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Analysis of Modern Barn Design

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Honors Research Paper

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Abstract

The agriculture industry is always changing. Barn structures are one of the most important aspects of the agriculture industry. As the agriculture industry changes, so does the design and construction of barns. There are many types of barns, but over the last 300 years four of the most prevalent types have been the Bank Barn, Open Span Truss Barn, Hoop Barn, and Transverse Frame Barn. The Bank Barn and Transverse Frame Barn have been popularly built for over 200 years. The Hoop Barn and the Open Span Truss Barn have been recently introduced to the industry, becoming popular within the last 50 years. These four types of barns all have advantages and disadvantages. They vary in efficiency, versatility, cost, constructability, and structural safety. To rank these barns with a definite number in each aspect is not entirely fair, because every barn is built differently based on the intended use. However, general assumptions can be made to rank these four barn types in each aspect. With all comparisons made between barn types, there is not one definite best barn design. Ultimately, the best barn design is based on the business plan and intended use of the farm where the barn resides.

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Introduction

Over the past 300 years the construction of agricultural barns has changed significantly. Some of the older barn designs are still used today but there are other designs that are widely used in new barn construction. Common designs include Bank Barns, Open Span Truss Barns, Hoop Barns, and Transverse Frame Barns. There are many variations of these designs, as well as other designs that are not encompassed in these few types. These are just a few of the most prominent types of barns in the agriculture industry and certainly not all encompassing. Different designs are selected based on the intended use of the barn, whether it be for livestock housing, bale and equipment storage, or both. Barn design is further dictated by the type of livestock, equipment, or bales. For example, sheep are housed much differently than chickens. An efficient sheep barn requires different design than a chicken barn. When it comes to storage, round bales of hay or straw are stored and accessed differently than square bales, so the barn designs will differ. The farmer's intended use will dictate the type and final design of the barn being built.

Bank Barns

Bank Barns are one of the oldest barn designs in America, and they are still in use today. These barns were popular in America by the early 1800's, but there are examples of written floor plans from the 1700's (1). Bank Barns are built into the side of a hill. This allows entry of equipment into the second level at the top of the hill. These barns always have at least two levels, sometimes more. They are very tall barns without trusses. Their structural design uses columns, beams, joists, and braces made of wood. Often the columns and beams are even pinned together using wooden pins. The bottom floor is typically dirt or concrete. The floor on the upper level is made of lumber. The walls on the bottom level are typically stone block, masonry, or concrete because these walls contact soil on at least one side of the barn (2). Some barns will have wooden walls around part of the bottom level, but any walls in contact with soil are not wood. The second story walls are usually wooden. Sometimes newer barns or ones that have been renovated will have sheet metal siding on top of, or instead of, the wooden siding. The roofs can be anything from slate to shingles or sheet metal. Bank barns have doors of different sizes in many locations both exterior and interior, with an unpredictable door plan.

The lower level of a bank barn is typically used for livestock housing. They are often divided into many different sections and are not meant for large quantities of animals. The

second level is meant for storage of crops and equipment. Years ago, this upper level was also used for processing crops by means such as thrashing. This space provided a place where wagons of grain crops could be pulled inside out of the weather and the grain could be separated from the stem. The grain was then stored in small rooms on this level, called a granary, and there were trapdoors that could be used to drop grain to the lower level. These methods of grain separation are no longer necessary due to advances in equipment, so the primary use of the second level in current times would be storage. There are no trusses below the roof supporting it. The beams, joists, and braces are designed with adequate strength to avoid trusses. This allows storage all the way up to the roof. Square bales of hay or straw can be stacked by the hundreds or even thousands all the way to the ceiling of the second level. This is done by means of hay elevator and a few able bodies.

Figure 1: A view of the uphill side of a bank barn, with entrances to the second level. Photograph by Author, taken on January 21, 2021.

Figure 1 shows the uphill side of a bank barn which allows the second level of the barn to be entered with large equipment. This picture shows the six large doors and the two small doors, all outlined with white trim. The opposite side of the barn has doors which allow access to the bottom level of the barn at ground level. Unlike the second level entrances which all lead into one large area, the bottom level doors often lead into separate rooms designed to house livestock

in small groups. The remaining two sides of the barn vary from barn to barn. Some have no doors on the two remaining sides, while some have doors. Most bank barns will have windows or vents on these two sides to allow adequate airflow.

Figure 2: The Northeast corner of the second level.

Figure 3: The east side of the second level.

Photographs by Author, taken on January 21, 2021.

Figures 2 and 3 show the columns, beams, joists, and braces used in the second level construction which support the roof and walls. The main structural columns run from floor to roof, where they meet a beam spanning the length of the roof. The bases of the columns rest on a series of beams visible from the lower level. These lower-level beams are supported by larger wooden columns set on top of concrete, stone, or masonry foundations. The smaller horizontal wood pieces pictured in Figures 2 and 3 along the walls are primarily in place to give extra places to nail the wooden siding. They also help to brace the structure and add stability. This wood is called wall strapping. This is similar to the strapping on the roof that runs parallel to the roof beams. The primary purpose of this roof strapping is to allow attachment of the roof material, but it also adds stability to the structure.

Loads that are applied to Bank Barns follow complex paths to reach the soil below the structure. Roof loads are transferred from the roof material (slate, shingles, metal, etc.) to the roof strapping directly below it. The load is then transferred to the joists which run perpendicular to the beams. The load is transferred from the joists to the beams. From the beams the load is transferred either directly to the columns (in locations near the columns) or to the braces and then the columns. From the second level columns, the load is transferred to the lower-level beams. There are lower-level beams spanning the width of the barn that capture the load from the second level columns and spaced out in between these beams are smaller joists. These beams transfer the load to the larger beams that run the length of the barn. From these larger beams the load is transferred to the lower-level columns and then into the foundations.

Loads on the second level floor are transferred to the floor lumber to the joists and beams directly below it that run the width of the barn. These loads are transferred to the beams that run the length of the barn. The loads are then transferred to the lower-level columns and finally to the foundations.

For both roof loads and second level floor loads, the transfer paths stated above apply to most of the loading areas. However, the area most near the outside wall on the uphill side of the barn has a different path. Roof loads still transfer from the strapping to roof joists, to roof beams, to columns. However, once they reach the second level columns, they transfer to the lower-level wall, which is typically stone, masonry, or concrete. The load is transferred directly from this wall to the foundations and into the ground. This leads to a slightly less complicated load path. Some bank barns have all lower-level walls made from stone, masonry, or concrete. If this is the case, then this modified load path occurs for all sides of the barn and not just the uphill side.

Loads on the lower-level floor depend on the construction of the floor. Many bank barns have dirt floors. In this case the load is directly transferred to the soil. If the floor is concrete, the load is transferred to the concrete, and then to the soil.

Loads applied to the walls are transferred from the siding to the wall strapping. The load is then transferred to the columns against the outside walls. The load from here is transferred to the bracing shown in Figures 2 and 3. The load is distributed in the bracing and then runs down both the outside column, the inner column, and the diagonal bracing to the lower-level beams. From the lower level beams the load makes its way to the columns and foundations.

Loads applied to a Bank Barn follow very complex load paths, especially those loads applied to the roof. A single tributary area on the roof could have a load path that goes through 10 different pieces before being distributed to the soil. The load could go through 2 different columns, three different beams, joists, straps, and several braces. All the loads described above are relevant to common bank barn use. Roof loads come in the form of snow, rain, and wind. Wall loads come in the form of wind, and from the lateral pressure of stacking of square bales against them. Second level floor loads come in the form of items being stored on the second level. These loads are some of the most prevalent and can sometimes be tens of thousands of pounds across the second level. Lower-level floor loads can be due to livestock or storage. Self-weight is significant in Bank Barn design. This is due to the large wooden beams and columns used on the second level that must be supported by wooden beams and columns on the bottom level.

Open Span Truss Barns

Open Span Truss Barns are much different from Bank Barns and Transverse Frame Barns. They are comparable in design to Hoop Barns, with a few key differences. Open Span Truss Barns are built for the purpose of commercial livestock housing and are rarely used for anything else. They are built to house livestock in large groups. The use of trusses allows for an open span barn with no interior columns. Open Span Truss Barns are typically rather large, but this is not always the case. These barns are built on level ground sometimes with a 1% or 2% slope running the length of the barn to allow drainage. Open Span Truss Barns have only one level, with the caveat of sometimes having a small, enclosed office area with storage space above it. The aisle in the middle is used for feeding livestock, rotating livestock to different pens, walking through the barn, and many other things depending on the operation at each barn. The pens on both sides of the aisle are separated with gates and by opening and closing gates the number of pens in the barn can be adjusted. In the barn pictured in Figures 4-7, the number of pens can vary from two (one on each side) to seven. The barn is directly connected to pasture to allow sheep to easily be put outside. Figures 4 and 5 show an Open Span Truss Barn from the outside. Figure 6 shows a view of the manure storage area on the west side of the barn. Figure 7 shows a view of the same barn from the inside. The barn shown in Figures 4-7 is designed for

sheep and is capable of housing up to 400 sheep. This barn is currently operated at 300 adult breeding ewes plus their lambs seasonally, with a footprint of 62’x168’.

Figure 4: South side of an Open Span Truss Barn.

Figure 5: East side of the barn in Figure 4.

Figure 6: The manure storage area on the west side of the barn.

Photographs by Author, taken on January 21, 2021.

Figure 7: The inside of an Open Span Truss Barn designed for sheep.
Photograph by Author, taken on January 21, 2021.

The construction of Open Span Truss Barns utilizes many different types of material. The roofing is typically sheet metal roofing, with insulation underneath. The roof is supported with many closely spaced trusses that run the entire width of the barn. These trusses are supported by treated lumber columns that are placed around the perimeter of the barn. The perimeter of the barn has concrete walls that can range in height. The barn pictured has concrete walls about 30” tall. Above the concrete, the remaining area of wall is made up of either wood or movable plastic curtains. These curtains can be opening or closed by hand and allow the amount of airflow in the barn to be adjusted substantially. The perimeter of the curtain is composed of wooden blocking to hold the curtain in place and transfer loads to the columns. The area composed of curtains also has a layer of wire mesh to keep animals and large debris from entering or exiting while the curtains are completely open. The entire floor is made up of concrete, with the center aisle being raised up 1-2 feet from the pens. Wooden columns about 4 feet in height are placed at the edges

of the aisle to allow lumber to be attached and work as fencing to keep livestock out of the center aisle. There are metal gates interspersed in this fencing as well as in the pens. There are large garage style doors on the two ends of the barn to allow entry with equipment used for feeding livestock and cleaning the barn. The two long sides of the barn often do not have any doors. Outside the barn there is a manure storage area. The manure storage area is a concrete slab attached to the barn that has walls on two sides. Manure is taken out of the barn and stacked against these walls. The walls can double as a fence for adjacent pasture.

Loads applied to Open Span Truss Barns follow simple paths. Roof loads are transferred from the roof material to the strapping below it and then to the wooden trusses. The trusses carry the load to the exterior columns. The columns transfer the load to the concrete walls, which are connected directly to the ground (the walls are continuous with the concrete footing).

Loads applied horizontally to the walls are either applied to the concrete section or the curtain section. The concrete section takes the load and transfers it directly to the ground. If the load is on the curtain section and the curtains are closed, the load is applied to the curtain. If the curtains are open, no loads are applied to this section (wind flows through freely). From the curtain the load is transferred to the wooden blocking around the perimeter and then to the columns. From the columns the load can go down into the walls and then into the ground. Loads are also applied to the concrete walls in the manure storage area, and similarly are dispersed directly from the concrete wall into the ground.

All loads applied to the floor are taken through the concrete flooring directly into the ground. The concrete floor, foundations, and walls are all continuous in these barns and act as one piece.

These loads are all common in usage of Open Span Truss Barns. Roof loads come in the form of snow, rain, and wind. Loads applied horizontally on the walls come in the form of wind, lateral pressure from manure, and from the use of equipment when cleaning the barn. Loads applied to the floor come from livestock, equipment, and manure. Self-weight of the roof material and the trusses is notable, but not significant.

Hoop Barns

Hoop Barns are new to the agricultural industry. They evolved out of the Round Roof Barn. There were studies done on Hoop Barns between 2000 and 2010 by universities and further published by the United States Department of Agriculture (USDA) (3). This grew their publicity. Hoop barns utilize a PVC fabric roofing stretched over a frame of metal arches. These metal arches can be very simple for small barn designs or incorporate more complex truss style arches into some of the larger barns. The older Round Roof Barn has the same shape but rather than use metal arches and a PVC fabric roof, they used wood arches and either wood or sheet metal roofing (4). These barns have only one level and can be used for a variety of things. Many people use these solely for storage of equipment or bales (usually round bales), but these are also popularly used for livestock. While many types of livestock can be housed in hoop barns, the most popular types are swine and cattle (5). Not only are these barns versatile, but they can be constructed very quickly as well. Modern Hoop Barns are quickly becoming popular in the agricultural industry. The PVC fabric and the steel arches used in this barn are hard to procure and for this reason a specialty contractor is needed. Two popular contractors for Hoop Barns are Britespan Building Systems Inc. (Figure 8) and FarmTek (Figure 9).

Figure 8: Inside a Hoop Barn used for cattle housing constructed by Britespan (6).

Figure 9: A Hoop Barn used for hay storage constructed by FarmTek (7).

The roof on a hoop barn is made of a PVC fabric, similar to a heavy-duty tarp. It is stretched over the steel arches. These arches are supported by sidewalls which are wood, concrete, or both. The floors of hoop barns can vary from concrete to existing soil. Sometimes the floor is composed of gravel placed on top of geotextile material. The two ends of the barn can be completely open or composed of metal livestock gates. One common variation of the hoop barn is having a back wall on one side of the barn so that only one end is open. Some storage hoop barns do not use the sidewalls, and simply run the steel arches and fabric roof all the way to the ground where they are bolted to concrete (such as in Figure 9).

Loads applied to Hoop Barns have very simple paths. Roof loads are applied to the PVC fabric. The load is transferred from the fabric to the steel arches, and then to the sidewalls which are made up of either wood or concrete. These sidewalls transfer the load to the soil. In the case of a wooden wall the load is transferred from the columns of the wall straight down into the soil where the base of the column sits. The base of the column is either resting on top of concrete footing or surrounded by concrete to give the column a wider footprint. Concrete walls are continuous with a footing below them and as load reaches the wall it is transferred through the footing to the soil. Any loads applied directly to the sidewalls reach the soil in the same way as mentioned above. Floor loads are either directly applied to soil or gravel, or if applied to concrete floor they are transferred directly from concrete to the soil.

Roof and sidewall loads come in the form of wind, snow, and rain. Floor loads come from livestock, bales, or equipment being stored in the Hoop Barn. Self-weight is not notable in loading of hoop barns due to lightweight roof and arch system.

Transverse Frame Barns

Transverse Frame Barns became popular in America during the 1800's (8). These barns serve a similar purpose to a bank barn with a couple key differences. Transverse Frame Barns are two floor multipurpose barns. The lower level is used to house livestock. The upper level is used for storage of square bales. Equipment and round bales cannot be stored in the upper level because there is no easy way to get these items to the top floor and back down. The square bales stored on the second level get there by hay elevator, or they are hand thrown to the second level. The bottom level has a middle aisle that runs the length of the barn. On either side of the aisle are pens for livestock to be housed in. These pens are separated by wooden walls or by metal gates which allow combinations of pens into one larger pen. The upper level can be one complete floor spanning the whole barn (Figure 11), or sometimes the middle aisle is open on the second floor (Figure 12). If the middle aisle is open, bales are thrown down through this aisle. If there is one continuous floor with no middle aisle, the bales are thrown down small bale sized holes to the lower level. The lower level usually has one large bay door on each end, and the upper level usually has doors on multiple sides that allow access for a hay elevator.

Figure 10: Exterior view of a Transverse Frame Barn.
Photograph by Author, taken on January 27, 2021.

Figure 11: A Transverse Frame Barn with a continuous floor on the upper level.

Figure 12: A Transverse Frame Barn with an open aisle on the upper level.

Photographs by Author, taken on January 27, 2021.

The construction of Transverse Frame Barns can vary greatly and has changed over the years. Barns of this type built now typically have a sheet metal roof and siding. While older barns have wooden siding with slate or shingle roof. In newer barns, there are usually livestock gates separating the different pens that allow combinations of multiple pens into one larger pen. Older barns typically had wooden walls separating the pens, so pens could not be combined. Lower-level floors on newer barns are typically concrete, while older floors were dirt. The remaining construction is mostly composed of wood. Upper-level floors are lumber, or plywood supported by wooden beams and joists. Older style barns would have lumber floors, while newer barns have plywood. Structurally, not much has changed over the years. The roof is attached to wooden strapping, which is attached to wooden joists. These joists are supported by wooden beams. In the case of Transverse Frame Barns, these beams are often 2x10 or 2x12 lumber that are doubled up with one on each side of the column (visible at the top of figure 12). The beams are attached to the columns which run continuous from the lower-level floor up to the roof beams. Typically, there are 4 rows of columns. Two rows run the outside length of the building (one row on each side) and a row runs on each side of the center aisle. There are often wooden braces used on the second level. These can be bracing anything from joist to joist, column to column, or beam to column.

Loads applied to the roof are transferred to the wooden strapping and then to the joists. The load is transferred from the joists to the upper beams. From the upper beams the load is transferred to the columns, and because the columns are continuous the load goes directly from here to the ground. Old style barns often had columns placed directly into the ground, while new barns have concrete footing either below or around the columns.

Loads applied to the upper-level floor are transferred to the joists below them. The loads are transferred from the joists to the lower beams, and from the lower beams to the columns. Again, the loads are transferred from these columns either directly into the ground or into the ground through a concrete footing. Loads applied to the lower-level floors are either applied directly to the soil or applied to concrete. If applied to concrete, the load is transferred from the concrete to the soil.

Loads applied horizontally to the walls are transferred from the siding to the wall strapping, and then to the exterior columns. From these exterior columns, the load is transferred directly into the ground or into the ground through a concrete footing.

The roof and wall loads come from wind, rain, and snow. The loads applied to the upper-level floor come from square bale storage and from farmers walking on them. The loads on the lower-level floor come from livestock, manure, and equipment. Self-weight is notable but not significant for Transverse Frame Barns.

Comparison of Versatility and Efficiency

There are many ways to compare different barn designs. A couple of the most important qualities of barns are versatility and efficiency. Comparing different barns in these aspects will allow a farmer to see which barn is right for them. Other areas to consider are location, price, and constructability. These are common traits to compare if considering building a new barn or looking to purchase a farm with pre-existing barns. Barns can also be compared structurally to determine which barns are the most structurally sound.

When it comes to versatility, the Bank Barn leads the group. The Bank Barn is the ultimate multi-purpose barn. In the top you can store nearly anything: square bales, round bales, loose hay, large equipment, wood, etc. You can drive equipment directly into the upper level which makes storing hay much easier for both square and round bales. This also makes for an indoor area to work on equipment out of the weather. Square bales can be stacked all the way to the roof, which is higher than most other barns. Grain can be stored in the granary. There are many doors which allow easy access to different areas of the barn and preventing items from being blocked in. On the lower level, nearly any type of livestock can be housed. A farmer could easily house half a dozen types of livestock in the same bank barn at the same time, so long as they were in small groups. However, the Bank Barn was not designed to house large numbers of livestock. The bottom level can also be used for storage. For the footprint used by a barn, it is hard to beat the Bank Barn in versatility.

Hoop Barns are versatile, but with only one level they cannot compete with Bank Barns. Hoop Barns can be used for storage of nearly anything that fits inside. While they can also be used for livestock housing, they are more open to the weather than other types of barns, so

certain livestock will not do as well in cold weather. For example, finishing cows out for slaughter in a hoop barn or housing dairy cows is fine year-round, while breeding sheep or pigs may lead to deaths of lambs or piglets due to cold weather. Hoop Barns are very versatile.

Transverse Frame Barns have a versatile lower level. The lower level can be used to house most types of livestock. The ability to change from many small pens to a few large pens simply by opening gates is a plus. However, the upper level is only accessible by hay elevator or ladder. There is no way to get equipment on the top level. This leads to a very limited possibilities on the upper level, and therefore the upper level is almost exclusively used for square bale storage.

Open Span Truss Barns are low on the versatility scale. These barns are designed to raise one type of livestock on a large scale. While it is true that Open Span Truss Barns can be designed to accommodate any type of livestock, once a barn is designed for cows it will not be efficient for pigs or chickens should the farmer want to make that change. These barns are not great for storage, due to the low trusses used in the open span design.

When it comes to efficiency, The Open Span Truss Barn is the most efficient at housing livestock. The Hoop Barn and Bank Barn are the most efficient for storage. With the Open Span Truss Barn, large groups of livestock can be stored together, and there are no permanent walls separating them. With no interior columns and a concrete floor, cleaning manure is far more efficient. The doors on the ends of the barns are big enough for equipment access and allow easy movement of manure to the storage area. Feeding the livestock is very efficient because of the ability to spread feed down both sides of the center aisle using equipment. All animals can access the center aisle, so feed only needs to be put in one place. It is also quick and efficient for a farmer to walk down the center aisle and check on the livestock's wellbeing. In an Open Span Truss Barn, a farmer can see all his livestock within a minute of walking and looking due to the elevated center aisle.

For storage, both the Hoop Barn and the Bank Barn can store anything you fit in them. You can drive large equipment into both these barns. Bank barns are more efficient for storing square bales due to the height and number of accessible bays in the barns. You can stack more square bales in a Bank Barn with the same footprint, and you can have access to more stacks at once to choose from. When storing round bales and equipment, the Hoop Barn is more efficient

because there are no interior columns to have to work around. These columns are easily stacked around in a Bank Barn with square bales. However, they get in the way when using equipment to stack round bales because they take longer to operate around and cause empty space in the stack. For this reason, storing equipment and round bales in a Hoop Barn is the more efficient choice.

Table 1: Common features and efficient uses of barns.

	Bank Barn	Open Span Truss Barn	Hoop Barn	Transverse Frame Barn
Multiple levels	X			X
Efficient Storage of square bales	X		X	X
Efficient Storage of round bales	X		X	
Efficient Storage of Equipment	X		X	
Large groups of livestock		X	X	X
Variety of livestock	X			X
Full weather protection	X	X		X

Table 1 shows the common features and efficient uses of different types of barns. It must be noted that barns can be used for things inefficiently when needed. For example, round bales can be stored in a Transverse Frame Barn if need be. They can only be stored on the first floor, and the low ceilings combined with close interior columns make it very inefficient for maneuvering equipment to access them. Similarly, square bales can be stored in an Open Span Truss Barn. This practice is extremely inefficient because the ceilings are often too low to pull a hay wagon or elevator into the barn, and the bales must be carried inside. The bottoms of the trusses are low and do not allow much height for stacking. While these two practices are inefficient, they can be done. It is untrue to say that these barns cannot be used for certain things just based on efficiency. When a farmer is in a pinch, they will do whatever they can to make something work. Therefore, the analysis of potential barn use is only based on efficient use and not possible use, to make for easier comparison.

Other Comparisons

When looking at where to build a new barn, location may affect the price. If you plan to build a Bank Barn, you will need a hill with a drivable slope on one side. If you do not already have this, you will have to move dirt to the building pad. If you want to build one of the other three types of barns you will need a level area for a building pad, and if you do not have a level

area you will have to move extra dirt. All four types could be built in the same location, but it may cost more to build a certain type based on your location if you need to move extra dirt. This leads to the next thing to consider when thinking about barn design: Price.

It is hard to put a price-tag on a specific barn type because the size of the barn is not dictated very closely by the type. Also, many barn designs will vary slightly from each other even within the same barn type. For example, a Transverse Frame Barn with a complete upper floor will cost more than the same type of barn with an open aisle. Another reason is the construction industry constantly changes. This means what may have been common practice in construction 100 years ago could now be specialty work, which will cost more. A rough price comparison can be found for each barn type, assuming the barns have the same footprint and that they all have concrete floors on the low level. For this comparison it is also assumed that the farmer is not completing the construction on their own, and it is contracted out.

The most expensive barn to build today is the Open Span Truss Barn. The main reason for this is the large variety of materials used in its construction. The large variety of materials used in its construction require extra labor to have installed in different sequences. There are a lot of prefabricated trusses that are very large in size. The concrete is thicker than in many other barn floors. There is extra concrete work required for the center aisle, walls, and manure storage area. On average these barns are the largest in footprint which also adds to price, but this is disregarded in the comparison.

The second most expensive barn to build today is the Bank Barn. The Bank Barn is expensive due to the height of the barn, and the fact that in the 21st century these barns are specialty work. The materials used are mostly wood, but the volume of material required is larger than the other barn types. New construction of Bank Barns today is not as common as it was just 50-75 years ago. For this reason, a specialty contractor is needed to complete this construction. Not all construction companies will be comfortable with putting together the intricate wooden beam, column, and brace structures correctly. These specially contractors will charge more for their select knowledge and experience.

The Transverse Frame Barn is the second cheapest type of barn to be built today. This barn is simple in design and uses mostly wood and/or sheet metal. These barns are not as tall as bank barns and require less material. This is not specialty work and most barn contractors will be

proficient. In fact, construction of this barn is sometimes undertaken by a farmer who has some knowledge and experience in construction. If the farmer undertakes the construction on his/her own, this barn can the cheapest option.

The Hoop Barn is the cheapest barn built today based on footprint. This is because there is very little material used and the construction time is extremely quick. Construction of Hoop Barns is specialty work, but with the large area of roof being PVC Fabric they go up cheap and fast. The prefabricated metal arches are expensive materials, but they allow labor costs to be significantly reduced.

In terms of constructability, the Transverse Frame Barn is the simplest to build. Farmers sometimes undertake this construction on their own. There is nothing complex in the design and all the materials are easily accessible. Hoop Barns have a very simple design, but the materials are hard to come by. This leads to using specialty contractors who can procure the materials. Bank Barns are low in constructability because they have complex structural systems, and the wooden beams can be hard to procure. Open Span Truss Barns are low in constructability because of the wide range of materials needed and complex construction sequence.

When it comes to structural safety, the Open Span Truss Barn and the Hoop Barn are the best. The Open Span Truss Barn has numerous wooden trusses that support the roof, and the even more numerous wooden columns that transfer load from the trusses to the concrete walls. The concrete walls and floor act as one structure and can take large loads. If one or two wooden trusses were damaged by a piece of equipment, the building would remain standing and likely no serious injury would come to the operator. The trusses or columns damaged are not very large and they are attached in many locations to other structural members. This makes them unlikely to harm the operator. Compare this with some other barns and this is not the case. In a Bank Barn, if someone operating heavy equipment were to seriously damage a wooden column or beam not only would the structure be at risk of failure, but the falling beam or column poses imminent danger to the operator. These wooden beams and columns have size large enough to kill the operator if they fall on them. Damaging these heavy wooden members would take substantial force, but with modern equipment it is very possible. Similarly, in a Transverse Frame Barn, if an operator were to take out an interior column the second floor could come crashing down on them from above. This is increasingly likely if the second floor is stacked full of square bales,

adding thousands of pounds to the falling load. Like the Open Span Truss Barn, the structural safety of the Hoop Barn is very high. There are no interior columns to hit, and if a metal arch were to be taken out the structure would still stand. The PVC fabric puts almost no load on the metal arches. The metal arch that is hit could fall, but it weighs little compared to the falling objects produced in the previous two scenarios. A big reason that Open Span Truss Barns and Hoop Barns are safer structurally, is they have no interior columns and there is less chance of critically damaging the structure through common use.

Table 2: Ranking of the barns in comparable aspects, where 1 is most favorable and 4 is least favorable for a given aspect.

	Bank Barn	Open Span Truss Barn	Hoop Barn	Transverse Frame Barn
Versatility	1	4	2	3
Storage Efficiency - Square Bales	1	4	2	3
Storage Efficiency - Round Bales, Equipment	2	3	1	4
Livestock Efficiency	4	1	2	3
Cost	3	4	1	2
Constructability	3	4	2	1
Structural Safety	3	1	2	4

It is important to note that the above Table 2 is ranking all four barn types in all categories, whether they are efficient in these categories or not. Table 1 only shows what barns are efficient for what purposes. For example, in Table 1 Transverse Frame Barns and Open Span Truss Barns are not listed for efficient storage of round bales or equipment. While in Table 2 both are ranked as unfavorable. While neither barn is favorable for this purpose, Table 2 recognizes that they are both capable and one is more favorable than the other.

The lifespan of a barn is also an important factor to consider. With how new to the industry Hoop Barns and Open Span Truss Barns are, it is not proven how long they last. Most of these barns that have been built are still around and in great shape. Of the two older styles of barns, more knowledge is available. It is widely thought that Bank Barns last longer than Transverse Frame Barns. This is because Transverse Frame Barns have smaller wooden columns which are often exposed to dirt or manure. This leads to the rotting of the main structural columns of the barn. Bank Barns avoid this by use of masonry, concrete, or stone, as walls in contact with the ground, and for foundations below wooden columns. The wooden columns are

also substantially bigger in Bank Barns. Due to the comparatively short time some barns have been in the industry, a fair comparison of all four types is not legitimate.

Conclusion

The Agriculture industry is always changing, and individual farmers always have specific business plans. Some farmers only need barns to store equipment and/or bales. While other farmers only need barns to store their livestock. Some farmers may need barns for housing livestock, storage of bales, and storage of equipment. Farmers may desire to put up one barn for all their needs, or to put up a dozen barns of various types and sizes. There is no one type of barn design that is superior to the others. Each barn type has advantages and disadvantages, and the best barn is determined by what the end use of the barn will be. Bank Barns, Open Span Truss Barns, Hoop Barns, and Transverse Frame Barns are all structurally sound and have very different ways of distributing loads into the soil that supports them. The constructability of these barns varies greatly. This variation is based on structural complexity and the different construction materials used. Older barns such as 100-year-old Bank Barns, were built using wood, nails, hand tools, hoisting ropes, manpower, and sometimes livestock. Modern Open Span Truss Barns are built using modern machinery and dozens of construction materials. The four barn types discussed are by no means all encompassing. These are just a few of the common types built in America over the past 300 years. There are many other types of barns, as well as modified versions of these four types. People are constantly modifying existing barn designs to make the barn more applicable to their business plan and daily operation. Agricultural construction has been, and will continue, growing more complex to fit the current agricultural industry. In the future, it will be interesting to see what happens in the agriculture industry, and what reflective changes are seen in barn design.

References

(1) *Pennsylvania Barn*, Pennsylvania Historical and Museum Commission. August 26, 2015

Date Accessed 1/19/2021

http://www.phmc.state.pa.us/portal/communities/agriculture/field-guide/pennsylvania-barn.html

(2) *Bank Barn*, History Colorado.

Date Accessed 1/19/2021

https://www.historycolorado.org/bank-barn

(3) *Hoop Barns for Livestock: An Innovating Housing System*, United States Department of Agriculture. September 14, 2007

Date Accessed 1/28/2021

https://reeis.usda.gov/web/crisprojectpages/0199570-hoop-barns-for-livestock-an-innovative-housing-system.html

(4) *Round-Roof Barn*, History Colorado

Date Accessed 1/21/2021

https://www.historycolorado.org/round-roof-barn

(5) *Hoop Structures for Beef*, Leopold Center for Sustainable Agriculture

Date Accessed 1/26/2021

https://www.leopold.iastate.edu/hoop-group/hoop-structures-livestock-beef

(6) *Beef and Cattle Barns*, Britespan Building Systems Inc.

Date Accessed 1/26/2021

https://www.britespanbuildings.com/uses/beef-barns/

(7) *Hay Storage Buildings*, FarmTek

Date Accessed 1/26/2021

https://www.farmtek.com/farm/supplies/cat1;ft_fabric_buildings;ft_hay_storage_buildings.html

(8) *Transverse Frame Barn*, History Colorado.

Date Accessed 1/21/2021

https://www.historycolorado.org/transverse-frame-barn