Final Project Report

Company: *Hewlett-Packard*
Product: *Smart Chair*

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Executive Summary

We began the project by setting a clear set of goals and objectives for our product that we developed in CSE 171A. We created a project plan as well as created tasks for everyone in our group that we would be responsible for. After we created the tasks for everyone, we then proceeded to update our final concept, write clear explanations, updated the FAST diagram, and the function structure. We then discussed how our general supply chain network would run, and created a stage and network representation for our supply chain.

Phase I of the project was to create an appropriate business model for the supply chain of our product. To start things off, we began by determining where our product and company stood in its competitive market, and began to brainstorm different types of competitive strategies that we could use to accelerate the selling of our product. We created a Porter's Five Forces model as well as listed various competitive strategies that we could use to our advantage to gain an edge in the market. From here, we created a supply chain strategy, stage view, and network view that was derived from the amount of suppliers that we needed along with our chosen process of how we were going to convert these components into subsystems, and then into a final product. We then attempted to create methods of estimating demand data that eventually was scrapped for a better and revised method of estimation that we placed at the start of phase II.

To begin our work in Project Phase II of the report, we were tasked with finding a method that was logical and reasonable to estimate our project's demand data. Our project did not have any directly related demand data that showed any sort of seasonality, so what we decided to do was to take demand data online that was related to the global shipments of laptops and desktops and correlate that to our product. Due to the fact that our product is a relatively expensive chair, we assumed that the shipments of PC systems were directly correlated to the demand for our chair making it a possible candidate for purchase when people decide to buy PCs. We scaled down the global demand data and related it to our product calculated reasonable demand data numbers that we could use to forecast. With all the methods learned in class, we decided to do all the different types of static and adaptive forecasting models, and we concluded that the best one for our project would be Winter's model as it includes the most amount of parameters that closely match our data.

Just as in the previous task, we were tasked with first coming up with a process in estimating our cycle and safety inventory. Using this process, we were tasked with conducting these calculations and estimations on two subsystems and our final product. We conducted our cycle and safety inventory calculations on the subsystems of power transmission and efficient sensors which gave us three components: motherboard, pressure sensors. and battery holders. From task #1, we were able to obtain the annual demand and forecasts which allowed us to calculate the safety and cycle inventory. The table below shows the cycle inventory and safety inventory for the components and final product

CYCLE INVENTORY				
	BATTERY HOLDER	**MOTHERBOARD**	**PRESSURE SENSOR**	**SMART CHAIR**
YEAR 1	2,098 UNITS	352 UNITS	3,976 UNITS	354 UNITS
YEAR 2	2,302 UNITS	387 UNITS	4,363 UNITS	527 UNITS
YEAR 1	305 UNITS	714 UNITS	746 UNITS	806 UNITS
YEAR 2	370 UNITS	527 UNITS	527 UNITS	978 UNITS

PHASE00: PROJECT PROPOSAL

Define the Problem

SP1 - Revise and update parts of the project proposal based on feedback provided in the proposal review meeting with Prof. Subhas. Specifically, Fast diagram; sub-systems; stage representation of your product's supply chain; network representation of your product's supply chain. Make sure that these individual parts are properly set up and explained, and related (or linked) to each other.

SP2 - Create a clear set of Goals/Objectives: To design and manage the supply chain for (your product name) in (your company name).

SP3 - Review the final conceptual design for your product (from last quarter) and correct any errors based on the feedback provided in your CSE 171A final report. Then, provide the updated final concept, with a clear explanation of this design concept; the FAST diagram for this final concept; and clear identification of the major subsystems of your final concept.

SP4 - Use the sub-systems from your FAST diagram to develop a preliminary version of the infrastructure for your product's supply chain: stage representation and network representation.
* (Here is the progression in how you need to think during this step: Concept -> FAST -> Subsystems ->Stage representation ->Network Representation.)Be sure to clearly explain both the stage and network representations of your supply chain.

Strategy/ Treatment

a. **What information is available for solving the problem?**
    i. Based on the requirements of SP1-SP4, it seems like the previous submission containing our project proposal is of vital importance for phase I. We will use the information given on previous homeworks including lectures and canvas files to solve this problem. On top of all the information stated above, we will also use all online resources to our advantage.

b. **What assumptions need to be made to make the solution process manageable?**
    i. We must assume that the SP1 is done in full completeness and thoroughness since we will be using that information to guide it through this phase. We will assume also that the historical demand data we provide will be accurate since it will be generated predominantly from online resources.

c. **What analysis needs to be performed to resolve the issues defined in Step 1?**
    i. Clearly, from the beginning a full reanalysis of our previous submission needs to take place with careful consideration of feedback provided to us. We also see the need to do a Fast Diagram and identify clearly the major subsystems of our final concept.

d. **Created FAST Diagram for our updated Final Product**
    i. We took the feedback from last quarter's Final Project and we created a more finalized concept and created a diagram for it

e. **Created Function Structure to clearly define our products subsystems**
    i. We took the FS diagram from last quarter in order to clearly pinpoint all the necessary subfunctions of our product

f. **In a small paragraph we defined the core features of our product**
    i. From the information we gained using the FS diagram we clearly identified all the subsystems through words.

g. **Create the supply chain stage view and network diagram**
    i. We clearly identified what suppliers and manufacturers are needed in order to be able to assemble and send the chair(product) to retail stores for customers to purchase. This process of developing the product goes from suppliers to manufacturers to retailers then to customers.

Execution

SP2 - Goals:

Our goal is to design and manage the supply chain for the Smart Chair in Hewlett Packard. We intend to reach this goal by splitting our project into 4 phases:

a. **Phase 1: Technology/Product Strategy and SC Strategy/Design**
b. **Phase 2: Supply Chain modeling and planning; demand forecasting**
c. **Phase 3: Supply Chain operations: cycle and safety inventory**
d. **Phase 4: Closure and Final Report**

In each phase, we are working to split up the work in a way that will allow all of us to deepen our knowledge on supply chain management so that we can apply it to the Smart Chair product. For our project proposal, we are setting up our initial supply chain infrastructure by creating a stage and network view of our supply chain. The creation of these diagrams requires us to dissect our final concepts so that we can extract the knowledge on what manufacturers we will need to buy from, the distributors we will need to go through, the retailers that will carry our products, and the customers that will be interested in our product.

SP3 - Final Conceptual Design:

Introduction to Final Conceptual Design:

The final conceptual design of our product is a scorpio-shaped luxurious, technologically equipped, smart chair. Our smart chair has several market applications, for example, Home Offices, Aeronautics, Command & Control, Cyber Security, Finance, Marketing, Medical, Monitoring, and Simulation & Training. Our Smart Chair offers functionalities that enable the user to experience unprecedented comfort and quasi total immersion through strategically positioned monitors and accessories, all driven by our mission to provide health, comfort, and productivity in the form of a chair. The result is a complete computer office, ergonomically optimized, with a minimal footprint that improves overall performance and productivity. Our Smart Chair's main feature is the ability to adjust posture and height on the chair wirelessly through a computer program. In order to create this product, we needed to go through a long arduous process of product development by defining the Sub-Functions, that would help us make the FAST Diagram, and make the Function Structure Diagram that defines all the different portions of our product. The Sub-Functions are defined as follows:

The Sub-Functions:

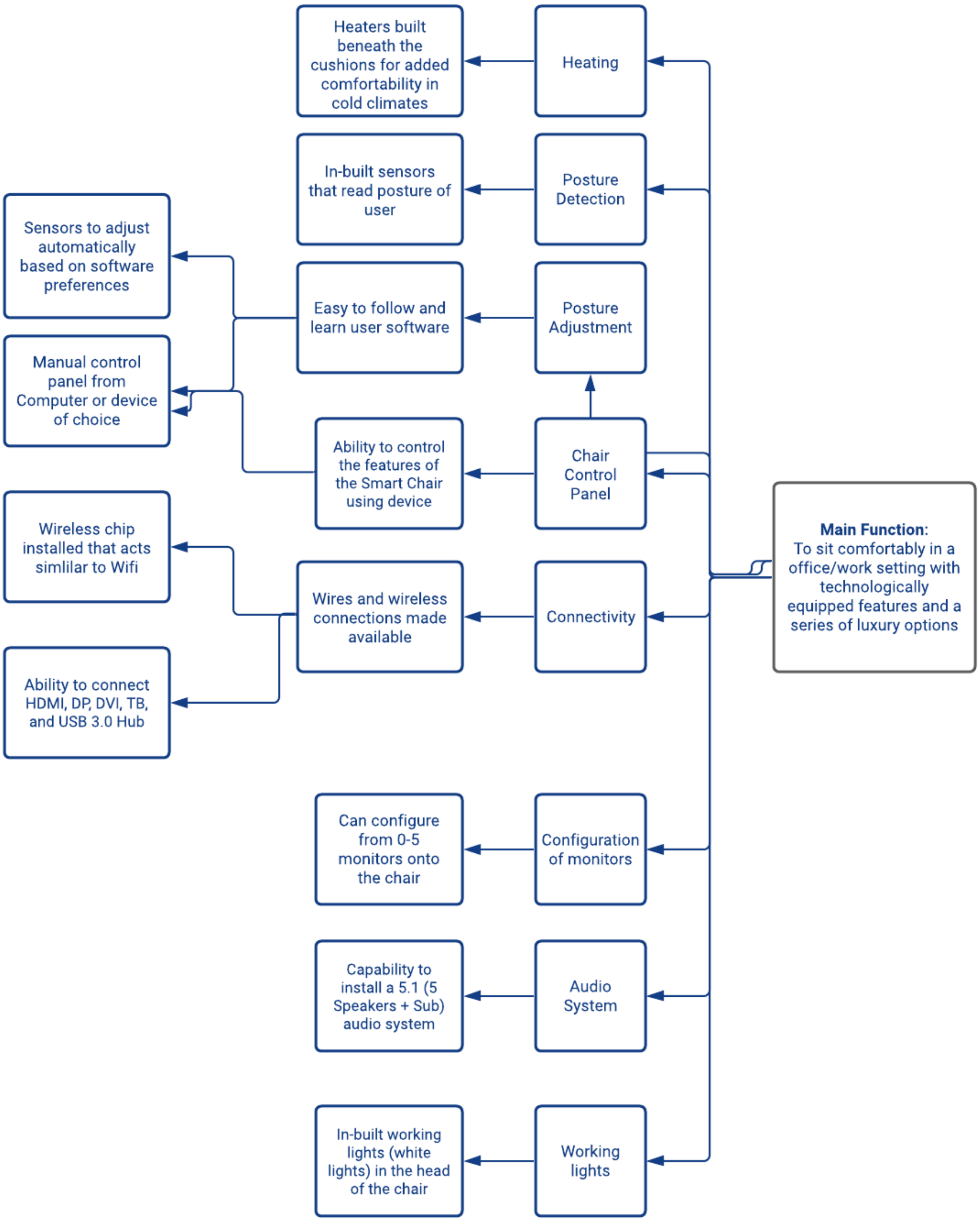
1. **Sub-Function 1: Heating**
    a. Ability to control the temperature of the chair as per the need of the user to maintain a stable body temperature for productivity or for comfort.
2. **Sub-Function 2: Posture Detection**
    a. In-built sensors have the ability to detect unhealthy and unproductive postures. Sensors categorize postures into 3 types - Comfort, Productive, and Health. It displays the 3 categories on its smart display screen as a mixture of the categories as per the user's posture.
3. **Sub-Function 3: Posture Adjustment**
    a. Provides the functionality of using the sensors and a computer program (that takes into account user's age, weight, etc) to correct the posture of the user based on setting on the dial that signifies the user's desired goal for using the chair from the 3 categories of comfort, productivity, and health (it can be a blend of all 3 - for example, some users may value comfort more than productivity when reading, whereas the same user may value productivity and health more than comfort when the user is working on typing out a report).
4. **Sub-Function 4: Chair Control Panel Installation on remote devices**
    a. This functionality provides the user the ability to control the features of the Smart Chair using whatever device they might be using by providing up a Control Panel installation that is compatible with Macs, PCs, Phones, and Tablets.
5. **Sub-Function 5: Configuration of monitors**
    a. Comes with a capacity of 5 monitors to be installed on the chair to make the ultimate work-station.
6. **Sub-Function 6: Connectivity**
    a. Comes with the ability to connect HDMI, DP, DVI, TB, and USB 3.0 Hub.
7. **Sub-Function 7: Audio system**
    a. Comes with the capability to install a 5.1 (5 Speakers + Sub) audio system to provide an extraordinary audio experience to the user.
8. **Sub-Function 8: Working Lights**
    a. In-built working lights (white lights) in the head of the chair to provide direct light to the table in front of the chair and to the screens which are attached to the chair to make up the perfect and elaborate workstation.

HP - Smart Chair Final FAST Diagram

The FAST diagram dissects our product and describes how it functions and why we created a product like this to sell in the market. The methodology that we used in order to create a complex yet simple design was to use all the features we view as luxurious when it comes to comfort, and fit them together with a productive use case chair. With the sub functions that we developed in the product development portion of this product, we created a function structure that shows everything that we wanted as a feature, in a simple diagram that is easy to understand.

The chair is successfully able to provide all of the sub-functions listed and described above in a seamless and easy-to-use manner as illustrated by the FAST diagram below. The chair utilizes the following subsystems to provide the functionality:

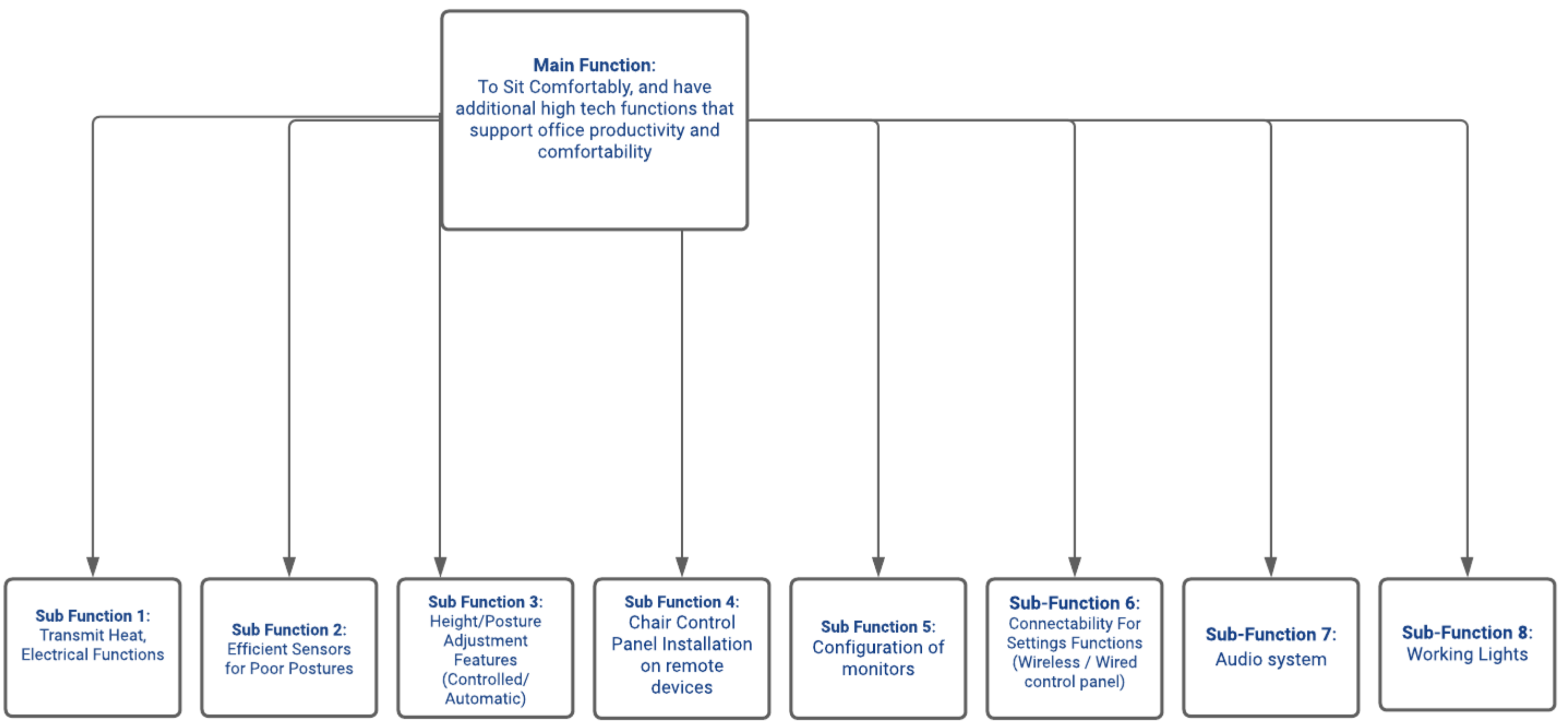
A. **List of important subsystems:**
    - Battery
    - Touch Button(s)
    - Microcontroller (Chip)
    - Speaker
    - LED/Screen
    - Heaters
    - Motion Sensors
    - In-built software that can be installed
    - Pressure Sensor
    - USB/HDMI, DP, DVI, TB, and USB 3.0 Hub & other External Port
    - Lights


Heaters built beneath the cushions for added comfortability in cold climates
Heating
In-built sensors that read posture of user
Posture Detection
Sensors to adjust automatically based on software preferences
Easy to follow and learn user software
Posture Adjustment
Manual control panel from Computer or device of choice
Ability to control the features of the Smart Chair using device
Chair Control Panel
Main Function: To sit comfortably in a office/work setting with technologically equipped features and a series of luxury options
Wireless chip installed that acts simlilar to Wifi
Wires and wireless connections made available
Connectivity
Ability to connect HDMI, DP, DVI, TB, and USB 3.0 Hub
Can configure from 0-5 monitors onto the chair
Configuration of monitors
Capability to install a 5.1 (5 Speakers + Sub) audio system
Audio System
In-built working lights (white lights) in the head of the chair
Working lights

HP Smart Chair - Function Structure

So as to improve readability and create a clear and concise diagram that communicates our subfunctions, we've extracted information from the FAST diagram and created a function structure that includes our six subfunctions:

- Transmit heat, electrical functions
- Efficient Sensor for poor postures
- Height/Posture adjustment features
- Chair Control Panel Installation on remote devices
- Connectability
- Configuration of monitors
- Audio system
- Working Lights



There are a total of 6 different sub functions that we decided upon when it came to the development of our product. We wanted comfort and productivity to mesh into one cohesive experience, and we came up with these sub functions. We wanted our product to have the ability to transmit heat, which provides a heating function for people who work in colder conditions, such as an office that is constantly air conditioned. We also wanted it to be able to have sensors which are utilized in the wireless control panel portion of our product. In order to do that, we needed to integrate height and posture adjustments to work well with these sensors. We wanted the adjustability of the chair to be high so that it can fit people of all different types of physical bodies. We wanted to have stable connectability between the computer control panel and the chair itself. With all these different types of sub functions, we were then able to make a supply chain infrastructure that gave us an idea of where to obtain our raw materials.

SP4 - Supply Chain Infrastructure

Due to the copious amount of components for each sub function, we decided to search for a list of manufacturers (per component) with the bolded manufacturers being the manufacturers we ended up choosing. Please refer to the table given below:

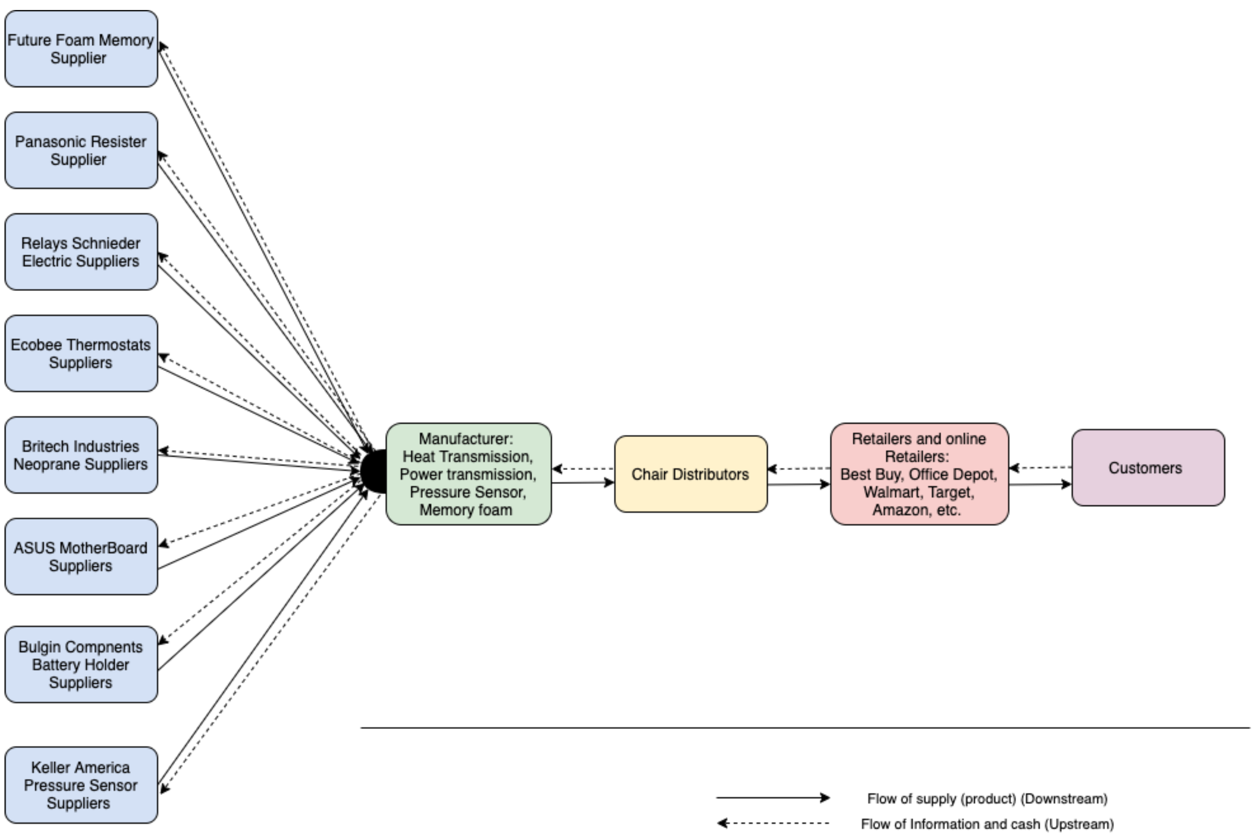
Sub-system Raw Material Manufacturers

Transmit Heat: *Electricity*	
COMPONENTS	**MANUFACTURERS**
Resistor	Arcol, Ohmite, **Panasonic**
Relay	Teledyne Technologies, TE Connectivity, Omron, **Schneider Electric**
Thermostat	Carrier, **Ecobee**, White-Rodgers Emerson, Honeywell
Heated Seat Cover Material (*Neoprene*)	RD Rubber Technology Corporation, **Britech Industries**, Accurate Products Inc.
Motherboard	ASrock, **Asus**, Bostar, EVGA Corporation
Transmit Power: *Electricity*	
Battery Holder	**Bulgin Components**, Omega Fusibili, Takachi Electronics Enclosure Co.
Motherboard	ASrock, **Asus**, Bostar, EVGA Corporation
Efficient Sensors: *Pressure Sensor*	
Pressure Sensor	**Keller America**, Wasco Switches and

	Sensors, Madison Co
Motherboard	ASrock, **Asus**, Bostar, EVGA Corporation
Comfortability Headrest: *Memory Foam*	
Memory Foam	**Future Foam**, Multiflex RNC, FXI Inc.

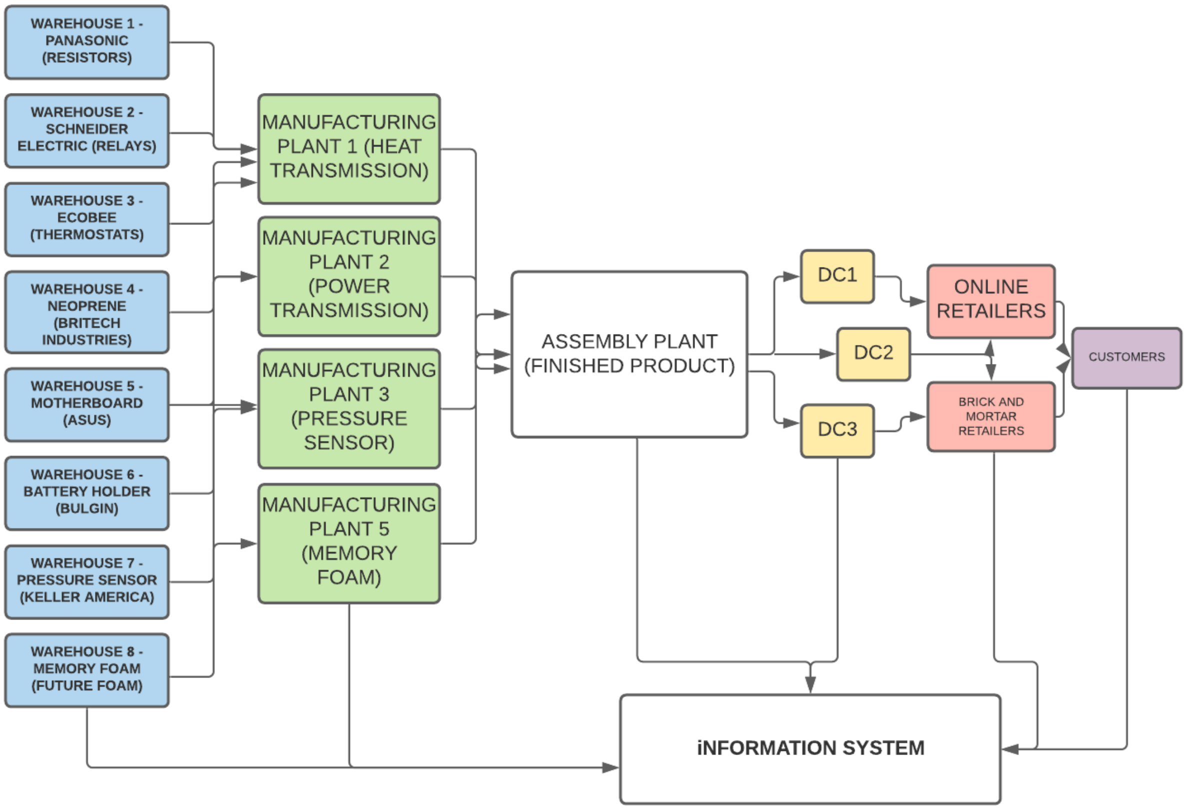
Supply Chain Stage View:

Shown above is a visual diagram for our supply chain stage and supply chain network with the respective manufacturers.



Supply Chain Network View

The detailed Supply Chain Network View is demonstrated in the diagram below. It illustrates each of the Manufacturers that our company chooses to work with in order to produce our Smart Chair in the most efficient manner.



While the planning of the product and its features are of high priority, the business model for the product's supply chain is an integral part to the overall success of our product. Coming up with an appropriate business model for our supply chain allows us to create a successful product for the best price given that how we set up the supply chain is closely linked to the strategy that we are going for.

Check Your Work:

a. **Is the work correct in every detail?**
   i. Yes, the work is correct in every detail due to the thorough evaluation of our previous work and intensive correction we made from the comments given to us. Although we created a project plan, the nature of the course is very fluid and constantly changing. This means that the plans and due dates we have listed may not be the final say. That being said, the details were correct in every aspect.
b. **Are my assumptions reasonable?**

i. Yes, to continue on the new stage of the project we needed to assume that all the information provided to us from the reviewers was accurate and we were competent enough to deliver. These assumptions were correct because of the detailed review we received from the lecture.

Learn and Generalize

a. As a group, we have met and reevaluated the way in which we will operate on this quarter concerning the group project. With the help of the professor in our meeting we have now found a functional way to operate and produce more work. We have also learned the importance of the feedback and reevaluation we have done from the previous final report and how it has helped us in framing the preliminary version of the infrastructure for our supply chain. As we are now, the stability and efficiency of the group work method has been improved and seems promising.

Phase00 and 01 Connector

With the Proposal now complete, we can begin work on building an appropriate business model for the Supply Chain. This means the work we will be doing can be narrowed down to a more fine level than what was being done for the Proposal. Once a product and its initial Supply Chain has been selected and refined, we can develop an overall strategy for our Supply Chain. We will also begin to do demand forecasting by collecting demand data and analysing it.

PHASE01

Define the Problem

SP1 - Revise and update parts of the project proposal based on feedback provided in the proposal review meeting with Prof. Subhas. Specifically, Fast diagram; sub-systems; stage representation of your product's supply chain; network representation of your product's supply chain. Make sure that these individual parts are properly set up and explained, and related (or linked) to each other.

SP2 - Develop an appropriate business model for the Supply Chain for your product. Revise your stage and network representations from the previous step, so these representations are consistent with your SC business model.

SP3 - Develop the overall supply chain strategy for your product, and clearly state how this strategy was derived.

SP4 - Create and implement a process to obtain 8-16 quarters of credible historical demand data for your product.

Strategy/ Treatment

a. **What information is available for solving the problem?**
    i. Based on the requirements of SP1-SP4, it seems like the previous submission containing our project proposal is of vital importance for phase I. We will use the information given on previous homeworks including lectures and canvas files to solve this problem. On top of all the

information stated above, we will also use all online resources to our advantage.

b. **What assumptions need to be made to make the solution process manageable?**
   i. We must assume that the SP1 is done in full completeness and thoroughness since we will be using that information to guide it through this phase. We will assume also that the historical demand data we provide will be accurate since it will be generated predominantly from online resources.

c. **What analysis needs to be performed to resolve the issues defined in Step 1?**
   i. We will have plenty of analysis performed this phase. We will provide a competitive strategy analysis and Porter's 5 forces Analysis.

Execution

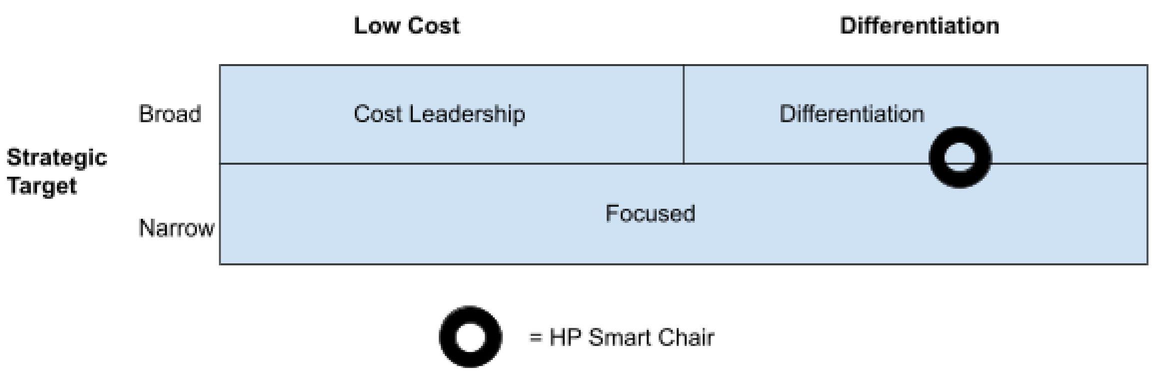
1. Revised Project Proposal

a. Refer above the Project Proposal above

2. Business Model for Supply Chain

Business Model for Supply Chain 2x2 Diagram

In the process of developing our business model for the supply chain management of this product, we decided to use a 2x2 diagram in order to figure out where our product lies in the general spectrum of business models. In order to have a successful business model, we needed to have a couple of different factors that stood out from our product. The 2x2 model is best used when trying to achieve this.



The 2x2 diagram shown above shows the general ideas behind finding a successful competitive strategy. When we think about how other companies are very successful in the ways they sell their products they have a couple of varying but common factors that can be seen. A couple of the competitive strategies that we found to be common throughout our competitors' businesses include: differentiation, cost leadership, operational expertise, and inventory management. These are some common strategies that we decided to use in our product as we figured it was the best and most efficient fit for our product. Our product is one of the first in the market, so by executing a proper business plan, we can predict the outcome of our success.

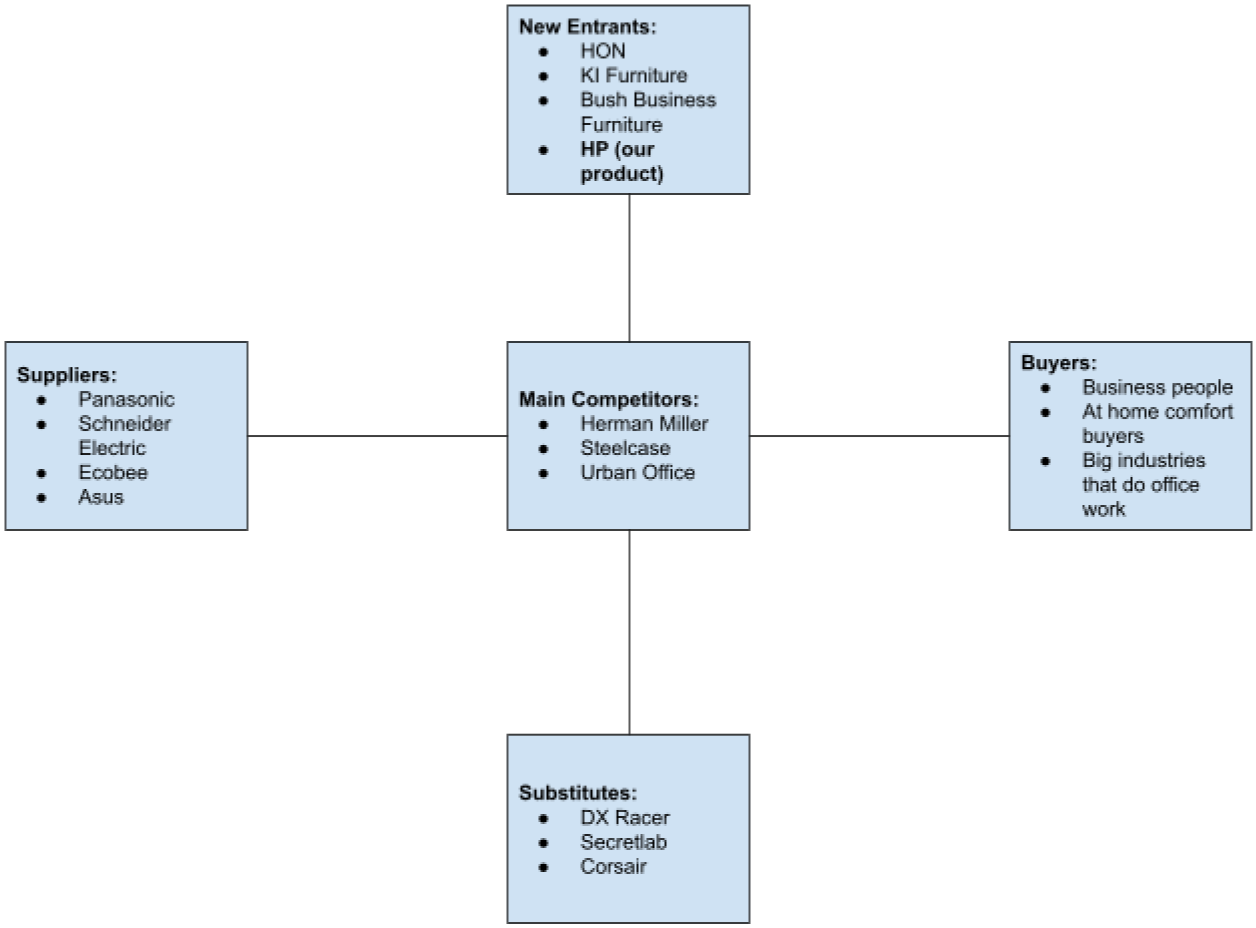
Product	**Competitive Strategy**	**Analysis**
HP Smart Chair	Differentiation	• Hewlett Packard (HP) is an already established and well known computer and printer manufacturer, using the already developed popularity of branding we can focus on branching outward to focus on a new set of customers • Purchasing of our products can be done through retailers such as Amazon, Bestbuy, Office Depot, Walmart, etc. and through our website which endorses proper marketing for our product • We focus towards the business process of innovation as well as marketing with new features as well as familiar older ones that brand together into a cohesive new product that feels like quality

		• Some of our key business partners would include, raw material suppliers such as Panasonic, leather distributors, and marketing logistic companies • HP prioritizes quality assurance to customers so that they remain satisfied • We look to have a long life span in the quality of our product so that customers could feel as if they are getting their "money's worth"
	Cost Leadership	• By producing a very unique product, we can expect to be the "leading" company that produces a chair that can do many different things at once. • We can expect to be the first in the market to produce a chair that would have a luxury feel for the fraction of the price of an already developed chair with the same amount of features. • By doing some research we discovered that a chair of our caliber is expected to be almost 5x the amount that we could produce our product for, so by utilizing good inventory management and operational expertise we can expect to lower that cost by a significant amount.

	Operational Expertise	• By using operational expertise, we can expect to see our product's starting marketing price to significantly drop in comparison to products that are already released • We can utilize a good manufacturing process in order to properly manage our inventory • Operational expertise includes doing research on our product to make it as efficient as possible while maintaining high quality raw material usage to manufacture it
	Inventory Management	• Every part of the supply chain management strategy is important but one that is most prominent is the management of inventory. By utilizing proper inventory management we can expect to reduce the cost of our product by a significant amount

Porter's Five Forces Model Analysis

The Porter's Five Forces Model can be used in order to figure out where our newly developed product would stand in the current industry that we are trying to enter. Due to the fact that our product is so new in the chair industry, and a luxury chair at that, we decided that our company and product would lie within the "new entrants" part of the Porter's Five Forces model. However, the supply chain management flows from the horizontal axis of this model, so we put our focus mainly on who our suppliers and who our consumers would be. We came down to a couple of different conclusions with the usage of this model.



HP would be considered a **New Entrant in the Smart Office Chair industry.** Our goal is to create a product that would be a substitute for people who work constantly and have problems with sitting for long periods of time. Due to the fact that our product is relatively new and has some innovative features, there is potential for it to thrive in the office furniture industry.

With our focus being primarily on the supply chain strategy with the usage of this model, we researched what type of suppliers we would need in order to achieve the luxury part of our chair. We have a varying amount of technologies implemented so we decided to change our suppliers to fit our needs more efficiently. We use the same suppliers as any other chair company would but with the inclusion of tech companies as well.

Forces	**Strength**	**Explanation**
Force 1: *Rivalry between Competitors*	High	The Main Competitors threat level in this industry is extremely high. Companies such as Herman Miller already sell extremely high-end top of the line products that cost upwards of $1000 USD. Companies are already established and people already know of top of the line luxury furnitures for office chairs that provide comfort.
Force 2: *Threat of New Entrants*	High	Given the Smart Chairs utilization of varying differentiating features, it will likely lead in the new industry of its kind. Despite this, many new entrants into the market such as KON and KI furniture do pose an extremely high threat as these competitors stride toward utilizing AI and incorporating technologies to create sophisticated products that outcompete the smart chair.
Force 3: *Threat of Substitutes*	High	The threat of substitutes is perhaps the highest threat faced by our product; the demand for office chairs could not be higher this day and age. Considering this, many customers have the prerogative in selecting from a myriad of office and work chairs even if they lack the technology and originality of the smart chair. Furthermore, customers have the option to go for any office chair that is cheaper in price even if it only has a fraction of the features as our chair does.
Force 4: *Buyer Power*	Low	The need for a product such as this comes at a time where working from home is not a luxury but a demand. The buyer power is low here knowing that the customer is at home realizing a product like this is not only useful for they're future health but also productivity/efficiency in a work-from-home era.
Force 5: *Supplier Power*	Medium	The supplier power is reliant on the

		advancement of the technology they can provide HP. As this product is the first of its kind, the supplier power stays at medium because it is dependent on how well this product does in the market.
Force 6: *Potential Compliments*	Low	Due to the originality of the Smart chair the closest a potential compliment is going to come is in non-office work spaces such as movie theater, massage parlor... Etc. It is extremely generous to even consider them as compliments.

Now that we have a business model for our supply chain, we move on to the actual designing of the supply chain. In designing this, we will particularly keep in mind our prospective buyers (business people, B2B companies, at home comfort buyers) along with our determined strategy of focusing on a strategy of product differentiation.

3. Designing the Supply Chain

When designing our supply chain for our smart chair product, we took various variables into consideration that include, but are not limited to:

- Product life cycle
- Level of value that supply chain partner may add to our product
- Cost versus quality
- Level of expertise that the supply chain partner has in their respective industry

In taking these factors into account, we reevaluated our initial suppliers, listing out the competitive advantage that they offer to our product.

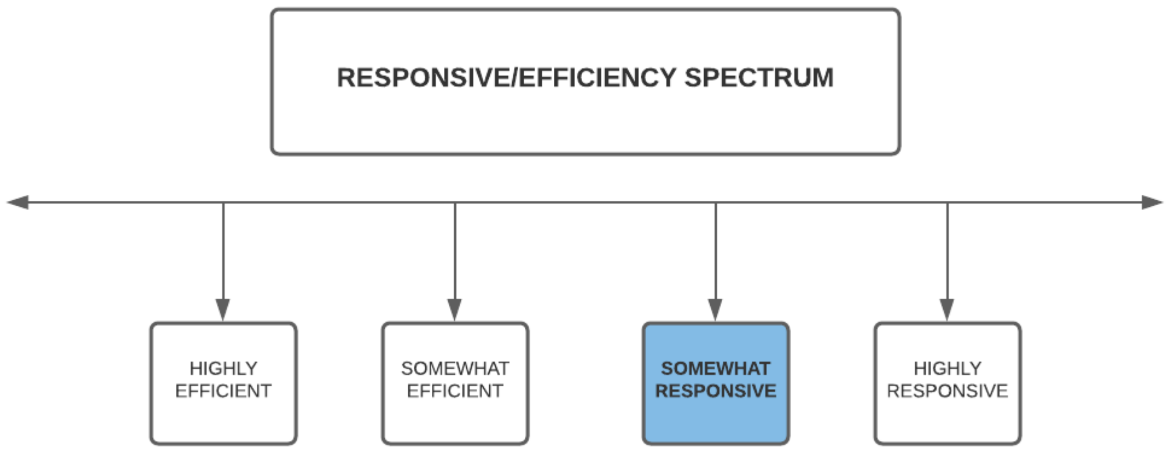
Manufacture Competitive Advantages:

COMPONENTS - MANUFACTURER	COMPETITIVE ADVANTAGE
Resistor - *Panasonic*	• Panasonic is a highly reputable company that is known for their high quality products

	• Based in Japan, a place know for innovation and quality in the electronics industry • Known for long-lasting electronics with high standards
Relay - *Schneider Electric*	• Named one of the World's Most Admired Companies • Leader in digital transformation of energy management and automation
Thermostat - *Ecobee*	• Advanced thermostat technology • Relatively small company that can possibly lead to an exclusive distribution agreement
Heated Seat Cover Material (*Neoprene*) - *Britech Industries*	• Prospered within their respective industry for 37 years ○ Annual revenue of $5 Million • Domestically based - cheaper shipping
Motherboard - *ASUS*	• Huge company with a highly reputable reputation • One of the lowest failure rates in the industry • Known for their relatively low prices for a high quality computer
Battery Holder - *Bulgin*	• Strong reputation for product quality and reliability • Global customer base of over 92,000 end users ○ Most of who serve primarily as specialist electronic distributors • Has various accounts with market-leading manufacturers in various submarkets
Pressure Sensor - *Keller America*	• Inventors of piezoresistive pressure transducer • Worldwide leader in pressure measurement solutions
Memory Foam - *Future Foam*	• Over 55 years of experience within the industry • Locations and manufacturing facilities placed around the world

Efficiency/Responsiveness Spectrum

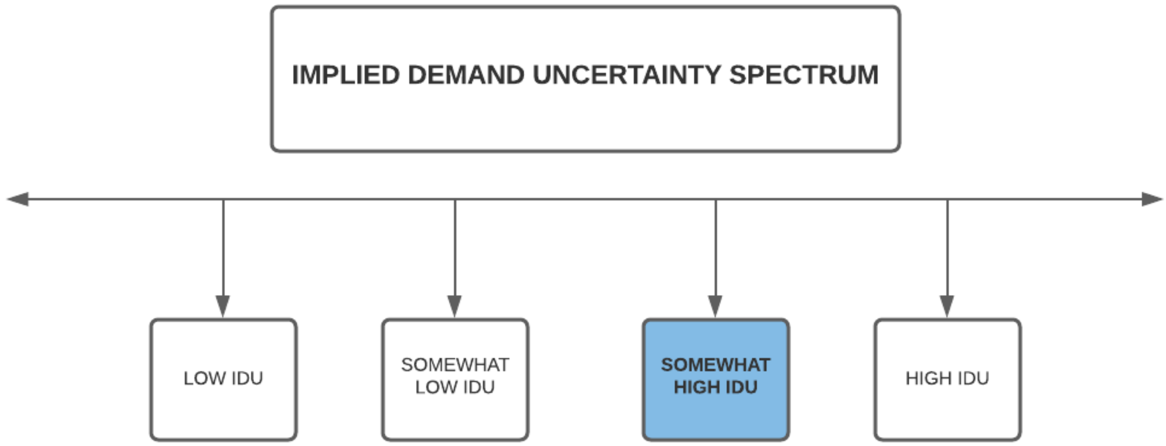
We characterize supply chains as efficient or responsive. Efficient supply chains are able to deliver products at a low cost, while responsive supply chains are capable of responding quickly to changing con- sumer needs.



We are placing our supply chain under *somewhat responsive* on the responsive/efficiency spectrum because the process of making our product only takes a few days to produce if there is no inventory left. The process is minimal so when an order is requested, our supply chain should quickly manage, sort, and access databases. This is to access all the inventory and warehouses we have to be able to start the process of completing an order.

Implied Demand Uncertainty

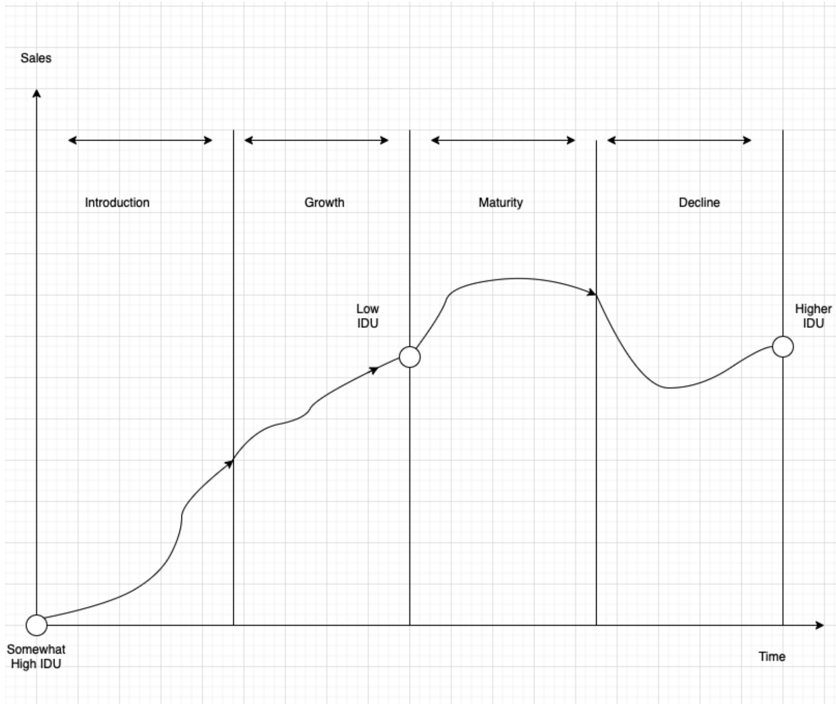
Implied demand uncertainty is the resulting uncertainty for the supply chain given the portion of the demand; the supply chain must handle and attribute the customer desires.



We placed our product under a somewhat high IDU on the implied demand uncertainty spectrum because due to the current pandemic it is hard to predict the demand of luxurious office chairs since most companies found ways to efficiently function remotely. However, there is still the possibility that the product will succeed because the long sitting hours will convince people to buy something that satisfies their comfortability needs.

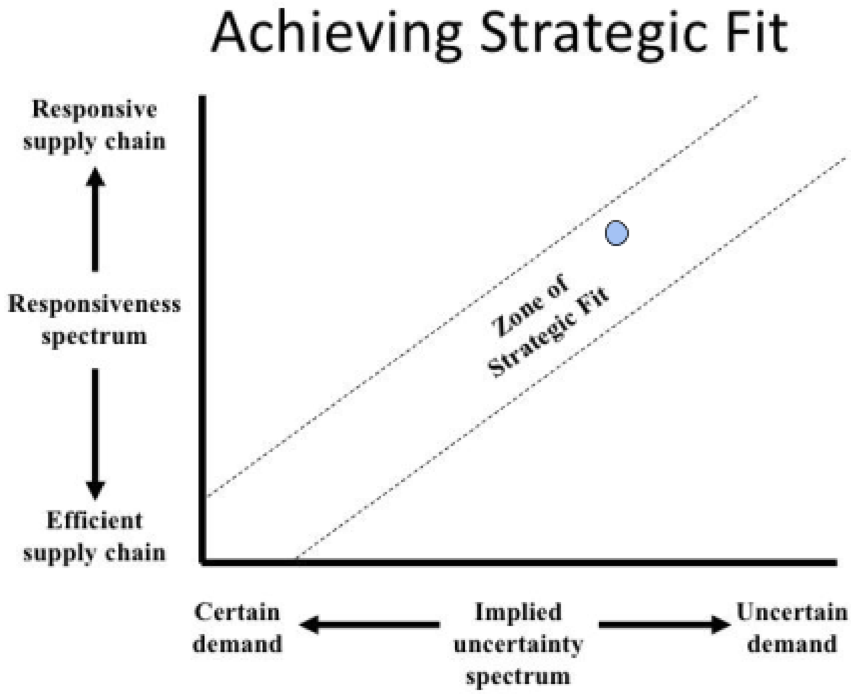
Product Life Cycle of Smart Chair in the Market

Due to the current condition regarding the pandemic, the Implied Demand Uncertainty (IDU) wavers as the customer's need for the product changes over time. When the Smart chair is introduced into the market it has a high IDU. As the product matures and is needed by more customers the IDU lowers. When the product stays in the market for a long time and isn't as desired by the customers anymore the IDU rises again or when the pandemic ceases to exist, it will rise again.



Supply chain Strategy Map

Our strategic fit diagram shown below is a reflection of both the responsive/efficiency spectrum along with the implied demand uncertainty spectrum. Given that our product is somewhat responsive along with holding a somewhat IDU, that places us within the strategic zone of fit, slightly right of the center. Ideally, we would like our product to be as far left as possible with regards to the constraint of our supply chain being one that values responsiveness. Our product moving into the realm of low IDU is dependent on the rollout of the vaccines and gradual phasing into normal pre-pandemic life, assuming that companies revert from remote work, to in person.



To achieve strategic fit the consistency between the customer priorities of a competitive strategy that it hopes to satisfy and supply chain capabilities that the supply chain strategy aims to build. This means that all functional strategies that make up the supply chain strategy must be aligned. A company may fail because of their poor strategic fit or because their process isn't designed to process their desired strategy.

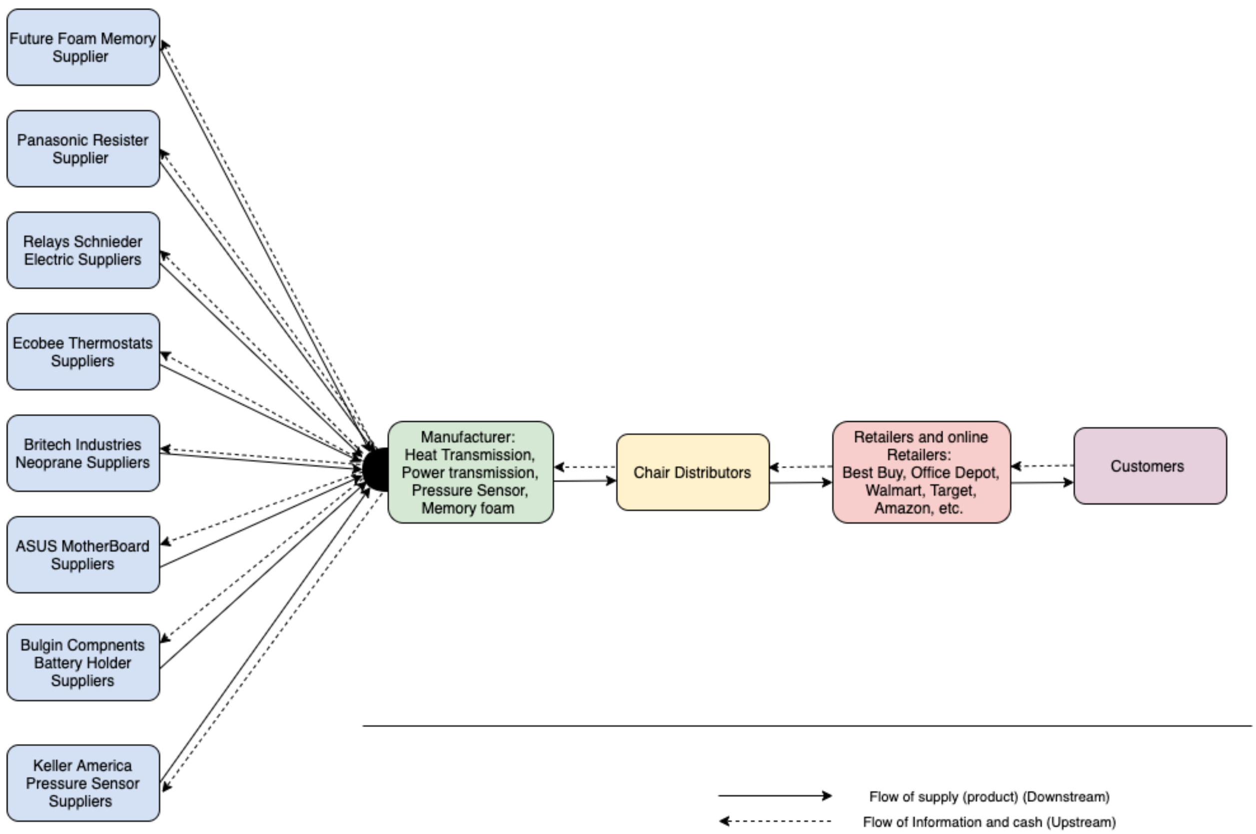
Structure of our Supply chain

This section of the report will contain information regarding the high level structure of the supply chain structure for the smart chair. This section will contain the stages of our supply chain, a general supply chain structure, operational cycles and other details associated with the smart chair.

The Stages of the Supply Chain

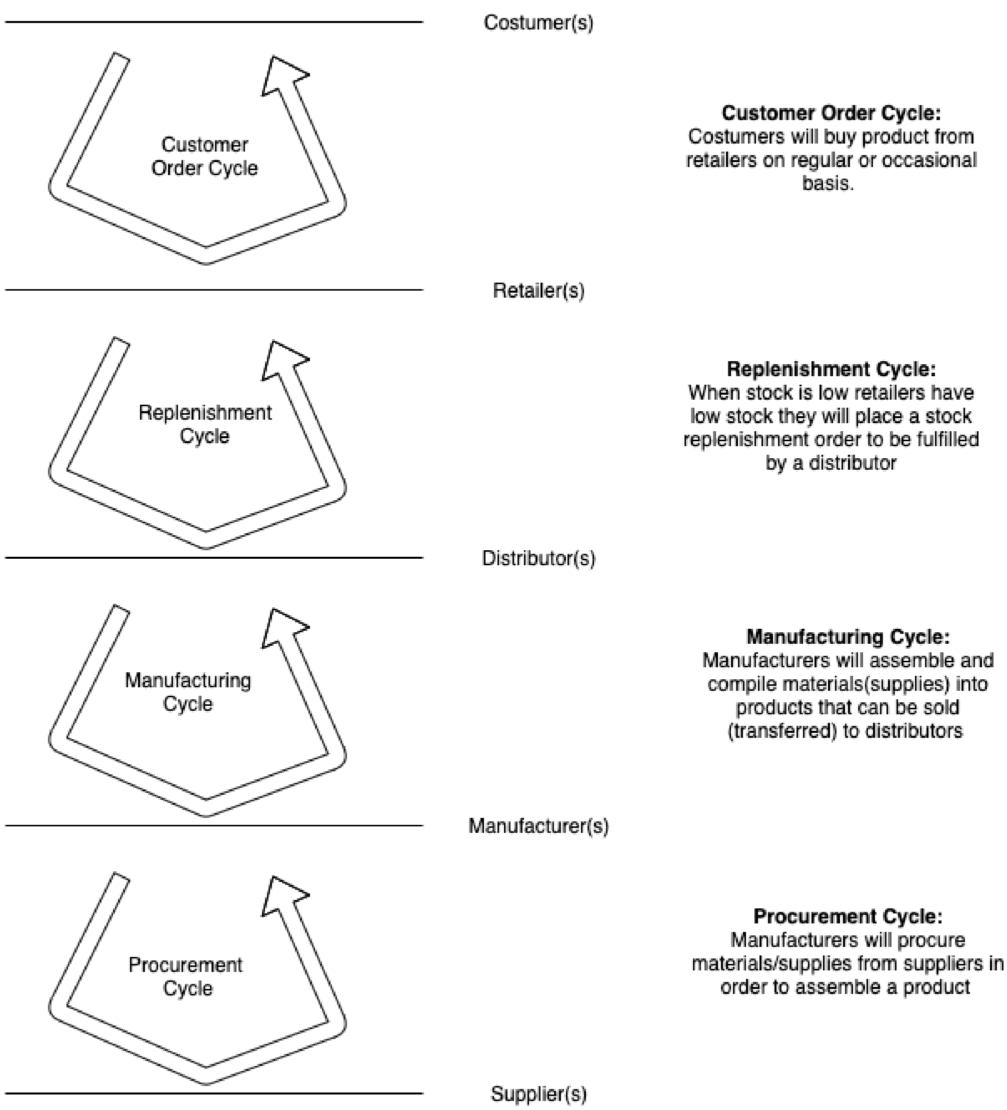
The stages of the supply chain connects the suppliers, manufactures, distributors, retailers, and customers are displayed in the diagram below

Explained more in depth with directionality in the following diagram, our supply chain follows a relatively simple method of going from supplier, to manufacturer, to distributor, to retailers, and then eventually into the hands of our customers.



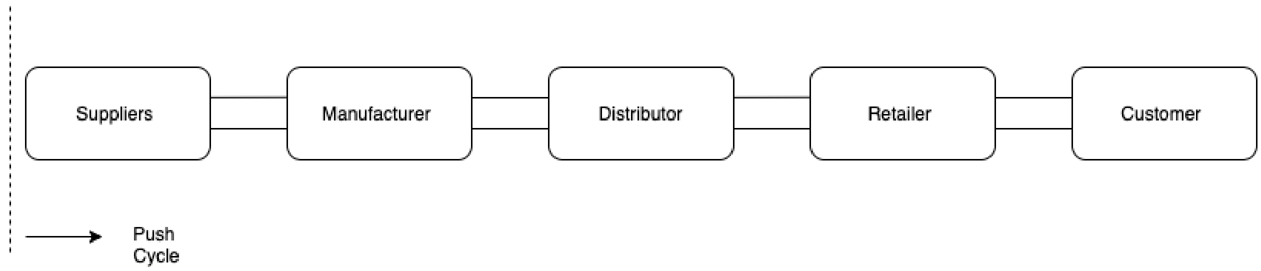
Operational Cycle View

Below is an operational cycle view of any two adjacent stages of the supply chain. Here, it lays out the customer order cycle, replenishment cycle, manufacturing cycle, and the procurement cycle. Each cycle has a set of operations associated with it that are important in the supply chain. This allows us to ask "what are the set of operations when someone orders our Smart Chair"

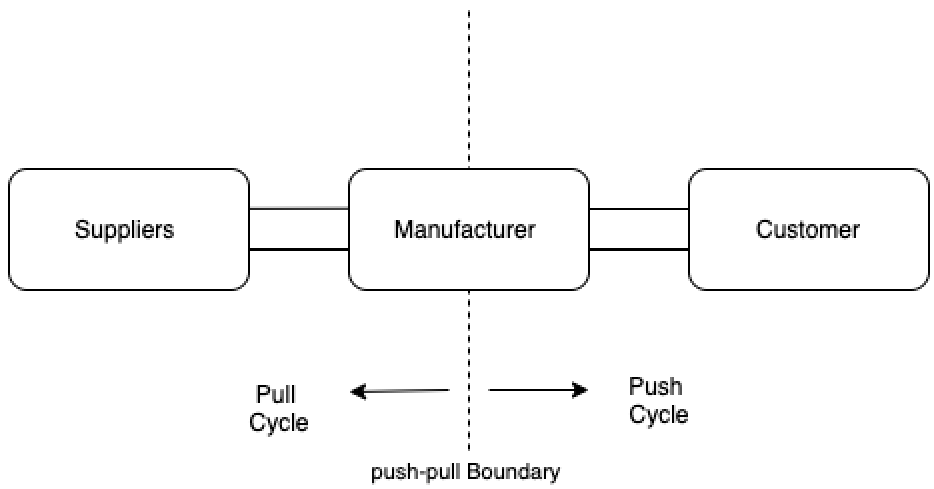


Push pull cycle/boundary

The push-pull cycle/boundary diagram shows where in the supply chain the push cycle happens and where the pull cycle happens. Starting from the left side of our supply chain diagram, we push our the components from the suppliers, then onto the manufacturers, distributors and so on



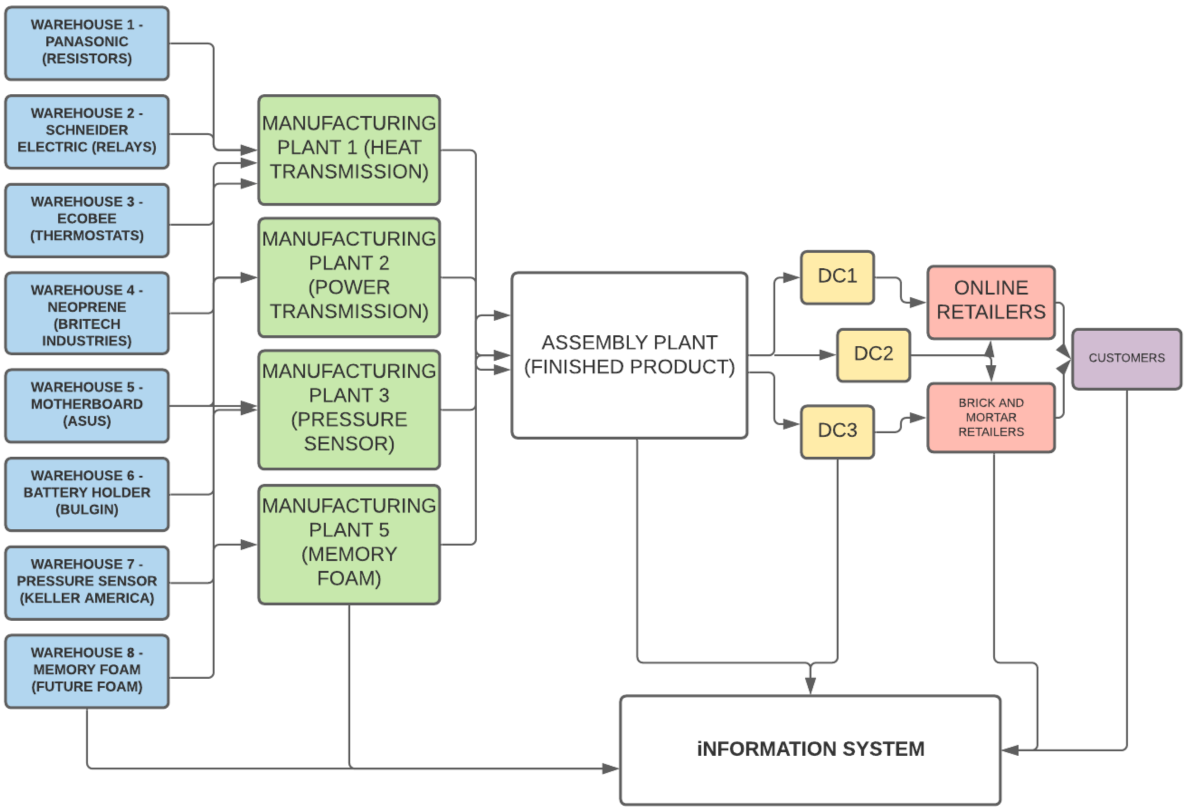
This diagram below shows where in the supply chain the push and pull cycle happen, it shows the boundary difference between the start of each cycle.



General Supply Chain Network for Smart Chair

The network diagram below shows the process that takes place to create our final product. This process starts out with our warehouses filled with components taken from the suppliers. From there, these components go from warehouse to the manufacturing plant catered to the appropriate subsystem. As the subsystems are manufactured to turn components into an independent and functional subsystem, they are sent off to the assembly plant where it all comes together to create a finished product, our Smart chair.

After the completion of the Smart chair, we push our product through 3 distribution channels which then push our product into online retailers and brick and mortar retailers who in turn push it out to customers.



Supply Chain Strategy Summary

Although every step of the supply chain is very important, our supply chain is one that is especially dependent on the efficient processes between the warehouse, manufacturing, and assembly plant due to the copious amount of players involved in the actual creation of our finished product. Our warehouses must always be properly stocked to allow for the creating of our subsystems which make up our finished product.

In saying these things however, the understanding of inevitable errors is ever present and will result in proper measures being taken to ensure when errors do arise. These measures and how we are looking to prevent these errors will be discussed and quantified in a later section. Before we do that, we must first forecast our demand so that we can come up with accurate predictions for our product, which we can then use to estimate cycle inventory, safety inventory, and other metrics that will allow us to create an efficient supply chain and profitable product.

To come up with the forecasted demand, we will use the next section to discuss how we will estimate reliable and historical data to come up with data that we will build our forecasts and inventory processes on top of.

Check your work

a. Is your work correct in every detail?
    i. We believe that the work is correct when it comes to Steps 1-3 but we were concerned about the part 4 of Phase I. We had resources and lecture notes to allow us to execute and also check our work for steps 1-3. Since Step 4 was a little out of our comfort zone and the data was difficult to come across, complications were met.
b. Is your assumption reasonable?
    i. The assumption was that we would have our previous work accurate to be able to go off of and this holds. When it comes to the 4th step, our assumptions lied on the fact that the accuracy of the online sources is legitimate. We are more inclined to believe their accuracy but there is still no way to fully trust it. For the most part, we have used our resources to solve this problem to our greatest ability. It is important to understand that the market we are stepping into does not necessarily exist which is why the historical data is a close best case representation instead of actual representation.

Learn and Generalize

We have found that the market for which our product will be exposed does not exist. This in turn did create complications in how to complete the historical data aspect of the problem. However we have provided the best estimation of how we believe the historical data would fit with our close competitors. We believe as the gaming industry increases, the gaming chair market will also rise and become a formidable competitor. For this reason, we also believe that they would provide an accurate way to predict our demand forecast due to not currently having a submarket.

Phase01 and 02 Connector

With Project Phase 01 now complete, we can begin on building and implementing a stepwise process to obtain credible demand data of 8 quarters for our product. After obtaining the demand data, we begin with forecasting demand for Year 3 and Year 4 based on the demand data that we obtained in the previous step. Then we perform a complete set of cycle and safety inventory calculations, interpret the results, and draw appropriate conclusions. All of the above is then compiled into a well-structured Project Report 02.

Project Phase02

High level Time - Schedule Project Planning

Task	Estimated Work Time (hr)	Actual Work Time (hr)
Planning	Meetings for planning - 2hrs	Meetings for planning - 4hrs
Problem 1- Refined Demand Estimates	3.5	6+hrs
Problem 2 - Forecasting	5hr	8.5+hr
Problem 3 - Cycle and Safety Inventory	2hr	9hr

Define the Problem

[1] - Refined Demand Estimates

- Create and implement an explicit step-wise process to obtain 8quarters (Years 1 and 2) of credible historical demand data for your product.

[2] - Forecasting

- Perform demand forecasting for years 3 and 4 based on the demand data obtained in the previous step.Make sure you draw relevant conclusions.

[3] - Cycle and Safety Inventory

- Cycle and Safety Inventory for your product's supply chain. Starting with the network representation of your product's supply chain, create and implement a process for performing cycle and safety inventory management for one or two key subsystems of your product; and for the finished product.

Strategy/ Treatment

a. What information is available to solve this problem?
    i. When it comes to solving the full problem from sub problem 1 to subproblem 3, the information provided to us was split between resources given to us by the prof. Or the plethora of online resources we have. Below is a high level list of all the information given to us to solve this problem.
        1. Online Sources (for finding the data relating to our product)
        2. The professor and TA's to guide us in our project phase 2
        3. Lecture videos
        4. Lecture notes (combined of all group members)
        5. Previous experience in all subjects of demand estimating, forecasting safety inventory and cycle inventory management. (This includes the previous hw and midterm)
b. What assumptions must be made to make the solution process more manageable?
    i. The biggest assumption we will make is having full trust in each other to fulfill all of the requirements at the planned time of submitting. Below will be listed more of the assumptions used to solve the problem
        1. We will assume all the information is correct and all the advice/help received from the instructors is correct and trustworthy.
        2. As we progress through the assignments we will assume all of the work done in the previous phase was correct and useful in this phase.
        3. On top of all the assumptions made, the final assumption is that we will assume the online information we extract will be accurate and useful to solve this problem.
c. What analysis needs to be performed to resolve the issues defined in step 1?
    i. There will be general analyses to be performed from demand estimation to demand forecasting and inventory analysis. Most analysis will be

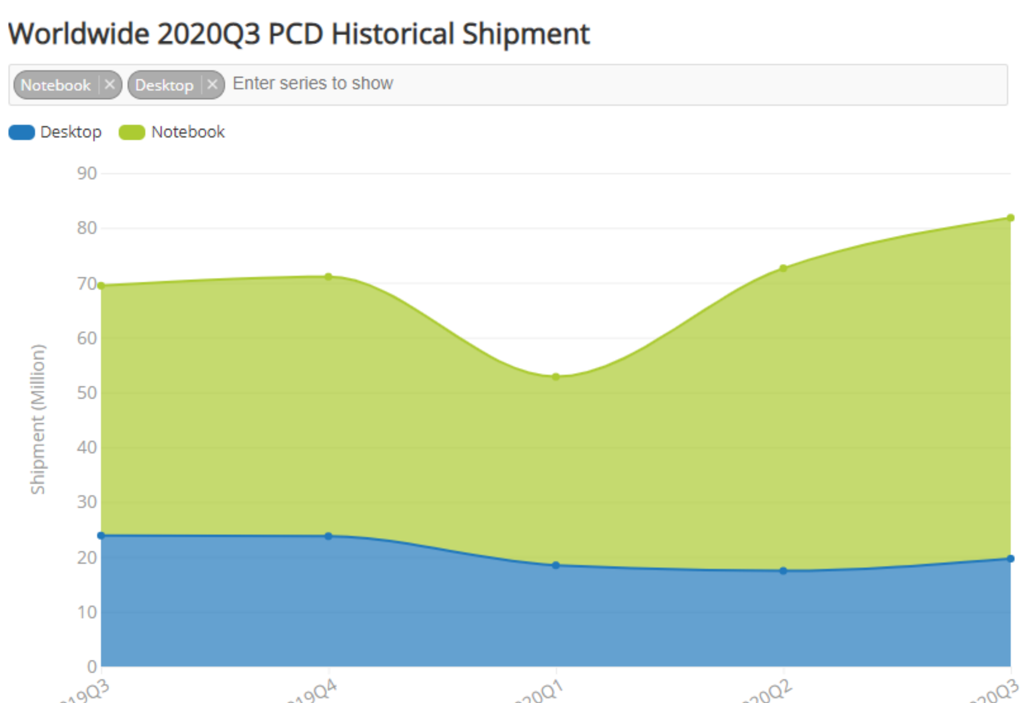
general and extracted from lectures and textbooks provided by the instructors.

Execution

[1] Refined Demand Estimates

In order to estimate demand for our product, the smart chair, we decided to find information regarding desktops and laptops in order to approximate our demand data. The reason why we chose PCs to estimate our data is because chairs are typically paired hand in hand with workstations. That means that in most situations where people decide to purchase PCs they also purchase chairs. This means that our product would become a possible candidate in the market for people who choose to buy these products so demand for office chairs like the smart chair should correlate with historical demand for PCs.

On the internet, we were able to find the worldwide shipment data for desktop and laptop computers as seen below with “Worldwide 2020 Q3 PCD Historical Shipment.” With the shipment data, we created a step by step process in order to shift the numbers to calculate our estimated demand data. Since we want to find the domestic demand for the smart chair, we scaled down the global demand data to domestic data by correlating it with global vs. US population and took a fraction of it based on our assumed market share for office chairs.



(Source: https://www.idc.com/promo/pcdforecast)

Step By Step Process and Assumptions for Approximating Demand Data:

Step 1	Take IDC's demand data for notebooks and desktops in order to start our chair's demand data model as a base to begin. To do this, we zoomed in on the points in the graph for each demand curve and summed them together.
Step 2	IDC's demand data for notebooks and desktop shipments are worldwide, but our product is targeted domestically. To estimate domestic demand data, take the total worldwide demand for notebooks and desktops and multiply by US population divided by worldwide population. We assume that the demand for PCs per capita is the same worldwide as it is for the US, even though this might not be the case realistically.
Step 3	Multiply the estimated domestic demand data by an estimated market share for our product in the office chair industry. We can assume that PCs to office chairs are at about a 1:1 ratio from the assumptions in the previous section and that we take up about 2% of the market share for office chairs due to the fact that this is a newly developed product in the market.
Step 4	The next step would be to figure out the next 3 quarters of the global shipment demand data because IDC only gives data for 5 quarters because we need a total of 8 quarters for the project prompt. The easiest way is to estimate this is to use the percentage increase between Q3 2019 and Q3 2020 and assume that the rest of the quarters follow a similar pattern of demand growth between each respective quarter in the next year. The global yearly demand growth was calculated to be about 17.83%.
Step 5	Estimate how much my company's market share would increase the next year. We can assume that it would increase by another 2%. In the latter 4 quarters, an additional 2% was multiplied onto the estimated demand data on top of the global yearly demand growth from the previous step in order to account for this.

Step by Step Process for Calculations in Excel:

	A	B	C	D	E	F	G	H
1	Year	Quarter	IDC Demand Data For PCs (in millions)	Estimated Domestic Demand for PCs (in millions)	Estimated Demand for our Product			
2	2019	3	69.45	2.97	59,404		Worldwide Population	7.67E+09
3	2019	4	71.09	3.04	60,807		US Population	3.28E+08
4	2020	1	52.84	2.26	45,197		Population Ratio	4.28E-02
5	2020	2	72.62	3.11	62,116			
6	2020	3	81.83	3.50	71,394		Company Market Share	2.00%
7	2020	4	83.76	3.58	73,080			
8	2021	1	62.26	2.66	54,319		Global Yearly Demand Increase	17.83%
9	2021	2	85.57	3.66	74,652		Company Yearly Market Share Increase	2.00%

Column C (in white)	This number was calculated by adding the global shipment data from IDC for laptops and desktops.
Column D	First the population ratio was calculated by dividing total US population by total world population (cell H4). The estimated domestic demand for PCs was calculated by multiplying the global PC demand data from IDC (column C) by the population ratio.
Column E (in white)	To get our estimated domestic demand for our product, we multiplied the domestic demand for PCs and multiplied it by our predicted market share for office chairs, which was 2% (cell H6). This number was also converted from millions to standard values.
Column C (in green)	First the yearly demand increase is calculated by finding the percent difference between Q3 2020, and Q3 2019 (cell H8). Percent difference was calculated by the following equation: $$Percent\ Yearly\ Increase = \frac{Q3\ 2020\ Demand - Q3\ 2019\ Demand}{Q3\ 2019\ Demand} \times 100\%$$ For each *x* quarter, the demand was calculated using this equation: $$Qx\ 2020\ Demand = (\ 1 + Percent\ Yearly\ Increase) \times (Qx\ 2019\ Demand)$$
Column E (in green)	The calculations in green are the same as the calculations in white with the addition of accounting for the company's yearly market share

	increase of 2% (cell H9) therefore we multiply the number we get in white by 1 + 2%.

[2] Forecasting

In order to evaluate how well our product would do in the market, we decided to use five different types of forecasting methods which consist of a static, simple exponential smoothing, moving average, Holt's model, and Winter's model.

Each model requires a different set of parameters and some methods do not require any parameters at all. The main differences between these models are that some require seasonality, some require level, and some require trend. Some models account for multiple parameters but others account for only one type of parameter.

We also used an alpha, beta, and gamma value of 0.1 throughout all the forecasting methods in order to have some sort of base value to account for error analysis. Each error analysis that was done for every model all followed the same sets of equations.

Error Analysis Equations for all Models

Error, Et	The Error can be calculated by taking the forecast of demand and subtracting that by the estimated historical demand. The equation for Error is given by: $$E_t = F_t - D_t$$ *Excel Reference Formula:* *Et = Forecast, Ft - Demand, Dt*
Absolute Deviation Error, At	Absolute deviation error is calculated by taking the value calculated under Error and taking the absolute value of the number. The equation for Absolute Error is given as: $$A_t = \lvert E_t \rvert$$ *Excel Reference Formula:* *At = ABS(Et)*
Squared Error,	Squared Error is calculated by using the equation:

MSEt	$$MSE_n = \frac{1}{n}\sum_{t=1}^{n} E_t^2$$ *Excel Reference Formula:* *MSE(n) = SUMSQ(Et(1):Et(n))/Period(n)* This formula sum squares all the error values and takes the sum of each previous number and divides it by the current period.
MADt	Mean Absolute Deviation (MAD) is defined to be the average of the absolute deviation over all periods which is expressed by the equation: $$MAD_n = \frac{1}{n}\sum_{t=1}^{n} A_t$$ *Excel Reference Formula:* *MAD(n) = SUM(At(1):At(n))/Period(n)*
% Error	Percent Error is calculated by taking the absolute deviation error and dividing it by the historical demand data. We then multiply it by 100 in order to achieve the percentage number. The lower that this number is the more accurate our forecasting model. *Excel Reference Formula:* *% Error = 100*(At/Dt)*
MAPEt	Mean absolute percentage error (MAPE) is the average absolute error as a percentage of demand which is given by the equation: $$MAPE_n = \frac{\sum_{t=1}^{n} \left\| \frac{E_t}{D_t} \right\| 100}{n}$$

	Excel Reference Formula: *MAPE(n) = AVERAGE(Et(1):Et(n))* The lower the number for MAPE, the more accurate the forecasting results. This error number is one of the more important values to look at when evaluating how accurate our forecasting models are.
TSt	Tracking signal (TS) is the ratio of the bias and the MAD which is given by the equation: $$TS_t = \frac{bias_t}{MAD_t}$$ *Excel Reference Formula:* *TS(n) = SUM(Et(1):Et(n))/MAD(n)* TS is just as important as MAPE and percentage error when evaluating the accuracy of our forecasting model. The general rule of thumb when looking at the TS error numbers is that the value should be less than 6 for the forecast to be acceptable.

Static Forecasting Model

The Static Forecasting Method

The static forecasting model can be seen below:

	A	B	C	D	E	F	G
1	Quarterly Demand for HP Smart Chair				Static Forecasting Model		
2	Year	Quarter	Period, t	Demand, Dt (Yellow is Forecasted Demand)	Deseasonalized Demand	Calculated Deseasonalized Demand, $\bar{D}t$	Seasonal Factor
3	1	3	1	59,404	-	52,898	1.12
4	1	4	2	60,807	-	55,689	1.09
5	2	1	3	45,197	58,380	58,481	0.77
6	2	2	4	62,116	61,412	61,273	1.01
7	2	3	5	71,394	64,087	64,065	1.11
8	2	4	6	73,080	66,794	66,856	1.09
9	3	1	7	54,319	-	69,648	0.78
10	3	2	8	74,652	-	72,440	1.03
11	3	3	9	84,162	-	-	-
12	3	4	10	85,240	-	-	-
13	4	1	11	62,743	-	-	-
14	4	2	12	85,459	-	-	-
15	4	3	13	96,654	-	-	-
16	4	4	14	97,439	-	-	-
17	5	1	15	71,412	-	-	-
18	5	2	16	96,873	-	-	-

The static forecasting model utilizes a certain set of equations that are used in order to predict future demand. The stepwise process in achieving the static forecasting model is as follows:

Step 1	The first thing that we needed to do was to look at the given forecasting equation in order to figure out how to find the demand for the next eight quarters. The equation in the textbook was given as: $$F_{t+l} = [L + (t + l)T]S_{t+l} \quad \textbf{(7.1)}$$ In this equation we needed to find the values of Level (L), Trend (T), and S_i (Seasonality). These values are found through the usage of other equations given in the textbook and lectures.

Step 2	The next step that we needed to find was the deseasonalized demand. The equation for finding deseasonalized demand based on historical values is given as: $$\bar{D}_t = \begin{cases} \left[D_{t-(p/2)} + D_{t+(p/2)} + \sum_{i=t+1-(p/2)}^{t-1+(p/2)} 2D_i \right] \Big/ (2p) \text{ for } p \text{ even} \\ \sum_{i=t-[(p-1)/2]}^{t+[(p-1)/2]} D_i/p \text{ for } p \text{ odd} \end{cases} \qquad \textbf{(7.2)}$$ Since there are an even number of periods per season, we use the first equation for (2p) for *p* even which is equal to 4. Due to the fact that the pattern in our estimated deseasonalized demand is the same as the examples given in the textbook and in lectures, we utilized the same equation in order to find deseasonalized demand which is given as: $$\bar{D}_3 = \left[D_{t-(p/2)} + D_{t+(p/2)} + \sum_{i=t+1-(p/2)}^{t-1+(p/2)} 2D_i \right] \Big/ (2p) = \left[D_1 + D_5 + \sum_{i=2}^{4} 2D_i \right] \Big/ 8$$
Step 3	Once we found all the deseasonalized values, we needed to find the linear regression equation for the deseasonalized demand. This can be done by graphing the plots in Excel in order to find and display the trendline on the graph. The equation for the trendline is given as: $$\bar{D}_t = L + Tt \qquad \textbf{(7.3)}$$
Step 4	The equation given from the deseasonalized trendline was given as y = 2791.7x + 50106. We used this equation to find the calculated deseasonalized demand which can be seen in column F of our forecasting model.
Step 5	The next thing we needed to do was to use the equation given in the textbook to find the seasonal factors. The equation is given as: $$\bar{S}_t = \frac{D_i}{\bar{D}_t} \qquad \textbf{(7.5)}$$ The numerator represents the historical demand and the denominator represents our calculated deseasonalized demand.

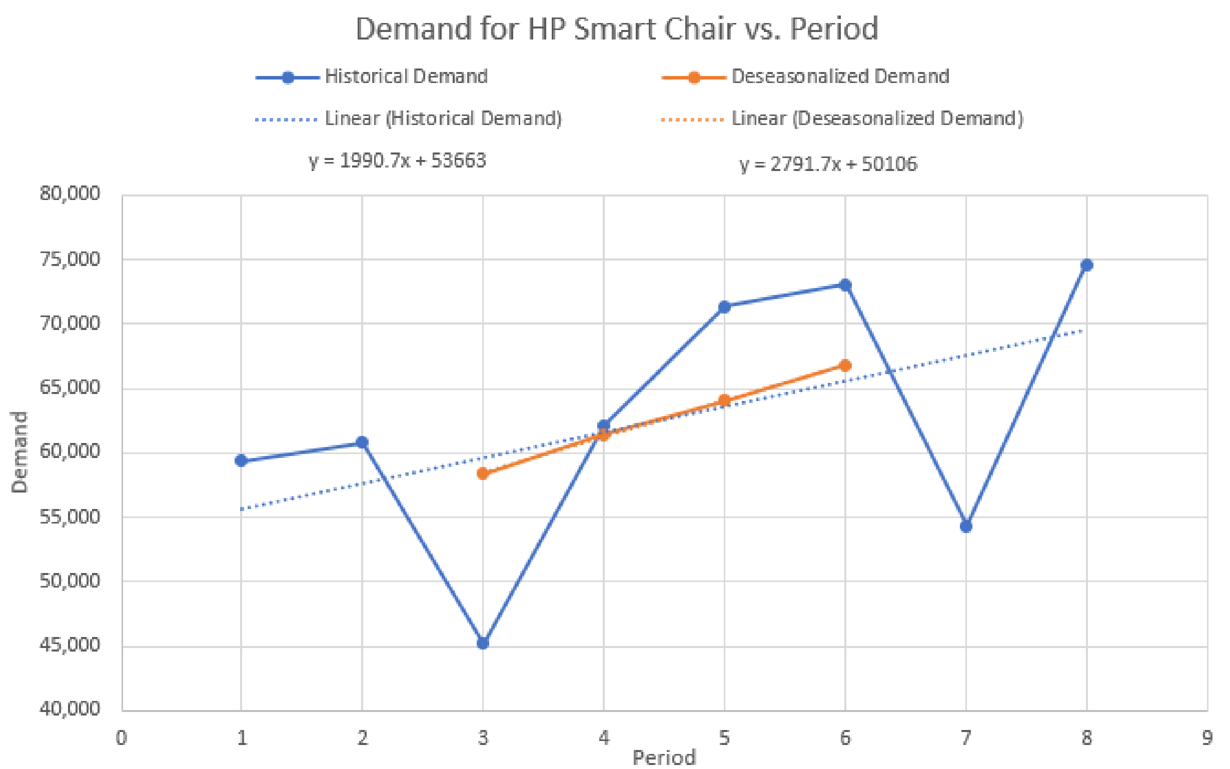
Step 6	Our next step was to find the calculated seasonal factor for each season. The formula given in the textbook can be seen as: $$S_i = \frac{\sum_{j=0}^{r-1} \overline{S}_{jp+i}}{r} \quad \textbf{(7.6)}$$ This formula calculates the average of the seasonal factor for each season. Since there are two cycles of seasons, we added the seasonal factors for the same season in each cycle and divided it by two. The calculated seasonal factors can be seen in the table below. ***Calculated Seasonal Factors*** **Calculated Seasonal Factor** **Season** | **Seasonal Factor** 1 (Q3) | 1.12 2 (Q4) | 1.09 3 (Q1) | 0.78 4 (Q2) | 1.02
Step 7	Now that we found all of our necessary values to plug into the forecasting equation shown in step 1, we can calculate the forecast for the following eight periods. The values are shown in the forecasting model above.

Calculated Seasonal Factors

Calculated Seasonal Factor	
Season	**Seasonal Factor**
1 (Q3)	1.12
2 (Q4)	1.09
3 (Q1)	0.78
4 (Q2)	1.02

Static Forecast Model Graph

The graph below represents the different types of demands. The estimated historical demand can be seen in blue and the deseasonalized demand can be seen in orange. The dotted lines below represent the linear equations of each respective trendline.



This graph was useful in calculating the forecast for the static method. The trendline equation for the deseasonalized demand was used in step 4 of our stepwise process.

Static Forecast Error Analysis

The error analysis for each model is useful in trying to evaluate how accurate the model was in forecasting demand. Each set of errors work with each other in order to come up with the 3 most important types of errors which include percent error, MAPE, and TS.

The error analysis for our static model and be seen below:

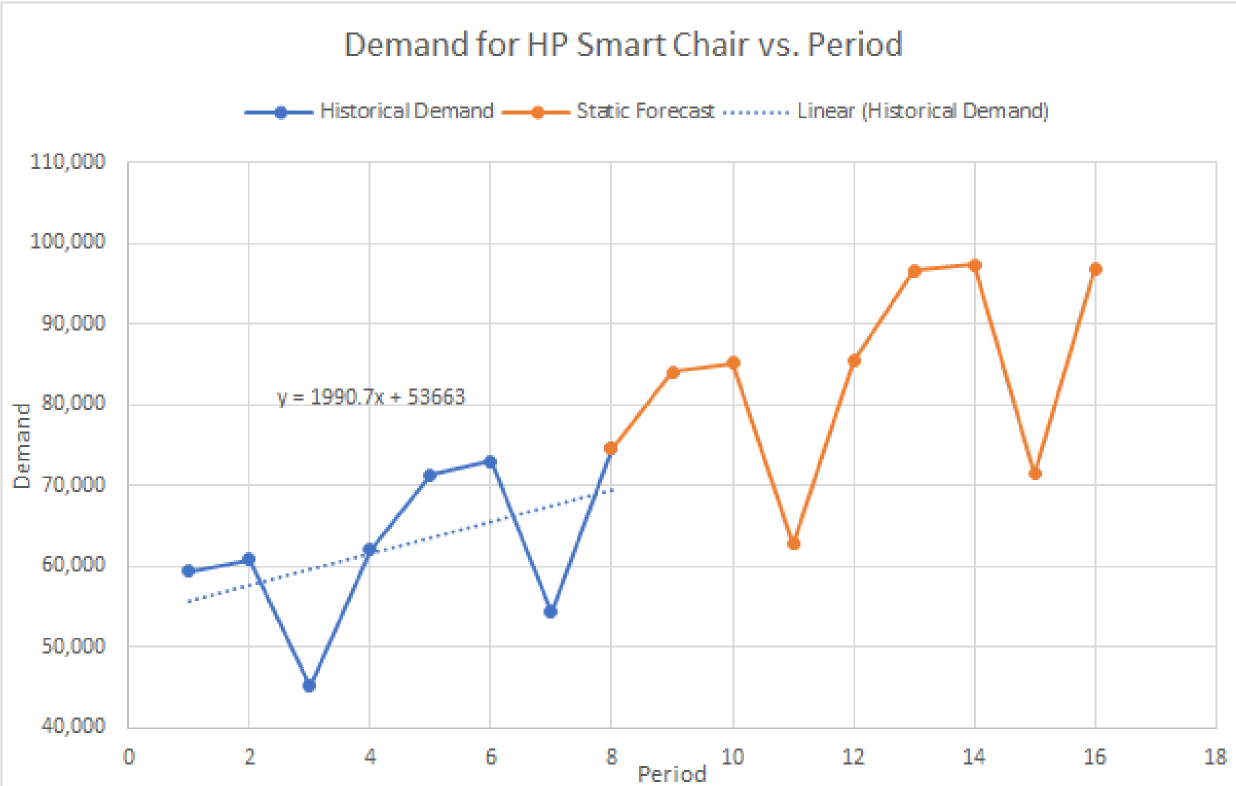
Quarterly Demand				Model	Error Analysis						
Year	Quarter	Period, t	Demand, Dt	Forecast of Demand, Ft	Error, Et	Absolute Error, At	Squared Error, MSEt	MADt	% Error	MAPEt	TSt
1	3	1	59,404	59,177	-227.56	227.56	51,785.82	227.56	0.38	0.38	-1.00
1	4	2	60,807	60,840	33.01	33.01	26,437.87	130.29	0.05	0.22	-1.49
2	1	3	45,197	45,403	206.37	206.37	31,821.38	155.65	0.46	0.30	0.08
2	2	4	62,116	62,630	514.26	514.26	89,981.19	245.30	0.83	0.43	2.14
2	3	5	71,394	71,669	275.60	275.60	87,176.50	251.36	0.39	0.42	3.19
2	4	6	73,080	73,040	-39.63	39.63	72,908.89	216.07	0.05	0.36	3.53
3	1	7	54,319	54,073	-245.78	245.78	71,122.69	220.32	0.45	0.37	2.34
3	2	8	74,652	74,044	-607.98	607.98	108,437.22	268.77	0.81	0.43	-0.34

Conclusion

With the error analysis done for the static forecasting model, we mainly look at three values when evaluating the accuracy. The percent error, MAPE, and TS values are usually the most prominent values to look at when determining how accurate our model is. As seen in the table above, the percent error mainly stays below 1%, the MAPE values are all below 1, and the TS values are all below the general accepted value of 6. That means that the static forecasting method is extremely accurate and is generally acceptable.

Static Forecast Demand Graph

With the graph below, we can see the forecasted demand that we calculated. Due to the fact that the static forecasting model accounts for three different parameters, level, trend, and seasonality, we can conclude that the accuracy of the static forecast is relatively good.



This graph helps visualize the numbers from the static forecasting model in the sections above and represents the numbers that we calculated to see if the model is accurate.

Simple Exponential Smoothing Forecast and Error Analysis

The simple exponential smoothing forecast model is a much more simple type of method that only utilizes the level parameter. The simple exponential smoothing forecast model is also a type of adaptive forecasting. The simple exponential equation dampens the demand into a single value. This method is generally acceptable when the data values have no visible seasonality or trend.

Estimated Demand for Smart Chair				Simple Exp. Smoothing		Error Analysis						
Year	Quarter	Period, t	Demand, Dt	Level, Lt	Forecast, Ft	Error, Et	Absolute Error, At	Squared Error, MSEt	MADt	% Error	MAPEt	TSt
-	-	0	-	62,621	-	-	-	-	-	-	-	-
1	3	1	59,404	62,299	62,621	3,217	3,217	10,346,904	3,217	5.41	5.41	1.00
1	4	2	60,807	62,150	62,299	1,492	1,492	6,286,799	2,354	2.45	3.93	2.00
2	1	3	45,197	60,455	62,150	16,953	16,953	99,995,227	7,221	37.51	15.13	3.00
2	2	4	62,116	60,621	60,455	-1,661	1,661	75,686,174	5,831	2.67	12.01	3.43
2	3	5	71,394	61,698	60,621	-10,773	10,773	83,758,835	6,819	15.09	12.63	1.35
2	4	6	73,080	62,836	61,698	-11,381	11,381	91,387,880	7,580	15.57	13.12	-0.28
3	1	7	54,319	61,985	62,836	8,518	8,518	88,696,713	7,714	15.68	13.49	0.83
3	2	8	74,652	63,251	61,985	-12,668	12,668	97,668,499	8,333	16.97	13.92	-0.76
3	3	9	63,251	63,251	63,251	-	-	-	-	-	-	-
3	4	10	63,251	63,251	63,251	-	-	-	-	-	-	-
4	1	11	63,251	63,251	63,251	-	-	-	-	-	-	-
4	2	12	63,251	63,251	63,251	-	-	-	-	-	-	-
4	3	13	63,251	63,251	63,251	-	-	-	-	-	-	-
4	4	14	63,251	63,251	63,251	-	-	-	-	-	-	-
5	1	15	63,251	63,251	63,251	-	-	-	-	-	-	-
5	2	16	63,251	63,251	63,251	-	-	-	-	-	-	-
Alpha	0.1											

The simple exponential smoothing forecasting method can be done with a stepwise approach:

Step 1	In order to calculate forecast, Ft using the simple exponential smoothing method, we first needed to find L_0 which can be done through calculating the average of all available demand data points. The initial Level can be found by using the equation given as: $$L_0 = \frac{1}{n} \sum_{i=1}^{n} D_i$$
Step 2	The current forecast for all future periods is equal to the current estimate of level which is given as: $$F_{t+1} = L_t \quad \text{and} \quad F_{t+n} = L_t$$
Step 3	Next we utilize the equation of the simple exponential smoothing method in order to find the next level value. We revise the estimate of the level as follows:

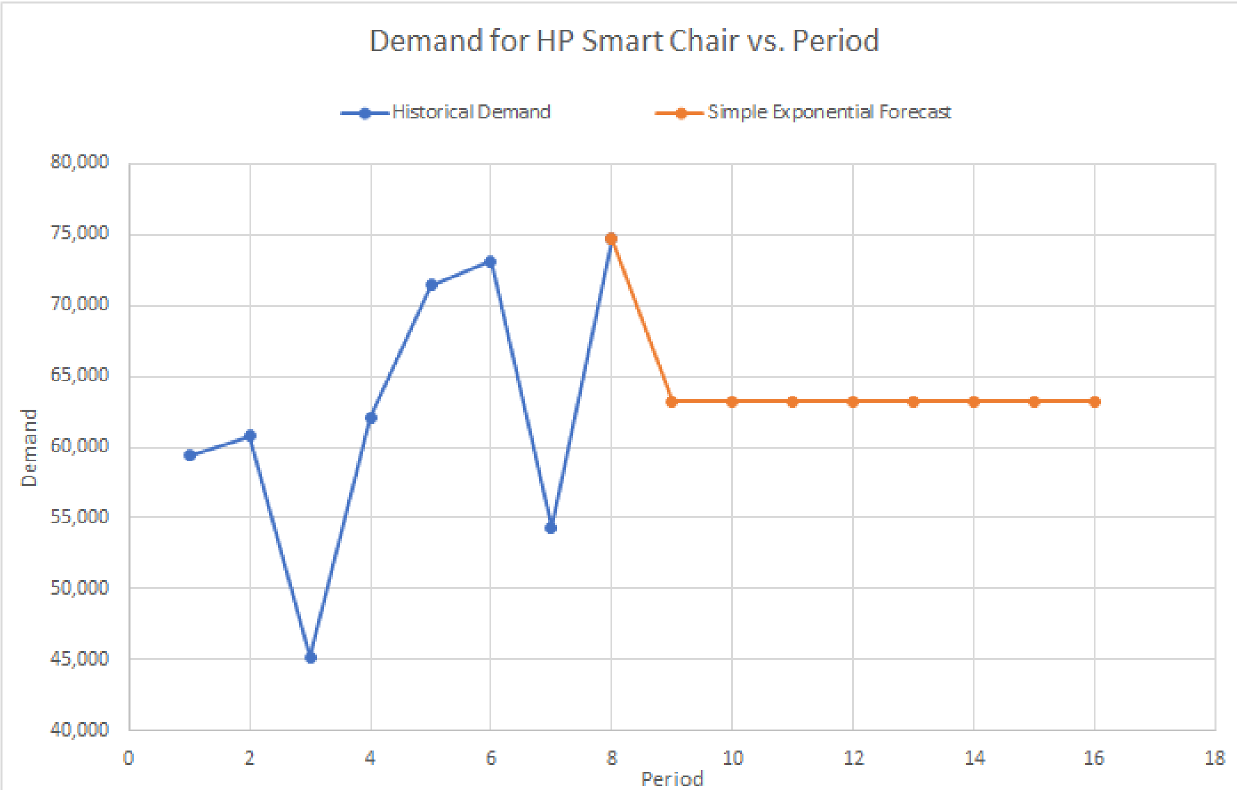
	$$L_{t+1} = \sum_{n=0}^{t-1} \alpha(1 - \alpha)^n D_{t+1-n} + (1 - \alpha)^t D_1$$ Alpha is the smoothing constant for the level, 0 < ***α*** < 1. The revised value of the level is a weighted average of the observed value of the level in period.
Step 4	Calculate the demand for the next eight quarters using the same methodology as mentioned in the previous steps. The next eight quarters should be equal to or about the same as a number that is close to the average of the historical demand data depending on the number chosen for the smoothing constant.

Conclusions for Error Analysis:

The error analysis for the simple exponential smoothing model shows many signs that it is not an acceptable forecast for the data that we estimated. The reason why it is not an acceptable forecast is mainly because the error values for percent error, MAPE, and TS are extremely high. By changing the smoothing constant we can try and adjust the values so that it is more acceptable, but due to the nature of our estimated demand data, the accuracy of this model is not good. Percent error gets to a high of about 17%, the MAPE values are all above 1 and the TS values are within acceptable range, but they do have a large range from values less than and greater than 1.

Simple Exponential Smoothing Forecasted Demand Graph

The graph below represents the forecasted demand values at the smoothing constant equal to 0.1. This graph is a visual representation of what is happening in the forecasting model. It shows that the next eight quarters are predicted to be at about the same demand point as the average which was calculated at L_0.



With this graph, we can conclude that the simple exponential smoothing model is not a very good representation of what we want to see in our forecasted demand data. Realistically, our demand would follow a pattern, and not all be smoothed out into one average value.

Moving Average Forecast (4 Point Moving Average) and Error Analysis

The moving average method is typically used when the demand has no observable trend or seasonality. It has the same type of parameters as the simple exponential smoothing method but does not account for an alpha smoothing value. For our estimated demand, we decided to use a 4 point moving average, as there are 4 different periods in any given cycle in our demand data.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Quarterly Demand for Smart Chair				Moving Average		Error Analysis						
2	Year	Quarter	Period, t	Demand, Dt	Level, Lt	Forecast, Ft	Error, Et	Absolute Error, At	Squared Error, MSEt	MADt	% Error	MAPEt	TSt
3	1	3	1	59,404	-	-	-	-	-	-	-	-	-
4	1	4	2	60,807	-	-	-	-	-	-	-	-	-
5	2	1	3	45,197	-	-	-	-	-	-	-	-	-
6	2	2	4	62,116	56,881	-	-	-	-	-	-	-	-
7	2	3	5	71,394	59,878	56,881	-14,512	14,512	42,122,408	2,902	20.33	20.33	-5.00
8	2	4	6	73,080	62,947	59,878	-13,201	13,201	64,146,764	4,619	18.06	19.20	-6.00
9	3	1	7	54,319	65,227	62,947	8,628	8,628	65,616,923	5,192	15.88	18.09	-3.68
10	3	2	8	74,652	68,361	65,227	-9,425	9,425	68,519,530	5,721	12.63	16.73	-4.98
11	3	3	9	68,361	67,603	68,361	-	-	-	-	-	-	-
12	3	4	10	67,603	66,234	67,603	-	-	-	-	-	-	-
13	4	1	11	66,234	69,213	66,234	-	-	-	-	-	-	-
14	4	2	12	69,213	67,853	69,213	-	-	-	-	-	-	-
15	4	3	13	67,853	67,725	67,853	-	-	-	-	-	-	-
16	4	4	14	67,725	67,756	67,725	-	-	-	-	-	-	-
17	5	1	15	67,756	68,137	67,756	-	-	-	-	-	-	-
18	5	2	16	68,137	67,868	68,137	-	-	-	-	-	-	-

The stepwise process for achieving the moving average forecast method is as follows:

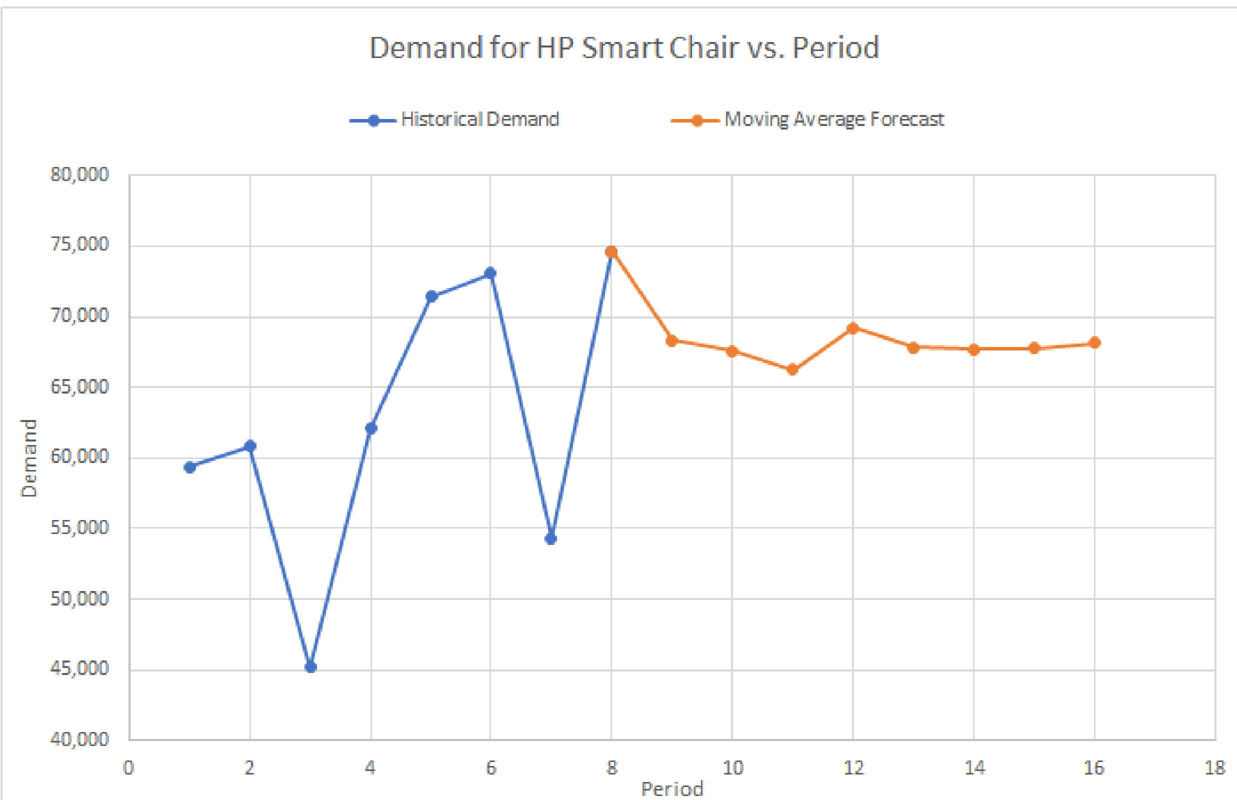
Step 1	The first step in calculating the moving average is finding out how many different periods there are during each cycle. For our estimated demand data we see that there are a total of 4 different periods for every year so we used a 4 point moving average.
Step 2	Using the 4 point moving average we discovered *N* which we plug into the equation given as: $$L_t = (D_t + D_{t-1} + \cdots + D_{t-N+1})/N$$ This lets us find the level of the 5th period which is the first period that comes after our first cycle. We take the average of the last cycle.
Step 3	The current forecast for all future periods is the same and is based on the current estimate of the level that we are calculating. The forecast is stated as: $$F_{t+1} = L_t \quad \text{and} \quad F_{t+n} = L_t$$
Step 4	After observing the demand for period $t + 1$, we can revise the estimates as: $$L_{t+1} = (D_{t+1} + D_t + \cdots + D_{t-N+2})/N, \quad F_{t+2} = L_{t+1}$$

Conclusions for Error Analysis:

The same types of principles discussed in the exponential smoothing method can be applied in the moving average method when it comes to determining how acceptable this model is for our estimated demand. The percent error, MAPE, and TS all have extremely high values and are typically considered unacceptable for this type of estimated demand. The percent error is extremely high, the MAPE values are also really high, and the absolute value of the highest number in the TS column is 6. This means that the forecasted method is typically very inaccurate and cannot be used to forecast our demand.

Moving Average Forecasted Demand Graph

The visualization of the moving average can be seen in the graph below. The forecasted demand using the moving average method can be seen in orange and the actual demand in blue.



Similar to that of the simple exponential smoothing method, we can see that the values are coming down to an average. This is typically not useful for our type of demand data as our demand data has seasonality, trend, and level to account for.

Holt's Model Forecast and Error Analysis

The trend-corrected exponential smoothing (Holt's Model) is typically used or appropriate when the demand is assumed to have a level and a trend but no seasonality. This means that we have two parameters to work with for this model and we have to account for 2 different smoothing values. This method is similar to exponential smoothing but it accounts for a separate parameter which should make it more accurate for our purposes.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Quarterly Demand for Smart Chair				Holt's Model			Error Analysis						
2	Year	Quarter	Period, t	Demand, Dt	Level, Lt	Trend, Tt	Forecast, Ft	Error, Et	Absolute Error, At	Squared Error, MSEt	MADt	% Error	MAPEt	TSt
3	-	-	0	-	53,663	1,990.7	-	-	-	-	-	-	-	-
4	1	3	1	59,404	56,029	2,028	55,654	-3,751	3,751	14,068,175	3,751	6	6	-1.00
5	1	4	2	60,807	58,332	2,056	58,057	-2,750	2,750	10,816,044	3,251	5	5	-2.00
6	2	1	3	45,197	58,869	1,904	60,388	15,191	15,191	84,130,035	7,231	34	15	1.20
7	2	2	4	62,116	60,907	1,917	60,772	-1,343	1,343	63,548,764	5,759	2	12	1.28
8	2	3	5	71,394	63,681	2,003	62,824	-8,570	8,570	65,526,619	6,321	12	12	-0.19
9	2	4	6	73,080	66,423	2,077	65,684	-7,396	7,396	63,721,341	6,500	10	11	-1.33
10	3	1	7	54,319	67,082	1,935	68,500	14,182	14,182	83,349,377	7,597	26	14	0.73
11	3	2	8	74,652	69,581	1,991	69,017	-5,635	5,635	76,899,939	7,352	8	13	-0.01
12	3	3	9	71,572	71,572	1,991	71,572	-	-	-	-	-	-	-
13	3	4	10	73,564	73,564	1,991	73,564	-	-	-	-	-	-	-
14	4	1	11	75,555	75,555	1,991	75,555	-	-	-	-	-	-	-
15	4	2	12	77,546	77,546	1,991	77,546	-	-	-	-	-	-	-
16	4	3	13	79,538	79,538	1,991	79,538	-	-	-	-	-	-	-
17	4	4	14	81,529	81,529	1,991	81,529	-	-	-	-	-	-	-
18	5	1	15	83,521	83,521	1,991	83,521	-	-	-	-	-	-	-
19	5	2	16	85,512	85,512	1,991	85,512	-	-	-	-	-	-	-
20														
21	Alpha	0.1												
22	Beta	0.1												

The stepwise process for achieving Holt's method is:

Step 1	The first thing we needed to do in order to achieve Holt's model is run a linear regression between Demand D_t and time Period *t*. This is given as: $$D_t = at + b$$ The linear regression equation for our demand trendline is y = 1990.7x + 53663. The systematic component of demand is also identified with the same linear equation as the trendline. Therefore our level and trend can be seen as:

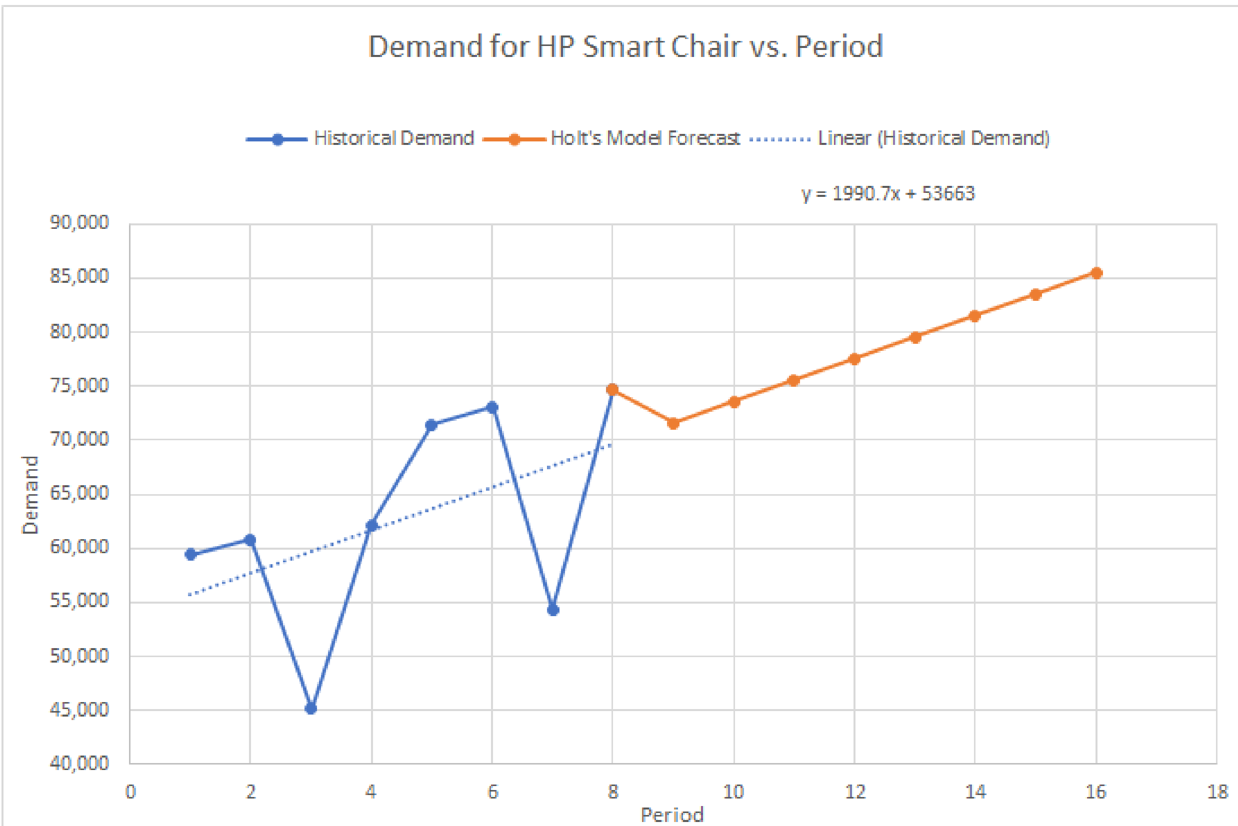
	Systematic component of demand = level + trend The slope would be *at* which is our trend and *b* would be our level which is 1990.7 and 53663 respectively.
Step 2	With the information we found in the previous step, we can use the slope and intercept values as our L_0 and T_0. The given estimates of level and trend, the forecast for future periods can be expressed as: $F_{t+1} = L_t + T_t \quad \text{and} \quad F_{t+n} = L_t + nT_t$
Step 3	After observing the demand for period *t,* we can revise the estimates utilizing alpha and beta values as a smoothing value. The revised equation would be shown as: $L_{t+1} = \alpha D_{t+1} + (1 - \alpha)(L_t + T_t)$ $T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$ These equations would be used in order to evaluate every value for level and trend starting from period 1. Alpha is the smoothing constant for level and beta is the smoothing constant for trend.
Step 4	Looking back at step 2, we can follow the equation to evaluate our future demand numbers. The forecast for any given period after 0 would be the addition of the previous level and trend values.

Conclusions for Error Analysis:

The error analysis for Holt's model can be barely acceptable for our purposes. The problem with Holt's model is that it does the same thing as simple exponential smoothing, with the addition of a separate parameter. This accounts for our expected increase in demand for the next eight quarters, but the accuracy of the forecast can have many errors associated with it. The percent error, MAPE, and TS values are within acceptable range but only barely. We think that Holt's model is a decent model but not good enough to consider for our demand data.

Holt’s Model Forecasted Demand Graph

The graph below is a visual representation of Holt’s model when forecasted for the next eight periods. As shown, we can see that the model follows the addition of trend but still only averages everything out depending on the smoothing constant that we decide to use.



Holt’s model is acceptable but not good enough for our purposes. We think that there are better models to help represent our forecasted data better with better accuracy.

Winter’s Model Forecast and Error Analysis

The trend and seasonality corrected exponential smoothing method (Winter’s Model) is most appropriate when the systematic component of demand has a level, trend, and seasonal factor. This is probably one of the best methods for our case of demand data estimations. Due to the fact that this method accounts for the most amount of parameters and smoothing constants, we expected it to fit our data the best and be one of the most accurate forecasting methods we could use out of the ones we have done.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Quarterly Demand for Tahoe Salt				Winter's Model				Error Analysis						
2	Year	Quarter	Period, t	Demand, Dt	Level, Lt	Trend, Tt	Seasonal Factor, St	Forecast, Ft	Error, Et	Absolute Error, At	Squared Error, MSEt	MADt	% Error	MAPEt	TSt
3	-	-	0	-	50,106	2,792	-	-	-	-	-	-	-	-	-
4	1	3	1	59,404	52,918	2,794	1.12	59,177	-228	228	51,786	228	0.38	0.38	-1.00
5	1	4	2	60,807	55,707	2,793	1.09	60,865	57	57	27,544	143	0.09	0.24	-1.19
6	2	1	3	45,197	58,471	2,790	0.78	45,418	221	221	34,618	169	0.49	0.32	0.30
7	2	2	4	62,116	61,212	2,785	1.02	62,619	503	503	89,179	252	0.81	0.44	2.20
8	2	3	5	71,394	63,978	2,783	1.12	71,619	226	226	81,546	247	0.32	0.42	3.16
9	2	4	6	73,080	66,775	2,785	1.09	72,930	-150	150	71,689	231	0.20	0.38	2.73
10	3	1	7	54,319	69,603	2,789	0.78	53,981	-338	338	77,763	246	0.62	0.42	1.19
11	3	2	8	74,652	72,462	2,796	1.02	73,943	-710	710	131,022	304	0.95	0.48	-1.38
12	3	3	9	84,197	75,258	2,796	1.12	84,197	-	-	-	-	-	-	-
13	3	4	10	85,282	78,054	2,796	1.09	85,282	-	-	-	-	-	-	-
14	4	1	11	62,778	80,850	2,796	0.78	62,778	-	-	-	-	-	-	-
15	4	2	12	85,511	83,646	2,796	1.02	85,511	-	-	-	-	-	-	-
16	4	3	13	96,709	86,442	2,796	1.12	96,709	-	-	-	-	-	-	-
17	4	4	14	97,502	89,238	2,796	1.09	97,502	-	-	-	-	-	-	-
18	5	1	15	71,462	92,035	2,796	0.78	71,462	-	-	-	-	-	-	-
19	5	2	16	96,945	94,831	2,796	1.02	96,945	-	-	-	-	-	-	-

Stepwise process for achieving Winter's Model:

Step 1	The first thing we needed to do for Winter's model is figure out all the different parameters that we needed. The systematic component of demand is different for Winter's model than it is for Holt's. The systematic component of demand is: *Systematic component of demand = (level + trend) x seasonal factor* The level and trend for this method refers back to the static method that we did earlier. The level is the intercept and the trend is the slope of the deseasonalized trendline that we found in the static model. The seasonal factors in this method are also taken from the static model that we achieved earlier as well.
Step 2	The forecast of future periods is given by: $F_{t+1} = (L_t + T_t)S_{t+1} \quad \text{and} \quad F_{t+l} = (L_t + lT_t)S_{t+l}$ This equation can be used in order to calculate future demand but due to the fact that this is a corrected method, we can further revise the equations in the next step.
Step 3	For observing demand for period *t + 1*, we can revise the estimates for level,

	trend, and seasonal factors as: $$L_{t+1} = \alpha(D_{t+1}/S_{t+1}) + (1-\alpha)(L_t + T_t)$$ $$T_{t+1} = \beta(L_{t+1} - L_t) + (1-\beta)T_t$$ $$S_{t+p+1} = \gamma(D_{t+1}/L_{t+1}) + (1-\gamma)S_{t+1}$$ The alpha, beta, and gamma values can be changed depending on what fits the data's error analysis the best. This is
Step 4	After using the equations to solve for the future levels, trends, and seasonal factors, we can now forecast using the numbers we just solved for. Forecast for any given period *t,* can be found by utilizing the equation: *Forecast = (Previous Level + Previous Trend) x Current Seasonal Factor* *Or* *Ft =* $(L_{t-1} + T_{t-1})$ *x* S_t

Parameters

The parameters that we used in order to properly achieve Winter's model is shown in the table below.

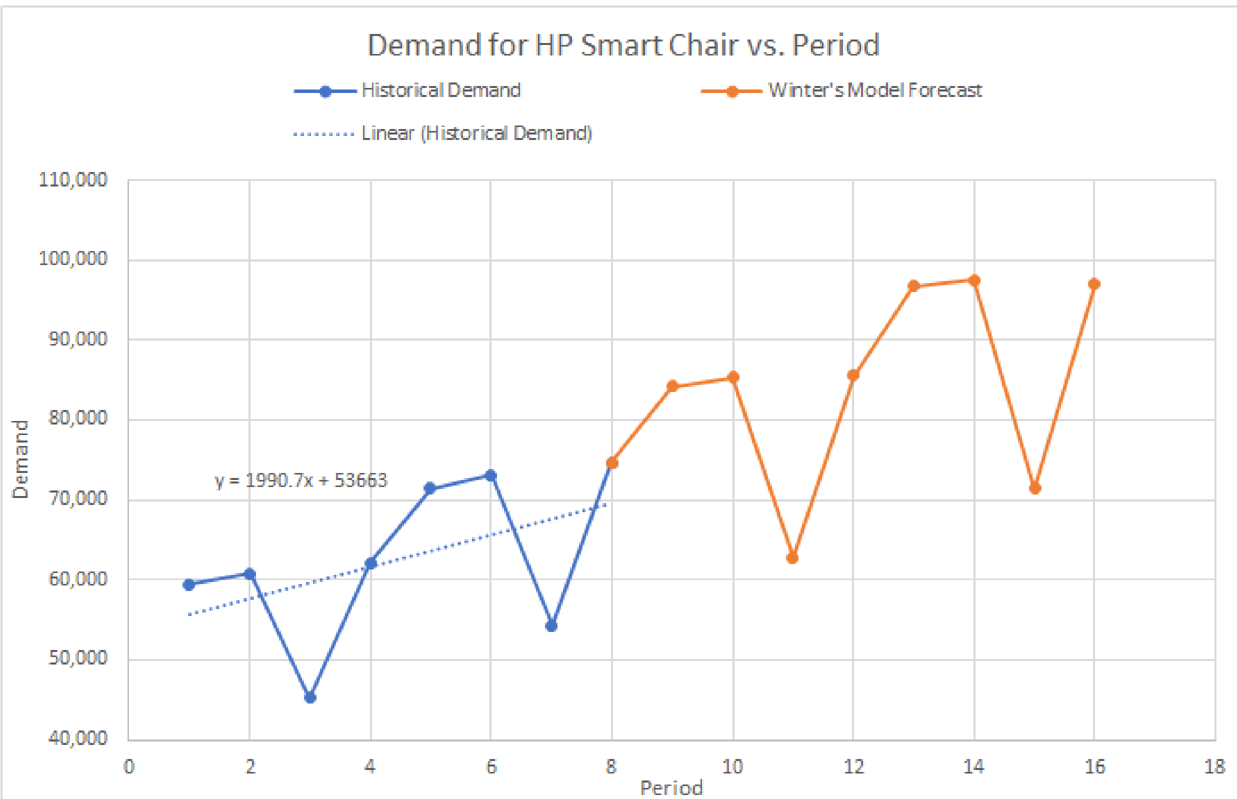
Parameters	
L0	50106
T0	2791.7
S1	1.12
S2	1.09
S3	0.78
S4	1.02
Alpha	0.1
Beta	0.1
Gamma	0.1

Conclusions for Error Analysis:

Based on the error analysis we can determine that the Winter's model is a rather accurate model for us to utilize in determining the forecasted demand for our data numbers. The parameters that come into this model are taken from the static model and corrected further in order to give us the best estimated forecast. The percent error is considerably low, which is typically a good thing. The MAPE values are all less than 1 and the absolute value for the TS error numbers are all less than 6. This means that this forecasting model is very accurate and acceptable for our demand data numbers.

Winter's Model Forecasted Demand Graph

The graph below is a visual representation of the forecasted demand using Winter's model. As it can be seen in the graph, it is clearly the best representation of what we were looking for our next eight quarters. As seen in the graph, the forecasted eight periods accurately follow the patterns in our historical demand.



Conclusions about every model:

Winter's model in our opinion is probably the most accurate and most representative of our forecasted demand data. This is because it has the most amount of parameters that utilizes three different smoothing constants and also accounts for seasonality. Our demand data has seasonality so, using either Winter's or the static model would be the most efficient pick for our demand data.

[3] Cycle and Safety Inventory Process

In conducting our cycle and safety inventory process, we have decided to focus on the components of our two most important subsystems along with the cycle and safety inventory of our finished product. The following table lists out these subsystems, their components and suppliers, our overall end product, and their respective positions within the supply chain network.

<table>
<tr><th>SYSTEM</th><th>COMPONENT</th><th>SUPPLIER</th><th>POSITION</th></tr>
<tr><td>Power Transmission</td><td>Battery Holder</td><td>Bulgin Components</td><td>Supplier</td></tr>
<tr><td>Power Transmission</td><td rowspan="2">Motherboard</td><td rowspan="2">Asus</td><td rowspan="2">Supplier</td></tr>
<tr><td>Efficient Sensor</td></tr>
<tr><td>Efficient Sensor</td><td>Pressure Sensor</td><td>Keller America</td><td>Supplier</td></tr>
<tr><td>SMART Chair</td><td>----</td><td>Brick and mortar & online retailers</td><td>Manufacturer</td></tr>
</table>

Cycle Inventory

We have decided to dissect our product, two subsystems, and their respective components to determine what our ideal lot sizes and cycle inventories will be. Below is our step by step process for conducting our cycle inventory

STEP 1	The first step is choosing our two subsystems based on their importance to the overall. As stated previously, have decided to choose the subsystems of power transmission and efficient sensors.
STEP 2	Given that it will dictate the process of calculating the cycle inventory, the next step we have chosen is to determine the type of lot sizing that we are fulfilling. Given that the components for our subsystems all come

	from their own respective suppliers with the expectation of being used jointly, a lot would fall under *multiple products with lots ordered and delivered independently*.
STEP 3	Determining the component to chair ratio that comes about from our subsystems. In this case, our three components include the battery holder, the motherboard, and the pressure sensor. Every component has a 1:1 ratio with the chair except for the pressure sensors, for which we have a 4:1 ratio.
STEP 4	Gathering the necessary costs relevant to our subsystems and cycle inventory calculations. These costs include: ● Annual demand ● Order cost per lot ● Unit cost per component ● Holding costs
STEP 5	Using the costs obtained from step 4, we will calculate the optimal lot sizing and from that, the cycle inventory
STEP 6	Calculate additional metrics: ● Number of orders per year ● Annual ordering and holding cost ● Average flow time

In arriving at these numbers, we must first consider the specific lot sizing method that best fits our product. Given the components for all of our subsystems all come from individual companies, we have decided to calculate our cycle inventory from the perspective of *multiple products with lots ordered and delivered independently*.

In computing the optimal lot sizing and cycle inventory, the most important variables include:

- **Annual Demand:** Using our information of data from task #1, we can attain our annual demand by summing up the demand quarters in groups of four. Hence, the first year is the sum of demand from quarters 1 through 4 and the second year is the sum of the demand from quarters 5 through 8.
- **Order cost per lot:** Given to us by the manufacturing websites for each component, this cost is the fixed cost attached to every order for shipping, transportation, and any additional fees.
- **Cost per unit:** Given to us by the manufacturing websites, this unit wavered and got smaller as we ordered more units. The prices listed on cost per unit are based off of the highest number of units that the company would allow us to purchase at a time

- **Holding cost:** We assumed this cost to be 25% or 0.25

The following tables includes the further information for how we arrived at each cycle inventory:

BATTERY HOLDER						
	ANNUAL DEMAND	**ORDER COST PER LOT**	**COST PER UNIT**	**HOLDING COST**	**OPTIMAL LOT SIZING**	**CYCLE INVENTORY**
YEAR 1	227,524	$115	$11.89	25%	4,196 UNITS	2,098 UNITS
YEAR 2	273,985				4,604 UNITS	2,302 UNITS

YEAR 1:

Optimal lot size = Q* = $\sqrt{\frac{2*227{,}524*115}{0.25*11.89}} = 4,196$

Cycle Inventory = $\frac{Q*}{2} = \frac{4{,}196}{2} = 2,098$

Number of orders per year = $\frac{D}{Q*} = \frac{227{,}524}{4{,}196} = 51.22$

Annual ordering and holding cost =
$\frac{D}{Q*}S + (\frac{Q*}{2})hC = (51.22)(115) + (2098)0.25 = \$6,415$

Average flow time = $\frac{Q*}{2D} = \frac{2098}{455048} = 0.005$

YEAR 2:

Optimal lot size = Q* =
$\sqrt{\frac{2*273{,}985*115}{0.25*11.89}} = 4,604$

Cycle Inventory = $\frac{Q*}{2} = \frac{4{,}604}{2} = 2,302$

Number of orders per year = $\frac{D}{Q*} = \frac{273{,}985}{4{,}604} = 59.51$

Annual ordering and holding cost =
$\frac{D}{Q*}S + (\frac{Q*}{2})hC = (59.51)(115) + (2302)0.25 = \$7,419$

Average flow time = $\frac{Q*}{2D} = \frac{2302}{547{,}970} = 0.004$

MOTHERBOARD						
	ANNUAL DEMAND	**ORDER COST PER LOT**	**COST PER UNIT**	**HOLDING COST**	**OPTIMAL LOT SIZING**	**CYCLE INVENTORY**
YEAR 1	227,524	$75	$275.33	25%	704 UNITS	352 UNITS
YEAR 2	273,985				773 UNITS	387 UNITS

YEAR 1:

Optimal lot size = Q* = $\sqrt{\frac{2*227{,}524*75}{0.25*275.33}} = 704$

Cycle Inventory = $\frac{Q*}{2} = \frac{704}{2} = 352$

Number of orders per year = $\frac{D}{Q*} = \frac{227{,}524}{704} = 323.19$

Annual ordering and holding cost =

$$\frac{D}{Q*}S + (\frac{Q*}{2})hC = (323.19)(75) + (352)0.25 = \$24,328$$

Average flow time = $\frac{Q*}{2D} = \frac{352}{455048} = 0.0008$

YEAR 2:

Optimal lot size = Q* = $\sqrt{\frac{2*273{,}985*75}{0.25*275.33}} = 773$

Cycle Inventory = $\frac{Q*}{2} = \frac{773}{2} = 387$

Number of orders per year = $\frac{D}{Q*} = \frac{273{,}985}{773} = 354.44$

Annual ordering and holding cost =

$$\frac{D}{Q*}S + (\frac{Q*}{2})hC = (354.44)(75) + (387)0.25 = \$26,690$$

Average flow time = $\frac{Q*}{2D} = \frac{387}{547{,}970} = 0.0007$

PRESSURE SENSOR						
	ANNUAL	**ORDER COST**	**COST**	**HOLDING**	**OPTIMAL**	**CYCLE**

	DEMAND	PER LOT	PER UNIT	COST	LOT SIZING	INVENTORY
YEAR 1	910,096	$225	$25.91	25%	7,951 UNITS	3,976 UNITS
YEAR 2	1,095,940				8,726 UNITS	4,363 UNITS

YEAR 1:

Annual demand = (pressure sensor:chair)(annual chair demand) = $4 * (227,524) = 910,096$

Optimal lot size = Q* = $\sqrt{\frac{2*910,096*225}{0.25*25.91}} = 7,951$

Cycle Inventory = $\frac{Q*}{2} = \frac{7,951}{2} = 3,976$

Number of orders per year = $\frac{D}{Q*} = \frac{910,096}{7,951} = 114.46$

Annual ordering and holding cost =
$\frac{D}{Q*}S + (\frac{Q*}{2})hC = (114.46)(225) + (3,976)0.25 = \$26,748$

Average flow time = $\frac{Q*}{2D} = \frac{3976}{1,820,192} = 0.0022$

YEAR 2:

Annual demand = (pressure sensor:chair)(annual chair demand) =
$4 * (273,985) = 1,095,940$

Optimal lot size = Q* = $\sqrt{\frac{2*1,095,940*225}{0.25*25.91}} = 8,726$

Cycle Inventory = $\frac{Q*}{2} = \frac{8,726}{2} = 4,363$

Number of orders per year = $\frac{D}{Q*} = \frac{1,095,940}{8,726} = 125.59$

Annual ordering and holding cost =
$\frac{D}{Q*}S + (\frac{Q*}{2})hC = (125.59)(225) + (4,363)0.25 = \$29,349$

Average flow time = $\frac{Q*}{2D} = \frac{4,363}{2,191,880} = 0.0020$

In estimating the costs for the SMART chair, we are able to use previous costs to help create an estimate for the order cost per lot and cost per unit.

As with the previous components, the holding cost will remain at an assumed 25% while the order cost per lot will be calculated out as the average of the previously calculated order cost per lot of previous components.

To find the cost per unit, we first considered the fact that we have only calculated the prices involved with 3 out of our 8 overall components used to make the finished product. This gives us a percentage of us having calculated out 37.5% of the costs involved with components, allowing us to use 62.5% (100% - 37.5%) as an method of estimation for how the following component costs will affect the price of our product. This gives us:

$$\frac{Battery\ Holder\ Order\ Cost}{Battery\ Holder\ Cycle\ Inventory} + \frac{Motherboard\ \ Order\ Cost}{Motherboard\ \ Cycle\ Inventory} + \frac{Pressure\ Sensor\ Order\ Cost}{Pressure\ Sensor\ Cycle\ Inventory} +$$

$$Battery\ Holder\ cost\ per\ unit\ + \ Motherboard\ cost\ per\ unit\ + pressure\ sensor\ cost\ per\ unit$$
$$= 0.548 + 0.213 + 0.059 + 25.91 + 275.33 + 11.89$$
$$= \$313.95$$

From this point, we assumed a 62.5% increase to account for the 5 remaining components:

$$= 313.95 + 196.22$$
$$= 510.17\ price\ per\ unit$$

SMART CHAIR						
	ANNUAL DEMAND	**ORDER COST PER LOT**	**COST PER UNIT**	**HOLDING COST**	**OPTIMAL LOT SIZING**	**CYCLE INVENTORY**
YEAR 1	227,524	$140	$510.17	25%	707 UNITS	354 UNITS
YEAR 2	273,985				776 UNITS	388 UNITS

YEAR 1:

Optimal lot size = Q* = $\sqrt{\frac{2*227,524*140}{0.25*510.17}} = 707$

Cycle Inventory = $\frac{Q*}{2} = \frac{707}{2} = 354$ units

Number of orders per year = $\frac{D}{Q*} = \frac{227,524}{707} = 321.82$

Annual ordering and holding cost =

$$\frac{D}{Q^*}S + (\frac{Q^*}{2})hC = (321.82)(140) + (354)0.25 = \$45,143$$

Average flow time = $\frac{Q^*}{2D} = \frac{354}{455048} = 0.0008$

YEAR 2:

Optimal lot size = Q* = $\sqrt{\frac{2*273,985*140}{0.25*510.17}} = 776$

Cycle Inventory = $\frac{Q^*}{2} = \frac{776}{2} = 388$ units

Number of orders per year = $\frac{D}{Q^*} = \frac{273,985}{776} = 353.1$

Annual ordering and holding cost =

$$\frac{D}{Q^*}S + (\frac{Q^*}{2})hC = (353.1)(140) + (388)0.25 = \$49,531$$

Average flow time = $\frac{Q^*}{2D} = \frac{3388}{547,970} = 0.0007$

Results/conclusion

- Based on the above calculations we have determined that for year 1 the Smart Chair must have **354 units** of cycle inventory to meet our usual demand. When it comes to our sub-systems: Pressure Sensor, Motherboard and Battery Holder, we have determined that each should carry **3976 units, 352 units,** and **2,098 units** respectively for us to meet our usual demand of Smart Chair.
- For year 2, we will need **388 units** of the Smart Chair, **4,363 units** for the pressure sensor, **387 units** for the motherboard, and **2,302 units** for the battery holder.

Safety Inventory

Having a calculated safety inventory is highly important because the withou tit, you run the risk of paying the price for an incorrectly forecasted demand that can cause a rippling effect through your supply chain, thus affecting profits. However there are many reasons why having a safety inventory is important to have. One reason is if there's an uncertain implied demand, a shortage can happen if the demand exceeds the forecasted demand. There are also times where a company experiences spikes in demand throughout the year and the safety inventory can also supply that extra demand that is being made. It is important to not over or underestimate the quantity of products that we are going to have because instead of it being beneficial it becomes an expense. Here we calculate the safety inventory that corresponds to our forecasted demand in task 2.

Below is our step by step process for conducting our safety inventory

STEP 1	Calculate annual demand using the static demand forecast
STEP 2	Calculate weekly demand by dividing annual demand 52 weeks per year
STEP 3	Decide on a desired cycle service level - * figure out the process of doing that
STEP 4	Plug values into optimal lot size formula
STEP 5	Acquire value for our optimal safety stock
STEP 6	Conclude what kind of safety inventory we should have for our product that will satisfy the fill rate.

BATTERY HOLDER								
	AVERAGE WEEKLY DEMAND	**SAFETY STOCK**	**LEAD TIME**	**ROP**	**STANDARD DEVIATION**	**CSL**	**ESC**	**Fill Rate**
YEAR 1	4,375	305 UNITS	2 WEEKS	9,055	6812	0.95	3.83	95.3%
YEAR 2	5,288	370 UNITS		10,946	8268		5	94.7%

YEAR 1:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$

$$ss = 1.644 * \sqrt{2\,weeks} * \frac{6813}{52\,weeks}$$
$$ss = 1.644 * \sqrt{2} * 131$$
$$ss = 305$$

$$ROP = (L)(Dw) + ss$$
$$ROP = (2)(4375) + 305$$
$$ROP = 9055$$

$$\sigma_{DL} = \sqrt{L} * \sigma_{D}$$
$$= \sqrt{2} * 131$$
$$= 185.261976$$

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_{L} * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$
$$ESC = -305[1 - NORMDIST(\frac{305}{185}, 0, 1, 1)] + 9635 * NORMDIST(\frac{305}{185}, 0, 1, 0)$$
$$= 3.83$$

$$f_{r}(fill\,rate) = \frac{(Q_{L})_{W} - ESC}{(Q_{L})_{W}}$$
$$f_{r}(fill\,rate) = \frac{81 - 3.83}{81}$$
$$f_{r}(fill\,rate) = 0.952716049$$

YEAR 2:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$
$$ss = 1.644 * \sqrt{2\,weeks} * \frac{8242}{52\,weeks}$$
$$ss = 1.644 * \sqrt{2} * 159$$
$$ss = 370$$

$$ROP = (L)(Dw) + ss$$
$$ROP = (2)(5288) + 370$$
$$ROP = 10946$$

$$\sigma_{DL} = \sqrt{L} * \sigma_{D}$$

$$= \sqrt{2} * 159$$
$$= 224.86$$

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$
$$ESC = -370[1 - NORMDIST(\frac{370}{225}, 0, 1, 1)] + 225 * NORMDIST(\frac{370}{225}, 0, 1, 0)$$
$$= 4.71$$

$$f_r(fill\,rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$$
$$f_r(fill\,rate) = \frac{89-4.71}{89}$$
$$f_r(fill\,rate) = 0.947$$

MOTHERBOARD								
	AVERAGE WEEKLY DEMAND	**SAFETY STOCK**	**LEAD TIME**	**ROP**	**STANDARD DEVIATION**	**CSL**	**ESC**	**FILL RATE**
YEAR 1	4,375	714 UNITS	11 WEEKS	48839	6813	0.95	13.3	95%
YEAR 2	5,288	527 UNITS		58685	8242		13.52	96.6%

YEAR 1:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$
$$ss = 1.644 * \sqrt{11\,weeks} * \frac{6813}{52\,weeks}$$
$$ss = 1.644 * \sqrt{11} * 131$$
$$ss = 714.3$$

$$ROP = (L)(Dw) + ss$$
$$ROP = (11)(4375) + 714.3$$
$$ROP = 48839.3$$

$$\sigma_{DL} = \sqrt{L} * \sigma_D$$
$$= \sqrt{11} \; * \; 131$$
$$= 434.47$$

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$
$$ESC = -714[1 - NORMDIST(\frac{714}{434}, 0, 1, 1)] + 434 * NORMDIST(\frac{714}{434}, 0, 1, 0)$$
$$= 13.33$$

$$f_r(fill\,rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$$
$$f_r(fill\,rate) = \frac{14 - 13.3}{14}$$
$$f_r(fill\,rate) = 0.95$$

YEAR 2:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$
$$ss = 1.644 * \sqrt{11\,weeks} * \frac{8242}{52\,weeks}$$
$$ss = 1.644 * \sqrt{11} * 159$$
$$ss = 527.34$$

$$ROP = (L)(Dw) + ss$$
$$ROP = (11)(5288) + 527.34$$
$$ROP = 58685.34$$

$$\sigma_{DL} = \sqrt{L} * \sigma_D$$
$$= \sqrt{11} \; * \; 158.5$$
$$= 325.69$$

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$
$$ESC = -527[1 - NORMDIST(\frac{527}{326}, 0, 1, 1)] + 326 * NORMDIST(\frac{527}{326}, 0, 1, 0)$$
$$= 13.52176$$

$$f_r(fill\,rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$$
$$f_r(fill\,rate) = \frac{14-7.29}{14}$$
$$f_r(fill\,rate) = 0.96584$$

PRESSURE SENSORS								
	AVERAGE WEEKLY DEMAND	**SAFETY STOCK**	**LEAD TIME**	**ROP**	**STANDARD DEVIATION**	**CSL**	**ESC**	**FILL RATE**
YEAR 1	17,500	746 UNITS	12 WEEKS	210,746	6813	0.95	17.07	89%
YEAR 2	21,152	527 UNITS		254,351	8242		9.52	94%

YEAR 1:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$
$$ss = 1.644 * \sqrt{12\,weeks} * \frac{6813}{52\,weeks}$$
$$ss = 1.644 * \sqrt{12} * 131$$
$$ss = 746.04$$

$$ROP = (L)(Dw) + ss$$
$$ROP = (12)(17500) + 746.04$$
$$ROP = 210,746$$

$$\sigma_{DL} = \sqrt{L} * \sigma_D$$
$$= \sqrt{12} * 131$$
$$= 453.79$$

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$
$$ESC = -746[1 - NORMDIST(\frac{746}{454}, 0, 1, 1)] + 527 * NORMDIST(\frac{746}{454}, 0, 1, 0)$$

= 17.07 $f_r(fill\,rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$ $f_r(fill\,rate) = \frac{153-17.07}{153}$ $f_r(fill\,rate) = 0.89$
YEAR 2: $ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$ $ss = 1.644 * \sqrt{12\,weeks} * \frac{8242}{52\,weeks}$ $ss = 1.644 * \sqrt{12} * 159$ $ss = 527.34$ $\sigma_{DL} = \sqrt{L} * \sigma_D$ $= \sqrt{12} * 159$ = 453.79 $ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$ $ESC = -746[1 - NORMDIST(\frac{746}{454}, 0, 1, 1)] + 454 * NORMDIST(\frac{746}{454}, 0, 1, 0)$ = 9.52 $f_r(fill\,rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$ $f_r(fill\,rate) = \frac{153-9.52}{153}$ $f_r(fill\,rate) = 0.9377$

SMART CHAIR								
	AVERAGE WEEKLY	**SAFETY STOCK**	**LEAD TIME**	**ROP**	**STANDARD D**	**CSL**	**ESC**	**FILL RATE**

	DEMAND				DEVIATION			
YEAR 1	4,375	806 UNITS	14 WEEKS	62,056	6813	0.95	13.77	98%
YEAR 2	5,288	978 UNITS		75,010	8242		14.91	99%

YEAR 1:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$

$$ss = 1.644 * \sqrt{14\, weeks} * \frac{6813}{52\, weeks}$$

$$ss = 1.644 * \sqrt{14} * 131$$

$$ss = 805.8$$

$$ROP = (L)(Dw) + ss$$

$$ROP = (14)(4375) + 805.8$$

$$ROP = 62055.8$$

$$\sigma_{DL} = \sqrt{L} * \sigma_D$$

$$= \sqrt{14} * 131$$

= 490.15

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$

$$ESC = -806[1 - NORMDIST(\frac{806}{490}, 0, 1, 1)] + 490 * NORMDIST(\frac{806}{490}, 0, 1, 0)$$

= 13.77

$$f_r(fill\, rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$$

$$f_r(fill\, rate) = \frac{14 - 13.77}{14}$$

$$f_r(fill\, rate) = 0.9836$$

YEAR 2:

$$ss = NORMSINV(0.95) * \sqrt{L} * \frac{\sigma}{52}$$

$$ss = 1.644 * \sqrt{14\, weeks} * \frac{8242}{52\, weeks}$$
$$ss = 1.644 * \sqrt{14} * 159$$
$$ss = 978.05$$

$$ROP = (L)(Dw) + ss$$
$$ROP = (14)(5288) + 978.05$$
$$ROP = 75010.05$$

$$\sigma_{DL} = \sqrt{L} * \sigma_D$$
$$= \sqrt{14} * 159$$
$$= 594.923524$$

$$ESC = -ss[1 - NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 1)] + \sigma_L * NORMDIST(\frac{ss}{\sigma_{DL}}, 0, 1, 0)$$
$$ESC = -978[1 - NORMDIST(\frac{978}{595}, 0, 1, 1)] + 595 * NORMDIST(\frac{978}{595}, 0, 1, 0)$$
$$= 14.9048$$

$$f_r(fill\, rate) = \frac{(Q_L)_W - ESC}{(Q_L)_W}$$
$$f_r(fill\, rate) = \frac{15 - 14.9048}{15}$$
$$f_r(fill\, rate) = 0.993654$$

Results/Conclusion

- Based on the above calculations we have determined that for year 1 the Smart Chair must have **354** units of safety inventory
- When it comes to our sub-systems: Pressure Sensor, Motherboard and Battery Holder, we have determined that each should carry **3976** units, **352** units, and **2,098** units respectively for us to meet our usual demand of Smart Chair.
- For year 2, we will need **388** units of the Smart Chair, **4,363** units for the pressure sensor, **387** units for the motherboard, and **2,302** units for the battery holder.
- Based off our ROP calculations for year 2, when the Smart Chair reaches the level of62056 units for year 1 and 75010units for year 2, the distribution center should

place an order with our assembly factory. Based on our ROP calculations for year 1, Battery Holder: **9,055**, MotherBoard: **48,839** units, and Pressure units: **210,746** units, our manufacturing sites should place an order with distributors. ROP calculations for year 2, Battery Holder: **10,946**, MotherBoard: **58,685** units, and Pressure units: **254,351** units, our manufacturing sites should place an order with distributors.

- Finally, we have determined by performing a fill rate calculation that Smart Chair should carry **354** Units for year 1 and **388** units if they want a fill rate of approximately 98% and 99% respectively.

Check your Work

- The work was correct in as much detail as we could provide. We double checked and proofread each other's work. Most of the assumptions that were made came to be correct and useful to manage the weight of the problem solving process. Including the online resources we used.

Learn and Generalize

- As we finish up the phase 2 submission, we have learned and put to practice all of what we have learned in the course including the lectures. Due to the problem being somewhat open ended, the team was able to discuss and come up with conclusions that were accurate but consisting of full autonomy. We have now learned deeper into how to forecast demand but also create proper inventory management skills to further help us in our final exam but also our careers.

Appendix

Work Contributions

Name:	Project Proposal	Project Phase 1	Project Phase 2

Jason Apostol	- Use sub-system from FAST diagram to develop preliminary version of the infrastructure for our supply chain
	- Sub-system Raw Material Manufacturers Table
	- Network Representation
		- Task #1 information and linking
		- Task#3
		  - Intro
		  - Components - competitive advantage table
		  - Efficient responsiveness spectrum diagram and description
		  - IDU diagram and description
		  - Supply chain strategy map diagram and introduction description
		  - Contributed to stages of supply chain description
		  - Contributed to Push/pull cycle description
		  - Supply chain network diagram and description
		  - Supply chain strategy summary
		- Task #4
		  - First draft of data collection process and diagrams (later scrapped)
			- Task #3
			  - Contributed to introduction
			  - Contributed to positional diagram
			  - Contributed to cycle inventory process
			  - Contributed to cycle inventory conclusions
			  - Contributed to safety inventory process
			  - Contributed to safety inventory conclusions
			  - Contributed to variable description
			  - Contributed to battery holder cycle inventory calculations
			  - Contributed to motherboard cycle inventory calculations
			  - Contributed to safety inventory cycle inventory calculations
			  - Contributed to battery holder safety inventory

			calculations - Contributed to motherboard safety inventory calculations - Contributed to safety inventory safety inventory calculations - Final report - executive summary contributions

Naman Sudan	- Was appointed to a new group
	- Familiarized myself with Group 04's product and all the work done in CSE 171A
		- Updated and integrated the overall formatting and alignment of the document that is to be submitted
		  - Updating all the diagrams according to new formatting
		  - Updated text and spacing
		  - Added table of contents
		  - Designed Title and Cover page for the doc
		- Solved several parts of problem 1 from project phase 1:
		  - Updated the content of fast diagrams/function structure from proposal
		  - Wrote sub-systems short descriptions
		  - Reviewed and revised the "set-up" and descriptions for all diagrams
		  - Elaborated and described the sub-functions
		  - Switched up the "headrest" sub-function with "connectivity" that provides connection to screens, central remotes, usb ports, hdmi ports, etc.
		  - Ordered and structured of the doc
		  - Researched and added description for optimal suppliers for manufacturing our
			- Revised the Project Proposal and Project Phase01
			  - Added descriptions to diagrams
			  - Updated the FAST Diagram to include all the new sub-systems and sub-functions
			  - Updated the Function Structure Diagram to include all the new sub-systems and sub-functions
			  - Ordered and structured the doc
			  - Updated and revised the Business Model Problem
			- Phase02
			  - Contributed to cycle inventory process
			  - Contributed to battery holder cycle inventory calculations
			  - Contributed to safety inventory safety inventory calculations
			- Final Report
			  - Executive

		product - a smart chair
		- Solved parts of problem 3:
		  - Researched and identifying 3 new competitors and substitutes for the Porter's 5 forces (companies that are more technologically enabled and offer intelligent and innovative solutions)
		  - Integrated companies identified for demand data collection in problem 4 to the porter's 5 forces diagram
		- Solved parts of problem 4:
		  - Ideated for methods to collect data
		  - identified a few more companies and some data points about their business (especially that can tell us about demand data)
		  - Provide data to Matthew for him to make visualizations and add descriptions for the demand data
			summary contributions
			- Updated and integrated the overall formatting and alignment of the document that is to be submitted
			  - Updating all the diagrams according to new formattin g
			  - Updated text and spacing
			  - Added table of contents
			  - Designed Title and Cover page for the doc

Sae Young Park	- Introduction to Final Conceptual Design
	- Identified Sub Functions
	- Initial FAST Diagram
	- Initial Function Structure
	- Descriptions between every diagram
	- Correction of Errors based on feedback
	- Clear explanation of design concepts
		- Beginning of Business model for the supply chain
		  - Introduction to the 2x2 model
		  - 2x2 model
		  - Description of the 2x2 model and what its purpose is
		  - Identified Competitive Strategies that could be implemented for our product
		  - Expanded upon Competitive Strategies and gave examples of what our company could do.
		  - Introduction of Porter's Five Forces
		  - Porter's Five Forces model
			- Edited the stepwise process done in phase 1 for obtaining estimated demand data
			- Implemented the stepwise process and calculated our estimated demand numbers
			- **Did all Forecasting Models**
			  - Added descriptions and details to all methods
			  - Static Forecasting Model
			    - Created Stepwise process for obtaining

		- Analysis of Porter's Five Forces model
		- Identified where our product stands in the model
		- Identified methods for demand data estimation collection
		- Implemented a stepwise process for obtaining estimated demand data
		- Calculated estimated demand data
			forecast data from static method
			- Error Analysis for static model
			- Conclusions for static model
			- Simple Exponential Smoothing model
			  - Created stepwise process for SES model
			  - Error analysis for SES model
			- Moving Average Model
			  - Stepwise process for moving average model
			  - Error Analysis and conclusions for error analysis
			- Holt's Model
			  - Created Stepwise process for Holt's model
			  - Error analysis and conclusions
			- Winter's Model
			  - Created

			stepwise process for winter's model - Included final conclusions using all forecasting methods - Created all graphs and models within forecasting section of the final report
Carlos Perez	- Use sub-system from FAST diagram to develop preliminary version of the infrastructure for our supply chain - Sub-system Raw Material Manufacturers Table - Stage Representation	- Task#3 - Intro - Components - competitive advantage table - Efficient responsiveness spectrum diagram description - IDU diagram description - Supply chain strategy map diagram - Contributed to stages of supply chain description - Contributed to pull cycle description - Network View - Supply chain network diagram and description - Revised the tasks for phase	- Task #3 - Contributed to introduction - Contributed to cycle inventory process - Contributed to cycle inventory conclusions - Contributed to safety inventory intro diagram paragraph - Contributed to safety inventory process - Contributed to safety inventory conclusions - Contributed to variable description - Contributed to battery holder cycle inventory calculations - Contributed to motherboard cycle inventory

			calculations - Contributed to safety inventory cycle inventory calculations - Contributed to battery holder safety inventory calculations - Contributed to motherboard safety inventory calculations - Contributed to safety inventory safety inventory calculations - Edited past paragraphs and diagrams for phase 1 and 2.
Ramin Eghtesadi	- Understood my responsibilities and laid out part of my and my teams strategy for the project - (I already kept in touch with my group mates about this-- I was unfortunately not as involved for this part as this was during the time of the passing of my grandmother and uncle-- I had emailed the TA, professor, and had mentioned it to my group	- **Solving problem 4:step 1** - helped craft the last two methods - Collected data on our competitors - identified possible competitive strategies to be implemented - did the last two steps of our Porter's diagram - **Step 4** - Collected data on our competitors - set the scenario of comparative analysis between us and our competitors - Provided input and data on potential new sub markets - **General** - contributed to all of the discussions by providing data regarding - competitive strategy and dissection - Researched our smart	- edited the supply-chain analysis - provided formulas in calculating the safety and cycle inventories - edited the stepwise process for the safety inventory - illustrated the idea of changing our data collection method to one that yielded more and better results - attended all group meetings and worked on re-editing phase 1 - attended group meeting with professor and took all the necessary notes for phase 01 and phase 02 revisions - helped with redefining our "define the problem" - helped add to and edit the executive summary - edited our analysis on zone of strategic fit and IDU

	mates. I did my best to make up for this by attending every single meeting after and taking initiative by working hard on phase 01 and phase 02)	chair and helped bring about updated features - attended all meetings with group	

Johnny Tilahun	- attended all meeting with group
	- Time-phased project plan
	- Creation of table with all deliverable for the project along with who is responsible for each task
	- define the problem, plan the treatment, check and generalize
		- attended meeting with Subhas
		- attended all meeting with group
		- group planning
		- SPSP structural format (Define the problem, plan the treatment,
		- Execute, check your answer, Learn and Generalize
		- Contributed to facilitation of work split
		- developed business model for Supply chain.
		- developed the porters forces analysis
		- completed the competitive strategy
		- Added to overall flow between parts
		- Final review of step 3
		- Helped with step 4
		- edited the supply chain network
		- edited the stages of supply chain
		- edited the operational cycle view
		- push-pull boundary
		- his is also on phase 2 work as well.
			- attended all meeting with Prof Subhas
			- attended all meeting with group
			- worked on re editing phase 1
			- edited the supply chain network
			- edited the stages of supply chain
			- edited the operational cycle view
			- push-pull boundary
			- sc strategy
			- Task #3
			  - Contributed to introduction
			  - Contributed to positional diagram
			  - Contributed to cycle inventory process
			  - Contributed to cycle inventory conclusions
			  - Contributed to safety inventory process
			  - Contributed to safety inventory conclusions
			  - Contributed to variable description
			  - Contributed to battery holder cycle inventory

			calculations - Contributed to motherboard cycle inventory calculations - Contributed to safety inventory cycle inventory calculations - Contributed to battery holder safety inventory calculations - Contributed to motherboard safety inventory calculations - Contributed to safety inventory safety inventory calculations - Final report - executive summary contributions