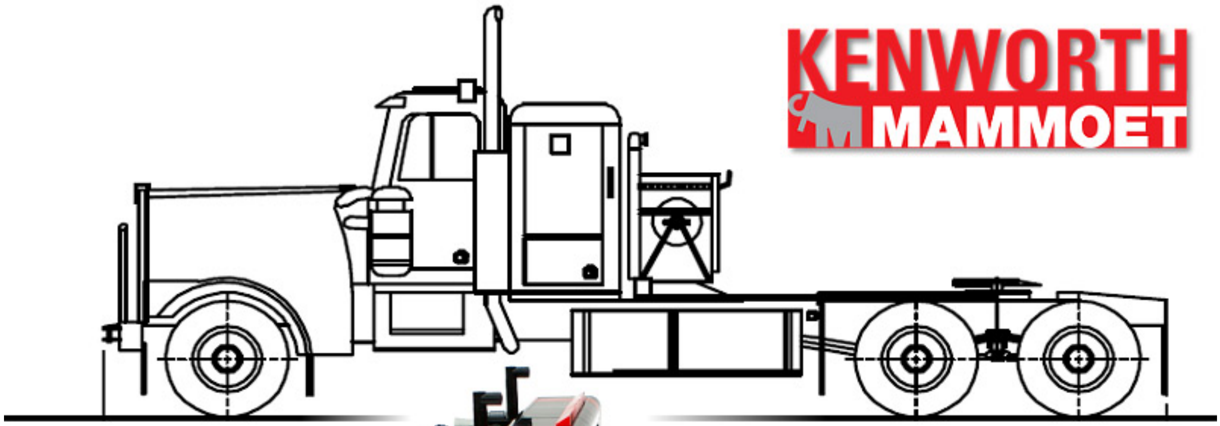


Scaling Tutorial for Vehicles (I)

This tutorial covers the rules for choosing a scale and calculate the dimensions for LEGO® models on wheeled or tracked vehicles, plus some general tips on models.

Text and pictures by Paul Ian Kmiec

This tutorial covers the rules of choosing a a scale and calculating dimensions for a LEGO® model of a wheeled or tracked vehicle, as well as some general tips on modeling.

My first tutorial (on Technic gears) has turned out to be very popular and useful. Many comments from builders who found it helpful have convinced me to continue with tutorials – this time I'm going to explain how to make a proper model of a wheeled or tracked vehicle.

Please note that I don't consider myself a very good model-builder. I often have to look for a compromise between the look and the functionality of a model, and my attention to details is usually insufficient. There are builders willing to spend months on getting all dimensions & proportions right, while I am ready to slightly compromise the accuracy of a model for the sake of its functionality or integrity. A good example is my Abrams M1A2 model whose road wheels were too small (3 studs in diameter instead of 4), because there were no larger LEGO wheels available and scaling the model accordingly to the 3-studs ones would result in a much smaller model with severely limited functionality. However, none of my models can be even remotely compared to the work of e.g. ZED or Arvo brothers.

Anyway, this tutorial explains all the rules needed to build a proper model, and how much attention is paid to the details is up to a particular builder. The rules of scaling remain the same for the best and the average model-builders. Please note that this tutorial assumes that you are going to build a motorized model with Power Functions elements, but if you just skip that part, it is just as useful for static models.

1. Choosing a vehicle to be modelled

Contrary to a popular impression, LEGO® model-builders usually seek to build their models as small as possible. This is because large size of a model results in many problems that are absent or insignificant with small models – such as the weight, mobility and the structural integrity (LEGO bricks become quite elastic under several kilograms of load), as well as e.g. distortion of the tires. This is a good direction, especially for inexperienced builders, and therefore this tutorial aims at building on as-big-as-needed scale, not on an as-big-as-possible one.

When choosing a vehicle to be modeled, you should focus on two crucial factors: its width and the size of the largest element you want to integrate into it.

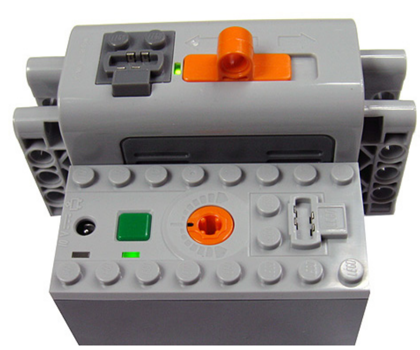
There is almost always a technical limit to the model's minimal width, and this limit is usually set by the axles. In case of the steered axle you should expect its structure to be at least 6 studs wide (a narrower steered axle is possible but very hard to build), and then add the width of the wheels. So if you're going to use a 2-studs wide wheels, then your minimal width is 10 studs, if you're going to use 3-studs wide wheels then it's 12 studs, and so on. A driven, not-steered axle is sometimes even more demanding: it usually requires at least 2 studs for the structure (e.g. for two 1-stud wide stringers of the chassis), 3 or 4 studs for the differential, and then there is the width of the wheels, which in case of e.g. trucks often includes 4 wheels rather than 2. It is possible to skip the use of a differential (small & light models don't really need it except for a better manoeuvrability) but it will still take at least 1 stud to transfer the drive to the axle.

Consider this example: the rear axles of my Kenworth Mammoet model use 4 wheels per axle, just like in the real truck. It results in more than half of the model's width being taken by the wheels:

We will expand the topic of the minimal width in section 2, for now it is important to discard vehicles that are unusually long and narrow, as well as the ones that have extremely tight space between their right & left wheels.

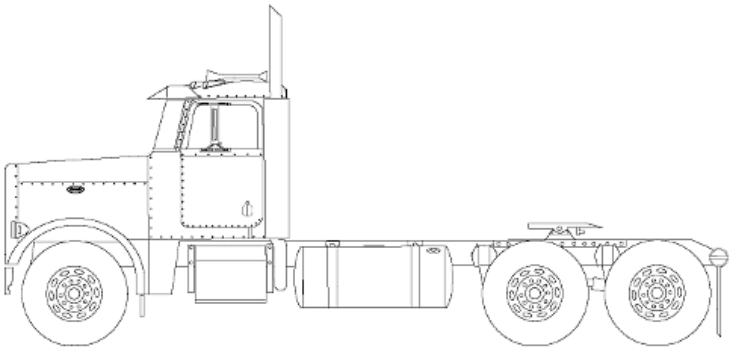
The largest element you want to integrate into a model is usually the most important factor. If we omit the multipart custom mechanisms, whose shape and size can be usually somewhat adjusted, what we are left with are large single-piece elements. In case of the models using Power Functions it's usually at least one battery box and at least one IR receiver, in case of the models using pneumatics it can be an airtank too. The traditional PF battery box is 4 x 11 x 7 studs large and requires some extra space on the top for the plugs and for the access to the on/off switch – it means that our model has to be larger than these minimal dimensions. For instance if you want your model to have sides built with bricks, with the battery box fully enclosed within because e.g. its color doesn't match, then one of your model's dimensions can't be smaller than 13 studs. The newer PF rechargeable battery, on the other hand, is 4×5×8 studs large with the same extra space needed on the top. Since the battery has smooth sides and is easily integrated into bricks-based constructions, it is possible to integrate it into an e.g. just 4 studs wide model.

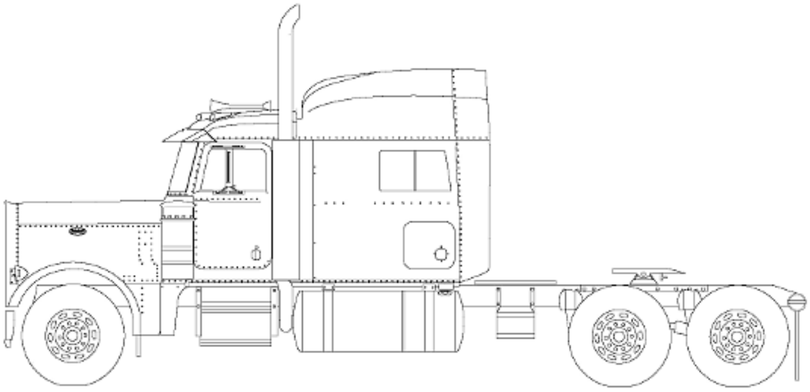
The PF battery box vs the PF rechargeable battery – the newer, the smaller:



The important thing is to estimate if it's possible to integrate the large elements into a model and where. If your model is going to be narrow, or run and turn at high speed, you should also seek to integrate all the heavy elements into its lower part, because e.g. a battery box integrated into the roof would be fatal for its stability. The trick is basically to look for parts of the vehicle that offer plenty of internal space, because we usually want to keep all the mechanical/electrical elements inside. For instance if you're going to build a model of a truck, and you want it to have a cabin with an interior plus a model of the engine under the bonnet, then you can only integrate large elements into lower parts of its chassis. This is very likely to be insufficient, and therefore you should look for trucks with some extra modules behind the cabin, which are very convenient for housing e.g. battery boxes and IR receivers.

Here are two versions of the same Peterbilt truck: the upper one offers very limited internal space and can be motorized only in a large scale, with the battery/battery box housed inside the cabin. The lower one comes with a large sleeper module and a longer chassis – even with a small model it's possible to house all the large elements inside this module and preserve space for the cabin interior.

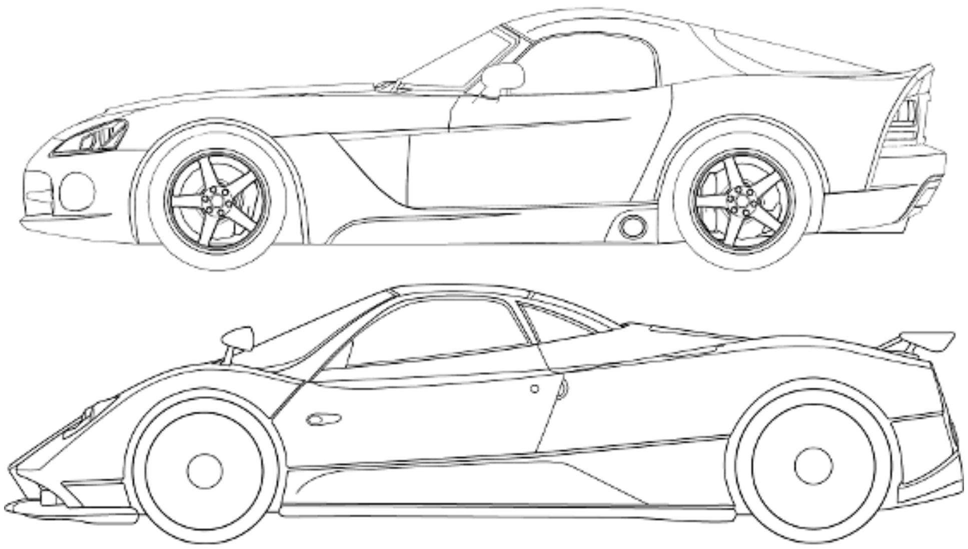




Side view of one of the trucks built for Hard Truck Contest reveals the traditional battery box housed inside the sleeper module (visible through the side window). Note the small size of this fully mobile model in comparison to the size of the battery box.

Situation with other types of vehicles is similar, but less obvious. When building a typical car with some space preserved for the interior, we are usually forced to place some elements in front of it and behind it. For instance we can place the steering motor in the front part of the chassis (usually the most convenient location), with drive motor and battery box located behind passengers' seats. It’s not a bad idea to pay attention to the location of the original engine while choosing a car. It’s actually quite important for e.g. sport cars with large engines, because the ones with engine in front will always provide plenty of space in front part of the chassis while the ones with the engine in the center/back will have more internal space behind the cabin.

Dodge Viper (engine in front) and Pagani Zonda (central engine), two supercars of similar size. Note the difference in their general proportions.



There is a number of tricks that allow to integrate multiple PF elements into a limited space – this subject will be focused on in section 5. The particular case of tracked vehicles will be focused on in section 4.

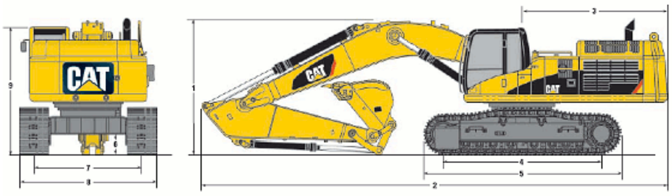
2. Choosing the scale for a model

There are two possible cases here: usually our choice of scale is limited by the size of LEGO® wheels we have at our disposal, but sometimes a fixed scale is required, e.g. when we’re building a vehicle for a competition whose rules determine the scale (for instance the Polish Truck Trial rules require all the vehicles to be at 13:1 scale). In the latter case we don’t have to choose a scale – it is already determined. In the first case we have to decide which wheels to use. When it comes to the scale, the only thing that matters is the diameter of the wheels (together with tires, obviously) – it will be explained further in the section 3. Therefore it doesn’t matter whether you’re going to use wheels with sport tires (flat profile) or cross-country tires (round profile), simply pick the ones you like, with the size in mind. You should, however, pay attention to one situation: if you’re going to use tires with a round profile located under mudguards or largely enclosed within vehicle’s body, they are going to appear smaller. This is caused by the optical appearance of the tires and can be prevented by using wheels larger by 10-20% that the size imposed by the scale.

3. Calculating the dimensions

At this point we are going to need a blueprint of the vehicle of our choice. Blueprints of popular and not-so-very-new vehicles can be easily found on specialized websites, the best of them being probably Blueprints.com, and of course the Google Image Search. It’s not a bad idea to look for it at places where many LEGO models are published (e.g. Brickshelf), as numerous model-builders (including me) have a nice habit of publishing their models along with some reference materials. When it comes to the construction equipment, the respective blueprints can be easily found via the websites of all the major manufacturers such as Caterpillar, JCB, Komatsu, Liebherr, Volvo etc. If you browse through their products catalogs every machine has usually a downloadable PDF brochure attached and all the dimensions are included in it. Hint: construction equipment often comes with multiple configurations of e.g. the bucket, and hence the bucket is not shown on the blueprint. If you look through the brochure closely, there are usually dimension tables that list size of every bucket variant available.

A typical blueprint from a manufacturer-provided product brochure. It’s impossible to tell the bucket’s width from the blueprint, but a dimension table included in this brochure lists width of every bucket variant available for this machine.



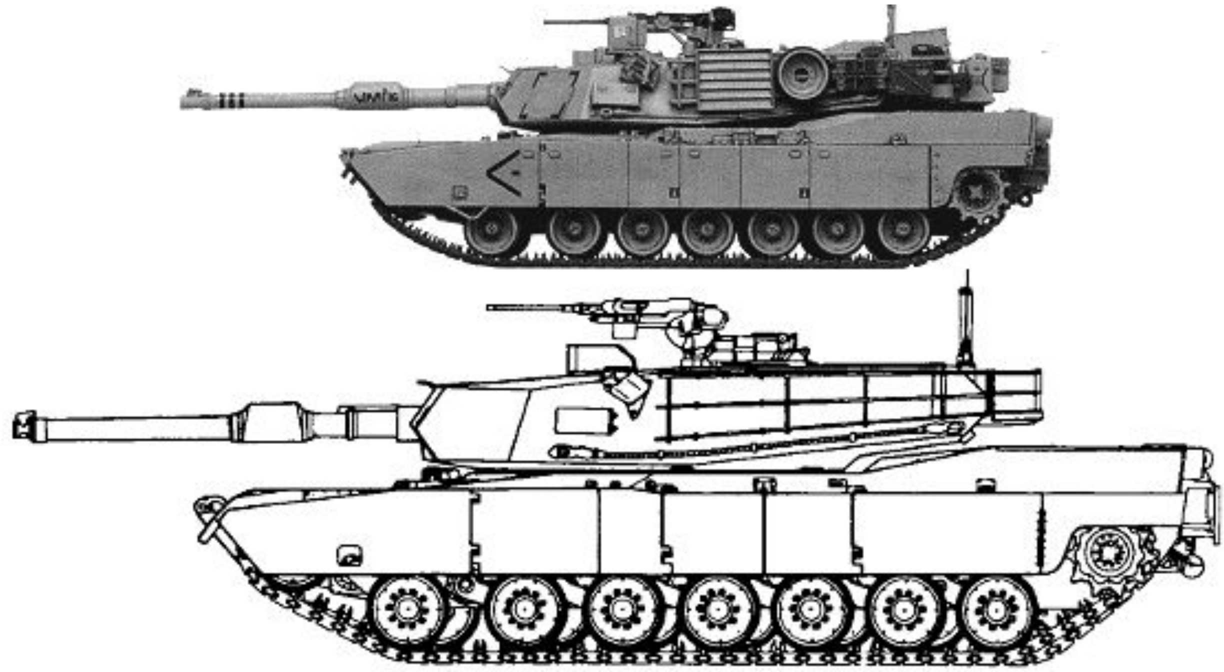
385C L Bucket Specifications and Compatibility

	Capacity*		Width		Tip Radius		Weight w/o tips		Teeth	Reach Boom Stick		GP Boom Stick	
	m³	yd³	mm	in	mm	in	kg	lb	Qty	R5.5HB	R4.4HB	R5.5HB	R4.4HB
HB Buckets													
General Purpose	2.1	2.75	1070	42	2372	93.4	2364	5207	3	●	●	●	●
	2.9	3.88	1374	54	2372	93.4	2761	6081	4	○	◒	●	●
	3.8	5.00	1678	66	2372	93.4	3085	6795	4	◒	◑	◒	●
	4.6	6.00	1982	78	2372	93.4	3500	7709	5	◒	◒	◑	○
Heavy Duty Rock	2.0	2.63	1070	42	2288	90.1	2551	5619	3	●	●	●	●
	2.7	3.63	1374	54	2288	90.1	3075	6773	4	○	◒	●	●
	3.5	4.63	1678	66	2288	90.1	3365	7412	4	◒	◑	◒	●
	4.3	5.63	1982	78	2288	90.1	3887	8562	5	◒	◒	◑	○

The perfect blueprint should:

- be large
- be clean
- include at least three views of the vehicle (side and front/rear view are usually crucial)
- not be distorted (by e.g. central perspective)
- consist of outlines only (blueprints are needed for dimensions only, if you want to check colors, markings etc., then it’s better to rely on photos)

Two blueprints of the same tank: the upper one is bad (and small – this is its full size), the bottom one is excellent. Note how the clutter on the upper blueprint's turret makes it difficult to determine the exact size & shape of the turret.

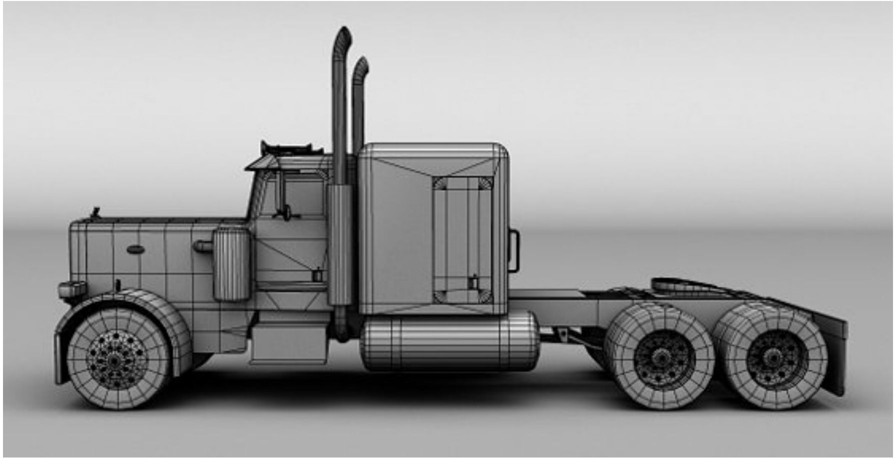


What if our long and laborious search returns no blueprints at all? In this case we can try to rely on photos, but this is a very inconvenient solution and should be avoided if possible. The Google Image Search is helpful here too, but there are many websites with galleries – e.g. a very substantial source of the cars' photos is provided by the NetCarShow.

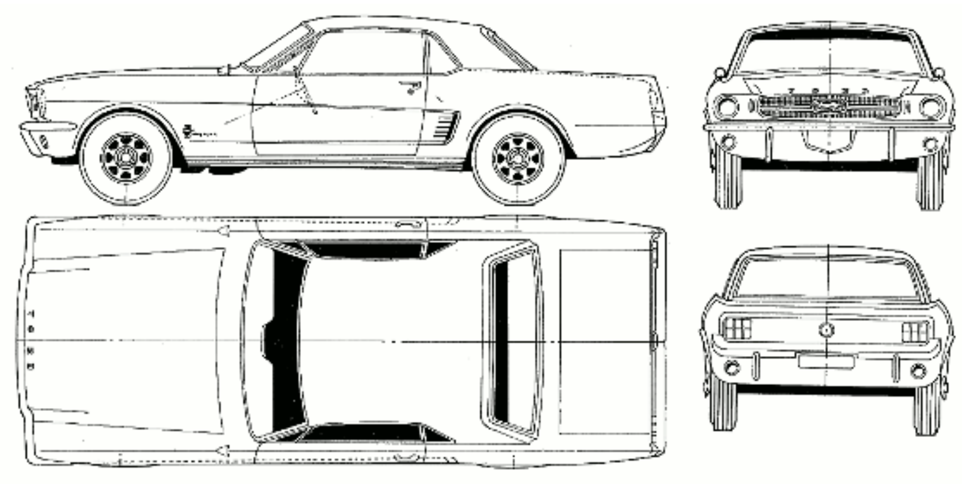
When looking for optimum photos, we should think of them blueprint-wise. That is, we should look for the photos that show the vehicle from definite angles (side, front, top etc.) and are as little distorted as possible (photos taken from partial angles such as front & side are always very distorted). The photos should be obviously large, clean, unobstructed and preferably bright.

On the top: three photos that are useless for calculating dimensions (taken from partial angles, obstructed etc.). On the bottom: three photos that are very useful.

If you have a hard time finding some usable blueprints or photos, try looking for 3D models – popular vehicles often have an abundance of 3D renderings available. Note this rendering of a 3D model of the Peterbilt 359 truck – even though distorted by a substantial central perspective, it is still useful for calculating dimensions.



Important: a proper blueprint should show all the views of the vehicle in exactly the same size (note the blueprint for the Ford Mustang below – the size is clearly maintained). If you are forced to compose your own blueprint using photos, try to make sure that all the views show the vehicle in the same size. If this is not possible, you will have to calculate dimensions for each view separately.



With the blueprint / set of photos at hand, we now need to take some measurements. This can be done in two ways: analogue (print it out, take ruler, calulate) or digital (open the file in some editing program, take measurements, write them down somewhere). Personally, I'm a big fan of the analogue way – not only does it make me computer-independent and lets me put the blueprint on the pinboard above my workshop, but it also lets me conveniently write the dimensions directly on the blueprint, along with some notes if necessary.

Now, as mentioned in the section 2, there are **two possible cases**: the scale is already determined and known, or the scale is correspondent to the size of the LEGO® wheels we're going to use.

In the first case we know the scale and it goes like something:1, for instance 13:1. It means that our model needs to be 13 times smaller than the original vehicle. In order to calculate the model's dimensions we need at least one dimension of the original vehicle. Blueprints usually come with no dimensions (with the usual exception of those of the manufacturer-provided blueprints for the construction equipment), so we need to find some dimension somewhere else. Wikipedia is quite a good place to search in, as it often provides the general dimensions of the specific versions of a given vehicle. The dimensions we're most likely to find are the length and width, and those are very useful, while dimensions such as wheel span or wheelbase are not. I recommend looking for the general length, because it's the largest dimension and it provides the best accuracy for our calculation.

Let's assume we have our blueprint printed out already, and we know the length of the original vehicle. We're going to use a ruler and a calculator, and to do some maths (I know, I hate it too). Let's say that our original vehicle is 6 meters long and we want to model it in the 13:1 scale. We proceed as follows (black marks the general steps, gray marks the result for our exemplary blueprint):

1- Convert the original vehicle's dimension to the smallest convenient unit, usually milimeters: 6000 mm
2- Measure the corresponding dimension on the blueprint: let's assume our printed vehicle is 200 mm long

3- Divide the original dimension by the bluerint's dimension – the resulting number will be referred to as printout ratio: 6000/200 = 30, so our printout ratio is 30

Now we can calculate any dimension of the model, let's assume we want to calculate its width:

1- Measure the width on the blueprint: let's assume it's 80 mm
2- Multiply the blueprint's dimension by the printout ratio: 80 * 30 = 2400
3- Divide the result by the scale (the first number of something:1): 2400 / 13 = approx. 184.615
4- Divide the result by 8 to get the dimension in studs (because we operate on milimeters and 1 stud is equal to 8 mm): 184.615 / 8 = approx. 23,077
5- Round the result (on assumption that the smallest size unit we can model in a typical LEGO construction is half of the stud) : 23,077 = 23 studs

We can get any final dimension by repeating the steps 1-5. As you can see this is not so scary (yet). If you're perverted enough to actually enjoy the maths, you will probably enjoy putting the steps 1-5 into a single mathematical formula:

blueprint's dimension (mm) * printout ratio / scale / 8 = model's dimension (studs)

E.g. 80 mm * 30 / 13 / 8 = 23,077 studs

If you're not operating on the metric system, you can convert your measurements to milimeters using one of many converters, or simply use the imperial version of the aforementioned formula:

blueprint's dimension (inches) * printout ratio / scale / 0.31496 = model's dimension (studs)

E.g. 3.1496 inches * 30 / 13 / 0.31496 = 23,077 studs

The **second case** is easier. All we need is the diameter of the LEGO® wheel we want to use (together with the tire, measured in studs) and the blueprint. Let's assume our wheel has a diameter equal to 8 studs. We proceed as follows (black marks the general steps, gray marks the result for our exemplary blueprint):

1- Measure the diameter of a wheel on the blueprint: let's assume it's 50 mm
2- Divide the diameter of our LEGO wheel by the diameter of the wheel on the blueprint – the resulting number will be referred to as scale ratio: 8 / 50 = 0.16, so our scale ratio is 0.16
3- The scale ratio simply shows how many studs in our model is equal to 1 mm on the blueprint, therefore we can now calculate any dimension by simply measuring it on the blueprint and multiplying it by the scale ratio: e.g. if our vehicle is 200 mm long on the blueprint, it will be 32 studs (200 * 0.16) long in the LEGO version
4- Again, the resulting numbers (scale ratio and final dimensions) should be rounded to reasonable values.

And again, the maths-loving perverts will enjoy putting steps 1-3 into a single formula:

(LEGO wheel's diameter / diameter of a wheel on the blueprint) * blueprint's dimension = model's dimension (studs)

This time the formula is units-independent. Consider two examples: we will calculate the same dimension (e.g. 100mm which is equal to 3.937 inches) with the same blueprint's wheel's diameter (e.g. 50 mm which is equal to 1.968 inches) for a LEGO wheel that has 8 studs in diameter using metric and imperial system separately:

Metric: (8 / 50) * 100 = 16 studs
Imperial: (8 / 1.968) * 3.937 = 16.004 studs (the .004 studs results from rounding the dimensions in inches and should be ignored)

This is it. You should now be able to calculate all required dimensions, regardless of the case and units system, using just a calculator and a measuring tool. For some extra tips on scaling please refer to the section 5.

In the next issue you will find in Chapters 4 and 5, dedicated to vehicles with chains and tips and tricks.
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