Smart Fridge

TIM 205
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Table of Contents

Title **Page #**

Executive Summary

The research completed by the Tech XY engineering team has been completed using the MDC Framework. The final analysis of this product suggests that the company should green-light the development of this product immediately. This decision is based on three definitive factors:

1. Management:
    a. The product fulfils the the goals of the company including the mission statement and values. Using an analysis of The financial success of this product will push the company towards the annual revenue goal of $536 million, which is a 16.5% increase of the company's previous target of $460 million.
    b. The Porter's 5 Force model analysis shows that the smart refrigerator market has an attractive appeal for new entrants. Tech XY as a new player in the industry would be able to dominate the market with the introduction of its new product. The market cap for this industry is estimated to be $1.069 billion. With a majority market share the revenue of the project would add a $75.915 profit to the financials of the company.
    c. Beyond the scope of the initial product, additional products in a project mix suggest an added value of $289.9 million after the sales cycles of the main product. This includes research and development into the main product which is being developed, additional products which augment the product platform, and partnerships with online grocery shopping services.
2. Development:
    a. Using a FAST Diagram and a House of Quality, we have engineered the design of the product to meet and exceed the needs of the customer, and align with the goals of the company. By performing an analysis of the sub-functions which are most important to the

consumer, we have tailored our product to focus on the features which really matter and save costs on the features which aren't important to the customer.

b. By using a morphological matrix we have selected the best conceptual design from a list of alternatives and combined features which were procedurally ranked by a team of experts. By comparison to the current market leader in the smart refrigerator industry, our product we have a highly competitive advantage by providing more finely tuned features while staying within a reasonable price range to promote sales.

c. A Failure Modes Effect Analysis shows the possibility of failure for the product in specific areas. The primary areas of concern have been addresses in order to prevent them from experiencing a technical fault. The engineering team has prioritized these issues using a fault tolerance methodology in the design of the product, so the customer can continue to use their product while repairs are being made.

3. Commercialization:

a. A financial model has been provided to show the time based development, release, and sales of the product. Using a set of base case parameters we can show the forecasted profit which will be created by the product. Parameters include the number of unit sold, the price and cost for an individual unit, and the budget to design and market the product. Using a 4-year NPV analysis with an annual discount factor of 10%, the base case scenario shows an estimated $75.915 million projected profit.

b. A sensitivity analysis of the NPV analysis uses a pessimistic forecast of the projected profit based on an unexpected increase in development costs and time. The pessimistic analysis still forecasts a $49.078 million profit based on an extended 2 quarter development time.

Report Description

Introduction

The structure of this report will be based on the MDC framework introduced in the TIM 205 course. The report is split into the three sections of the framework (i.e. Management, Development, and Commercialization). However, the entire body of work was conducted in a few phases across the term of the course and therefore will be organized into three phases, each split into five steps to solve the problem(s) for the respective phase (i.e. define the problem, plan the treatment of the problem, execute the plan, check your work, and learn and generalize.) The following paragraphs will briefly introduce each part of the three sections (these are also displayed in the diagram above).

Section 1 - Management

The primary section of this report will focus on the management of information relating to the connection between the industry and the goal of the company itself. The primary steps included developing business goals, a firm level strategy, developmental goals, and functional maps. The collection of this information allows for the company to understand the competitive market atmosphere that will relate to the potential product idea being considered for development. The following steps include the aggregate project plan, developmental funnel, and project planning for management. The aggregate project plan and developmental funnel initialize the development process for the product idea. The project planning step can be applied to the entire project, however, for the purpose of convenience, we have developed a project plan for management and another for the second section of development.

Section 2 - Development

The secondary section of this report will focus on the development of the product. The initial step in this section is "Quality Function Deployment", this has been completed in the previous section under the "House of Quality" step as the two overlap. The next step is reverse engineering followed by conceptual design. These two steps begin to realize the product and organize the selection process for choosing the most robust design for the product by implementing a utility function. After choosing the concept design, we then move on to prototyping strategy and product architecture/product strategy to determine how to incorporate the product into the various relevant market segments. Finally, we perform a failure modes and effects analysis to determine the potential risks of the product.

Section 3 - Commercialization

The tertiary and final section of this report will focus on the financial modeling of the product's lifecycle which allows the company to understand the expected profits/payoffs from the product development projects over a specified time-frame. Finally, we develop a product release map to relate back to our product strategy and visualize the introduction of the product to the previously defined market segments.

Section 1: Management

Phase I

Define the problem.

1. Provide a clear and concise description of your company: vision, mission, business goals, technology strategy, product/market strategy, competitive strategy, developmental goals.
2. Identify technologies and products that are related to your proposed new product/service. Then construct functional maps to show the evolution of these new technologies and products.
3. Perform a thorough and **specific** competitive analysis of the industry/market landscape for your proposed new product/service: identify competitors, suppliers, buyers, etc. Are you a new entrant? Are you creating a substitute product? Etc. (Suggestion: Start by identifying the industries relevant to your new product.)
4. Perform a market sizing (revenue map) and market (customer) needs analysis for your new product/service.
5. Create an aggregate project plan, i.e., an appropriate project mix (R&D, core products, etc.), within the context of (1) your developmental goals (2) your market needs analysis, and (3) your technology, product/market, and competitive strategies.
6. Perform a preliminary risk analysis of your project mix, using Decision Trees and Decision Analysis, in order to determine which particular product to develop initially.

Plan the treatment of the problem.

1. Reference pages 17-18 in the "Lecture Notes for Competitive Strategies" handout to understand the process and format for executing a company analysis.

2. Using online resources, research the necessary information and perform the company analysis:
    a. Establish Vision and Mission Statements.
    b. Establish the business goals and objectives for the company.
    Identify the current statistics and determine future statistic goals:
        i. ROI
        ii. Market Share (%)
        iii. Annual Sales Revenue ($)
        iv. Growth (%)
        v. Profit ($) or Net Income ($)
        vi. Profit Margin (%) = Net Income/Sales Revenue x 100
    c. Determine the technology strategy.
        i. Define a technology strategy
        ii. Identify the company's technology strategy
    d. Determine the product/market strategy for the company.
        i. Define a product/market strategy.

    ii. Identify the company's product/market strategy.
e. Perform a competitive analysis of the industry/market landscape.
    i. Implement Porter's Five Forces model
f. Define the overall development goals and objectives to align business goals, technology, and market strategies.
    i. Define developmental goals.
    ii. Identify the company's developmental goals.
g. Develop the functional evolutionary maps of the markets and industry in which the company is embedded. Create functional maps for technology, product market, and manufacturing strategy of the firm.

3. Create an aggregate project plan.
    a. Identify a set of projects for Tech XY..
    b. For each project Pi (i=1,2...n)
        i. Estimate cost, Ci (i=1,2...n)
        ii. Perform decision analysis(DA) to compute the expected monetary value (EMV) for each product, Vi (i=1,2...n).
    c. State the project that has been chosen to proceed in product development.

1.1 BUSINESS GOALS

Execute the plan.

1. Establish Vision and Mission Statements.
    a. Vision Statement: Universal adoption of smart refrigeration by replacing traditional refrigerators.
    b. Mission Statement: To improve the quality of life by making refrigerators "smart".

2. Establish the business goals and objectives.
   Identify the current statistics and determine future statistic goals:
    a. Current ROIC (%): 5.10%
        i. Goal: **7.00%**
    b. Current Market Share (%): 5.24%
        i. Goal: **15% total market share** by end of Q4 2018
    c. Current Annual Sales Revenue ($): $460 million
        i. Goal: **$530 million**, a 16% growth from the previous year
    d. Current Growth (%): (460 - 463.8) / 463.81 = -0.82%
        i. Goal: **Achieve a 4.125% growth** in annual sales revenue in the year 2018
    e. Current Profit ($) or Net Income ($): $350 million
        i. Goal: Post a **net income of $600 million** for 2018, 15% increase

f. Current Profit Margin (%) = Net Income/Sales Revenue x 100 = 350 /460 x 100 = 76.0%
    i. Goal: 600 million / 745 million * 100 = **80.5% profit margin** target, a 4.5% increase

1.2 FIRM LEVEL STRATEGY

3. Determine the technology strategy and product market strategy for the company.
    a. Technology Strategy:
        1. What are the core technologies that give the company a technological advantage over its competitors?
            a. Tech XY has a long history of being a leading edge innovator in the design and integration of exciting features. The company was the first to design and bring to market the bottom freezer and side-by-side refrigerator. This has lead the company to be awarded Innovation and Design Awards by several media outlets, such as Consumers Electronics Show and many others.
            b. Tech XY will be the first to introduce refrigerators with smart tech capabilities on a wide scale, while also maintaining a consumer conscious price tag.
        2. What is the company's approach to product and technology development?
            a. Tech XY's focus for product and technology development is to increase the functionality of their appliances via introduction of smart tech and product partnerships. (i.e. Smart Home appliances with connective capabilities to products such as Amazon Alexa and Nest Thermostat, etc.)

    b. Product/Market Strategy:
        i. What differentiates the company's product from its competitors?
            1. Tech XY distinguishes itself from its competitors through its commitment to providing quality service products with customers in mind.
            2. Tech XY focuses on:
                a. Compatibility with Smart Technologies
                b. Compactability
                c. Reliability
                d. Eco-friendly
                e. Quality Customer Service
        ii. What markets does the company serve?
            1. Consumers
                a. Nutrition conscious market

   b. Inventory tracking market
   c. Order/delivery service market
   d. Power monitor market
2. Small businesses- specifically restaurants
   a. Inventory tracking market
   b. Order/delivery service market
   c. Quality control market
   d. Power monitor market

c. Perform a competitive analysis of the industry/market landscape.
   i. Implement Porter's Five Forces

ii. Five Force Analysis
    1. Force 1: Rivalry between competitors (High)
        a. The largest smart refrigerator manufacturer are as follows:
            i. Samsung
            ii. LG
            iii. GE
            iv. Electrolux
            v. Whirpool
        b. Each of these companies share the same smart refrigerator market as well as provide the same services.
        c. These firms compete at providing the newest and most innovative refrigerator on the market through usage of various technologies such as:

i. Touchscreen
ii. Software Application Integration
iii. Food Inventory Monitoring
iv. Energy Efficiency Monitoring
v. Wifi / Bluetooth Connectivity

2. Force 2: Threat of New Entrants (Medium)
    a. The threat of new entrants is significant as current refrigerator companies are slowly entering the market for smart refrigerator appliances.
    b. New entrants include current companies such as:
        i. Maytag, Amana, KitchenAid, Frigidaire, and Kenmore.

3. Force 3: Threat of Substitutes (Low)
    a. Only present substitutes are the traditional refrigerators that are already in the market. Our new product aims to revolutionize the traditional methods of refrigeration with a smart tech perspective.

4. Force 4: Supplier Power (Low)
    a. The table below describes the component that needs to be supplied and its corresponding supplier company:

Component	**Supplier**
LCD screens	Phoenix Display
Freon Tubes	StreamLine
Water Filters	Frigidaire
Insulation	General Plastics Manufacturing Company
Plastic	Piedmont Plastics
Lights	SATCO
Stainless Steel	Atlantic Stainless
Wifi	Google
Application	Our company

b. Our company must integrate other companies products to create the desired smart refrigerator because the company's focus should be on developing the features of the refrigerator and the application.
c. The suppliers have low power because if a supplier will not agree to work at a specific price, our company will find another vendor that will comply, especially since the components of a refrigerator and their corresponding vendors are common.

5. Force 5: Buyer Power (Medium)
    a. Target Consumer Market: Young families/households (ages 25-35).
    b. Consumers will decide whether to purchase refrigerators with smart tech functions. Level of buyer power can change depending upon the changes in consumer tastes and preferences/future trends. Our target market will determine the factors that adjust this force. Determining factors can include multi-functionality of the product, integration, switching cost from conventional refrigeration to smart tech refrigeration, etc.

6. Complements (medium)
    a. The products that complement our smart refrigerator are:
        i. Kitchen appliances (microwave, toaster, coffee maker, etc.)
        ii. Smart home appliances (smart television, smart temperature control, tablets, etc.)
        iii. Smart cell phone
    b. The complements have medium power because most consumers will not buy a smart fridge based on whether or not they own certain kitchen appliances, but they might have a higher chance of buying a smart fridge if they already own smart home appliances and a smart cell phone.

1.3 DEVELOPMENTAL GOALS

4. Define the overall development goals and objectives to align business goals, technology, and market strategies.
    a. What products and technologies should the company develop over the upcoming years?
        i. Smart Technology Home Appliances
        ii. Automated appliances
        iii. Self-sustaining devices
        iv. Integration with other Smart Technologies

v. Industrial Smart Tech Appliances for small businesses

b. What sales volume (# of units of the product sold per year) should be targeted for each product?

2016 total refrigerator units shipped in North America totalled 10.90 million with an average growth over the last 4 years of 5.17%. For the 2018 target the estimated total units shipped will be 12.03 million units, with a 15% market share we estimate over 20K total units sold by Tech XY. At an average price point of $3,700 total sales will be about **$745 million** for 2018.

c. What is the target price per unit?

i. Our target price is around $3,400 ~ $4,000.

Sensitivity Analysis (±10%)

	Low	Base	High
Market Growth (%)	4.65%	5.17%	5.69%
Units Sold (Thousands)	71	20.15	269
Market Share (%)	5.24%	15%	20%
Product Price ($)	$3,400	$3,700	$4,000
Total Profit ($ Million)	**$241.4**	**$745**	**$1,076**

The optimistic scenario for profit in the 2018 fiscal year is $1.076 billion dollars to North American consumers. The pessimistic scenario for profit in the 2018 fiscal year is $241.4 million dollars to North American consumers.

1.4 FUNCTIONAL MAPS

5. Develop the functional evolutionary maps of the markets and industry in which the company is embedded. Create functional maps for technology, product market, and manufacturing strategy of the firm.

Technology Strategy:

- Functional Map - Technology Strategy Conclusion: This functional map displays the evolutionary progression of the refrigerator industry. As seen from the map, the traditional refrigerator used currently has been present in the industry since the 1930s. The refrigerator has not changed much in terms of functionality for over 80 years. Therefore, we can conclude from this map that updating the current refrigerator by adding more functionalities would be a reasonable decision in product development moving forward.

- Functional Map - Technology Strategy Conclusion: This functional map shows the evolution of the smart product industry along with the device's name. This functional map dates the start of smart technology at 1992 with the smartphone made by IBM which was the "Simon Personal Communicator". The map indicates that smart products have only been recently developed since the early 1990's. This exemplifies the growing consumer market for smart products which evidently can be expanded upon with our smart refrigerator.

Refrigerator Industry: Total Market Size for 2015: $61.69 billion

Small Businesses		$75M 0.75% / YR
Consumers	$59B 2.7% / YR	$670M 1.5% / YR
↑Markets →*Products/ Models*	***Traditional Refrigerator***	***Smart Refrigerator***

- Functional Map - Market Sizing Conclusion: This functional map displays how the smart refrigerator would be segmented in the associated markets. As seen from segmentation, a smart refrigerator product would prove to be most profitable it targeted to consumers. This is because there is generally a refrigerator in each home, therefore as a domestic home appliance, a smart fridge is most attractive to consumers/homeowners.

1.5 AGGREGATE PROJECT PLAN

6. Aggregate Project Plan
    a. Identify a set of projects for Tech XY.

Potential Projects:

1. Incremental and derivative products:
    a. **Project 1 - P1**: Develop an application to connect smartphones to the smart refrigerator to enable remote control over the systems.
    b. **Project 2 - P2**: Development of inventory control system within refrigerator.
    c. **Project 3 - P3**: Device that monitors the sub-systems within the refrigerator (i.e. energy efficiency, content data, etc.)

2. R&D Projects:
    a. **Project 4 - P4**: Understanding customer needs to achieve energy efficiency in a refrigerator.

3. Partnerships and Acquisitions:
    a. **Project 5 - P5**: Create an application on the fridge which connects to Amazon for ordering groceries

b. For each project P_i (i=1,2...n)
    i. Estimate cost, C_i (i=1,2...n)
        1. **Project 1 - P1**: Cost of integrating smartphone with smart refrigerator: This project will require a fair amount of capital expenditure to get off the ground, as it require various products to make it work. One of the first things that the company will need to decide is whether or not it wants to invest in building smart fridges at all. The capital required to prototype a functioning smart fridge is $100 million. There is a 30% chance that Tech XY is unable to create a prototype that would satisfy the needs for its users. After that the company must decide on how it wants to build an app to integrate with the fridge. Tech XY has the option of outsourcing this to a third party developer for $40 million. This would also lock the company into an IT service contract, $10 million. There is about a 25% risk included with this as it is possible that the app could have bugs, and would require an additional $5 million to fix. The other option that Tech XY has is to design the app in house. This would cost about $20 million dollars, but there would be about a 40% chance of bugs, which would also need to be fixed for $10 million. The flip side of this is that Tech XY would not need to sign into an IT support contract Finally, if Tech XY was able to successfully bring this product to market, the EMV would be $400 million.

        2. **Project 2 - P2**: Developing an inventory control system. This project aims to develop a built-in barcode system into the refrigerator which will scan products that will then be added to the refrigerators database. The first decision needed to be made is the decision to build an inventory control system. The funding necessary for such a prototype would be approximately $13 million due to necessary components and labor required. There is a 20% chance of failure to create a working prototype. If the the production of the prototype is successful, Tech XY must decide whether or not to develop the product in-house. The probability of successfully developing in-house is 85% with cost of in-house production being $15 million. If Whirpool decides to use a third-party to manufacture an inventory control system, the estimated cost would be around $35 million due to licensure of software and hardware

production. Thus if production of an inventory control system is successful, the EMV would be approximately $120 million.

3. **Project 3 - P3**: Sub-system monitoring service. This project will be simple to integrate with the existing model of refrigerator in a second-generation model product. By implementing a dedicated single board computer, we can affix sensors to deliver information to the main computer. The cost associated with researching and developing the monitoring service would not exceed $15 million. If the monitoring system was implemented the development team would need to decide if the existing internal components of the refrigerator must be redesigned. This would incur an additional $25 million cost, but if not completed would cause technical issues and may reduce sales by 30%. The additional features of sub-system monitoring would add an additional $100 to $200 on to the base price of the smart refrigerator, with a probability of 75% and 25%, respectively. A base sales estimate forecasts 201.5 thousand units sold in the first year with a 63% likelihood. Low estimates would be 71 thousand units with a 18.5% likelihood, and high estimates would be 269 thousand units sold with 18.5% likelihood. Development wants to forecast the EMV of upgrading the product to a second generation model versus not upgrading.

4. **Project 4 - P4**: Research and development for achieving an energy efficient product. This motive of this project is to understand customer needs in regards to energy efficiency in order to develop a product (i.e. an energy efficient refrigerator) to meet this need. Tech XY would first need to conduct research to understand the consumer/environmental needs in regards to energy efficiency and based on the results of this research, decide whether to convert and implement solar power as a usable power source for the product. The funding needed/cost for the research and development of this project is $36 M. There is a probability of 80% that the customer/environment needs research will be successful and a 70% chance that the development of the product will be successful.

5. **Project 5 - P5**: Amazon Grocery Integration: This project is being undertaken assuming that we have already invested in the next generation of smart fridges. In other words, we will not be including the cost to R&D the fridge. It will instead build off the platform we used for project 1. Before we can begin design of an app that directly integrates with Amazon, we must secure the company's support and partnership. This will cost around $5 million if it is not successful and $20 million if it is and we attempt to develop the app. We must first communicate and agree to terms with Amazon, which require manhours, meetings, and

project proposals.. After that, we will have to figure out some sort of fee paid to Amazon to use their platform. We are going to assume that they will request a flat fee rather than a percentage of the revenue made, as they will be making money off the deliveries. In addition to all of that, TechXY must find some way to profit off of this. The probability that TechXY is able to come to an agreement with Amazon is 90%. After this, we must decide whether or not we want to actually follow through with the app development. If TechXY decides not to, they still incur a cost of $15 million, the cost of working out the agreement plus the flat fee paid to Amazon. If we do follow through with the app development, there is a 80% chance of success. A successful app development will bring in a revenue of $80 million, or profit of $50 million. The cost of developing an app is $10 million and as we mentioned above, the cost of partnering with Amazon is $20 million, the $15 million plus $5 million in revenue sharing. An unsuccessful app development will cost $20 million, but will only bring in $50 million in revenue.

ii. Perform decision analysis(DA) to compute the expected monetary value (EMV) for each product, Vi (i=1,2...n).

1. **Project 1 - P1**: SmartPhone Integration
    a. Building blocks: The first step in solving this is to identify the various building blocks for our decision analysis. We are going to use three types: decision blocks, uncertainty blocks, and outcome blocks.

        i. Decision Blocks:

ii. Uncertainty Blocks:

iii. Outcome Blocks:

b. Influence Diagram: We will now use our building blocks to construct a chronological Influence diagram to show how these events play out.

c. Decision Tree: Now that we have clearly laid out Influence diagram, we add branches to it so that it can become a decision tree (note: all values are in millions):

d. Decision Tree Foldback: Now that we have drawn out our decision tree, we will now fold back the decision tree to find each of the values for specified choices. From there, we will be able to make some recommendations on what the best choices are.

    i. Success in Coding in House?: We can do some brief calculations to find the payoff if we decided to design the app in house. 380*.6 + 370*.4=376. From this calculation, we can see that programming the app in house has a payoff value of $376 million.

    ii. Success in Coding Outsourced: We will again do some brief calculations to find the associated payoff of this uncertainty. 350*.75 + 345*.25=348.75. From these calculations, we can see that our value of outsourcing the design is $348.75 million. We can also now see that designing the app in house is the better option.

    iii. Success in building fridge: We can now use the greater of the two payoffs, $376 million, to estimate the payoff if we built the fridges. 376*.7 + (-100)*.3= 233.2. From the these calculations, we can see that building these fridges has a total payoff of $233.2 million dollars.

e. Conclusion: From the decision tree analysis, we can see that it would be very fruitful to build a smart fridge that integrates directly with smartphones. In total, after adjusting for capital expenditures, this project would generate $233.20 million dollars for Tech XY. This is against a cost of $120 million

2. **Project 2 - P2**: Inventory Control System
   a. Building blocks: To solve this problem we must identify the building blocks in a decision analysis.
      i. Decision Blocks:

      ii. Uncertainty Blocks:

      iii. Outcome Blocks:

b. Influence Diagram:

c. Decision Tree:

d. Foldback Decision Tree:

e. Conclusion: The total cost of pursuing this project would be $28M for a successful product that is developed in-house which would generate $56.6 M additional revenue for Tech XY.

3. **Project 3 - P3**: Sub-system Monitoring

   c. Building blocks: To solve this problem we must identify the building blocks in a decision analysis.
      i. Decision Blocks:

      ii. Uncertainty Blocks:

      iii. Outcome Blocks:

b. Influence Diagram:

f. Decision Tree:

g. Decision Tree Foldback:

The sales volumes of the above outcomes would give the following EMVs when the decision tree is folded back:

The decision to refit the interior components of the smart refrigerator to add the monitoring system would then have the following EMV:

Conclusion: The optimal strategy which would have the highest payoff would be to develop the monitoring system smart refrigerator and then not refit the new design, despite the loss of 30% of sales. The monitoring system would give an EMV of $1.6M added to net profit against a cost of $40M.

4. **Project 4 - P4**: Understanding customer needs to achieve energy efficiency in a refrigerator.
    a. Building blocks

b. Influence diagram

c. Decision tree

d. Folded back decision tree

Conclusion:
From the rollback, it is shown that our expected monetary value is $11.52M. Our revenue was $72M and our total cost was $36M, so our profit was $36M (Profit = Revenue - Cost). Our expected monetary value is low, so this project may end up getting rejected in our table-lookup.
Total cost: $36M
EMV: $11.52M

5. Project 5: Amazon Grocery App integration

a. Building Blocks

i. Decision Blocks:

ii. Uncertainty Blocks:

iii. Outcome Block:

b. Influence Diagram: There is no specific time span that this will be occurring over, so we will be reading this diagram as time increasing from left to right.

c. Decision Tree:

d. Decision Tree Rollback: Now that we have constructed a decision tree for this problem, we can conduct a rollback to find the EMV of each specific decision.

   i. Successful App Development: We will now do some simple calculations to find the weighted average of our decision to follow through with the app development. The probability that we have a simple process in designing the app is 80%, with a payoff of $50 million. This means that our probability of a rough development cycle is 20%, with a payoff of only $10 million. The calculations are as follows:
   $(0.8) \times \$50 + (0.2) \times \$10 = \$42$. This gives our decision to follow through with app development has a payoff of $42 million. The rollback is shown below.

   ii. Successful Partnership with Amazon: From the rollback we just performed, we can easily see that it is definitely in TechXY's best interest to follow through with development if they get approval from Amazon. We must now compute the EMV of trying to partner with Amazon, against the cost it takes to do so. The probability of a successful partnership with Amazon is 90%, with an EMV of $42 million, while the probability it is unsuccessful is 10% and a cost of $5 million. The computations are shown here:
   $(0.9) \times \$42 + (0.1) \times (-\$5) = \$37.3$. The estimated value from partnering with Amazon, and hence this project is $37.3 million. The rollback is shown below:

e. Conclusion: From the rollback we just performed, we know that the total cost of a successfully programmed app that integrates with Amazon is $30 million, against an EMV of $37.3 million

1.6 DEVELOPMENT FUNNEL

Table Lookup: This problem is asking us to pose the integer programming optimization problem, using table lookup. It is also important that we define our capital budget constraint, at $150 million. We are going to try and optimize the value of our projects while striving to stay under the capital budget constraint. We will be using Excel to perform all of this.

On the following page is the comprehensive data, compiled using Excel. We used the value and cost optimization process to find out the nominal costs of each project mix. Now that the table has been compiled, we can use the table function in Excel to sort them by whether or not they are viable and which has the most cumulative value. This sorted table is shown below:

After compiling our data, and filtering out non-viable mixes (those which exceed the capital budget constraint), we sort the mixes in terms of most value, hence our table lookup. From this table lookup, we can see that the optimal project mix within our constraint is mix #4, which has an EMV of $289.8 million against a cost of $148 million. By looking at our table of raw data, we can easily see that

mix #4 means we should do the new smartphone integration capabilities and fridge development, P1, as well as develop an inventory control system for the fridges, P2.

Check your work.

- We have checked our work and based on the notes given in lecture and the Lecture Notes for Competitive Strategies, we believe that we have performed an accurate and thorough company and product analysis for Tech XY Smart Fridge. The decision analysis and table lookup process was completed using the Excel software, and is completely accurate for the numbers that we found.

Learn and generalize.

- We have learned that when analyzing a large company, such as Tech XY, it is important to take many factors into account in order to perform a detailed and organized analysis. An important method in this process is the use of functional maps as they can organize extensive data for established companies in a concise manner. In regards to the process of deciding upon which projects to proceed with in development, it is important to compare the mix of projects to determine the project with the highest payoff; this is where the decision analysis and use of the aggregate project plan comes into play and provides an organized methodology for efficient product development. It was also interesting to see how little value was generated by many of the projects and how the mix only needed two projects to be of effect.

Phase II

Define the problem.

1. Complete and refine work done in Phase I.
2. Develop a comprehensive project plan for the current phase (Phase II) and the next phase (Phase III).
3. Develop a House of Quality (HOQ) for the smart refrigerator.
4. Create an Aggregate Project Plan to analyze products and determine projects for further development.
5. Reverse engineer existing products that are similar to the smart refrigerator.
6. Apply the conceptual design process to create several alternative concepts for the smart refrigerator.
7. Create a well structured Phase II report documenting all the work done.

Plan the treatment of the problem.

1. Reference notes taken in Phase I Review and apply appropriate edits to Phase I.

2. *Project Planning*
    a. Clearly state the intent of the project.
    b. Determine the design/development subtasks and activities.

c. Create a design/development activity matrix to understand the dependencies between the sub-tasks.
    i. Define conventions for the matrix.
d. Create a time schedule of tasks using a GANTT chart.
e. Identify the critical path for the project using a PERT chart.
f. Assign clear roles and responsibilities and keep track of progress.

3. *House of Quality (HOQ)*
    a. Make a structured and prioritized list (1) of the customer needs for the intended product based on market research and (2) assess the importance of each need using a convenient scale.
    b. Make a list of technical metrics (3) and assess the importance of each need using a convenient scale (4).
    c. Correlate the customer needs and the technical metrics (or engineering requirements) using a convenient scale to create a correlation matrix (5).
    d. Illustrate the dependencies between the technical metrics and correlate them in a matrix (6)
    e. Asses a set of competing products from the viewpoint of the customer (customer benchmarking) (7), and from a technical viewpoint (technical benchmarking) (8), using a convenient scale.
    f. Set target for customer needs (9) and technical metrics (10) for a new product.

4. *Reverse Engineering*
    a. Identify existing products that are similar to the smart refrigerator.
    b. Create a FAST diagram for an existing reference product.
        i. Understand how the product works using Internet research.
        ii. Identify the primary of main function of the product, and place it on the extreme right of the diagram.
        iii. Identify the subfunctions of the produce and place them to the left of the primary function in the diagram.
        iv. Systematically ask “HOW?” and “WHY?” questions, and organize the answers with the “WHY’s” to the right and the “HOW’s” to the left of the diagram.
        v. Stop when the level of subsystems is reached.
        vi. Connect each subfunction to it’s respective subsystem.

5. *Conceptual Design*
    a. Function Structure (FS)
        i. Establish customer needs and technical metrics (specifications) for the smart refrigerator using the HOQ.
        ii. Identify the primary function of the smart refrigerator.
        iii. Identify one or more related products, and reverse engineer (dissect) these products using FAST.

iv. Create an abstract functional representation of the smart product, called the Function Structure (FS).

b. *Morphological Matrix (MM)*
   i. For each sub-function defined in the FS, generate alternative solution principles for realizing that sub-function.
   ii. Organize the solution principles (SPs) in a morphological matrix (MM).
   iii. Generate 6-10 alternative concepts by suitably combining the solution principles in the MM.
      1. Sketch and explain each concept design alternative generated from the MM.

c. *Concept Selection*
   i. Identify an appropriate set of selection criteria to assess or compare the alternatives generated in the MM. Organize this information in a table.
   ii. Use the selection criteria to create a utility function (UF) to compare, rank , and select from the alternatives.
      1. Organize the selection criteria, that will be used to compare the design alternatives, as a hierarchy.
         a. Define the convention for the hierarchal structure.
      2. At each level of the hierarchy, assign relative weights for the selection criteria.
      3. At each level of the hierarchy, compute the absolute weights for each criteria.
   iii. Utility Function Analysis
      1. Compute the cumulative utility (CU) for each concept.
      2. Rank the concepts based on the CU.
      3. Select 1-2 feasible concepts with the highest CUs.

6. Write a Project Phase II report documenting the work detailed in the plan above.

Execute the plan.

1. We have referenced our Phase I Review notes and made the necessary edits to our previous work.

1.7 PROJECT PLANNING FOR MANAGEMENT

2. *Project Planning*
   a. Intent of the Project: To design and develop a multi-functional smart refrigerator.
   b. Design/development subtasks and activities.
      i. Phase II tasks:
         1. House of Quality (HOQ) - TASK A
         2. Aggregate Project Plan (APP) - TASK B

3. Reverse Engineering - TASK C
4. Conceptual Design - TASK D
5. Phase II Report - TASK E

ii. Phase III tasks:

1. Completion of product conceptual design - TASK F
2. Product platform/line strategy - TASK G
3. Economic/Financial Analysis - TASK H
4. Failure modes and effects analysis - TASK I

c. Design/Development Activity Matrix

i. Rationale: To understand the dependencies between the sub-tasks.

ii. Matrix Conventions

1. X = "depends on"

iii. Matrix:

← Phase II Tasks →						← Phase III Tasks →			
Tasks →	A	B	C	D	E	F	G	H	I
A	A	X	X						
B		B							
C			C						
D	X		X	D					
E	X	X	X	X	E				
F				X	X	F			
G	X	X	X	X	X		G		
H	X	X	X	X	X			H	
I	X	X	X	X	X				I

NOTES - Phase II Tasks:

i. Task A (HOQ) is dependent upon Task B (APP) and Task C (Reverse Engineering).

ii. Task B (APP) and Task C (Reverse Engineering) are not dependent upon any other tasks and can be performed in parallel

iii. Task D (Conceptual Design) can be done in parallel with Task A (HOQ) and Task C (Reverse Engineering). However, Task A is dependent upon Task C, therefore these tasks will be completed before Task D.
iv. Task E (Phase II Report) is dependent upon the completion of Tasks A - D.

NOTES - Phase III Tasks:
i. Task F (Completion of Product Conceptual Design) is dependent upon Task D (Conceptual Design) and Task E (Phase II Report), therefore these tasks are done sequentially.
ii. The information needed to understand the following Phase III tasks (Tasks G - I) has not yet been provided. Our basic assumption is that these tasks will be dependent upon the completion of all tasks in Phase II, but it is too early to decide the dependencies between Phase III tasks.

d. GANTT Chart
   - (Related to Tasks A - I and Design/Development Matrix, defined in parts 2b and 2c.)
   - Dark - shaded areas relate to progress made on each task by the Final Phase II Team Meeting (11/11/17).

e. PERT Chart.

Critical Path: Task C → Task A→ Task D → Task E → Task F

- Comments on critical path:
  1) Task C is on the critical path because Task B has a "slack" of 9 days.
  2) Task F is on the critical path because it is a continuation of Task D and our assumption is that it will require less time than the rest of the tasks designated for Phase III.

f. Roles and Responsibilities

Name	Role/Title	Responsibilities
Nischa Kaur	Project Manager	- Oversees organization across all phases of the startup including initialization, design, marketing, etc. - Assists group to meet deadlines promptly - Schedules and facilitate meetings to ensure efficiency
Olivia Ahmed	Product Manager	- Finds models to determine competitive strategy, as well as cost and product differentiation within the market - Conducts market and industry analysis
Will DeBois	Product Analyst	- Conducts research on target market(s) and technical features of product - Documents new information and provides it to other project members
Dailon Dolojan	VP of Product Marketing	- Monitors business metrics in regard to revenues, profitability, market share and product portfolio mix. - Ensure the development of all strategic product strategies/marketing plans - Develop and manage the marketing budget
James McKenna	Financial Analyst	- Oversees financial aspect of product - Responsible for defining budgetary values - Responsible for salaries and stock division

1.8 HOUSE OF QUALITY

3. *House of Quality (HOQ) for Tech XY's "Smart Fridge"*
    a. Customer Needs and Importance.

Customer Needs	**Importance**
(A) Store and preserve food	10/10
(B) Keep inventory of contents	7/10
(C) Connect to digital devices (smartphone, app., etc.)	8/10
(D) Allow for customer to scan contents	7/10
(E) Provide energy efficiency	6/10

b. Technical Metrics and Importance.

Technical Metrics	**Importance**
(1) Noise reduction (dB)	6/10
(2) Volume (cubic ft.)	6/10
(3) Power output (W)	6/10
(4) Temperature (F)	9/10
(5) Smart application count (#)	9/10
(6) Digital storage (GB)	9/10
(7) Network Connectivity (Mb/sec)	8/10

c. Consumer Needs and Technical Metrics Correlation Matrix.
    i. Convenient Scale

*	Strongly Correlated
●	Moderately Correlated
	No Correlation

ii. Matrix

Tech. Metrics → Customer Needs ↓	1	2	3	4	5	6	7
A		*		*	●		
B		●			*	*	●
C					*	●	*
D					*	*	*
E	●		*				

d. Technical Metrics Correlation Matrix.

Tech. Metrics → Tech. Metrics ↓	1	2	3	4	5	6	7
1	*		*				
2		*	●	●			
3	*	●	*	*			
4		●	*	*			
5					*	*	*
6					*	*	
7					*		*

e. Benchmarks

i. Customer Benchmarking

Customer Needs → Competitors ↓	Store and preserve food	Inventory of contents	Digital device connection	Scan contents	Energy efficiency

Samsung Family Hub 2.0	9/10	8/10	6/10	6/10	3/10
LG Instaview Door-in-door	8/10	4/10	4/10	4/10	3/10
GE Cafe Series Smart Fridge	8/10	3/10	8/10	5/10	4/10
Our Product	9/10	7/10	8/10	8/10	5/10

ii. Technical Benchmarking

Technical Metrics → Competitors ↓	1	2	3	4	5	6	7
Samsung Family Hub 2.0	50 dB	28 cu	778 kWh/yr	-32° - -55° F	15 apps	32 gb	Up to 1 gb/s
LG Instaview Door-in-door	50 dB	23.5 cu	716 kWh/yr	-32° - -55° F	2 apps	0	Up to 1 gb/s
GE Cafe Series Smart Fridge	50 dB	27.8 cu	725 kWh/yr	-32° - -55° F	2 apps	0	Up to 1 gb/s
Our Product	50 dB	30 cu	650 kWh/yr	-32° - -55° F	18 apps	64 gb	Up to 1 gb/s

f. Target Specifications

i. Customer Needs Specifications:

Customer Needs	**Target Specs.**
Store and preserve food	9/10
Keep inventory of contents	7/10
Connect to digital devices (smartphone, app., etc.)	8/10
Allow for customer to scan contents	8/10
Provide energy efficiency	5/10

1. *Store and Preserve Food*: As standard fridge, consumers expect their product to maintain food and keep it good until the expiration date. This is by far the most important aspect of a refrigerator, and as such any new product must be equal, if not better, than existing products in the market. We are using the Samsung Family Hub 2.0 as a the strongest comparison, so we are expecting that our device does as good of a job. Therefore, we assigned a value of 9 to this aspect.

2. *Inventory of Contents*: The ability to inventory the items inside a fridge is one of the main differentiating factors of smart fridges from standard fridges. As such, we know that we need a sub-system to make this happen. This will not be the main thing our product is known for, so we are placing an importance of 7/10, slightly less than that of the Samsung Hub 2.0

3. *Digital Device Connection*: Another key feature of smart fridges is the ability to use a internet enabled digital device to control various functions of the smart fridge. Our product seeks to be one of the leaders in new functionalities for the integration of mobile technology by using new and inventive applications to get the most out of smart fridges. Our fridge would be able to control temperature and check inventory among many things. For these reasons, we have assigned a value of 8/10 to digital device connectivity.

4. *Scan Contents*: This feature is what we will be placing our key differentiation factor on is the ability to remotely scan and identify the products in the fridge. While some existing smart fridges already have a function like this, we would be hoping to bring it to the next level. Our product would hopefully be able to get specific counts or quantities on the contents of the fridge, as well as the ability to send alerts to the user about products being near or completely gone. To this effect we have assigned a value of 8/10 for this, significantly above all of the competition.

5. *Energy Efficiency*: Finally, we will focus on energy efficiency as another way to differentiate our smart fridge from its competitors. Having a eco-friendly fridge that functions well is considered the holy grail among home appliance manufacturers, and based on the research we have done it is clear that smart fridges are fairly inefficient compared to the competition. We will place a greater priority on this, and assign a 5/10 value to this metric. This value is the highest among all of the competition we did.

ii. Technical Metrics Specifications:

Technical Metrics	Target Specs.
Noise reduction (dB)	50 dB
Volume (cubic ft.)	30 cubic ft.
Power output (W)	650 kWh/yr.
Temperature (F)	-32℉ to 55℉
Smart application count (#)	15 - 18 apps
Digital storage (GB)	64 GB
Network Connectivity (GB/sec)	~ 1 GB/sec

1. *Noise Reduction*: This is one of the least important technical metrics for our fridge, and as such we will simply seek to hold par with the other household appliance manufacturers. We will set our target to be 50 decibels, equivalent to a quiet domestic conversation.

2. *Volume*: The volume of the fridge is also an important feature of the product. We are seeking to have a product that has more food storage space than any other smart fridge on the market. We are attempting to build a fridge that has a volume of 30 cubic feet, about 2 cubic feet more than the competition.

3. *Power Output*: As a factor of trying to improve the energy efficiency of our smart fridge, we will be trying to lower the energy usage of the system to below that of the other brands. This will definitely be the most difficult of all the technical perspectives to happen, as we are trying to lower it to 650 kWh/yr, a decrease of 60 from the closest competition.

4. *Temperature*: Our fridge will maintain the same range of temperature as the other brands in this comparison, -32 to 55 degrees fairenheit. This seems to be the industry standard and is necessary for us if we hope to compete with the other brands.

5. *Application Count*: Another main differentiating factor we hope to have is an increased number of applications that work with the fridge. These apps would range from grocery order and delivery management to fridge

inventorying. Our goal is to have slightly more compatible apps than the Samsung Family Hub 2.0, 18 to 15.

6. *Built-in Storage*: Another factor we hope to include is a greater amount of native storage. This would allow our users to save more data and allow the entire system to operate more efficiently by increasing RAM capabilities. While most smart fridges do not have native storage, the Samsung Family Hub 2.0 has 32 gb. We are hoping to double the amount of local storage and have 64 gbs.

7. *Network Connectivity*: We also must maintain a decent level of network connectivity, and be equivalent to that of the other smart fridges. It seems that the other fridges are around a gb/sec speed. We will set our speed at the same a strive to hold par with them.

- House of Quality - Relevant Conclusions:
The technical specifications and consumer needs we generate all seem consist with what people are looking for in a fridge. The more significant issue with this is going to be to actually implement the ambitious goals we have. We believe that the most difficult of these to implement is going to be the increase of energy efficiency combined with increased volume. This is difficult since it requires more power to keep a larger fridge cool, but we are also striving to lower the total consumption for our fridge. This will be doable, but very difficult to implement and stands as the greatest challenge to our product.

Section 2: Development

2.1 QUALITY FUNCTION DEPLOYMENT

(See Section 1.8 for comprehensive House of Quality)

2.2 REVERSE ENGINEERING

4. *Reverse Engineering*
    a. Identify existing products that are related to TechXY's new Smart Fridge product.
        i. Traditional Refrigerator
            1. The traditional refrigerator is produced by multiple companies (including GE, Samsung, LG, Kenmore, etc.). The traditional refrigerator is available in various sizes and designs but ultimately maintains the same primary function and associated subfunctions/subsystems.

b. Create a FAST diagram for an existing reference product.
    i. Primary Function: To store and preserve food.
    ii. Subfunctions
        1. Refrigerate food
        2. Freeze food
        3. Provide power
        4. Slow down activity of bacteria
        5. Provide storage
        6. Keep food at it's required temperature
        7. Organize contents
        8. Adjust temperature

    iii. Subsystems
        1. Thermostat
        2. Coolant/Refrigerant
        3. Compressor
        4. External/Internal Heat Exchanging Pipes
        5. Expansion Valve
        6. Shelves
        7. Drawers
        8. Racks/Track
        9. Gas

iv. FAST Diagram for existing refrigerator.

2.3 CONCEPTUAL DESIGN

5. *Conceptual Design*
    a. Function Structure (FS)
        i. Customer Needs and Technical Metrics (specifications) for the smart refrigerator using the HOQ.

            1. Customer Needs Specifications:

Customer Needs	**Target Specs.**
Store and preserve food	9/10
Keep inventory of contents	7/10

Connect to digital devices (smartphone, app., etc.)	8/10
Allow for customer to scan contents	8/10
Provide energy efficiency	5/10

2. Technical Metrics Specifications:

Technical Metrics	**Target Specs.**
Noise reduction (dB)	50 dB
Volume (cubic ft.)	30 cubic ft.
Power output (W)	650 kWh/yr.
Temperature (F)	-32℉ to 55℉
Smart application count (#)	15 - 18 apps
Digital storage (GB)	64 GB
Network Connectivity (GB/sec)	~ 1 GB/sec

ii. Identify the primary function/subfunctions of the smart refrigerator.
    1. Primary Function: To enhance the storage and preservation of food.

iii. Identify one or more related products, and reverse engineer (dissect) these products using FAST.
    1. Samsung Family Hub 2.0 - Currently the highest level of technology in smart refrigerators and the main competitor for the TechXY smart refrigerator.

Main Function of product:

Integrated Refrigerator and Smart application provider

Sub-functions of product:

a. Provide a french-door opening style and a bottom freezer unit
b. Provide internal view cameras
c. Provide refrigerator related apps for temp control and recommendations
d. Provide productivity apps such as weather, photos, music, and memos
e. Provide a mobile application software interface
f. Provide voice recognition software controls
g. Provide a filtered water and ice dispenser

h. Provide a well designed food storage device
i. Provide a touchscreen panel

iv. Function Structure (FS)

b. *Morphological Matrix (MM)*
   i. Morphological matrix (MM)

1. Organized form of all the sub-functions defined in the FS and their associated alternative solution principles (SPs) for realizing that sub-function.

ii. Generate 6-10 alternative concepts by suitably combining the solution principles in the MM.

1. Sketch and explain each concept design alternative generated from the MM.

Concept 1 - Standard alternative:

This alternative has the most closely related features to the Samsung Smart Hub 2.0. The refrigerator uses heatsinks and fans, and is a left and right freezer and fridge combo. The product will plug into the wall like a standard fridge. As food is passed in, a camera will register the barcode and the data is stored in an internal database. The application software is accessed through an internet browser.

Concept 2 - Aesthetic alternative:

This alternative will have the highest visual stimulation of all given solution principles. The refrigerator will be powered by a lithium ion battery and run a water cooling system. The storage operates by rotating internal containers to give access to the food. As food is placed inside, a laser will scan the barcode to an integrated database. The front door has a computer for accessing the application software.

Concept 3 - High technology alternative:

The high technology alternative offers the most advanced technology for the product. This is an alternative which will appeal to users interested in fringe technology despite a high price. The fridge is cooled by a gas injection system and operates on a rechargeable lithium ion battery. The storage features a left/right fridge freezer combo. The fridge recognizes voice commands as food is placed inside. Information about the inventory is stored in a cloud database. The application is accessed using a smartwatch.

Concept 4 - Practical alternative:

The practical alternative is the set of solution principles which maximize simplicity and minimize the risk of a component breaking. The practical alternative uses heatsink fans and plugs into the wall. The storage is a simple sliding rack and shelf system. The fridge scans your paper receipt for items that are placed inside. A database of stored food is available on your smartphone and the application software is also a smartphone application.

Concept 5 - High powered alternative:

The high powered alternative offers the most powerful cooling solution principles while ignoring energy efficiency and low cost. The high powered alternative uses chemical reactive cooling and is powered by a gas generator. The storage is managed by rotating buckets on a carousel. The inventory is tracked by a camera photography system which uploads information to a cloud database. The applications and database are accessed through a computer on the front door.

Concept 6 - Minimum cost alternative:

The minimum cost alternative uses the least amount of non-renewable energy at the expense of cooling power. The cooling system is driven through a solar pump which displaces heat from the fridge to outside. The power is also obtained by solar rays and the

storage is composed of simple sliding racks and shelves. The barcode scanner uses a low power laser to track food in and out of the fridge. The database is a photo album of the interior space which is available through a simple internet browser.

c. *Concept Selection*

i. Selection Criteria Table

1. Note: Design Concepts are ranked on a scale of 1-5 for each selection criteria. (1 being the lowest rank, 5 being the highest rank)

Design Concept → **Selection Criteria ↓**	**Concept 1**	**Concept 2**	**Concept 3**	**Concept 4**	**Concept 5**	**Concept 6**
Storage/Preservation of food	4	3	4	3	5	2
Maintenance of temperature	5	4	4	4	5	2
Volume	4	3	4	3	4	4
Content barcode scanning capabilities	4	4	5	5	4	3
Smart Capabilities	4	3	5	5	4	3
Web application interface	4	3	4	4	3	3
Digital inventory of contents/database	5	4	4	3	3	2
Cost	4	3	2	3	1	5
Production Cost	3	3	1	4	1	5
Material Cost	4	3	2	3	2	4

ii. Use the selection criteria to create a utility function (UF) to compare, rank, and select from the alternatives.

1. Organize the selection criteria, that will be used to compare the design alternatives, as a hierarchy.

a. Define the convention for the hierarchal structure.

2. At each level of the hierarchy, assign relative and absolute weights for the selection criteria.

iii. Utility Function Analysis

1. Compute the cumulative utility (CU) for each concept.

		Concept 1	*Concept 2*	*Concept 3*	*Concept 4*	*Concept 5*	*Concept 6*
Selection Criteria	**Absolute Weight**	**Concept Rating and Utility**	**Concept Rating and Utility**	**Concept Rating and Utility**	**Concept Rating and Utility**	**Concept Rating and Utility**	**Concept Rating and Utility**
SI11	0.16	Rating: 5	Rating:4	Rating:4	Rating:4	Rating: 5	Rating: 2

		Utility = 0.8	Utility = 0.64	Utility = 0.64	Utility = 0.64	Utility = 0.8	Utility = 0.32
SI12	0.08	Rating: 4 Utility = 0.32	Rating: 3 Utility = 0.24	Rating: 4 Utility = 0.32	Rating: 3 Utility = 0.24	Rating: 4 Utility = 0.32	Rating: 4 Utility = 0.32
SI13	0.16	Rating: 4 Utility = 0.64	Rating: 4 Utility = 0.64	Rating: 5 Utility = 0.8	Rating: 5 Utility = 0.8	Rating: 4 Utility = 0.64	Rating: 3 Utility = 0.48
SI21	0.20	Rating: 4 Utility = 0.8	Rating: 3 Utility = 0.6	Rating: 4 Utility = 0.8	Rating: 4 Utility = 0.8	Rating: 3 Utility = 0.6	Rating: 3 Utility = 0.6
SI22	0.20	Rating: 5 Utility = 1.0	Rating: 4 Utility = 0.8	Rating: 4 Utility = 0.8	Rating: 3 Utility = 0.6	Rating: 3 Utility = 0.6	Rating: 2 Utility = 0.4
SI31	0.08	Rating: 3 Utility = 0.24	Rating: 3 Utility = 0.24	Rating: 1 Utility = 0.08	Rating: 4 Utility = 0.32	Rating: 1 Utility = 0.08	Rating: 5 Utility = 0.4
SI32	0.12	Rating: 4 Utility = 0.48	Rating: 3 Utility = 0.36	Rating: 2 Utility = 0.24	Rating: 3 Utility = 0.36	Rating: 2 Utility = 0.24	Rating: 4 Utility = 0.48
□	1.00	CU1 = 4.28	CU2 = 3.52	CU3 = 3.68	CU4 = 3.76	CU5 = 3.28	CU6 = 3.00

2. Rank the concepts based on the CU.
    a. Concepts ranked from Highest CU to Lowest CU:
        i. Concept 1
        ii. Concept 4
        iii. Concept 3
        iv. Concept 2
        v. Concept 5
        vi. Concept 6

3. Select the feasible concepts with the highest CU.
    a. We have chosen the following concepts with the highest CU.
        i. **Concept 1:** - Standard alternative: This alternative has the most closely related features to the Samsung Smart Hub 2.0. The refrigerator uses heatsinks and fans, and is a left and right freezer and fridge combo. The product will plug into the wall like a standard fridge. As food is

passed in, a camera will register the barcode and the data is stored in an internal database. The application software is accessed through an internet browser.

ii. Conclusions: This concept was chosen because it maintained higher rankings for the majority of the selection criteria, and therefore proves to be the most reasonable product to develop based on its performance in the utility function analysis.

6. Phase II Summary Report

In Phase II, our team implemented tools provided in lecture to facilitate the product development progress for our company's product. We began this phase by referencing the previous phase and adjusting our work based on notes provided by the instructor during our Phase I review. We then proceeded to plan the upcoming tasks for Phase II using project planning tools such as GANTT and PERT charts. This required a unanimous collaborative effort by the team to determine the schedules and team deadlines for each task.

After planning the timeline of our tasks, we began to design our House of Quality. In order to do this, we referenced Homework 5 Problem 3, in which we had to build an HOQ by establishing customer needs and technical metrics that our company would expect to meet. Next, we implemented the Table Lookup process to our Aggregate Project Plan that we had started in Phase I. Using the Decision Analysis and Optimization Framework detailed in lecture, we were able to decide upon a project mix that had the highest expected maximized value.

We then proceeded to focus on the product itself. By researching existing products similar to the one our company's product idea, we were able to dissect the functions and systems of the standard products and reverse engineer similar products. After completing this process, we developed a Function Structure for our new product and created a morphological matrix to generate various design concepts that would realize solutions for the subfunctions defined in the function structure. After defining six design concepts, we developed a set of selection criteria with which to evaluate each design concept. Our selection criteria were mainly based on the customer needs and technical metrics stated in our HOQ.

Finally, we created used the concept selection process defined in class to evaluate the cumulative utilities of each design concept idea based on absolute weights determined for each selection criterion and also based on the respective rankings for the selection criterias for each design concept. Our concluding result led us to decide on 1-2 feasible concepts with the highest CUs. These concepts are Concept 1 and Concept 4 and they will represent the product that our company has decided to pursue with in further product development.

Check your work

- We have checked our work and believe that we have solved all defined problems to the best of our knowledge using the information provided and assumptions made throughout the processes.

Learn and generalize

- We have learned the value of project planning in particular with this phase because there were various tasks that were involved. Some tasks were performed in parallel while others had to be performed sequentially, therefore detailed organization and a structured timeline was useful for the execution of this phase. Our team has learned how to incorporate our previous ideas in the preliminary product development phase and expand on our knowledge of customer needs and technical metrics to develop more robust ideas and design concepts.

Phase III

Define the problem.

1. Conduct a team meeting to develop a comprehensive project plan for the remaining weeks of our project.
    a. Complete any backlog for Phase II.
2. Develop a product platform/line strategy.
3. Perform economic/financial modeling for TechXY's "Smart Fridge".
4. Perform failure modes and effects analysis (FMEA)
5. Discuss prototyping strategies

Plan the treatment of the problem.

1. *Project Planning*
    a. Clearly state the intent of the project.
    b. Determine the design/development subtasks and activities.
    c. Create a design/development activity matrix to understand the dependencies between the sub-tasks.
        i. Define conventions for the matrix.
    d. Create a time schedule of tasks using a GANTT chart.
    e. Identify the critical path for the project using a PERT chart.
    f. Assign clear roles and responsibilities and keep track of progress.

2. *Product Platform/Line Strategy*
    a. Define the underlying elements of the product platform.
        i. Core technology elements
        ii. Supporting technology elements
    b. Segment the market based on competitive and product/market strategies; then prioritize target market segments for the product.
    c. Establish the product lines to address the different target market segments.

d. For each product line, create the necessary project plan to introduce the product to its target market segment.
e. Introduce the product lines to the market in a time phased manner to reach all the desired target market segments.

3. Prototyping Strategy
    a. Describe the strategies used in prototyping the different products and features
    b. Describe why each strategy was appropriate for the product or feature

4. Failure Modes and Effect Analysis (FEMA)
    a. Perform a FMEA analysis of the TechXY smart fridge

5. *Economic/Financial Modeling*
    a. Perform an NPV analysis to understand the profitability of TechXY's new project.
    b. Perform a rudimentary sensitivity analysis on our new project.

Execute the plan.

2.4 PROJECT PLANNING FOR DEVELOPMENT

1. *Project Planning*
    a. Intent of the Project: To complete the design and development a multi-functional smart refrigerator.

    b. Design/development subtasks and activities.
        i. Phase II Backlog - TASK A
        ii. Product Platform/Line Strategy - TASK B
        iii. Economic/Financial Analysis - TASK C
        iv. Failure modes and effective analysis - TASK D
        v. Prototyping Strategy - TASK E
        vi. Integration - TASK F
        vii. Phase IV Tasks - TASK G

    c. Design/Development Activity Matrix
        i. Rationale: To understand the dependencies between the sub-tasks.
        ii. Matrix Conventions
            1. X = "depends on"

iii. Matrix:

Tasks →	A	B	C	D	E	F	G
A	A						
B	X	B			X		
C	X	X	C				
D	X	X	X	D			
E	X	X			E		
F	X					F	
G	X	X	X	X	X	X	G

NOTES:

a. All task are dependent upon Task A (Phase II backlog) therefore Task A needs to be completed before moving on to any other task.

b. Tasks A, B, C and D are sequential.

c. Tasks B and E are coupled tasks.

d. Task F is not dependent on any other tasks except Task A, therefore it is performed in parallel (or concurrently) with Task B - E.

e. Task G is dependent upon the completion of Phase III Tasks (A-F)

d. GANTT Chart

- (Related to Tasks A - F and Design/Development Matrix, defined in part 1b.)
- Dark - shaded areas relate to progress made on each task by 11/20/17.

e. PERT Chart.

Critical Path: Task A → Task E → Task C → Task D → Task F → Task G

- Comments on critical path:
  1) Task E is on the critical path because Task B has a "slack" of 4 days.
  2) Task F is on the critical path because it is an integration of all tasks
  3) Task G is on the critical path because it represents the final phase.

f. Roles and Responsibilities

Name	Role/Title	Responsibilities	Phase III Contributions	Phase I and Phase II Contributions
Nischa Kaur	Project Manager	- Oversees organization across all phases of the startup including initialization, design, marketing, etc. - Assists group to meet deadlines promptly - Schedules and facilitate meetings to ensure efficiency	- Creates base plan - Identifies Phase II backlog - Schedules meetings to complete tasks - Performs final edits of each task	- Competitive Strategy - Industry Analysis - Project Planning - HOQ/Reverse Engineering - Concept Selection
Olivia Ahmed	Product Manager	- Finds models to determine competitive strategy, as well as cost and product differentiation within the market - Conducts market and industry analysis	- Develops product platform/line strategy with Product Analyst - Complete relevant Phase II backlog	- Competitive Strategy - Aggregate Project Plan - Project Planning - HOQ/Reverse Engineering

Will DeBois	Product Analyst	- Conducts research on target market(s) and technical features of product - Documents new information and provides it to other project members	- Develops product platform/line strategy with Product Manager - Complete relevant Phase II backlog	- Competitive Strategy - Aggregate Project Plan - Table Lookup - Project Planning
Dailon Dolojan	VP of Product Marketing	- Monitors business metrics in regard to revenues, profitability, market share and product portfolio mix. - Ensure the development of all strategic product strategies/marketing plans - Develop and manage the marketing budget	- Performs economic/financial analysis with Financial Analyst and produces failure modes and effects analysis - Complete relevant Phase II backlog	- Competitive Strategy - Industry Analysis - Aggregate Project Plan - Project Planning
James McKenna	Financial Analyst	- Oversees financial aspect of product - Responsible for defining budgetary values - Responsible for salaries and stock division	- Works with VP of Product Marketing to conduct economic/financial analysis and produce failure modes and effects analysis	- Competitive Strategy - Aggregate Project Plan - Morphological Matrix - Concept Selection - Project Planning

2.5 PRODUCT ARCHITECTURE/PRODUCT STRATEGY

2. *Product Platform/Line Strategy*
    a. Define the underlying elements of the product platform.
        i. Core technology element(s)
            1. Inventory Control System

        ii. Supporting technology elements
            1. External touch screen
            2. Bar-code scanner

3. Web/mobile application
4. Camera
5. Fast performance
6. Size
7. Pricing control

b. Segment the market based on competitive and product/market strategies; then prioritize target market segments for the product.
   i. Market Segments
      1. Segment 1: Consumer - HIGH priority
      2. Segment 2: Small Business - LOW priority

c. Establish the product lines to address the different target market segments.

Product Lines

Product Line	**Consumer (Commercial)**	**Small Business (Industrial)**
Characteristics	External touch screen	External touch screen
	Bar-code scanner	Bar-code scanner
	Web/mobile application	Web/mobile application
	Camera	
		Fast Performance
	Size (small/medium)	Size (large)
		Pricing control

Conceptual Sketch of Product Platform/Product Lines

d. For each product line, create the necessary project plan to introduce the product to its target market segment.

2.6 PROTOTYPING STRATEGY

3. Prototyping Strategy:

a. We will discuss the different strategies used to prototype the design and development of the TechXY smart refrigerator.

The conceptual design we have decided to prototype is a smart refrigerator closely related to the Samsung Smart Hub 2.0 refrigerator. The concept will have the following features:

- Food refrigeration and freezing using heat-sinks and fan cooling
- Storage systems using french door racks
- Power supplied by a 120v wall outlet
- Barcode scanner using a camera sensor
- Inventory management using an integrated database
- Web interface using internet browser dashboard

The sequence of prototyping will take the following path as seen in the figure above:

1. Computer integration of systems:

   This is the first step in prototyping which will show the various computer software which can be embedded in the system. This includes an operating system choice of a portable Windows, Android, or Linux distribution. The GUI will be run on this system and allow I/O from the user and various internal systems.

2. Alpha prototype:

   A proof of concept of the integrated computer system that controls the smart technology in the fridge. This will specifically be a unit which is within the size constraint of the refrigerator door. The housing will contain a single board computer which connects to various sensors such as temperature, pressure, power, and camera recognition. The unit is interfaced by a 10.1” capacitive touch-screen monitor. The concept will show that the technology needed to build a smart fridge does exist and the development can continue.

3. Virtual Prototype

   A CAD software designed virtual prototype of the full operational system which will show the technical metrics such as use on various subsystems of the refrigerator and size constraints. This will be written in

a program such as Solidworks or AutoCAD. This is a computer based simulation of the software and will therefore be able to be changed at will to accommodate changes.

4. Experimental prototype

   This prototype is a physical system which proves the functionality of the system as a whole. The experimental prototype will be finalized before the development of the final state products and must include all the systems for the final design. This includes the working software systems and the working hardware.

5. Manufacturing prototype

   This prototype is the initial release model which will undergo mass manufacturing before entering the market. This stage in development reveals much information as the product is built. Manufacturers will discover defects or small features in design as the process is repeated.

6. Product

   This is the final step where the product is shipped to distributors and purchased by customers. This is beyond the horizon of prototyping.

2.7 FMEA

4. FMEA Analysis:

a. Use the previously defined FAST diagram for the existing refrigerator.

b. For each sub-system, identify potential failure modes.

Sub-System	**Failure Mode**	**Effect**
Thermostat	Defective temperature sensing bulb on the temperature control	Refrigerator freezes everything
Coolant/Refrigerant	Leaking Freon	Refrigerant poisoning
Compressor	Compressor fan stops	Refrigerator could overheat and the fan will make noises.
External/Internal Heat Exchanging Pipes	Do not remove heat from the refrigerator	Refrigerator could overheat
Expansion Valve	Restricted expansion valve	Does not allow the refrigerant to provide its functions to the refrigerator
Shelves	Does not support refrigerator	Broken shelf

	contents	
Drawers	Incompatible design for refrigerator	Unsatisfied customer
Racks/Trays	Does not last for long enough period	Customer must spend money to replace
Gas	Loss of gas	Cooling process does not work

c. For each failure mode, call a Risk Priority Number (RPN):
RPN = (S) x (O) x (D)
where
S = severity of the failure mode (how severe is the effect of the failure mode)

O = frequency of the occurrence of the failure mode (how frequently do we expect this failure mode to occur?)

D = ease of detection (How easy is the failure to detect)

Sub-System	**Failure Mode**	**Effect**	**Severity of the failure mode (S)**	**Frequency of the occurrence failure mode (O)**	**Ease of detection (D)**	**RPN = S*O*D**
Thermostat	Defective temperature sensing	Refrigerator freezes everything	2	2	1	4

	bulb on the temperatur e control					
Coolant/Ref rigerant	Leaking Freon	Refrigerant poisoning	8	1	8	64
Compressor	Compressor fan stops	Refrigerator could overheat and the fan will make noises.	2	3	1	6
External/Int ernal Heat Exchanging Pipes	Do not remove heat from the refrigerator	Refrigerator could overheat	2	1	2	4
Expansion Valve	Restricted expansion valve	Does not allow the refrigerant to provide its functions to the refrigerator	2	2	2	8
Shelves	Does not support refrigerator contents	Broken shelf	1	2	1	2
Drawers	Incompatibl e design for refrigerator	Unsatisfied customer	2	1	1	2
Racks/Trays	Does not last for long enough period	Customer must spend money to replace	2	1	1	2
Gas	Loss of gas	Cooling process does not work	3	1	2	6

d. Prescribe suitable actions for each failure mode for which RPN > 10

Sub-System	**Failure Mode**	**Effect**	**Severity of the failure mode (S)**	**Frequency of the occurrence failure mode (O)**	**Ease of detection (D)**	**RPN = S*O*D**	**Actions when RPN > 10**
Thermostat	Defective temperature sensing bulb on the temperature control	Refrigerator freezes everything	2	2	1	4	No action needed
Coolant/Refrigerant	Leaking Freon	Refrigerant poisoning	8	1	8	64	-Hire a highly skilled team of engineers to develop the coolant/refrigerant systems. -Introduce in-process checks during manufacture
Compressor	Compressor fan stops	Refrigerator could overheat and the fan will make noises.	2	3	1	6	No action needed
External/Internal Heat Exchanging Pipes	Do not remove heat from the refrigerator	Refrigerator could overheat	2	1	2	4	No action needed
Expansion Valve	Restricted expansion valve	Does not allow the refrigerant to provide its functions to the refrigerator	2	2	2	8	No action needed
Shelves	Does not support refrigerator contents	Broken shelf	1	2	1	2	No action needed
Drawers	Incompatible design for refrigerator	Unsatisfied customer	2	1	1	2	No action needed
Racks/Tra	Does not	Customer	2	1	1	2	No action needed

ys	last for long enough period	must spend money to replace					
Gas	Loss of gas	Cooling process does not work	3	1	2	6	No action needed

Section 3: Commercialization

3.1 FINANCIAL MODEL

5. Economic/Financial Modeling

e. Perform an NPV analysis to understand the profitability of TechXY's new project.

In order to complete an NPV calculation model, we must estimate the financial success of the product based on the timing of the development and the ongoing sales. The estimated development quarterly cost will be a determined by the overall development cost and the number of quarters in which the technology can be developed. After the completion of the development period, there will be a ramp up cost in which the product is transitioned to the market. This is forecasted to take 2 quarters. When the product begins sales in the 5th quarter the sales are estimated to last for 11 quarters after which a new product will be prototyped and launched.

The scenario parameters for this NPV model will have the following values.

The estimated total sales volume and unit price are taken from the Business Goals in Phase 1 (Section 1.1) and the unit production cost is an optimistic estimate at half the cost of the unit sales price.

The base case model has the following cash outflows and inflows. All values given are in thousands. The entire model lasts for 4 years, or 16 quarters when sales are projected to end. The first year will have no cash in-flows as all that is happening is development. The ramp-up will last 2 quarters and start during the 4th quarter.

The overall NPV model will track the overall value of the project by summing up the entire costs for each quarter, and summing up all 16 quarters. The following table gives the total cash flow based on a quarterly discount of 2.5%, or 10% annual discount factor. The NPV of the project is forecasted to be $75,915,000 for the four year lifecycle of the product. The development cost is $23,125,000, the ramp up cost is $9,250,000, the marketing cost is $4,625,000. The entire project will return a total revenue of $255,351,000, with a cost of goods sold equal to $127,675,440. $37,000,000 of this revenue will be sunk costs in the outward cash-flows. The positive profit in the NPV suggests a go-ahead with the product development based on the high expected mean value for the project.

b. Sensitivity Analysis of NPV: To properly evaluate the sensitivity of the new product, we will increase the development time by two quarters, but leave the total development costs the same. We will also not adjust our time span to accommodate this increased development time. After finding the percent change for this from the base case, we will increased the base development cost by 10% but keep the time the same. These changes will give us a decent understanding of the sensitivity of the project.

As we can see, by increasing the development time from the 4 quarters to 6 quarters, our NPV has fallen to $49,078,000. We can compute the percent change fairly easily by using the following equation:

$$\Delta\% = \frac{NPV_N - NPV_B}{NPV_B} * 100\% \rightarrow \frac{49{,}078 - 75{,}915}{75{,}915} * 100\% = -35.35\%$$

From the calculations above, we can see that the slight increase in development time decreases the NPV by 35.35% from the base case. Now that we have performed this sensitivity analysis, we will move onto the 10% increase and decrease in development cost. We will start with the 10% increase in cost:

From this analysis, we can see that the the NPV has fallen to $73,686,000. We will now do a percent change analysis to further evaluate it:

$$\Delta\% = \frac{NPV_N - NPV_B}{NPV_B} * 100\% \rightarrow \frac{73{,}686 - 75{,}915}{75{,}915} * 100\% = -2.94\%$$

This analysis indicates that our NPV falls by 2.94% when the development cost increases by 10%. We will now do the exact same thing, but with a decrease of 10% in development cost.

Here we can see that the NPV has increased to $78,145,000. We will once again perform percent change to see how much of an effect this had on the bottom line. The equation is as follows:

$$\Delta\% = \frac{NPV_N - NPV_B}{NPV_B} * 100\% \rightarrow \frac{78{,}145 - 75{,}915}{75{,}915} * 100\% = 2.94\%$$

From these simple calculations we can see that when we lower our development costs by 10%, our NPV increases by 2.94%. It is interesting to note that this is the exact same absolute change as when our development costs increase by 10%. This was a very simple sensitivity analysis and can easily be expanded on using Excel.

3.3 PRODUCT RELEASE MAP

- As shown in the Product Release Map, the expectations is that the product lines (domestic and industrial) for Tech XY's Smart Fridge will be present in both market segments by 2018, maintaining heavy concentration in the Consumer market segment by 2019.

Check your work: Based on the analysis and research we have performed,we believe that the work we have done is correct. We did not make any significant assumptions on this problem and therefore we do not need to take any further steps.

Learn and generalize: This phase was very useful in allowing to catch back up on the backlog of the project as well as further refine our previous project phases any further. It was useful to create a product line strategy as well as perform a financial analysis. These are both skills that will serve us well moving forward in this course.

Team Contributions to Project

Team Member	Contributions (Primary Driver)	Secondary Driver
Olivia Ahmed	HOQ	Industry Analysis
	Reverse Engineering	Company Analysis
	Conceptual Design	Aggregate Project Plan
	Product Platform/Product Lines	
	FMEA	
William DeBois	Decision Trees	Financial Modeling
	Sensitivity Analysis	Target Specifications
	Integer Programming	Company Analysis
	Technical Specifications	Aggregate project plan
Dailon Dolojan	Business/Customer Needs	Aggregate Project Plan
	Market Analysis	HOQ
	Industry Analysis	Decision Trees
	Functional Maps	Reverse Engineering
	Conceptual Design	Product Platform/ProductLines
Nischa Kaur	Competitive Strategy	Reverse Engineering
	Industry Analysis	Market Analysis
	Project Planning	Product Lines
	HOQ	
	Concept Selection	
	Product Platform/Architecture	
	Product Release Map	
James McKenna	Executive Summary	Business Goals
	Concept Generation	Sensitivity Analysis
	Prototyping Strategy	Technical Benchmarking
	NPV Model	Aggregate Project Plan
	Morphological Matrix	Reverse Engineering