09/03/24

Scale Size, Proportions, Perception, Perspective, Compression, and Deception

Besides the occasional operating sessions on my “train table”, I’d not done any real work on my model railroad structures, scenery, rolling stock or conversion of another locomotive to dead rail using the LocoFi™ system since March of 2024.

I’d been “stuck” in thinking mode, or possibly “over thinking” mode, for many months, about why some model structures look very realistic, while others look like “model railroad buildings”.

I did a lot of research on many various topics.
Apparent size, or angular size, based on distance, including real world observations of both full size and models
Vision and how it works, as well as how the brain perceives things
3D Printing and Learning TinkerCAD
Practical Minimum Sizing for Different Model Railroad Scales
Window construction including muntin sizing
Many useful, and not so useful, links on these topics

I saved all of that research as a .pdf. https://theampeer.org/HO/Apparent-Size-PDF.pdf

From all of that extensive research, it became apparent that the scale model structure’s practical minimum lumber sizes, for the most popular sizes for model railroading in the USA, was extremely important.

A good example of this is **one by lumber**. In the USA 1 by 4 lumber actually measures closer to 3/4” x 3-1/2”.
O Scale (1:48) 1 by lumber thickness: 0.015625”, 1/64” or about 0.40mm
S Scale (1:64) 1 by lumber thickness: 0.0117188” or about 0.30mm
HO Scale (1:87) 1 by lumber thickness: 0.0086207” or about 0.22mm
N Scale (1:160) 1 by lumber thickness: 0.0046875” or about 0.12mm

The one by thickness plays a key role in how we perceive the model's overall structure. The one by thickness applies to window muntins as well.

Putting the "One By" Knowledge into Practice

I had chosen to create my first structures using cardstock.
https://theampeer.org/HO/#STRUCTURES

Cardstock structures were used because they are relatively inexpensive, required no painting, except for weathering, and are built relatively quickly, and they looked "right", to me, when compared to plastic or wood craftsman type kits, including laser cut wood kit structures. At that time, I was unaware of the importance of "One By".

Scratch building from wood and other materials was beyond my ability and time constraints at that time.

In the spring of 2023, while creating the the various cardstock structures for the train table, I became convinced that it was the doors and windows of most model structures that just didn't look right to me. This was something that I'd noted as both a youth and young adult when model railroading, and it came to the forefront during this time.

During the July 24, 2024, New Tracks Modeling meeting, Father Ron Walters, OFM, demonstrated "How to make Plastic look like Wood" using a vintage Walthers' Trackside Structure Kit. This structure is in HO (1:87) Scale.
https://youtu.be/oQ_BrieuLT0

While his technique produced a beautiful model, that did not look like it was made of plastic, it still didn't look quite right to me. It still looked like a model railroad structure.

Images captured from that video are assumed to be from Father Ron Walters

Note how far the window and door frames protrude from the sidewalls and the size of the muntins compared to the overall size of the structure.

muntins: A muntin (US), muntin bar, glazing bar (UK), or sash bar is a strip of wood or metal separating and holding panes of glass in a window. Muntins can be found in doors, windows, and furniture, typically in Western styles of architecture.
https://en.wikipedia.org/wiki/Muntin#:~:text=A%20muntin%20(US)%2C%20muntin,in%20Western%20styles%20of%20architecture.

The Scale of the Scale Model Makes a Huge Difference

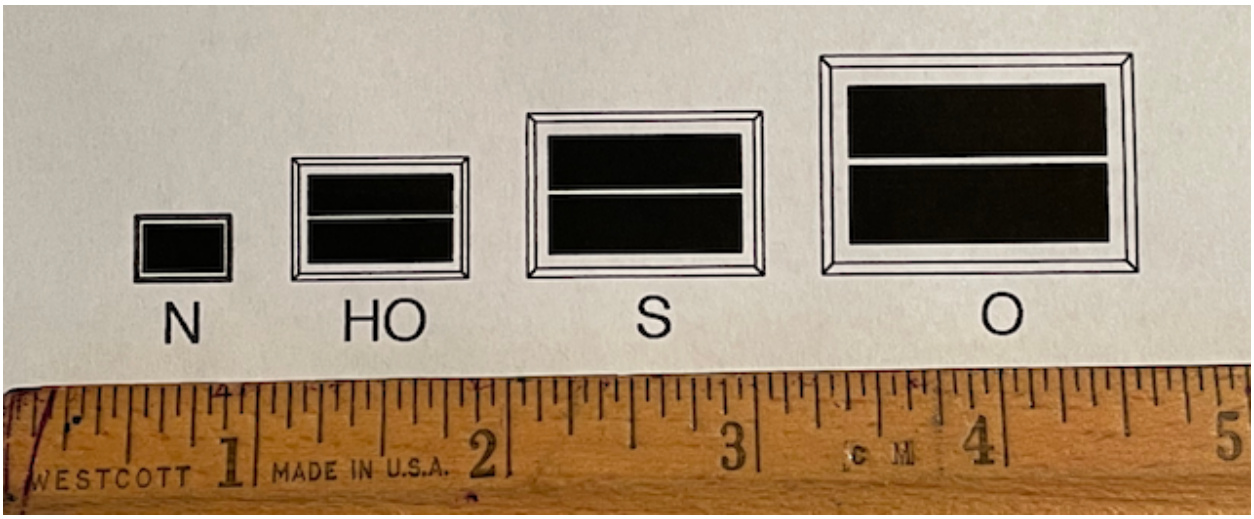
On April 27, 2023, I downloaded the Free O scale Clever Models' Tower Crossing Kit. The HO version did not become available until October 24, 2023.
http://clevermodels.squarespace.com/free-downloads-01/e-o-crossing-tower-kit/

When I printed it, I did the math conversion of the O scale size , 48/87=55%, to print it in HO scale.

I could not successfully assemble the now HO scaled size version. It was just too difficult to cut out the parts. I described this failure in the section of my Website titled, "Clever Models HO Scale Crossing Tower".
https://theampeer.org/HO/#TOWERFAIL
The details are covered here.
https://theampeer.org/HO/ARC58.html

While attempting to complete this model, I decided to look at what happens when the scaling of an object is changed up or down. I measured the interior of our bedroom window and then scaled that window to the four most popular scales in the USA for model trains.

This photo was shown in the previously noted details section link.



The four scaled windows, using 1:160 for N scale, 1:87 for HO, 1:64 for S, and 1:48 for O, were printed next to each other and a ruler laid on the print to give the prints scale.

As I completed many structures for my “Train Table”, created several YouTube videos, and started work on a new dead rail conversion, that information, which had been filed into the part of my brain used for “things that bug me”, began to really get to me.

I finally had to just give into my desire to learn more. All physical work on the train table and Dead Rail conversions, came to a halt in early March of 2024.

The Research

A lot of research led me down a rabbit hole that lasted from early March to early September of 2024.

Deeper Into Scaling

I created a spreadsheet that compared various Imperial units, in full scale, to the four popular model railroad scales previously mentioned. That spreadsheet was a bit useful, but being able to visually comprehend the information regarding such small units of measure was extremely difficult.

1 by 4 board is used as much of the trim on my house at the corners. In the US, a board known as a 1 by 4 usually measures about 3/4” x 3-1/2” x in actual length, which is usually in feet (25mm x 100mm in the UK). The exterior window trim is also 1-by, but of varying widths of 6” and 8”. The length is not essential, at this point, in understanding what’s going on when scaling.

O-scale 1 x 4 is 3/4” (0.75”) thick divided by 48 or 0.015625” (~0.383mm).
Note: The tilde (~) symbol can be used to mean “about, around or almost”.

Using the Fraction-Decimal Conversion Chart, available on the Web, shows that 0.015625” is 1/64”.
https://www.thegeekpub.com/wp-content/uploads/2022/02/Fraction-to-Decimal-Conversion-Chart-PDF.pdf

3.5” divided by 48 = 0.0729167” which is between 1/16” and 5/64” (~1.786mm)
Other scales can be calculated using the same process, but since I’m using HO scale, it is computed here.
For HO-scale 0.75” = 0.0086207” that is very close to the thickness of common card stock. (~0.211mm).
Note that I did not give an actual fractional equivalent, in Imperial units of measure, but used something that makes a comparison to a relative size. “Thinking” extremely small is difficult.
HO-scale 3.5” = 0.0402299”, which is between 1/32” and 3/64” (~0.986mm which is pretty close to 1mm).

Looking again at Father Ron's beautiful model, it should be apparent that the framing around the door and windows is much, much thicker than the thickness of the card stock that I use, which is 0.22mm or 0.0089796" . The window framing and muntins also appear to be too large.

Even the corner trim pieces appear to be "thicker" than typical card stock.

The corner trim, in proportion to the rest of the structure, appears to be wider than 1mm.

On August 28, 2024, I purchased a Walthers Brick Cape Cod house to make some actual measurement of a plastic kit.
https://www.walthers.com/brick-cape-cod-house-kit-4-1-4-x-3-5-8-x-3-quot-10-7-x-9-2-x-7-6cm

Various measurements were made of the front dormer wall, which included the window. The window muntins, in that part, were measured, as well as all of the other measurements. The window muntins, measured with my caliper, were 0.50mm. I do all small measuring using millimeters (mm) and then convert to inches by dividing the mm value by 25.4.

0.50mm = 0.0204082" To get the full HO scale width, the scaled inches were multiplied by 87, which is 1.7755102". The muntins, molded onto the side wall, as well as the window frame exterior side frames, were 0.43mm (~0.017551") thick. Full scale would be just over 1-1/2". That is about twice the thickness of 1 by lumber.

Some Real World Data Regarding Window Muntins

From Starline Windows
https://www.starlinewindows.com/files/product-documents/5c5c5e061d56f/Muntin-Bars--Plant-On-Bars.pdf

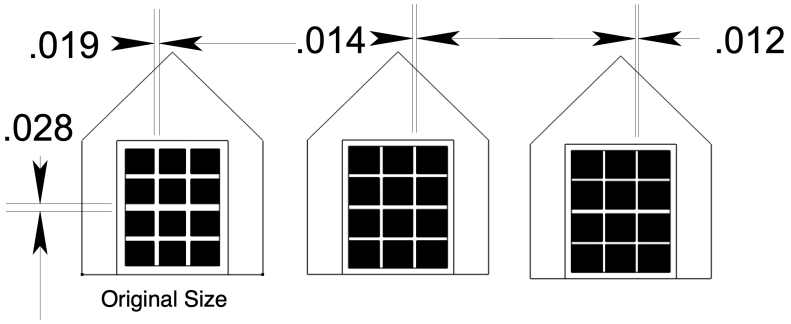
"Interior muntin bars are available in the following sizes: 3/8", 5/8", & 1" "
In HO that is 0.004310345", 0.007183908" & 0.011494253"
In HO that is 0.109482763mm, 0.1824712632mm & 0.2919540262mm

"External Plant on Bars" AKA Astragal-Bars or Georgian bars
7/8", 1-1/4" & 2-1/2"
In HO that is 0.010057471", 0.014367816" & 0.028735632"
In HO that is 0.2554597634mm, 0.3649425264mm, 0.7298850528mm

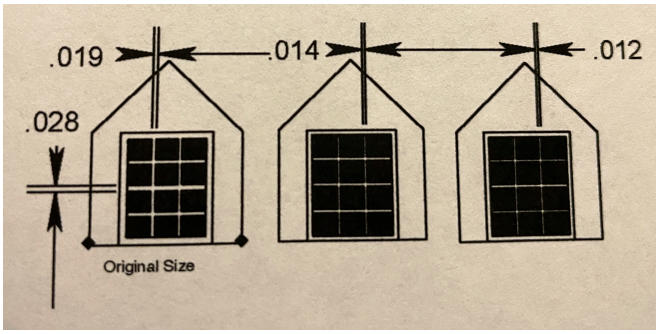
Exploring the Dormer Front Wall

The window muntins, of the dormer window, were too wide (1.7755102”) to be Starline Windows’ Interior Muntins, but they reasonably could be from some other manufacturer. Therefore the width falls within a “reasonable range”, but the window muntins still “looked to me” to be too wide.

The window frame, around the window, was 0.43mm (~0.017551”) thick and 0.75mm (~0.0306122”) wide. That indicated, that the frame, in full scale, was 1.527” thick and 2.66” wide. The width of the frame appeared to be in an acceptable range, but it was about twice the thickness that it should be. I laid a piece of the 0.22mm (0.0089796”) card stock, that I use for my structures, next to the frame, and it was obvious that the frame was about twice as thick as the card stock. Therefore, the frame protruded from the dormer wall too much.



I used my CAD program to create versions of the dormer front wall with different size window muntins in inches. The window muntins of the original (.019”) equaled 1-5/8” in full scale. The wider horizontal line (.028”) is where the double hung window sashes cross each other. The .014 window muntins equaled just less than 1-1/4” in full scale. The .012 window muntins equaled 1” in full scale.



The CAD drawing, of the different size window muntins, was printed full size, with the printer set at “best”, to print from the CAD program.

The .012”, 1” full-scale window muntins, were barely visible when printed.

A closeup photo of the printed area.

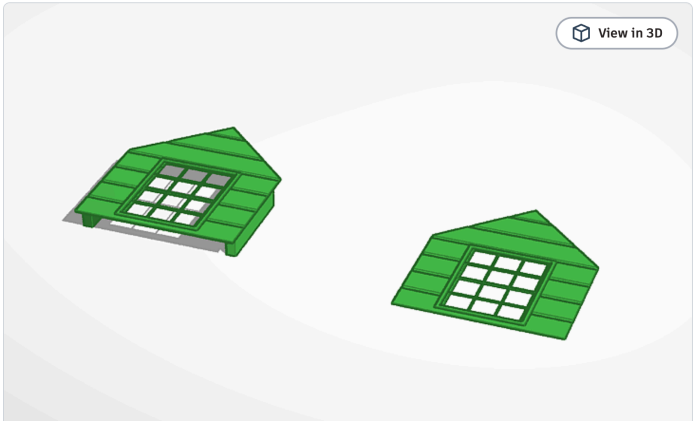
It looked like my printer could not handle the window muntin’s smaller widths very well.

Does a 3D Printer Work?

I wondered if a 3D printer would work.

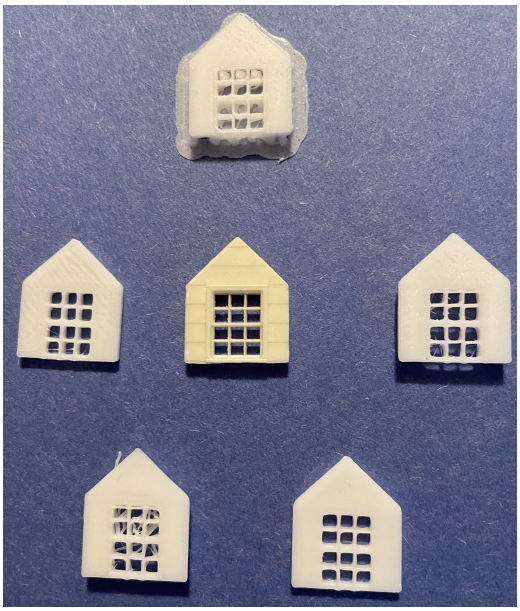
I had to learn TinkerCAD https://theampeer.org/HO/Using%20TinkerCAD.pdf

Copy of Cap Cod Dormer



I do not have a 3D printer, but a good friend does. It is a CREALITY Ender-3.
https://www.creality.com/products/ender-3-3d-printer

I knew absolutely nothing about 3D printing, but I asked him if he'd do a couple of small prints for me. The answer was "sure".



I'd never used any type of 3D CAD program. I spent the next couple of days learning the free, Web-based TinkerCAD 3D CAD program and then creating the dormer side wall in 3D.
https://www.tinkercad.com/

Several attempts were made to print various iterations. The screen capture shows the TinkerCAD drawing of the last attempt. None were successful in producing the 1" (25.4mm) full scale window muntins to 1:87 scale. The Walthers' injected molded dormer side wall is shown in the center of the photo.

One 3D print had the correct window frame depth, but the muntins never printed smaller.

There was a good reason why the muntins never printed thinner. The nozzle size on my friend's printer was a 0.4mm nozzle.

While there are 0.2mm nozzles, we didn't try that.

Many, many weeks later, I did learn how to create smaller window muntins, with a new technique, not 3D printing, which is explained later.

Looking At It Differently

The scaled drawing of our bedroom window and the drawing of the dormer side wall indicated something else to me.

What was that?

The apparent size of an object varies with the distance of the object from the viewer.

The CAD drawings of the bedroom windows are their actual sizes when measured for each scale.

Because of the way our eyes work, we cannot actually view the drawing at the actual size. According to my eye research, people with normal vision have a near point (eye focus) of their vision at approximately 25cm or about 10”.

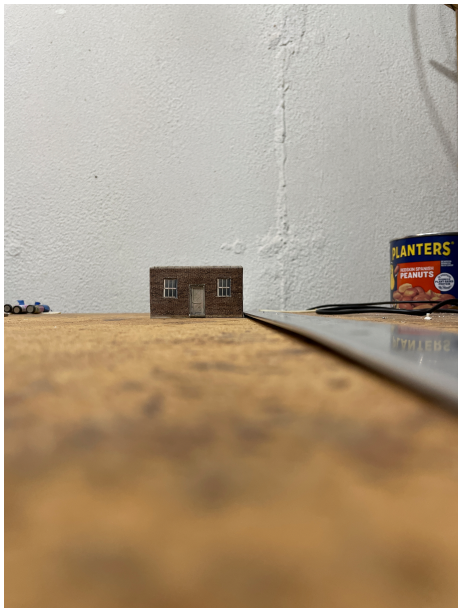
That means that a person with normal eyesight needs to hold the paper about 10” away to view it clearly. That has already reduced the apparent size a bit and a measuring tool must be used to know what the actual size is.

Apparent Sizing led through many, many weeks of various topics.
1. Understanding How Apparent Size Works
2. How the eye works when looking at objects at various distances
3. Perspective
4. Proportions
5. How to measure a tree with a yardstick
6. and much more!

I finally came up with a way to clarify it all in my mind.

While I didn’t know it at the time, apparent size, really does not affect how we perceive model structures. For the most part, model structures are viewed at relatively close distances.

The wall of this building measures 1-11/16” or 1.6875” high and 3” wide.
Proportions or ratios: 1.6875/3 = 0.5625 or if inverted, 1.77777778.
Either dimension can be used.



The two photos show the relative size of the wall side of one of my buildings. It appears larger, to the iPhone, on the left and smaller on the right.

The photo on the left shows what it looked like using the iPhone camera at a distance of 3”. The photo on the right shows what it looked like to the iPhone’s camera at 15”.

Unfortunately, this perception did not prove to be true when viewing with the human eye.

How This Works

If an object is twice the distance away, it appears exactly half the size compared to its appearance at the original distance.

The following is a direct quote I got through Google AI.

Explanation:

Angular size:
How large an object appears to be is determined by the angle it takes up in your field of vision, called its "angular size."

Distance and angle:
As the distance to an object increases, the angle it creates in your vision decreases, making it appear smaller.

Double the distance, half the angle:
If you double the distance to an object, the angle it creates in your vision is halved, resulting in it appearing half the size.

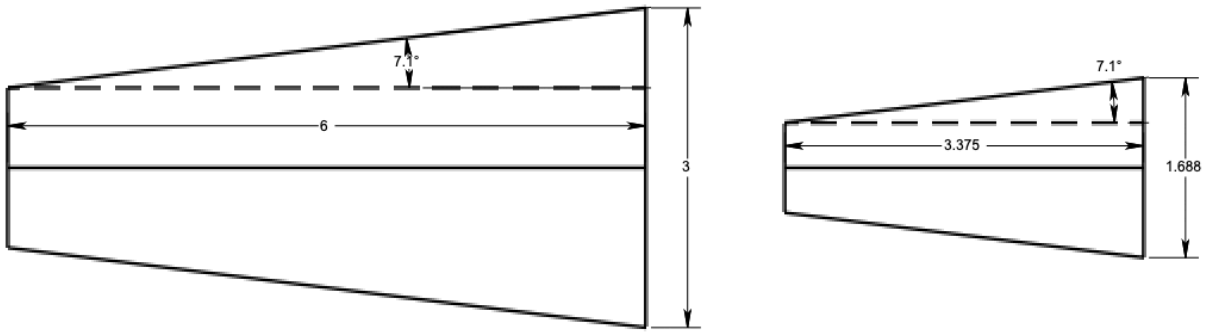
Key point: The relationship between apparent size and distance is inversely proportional, meaning as distance increases, apparent size decreases proportionally.

As previously noted, the wall of this building measures 1-11/16” or 1.6875” high and 3” wide.

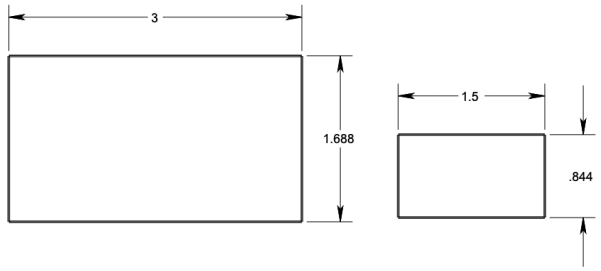
At first, I thought that the near point of the eye, ~10” for normal vision, needed to be taken into consideration when selecting a value to use, but this later proved to be false.

To find the value:
3” x 2 times as far away = 6” as the distance
1.6875” x 2 times as far away = 3.375” as the distance

The following diagram illustrates using both those values.



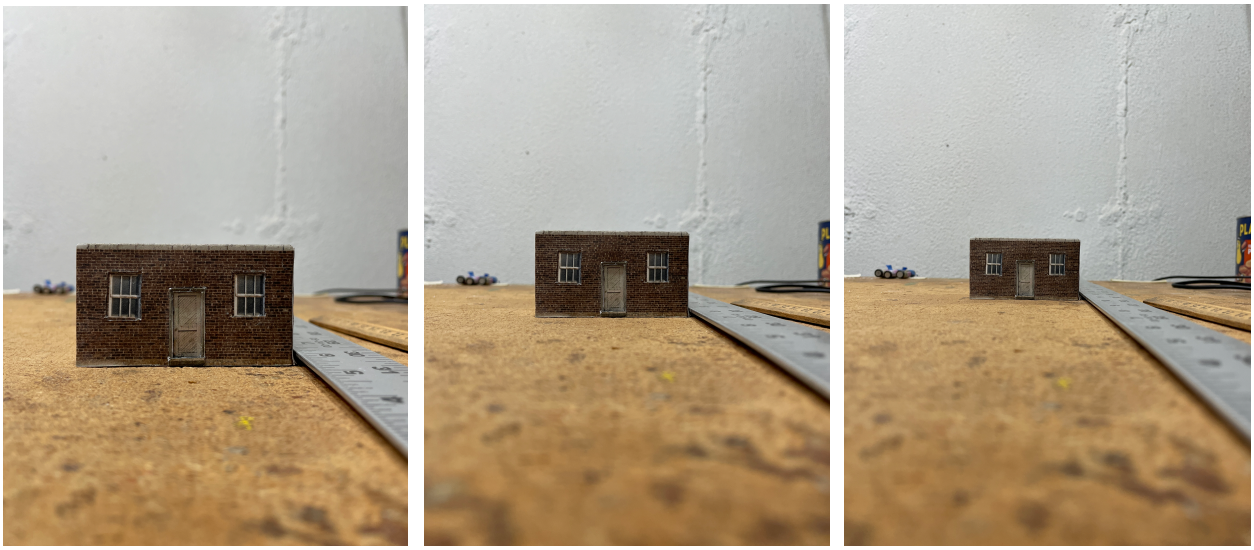
Based on the original measurement of 3 x 1.6875 a 50% reduction now looked like this.



It is pretty clear that many of the details, on the full size wall, are lost at 1/2 size. But a question arose then; “Is it really perceived as 1/2 size?”

Unfortunately, or quite fortunately for us, our eyes don’t work like a fixed focus lens of a camera. Our eyes use a process known as accommodation to adjust the clarity of near and far objects and transmits that information to the brain where it is processed.
http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/camacc.html#c1

That means that, unlike a fixed focus camera, size change at relatively close distance, of relatively small objects, is not processed by the brain in the same manner as more distant objects of a relatively larger size.



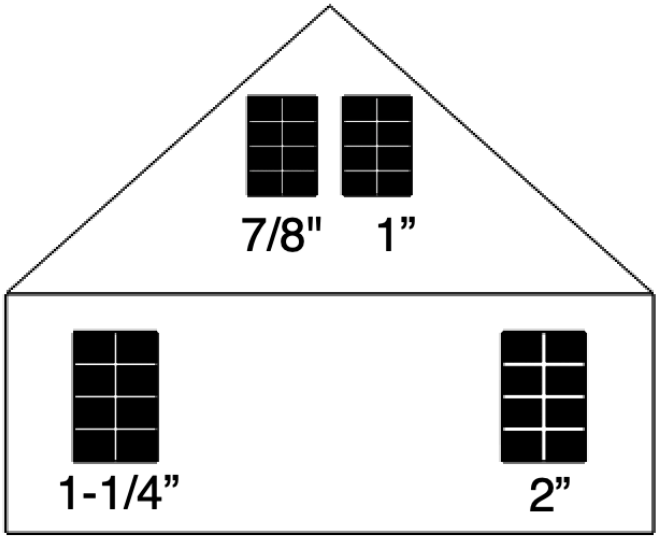
The iPhone camera, set at 1x can clearly demonstrate the proportional changes, as shown in the photos, between 6”, 9” and 12” away from the iPhone camera lens. If the structure is picked up, held in hand and then looked at at the same distances previously mentioned, it does appear to get proportionally smaller as the object is moved away, but that’s about all that can be said. At all three distances, the structure appears to be much larger than the proportions suggested by the mathematics. The eye and the brain are “accommodating” and the actual proportional dimensions are no longer valid.

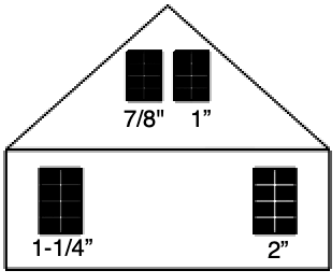
The most important thing to note here is that as the viewing distance increases the apparent size does get smaller.

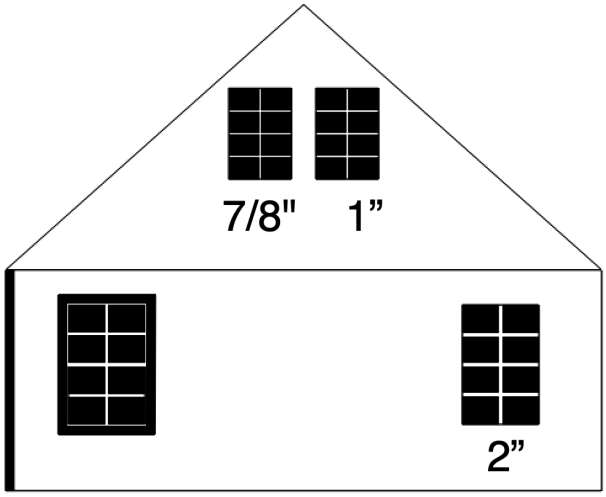
That leads to the question, “How Small is Too Small?”

How Small is Too Small?

Before learning about eye accommodation, I drew the sidewall and scaled it to 50%.







Once I realized that our eyes don’t scale objects that are relatively small and close, I looked at the sidewall in another way.

With good lighting, the **original** printed sidewall was placed 5’ away and only the 2” scaled muntins were visible. At 6’ away, the 2” scaled muntins were only just barely visible.

Note: The amount of detail visible depends on the eyesight of the viewer. All viewer's distances will vary.

My viewing distances only apply to my vision, which is not that great, even with my glasses on.

The original CAD drawing of the sidewall, with the original window muntins scaled to 1-1/4" was replaced. The **new window** used 1-1/2" scaled muntins (~0.017", ~0.42mm). A 2" scaled center horizontal line represent where the upper and lower sashes of the double hung window cross. A scaled 4" (~0.046", ~1.13mm) frame was placed around the window. A scaled 4" trim piece was add to the left side of the wall.

The drawing was set up 5' away from me, and for me, the 1-1/2" scaled muntins were barely visible. The scaled 2" horizontal line was clearly visible.

At a viewing distance of 4' the 1-1/2" scale muntins were sort of, but not clearly visible.

When viewed at 3-1/2', the 1-1/2" muntins were definitely visible, but very small.

This demonstrated, to me, that details of less than those scaled to 1.5" or 0.0172414" (~0.44mm) in HO scale (1:87) don't really show up at **my** typical viewing distances.

I found three videos that demonstrate possible ways to create muntins scaled to 1.5" for HO.

Scratch building cheap and easy window frames - the sticky label technique for model window frames
https://www.youtube.com/watch?v=_pU0WqGSH3Y
Chandwell (By Michael Scott)
Really good video for windows with small muntins.

In his video he notes using a 0.3mm size, which is 0.011811" according to an online converter that I used, but mathematically 0.3mm divided by 25.4 = 0.011811". About 0.012" is close enough. 0.12" x 87 equals 1.044", or just about 1" in HO scale.

Near the beginning of the video he notes that the frame elements are 1/3mm wide. He later notes zero point three millimeters wide, 0.3. That is ~1.75" wide in UK N scale, 1:148, which, to me, is pretty wide for UK N-scale.

Model Windows for miniature houses - Detailed guide DIY
https://www.youtube.com/watch?v=sCJEvnYjNV4
Marklinofsweden notes the "window" problem:
He paints 1mm muntins. This technique might be useful for other color muntins/ windows, but 1mm is equivalent to about 3.55" in HO scale, which is very wide.

Two ways of making prototypic miniature windows
https://youtu.be/yXaTwVshN2Q
Resin 3D resin printing and painting on clear plastic using an engineering or architectural drawing tool.

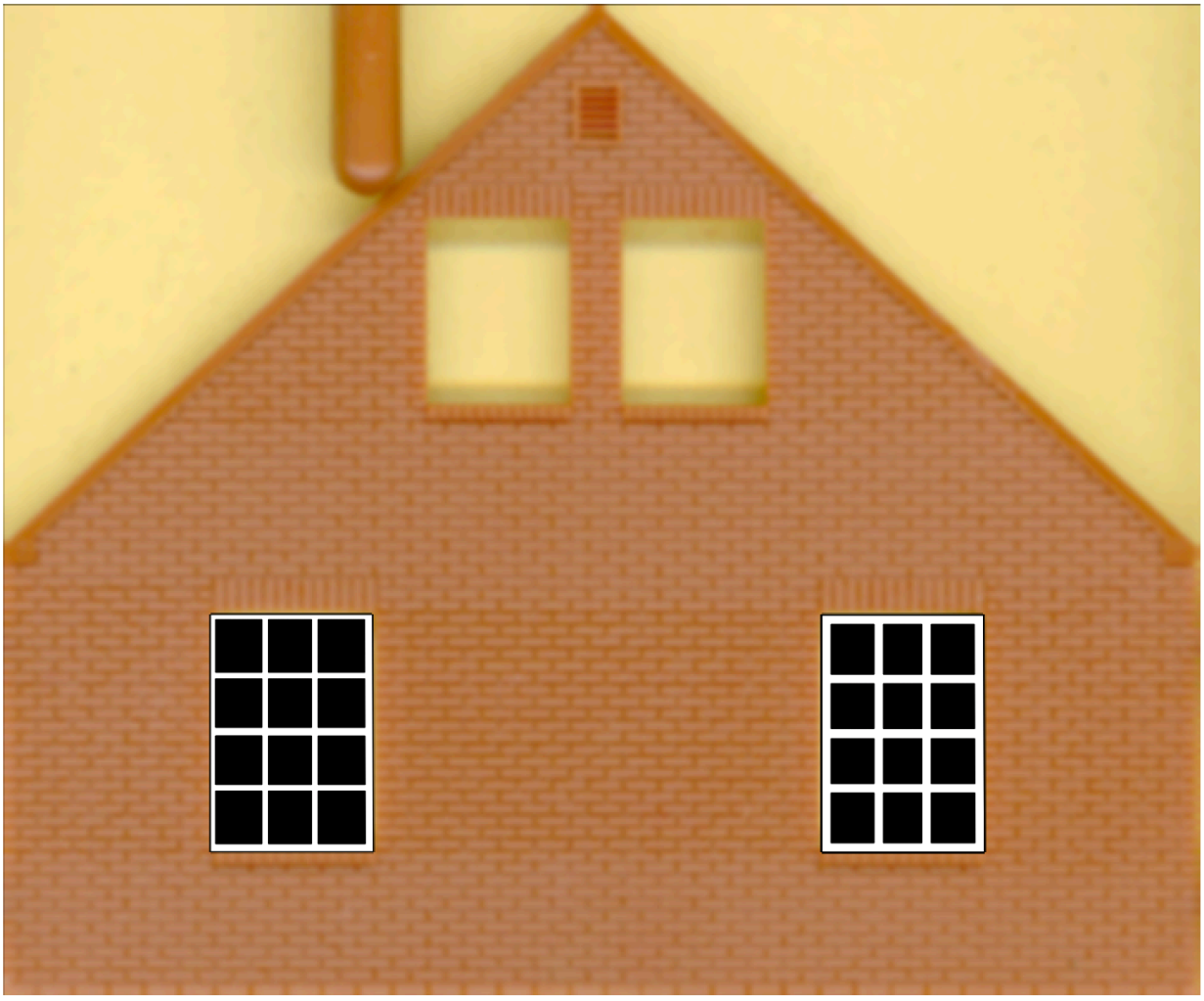
Where to Find Photos of Buildings Where the Windows "Look" Right To Me

I am a member of the Model Rail Buildings - Mostly Card & Paper Facebook Group.
https://www.facebook.com/groups/573038996168181

There are many very good examples shown in that group.

The group is European centric, but many scales are covered, including HO.

David Rarig posted this HO scale structure, to the group, on July 26, 2019. He is from Mayville, NY.



I scaled a scan of the sidewall from the Walthers' kit and then sized it to scale in my CAD program. I used the HO scaled muntin width of 1.5" (0.017") and a sash crossing width of 2" (0.023") on the drawing of the window on the left. The window on the right uses the Walthers' kit measurements; 0.25" for the muntins and 0.27" for the sash. That scales up to 2.175" for muntins and 2.349" for the sash crossing.
With a casual glance, they both look okay. They both give the impression/illusion that the double hung windows have muntins. But compare the windows to the brickwork. Also keep in mind that the full width of the sidewall, which is included in the screen capture, of this sidewall, is 3-3/8", which scales to about 25 and a half feet in HO scale.

Generally, brick sided houses, and other bricked or stone structures, have recessed windows with no exterior framing. Therefore there is no frame protruding from a side view of this wall.

I set up this printed version of the sidewall and viewed it from various distances.

At about 6', the Walthers sized window details were clearly visible, but my scaled window details were just barely visible.

Of course as I got closer, my window details became more apparent.

Conclusions

While apparent size plays a role in how much detail and what size details are important to include on a structure, it does NOT dominate the considerations when building and detailing a structure.

Modelers like to photograph their trains up close with structures and scenery in the photograph.

That means that the lens, camera or eye, is refocusing for close viewing.

The dominate factor then becomes; how small can the detail parts actually be created.

Discovering the **one by** relationship was eye opening.

1 x 4 (0.75" x 3.5") in various scales
Note that wood is not really workable at these thicknesses and the widths are pretty thin as well.
O scale (1:48) 0.015625" x 0.0729167", about 1/64" x 5/64", about 0.40mm x 1.85mm
0.015625" is 15pt ~ 100lb. or ~270 gsm Cover paper
S scale (1:64) 0.0117188" x 0.0546875", about 0.30mm x 1.39mm
0.0117188" is 12pt ~80lb. or 215gsm Cover or 110lb. Index
HO scale (1:87) 0.0086207" x 0.0402299", about 0.22mm x 1mm
0.0086207" is 9pt ~59lb. or ~160gsm Cover or 67lb. Bristol board
N scale (1:160) 0.0046875" x 0.021875", about 0.12mm x 0.56mm
0.0046875" is 5.5pt ~60lb. or ~162gsm Cover

I believe that this is why "paper" structures can look more realistic than wood or plastic.

Info on paper can be found on the link on the following pages, as well as the weight and point (pt) chart.

20 lb (75 gsm): Standard copy paper used for everyday printing and document reproduction. Perfect for internal memos and drafts where function trumps form.
https://www.printingcenterusa.com/blog/paper-weight-guide-how-to-choose/?srsltid=AfmBOoo_wlBliDp1KV_qAEIX3HYQ5uh91jlSYtFheALg37VZhTPypvGR

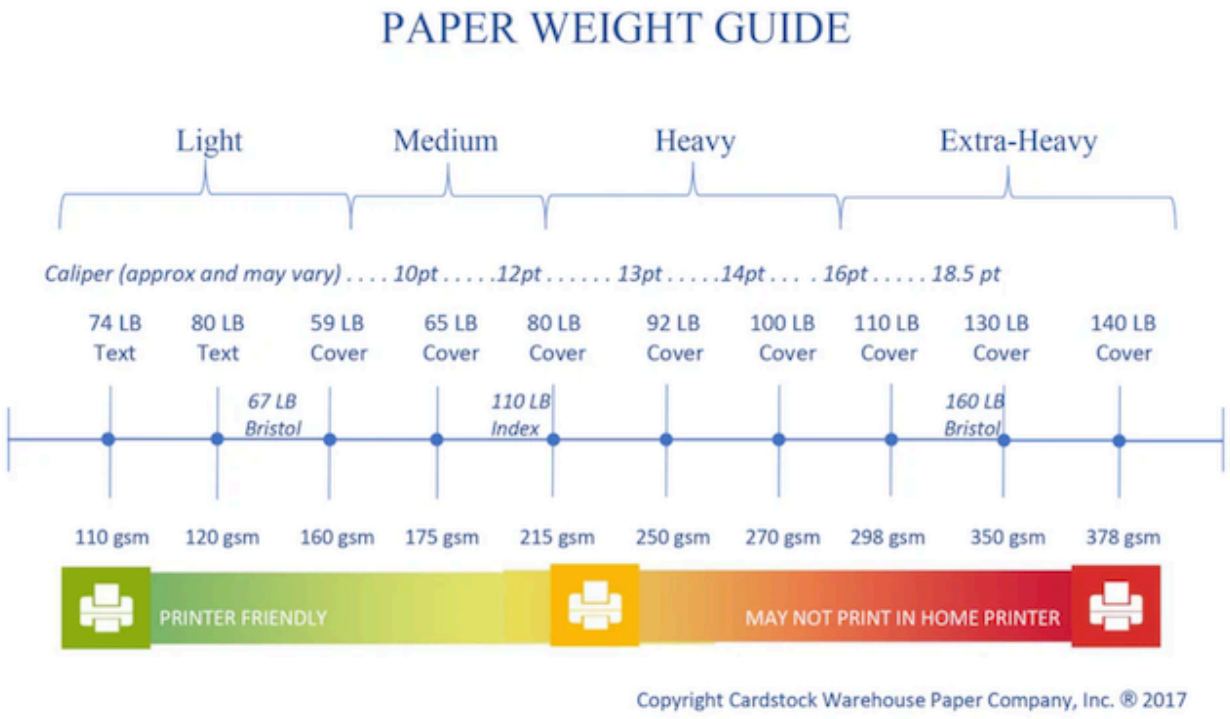
TEXT	COVER	GSM	CALIPER	COMMON USES
25 lbs		40 gsm		Tracing Paper
40 lbs		60 gsm		Newspaper
50 lbs		74 gsm		Standard Printer Paper
60 lbs		89 gsm	3 pt	Book Pages, Notepads, Ltterheads
70 lbs		104 gsm	3.5 pt	Book Pages, Envelopes, Flyers
80 lbs		118 gsm	4 pt	Book Pages, Posters, Brochures, Flyers
	60 lbs	162 gsm	5.5 pt	Book Pages, Posters, Brochures
	80 lbs	216 gsm	8 pt	Book Cover
	100 lbs	271 gsm	10 pt	Book Cover, Postcards, Door Hangers
	110 lbs	298 gsm	12 pt	Business Cards
	120 lbs	325 gsm	14 pt	Book Cover, Greeting Cards, Business Cards, Greeting Cards, Invitations, Folders, Door Hangers
	130 lbs	400 gsm	16 pt	Business Cards, Invitations, Door Hangers
		460 gsm	18 pt	Business Cards, Non-folding Invitations
		590 gsm	24 pt	Double or Triple layered stock for Business Cards, Non-folding Invitations
		1000 gsm	38 pt	Double or Triple layered stock for Business Cards, Non-folding Invitations
			60 pt	Hardcover Book Cover

The values shown in the above chart are for reference purposes only, and may vary depending on the type of paper or cardboard material.

ALL YOU NEED TO KNOW ABOUT CARDSTOCK PAPER WEIGHT AND THICKNESS
https://www.elegantepress.com/blog/all-you-need-to-know-about-card-stock-paper-weight-and-thickness/

Choosing the Right Paper Thickness for Printing: A Detailed Paper Weight Guide
https://www.printingcenterusa.com/blog/paper-weight-guide-how-to-choose/?utm_term=what%20thickness%20is%20printer%20paper&utm_campaign=&utm_source=adwords&utm_medium=ppc&gad_source=1&gclid=CjwKCAjw9eO3BhBNEiwAoc0-jcmyVflkK_qUWGWmjljdDcumEwkvjcO76T2aJBfVumqt8Xq1CWpwjRoCS4QQAvD_BwE
Details include: Writing and Office Papers (20-50 lb | 75-90 gsm), Text Papers (60-100 lb | 89-148 gsm), Light Cardstocks (58-70 lb | 157-190 gsm), Midweight Cardstocks

(80-100 lb | 216 – 280 gsm), Heavy Cardstocks (110-130 lb | 298-352 gsm), Specialty Papers (140 lb and up | 378 gsm and more)



Paper Weight Guide - a lot of info about paper/cardstock/chipboard, etc.
https://www.cardstock-warehouse.com/pages/cardstock-paper-basis-weight-chart