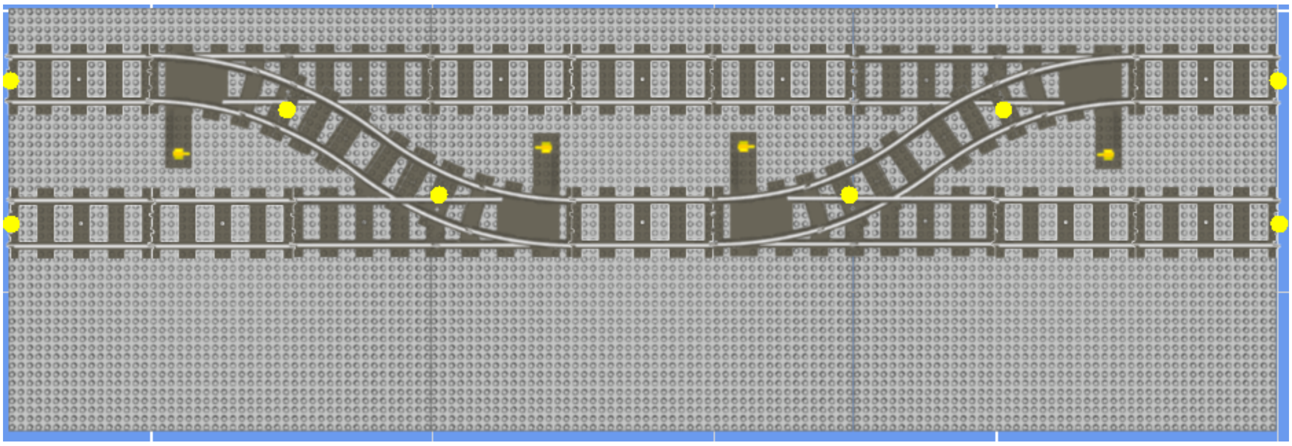

Fig. 17: *Cut points. Points consume less space with this arrangement and more autenthic geoemtries are available with this solution.*

Station geometry examples

Let's draw some stations with the techniques we've learnt above (*Fig. 18*)!

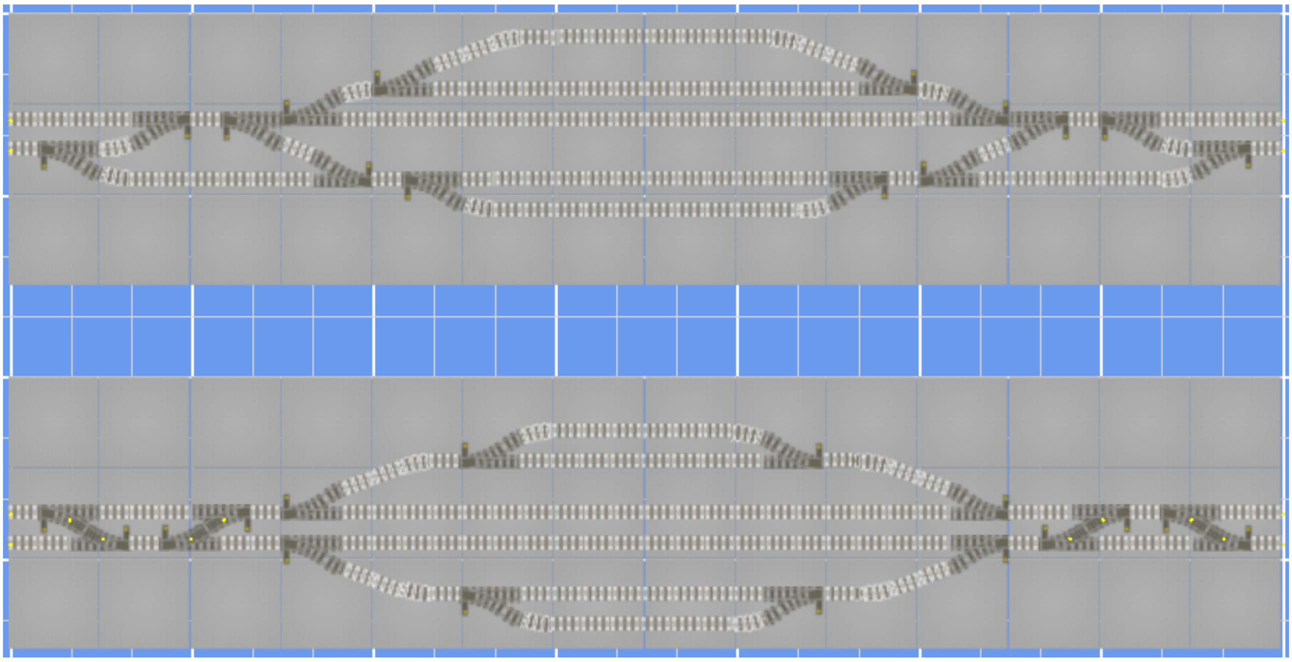

Fig. 18: *Station geometries with unmodified tracks (above) and cut points (below). Please note that these arrangements' length is 4608 mm, and there is only a small place between tracks to build platforms for longer trains. To get started I recommend station with a geoemtry shown on* Fig. 11*, if you are not satisfied with it and need more, you can move on to bigger yards.*

5. Long radius curves built from straight track pieces

Those who build trains from LEGO-bricks often face problems originated from the short radius (40 studs) of curved track segments. If we build a train proportional to LEGO tracks' gauge the radius in scale will be around 13 metres! On real railways the radius of curves are at least 50 metres, but only at the area of train sheds, lines have curves with radius of 100-150 metres at least (except trams and narrow gauge lines). And even if we succeed and our train can handle the radius, long passanger cars and locomotives don't look good at standard curved tracks. Our locos can suffer with three or more of long cars on curves, and derail easily if we don't care of speed.

This section is mostly based on Holger Matthes' technique described in Railbricks #1 (2007, pp. 32-33). He produced long radius curves using only straight track segments. The trick is putting the straight tracks together with a half stud offset on one side. This one will be the outer side of the „curve". Tracks can be connected with 1×4 hinge plate under inner side and using an 1×3 plate with an 1×1 plate and an 1×2 jumper plate on it. But take a look at Holger's video:

https://www.youtube.com/watch?v=X-9DbhEs37k

Long radius loops built from straight track segments

Holger Matthes and many exhibitors in Western Europe and on other continents built full and half loops with this technique. These loops allow long and heavy trains going fast and look awesome on these curves instead of struggling on sharp turns. But the radius of such a curve (*Fig. 19*) is 1.9 metres, and sometimes we don't have this space. Also this technique can be used in station geometries as well, not only in half or full loops.

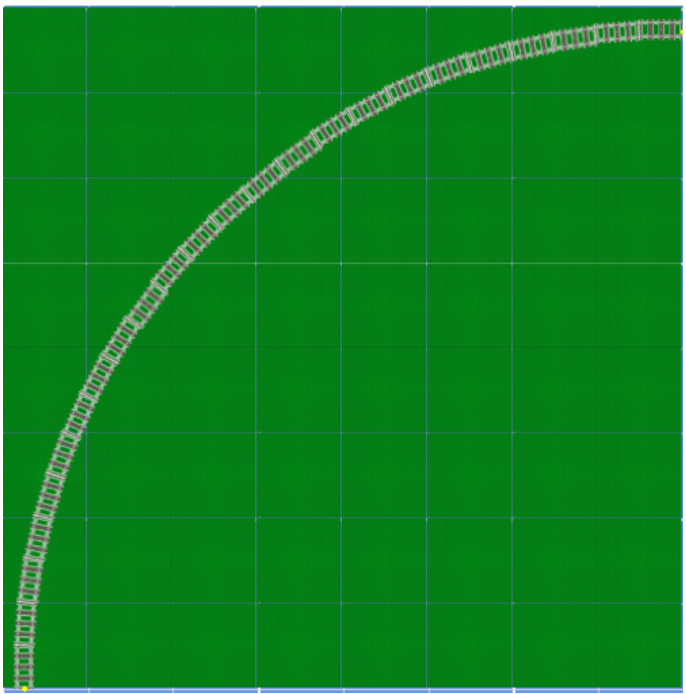

Fig. 19: *Long radius curve in BlueBrick layout software. Since the software doesn't know how to connect tracks with this technique we produced this image putting tracks differing in 4 degrees angle next to each other. There are 24 straights and 23 connections, 22 connections have 4 degrees difference, last one has 2 degrees. The angle difference between each track built with Holger's technique is around 3.91 degrees in reality.*

Jumping between baseplate-rows

It consumes less space than full loops, but pretty solution to jump a normal baseplate or a half perpendicular to the direction of tracks (*Fig. 20*). It is often problematic that our tracks run on the first baseplate in front of the visitors, but at some stations we need our tracks to run on the second baseplate from visitors. We can jump only two normal baseplates backwards using simple geometry only (3 curves, one straight, 3 curves in opposite direction). Our long trains also won't like sharp turns, and we can build nicer geoemtries using long radius curves.

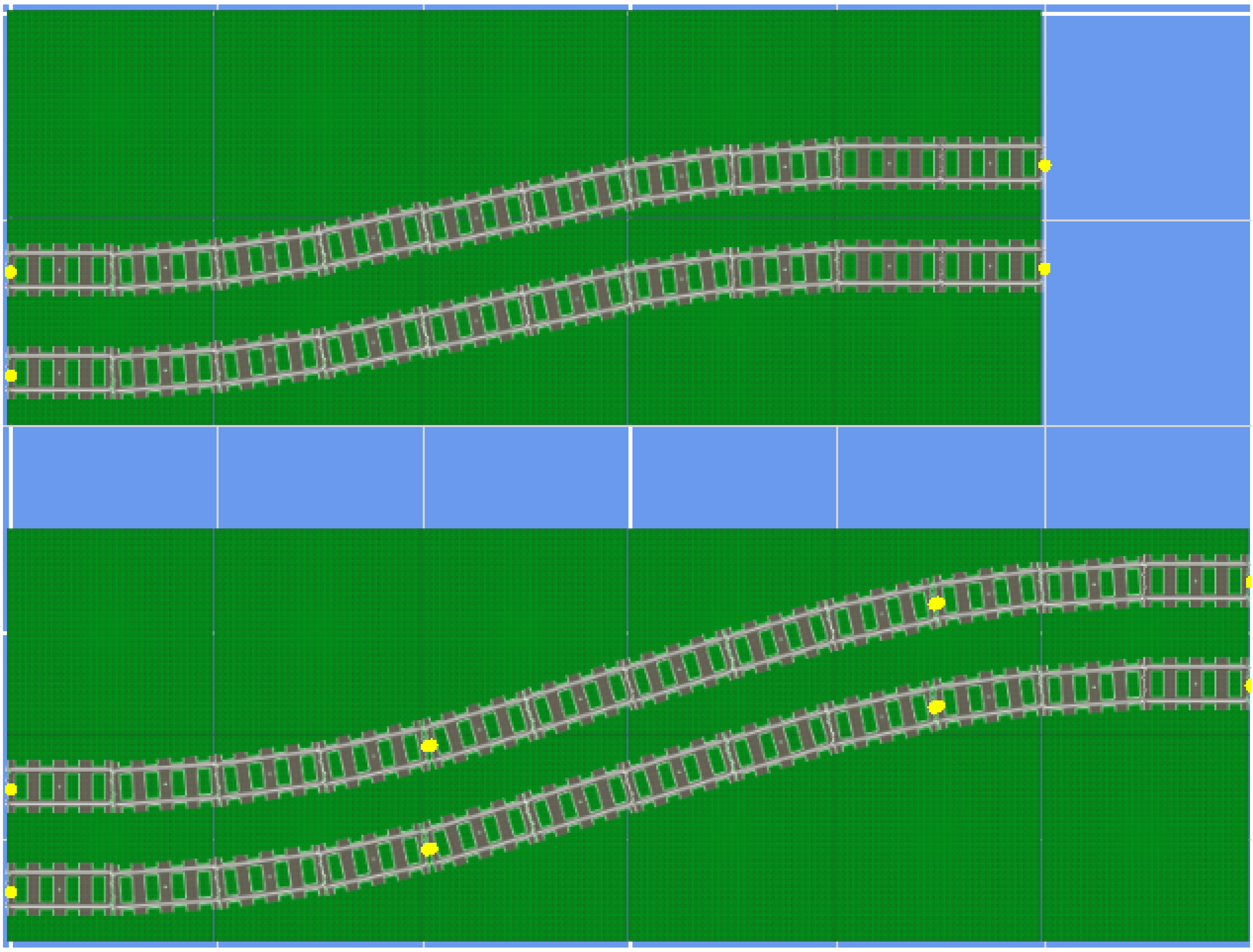

Fig. 20: *Jumping half baseplate (above) and one normal baseplate (below). It is easy to make half baseplate jump in BlueBrick, but we need some stressing of connections when we try to jump one normal baseplate (but it is tested and fits, too).*

Long radius curves built from straight track segments in station geometries

Let's try these baseplate-jumps by station geometries. We faced a problem with connections between two parallel through line tracks, now it is quite easy to solve (*Fig. 21*).

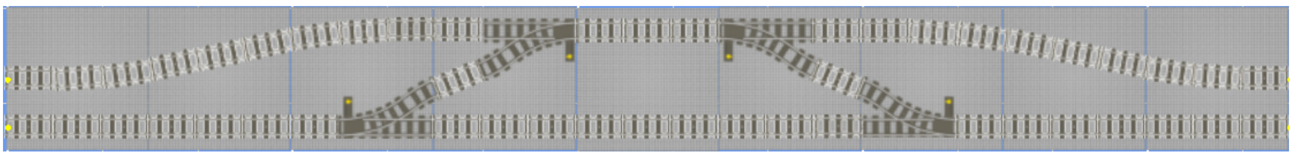

Fig. 21: *Jumping half baseplate to build unmodified points into our geometry. We can also build a platform between our tracks and we can start additional tracks with more points using the techniques we presented previously.*

There are many exhibitions where full loops of these curves are presented, so we present two examples when this technique was used in station geoemtries. Teunis Davey fitted one more track between his through lines increasing the distance between these tracks using long radius curves (*Fig. 22*). I also used this technique at my train station in 2012, I needed increased width between my tracks for a platform (*Fig. 23*).

Fig. 22: *Teunis Davey's station geometry.*

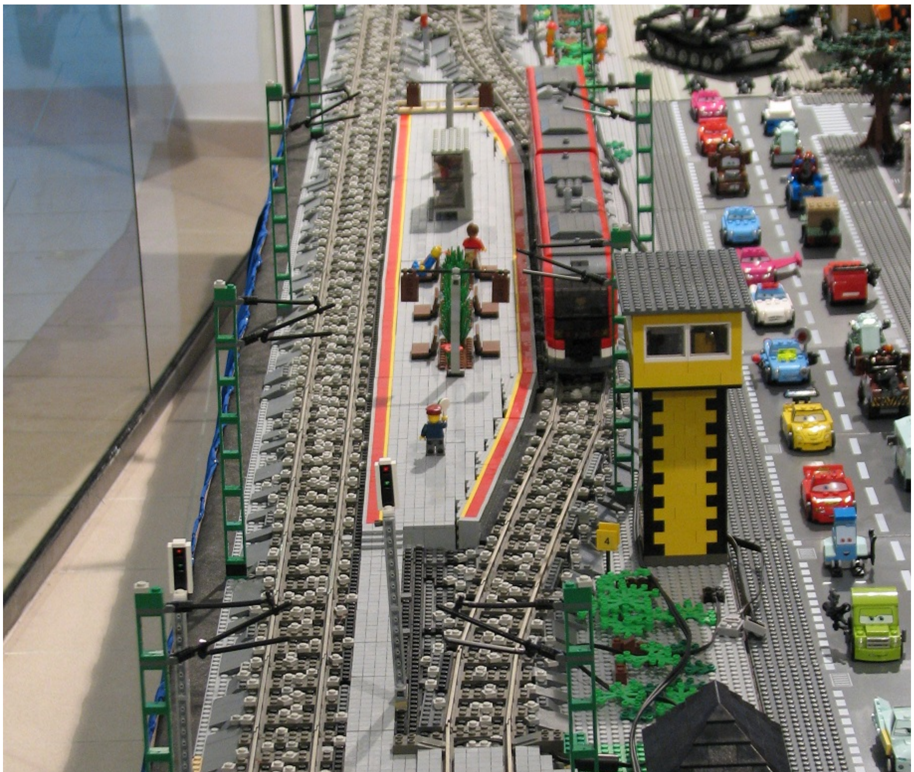

Fig. 23: *Using long radius curves I built a platform with one side curved.*

Even longer radius curves built from straight track segments

If we think that 1.9 metres of radius is not enough we can also go for better. I improved Holger's technique using not half stud, but only half plate separation between tracks at outer side of the curve. It can be done easily by a single bracket (1×2 * 2×2), refer to *Fig. 24.* The inner side can be connected with the 1×4 hinge plate similar to Holger's design. With this technique you can build curves with radius of 4.56 metres, but for a full loop you need an area of 9.25 metres × 9.25 metres. You need 56 straight tracks for a 90 degrees turn and 224 for a full loop.

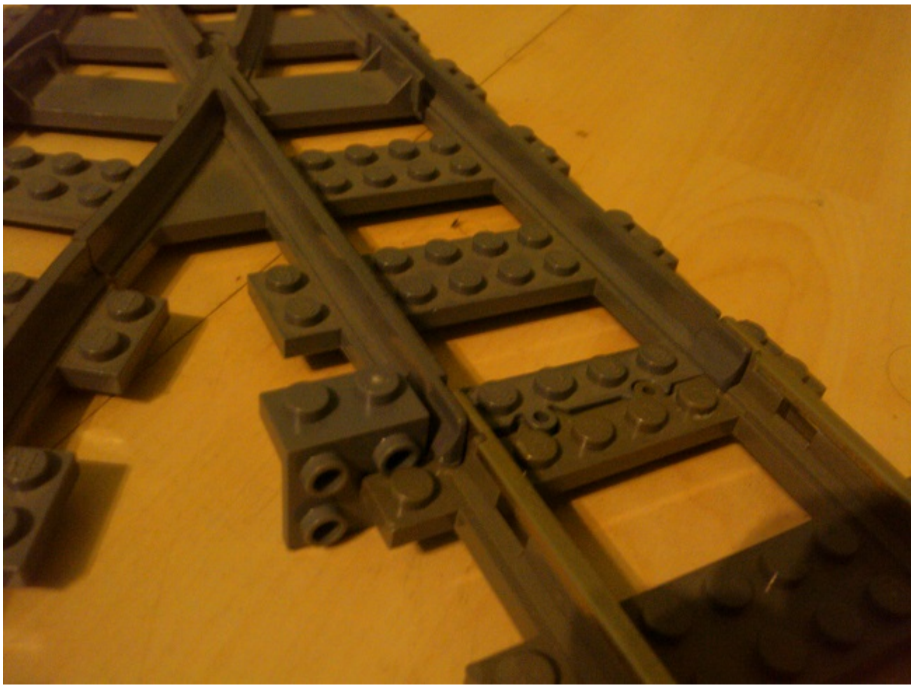

Fig. 24: *Even longer radius curves can be built using a bracket on the outer side and 1×4 hinge plate under inner side of the curve. The radius of such a curve is 4.56 m.*

6. Acknowledgements

Thanks for Holger Matthes to design something used now worldwide.

Thanks for Bill Ward to collect simple geoemtry rules long years ago on his site Brickpile.

Thanks for Teunis Davey for his photo of his station track geoemtry.

All figures except photos have been made using BlueBrick Layout Software 1.8.1.

You can download the .bbm file containing station geometries and geoemtries using long radius curves for free from here:
http://www.brickshelf.com/gallery/AshiValkoinen/BuildingTricks/geometries.bbm