## 1.6 Concept Generation

### 5 Medium Fidelity Concepts

After the team generated 100 various ideas and concepts that would be feasible options for the *103 SD* team to develop, the list was re-evaluated to consider only options that the team could see being developed and utilizing the greatest number of key functions. Though there are multiple concepts that fit the key functions, only the strongest 8 were selected for further evaluation. The first five concepts selected were deemed the five medium fidelity concepts, as these were selected by evaluating their potential ability to contribute and perform the best for the Biosense Webster team. These concepts are as listed below:

*Idea #7: Wooden testing arena utilizing image processing to detect deflection of the catheter, with a wire USB connection to transmit data, while the catheter is submerged in all 3 fluid mixtures to mimic the viscosity of blood. MATLAB will be used to read the data.*

*Idea #12: Wooden testing arena with ultrasound sensor on the end of the catheter to detect deflection, with a wire USB connection to transmit data, while the catheter is submerged in corn syrup to mimic the viscosity of blood. Excel will be used to read the data.*

*Idea #65: Metal testing arena with RFID tags on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in corn syrup to mimic the viscosity of blood. Excel will be used to read the data.*

*Idea #74: Metal testing arena with ultrasound sensors on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in corn syrup to mimic the viscosity of blood. Matlab or some other coding language will be used to interpret data.*

*Idea #78: Metal testing arena with pressure sensors on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in* *water to mimic the viscosity of blood. Matlab or some other coding language will be used to interpret data.*

**1st High Fidelity Concept**

The first high fidelity concept identified by the *103 SD* team is to incorporate a wooden base structure to stabilize the catheter and allow the catheter testing arena to be easily stored, *Idea #1*. Since Dr. Arce has communicated that the testing arena need to be easily storable, the wooden testing arena shall be constructed with metal hinges so that it is foldable. The method of tracking the deflection of the catheter shall utilize a magnetic GPS module that transmits the GPS signal from the catheter tip via a Bluetooth connection to a computer. The GPS signal shall then be gathered and interpreted through MATLAB code. The solution that the catheter will be deflected through inside the testing arena shall be a corn syrup/water solution that is similar to the viscosity of human blood.

**2nd High Fidelity Concept**

The second high fidelity concept identified by the *103 SD* team is detailed in the appendix as *Idea #23* and states will utilize an identical wooden testing arena to the concept above, but instead will track the position of the catheter using RFID tracking. An RFID tag will be placed on the tip of the catheter, while RFID readers will be placed surrounding the testing arena to transmit a signal to activate the tag and then receive signals to monitor its position in real time. The RFID readers will be connected to a computer via a wired USB connection, where the data will then be actively interpreted using MATLAB code. Similar to the concept above, the catheter will be maneuvered through a corn syrup/water solution to mimic the viscosity of human blood.

**3rd High Fidelity Concept**

The final high-fidelity concept discussed by the *103 SD* team is to construct a metal testing arena to stabilize the catheter while also implementing modular components for easier storage, this is notated in the appendix as *Idea #75*. The tracking of the catheter tip will be completed using a portable ultrasonic probe outside of the testing arena enclosure. This probe will send sound waves through the testing arena and monitor the distance and positioning of the catheter tip based off the signals that return to the probe. The probe will transmit data to a computer via a Bluetooth connection, while the data is read and interpreted in real time through a MATLAB script. This concept shall also test the movement of the catheter through a corn syrup/water solution that has similar viscosity to human blood.

**Concept Generation Tools**

To innovate catheter testing within a controlled environment, the *103 SD* team proposed an integration of diverse methodologies using concept generation tools. The first technique demonstrated by the team was a crap shoot, where members discussed singular items that may fit the requirements and scope of the project, such as *idea #43.* The senior design group implemented a morphological analysis to systematically evaluate various sensor technologies (electromagnetic, ultrasound, pressure, GPS, and RFID) in conjunction with different communication methods (wired USB and Bluetooth) to identify optimal combinations for accurate deflection detection. Considering that the senior design project will ultimately be implemented into a human body, biomimicry was a great tool for the group's discussion. Bainstorming sessions then facilitated the exploration of suitable test fluids (water, corn syrup, saline) that best mimic blood viscosity, ensuring realistic simulation conditions. Moving forward, team meetings will utilize the application of a Pugh matrix to compare the feasibility, cost, and performance of each proposed system, which leads to a balanced decision-making process.

**Codes and Standards**

We have been given no codes or standards by our sponsor Biosense Webster as this is a testing method for production purposes.

**1.7 Concept Selection**

From the *103 SD* team's list of most logical ideas, the design team was able to narrow the ideas down further to three ideas of high fidelity, meaning they are the most feasible, and five ideas of medium fidelity, which are less feasible but may still be successful. The name following each idea, in parentheses, is its shortened title that will be used in the *103 SD* teams's decision charts.

**Three high fidelity ideas:**

1. *Idea #1: Wooden testing arena with GPS module on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in a corn syrup water mixture to mimic the viscosity of blood. We will use Matlab or some other coding language to interpret data.*
2. *Idea #23: Wooden testing arena with RFID tags on the end of the catheter in order to detect deflection, with a wire USB connection to transmit data, while the catheter is submerged in a corn syrup/water mixture to mimic the viscosity of blood. We will use Matlab or some other coding language to interpret data.*
3. *Idea #75: Metal testing arena with ultrasound sensors on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in water corn syrup mixture to mimic the viscosity of blood. We will use Matlab or some other coding language to interpret data.*

**Five medium fidelity ideas:**

4. *Idea #7: Wooden testing arena utilizing image processing to detect deflection of the catheter, with a wire USB connection to transmit data, while the catheter is submerged in all 3 fluid mixtures to mimic the viscosity of blood. MATLAB will be used to read the data.*
5. *Idea #12: Wooden testing arena with ultrasound sensor on the end of the catheter to detect deflection, with a wire USB connection to transmit data, while the catheter is submerged in corn syrup to mimic the viscosity of blood. Excel will be used to read the data.*
6. *Idea #65: Metal testing arena with RFID tags on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in corn syrup to mimic the viscosity of blood. Excel will be used to read the data.*
7. *Idea #74: Metal testing arena with ultrasound sensors on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in corn syrup to mimic the viscosity of blood. Matlab or some other coding language will be used to interpret data.*
8. *Idea #78: Metal testing arena with pressure sensors on the end of the catheter to detect deflection, with a Bluetooth connection to transmit data, while the catheter is submerged in water to mimic the viscosity of blood. Matlab or some other coding language will be used to interpret data.*

For the comparisons, the Biosense Webster team knew it was necessary to have a pre-existing product to evaluate how their selected ideas would perform. After doing research, the team concluded there is no existing torsional, rotational, and translational measuring tool that is comparable to their options, and therefore would need to compare the grabbing capabilities of their product to a similar tool that can performs as many of the same functions. The *103 SD* chose to compare their product to a protractor instead of a medical grade measuring tool because the main appeal of the product will be its ability to measure deflection and translation.

**Binary Pairwise**

The first step in more accurately ranking the designs to eventually selecting a final design was to create a Pairwise Comparison. In order to do this, the design team utilized various methodologies and techniques common in this concept selection tool, more specifically, this is done by pinning the customer requirements to the customer requirements in a table, anywhere the customer requirement is against the same customer requirement, a dash is put. For each comparison, the row is put against the column, if the row is more important to the compared column, a value of "1" is given, otherwise the value given is a "0". This was only needed on the bottom half of the dashes, in order to complete the chart, the design team then followed the row to the dash, go up to above the dash, and insert the inverse value in that place. After this is done, the sum is calculated to the right hand side of the entire table, allowing the SD group to see which of these rows had the largest total value. These values give the "Importance Rank" factor which is used in the House of Quality. All of these values can be noted in *Table 4* in the Appendix.

List of Customer Needs:

| |
|---|
| Compatability |
| 1:1 Rotational Promise |
| Measures Translation |
| Simulated Environment of the Human Heart |
| Replication |
| Data Collection |
| Sensor Adjustability |
| Non-invasive |
| Analyze Data |

| |
|---|
| Maintain Functionality |
| Sensor Durability |

**Table 3**

*Binary Pairwise Chart*

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Compatability | - | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 2. 1:1 Rotational Promise | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 |
| 3. Measures Translation | 1 | 0 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 9 |
| 4. Simulated Environment of the Human Heart | 1 | 0 | 0 | - | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 6 |
| 5. Replication | 1 | 0 | 0 | 0 | - | 0 | 1 | 1 | 0 | 1 | 1 | 5 |
| 6. Data Collection | 1 | 0 | 0 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 8 |
| 7. Sensor Interchangability | 1 | 0 | 0 | 0 | 0 | 0 | - | 1 | 0 | 0 | 0 | 2 |
| 8. Non-invasive | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 | 0 | 0 | 0 |
| 9. Analyze Data | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | - | 1 | 1 | 7 |
| 10. Maintain Functionality | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | - | 1 | 4 |
| 11. Sensor Durability | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | - | 3 |
| Sum | 9 | 0 | 1 | 4 | 5 | 2 | 8 | 10 | 3 | 6 | 7 | |
| Check | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |

**House of Quality**

In the House of Quality for our catheter measurement device, the outcomes have been intricately analyzed and articulated, showcasing a direct correlation between customer requirements and engineering design specifics. The chart elucidates how precise manual inputs at the proximal end of the catheter translate to the distal end, a crucial aspect considering the new material introduced by Biosense Webster. Each customer need, such as the accuracy of 1:1 rotational translation and torsional deflection, is quantified and paired with relevant engineering metrics, like degrees of rotation and deflection, and milliseconds for data acquisition. The prioritization of these specifications is reflected in the weighted importance factors, ensuring that the final design will adhere to the promised functionality and reliability. The raw scores and relative weights computed from these factors present a clear roadmap for development, ensuring that the project's key goals of designing a robust and precise measurement device are not just met but validated through a data-driven approach.

List of Functions:

| |
|---|
| Detect Translation |
| Detect Rotation |
| Detect Deflection |
| Data Acquisition |
| Data Manipulation |
| Veinal Replication |
| Sterilization |
| Sensor Adjustability |
| Reproducability |
| Stabilization |

**Table 4**

*House of Quality Chart*

| Improvement Direction | | ↑ | ↑ | ↑ | ↓ | ↓ | ↑ | ↑ | ↑ | ↑ | ↑ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Units | | mm | degrees | degrees | milliseconds | milliseconds | percentage | percentage | percentage | percentage | millimeters |
| Customer Requirements | Importance Weight Factor | Detect Translation | Detect Rotation | Detect Deflection | Data Aquisition | Data Manipulation | Veinal Replication | Sterilization | Sensor Adjustability | Reproducability | Stabilization |
| 1. Compatability | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 3 |
| 2. 1:1 Rotational Promise | 10 | 9 | 9 | 9 | 3 | 3 | 1 | 0 | 3 | 3 | 3 |
| 3. Measures Translation | 9 | 9 | 9 | 9 | 3 | 3 | 1 | 0 | 3 | 3 | 3 |
| 4. Simulated Environment of the Human Heart | 6 | 3 | 3 | 9 | 0 | 0 | 9 | 3 | 0 | 9 | 1 |
| 5. Replication | 5 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 3 | 9 | 3 |
| 6. Data Collection | 8 | 1 | 1 | 1 | 9 | 3 | 0 | 0 | 3 | 3 | 0 |
| 7. Sensor Interchangability | 2 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 9 | 3 | 0 |
| 8. Non-invasive | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9. Analyze Data | 7 | 1 | 1 | 1 | 3 | 9 | 0 | 0 | 1 | 1 | 0 |
| 10. Maintain Functionality | 4 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 1 | 3 | 9 |
| 11. Sensor Durability | 3 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 9 | 1 | 0 |
| Raw Score (#) | 1651 | 204 | 204 | 240 | 178 | 159 | 109 | 22 | 207 | 211 | 117 |
| Relative Weight (%) | | 12.36 | 12.36 | 14.54 | 10.78 | 9.63 | 6.60 | 1.33 | 12.54 | 12.78 | 7.09 |
| Rank Order | | 4.5 | 4.5 | 1 | 6 | 7 | 9 | 10 | 3 | 2 | 8 |

## Pugh Chart

The Pugh Chart methodically evaluates multiple design concepts against a set of criteria, using a datum for comparison. In our project, the chart has been instrumental in differentiating the potential of various concepts based on their performance characteristics. For instance, Concept 7 shows a notable advantage in key areas denoted by the number of positive scores, whereas Concept 23 demonstrates a balanced profile with an emphasis on specific criteria where it excels, as indicated by the 'S' symbols. The summation of scores at the bottom of each concept column indicates their overall standing against the datum, with higher scores reflecting a more favorable assessment. This systematic approach has led us to prioritize Concept 7 for further development due to its superior alignment with our project goals, providing a clear direction for the next stages of design refinement. The outcomes of this chart have thus been pivotal in shaping our decision-making process, ensuring that we advance with a design that promises the best alignment with our objectives and constraints.

**Table 5**

*Pugh Chart*

| Selection Criteria | Datum (Protractor) | Concept 1 | Concept 23 | Concept 75 | Concept 7 | Concept 12 | Concept 65 | Concept 74 | Concept 78 |
|---|---|---|---|---|---|---|---|---|---|
| Detect Deflection | | - | + | - | + | S | + | S | + |
| Reproducability | | - | - | - | - | - | - | - | - |
| Sensor Adjustability | | + | + | + | + | + | + | + | + |
| Detect Translation | | + | + | + | + | + | + | + | + |
| Detect Rotation | | S | + | + | + | S | + | S | - |
| Data Acquisition | | + | + | + | + | + | + | + | + |
| # of Pluses | | 3 | 5 | 4 | 5 | 3 | 5 | 3 | 4 |
| # of Minuses | | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 |

Initial Pugh Chart

| Selection Criteria | Concept 78 | Concept 23 | Concept 7 | Concept 65 |
|---|---|---|---|---|
| Detect Deflection | | + | + | + |
| Reproducability | | + | + | S |
| Sensor Adjustability | | + | + | + |
| Detect Translation | | + | + | + |
| Detect Rotation | | S | + | S |
| Data Acquisition | | + | + | S |
| # of Pluses | | 5 | 6 | 3 |
| # of Minuses | | 0 | 0 | 0 |

Final Pugh Chart

### Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is important for decision-making because of its ability to break down complex problems into hierarchies of selection criteria. It is useful when there are many components and multicriteria decision making is needed. AHP was used due to its ability to make decisions without user bias, allowing for unbiased and reliable results. It allows for the ranking and prioritizing of the alternatives as well as incorporates the stakeholder's values to make informed decisions. AHP allows for both qualitative and quantitative factors to be incorporated, making it an important tool for an informed decision-making process.

**Table 6**

*Analytical Hierarchy Chart*

| Selection Criteria | Normalized Criteria Comparison Matrix (normC) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Detect Deflection | Reproducibility | Sensor Adjustability | Detect Translation | Detect Rotation | Data Acquisition | Criteria Weights (W) |
| Detect Deflection | 0.58 | 0.39 | 0.35 | 0.60 | 0.66 | 0.66 | 0.54 |
| Reproducibility | 0.07 | 0.04 | 0.19 | 0.02 | 0.03 | 0.03 | 0.06 |
| Sensor Adjustability | 0.07 | 0.01 | 0.04 | 0.02 | 0.03 | 0.03 | 0.03 |
| Detect Translation | 0.12 | 0.22 | 0.19 | 0.12 | 0.09 | 0.09 | 0.14 |
| Detect Rotation | 0.08 | 0.13 | 0.12 | 0.12 | 0.09 | 0.09 | 0.11 |
| Data Acquisition | 0.08 | 0.22 | 0.12 | 0.12 | 0.09 | 0.09 | 0.12 |
| Sum | 0.99 | 1.01 | 1.01 | 1.00 | 1.00 | 1.00 | |

Figure 7: Normalized Criteria Comparison Matrix

### Final Selection

SD team 103 decided on their final selection being idea #7: *Wooden testing arena utilizing image processing to detect deflection of the catheter, with a wire USB connection to transmit data, while the catheter is submerged in all 3 fluid mixtures to mimic the viscosity of blood. MATLAB will be used to read the data.* After completing multiple decision-making charts and processes, this idea outperformed the rest and fits the stakeholder's requirements as well as the engineering functions. This descion was supported by numerous system decision making processes that involved tools, including Binary Pairwise Comparison, House of Quality, Pugh

Chart, and Analytical Hierarchy Process. The combination of these techniques ensures a well-informed decision-making process, resulting in the selection of the most practical and effective solution, idea #7.