Team Nugget's Hands-Free Door Opener

Phase 2 Progress Report

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<u>Team Nugget</u>

ME 26300-129

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Executive Summary

The objective of this report is to provide information regarding the process Team Nugget used to create a product design along with an update to the problem definition and analysis of the financial feasibility of said product. Team Nugget's product provides a method for people to open pull side doors by simply stepping on a pedal. Team Nugget chose to improve upon hands-free door opening devices due to the lack of options within the market and the problems the current products have.

Team Nugget's design process began with creating a function decomposition in order to define precisely what functions our product must achieve. All the essential functions of the door were divided into four distinct categories: full door functionality, secure the door, easy user interface, and force transformation. Team Nugget found a total of 13 functionalities between the four categories previously listed. Those 13 functionalities were then organized into a morphological chart to find methods to achieve those functionalities. A minimum of two drawings were created per functionality, providing a potential method to achieve said functionality. Using all those functionality ideas, in-depth drawings were created that combined the ideas seen in the morphological chart to outline potential products. A total of 16 fleshed out product designs were created, of which four were selected and compared against a decision matrix. The decision matrix compared each product to how it met customer requirements with associated weights, with our final design scoring the highest of the selected product design.

The product itself is two distinct units, a pedal and a door mounted hydraulic piston unit, connected via a rubber hose. The step is composed of two metal side plates that allow it to be mounted to a wall, a hinge for the pedal and a bag filled with hydraulic fluid. The piston unit is mounted to the door via screws with a plastic shell to hide the components. The piston will receive fluid via the step and extend, pushing a gear that rotates the arms of the unit, opening the door.

Once the product had been designed, Team Nugget created a bill of materials and performed a financial analysis. The bill of materials contains all the parts required to create the product along with the estimated cost associated with purchasing said parts and manufacturing. The total cost to assemble one unit of our product is $131.67, which leads to a retail price of $526.68, significantly higher than Team Nugget anticipated. Originally, Team Nugget planned to sell 90,000 units over the 15 quarter period that the financial analysis was applied over, however the significant increase in cost had Team Nugget re-evaluate. Team Nugget performed a second market analysis, selecting a different prime competitor based on the functionalities our product fulfills and changed estimated sales to 57,600 units over three years. Taking into account R&D costs along with other upfront costs, our product sees its break even point during the 8th quarter along with a 46.83% return on investment.

Moving forward, Team Nugget hopes to further refine the design to be the most effective and cost efficient it can be, along with creating a prototype of the product. Team Nugget hopes that the product can undergo thorough testing in order to analyze potential weaknesses that went unnoticed in design and present the optimal version of the team's product.

Table Of Contents

I. Introduction 1

II. Problem Definition Overview and Updates 1

III. Concept Generation 2

IV. Concept Selection 2

V. Primary Concept Description 3

VI. Bill of Materials 4

VII. Financial Analysis 4

VIII. Project Scheduling 5

IX. Conclusions and Recommendations 5

X. References 5

XI. Appendices 6

I. Introduction

The purpose of this report is to address the problem of a non-user friendly way to open doors and discuss improvements upon our original design ideas. All over the world people need an easier way to open doors hands-free that the current products on the market don't provide. Our team's idea for tackling this product is a foot operated hydraulic unit. We decided that a foot operated door was most convenient for the user and with the incorporation of hydraulics, it remains purely mechanical.

The motivation for this project comes from personal experience with opening doors. Throughout the university, doors have foot openers that take a large amount of force in order to open them. Also, some of the doors are in awkward places which renders the foot opener useless. Along with the foot opener, the automatic door openers take a long time to open the door, which is inefficient. All products today that try to tackle this problem have some part of them that does not satisfy customer needs.

For our problem statement, as previously stated, Team Nugget decided to design a "Foot Operated Hydraulic Unit". While our initial statement said hands-free, any body part other than feet seemed inconvenient to the user. Also, the hydraulics help it function similar to current door closers, so users will not have to deal with a completely new product design. We incorporated that into our final design.

II. Problem Definition Review and Updates

Team Nugget's problem definition has seen some minor changes since the previous report. The desired functionality of the product remains the same, however our price goal and our financial viability reference has changed quite drastically. Previously, the product's goal selling price was around $80, however after completing the bill of materials and financial analysis, Team Nugget realized that price point was not viable. From the financial analysis our unit price has changed to $530, a 660% increase. With the modification of our price and the method of how the product will perform the outlined functionalities being realized, Team Nugget came to the conclusion that we must reframe our predicted position in the market. This involved shifting our primary competitor to Automatic Doors and Hardware, and performing another estimate of product sales based on the U.S construction market, the requirements of the Americans with Disabilities Act, and assuming a 1% share of that market. Besides these modifications, Team Nugget's problem definition remains unchanged and is outlined in the remainder of this section.

From Team Nugget's research, the key customer requirements for the product to fulfill are that it must be easy to operate, durable, low effort, safe, and quick hands-free door opener. Team Nugget has found that the market for doors and specifically hands-free operated doors is expanding and believes that it can reach up to 1% of the current market, or 19,200 first year units. Team Nugget has established engineering specifications in accordance with the customer requirements. Team Nugget plans to address these requirements by creating a product that has a functional lifespan of minimum 10 years, requires 67 or less newtons of force to open, and takes 2 or less seconds to open, while being completely hands free.

Our current goal is to improve the current method of opening doors without needing to use someone's hands. The potential customer includes hospitals, warehouses, universities, and handicapped people. In a hospital and a university, it should prevent the spread of germs. Also, the customers should be able to open the door while holding a lot of stuff in their hands. For warehouse and handicapped people, people should be able to open the door easily without someone's help. In these cases, the door should not require more than 76 Newtons to open, which is equivalent to the force of lifting two wooden chairs. It should take 2 seconds or less to open, which will avoid wasting time especially in an emergency. It should maintain its functionality for at least for 10 years, and should not incorporate more than 3 pinching parts because more components and more moving parts are more likely to be broken.

III. Concept Generation

We began the concept generation process with a functional decomposition of our product. Given the primary function of opening a door without the use of hands, we further broke this function down into the following four sub-functions: force transmission, easy user interface, secured to the door, and full door functionality. Each of these four sub-functions were then further broken down into their key components which help define what exactly each sub-function entails. For example, the force transmission sub-function is made up of the following three key aspects: Opened by applying a downward force, Efficient use of applied force, and Does not take excessive force. Another example of a sub-function break-down would be the retro compatibility and simple installment aspects of the "secured to door" sub-function.

After completing the product's functional decomposition we focused on developing possible designs which addressed the selected product aspects. In order to do so, 2-4 designs were created for each of the following product aspects: can be opened by a handicapped person, obvious how to use, comfortable to use, closes on its own after opening, adjustable time to open/close, customizable pedal location, opened by applying downward force, and efficient use of applied force.

IV. Concept Selection

After we had several solutions for each subfunctions, we started to put each part together and see if they would work together. Finally, we had four candidates fighting for the position, named Alpha, Bravo, Charlie, and Delta. Based on the customer requirements and their weights, we scored the four candidates and put them in a rank. The customer requirements can be found in the previous memos, but here are the requirements that weigh four and five. They are ease of operating the door, durability, effort to open the door, low cost, and safe to operate. We evaluate each candidate and give them a one if the requirement is met, a zero if the requirement is not met, and a negative one if the candidate has a negative effect on that requirement. Then each score was multiplied by the weight and added together to get a final score.

Candidate Bravo got the lowest score of four due to its complexity. Charlie got a fourteen, and Delta got an eighteen. The final selection Alpha got a twenty and won Delta just by a score of two due to its low cost.

V. Primary Concept Description

Our final selection mainly contains the following four parts: a pressure plate, fluid tube, "Bob", and "Tom".

1. Pressure Plate

This is where everything starts to happen. It requires a person to step on it to activate the system. When the downward force is applied on the plate, it's also pushing and squeezing the fluid bag and the spring in it. The fluid in the fluid bag is pushed out and transferred into the piston. To close the door, the spring could release the potential energy, push up the plate and the fluid bag whose top side is glued to the bottom of the plate and the bottom side is glued to the bottom of the casing. This will cause the fluid bag to expand in volume and suck back the fluid from the piston to close the door.

2. Fluid Tube

   Fluid tube is used to transfer the fluid and change the direction of the force. It transfers the fluid from the fluid bag in the pressure plate to the piston on the top of the door. With the fluid tube, the installation can be flexible.

3. "Bob" - Force Transformation Device

"Bob" transfers the linear motion from the piston into the rotational motion on the door. When the fluid is pushed into the piston, the piston expands and pushes the gear rack out. When the gear rack is moving in one direction, it rotates a gear and a main shaft. The main shaft connects the gear and the scissor arm. The rotation of the gear causes the scissor arm to rotate and push against the door frame to open the door. It works similar to the ordinary door closing device.

4. "Tom" - Resistance Fluid Tank

"Tom" is a fluid tank that slows down the door when closing and contains a casing, a shaft, fluid fins, and the fluid. The shaft is connected to the main shaft, and they both rotate together. The shaft is connected to the fluid fins, and the fins are submerged in the fluid which is held by the main casing. When the shaft is rotating, it's also spinning the fluid fins. When the door is opening and the fluid fins rotate in one direction, it decreases the coefficient of drag in the fluid by changing the shape into a thin triangle like airfoil. During the opposite direction of rotation, the drag opens the fins and creates more drag. This increases the coefficient of drag by changing the shape.

When the coefficient is low, the drag is low, so the net force is high with the same applied force. The effort to open the door is low, and the acceleration is high, so the time required to open the door is low. When the coefficient of drag is high, the drag is high, so it can slow down the door when closing.

A long screw on the side of the tank can adjust the height of the tank, thus we can change the portion of the fins that is submerged in the fluid. By changing this, we can change the coefficient of the drag, thus we can change the time required to close it.

VI. Bill of Materials

The Bill of Materials for Team Nugget's door opening/closing product appears rather long when compared to other product's BOMs. This is primarily due to the inner workings of the hydraulic system which require a multitude of components.

The BOM is split into four different sections: pressure plate triggering/force transformation, door opening, door closing, and assembly. The assembly section is the cheapest at a total cost of $14.50, followed by the force transformation section whose components cost a total of $26.03. Higher expenditures came from the door opening and closing component groups. This is where all the hydraulic system components were listed so it makes sense why these two sections were drastically larger than the other two. The door closing section totaled a cost of $43.89 with the majority of these expenses pertaining to the parts which make up the door closing box on the top of the door. Finally, the most expensive section of the BOM was the door opening components group. The total cost of the door opening section was $46.76 and consisted mainly of the piston, gear, and shaft expenditures.

Our total purchased and custom manufactured parts costs were surprisingly similar at $58.57 for purchased parts and $58.80 for custom manufactured costs. Combine these with the rounded assembly cost of $15.00, and we get our total product cost of $131.67. Multiplying this calculated cost by four, we were able to reach our retail price of about $530.

VII. Financial Analysis

Team Nugget's financial Analysis was informative and challenged the team to reframe our products' financial references and assumptions. Team Nugget performed several iterations of the financial analysis as we realized that our initial assumptions were no longer valid due to the massive increase in price, scaled those assumptions to the new price, and then realized that our reference point was lacking as due to the differences in each product's functionality. Team Nugget's current iteration of the financial analysis sees 57,600 product sales over the three year production period, a number based on the team's new market research. From these estimated sales, we find that the product will break even within the 8th quarter. The upfront costs include R&D and tool and fixture costs which total to be $553,264. The graphs showing the products net worth over the production cycle can be seen in Figures 12 and 13 in the Appendices section.

From the analysis it was concluded that the return on investment for the product is 46.83% while the rate of return for the project is 69.19%.

VIII. Project Scheduling

Team Nugget will begin phase 3 of the design process. This phase will be marked by the physical development of a prototype/product. The prototype will be subject to a myriad of analyses with the intent of measuring market viability. At the conclusion of phase 3, Team Nugget will present the final product as well as the culmination of data collected along the way. It will be the team's goal to prove the final product's ability to address an everyday issue with a well-tested mechanical solution.

IX. Conclusions and Recommendations

Throughout the second phase of our product, our team has been working to refine our final product through concept generation and concept selection. We have also been analyzing our final product design financially through a bill of materials and a financial analysis. All this data collection and analysis has allowed the team to construct a complete understanding of what our product must be able to achieve given the customer requirements which were translated into engineering specifications.

One key takeaway from Phase 2 is that our product is financially feasible. We can see this from our BOM (Bill of Materials) and our Financial Analysis. Our unit cost is high, coming in at around $530, but it is still under some of our competitors such as the handicap door opening system. Our return on investment per year is right around 50%, which allows us to break even during the 7th quarter, and start becoming profitable in the 8th quarter.

Moving forward Team Nugget will try to further enhance our design to meet our customer requirements and engineering requirements. We will also fabricate a prototype and analyze it. This process will allow us to see a physical representation of our design for the first time, which will allow us to make improvements and enhance the final product. This prototype will be a simple one, with little to no actual working parts. Instead, it will allow us to see our put together design for the first time to see how it will all work together to open a door.

As stated in the project plan section, Team Nugget is entering the third phase of the design process. The ultimate goal of phase 3 is the actual physical creation of a prototype. In order to be in good standing for phase 3, it will be crucial that the team is able to nail down key design aspects that address the customer requirements, which we did during our concept generation and concept selection.

X. References

No references were used for this report.

XI. Appendices

PROJECT TITLE	Phase 3	TEAM NAME	Team Nugget
GROUP MEMBERS:	Graham,Saul,Barne,Lu	DATE	2/11/22

TASK TITLE	START DATE	DUE DATE	DURATION
Completion of Modeling and Product Design	3/21/22	4/1/22	10
Operational Description	3/21/22	4/1/22	10
Part Drawings	3/21/22	4/1/22	10
Assembly Drawings	3/21/22	4/1/22	10
Update Bill of Materials	4/1/22	4/3/22	3
Justify Final Design	4/4/22	4/8/22	4
Performance Analysis	4/9/22	4/13/22	4
Assembly Analysis	4/5/22	4/8/22	3
Economic Analysis	4/4/22	4/7/22	3
Phase 3 Prototype	4/4/22	4/24/22	20
Preapre Final Report	4/19/22	4/24/22	5
Audience Analysis	4/19/22	4/20/22	1
Content	4/21/22	4/23/22	2

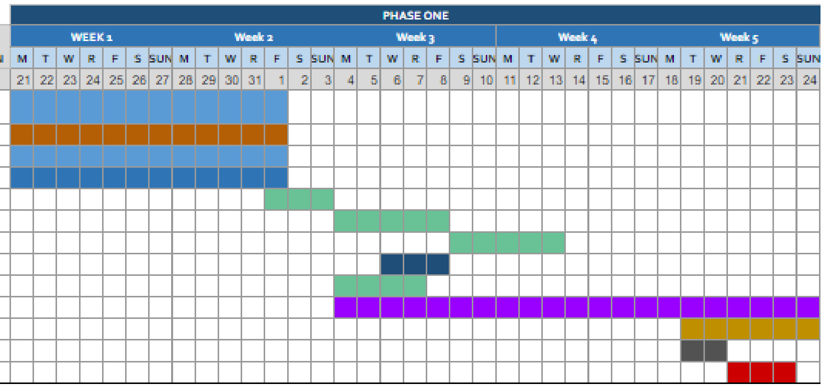


Figure 1: Phase 3 Gantt chart

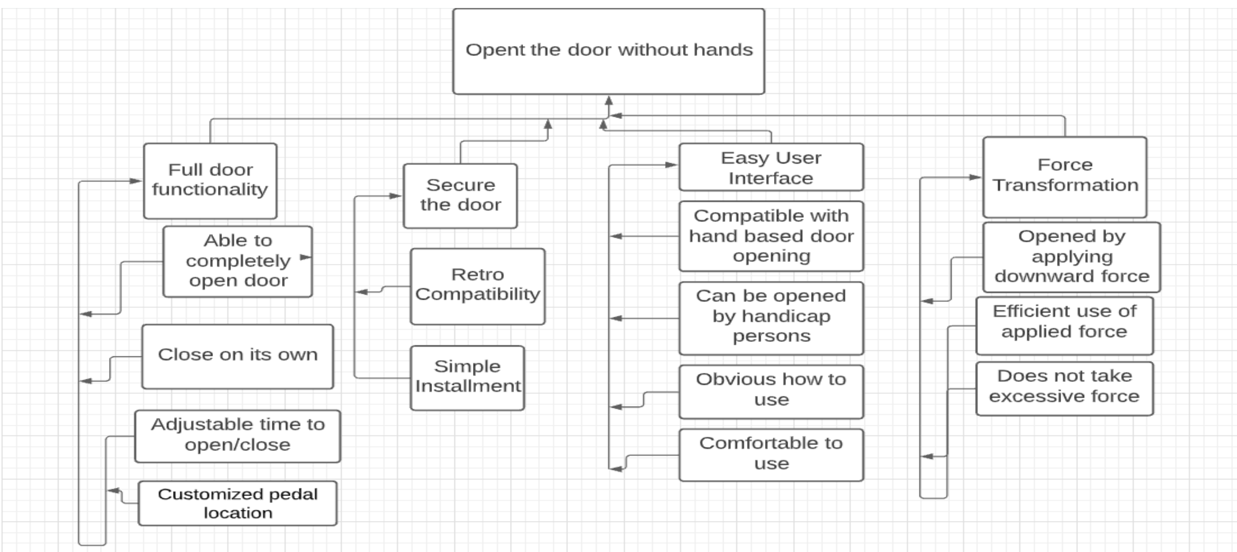


Figure 2: functional decomposition

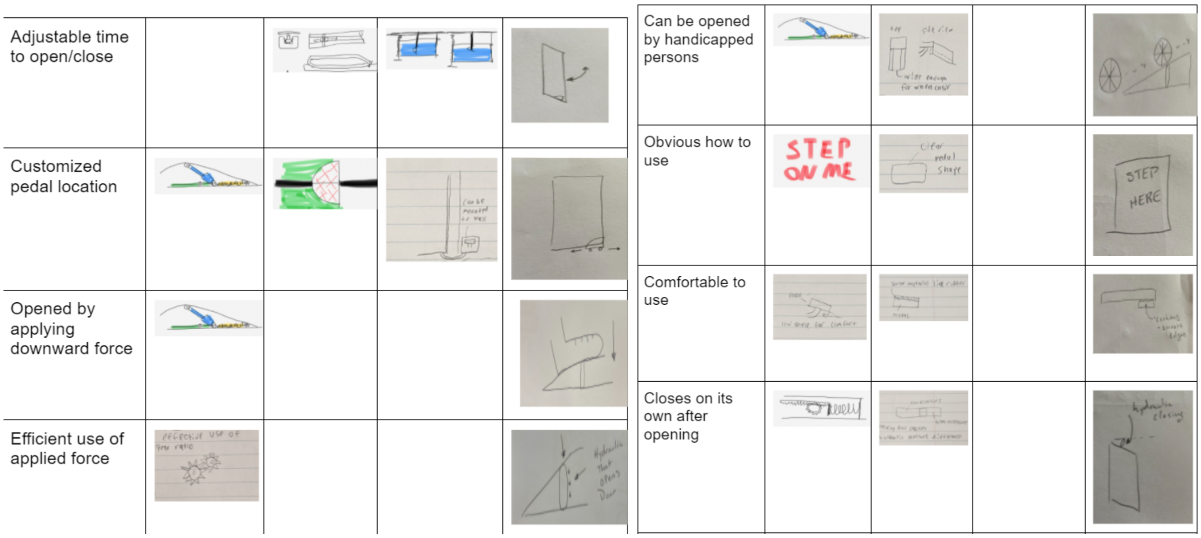
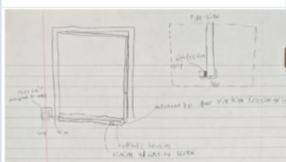
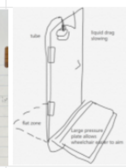
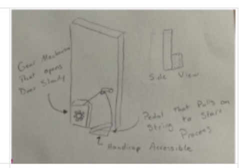


Figure 3-4: concept generation overview



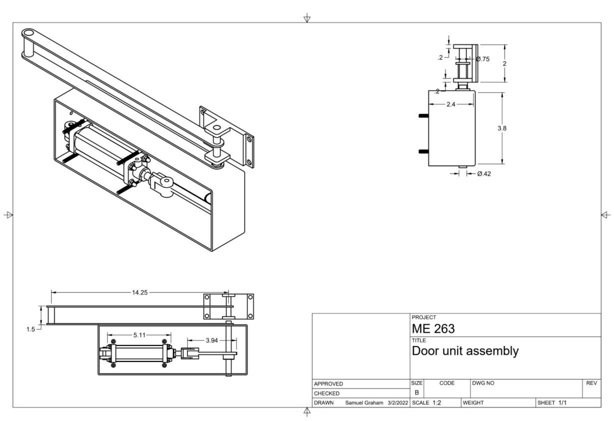


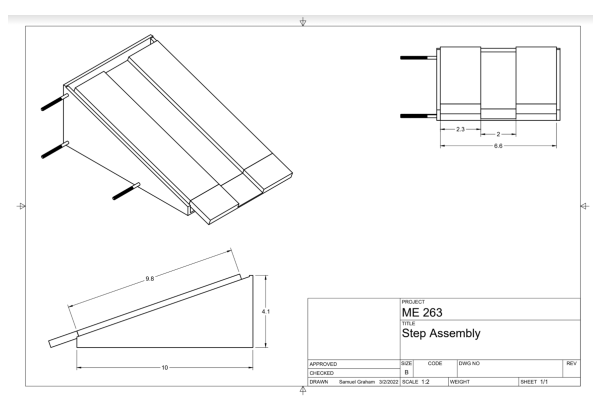
Customer Requirements	Concept 1	Concept 2
Effort to open the door (low)	1	1
Ease of operating the door (easy)	1	1
Time required to operate door (short)	1	0
Space filled by unit (small)	0	-1
Ease of installation (easy)	0	0
Low Cost (low)	-1	-1
Durability (durable)	0	1
Aesthetically pleasing (good)	0	1
Ease of repair (easy)	-1	0
Safe to operate (safe)	1	1
Retro-Compatibility (compatable)	1	1
Quiet (true)	1	1
Purely Mechanical (true)	1	1
Customizability of door operation time	0	1
Total +	7	9
Total -	-2	-2
Overall Total	5	7
Weighted Total	14	18



Customer Requirements	Weights	Concept 3	Concept 4
Effort to open the door (low)	4	1	1
Ease of operating the door (easy)	5	1	1
Time required to operate door (short)	3	0	-1
Space filled by unit (small)	2	1	-1
Ease of installation (easy)	3	0	0
Low Cost (low)	4	0	-1
Durability (durable)	5	0	0
Aesthetically pleasing (good)	1	0	-1
Ease of repair (easy)	2	0	-1
Safe to operate (safe)	4	1	1
Retro-Compatibility (compatable)	2	1	1
Quiet (true)	1	1	-1
Purely Mechanical (true)	1	1	1
Customizability of door operation time	1	1	1
	Total +	8	6
	Total -	0	-6
	Overall Total	8	0
	Weighted Total	20	4

Figure 5-6: concept selection





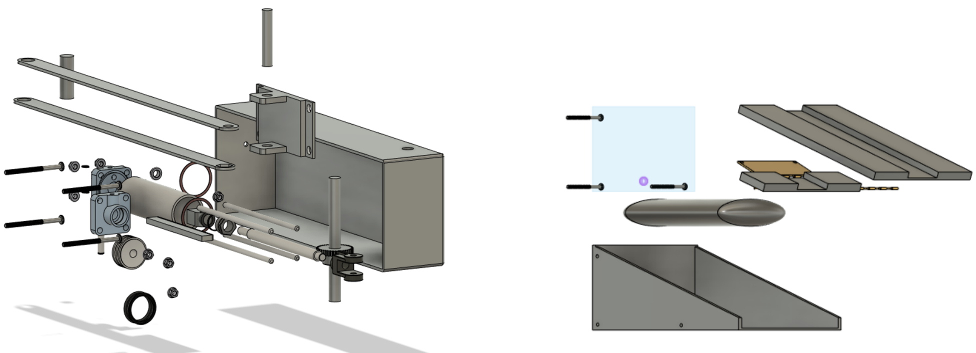


Figure 7-10: prototype designs

Total Purchased Parts $	58.57
Total Custom Manufactured Parts $	58.80
Total Assembly Cost $	15.00
Total Cost $	131.67

Figure 11: aggregated BOM

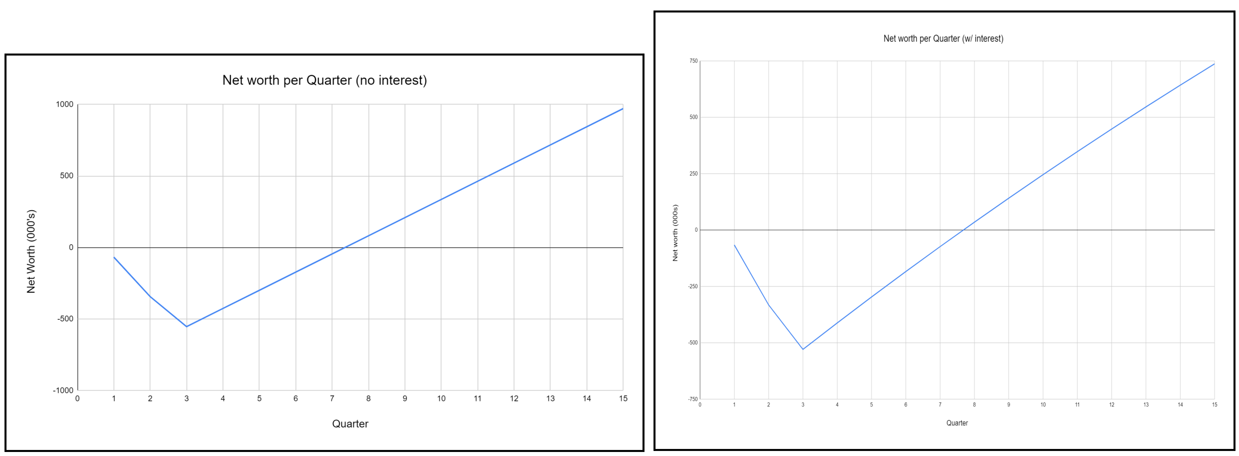


Figure 12-13: net worth charts with and without interest