Sustainable Skyscraper Design
Activity Specifications
MESA Day 2020

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ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

LEVEL:	Middle School/High School
NUMBER OF TEAMS:	One (1) team per school can participate at the MESA Day state competition. Up to Three (3) teams can participate at MESA Regionals. Subject to change.
TEAM MEMBERS:	Two (2) to four (4) students
OBJECTIVE:	Students will design a skyscraper while considering sustainable engineering, existing techniques civil engineers use for sustainable development, and how they can improve a project overall.

MISSION AND SUMMARY

Civil Engineering is challenged with various aspects of infrastructure every day. The MESA ***Support the Sky Competition*** increases awareness of real-world engineering issues such as spatial constraints, material properties, strength, serviceability, fabrication and building processes, safety, esthetics, project management, and cost. Success in this competition requires application of engineering principles and theory, and effective teamwork. Future engineers are stimulated to innovate, practice professionalism, and use materials efficiently. Students must design the skyscraper themselves but may consult with faculty and other advisors. Students gain maximum benefit if they plan out and design the building by themselves. Safety is paramount. ASCE requests that competitors, advisors, hosts, and judges take all necessary precautions to prevent injury to competitors, judges, host personnel, and spectators. Risky procedures are prohibited. The Competition provides design and management experience, opportunities to be creative with building layouts, and the excitement of networking with and competing against teams from other schools.

The rules simulate a request for proposal with realistic challenges encountered in building design work and construction. Competition judges and the Rules Committee take the role of the "*owner*" and have authority to accept and reject entries.

The rules accommodate a variety of designs and encourage innovation and creativity. Students must consider the comparative advantages of various alternatives. For example, what materials will be used to construct different parts of the building? Consider functionality or aesthetics (e.g. layout, furnishing, space planning, etc). How tall or wide do you need your building to be?

Successful teams compare alternatives prior to fabrication using value analysis based on scoring criteria.

The rules are intended to be prescriptive but may require some interpretation. The procedure for requesting clarification is on the MESA website.

Members of the Sustainable Skyscraper Design Rules Committee are:

- Benjamin Mitchell, ASCE Southern Arizona Branch Younger Member Forum Treasurer
- Daniela Shelley, ASCE Southern Arizona Branch Younger Member Forum Secretary
- Jose A. Aguilar, P.E., ASCE Southern Arizona Branch Younger Member Forum President

PROBLEM STATEMENT

The City of "MESA" has provided the funds to design and build a new skyscraper. This project is to increase the highrise buildings in the main downtown area, but doing so with the least cost to the city. The new building is to provide a new home for many new small companies and citizens, who will be renting out sections of the building for office space and housing. The City of "MESA" requests that each team minimize the design costs of the skyscraper while also getting the most out of the total floor space. By today's definition, a building must be at least 40 floors to be considered a skyscraper. Tall buildings, such as skyscrapers, need a well-supported foundation. Soil type and loads such as wind loads and earthquakes should be taken into consideration for the new skyscraper's location. Serviceability, construction cost and duration, material cost, and aesthetics are critical considerations as well. As engineers, we are always considering sustainable efforts for the future. The U.S. Green Building Council (USGBC) formed a rating system to help guide and aim us towards "going green." This system is known as Leadership in Energy and Environmental Design (LEED) . You are challenged to earn a LEED certification for your skyscraper. We included a simplified version of an excel checklist for you to reference. Each competing firm (team) is requested to submit a building model to demonstrate their vision and concept. The City of "MESA" engineers will judge the concept drawings, an engineering design notebook, and presentation by multiple criteria that is included below and in the rubric. The contract will be awarded to the "firm" who's concept satisfies specified requirements and best achieves project objectives.

GLOSSARY

- *Building* - A structure with a roof and walls, such as a house, school, store, or office.
- *Skyscraper* - A continuously habitable high-rise building that has over 40 floors and is taller than 150m(492ft).
- *"Going Green"* - To pursue knowledge and practices that can lead to more environmentally friendly and ecologically responsible decisions and lifestyles, which can

help protect the environment and sustain its natural resources for current and future generations.

- *Building Footprint* - The outline of the total area of a site that is surrounded by the exterior wall of a building.
- *Scale* - The relationship (or ratio) between distances, areas and/or volumes.
- *Floor Plan* - A drawing to scale, showing a view from above, of the relationships between rooms, spaces, traffic patterns, and other physical features at one level of a structure. Dimensions are usually drawn between the walls to specify room sizes and wall lengths.
- *Foundation* - The lowest load-bearing part of a building, typically below ground level.
- *Column* - An upright pillar, typically cylindrical and made of stone or concrete, supporting an entablature, arch, or other structure or standing alone as a monument.
- *Arch* - A curved symmetrical structure spanning an opening and typically supporting the weight of a bridge, roof, or wall above it.
- *Entablature* - A horizontal, continuous support on a building supported by columns or a wall.
- *Entrance* - An opening, such as a door, passage, or gate, that allows access to a place.
- *Exit* - A way out, especially of a public building, room, or passenger vehicle.
- *Parking Lot* - An area where cars or other vehicles may be left temporarily.
- *Crosswalk* - A marked part of a road where pedestrians have the right of way to cross.
- *Floor* - The lower surface of a room, on which one may walk.
- *Door* - A hinged, sliding, or revolving barrier at the entrance to a building or room.
- *Window* - An opening in the wall or roof of a building that is fitted with glass or other transparent material in a frame to admit light or air and allow people to see out.
- *Wall* - A continuous vertical brick or stone structure that encloses or divides an area of land.
- *Roof* - The structure forming the upper covering of a building.
- *Swimming Pool* - An artificial body of water for swimming in.
- *Hallway* - An area in a building onto which rooms open; a corridor.
- *Deck* - A flat surface capable of supporting weight, similar to a floor, but typically constructed outdoors, often elevated from the ground, connected to a building.

- *Brick* - A small rectangular block typically made of fired or sun-dried clay, used in building.
- *Wood* - The hard fibrous material that forms the main substance of the trunk or branches of a tree or shrub, used in building.
- *Steel* - A hard, strong, gray or bluish-gray alloy of iron with carbon and usually other elements, used extensively as a structural and fabricating material.
- *Concrete* - A heavy, rough building material made from a mixture of broken stone or gravel, sand, cement, and water, that can be spread or poured into molds and that forms a mass resembling stone on hardening.
- *Masonry* - The art and craft of building and fabricating in stone, clay, brick, or concrete block.
- *Glass* - A hard, brittle substance, typically transparent or translucent, made by fusing sand with soda, lime, and sometimes other ingredients and cooling rapidly.
- *Plexiglass* - A transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass.
- *Furnishing* - Furniture, fittings, and other decorative accessories, such as curtains and carpets, for a house or room.
- *Lighting* - Equipment in a building for producing sufficient and artistic light.
- *Space Planning* - A fundamental element of the interior design process. It starts with an in-depth analysis of how the space is to be used.
- *Storage* - A space available for storing items for future use.
- *Builder* - Student members of a team who are within the construction site at the start of timed construction.
- *Tool* - A device or implement, especially one held in the hand, used to carry out a particular function.
- *Load* - Forces applied to structural components or members.
- *Dead Load* - The intrinsic weight of a structure or vehicle, excluding the weight of passengers or goods.
- *Live Load* - The weight of people or goods in a building or vehicle.
- *Snow Load* - The downward force on a building's roof by the weight of accumulated snow and ice.
- *Wind Load* - The force on a structure arising from the impact of wind on it.

- *Earthquake (Seismic) Load* - Application of an earthquake-generated agitation to a building structure.
- *Free body Diagram (FBD)* - A graphical illustration used to visualize the applied forces, moments, and resulting reactions on a body in a given condition.
- *Member* - A rigid component composed of a strong material. A member shall retain its shape, dimensions, and rigidity during construction and load testing.
- *Force* - Any action applied to an object which would cause the object to move, change the way it is currently moving, or change its shape. A force can also be thought of as a push (compressive force) or pull (tensile force) acting on an object.
- *Force Vector* - A force vector is a graphical representation of a force.
- *Deflection* - The distance, perpendicular to the load, at which a structure displaces under said load.
- *Lateral Force* - The force that acts in the direction parallel to ground and perpendicular to the direction of gravitational pull of earth.
- *LEED (Leadership in Energy and Environmental Design)*- is an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO_2 emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts.

DESIGN PARAMETERS

1. Design a skyscraper! Consider the definition of a skyscraper in today's age. How tall does the building have to be to be considered a skyscraper? How many floors? How tall (in feet) and how many floors is your skyscraper? (see current definition of skyscraper) Include the references you used to determine this. Civil engineers design to meet the client's needs while considering sustainability. Consider this in your design. (ex: a 3,000 ft tall building might be cool, but it might be excessive and over budget)
2. What might happen to a skyscraper when *lateral forces (see glossary)* from wind or an earthquake are applied to it compared to a shorter building? How does the building react to these forces? Include a description and if possible an analysis in your notebook.
3. What is the shape of your skyscraper? Why did you decide to use this shape?
4. What material(s) is your skyscraper made of? Justify why you used this material.
5. Using google maps, find a location where you would construct the skyscraper. **Include** a screenshot of the area with a *building footprint (see glossary)* of where the skyscraper will sit on the land. Consider the best soil type for construction.What makes this soil the

most desirable for construction? What are some extreme weather conditions that the structure may have to withstand? (For this project, you may choose to construct anywhere in the United States, even if there are buildings existing in the area.) Explain why you chose to construct in this location.

6. **Include** an architectural sketch that shows what you want the building to look like from the outside. You can draw by hand or use any design software such as SketchUp, TinkerCAD, OnShape, Minecraft, Factorio, etc. You will be judged based on creativity, not technical skill, so get creative!!

7. **Include** engineering drawings. Using the grid paper and scale provided, draw at least 2 floor plans, 1 front view drawing, and 1 side view drawings. Label entrances, exits, dimensions, etc. (See the example for guidance)

8. How can you make your overall design sustainable? How can you promote sustainability for visitors? (e.g. use less material, include recycle bins inside, solar panels, skylight etc.) Aim to achieve a LEED certification for your skyscraper. (Reference the LEED table for more ideas.) What certification did you get to and why?

Engineering Notebook & Drafting

The team will be required to submit an Engineering Design Notebook. Each person in the group may have their own notebook, but the team will need to compile the information into one project notebook for scoring purposes. The Engineering Design Notebook will be judged by the criteria shown in the attached rubric. Include a table of contents with labeled sections based on the rubric's sections.

Engineering Presentation

The team will be asked to present or submit a recorded video presentation. The presentation is judged by the criteria shown in the rubric below. The presentation needs to be between 5 and 10 minutes in length. Presentations under or over will be penalized. See rubric for more information. All presentations will be cut off at 10 minutes. Students will be given a warning when they have 3 minutes left and when they have 1 minute left.

Scoring

Design Notebooks will be worth a total of 34 points then multiplied by 2 for a total of 68 points.

This can be found on the Engineering Design Notebook (EDN) Rubric.

"LEED" certifications are worth a total of 6 points and are then multiplied by 2 for a total of 12 points. This can be found on the Engineering Design Notebook (EDN) Rubric.

Presentations are worth a total of 50 points and are then multiplied by 2 for a total of 100 points. This can be found on the Engineering Presentation Rubric.

Final Score will be a sum of the above three categories and worth up to a total of 170 points.

RESOURCES

Grid Paper (if you can't print, create your own grid paper following this tutorial):

https://www.youtube.com/watch?v=RxN4Ph-DPuo

How to establish a scale:

https://www.wikihow.com/Draw-a-Floor-Plan-to-Scale

LEED:
https://www.usgbc.org/?utm_medium=ppc&gclid=Cj0KCQjw7Nj5BRCZARIsABwxDKIv5JoloQgK0BL98qmWkkQ2hI5uOyNFOyk3ufgNJ497aZDIClw6y6YaAuCNEALw_wcB

Digital Notebook Templates are available; ask your MESA Advisor for more information.

Explanation of MESA LEED Certification*

LOCATION AND TRANSPORTATION:

The building is in a space where it is easy for people to get to it while reducing their carbon footprint.

LEED for Neighborhood Development Location

The building is designed to be a gathering place for large numbers of people. Examples include: Community Center, Library, University building.

Sensitive Land Protection

The building is replacing an older building OR does not harm the environment (i.e. floodplain, critical habitats, bodies of water, etc)

Surrounding Density and Diverse Uses

The building is created to be both commercial (stores, restaurants, etc) and residential (living spaces) to be comfortable for all users (not overcrowded)

Access to Quality Transit

Access to public transit (bus, streetcar, etc) is within ¼ mile of the building. The access point needs to be a high traffic point

Bicycle Facilities

The building must have bicycle parking within 200 yards of the building for, at minimum, 5% of building users

Reduced Parking Footprint

The new construction does NOT have parking in front of building. Parking is ground level or below (if under building). Spaces for carpooling/shared use are in best parking locations

Green Vehicles

5% of parking spaces are for green vehicles (electric, hybrid, etc) with charging stations

Sustainable Sites

The site has been checked to make sure it will be part of the natural environment and will not cause damage to the habitats around it.

Site Assessment

The designers look at topology (the shape of the land), climate (solar access, temperatures, etc), and human use (views, access to transportation, neighborhood)

Site Development - Protect or Restore Habitat

The building protects habitats of plants and animals within the building space OR works to restore habitats that are in danger of extinction

Open Space
The building's design creates exterior open space that encourages interaction with the environment, social interaction, passive recreation, and physical activities.

Rainwater Management
The building uses rainwater harvesting for watering plants and has a holding tank for excess to be used in times of little rain

Water Efficiency
The building is designed to be water efficient. Measures are in place to ensure this both inside and outside the building.

Outdoor Water Use Reduction
Indoor Water Use Reduction
Building-Level Water Metering
These plans need to be in place. The sections below expand on these.

Outdoor Water Use Reduction
The building does NOT need outside irrigation for the plants

Indoor Water Use Reduction
The building has plans to limit water flow and reuse water (if applicable)

Energy and Atmosphere
The building collects and uses energy from natural sources (solar, wind, etc)

Optimize Energy Performance
The building can has systems in place (solar panels, windmill, etc) to harvest and store energy for the building's use.

Renewable Energy Production
The building has a high percent of its energy from natural resources

Green Power and Carbon Offsets
At least 50% of the power used by the building is from natural resources or carbon offsets (demonstrating the drop in carbon energy by 1 metric ton)

Indoor Environmental Quality
The interior of the building ensures that the environment is pleasant and safe for all users.

Environmental Tobacco Smoke Control
Controls to prevent any smoke from tobacco users enters the building are in place

Enhanced Indoor Air Quality Strategies
Main entry point is, at minimum, 10 feet long to control dust entering the building, natural ventilation is used as often as possible, and rooms where hazardous gases (car exhaust, printing, etc) are present are naturally ventilated.

Thermal Comfort
Users of the building have access to thermal controls (i.e. thermostat) to control energy efficient HVAC systems

Interior Lighting
The lights are designed for at least 90% of users to have access to controls. The lights are also energy efficient and simulate natural lighting

Daylight
Natural lighting is used to light spaces and reduce the need for artificial lighting in at least 25% of the building.

Quality Views
Users of the building have multiple views of nature with a 90 degree angle of view

Innovation
Innovation is design is evident in the building's design.

Presentation:

Category	Exceeded Criteria (3 points)	Met Criteria (2 points)	Poor (1 point)	Not Present (0 points)
Introduction: The team introduced all members and their school			YES	NO
Flow: The ideas/concepts flowed well together				
Organization: The information presented was well organized and easy to follow				
Transitions: All transitions are smooth				
Teamwork: The team worked well together				
Professionalism: The team was professional during the presentation				
Content: The team provides thorough explanations of their design				
Extra Information: All information was related to the building and no extra information was present				
Knowledge: The team's knowledge of the concepts is strong				
Presentation: The presentation has style and creativity				
Media Choice: The presentation media (Google slides, PowerPoint, etc) is well utilized in supporting flow of presentation?				
Visual Aids: Visual aids (drawings, images, charts, etc) were used effectively to highlight important points or features				
Visual Aid Integration: Visual aids fit into the presentation and enhanced talking points				
Creative Media: Creative media (CAD program, Minecraft, etc) was used effectively to create a prototype				
Sound: Voiceover was clear and easily heard				
Team Contribution: Each team member had a chance to speak or participate				
Speaking speed: Speaking speed was natural for team members. The information was not read.				
Time: The presentation was within 5 to 10 minutes	**TIME:**		YES	NO
Column Totals				
			SUBTOTAL	
			SUBTOTAL x2	
			TOTAL SCORE	

Sustainable Skyscraper Design
Notebook Rubric
MESA Day 2021

Rubric for Engineering Design Notebooks (EDN)

EDN Goals:

1. Explore	**3**	**2**	**1**	**0**
□ Described Design Objective □ Described Prior Knowledge □ Described Brainstorming	All	Most	Some	None
□ Has Research documented with at least 5 sources (website, book, video, article, interviews, etc.) □ Research is reliable (i.e. from experts, researched websites, several sources agree, etc.)	All	Most	Some	None
2. Design	**6**	**4**	**2**	**0**
□ Appropriate building height (using current skyscraper definition and considering sustainability—do not be wasteful of material) □ Described materials used. Justify why you chose this material. □ Described Architecture (what kind of rooms are inside, what is the building used for, etc.) □ Described shape of skyscraper overall. Why did you decide to use this shape?	All	Most	Some	None
□ Explanation of lateral force causes and effects that a skyscraper would see. (ex: wind is a lateral force. What are its effects on such a tall structure?) □ Google maps building footprint (see example provided) □ Described selected soil type. What makes this good soil to build on? □ Described sustainable design considerations. Use the LEED table for reference.	All	Most	Some	None
□ Includes sketch/photo of initial prototype □ Includes sketch/photo of final prototype	All	Most	Some	None
3. Engineering/Architectural Drawings	**6**	**4**	**2**	**0**
□ Creativity of architectural drawings (Judged based on creativity, cleanliness, and labeling--NOT technical skill) □ Quality of Engineering drawings (dimensioning, labeling, accurate scale, etc.) □ Includes 2 floor plans, 1 front view, 1 side view	All	Most	Some	None
4. EDN Organization	**3**	**2**	**1**	**0**
□ Has Table of Contents or clearly labelled sections □ Notebook is organized	All	Most	Some	None
4.2 Labeled. □ Clearly labeled with School and Team Members names.			Yes (1)	No (0)

5. LEED Credits	**6**	**5**	**4**	**3**	**0**
□ LEED Certification	**Platinum**	Gold	Silver	Certified	None
Column Totals (for selected categories)					
			Total (out of 40)		

Comments/Suggestions:

LEED v4 MESA for New Construction

Project Checklist

Project Name:

Date:

Key:
2 = Definitely present
1 = Is partially present
0 = Not present

2	1	0				
			Credit	Integrative Process		0
0	0	0	**Location and Transportation**			0
			Credit	LEED for Neighborhood Development Location		
			Credit	Sensitive Land Protection		
			Credit	Surrounding Density and Diverse Uses		
			Credit	Access to Quality Transit		
			Credit	Bicycle Facilities		
			Credit	Reduced Parking Footprint		
			Credit	Green Vehicles		
0	0	0	**Sustainable Sites**			0
			Credit	Site Assessment		
			Credit	Site Development - Protect or Restore Habitat		
			Credit	Open Space		
			Credit	Rainwater Management		
0	0	0	**Water Efficiency**			0
			Prereq	Outdoor Water Use Reduction		
			Prereq	Indoor Water Use Reduction		
			Prereq	Building-Level Water Metering		
			Credit	Outdoor Water Use Reduction		
			Credit	Indoor Water Use Reduction		
0	0	0	**Energy and Atmosphere**			0
			Credit	Enhanced Commissioning		
			Credit	Optimize Energy Performance		
			Credit	Renewable Energy Production		
			Credit	Green Power and Carbon Offsets		

0	0	0	**Materials and Resources**			0
			Prereq	Storage and Collection of Recyclables		
				Building Life-Cycle Impact Reduction		
			Credit	Building Product Disclosure and Optimization - Environmental Product		
			Credit	Building Product Disclosure and Optimization - Material Ingredients		
0	0	0	**Indoor Environmental Quality**			0
			Prereq	Environmental Tobacco Smoke Control		
			Credit	Enhanced Indoor Air Quality Strategies		
			Credit	Thermal Comfort		
			Credit	Interior Lighting		
			Credit	Daylight		
			Credit	Quality Views		
0	0	0	**Innovation**			0
			Credit	Innovation		
			Credit			
0	0	0	**Regional Priority**			0
			Credit	Regional Priority: Specific Credit		
			Credit	Regional Priority: Specific Credit		
			Credit	Regional Priority: Specific Credit		
			Credit	Regional Priority: Specific Credit		

0	0	0	**TOTALS**	Possible Points:	0

Certified: 30 to 39 points, **Silver:** 40 to 49 points, **Gold:** 50 to 64 points, **Platinum: 65** to 72