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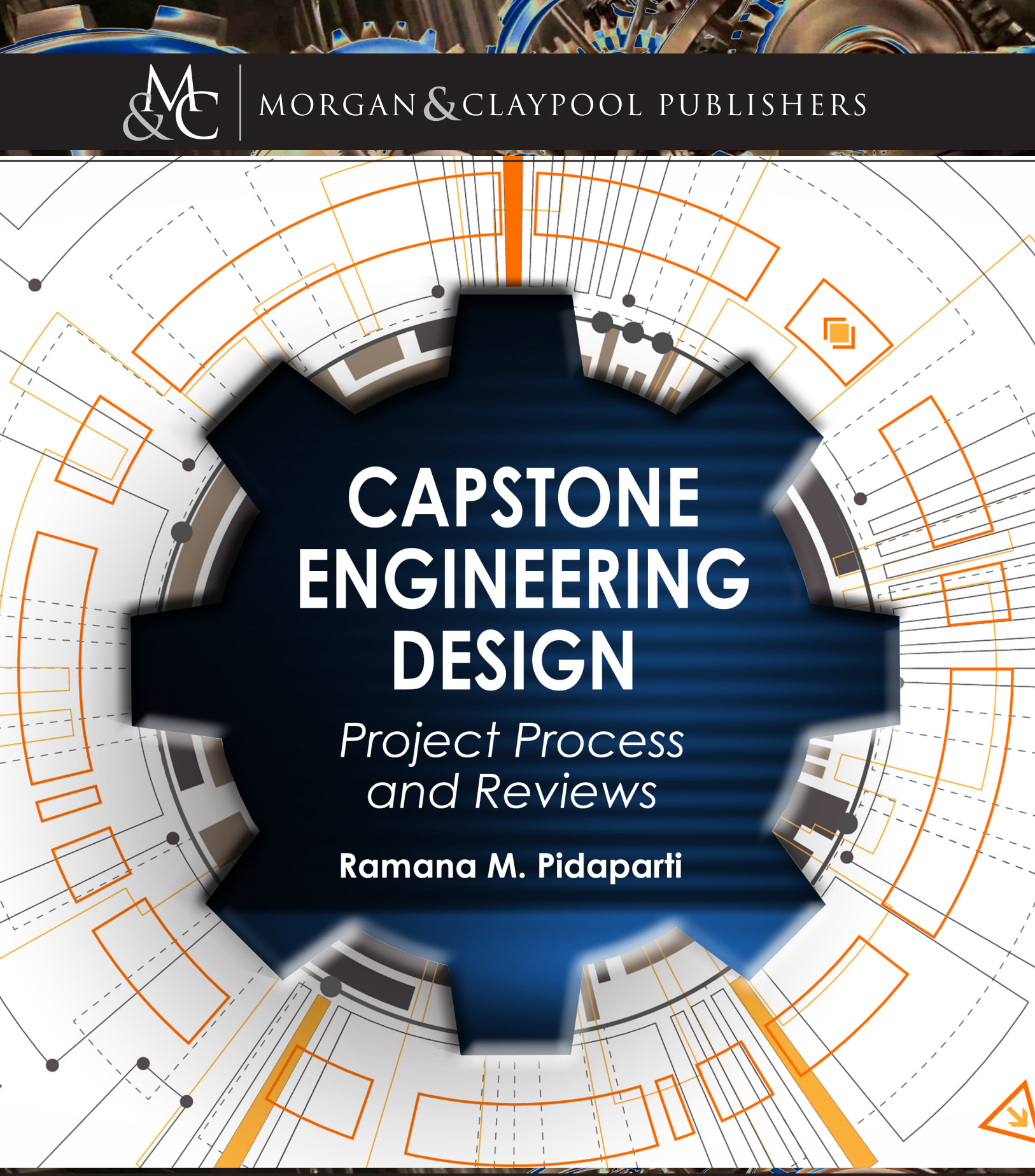


CAPSTONE ENGINEERING DESIGN

Project Process and Reviews

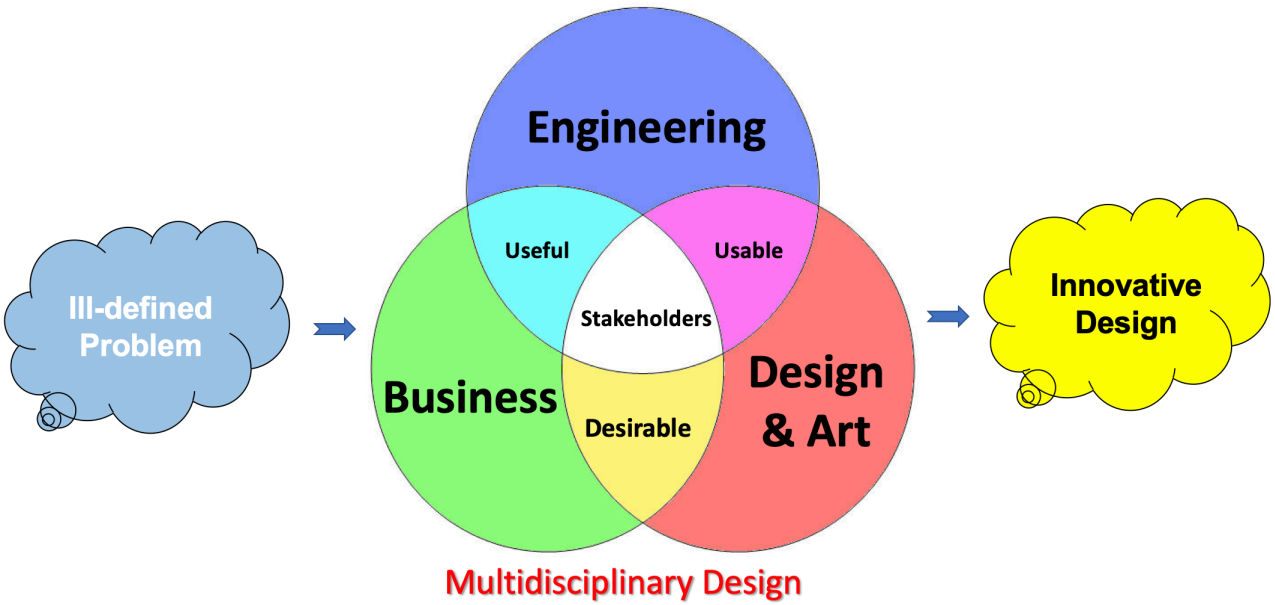
Ramana M. Pidaparti

SYNTHESIS LECTURES ON MECHANICAL ENGINEERING

Capstone Engineering Design:

Project Process and Reviews

(Student Engineering Design Workbook)



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PROGRAM/YEAR:

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Capstone Engineering Design:

Project Process and Reviews

(Student Engineering Design Workbook)

Ramana Pidaparti
College of Engineering, University of Georgia

SYNTHESIS LECTURES ON MECHANICAL ENGINEERING #34

MORGAN & CLAYPOOL PUBLISHERS

ABSTRACT

Capstone Design: Project Process and Reviews (*Student Engineering Design Workbook*) provides a brief overview of the design process as well as templates, tools, and student design notes. The goal of this workbook is to provide students in multiple disciplines with a systematic iterative process to follow in their Capstone Design projects and get feedback through design reviews.

Students should treat this workbook as a working document and document individual/team decisions, make sketches of their concepts, and add additional design documentation. This workbook also assists in documenting student responsibility and accountability for individual contributions to the project. Freshman- and sophomore-level students may also find this workbook helpful for design projects. Finally, this workbook will also serve as an evaluation and assessment tool for the faculty mentor/advisor.

KEYWORDS

Capstone Design, design projects, design reviews, engineering workbook, templates, tools, student notes

Contents

Preface

Every engineering student engaged in design activities or Capstone Design course is required to keep a design workbook or log that contains all the documentation related to the design. The documentation may include all the design project details, important ideas, and data/information.

In design curriculum and engineering education, it is necessary to document student's understanding of the design process and the decisions made during the project. Each student's contributions (all sketches, notes, and design ideas) related to the design project will be entered into this student design workbook and may serve to protect the intellectual property.

This workbook also provides a brief introduction to the design process (steps 1–6) and the associated design activity templates and tools for students to complete as part of the Capstone Design process/journey. The student notes pages are left blank for students to fill in as they work on their Capstone Design project. In the Capstone Design course, the design reviews occur at the end of the "Design Requirements" (*Review #1*), "Conceptual Design" (*Review #2*), and "Detail Design" (*Review #3*) steps of the design process with all stakeholders to ensure the design meets all the requirements related to the project. Usually, the design reviews are comprehensive and document processes intended to evaluate the design from multiple stakeholder's perspectives and at the same time identify any potential problems/risks. This workbook scaffolds the design process journey for students and prepares them to conduct reviews to ensure successful designs. It can also be used for review/feedback and assessment purposes by mentors and faculty advisors.

The author acknowledges the support and guidance of many of his colleagues, and sincere thanks to many of his design students at UGA, VCU, and IUPUI for their help and feedback.

Ramana Pidaparti
August 2021

Acknowledgments

Most of the materials/templates are taken from: *Design Engineering Journey* by Ramana M. Pidaparti, 2018, Morgan & Claypool Publishers (www.morganclaypool.com), ISBN: 978681732602.

Design Workbook Information

Student Name:	
Contact Information:	
Team Member:	
Team Member:	
Team Member:	
Team Member:	
Team Member:	
Team Member:	
Project Name:	
Project Sponsor:	
Project Mentor:	
Course Coordinator:	
Degree/Program:	
Start Date:	
Student Signature:	

About this Design Workbook

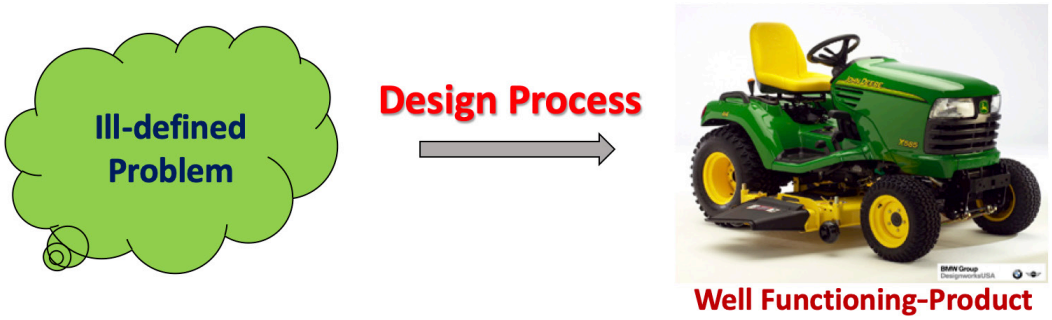
As part of the Capstone Design project, students will work on a real-world problem by following the design process and meeting all the expectations. Every engineering student engaged in design activities or a Capstone Design course is required to keep a design workbook or log that contains all the documentation related to design. The documentation may include all the design project details, important ideas, and data/information. As engineers, students must know that their design solution will work as they designed without fail. The purpose of this design workbook is to guide students to follow the systematic design process (emphasizing the iterative nature of the design), track the project development process, review multiple approaches/solutions, and understand and reflect on the decisions. It is important that students are aware of what needs to be done to make sure the design solution is acceptable for all stakeholders involved.

Students should treat this workbook as a working document that documents individual/team decisions, makes sketches of their concepts, and adds additional design documentation. This workbook also assists in documenting student responsibility and accountability for individual contributions to the project. This design workbook will also serve as an evaluation and assessment tool for the faculty mentor/advisor.

A brief introduction to each step of the design process and the associated design activity templates for students to complete as part of the Capstone Design process/journey is presented. In the next few sections, various steps of the design process and design reviews are briefly described.

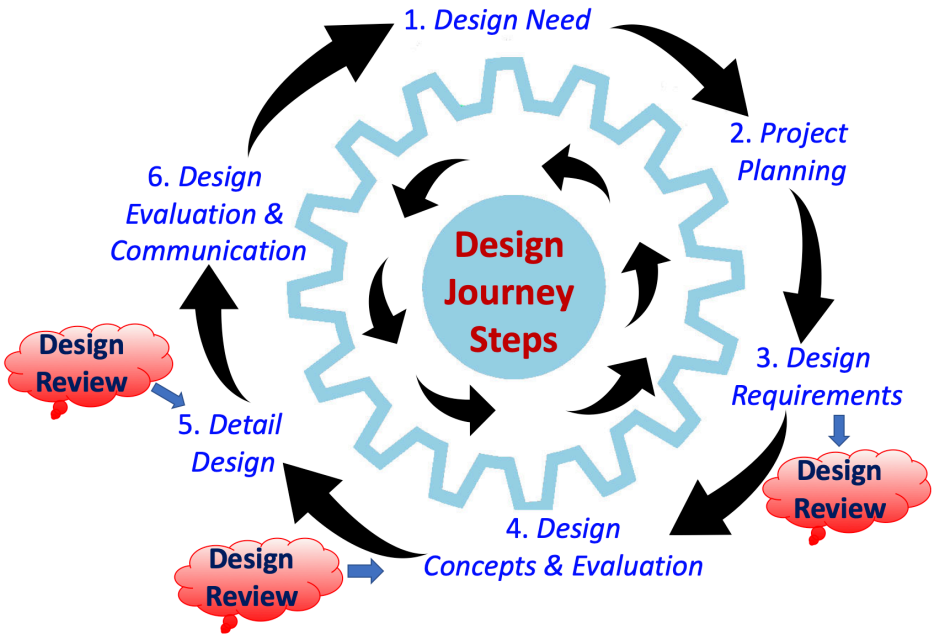
What is the Engineering Design Process?

Design is essentially a process of problem solving—coming up with the best match or solution to an identified problem or need, as shown in the figure below.



The transformation of an ill-defined design problem into a complete functioning product requires the following steps: establishing a need, developing a plan (how to solve the problem), understanding the problem, developing requirements and comparing to existing solutions (if any), generating and evaluating additional concepts, deciding or choosing a final solution, and communicating the results.

The design process is a sequence of steps that helps define various aspects of the design in a systematic and iterative manner, as shown in the figure below.

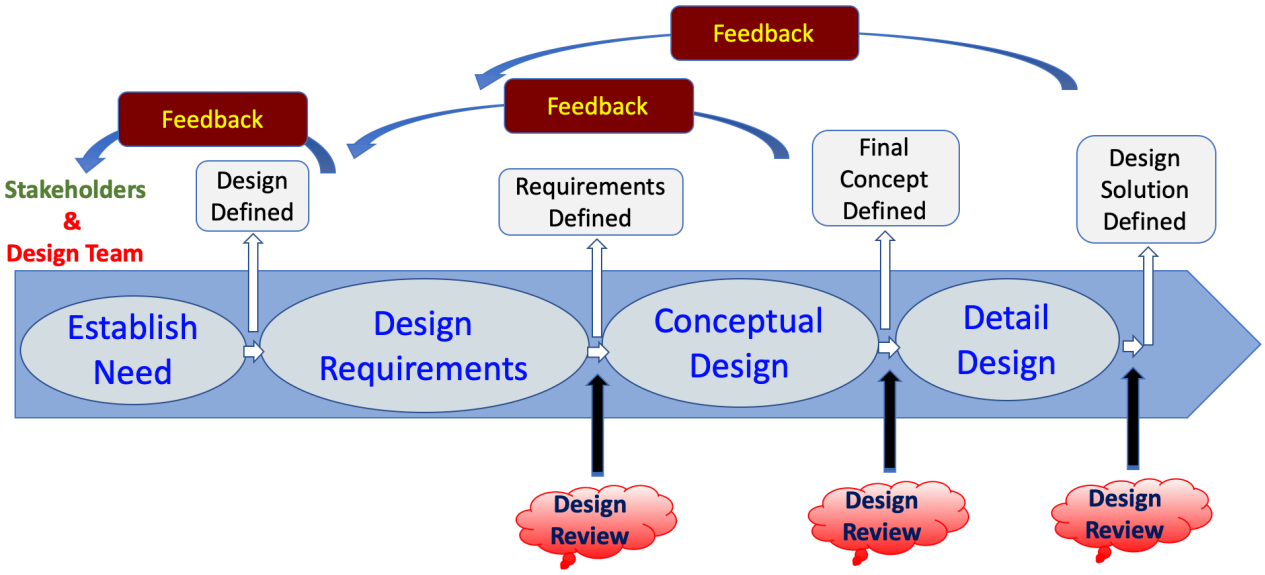


The goal of the design process is to find the best possible solution to an ill-defined problem that leads to a quality product with the least commitment to time and other resources through the organization and management of people and information. The design process is successfully accomplished through consistent communication among the members of the design team.

Design Reviews

At critical steps of the design process, design reviews are conducted with all stakeholders to ensure the design meets all the requirements related to the project (see the figure below). Usually, the design reviews are comprehensive and document processes intended to evaluate the design from multiple stakeholder's perspectives and at the same time identify any potential problems/risks. Detection of errors early in the design process may prevent unnecessary costs, failures, and the associated time spent on the projects.

An overview of the design reviews along with the design process is shown in the figure below. Usually, design reviews should be conducted at important milestones in the design process to ensure that expectations are accomplished and support the next step of the design project.



In the Capstone Design course, the design reviews occur at the end of the "Design Requirements" (Review #1), "Conceptual Design" (Review #2), and "Detail Design" (Review #3) steps of the design process. In a two-semester Capstone Design sequence, design reviews # 1 and 2 will take place in semester 1 and the design review #3 in semester 2. As shown in the figure above, based on review and feedback, you may need to revisit earlier design steps.

Team Contract and Meetings

As part of the Capstone Design, student teams are required to work together with specified roles, responsibilities, and expectations. Also, in order to make progress toward the design and meet deadlines, student teams are encouraged to meet regularly and evaluate the project progress.

Name	Role(s)	Responsibilities	Signature

Team Goals	Responsible Member and Expectations

It is important that everyone comes prepared to every meeting with your team. Some of the items required to make an effective meeting include:

- Date and Time; Reason for meeting and topics to be covered
- Last meeting items that require follow up; Presentation materials; Meeting notes
- Issues or concerns; Discussion; Decisions Made
- Date and action items for next meeting

CONFLICT RESOLUTION STRATEGIES (IF ANY):

Contents
(Student Design Notes)

Page #	Topic	Date
Signature:		

Capstone Design Process

STEP 1

Design Need

Identifying a design need and defining the need in measurable terms is not as easy as it may seem. Needs may be market-driven, or may come from private industry or introduction of new technology. In addition, the design problems may come from faculty or students that might be a part of research projects or interest. Most design problems are not well defined and are open ended. The design project statement may not give all the information needed to find the solution. Identifying the missing information will be the key to fully understanding what needs to be designed. The goal in product design is to find the best solution that leads to a quality product with minimal cost and limited resources.

It is the primary task of the designer/team to communicate closely with the clients and end users to fully understand the need, and assist the clients in creating a product or service that most closely meets that need. Clients, stakeholders, users, and designers typically work together in teams in defining and carrying out design-related projects.

During the *design need* identification step, the designer/team has to identify customer/stakeholder needs, which in itself is a process. Please look into the following aspects during the "design need" step.

- **Market Research:** Several aspects should be reviewed including demographics (Who uses? Who buys?), socio-economic and cultural factors, sustainability factors, aesthetic parameters, and applicable technologies.
- **Existing Designs:** This includes looking into reverse engineering the designs from functional performance, mechanical features, materials, manufacturing processes, and aesthetics perspectives.
- **End Users:** This involves looking into how the end users are using the design through observations of physical interaction, psychological aspects, and how they are using/misusing the design/product.
- **Human Factors:** This includes looking into how ergonomics (physical interface, tactile feedback, and user interface) and intuition facilitate using the design for communicating the function, design graphics, arts, visuals and icons, and their appeal to the end user.
- **Design Integration:** This includes looking into how various electrical, mechanical, materials, and manufacturing requirements are integrated in an interdisciplinary fashion to achieve the required design.

The following are the three methods commonly used to gather information to determine customer/stakeholder requirements.

- **Observations:** This method involves observing customers using the existing product in order to see whether the product needs to be redesigned or develop a new design with improved properties and performance that would compete with the products already available in the market. Many requirements can be found by observing customers using the product since most new products are refinements of existing products.
- **Surveys:** The survey method is generally used to gather specific information or ask people's opinions about a well-defined subject. Surveys make use of questionnaires that are carefully designed and applied through the mail, over the telephone, or in face-to-face interviews. They are well suited for collecting requirements on products to be redesigned or on new, well-understood product domains.

- **Focus Groups:** These are used to capture customer requirements from a carefully sampled group of potential customers. This technique is best suited for developing original products or to gather the customers' views on product/design improvement.

STEP 2

Project Planning

The *project planning* step of the design process includes developing a plan for the design process with respect to scope and resources available at hand to accomplish the design activities of the problem identified in step #1. There are various reasons for project planning, including obtaining a better understanding the project objectives, eliminating the uncertainty and improving the efficiency of operations, and providing/guiding the project teams and minimizing the risk for project completion.

The resources may be categorized in terms of time, money, people, and manufacturing and testing capabilities. The main activities in the project/design planning step are:

- form a design team, assess team skills, and assign roles and responsibilities to each member,
- develop tasks,
- research the market, and
- estimate schedule and cost.

2.1 PROJECT PLANNING AND MANAGEMENT—GANTT CHART

Generally, a project plan is developed by the design team to meet the project deadline, and manage various tasks involved in the design project. Gantt charts are used to represent the timing of various tasks planned in the design project. The horizontal axis shows the time line and the vertical axis shows various tasks to be completed. The start and end of a task is usually represented by a horizontal bar. If the task is completed, then it is represented by a completely filled bar. The unfilled bars represent the fraction of the task that is completed. In addition to a project plan, each student should develop their own timeline, deliverables, and a chart.

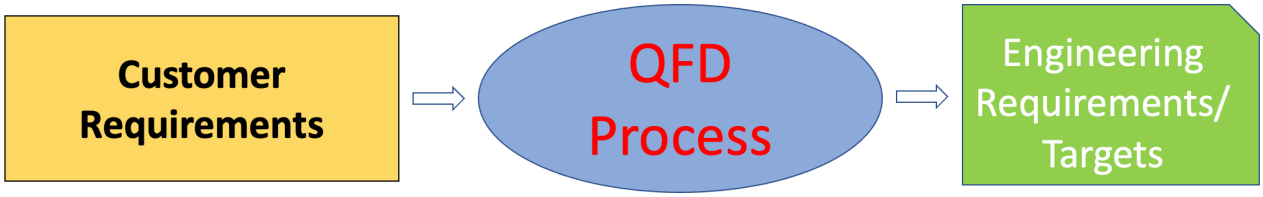
2.1.1 PROJECT PLANNING TOOLS

- Gantt Chart (Project Schedule as in MS Project Manager)
- CPM (Critical Path Method)—to account for interdependency of tasks
- PERT (Program Evaluation and Review Techniques)

STEP 3

Design Requirements: Specifications Development

In order to develop the best possible design, it is essential to develop a good understanding of the design problem and generate a set of design criteria/engineering specifications. Misunderstanding a design problem may result in bad design, higher cost, and delay in time to market. Therefore, it is very important to understand the design problem first before searching for any possible solutions. The goal in understanding the design problem is to translate customer needs into engineering specifications with specific target values through the use of the QFD (Quality Function Deployment) process.

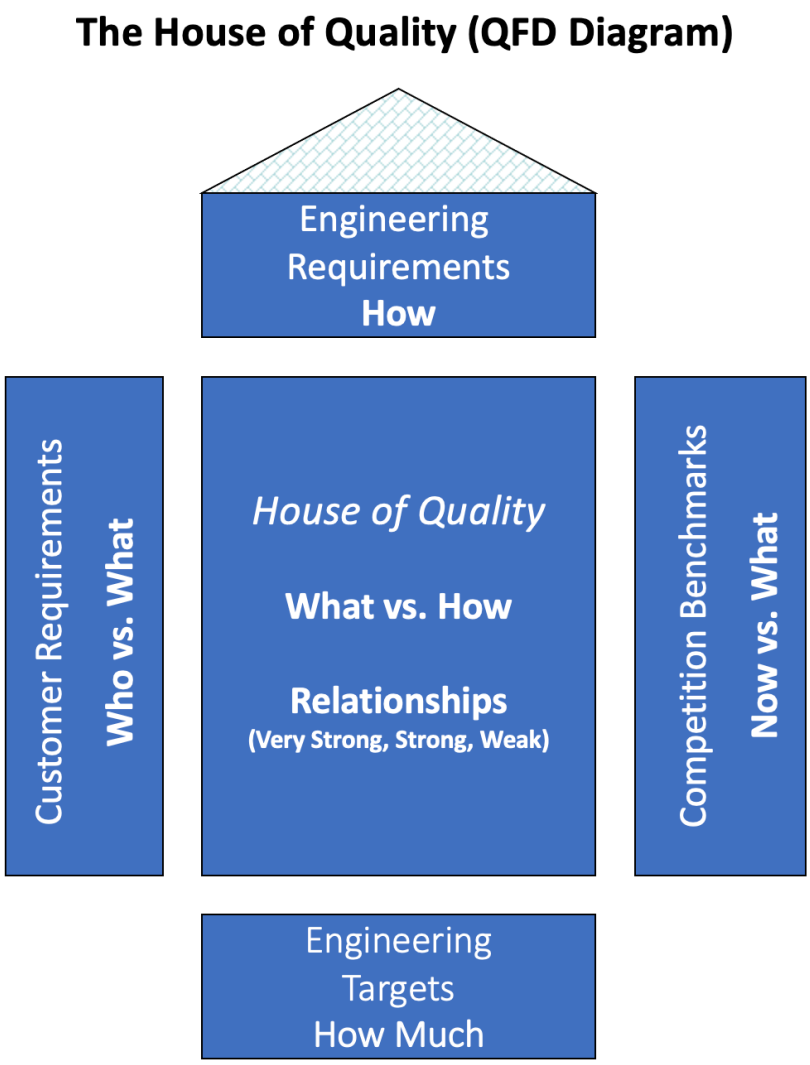


Translation of customer requirements into engineering requirements.

3.1 QFD PROCESS

The QFD process involves the following steps.

- Identify the customers/stakeholders
- Determine the customer requirements
- Determine requirement weights
- Benchmark the competition through market analysis for creating a viable and useful design for customers
- Convert requirements to quantifiable engineering specifications with units
- Correlate customer requirements to engineering specifications
- Cross-correlate engineering specifications
- Set the engineering targets with units



More details about QFD process can be found in *Design Engineering Journey* by Ramana M. Pidaparti, 2018, Morgan & Claypool Publishers (www.morganclaypool.com), ISBN: 978681732602.

STEP 4

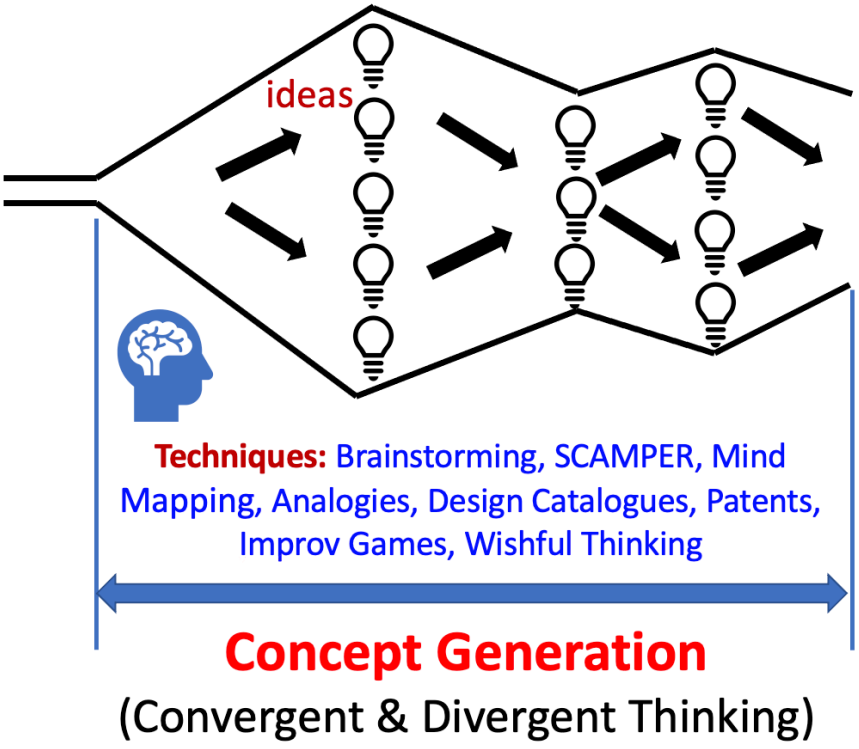
Design Concepts: Generation and Evaluation

4.1 CONCEPT GENERATION

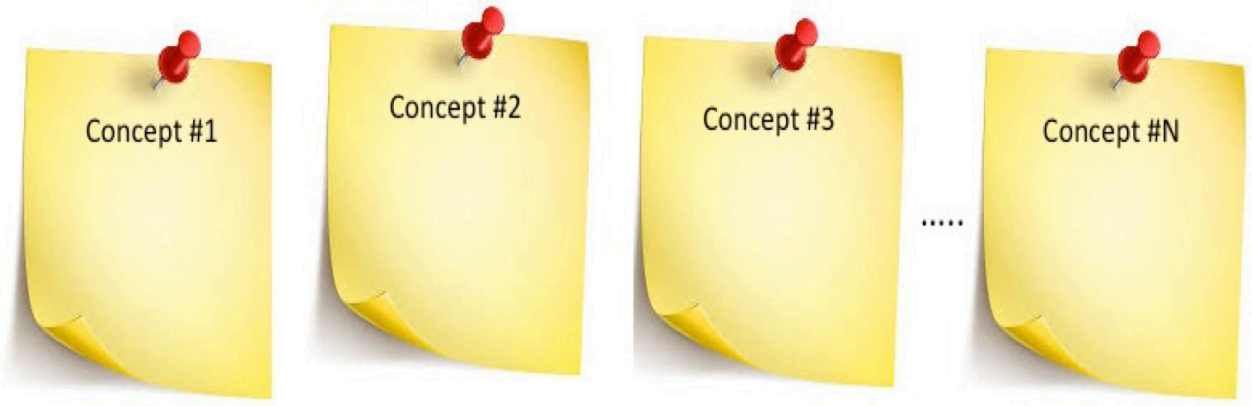
Usually, the concepts come primarily from the designer/team's own knowledge and experience, but are usually enhanced through the use of the following methods:

- based on the functional requirements of the design,
- brainstorming, mind-mapping, SCAMPER, and others,
- using experts/surveys/questionnaire/focus groups,
- patents, and
- reference books and trade journals.

It is important to mention that the design team should develop as many concepts as possible. Each of the developed concepts is evaluated based on the design specifications (customer requirements) discussed.

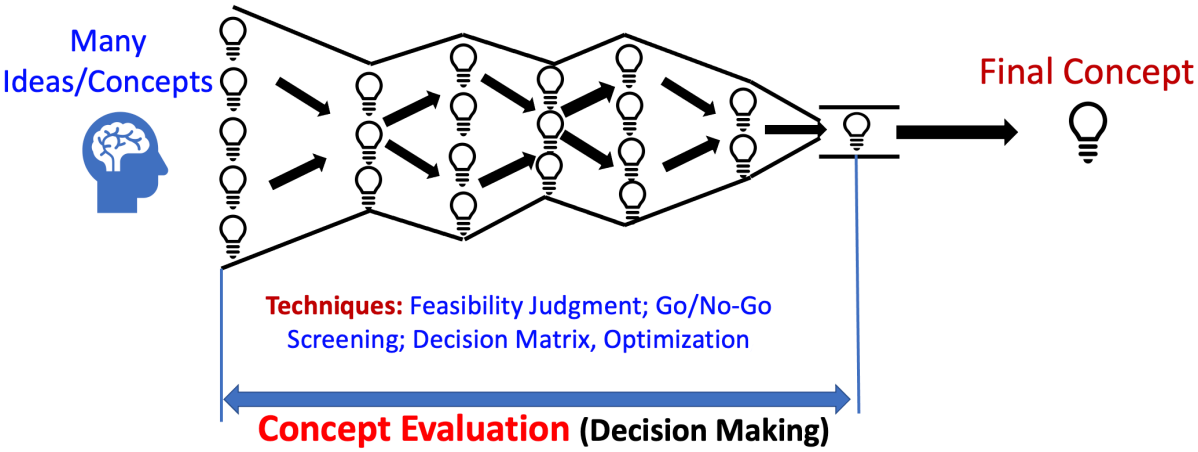


Design Concepts – Generation



4.2 CONCEPTS EVALUATION

- Design analysis information used to identify the best concept/solution.
- List the advantages and disadvantages of each concept.
- Construct a Decision Matrix for evaluation of alternate concepts.
- Preliminary prototype and testing for functionality.
- More sophisticated, computer-based optimization methods are also available for complicated cases.



Basic Structure of a Decision Matrix

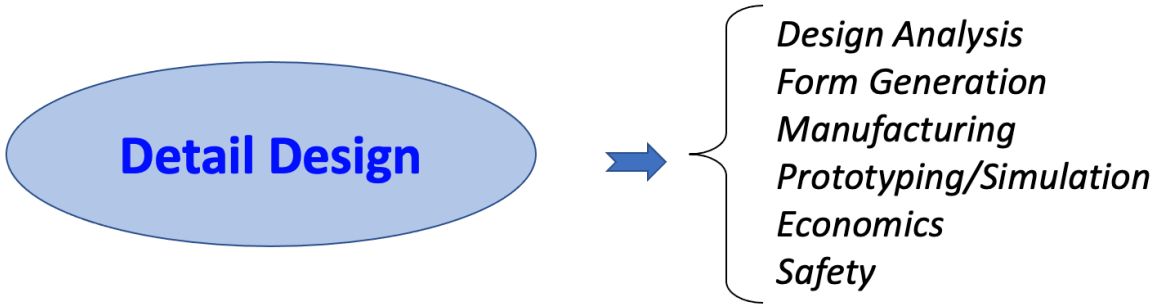
1	2					
Design Specifications	Relative Importance	Alternatives				3
		Alternative 1	Alternative 2	...	Alternative m	
Criterion 1	xx	Evaluation 1-1	Evaluation 2-1	...	Evaluation m-1	4
Criterion 2	yy	Evaluation 1-2	Evaluation 2-2	...	Evaluation m-2	
.	.	...	...	...	...	
.	.	...	...	...	...	
Criterion n		Evaluation 1-n	Evaluation 2-n	...	Evaluation m-n	
	Satisfaction	Score 1	Score 2		Score m	5


Design Review #2
Design Concepts
Concepts – Generation and Evaluation
Final Concept
Design Review

STEP 5

Detail Design and Analysis

After design concepts have been generated and evaluated as discussed in the previous section, the candidate/final concept should be refined into an actual product or final design. The design realization and evaluation step emphasizes the importance of the concurrent design of the product and the manufacturing process, as shown in the figure below.



5.1 DESIGN STANDARDS

When designing, students need to be aware of various standards that need to be followed in order for the design to be marketable and acceptable to customers. These standards may involve rules, policies, guidelines and are recognized by professional organizations (ASTM – American Society for Testing and Materials; ASME – American Society of Mechanical Engineers; ANSI – American National Standards Institute, etc.), state and federal governments and agencies (NTSB – National Transportation Safety Board; FDA – US Food and Drug Administration), and others. A number of national and professional organizations require implementing standards in the designs that are applied to specific applications.

STEP 6

Design Evaluation and Communication

Specifying and Communicating the Final Design

Once the final design is selected and evaluated, the next step will be to make sure that all stakeholders (members of the design team, management, client, users, manufacturing, etc.) are provided sufficient details on the development and implementation aspects. The design process communication may be accomplished through oral presentations, face-to-face or telephone conversations, progress reports, or formal project reports. Detailed documentation will need to be provided on the costs, material specifications, technical drawings of components or assembly, quality and reliability, and other design specifications as needed.

Implementing the Design Decision

Before implementing a full-scale version of the final design, it may be helpful to develop and test a pilot model through rapid prototyping or working prototype or simulation to further identify technical specifications required to generate the best solution. Design projects being implemented in this day and age are increasingly requiring multidisciplinary interactions between engineers from various fields (business, electrical and computer engineering, chemical engineering, biomedical engineering). It is therefore important to keep in mind that communication skills are just as important to the success of a project as are technical skills.

Verifying and Evaluating the Design

The last step in the design process involves evaluating whether the design project met the required design specifications and performance criteria. A variety of methods including focus groups and satisfaction surveys may be used along with sampling or testing the product, proces, or system to ensure achievement of the optimum design. Typically, modifications and further refinement of the design will be required before the optimum design can be achieved. The closing step of the design process often marks the start of a new design process in search of the next generation of products, processes, and systems because technology changes so rapidly.

Design Strategy

Due to the complexity in product design and conflicting requirements, the final product design needs to be selected based on tradeoffs among various requirements such as performance, cost, weight, robustness, manufacturing, implementation, aesthetics, etc. Different tradeoffs will lead to a variety of designs.

6.1 DESIGN COMMUNICATION

The designers and the design team should be able to clearly communicate with all stakeholders as well as management or manufacturing teams, or clients or vendors following the development of a quality design.

Templates and Tools

Scope of Your Project

Start by thinking about your project scope in terms of opportunity, explore from broader and narrower perspectives, and reasons and barriers for the opportunity.

You might refine your scope after discussion with your team/others.

Project Scope Opportunity

Broader and Narrower Perspectives

Reasons and Barriers

Make Your Plans

Three different elements that need to be considered explicitly.

- Activities—what tools you will use and what you will do?

- People—Who are stakeholders and supporters?

- Research—How will you gather data and inform your work?

Design Brief or Need Statement

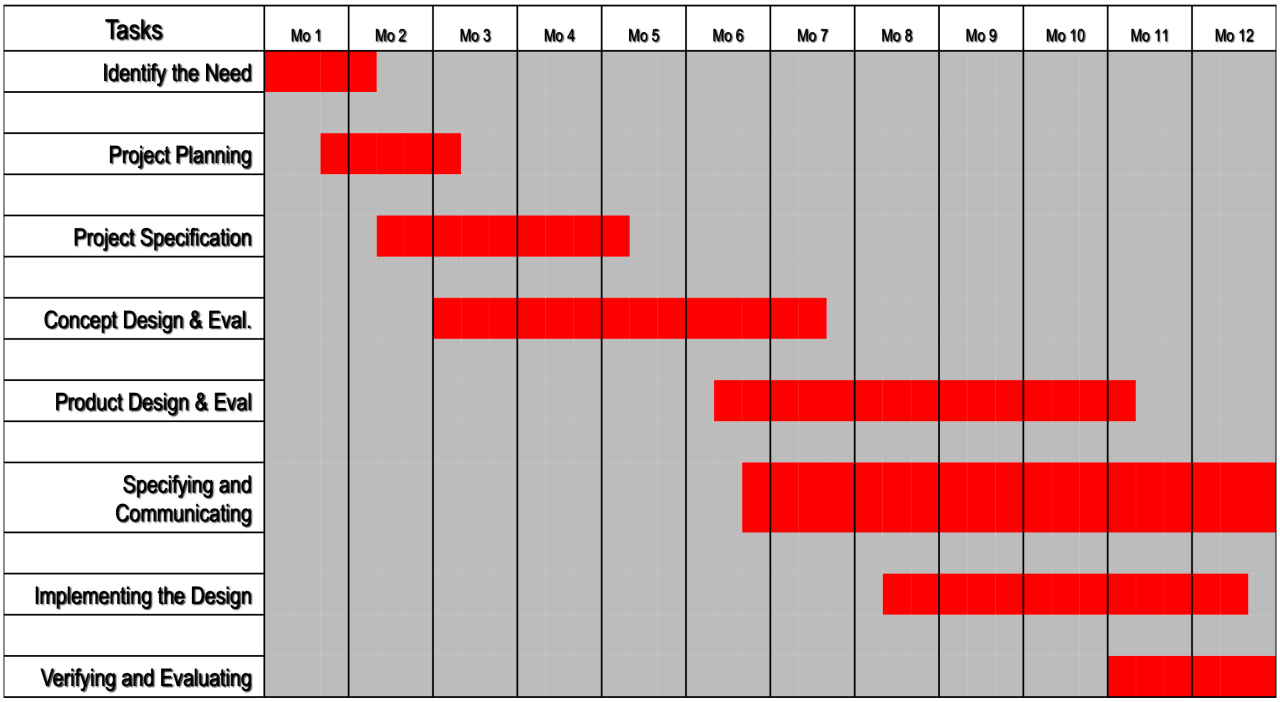
A well-constructed design brief clarifies the project/design scope involving stakeholders and provides a clear description of the design need. This design brief is the first document that designers/engineers develop and inform all identified stakeholders. As the understanding of the design problem evolves, changes can be made and the design brief may be updated as the project moves ahead in the design journey process.

A typical design brief includes the following:

- Describe the design problem and specify the objectives.
- What is the focus within/outside of the scope of the project?
- Who are the target users and the stakeholders that need the design?
- What are the constraints, assumptions, and standards that need to be considered?
- What are the key exploratory questions that need to be answered for various stakeholders through research, literature, and benchmarking?
- What are the expected outcomes and innovations?

Write down your project Design Brief

Typical Gantt Chart



Understanding the Design Problem (Customer Discovery)

List all key stakeholders/customers (internal/external) and their needs.

Stakeholder Needs (Internal and External)	
Stakeholder	**Need(s)**
Internal	
o	o
o	o
o	o
o	o
o	o
o	o
	o
External	o
o	o
o	o
o	o
o	o
o	o
o	o
	o

Value and Opportunities?

Value/Opportunities	
Human	**Financial**
o	o
o	o
o	o
o	o
o	o
o	o

Competition/Risk?

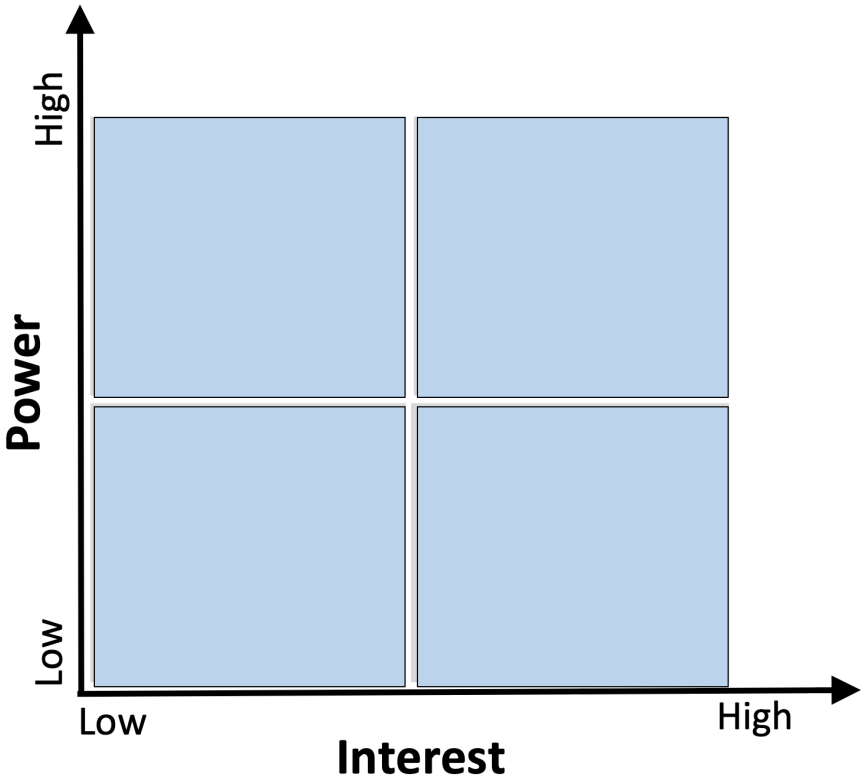
Competition/Risk	
Current/Existing	**Future**
○	○
○	○
○	○
○	○
○	○
○	○

Codes and Regulatory?

Professional Codes/Regulatory	
Technical Codes/Standards	**Regulatory Agency**
○	○
○	○
○	○
○	○
○	○
○	○

PRIORITIZE STAKEHOLDER REQUIREMENTS

(Mapping stakeholders as per their interest and power)



Notes:

Adopted from Stakeholder Analysis. https://www.mindtools.com/pages/article/newPPM_07.htm

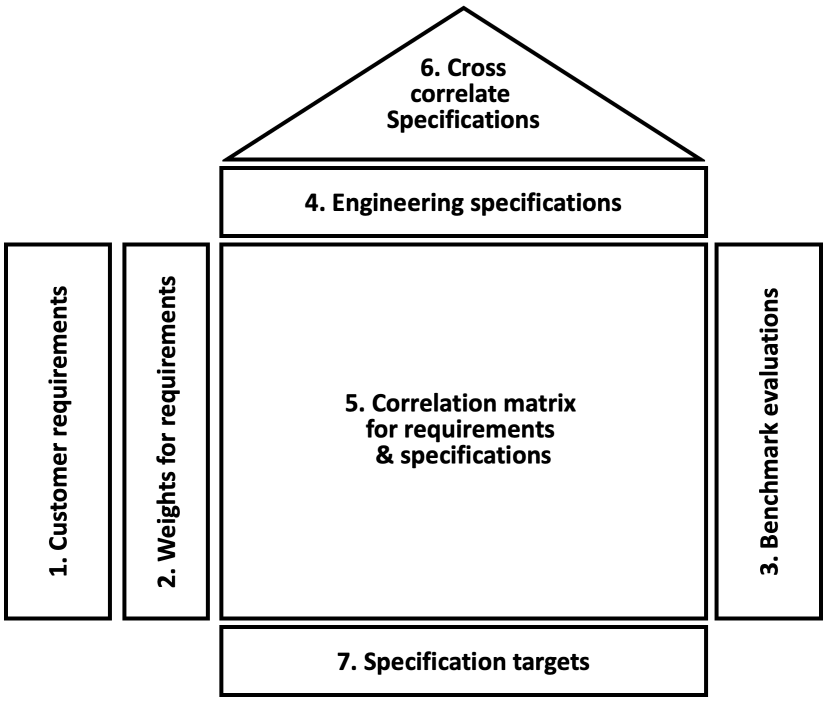
Translate Stakeholder Requirements into Engineering Requirements and Targets through QFD Process

Stakeholder Requirements	Engineering Requirements	Targets

Benchmarks/Competitions:

-
-
-
-
-
-

TYPICAL QFD CHART



Design Project Proposal: Template

The design project proposal serves as a document for design specifications and for communication within the team as well as all stakeholders.

- **Project Description:** What is the opportunity? Describe the project scope and objective.

- **Stakeholders (Voice of Customers):** Who are the customers/what do they need/why is this important?

- **Exploration Questions:** Key questions through research; learn about stakeholders and their likes/dislikes, beliefs, etc.

- **Parameters/Constraints:** What parameters/constraints related functional, performance, cost, and environmental requirements are needed for the design?

- **Existing/Current Design Solutions:** Benchmarking/competitive designs/shortcomings?

- **Expected Outcomes (VALUE Creation):** What outcomes should the design solution/innovation accomplish?

- **Project Plan and Schedule:** Gantt chart?

Design Review #1
Project Proposal and Design Requirements Review

Feature	Comments/ Feedback
Establish Design Need: How are the needs identified and from what sources? Who are the stakeholders?	
Design Objective: What is the focus of the identified need? Write a design statement related to the scope of the project.	
Gathering Requirements: How was the information gathered? What resources were used to gather different requirements? Have constraints (time, budget, etc.) been identified?	
Project Planning: Does the design team have a project schedule and plans for next design steps?	
Target Users: Who are you designing for? Why are they important? What requirements need to be met? What are the engineering requirements and targets?	
Research the Market Questions: What key questions do you need to answer through your research? Who are your competitors/why is your design likely to be superior?	
Next Steps: Are there plans as to how the design concepts will be developed?	

DESIGN ACTIVITY TEMPLATE: CONCEPTUAL DESIGN

1. Write the design problem requirements.

2. Conceptual design. Brainstorm possible solutions.

3. Research the solution (patents, review of literature, analyze the solution for feasibility, safety, and implications).

4. Evaluate generated concepts.

5. Prepare final design concept and conceptual/CAD drawings or sketches.

DEVELOP CONCEPTS FOR YOUR PROJECT

Concept #	Name

Concept Description: Briefly describe the concept with various design features, functionality, capabilities, etc. You can also provide a sketch to further illustrate the concepts and details.

Stakeholder Needs: What stakeholder needs are addressed in this concept?

Advantages/Disadvantages: What are the Pros/Cons of this concept in meeting stakeholder needs?

Potential Risks/Competitions: What are the risks to stakeholders? What are the costs, technical feasibility, and IP aspects of this concept?

Strategic Value/Opportunities: What potential innovations of this concept will lead to value, market position, and Return On Investment (ROI)?

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PRELIMINARY PROTOTYPING AND TESTING

User:	
What worked?	
What didn't work?	
Which of your needs did the prototype meet?	
Is the prototype useful?	
What would you change, if anything?	
Other feedback?	

SUMMARY:

CONCEPTS EVALUATION: GO/NO-GO SCREENING

Concept	Criterion #1	Criterion #2	Criterion #3	Criterion #4	Criterion #5	Criterion #6	Criterion #7
#1							
#2							
#3							
#4							

SUMMARY:

CONCEPTS EVALUATION: DECISION MATRIX

Select one concept as "datum" and score relative to other concepts as same (0), or better (+) or worse (-)

Criteria	Weight (%)	Concept #1	Concept #2	Concept #3	Concept #4
#1					
#2					
#3					
#4					
#5					
#6					
Total (+)					
Total(-)					
Overal Total					
Weighted Total					

FINAL CONCEPT FOR YOUR PROJECT

Concept #	Name
Concept Description: Briefly describe the concept with various design features, functionality, capabilities, etc. You can also provide a sketch to further illustrate the concepts and details.	
Stakeholder Needs: What stakeholder needs are addressed in this concept?	
Advantages/Disadvantages: What are the Pros/Cons of this concept in meeting stakeholder needs?	
Potential Risks/Competitions: What are the risks to stakeholders? What are the costs, technical feasibility, IP aspects of this concept?	
Strategic Value/Opportunities: What potential innovations of this concept will lead to value, market position, and Return On Investment (ROI)?	

Design Review #2: Concepts Evaluation Review

CONCEPTUAL DESIGNS REVIEW

Feature	Comments/ Feedback
Concept Generation: What techniques were used to generate concepts?	
Quality of Concepts: Were all concepts generated with quality to meet the requirements? Are there enough concepts generated spanning the design space?	
Evaluation of Concepts: How are the concepts evaluated? Did the team use customer requirements in their evaluation of concepts?	
Final Concept: Does the final concept meet all the requirements? Are there possibilities for concept refinement? Are there any plans to realize the final concept?	
Overall Innovation: How does the overall concept generation/evaluation process lead to innovation?	

PROTOTYPE COSTS: PARTS, BUDGET, AND ORDER LIST (ITEM, VENDOR, PRICE, WEBSITE)—BILL OF MATERIALS (BOM)

REFLECTIONS ON CAPSTONE DESIGN I (SEMESTER 1)

Provide a summary of key points you have learned from working through the **Capstone Design I**, specifically, the *design process* and *concepts/prototype development*.

1. How did the team work together? What are the challenges you faced as a team?
2. How did the conceptual design go for your team?
3. Are you happy with your team concepts and preliminary prototype?
4. What changed during the process?
5. Did the workbook help to scaffold the design process?
6. Comment on your valuable experiences, frustrating experiences, conflicts, and any changes/modifications in the future.

Design Review #3
Design Realization Review

Feature	Comments/ Feedback
Detail Design: What aspects of detail design are investigated? What types of model/simulation and analysis techniques were used? What are the key features/functions of the final design? How are they evaluated? How are the simulations/prototyping/ testing being conducted to evaluate the engineering requirements? How will the design solution be realized? What design strategies were followed to address tradeoffs among various criteria? How will the final design solution be implemented? Are there any risks/failure modes that affect the safety of the design?	
Design Innovations: How will the final design lead to innovation?	

EVALUATION OF FINAL PROJECT DESIGN REQUIREMENTS

Engineering Requirements	Does the Design Meet the Requirements?

Final Design Review: Summary and Recommendations

Capstone Design Report Format

Project Report Format (typical outline):

Cover Page: Project Title, Names of Design Group, Faculty Mentor/Coordinator, Address, and Date. Signatures can be included as well.

1. **Abstract (or Summary):** Describe the goals or objectives of the design, the product developed, and its applications. Summarize the project accomplishments.

2. **Introduction:** Summarize relevant background information including the need for the project. Clarify the technical design requirements and cost benefit analyses. State the project objectives.

3. **Design:** Review the engineering specifications and targets; summarize and evaluate existing benchmarks with particular emphasis on any gaps which the project is intended to fill; discuss the concept generation and evaluation aspects of the project, followed by justification for developing the final product; provide a detailed description of the procedures used for product evaluation; and share the details of analysis, experiment, or field test results.

4. **Design for X:** Discuss how the product addresses a number of factors (X) such as cost, safety, sustainability, and impact on the environment and society.

5. **Conclusions:** Provide empirical evidence to support major project accomplishments and demonstrate that the project has satisfied critical engineering specifications.

6. **Recommendations:** Discuss any recommendations you may have for extending/improving the design in the future.

7. **References:** Use appropriate professional style and language in citing sources (internet, books, journals, etc.) used in the design project. Provide an alphabetized bibliography of references at the end of the design report.

8. **Appendices:** Attach supplementary materials such as drawings (layout drawings, detail drawings, assembly drawings), design analysis results (stress contours, failure plots), product development plans, etc.

Student Reflections on Capstone Design

Provide a summary of key points you have learned from working through the Capstone Design project. This includes *design process* (how did the design go for your team, how the team worked together, challenges as a team, what ways did the design workbook help the design process?), *designed product/prototype* (happy with what your team created, how the design changed during the process, some unexpected challenges, and how you handled them). And how would you go about changing/modifying the process in future?

Include "Individual Reflection" as well: the process, teamwork, learning outcomes, engineering design workbook, and any additional reflections.

Scoring Rubric

The purpose of this form is to guide faculty mentors in assessing the Capstone Design project student's contribution to each phase of the design process through the entries by student in the design workbook.

Please use the following ratings: 1 = Poor; 2 = Average; 3 = Good; 4 = Very Good; 5 = Excellent

Design Phases	Performance	Feedback
Project Scope (project exploration, client/sponsor consultation, team skills, brainstorming, and design statement)		
Project Planning and Teamwork (project schedule, team roles, individual plan, and leadership, treat others with respect, work collaboratively, conflict resolution)		
Project Understanding and Requirements (stakeholders/needs, criteria and constraints, value statement, market research/benchmarking, ethical responsibility, sketches)		
Design Quality (concepts, innovation, functionality, feasibility, cost, safety, and durability)		
Prototyping (CAD models, prototypes—testing and documentation, design iteration, analysis, and optimization)		
Communication (presentations, reports, documentation, and reflection)		
Design Workbook Quality (completeness, sketches, meeting decisions, following design process, neatness)		
Overall score (Total of above 7 scores)		

Student Design Notes

Topic **50**

Signature: Date:

Topic **51**

Signature: Date:

Topic **52**

Signature: Date:

Topic **53**

Signature: Date:

Topic **54**

Signature: Date:

Topic **55**

Signature: Date:

Topic **56**

Signature: Date:

Topic **57**

Signature: Date:

Topic **58**

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Topic **59**

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Topic **60**

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Topic **61**

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Topic **62**

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Topic **63**

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Topic **64**

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Topic **65**

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Topic **66**

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Topic **67**

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Topic **68**

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Topic **69**

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Topic **70**

Signature: Date:

Topic **71**

Signature: Date:

Topic **72**

Signature: Date:

Topic **73**

Signature: Date:

Topic **74**

Signature: Date:

Topic **75**

Signature: Date:

Topic **76**

Signature: Date:

Topic **77**

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Topic **78**

Signature: Date:

Topic **79**

Signature: Date:

Topic **80**

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Author Biography

Ramana Pidaparti is a professor and distinguished faculty scholar in the College of Engineering at the University of Georgia. He received his Ph.D. in Aeronautics and Astronautics from Purdue University, West Lafayette, Indiana. He previously taught at Virginia Commonwealth University and the Purdue School of Engineering and Technology (IUPUI). He taught design courses including capstone design for about 25 years. He won several design awards and presented papers at various conferences based on the student design projects. He is a Fellow of ASME (American Society of Mechanical Engineers), Fellow of American Association for Advancement of Science (AAAS), Fellow of Royal Aeronautical Society, Associate Fellow of AIAA (American Institute for Aeronautics and Astronautics), and a member of ASEE (American Society for Engineering Education). His current research interests include multidisciplinary design innovation, AI-driven and computational approaches to multi-physics systems, and STEM education.