AC 2008-459: VERTICALLY INTEGRATED MULTI-DISCIPLINARY DESIGN PROBLEM CASE STUDY ASSESSMENT

Zachary Gutierrez, University of Wyoming
Graduate Reserach Assistant

Charles Dolan, University of Wyoming
H. T. Person Professor of Engineering, University of Wyoming

Vertically Integrated Multi-Disciplinary Design Problem Case Study Assessment

Abstract

The National Science Foundation is sponsoring a vertically integrated multi-disciplinary capstone problem study based on the technology of wind turbines and windmills. The project develops a series of capstone problems and provides background information and an instructor's solution manual. Students use the background information to solve problems for classes in Introduction to Engineering, Engineering Problem Solving, Statics, Dynamics, Mechanics of Materials, Thermodynamics, Fluid Mechanics, Circuits, and Structural Analysis.

The assessment methodology uses a rubric based on Bloom's Taxonomy to evaluate how multiple experiences with the same problem from various perspectives improve students' critical thinking. The paper explains the development of the Learning Score rubrics based on Bloom's Taxonomy and includes data on a semester of evaluation.

Introduction

The purpose of this study is for the University of Wyoming and associated colleges to evaluate the level of learning that the students display in a longitudinal study. By comparing the results of similar courses inside and outside of specific departments, instructors have the opportunity to adjust their courses to improve the students educational experience. Tying the Engineering Science Courses together with a realistic and interesting project, such as wind turbines, is intended to increase student interest and create a desire to further their education as well as increase their learning levels.

Bloom's Taxonomy[1,2,3] was selected as an assessment tool for this project. It is one of the most identifiable tools for examining student's cognitive skills. In this case the cognitive skills are the learning levels and critical thinking skills of engineering students. Since its creation in the 1950's, Bloom's Taxonomy has been widely studied and accepted as the standard evaluation tool. By using Bloom's Taxonomy, people not associated with engineering education can identify with this multi-disciplinary project and its objectives. Bloom's Taxonomy forms the basis for the development of assessment rubrics used as evaluation tools.

The assessment evaluation is independent of problem grading. The class grade is based on the instructor's objectives, while the cognitive assessment is based on rubrics independent of the numerical solution. It was never Bloom's idea to have his taxonomy used to provide course grades. A participating student may demonstrate a high level of critical thinking, yet receive a poor course grade or vice versa. Therefore, the use of Bloom's Taxonomy to provide a course grade is invalid.

Experimental Approach

The integrated program focuses on Engineering Science courses. These include Statics, Dynamics, Mechanics of Materials, Fluids, Thermodynamics, Circuits, Structural Analysis, and Engineering Economics. A comprehensive problem is developed for each course and is assigned midway through the term. Midway was selected by participating faculty because sufficient principles have been presented and the timing avoids conflict with year-end exams.

Bloom's Taxonomy identifies six levels of cognitive reasoning: knowledge, comprehension, application, analysis, synthesis, and evaluation. These are summarized in Appendix I. Each problem is developed to require students to apply concepts (Bloom's Taxonomy level 3) and to analyze results (Bloom's Taxonomy level 4). Each student's submittal is evaluated and assigned a Learning Score between 1 and 6 roughly correlating to Bloom's Taxonomy levels. The average Learning Score for a class should be between 3 and 4 the first time students are exposed to a problem. Over a longitudinal exposure to multiple problems, the Learning Scores would be expected to rise. In addition to Learning Scores, each problem is identified with one or more of the ABET a-k outcomes[4]. Learning Scores in combination with ABET outcomes allow creation of three rubrics; a short and long term cognitive assessment, and an ABET assessment. Learning Scores as an assessment mechanism will be examined first.

Two Learning Score rubrics are developed based on Bloom's Taxonomy levels. A general rubric, Appendix I, provides the global definition of the six levels of cognitive thinking. The specific rubric, Appendix II, interprets the general rubric for a specific problem. The specific rubric provides the criteria used for the assessment of individual cognitive skills in this project. The rubrics use the labels from Bloom's Taxonomy to provide evaluators and instructors with a recognizable, standard label for each level.

Two rubrics provide consistency of evaluation. First, the general rubric identifies characteristics that apply to all of the problem sets. The general rubric organizes the information to ensure each specific rubric follows the same format and preserves the integrity and consistency of the project results. Information that applies to an individual problem is summarized and captured in a specific rubric. Both rubrics are essential to the success of the assessments.

All problem sets are based on a 1.8 kW residential wind turbine. The residential turbine was selected because there is considerable data available to provide background information, actual sizes for comparison, and the students can relate to this size project. Alternative problems may be developed for ranch windmills and commercial wind turbines. Using a common turbine assures that lessons in one class carry forward to the next class. Thus, the same turbine evaluated in the statics problem is revisited in the dynamics, thermodynamics, and mechanics of materials problems.

The statics problem shown in Appendix III demonstrates the project and the use of Learning Scores. This residential wind turbine installation problem is developed to meet five objectives. First, students will have the opportunity to visualize the installation of the turbine. Second, they use statics to perform calculations to determine forces in a cable. Third, they size the cable and evaluate the solution. Fourth, they comment on concerns they have and offer suggestions to improve the methods and equipment used to erect the residential wind turbine. Finally, the students develop writing skills by summarizing their results in a one page typed memo to the course instructor. The memo provides supplemental insight to assess the students' global understanding and cognitive level.

The problem shown in Appendix III has a problem statement and a schematic diagram to help the students visualize the problem. Background data provides the basis for design choices and the completion of this project. The solution requires critical thinking and knowledge of statics' principles to complete the problem. The problem includes elementary design judgment by requiring the student to select appropriate cables.

This problem is designed to be more difficult and complex than the typical textbook exercise. The capstone problem requires a comprehensive understanding of several principles covered in statics. In addition, the problem suggests a parametric solution. The student must estimate anchor locations and solve the geometry multiple times to produce an optimal solution. Thus, the problem has been designed to use software packages such as Microsoft Excel, MathCAD, Engineering Equation Solver, or Matlab. The problem increases interest in the course by examining a real life problem at a scale students relate to and asking the students to give their feedback. According to one course instructor, the students were discussing the problem long after it had been turned in for evaluation.

This project assumes there is a course instructor and a student teaching assistant (TA). The general rubric for this problem is the same for all problems in the 1.8 kW wind turbine series and contains the background information for the project. This information is given in the "Assessment Notes" section. It informs the instructor and the TA of the project details. The "Assessment Notes" section presents the order of proceedings for the project. This lets the instructor and the TA know their contributions to the overall project and helps them incorporate the capstone problems into their schedules. One objective of the research is to allow the TA to conduct the Learning Score evaluation.

The section in the general rubric labeled "Bloom's Taxonomy General Assessment: Leading to Creation of Learning Scores" ties the students' solution to the learning levels associated with Bloom's Taxonomy. Under each Learning Score heading is a description that the TA uses to evaluate the qualities of the students' solutions. The students' solutions won't follow the exact qualities stated in the rubric because it is impossible to list the infinite number of student solutions. Based on this overview the TA assigns a Learning Score of 1 to 6 to each student's solutions.

The specific rubric applies to the individual course problem. It identifies specific features of the solution that correspond to the Learning Score and assists in providing consistent, repeatable assessment results. The specific rubric contains background information on which ABET objectives are incorporated in the problem.

Problem Development & TA Training

The creation of the specific rubric coincides with the creation of its accompanying problem. Joint development ensures that the problems and rubrics are appropriately linked. Concurrent development improves the chances of targeting the problem at the appropriate Learning Score when creating the documents and improves the problem and solution flow. The problem flow is important for evaluation since problem flow allows for the TA to examine the students' solution and identify qualities and cognitive skills. This ensures that there are fewer evaluation issues and reduces scatter that could occur with this type of study.

The integrated problem assessment proceeds in the following order. The problems are distributed among the classes. While students solve the problems, there is an evaluation training session to teach the TAs the assessment process. The problem solutions are collected, graded for class purposes, and Learning Scores are recorded separately. The assessment data is then compiled and analyzed.

All TAs meet and are trained simultaneously. This is beneficial since they all hear the methodology, questions, and concerns that are asked by the other TAs during training. During the training seminar, a brief presentation on Bloom's Taxonomy is given leading to the establishment of Learning Scores. The problems, solutions, and the grading rubrics for all of the Engineering Science courses are reviewed and the details are discussed. This ensures that the TAs thoroughly understand the material presented in the seminar. Also, feedback on the information covered is solicited from the TAs.

The Learning Score process was calibrated with a double blind study. For the study, each TA chooses five solutions at random from their respective class. They remove the name and all marks corresponding to their evaluations. The graduate student coordinating the project provides a second independent assessment. These scores are then compared to those assigned by the TAs. If the average class Learning Scores are within $\pm$ 0.3, the set is considered a valid and accurate assessment of the course. If the scores are not within this limit, that set of data would be considered invalid and the problem re-evaluated. At the University of Wyoming the 2007 summer session was used for the refinement of the first problem and the fall semester included the first full course evaluations. Faculty members offered suggestions that were incorporated prior to the full semester release.

The Learning Score is independent of the grading used for the class. The TA typically grades the problem to establish the grade that is recorded for the assignment. The TA then goes through the problem set a second time to assign a Learning Score. That Learning Score is recorded separately and is not part of the class record. The entire process adds approximately 30 minutes to the grading effort. The longitudinal data will assess how much the average student Learning Scores increase with the number of times they have seen these problems. A consistent increase in Learning Scores suggests the program is effective in expanding students' critical thinking skills.

A second problem assessment examines the ABET a-k outcomes. The basic premise is that each problem contains a portion of work that can be directly tied to one or more of the ABET a-k criteria. A student completing several problems in the set, each of which contains a common ABET a-k outcome component, is considered to have demonstrated proficiency toward that outcome. For example, a student completing four problems in the series will have demonstrated competence in application of scientific and mathematical principles to engineering practice. Because every problem does not contain components of each ABET a-k criterion, it is possible for student to miss one component. Information needed for this assessment is located at the bottom of each problem page. ABET compliance information is compiled from data recorded at the end of the problem statement, for example see Appendix III. The students' responses determine how many times they have completed a problem in the wind turbine series. The incorporation of ABET assessment into the problem set is an ongoing endeavor.

Results

This project is still in its developmental stages. It has only been tested during two semesters. The first trial was done during the summer semester, and no data was recorded. In the first full semester of testing, the participants involved with the project were pleased with the problem sets and the results. In one section of Dynamics, the mean Learning Score was 3.5, right on target for the project. Therefore, there will not need to be any modifications to this particular problem or its corresponding assessment rubrics. This section of Dynamics had a standard deviation of 1.2 and a mode of 4. These results were also expected, which suggests that the methodology is sound. Other classes provided data to improve the reliability of the assessment.

In these early assessments, there were no Learning Scores of 1 or 6. The lack of ones is encouraging because it implies that the students are learning at levels appropriate for the courses. The lack of sixes suggests that students are not yet synthesizing the implications of the problems. Continuous longitudinal studies would expect an increase in scores of 5 and occasional scores of 6 as the students learn that these problems require additional consideration.

Through the calibration study, it was shown that the evaluations completed by the TAs are accurate and repeatable. For instance, the Dynamics course had Learning Scores that were identical between the TA evaluation and the graduate student evaluation. In this case, the problem, solution, and corresponding assessment rubrics were judged complete.

Conclusions and Recommendations

The issuance of the problems, solutions, and rubrics seemed to be fairly seamless with each course syllabus. The student solutions were appropriate for the more complex problem. Also, students were discussing the problems and their recommendations long after the problem had been submitted. This continued discussion indicates student interest in the problems. Through future assessments and problems, we are confident that the participating students will show further interest in the problem sets and the Learning Scores will improve.

This program is being integrated into the Engineering Science curriculum. Incorporation will provide the University of Wyoming and its associated community colleges the opportunity to monitor the student's cognitive skills through a longitudinal study. It is the author's intention that this project be published on the internet for other universities to use. This will provide the opportunity to improve engineering education across the nation, and provide all students with a new drive to continue learning. The fall set of problems and assessments can be found at HTTP://wwweng.uwyo.edu/civil/Kester-Lab/

Acknowledgements

This research on a "Vertically Integrated Multi-Disciplinary Capstone Problem Study Based on the Technology of Wind Turbines and Windmills" was sponsored by the National Science Foundation award number 0442582, program officer Dr. Sheryl A. Sorby. Without NSF's support, this project would not have been possible. The views expressed in this paper are those of the authors and not the National Science Foundation.

Bibliography

1. Benjamin S. Bloom in "Bloom's Taxonomy: A Forty-Year Retrospective," edited by L.W. Anderson, University of Chicago Press, 1994.
2. R.M. Felder, R. Brent, "The ABC's of Engineering Education: ABET, Bloom's Taxonomy, Cooperative Learning, and So On," Session 1375, Proceedings of the 2004 American Society for Engineering Education Conference and Exposition, Salt Lake City, UT, June 2004.
3. Forehand, M. (2005). Bloom's taxonomy: Original and revised.. In M. Orey (Ed.), Emerging perspectives on learning, teaching, and technology. Retrieved January 2, 2008, from http://projects.coe.uga.edu/epltt/.
4. ABET, (2007, March, 17). Criteria for Accrediting Engineering Programs. Retrieved June 17, 2007, from ABET Web site: http://www.abet.org/forms.shtml

Appendix I
General Assessment Rubric

Assessment Notes:

The purpose of this study is for the University of Wyoming and associated community colleges to evaluate the level of cognitive skills that students are displaying and developing an ongoing class assessment program. By tying all of the Engineering Science Courses together and using a realistic interesting project such as the residential wind turbine, the project creates an interest for students to further their education while increasing their learning level.

An important aspect of this assessment is recognizing that a student's level of learning is not a reflection of the student's knowledge of the subject. A student may be at any learning level and still be proficient at generating a solution. In addition, a student may be at any learning level and receive a superior grade for the course. This is possible because this project's assessment and the course grades are two different and independent activities.

The student's learning levels will be assessed by assigning a "Learning Score" based on Bloom's Taxonomy. The Learning Score is a measure of cognitive ability, not problem solving skills. The problems will be disbursed to the classes. There will be a training session for evaluating and assigning Learning Scores. The seminar teaches TAs how the assessment process is executed. Following assignment of Learning Scores, the data will be compiled and analyzed. The problems and their corresponding solutions are not returned to the students but should be discussed with an emphasis on the synthesis and evaluation aspects of the problem. The solutions to the problems should not be copied or distributed to the students as it may affect the results of future assessments.

Bloom's Taxonomy General Assessment: Leading to the Creation of Learning Scores.

The following paragraphs contain the Learning Score and corresponding cognitive skill set associated with that score.

1. Knowledge

This problem cannot be completed by merely repeating items verbatim. Solution does not reveal the students knowledge of the subject. The assessor will see that the solution has little effort applied to it. The solution may have the repeated problem statement, with a few ideas or concepts expressed.

2. Comprehension

The solution displays a basic level of comprehension. The solution indicates that the thought process is on the right track. The assessor sees that the student was able to explain the problem in his or her own words and was able to conceptualize the problem requirements. The solution may indicate that not all of the concepts are understood.

3. Application

The solution shows that the student is able to take the concepts from class and apply them to solving the problem. Solution indicates that all of the principle requirements of the problem have been addressed in some manner. Still there are a few critical or procedural errors in the solution. These may include a lack of a parametric approach. The solution at this level will show that all of the free body diagrams have been defined, and some equilibrium equations have been applied to find required forces.

4. Analysis

The solution has displayed an ability to rationalize the problem solving process by using explanations for the presented solution or mathematical process. In addition, the solution also displays a systematic approach to solve the problem. At this level it is apparent to the assessor that the solutions is mostly correct. Few computational errors typify this category.

5. Synthesis

Solution displays the ability to synthesize using a definite systematic approach. To synthesize a solution the student designs an object or formulates a comprehensive parametric solution. For example the solution for the statics problem must recognize that the longest gin pole always gives the most economical line. Their conclusion can be “intuitive” or from an analysis effort. The assessor sees that the solution contains all correct answers and all of the requirements of the problem have been met.

6. Evaluation

Solution indicates the thought process is above and beyond the requirements of the problem. The solution to the problem contains all correct answers. To achieve the evaluation level of the problem, the solution must select or verify an alternative way of solving the problem, critiquing, judging or making recommendations about the problem itself.

Specific Learning Score Assessment **for Statics Problem** Based on Bloom's Taxonomy

Learning Score Specific Assessment:

1. Knowledge

The solution contains rudimentary free body diagrams or equilibrium equations. At this level of learning these free body diagrams or equilibrium equations may or may not be correct. The solution is mostly incomplete, even if the numerical solution is correct. There is no parametric study.

2. Comprehension

The solution has free body diagrams, but the corresponding equilibrium equations do not match the free body diagrams. It could also contain incomplete equilibrium equations. The solution may present an abbreviated process to obtain an answer or uses an incorrect methodology. The parametric study is incomplete.

3. Application

The solution presents a repeated problem statement that indicates that the student was able to conceptualize the problem while achieving some correct answers. A parametric study is presented without discussion. The solution discussion is limited in scope.

4. Analysis

The solution presents correct free body diagrams and equilibrium equations. The problem discussion of the effects on the truck was omitted and there was no recognition of the relationship between the angle of the lines and optimum line tension.

5. Synthesis

All of the free body diagrams and equilibrium equations are completely correct. The parametric study is discussed. The truck behavior is qualitatively assessed, and the report considers the issues that are related to connecting a steel cable versus a nylon strap to the tower or gin pole.

6. Evaluation

An example of evaluation would be the solution using the effects on the truck to discuss the loss of traction due to the uplift on the rear tires. It could also discuss other ways of alleviating this concern by using different types of tires, or by adding weight to the back of the truck. In addition, the report would comment on the relationship between the angle of the lines and the optimum line tension.

ABET:

This problem incorporates part or all of ABET outcomes a, e, g, and i.

Note: Each problem incorporates one or more ABET outcomes. In this case a, e, g, and i are utilized. A student completing 3 or more "a" outcomes, is evidence of compliance with that particular ABET objective. One problem is not sufficient for evaluation but several problems with the same ABET criterion implies compliance. The longitudinal study and comprehensive database is needed to evaluate compliance.

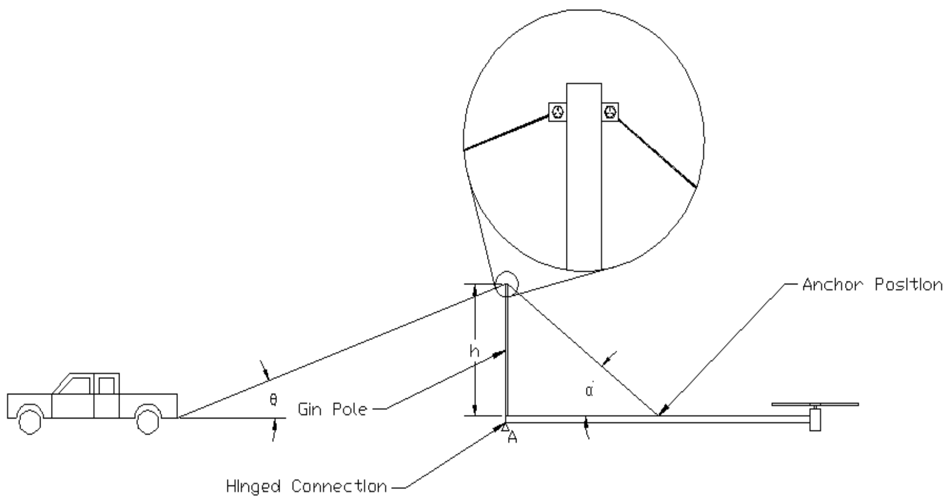
Appendix III Statics Problem and Solution

Name________________

Return this page with your solution

Statics

Shown in the diagram below is a residential wind turbine. To erect the tower and wind turbine, a line is tied to the tower, attached to the gin pole, and then attached to a truck. The gin pole has been fastened to the tower base. Your job is to define the length of the gin pole, the line's anchoring position on the tower, the length of the two line segments, and select a cost efficient cable size or strap. The length of the tower is 52 feet, and the available length of the line is 95 feet which needs to be divided in to two pieces. The tower weighs 150 lbs, while the turbine and blade assembly weights 92 lbs. Use either Excel or MathCAD to produce a worksheet that displays a range of possible answers, then select your choice of solution. Discuss and summarize your recommendations in a one page typed memo accompanied by your solution. Include sketches of all diagrams, and figures necessary to solve the problem, including the effects on the truck. The maximum length of the gin pole is 30ft and the cables are attached as shown below.



Schematic of Tower Erection

Erected Position

Cable		Nylon Strap	
Size	Capacity	Size	Capacity
1/16"	480 lbs	1 3/4"	960 lbs
3/32"	1000 lbs	2"	1882 lbs
1/8"	1760 lbs	3"	2820 lbs
5/32"	2400 lbs	4"	3756 lbs
3/16"	3700 lbs	6"	5640 lbs

Circle the windmill problems you have previously completed?

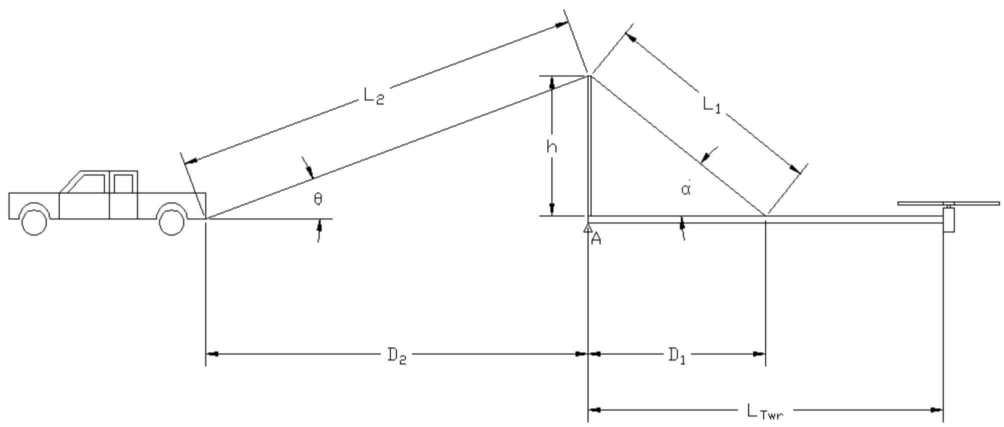
Introduction to Engineering Engineering Problem Solving Statics Dynamics
Mechanics of Materials Thermodynamics Fluid Mechanics Circuits Structural Analysis

Circle your Major

ARE CHE CE CPEN EE ME PETE COSC

This problem is developed under a grant from the National Science Foundation for the improvement of engineering. Anonymous data will be implied to evaluate the success of this grant.

Solution:



Tower Length	52	ft
Tower Weight	150	lbs
Generator and Blade Weight	92	lbs
Gin Pole Length	30	ft

Note: Solver was used to find a gin pole length that minimizes the tension in the cable.

Cable		Nylon Strap	
Size	Capacity	Size	Capacity
1/16"	480 lbs	1 3/4"	960 lbs
3/32"	1000 lbs	2"	1882 lbs
1/8"	1760 lbs	3"	2820 lbs
5/32"	2400 lbs	4"	3756 lbs
3/16"	3700 lbs	6"	5640 lbs
7/32"	5000 lbs		
1/4"	6100 lbs		
5/16"	9000 lbs		
3/8"	12500 lbs		
1/2"	21000 lbs		
5/8"	35000 lbs		

$$L_1 = \sqrt{(D_1)^2 + (h)^2}$$

$$D_2 = \sqrt{(L_2)^2 - (h)^2}$$

$$T_1 = \frac{-F_{Twr}\left(\frac{L_{Twr}}{2}\right) - F_{GB}(L_{twr})}{\sin(\alpha) * (D_1)}$$

$$T_2 = \frac{T_1 \cos(\alpha)}{\cos(\theta)}$$

$$R_{TruckX} = T\cos(\theta)$$

$$\alpha = \tan^{-1}\left(\frac{h}{D_1}\right)$$

$$L_2 = 120' - L_1$$

$$\theta = \tan^{-1}\left(\frac{h}{D_2}\right)$$

$$R_{AX} = T\cos(\alpha)$$

$$R_{AY} = F_{Twr} + F_{GB} - T\sin(\alpha)$$

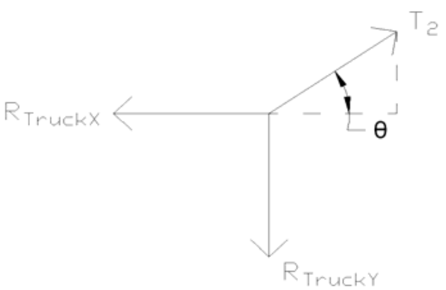
$$R_{TruckY} = T\sin(\theta)$$

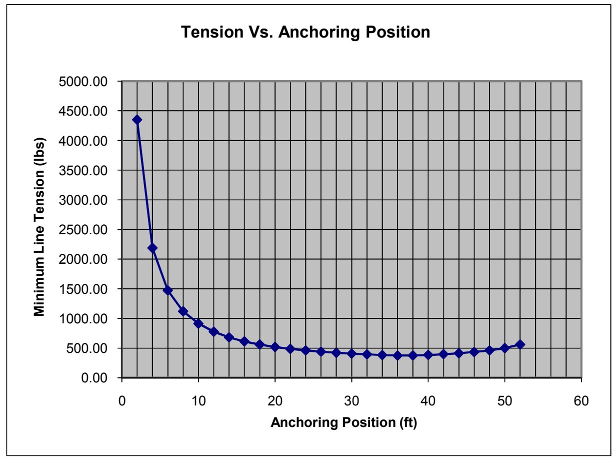
Anchor Position (D_1) (ft)	α (degrees)	L1 (ft)	L2 (ft)	D2 ft	θ (degrees)	T_1 (lbs)	T_2 (lbs)	T_{MIN} (lbs)	R_{AX} (lbs)	R_{AY} (lbs)	Truck $Reactions_X$ (lbs)	Truck $Reactions_Y$ (lbs)
2	86.19	30.07	64.93	57.59	27.52	4351.64	326.39	4351.64	289.47	392.80	289.47	150.80
4	82.41	30.27	64.73	57.36	27.61	2190.21	326.66	2190.21	289.47	393.39	289.47	151.39
6	78.69	30.59	64.41	56.99	27.76	1476.00	327.12	1476.00	289.47	394.37	289.47	152.37
8	75.07	31.05	63.95	56.48	27.98	1123.43	327.77	1123.43	289.47	395.76	289.47	153.76
10	71.57	31.62	63.38	55.83	28.25	915.37	328.61	915.37	289.47	397.55	289.47	155.55
12	68.20	32.31	62.69	55.04	28.59	779.41	329.67	779.41	289.47	399.76	289.47	157.76
14	64.98	33.11	61.89	54.14	28.99	684.50	330.94	684.50	289.47	402.41	289.47	160.41
16	61.93	34.00	61.00	53.11	29.46	615.12	332.45	615.12	289.47	405.50	289.47	163.50
18	59.04	34.99	60.01	51.98	29.99	562.62	334.22	562.62	289.47	409.07	289.47	167.07
20	56.31	36.06	58.94	50.74	30.59	521.84	336.28	521.84	289.47	413.15	289.47	171.15
22	53.75	37.20	57.80	49.40	31.27	489.49	338.66	489.49	289.47	417.78	289.47	175.78
24	51.34	38.42	56.58	47.97	32.02	463.37	341.41	463.37	289.47	423.02	289.47	181.02
26	49.09	39.70	55.30	46.46	32.85	441.98	344.58	441.98	289.47	428.93	289.47	186.93
28	46.97	41.04	53.96	44.86	33.77	424.24	348.24	424.24	289.47	435.60	289.47	193.60
30	45.00	42.43	52.57	43.17	34.79	409.37	352.49	409.37	289.47	443.14	289.47	201.14
32	43.15	43.86	51.14	41.41	35.92	396.78	357.44	396.78	289.47	451.70	289.47	209.70
34	41.42	45.34	49.66	39.57	37.17	386.04	363.25	386.04	289.47	461.46	289.47	219.46
36	39.81	46.86	48.14	37.65	38.55	376.80	370.13	376.80	289.47	472.67	289.47	230.67
38	38.29	48.41	46.59	35.64	40.09	368.80	378.37	378.37	289.47	485.66	289.47	243.66
40	36.87	50.00	45.00	33.54	41.81	361.83	388.36	388.36	289.47	500.91	289.47	258.91
42	35.54	51.61	43.39	31.34	43.75	355.73	400.70	400.70	289.47	519.07	289.47	277.07
44	34.29	53.25	41.75	29.03	45.94	350.35	416.27	416.27	289.47	541.14	289.47	299.14
46	33.11	54.92	40.08	26.58	48.46	345.59	436.49	436.49	289.47	568.70	289.47	326.70
48	32.01	56.60	38.40	23.96	51.38	341.35	463.80	463.80	289.47	604.38	289.47	362.38
50	30.96	58.31	36.69	21.12	54.85	337.57	502.80	502.80	289.47	653.11	289.47	411.11
52	29.98	60.03	34.97	17.96	59.09	334.19	563.48	563.48	289.47	725.44	289.47	483.44

Note: The optimal tension in the line occurs at a point where both of the tension forces are in equalibrium.

Optimal Tension	376.80	(lbs)
Pulling force required	289.4666667	(lbs)
Anhor position to be used	36	ft
Cable to be used	1/16	
Strap to be used	1 3/4	

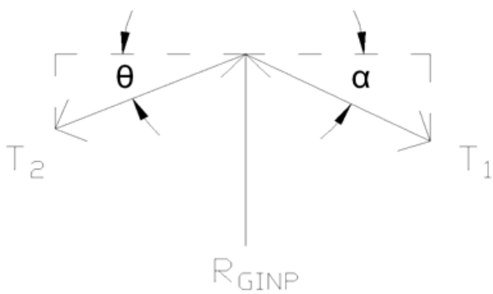
FBD #1





The optimal line tension is the minimum of the shown graph.

FBD #2



FBD # 3