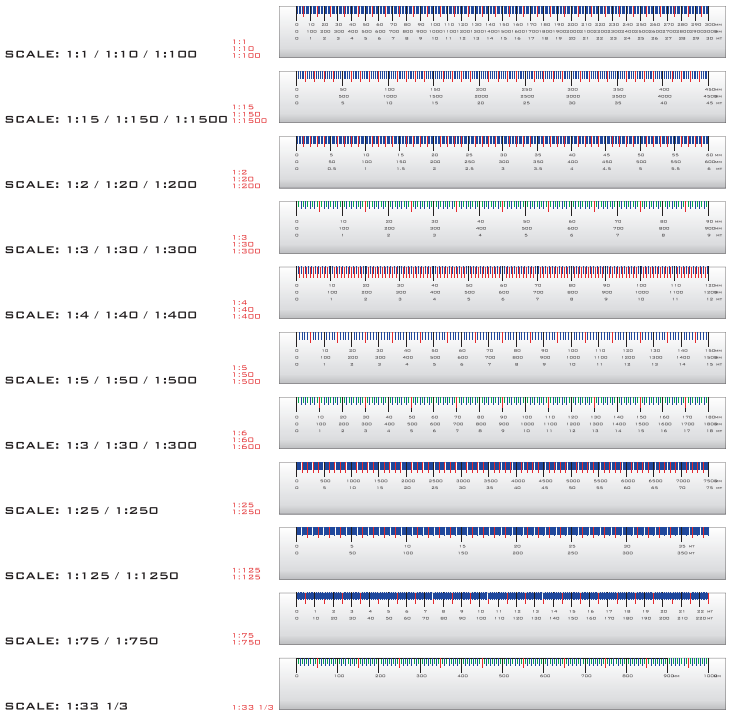
Scale

SCALE is crucial to every design and every technical drawing. It is an essential element that allows an engineering or architectural design to be accurately converted to a physical object. Your ability to enlarge or reduce a technical drawing also allows you to show an object's vital details and dimensions. To ensure that a drawing includes accurate dimensions and details, drafters use scale tools: civil engineering, architectural, and metric scale rulers. The rulers pictured here are metric scales that use millimeters as their base unit.



Objective:

Explain scale.

Key Terms:

1:1 scale
1:2 scale
base unit
drafting
manual drafting
metric scale
metric system
ratio
scale
scale drawing
scale factor
scale ruler
scaling
scales
technical drawing

Scale: Instruments, Uses, and Notation

Drafting is the systematic representation and dimensional specification of mechanical and architectural structures. **Manual drafting** is the practice of creating drawings by hand with

pencil or ink on various mediums including papers and films. CAD (computer-aided drafting) evolved from advanced manual drafting techniques. A **technical drawing** is a sketch, illustration, or diagram that visually communicates how something works or is constructed. Drafters use manual means and CAD software to convert the designs of engineers and architects into technical drawings.

Technical drawings are drawn to scale so that engineers, architects, and builders are able to create objects in the drawing to exact specifications "on the ground." Anyone reading or creating technical drawings must not only understand scale, they must be adept at using and notating that scale accurately.

An object may be drawn full size (actual size), reduced (smaller), or enlarged (bigger). A **scale drawing** is an illustration that is of the same shape as the actual object but of a different size. Typically, the scale of the drawing appears in the title block or below the view of an object. To determine the correct scale for a drawing, the drafter considers the:

- Actual size of the object
- Amount of detail desired/required
- Media size selected
- Amount of dimensioning and notes required

SCALE

Scale is an arrangement of numbers in some order at uniform intervals. **Scaling** is the process of enlarging or reducing objects to fit properly on a standard sheet of paper. The drawing scale represents the ratio between the actual and the drawn size of an object. A **ratio** is the relationship between two numbers indicating how many times the first number contains the second. **Scale factor** is a ratio that compares the sizes of the parts of the scale drawing of an object with the actual sizes of the corresponding parts of the object.

READING: When reading scales, the number on the left is equal to the measurement on the drawing and the number on the right is the actual size. A full-scale drawing is shown the actual size of the object. Other objects are scaled up or down. As most objects drawn to technical specifications are either larger or smaller than standard paper sizes, a drafter/designer must scale up (enlarge) or scale down (reduce) the image to "fit" the paper.

INSTRUMENTS: **Scales** are instruments used to make technical drawings of full size objects at a given reduction or enlargement. A **scale ruler** is an instrument with metric and English calibration systems graduated in decimals, feet, and inches. It is similar to a standard ruler except that it is divided into a range of common scales and ratios that allow the drafter to both create and read technical drawings at a specific scale. When creating technical drawings, three types of scale tools are commonly used: civil engineering, architectural, and metric.

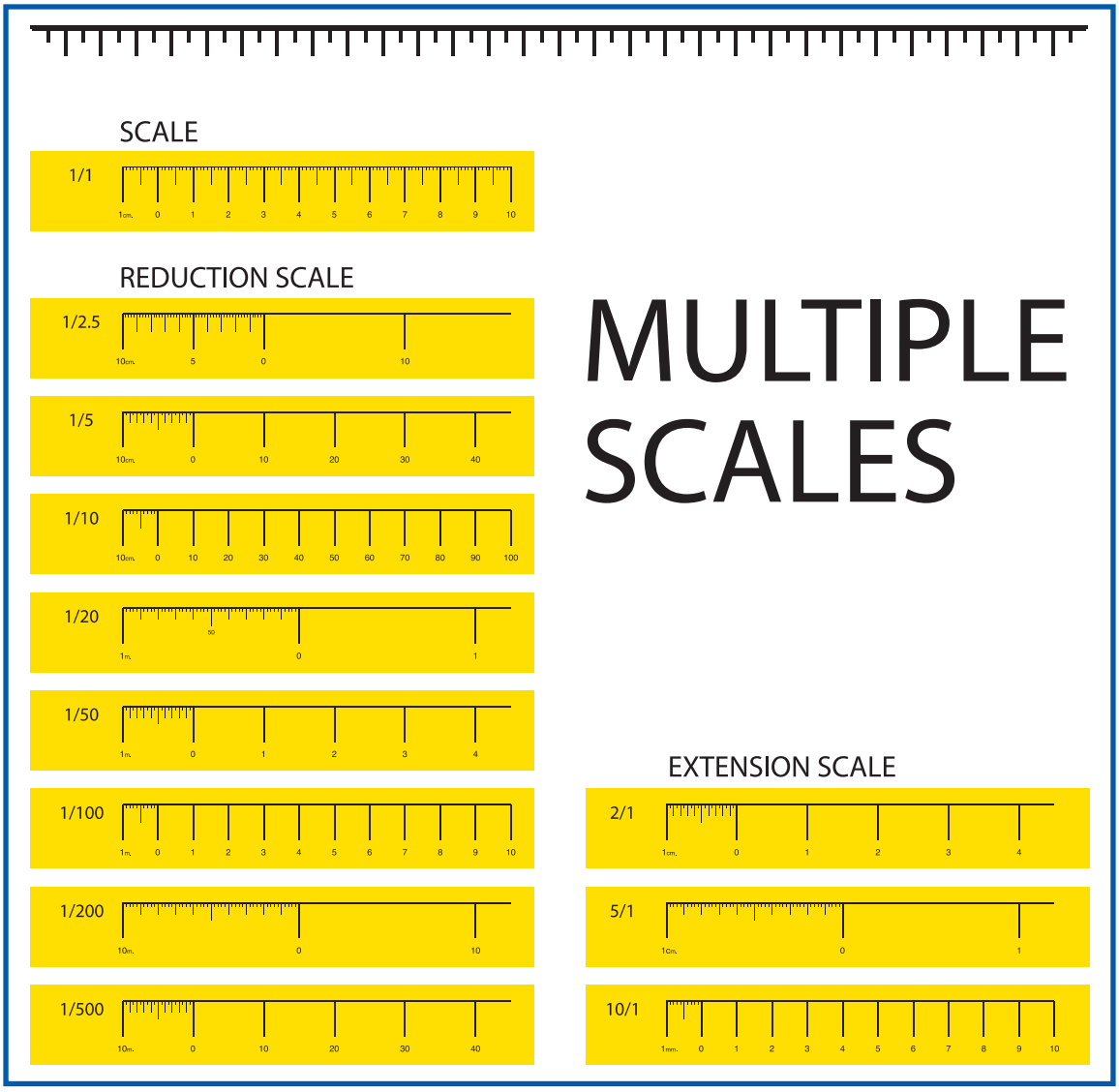


FIGURE 1. All technical drawings are created to scale so that engineers, architects, and builders are able to create objects in the drawing to exact specifications "on the ground." Anyone reading or creating technical drawings must not only understand scale, they must be adept at using and notating that scale accurately.

Civil Engineer's Scale

USE: Drawings are produced for large-scale projects such as roads, bridges, and waterways. NOTATION: The scale is typically shown in whole numbers. A civil engineer's scale divides 1 inch into equal decimal units: 10, 20, 30, 40, 50, etc.

- Plans are drawn in:
  - 10-scale (e.g., 1 inch = 2 feet OR 1 inch = 100 feet)
  - 20-scale (e.g., 1 inch = 20 feet OR 1 inch = 200 feet) [NOTE: Larger engineering drawings may be written as direct ratios. The scale on the drawing may be noted as 1:100. Scale can be based on direct unit relationships, and if so it must be noted. For example, the 1:100 ratio could be stated as 1-inch = 100 feet.]

Architect's Scale

USE: Drawings are typically produced for buildings and structures that include interior and exterior room, wall, door, and window dimensions and for both large- and small-scale plans. NOTATION: This scale is typically shown in fractions. With this scale, inches are converted into feet, such as "X inches = 1 foot 0 inches." For example: ¼ inch = 1 foot is a common scale in architectural plans. At this scale, the actual building structure is drawn at 1/48 size on the drafting medium. [NOTE: U.S. Customary system scales are based on the scale 12 inches = 1 foot and divide an inch by factors of 1, 1/2, 1/4, 1/8, 1/16, 1/32, 1/64, etc.]

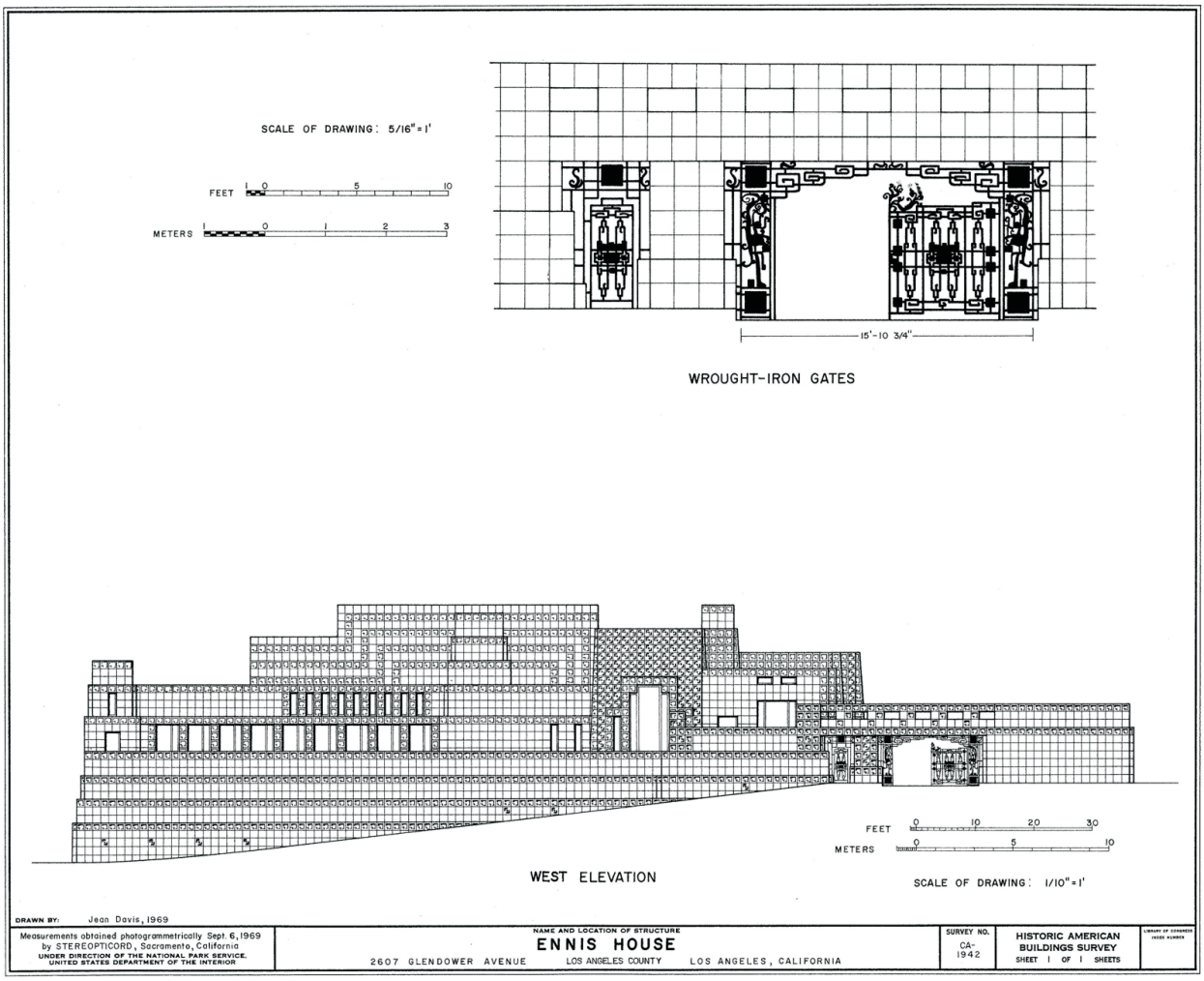


FIGURE 2. This West Elevation plan for the Ennis House, Los Angeles, CA, was hand-drawn by the architect Frank Lloyd Wright. The drawing scale is shown in the lower right corner of the drawing and above the scale is both the U.S. Customary and metric scales. The drawing scale is a graphic way to "see" the scale of the house. (Image courtesy Wikipedia at https://commons.wikimedia.org/wiki/File:Ennis_House.JPG)

Metric Scale

USE: Drawings are produced for large- and small-scale projects worldwide. Metric scales are easy and straightforward to use as every unit in the metric system is equally divided by fac-

tors of ten. A common metric ruler is ten centimeters long and each centimeter is divided into ten millimeters. NOTATION: The metric scale base is in multiples of 10 and 'millimeter' is the base measurement. Scale could be written as 1mm = 1m OR the actual ratio 1:1000.] [NOTE: Full size is 1:1 and half-size is 1:2. For half-size, 1 unit on the drawing scale is equal to 2 units on the object. Also, a designer would use an enlarged scale (e.g., 2:1) when an object is so small that drawing it full size would eliminate meaningful details.] Examples of metric length equivalents are:

- 10 millimeters = 1 centimeter
- 10 centimeters = 1 decimeter
- 10 decimeters = 1 meter
- 1,000 meters = 1 kilometer

CAD Drawings

Most CAD drawings are created at full scale or 1:1 (e.g., the actual dimensions of the object are used when the illustration is drawn). This makes it easy to plot/print the drawing at any scale needed. It also makes it easy to create a full drawing and then simply select portions of the drawing to plot. The question of scale becomes important when the drawing needs to be plotted.

- A full-scale drawing typically does not fit on a standard sheet of paper. This requires the drafter to scale the drawing: enlarge or reduce its size. The drawing itself is not changed just the ratio of the plot to the original size of the drawing is adjusted.
- To select the correct ratio or scale the drawing must be viewed in the CAD program's layout tab (AKA "paper space"). Here the drafter can set the drawing scale and locate or place the original drawing onto the paper space and select the appropriate scale to fit. First, the plot, or paper size, is selected from a host of common scales or ratios. CAD offers standard drawing scale relationships for selection to ensure the drawing fits on common paper sizes. Common scales are available in both the metric and U.S. Customary systems.
- Drawings and designs are plotted (or drawn) at different scales depending on the amount of detailed dimensions and other information required for the drawing. Selection of the drawing scale requires operator knowledge and the ability to use and understand scales. Factors to consider when selecting the drawing scale are:
  - OBJECT SIZE: The main factor is the size of the required drawing. Size selection is based on the amount of information that must be shown and its relationship to the original size of the object. The drawing must be large enough to be read while including all essential information and details required by the builder, engineer, architect, designer, etc. to create an object to specifications.
  - DETAIL: To add detailed dimensions and notes, the larger the drawing scale must be. However, large scales take up more space. A small-scale drawing, though it would allow the operator to show more of the object, may not allow enough details about the original object. The amount of dimensioning and notes required on the object plays a role in determining the best scale.

- PAPER SIZE: The selection of scale is based in part on the size of the paper selected to print/plot the drawing. Also, a builder, manufacturer, government, municipality, etc. may require a specific paper size, which impacts scale selection.

METRIC SCALE

Metric System

The **metric system** is an international standard of measurement based on the meter. It is a recognized decimal system of measurement now known as the International System of Units (SI). The metric system is used to measure mass, height, speed, and volume. The primary SI linear unit for engineering is the millimeter (mm). One millimeter equals 1/1000 of a meter. Dimensions given in U.S. customary units (inches and feet) are easily converted to metric units.

- To convert inches to millimeters, multiply inches by 25.4
- One foot equals 304.8 millimeters, or 0.3048 meter.

Prefix		Base 1000	Base 10	Decimal	English Word	
Name	Symbol				Short Scale	Long Scale
yotta	Y	1000^{8}	10^{24}	1 000 000 000 000 000 000 000 000	septillion	quadrillion
zetta	Z	1000^{7}	10^{21}	1 000 000 000 000 000 000 000	sextillion	trilliard
exa	E	1000^{6}	10^{18}	1 000 000 000 000 000 000	quintillion	trillion
peta	P	1000^{5}	10^{15}	1 000 000 000 000 000	quadrillion	billiard
tera	T	1000^{4}	10^{12}	1 000 000 000 000	trillion	billion
giga	G	1000^{3}	10^{9}	1 000 000 000	billion	milliard
mega	M	1000^{2}	10^{6}	1 000 000	million	
kilo	k	1000^{1}	10^{3}	1 000	thousand	
hecto	h	$1000^{2/3}$	10^{2}	100	hundred	
deca	da	$1000^{1/3}$	10^{1}	10	ten	
		1000^{0}	10^{0}	1	one	
deci	d	$1000^{-1/3}$	10^{-1}	0.1	tenth	
centi	c	$1000^{-2/3}$	10^{-2}	0.01	hundredth	
milli	m	1000^{-1}	10^{-3}	0.001	thousandth	
micro	µ	1000^{-2}	10^{-6}	0.000 001	millionth	
nano	n	1000^{-3}	10^{-9}	0.000 000 001	billionth	milliardth
pico	p	1000^{-4}	10^{-12}	0.000 000 000 001	trillionth	billionth
femto	f	1000^{-5}	10^{-15}	0.000 000 000 000 001	quadrillionth	billiardth
atto	a	1000^{-6}	10^{-18}	0.000 000 000 000 000 001	quintillionth	trillionth
zepto	z	1000^{-7}	10^{-21}	0.000 000 000 000 000 000 001	sextillionth	trilliardth
yocto	y	1000^{-8}	10^{-24}	0.000 000 000 000 000 000 000 001	septillionth	quadrillionth

FIGURE 3. Metric (SI) Units and Symbols (Source: Wikipedia at https://en.wikipedia.org/wiki/Metric_prefix)

Metric Scale

Metric scale is the system of measurement used in the metric system with units based on multiples of 10. The metric scale and its units are in direct proportion as they consist of direct

FURTHER EXPLORATION...

ONLINE CONNECTION: Using a Metric Scale

Drawing with a metric scale is relatively simple. The scale is based on multiples of 10 that make it easy to produce drawings that, at a scale of 1:100 (one centimeter to a meter) or 1:1000 (one millimeter to one meter). As a drafter/operator it's important that you understand how to use the metric scale. To learn more, watch the two "Metric Scale" videos at https://www.youtube.com/watch?v=2nrEIDxEGIs and at https://www.youtube.com/watch?v=w6__oQQI3oE.

This scale ruler is calibrated to 1:100. If the scale noted on a drawing is 1:100, the information on the drawing that is one centimeter (cm) in length is one meter (m) on the actual object. The drawing is one hundredth of the original size.

ratios. To best utilize the metric scale a drafter needs to first understand how the metric units are subdivided and noted.

- The **1:1 scale** is full size. Each division is 1 mm in width, with the numbering of calibrations at 10-mm intervals.
- The **1:2 scale** is one-half size. Each division is 2 mm in width, with the numbering of calibrations at 20-mm intervals.

Base Units

The metric system is comprised of base units of measurements. A **base unit** is a fundamental measurement division in the SI system including meter, kilogram, second, ampere, kelvin, mole, and candela. Different base units exist for mass, height, speed, and volume. Each metric measurement unit is a fraction or multiple of the base unit in factors of 10, 100, 1000, etc. This creates a direct relationship between the units and the metric scale.

DISTANCE: The metric base unit for distance is the meter (m). The meter is used to measure length in a technical drawing. The primary metric unit used for manufacturing and technical engineering drawings is the millimeter (mm).

PREFIX: A prefix is added to the unit of measure describing its ratio to the base (meter) and includes:

- Milli-: Millimeter (mm) notates a factor of 1/1000 (0.001).
- Centi-: Centimeter (cm) notates a factor of 1/100 (0.01).

- Deci-: Decimeter (dm) notates a factor of 1/10 (0.1).
- Deka-: The deka- prefix notates a factor of 10.
- Hecto-: The hecto- prefix notates a factor of 100.
- Kilo: The kilo- prefix notates a factor of 1000.

Ratios

Metric system ratios make it easy to scale up or down by basic multiplication or division (enlarging or reducing it by factors of ten). In the metric scale, it is assumed that the ratios are in proportion to the base unit, such as the meter. So, if the scale noted on a drawing is 1:100, the information on the drawing that is one centimeter (cm) in length is one meter (m) on the actual object. The drawing is one hundredth of the original size. If a drawing scale were 1:1000, one millimeter on the drawing would equal one meter on the actual object. The drawing is one thousandth of the original size.

- Ratios or commonly used scales for the metric system include:
  - 1:1 = full scale
  - 1:2 = half scale
  - 1:10
  - 1:20
  - 1:50
  - 1:100
  - 1:1000
- Other scales and notations used in the metric system depend on the use, the type of technical drawing, and common sizes of objects. They include:
  - One-fifth scale (1:5)
  - One twenty-fifth scale (1:25)
  - One thirty-three and one-third scale (1:33½)
  - One seventy-fifth scale (1:75)

Summary:

Scale is an arrangement of numbers in some order at uniform intervals. Scaling is the process of enlarging or reducing objects to fit properly on a standard sheet of paper. The drawing scale represents the ratio between the actual and the drawn size of an object. Scale is crucial to every design and every technical drawing. It is an essential element that allows an engineering or architectural design to be accurately converted to a physical object. To ensure that a drawing includes accurate dimensions and details, drafters use scale tools: civil engineering, architectural, and metric scale rulers.

Technical drawings are drawn to scale so that engineers, architects, and builders are able to create objects in the drawing to exact specifications "on the ground." Anyone reading or creating technical drawings must not only understand scale, they must be adept at using and notating that scale accurately.

An object may be drawn full size (actual size), reduced (smaller), or enlarged (bigger). A scale drawing is an illustration that is of the same shape as the actual object but of a different size. Typically, the scale of the drawing appears in the title block or below the view of an object. To determine the correct scale for a drawing, the drafter considers the: actual size of the object, amount of detail desired/required, media size selected, and amount of dimensioning and notes required

Checking Your Knowledge:

1. Describe scale, scale factor, and ratio.
2. What is a scale ruler? What are three commonly used types of scale ruler?
3. Write a notation for drawing scale in two ways.
4. Describe common base units in the metric system.
5. Why are technical drawings drawn "to scale?"

Expanding Your Knowledge:

A great way to expand you ability to use scales is to draw the same object at different scales. Take an existing drawing and re-draw it at several different scales. Note the amount of detailed dimensions and notes information as you move to larger scales. Also, take time to study a full set of design drawings that include a range of scales. Typically, each drawing may be drawn at a different scale in order to showcase different dimensions and details.

Web Links:

Drafting Scales Calculator
http://www.metrication.com/drafting/scales.html

How Does a Scale Ruler Work?
https://sciencing.com/scale-ruler-work-4568637.html

Scale Drawings
https://www.mathsteacher.com.au/year8/ch06_ratios/06_scale/draw.htm

Using Metric Units in AutoCAD and Land Desktop
https://www.cadmasters.com/techsupp/ldt/metric.html