Concept Selection

House of Quality

To convert each of the customer needs to quantifiable parameters that can be used for selecting a design, a House of Quality (HoQ) was created. To construct the HoQ, the importance weight factor for each customer requirement was chosen. The weight factor was chosen through determining the priority of a certain requirement in comparison to the other requirements. These importance weight factors were formulated using Table 4. A box was marked with a one (1) when the characteristic of the row was determined to be more important than the one in the column. The monitor air quality requirement was found to have the highest importance weight factor while the no heat requirement had the lowest.

Table 1: Comparison of customer requirements to determine importance weight factor

	Monitor Air Quality	Portable	No Noise	No Heat	Reduces Contamination	Internal Power Source	Compatiable with Honeywell Products	Doesn't Interfere with Existing Infrastructure	Total
Monitor Air Quality	-	1	1	1	1	1	1	1	**7**
Portable		-	1	1					**2**
No Noise			-	1		1			**2**
No Heat				-					**0**
Reduces Contamination		1	1	1	-	1	1	1	**6**
Internal Power Source		1		1		-			**2**
Compatiable with Honeywell Products		1	1	1		1	-		**4**
Doesn't Interfere with Existing Infrastructure		1	1	1		1	1	-	**5**

The engineering characteristics chosen for this project during the targets and metrics phase were then compared to the customer requirements in the HoQ. Each engineering characteristic was given a value ranging from 0 to 9, depending on how heavily that characteristic impacts the customer requirement. The HoQ pictured in Table 5 shows the relationship between the engineering characteristics and the customer requirements.

Table 2: House of Quality

		Engineering Characteristics							
Improvement		↑		↑	↓	↓	↓	↓	↓
Units		µg/m3		ft3/min	dBA	Watts	ft3	sec	µm
Customer Requirements	**Importance Weight Factor**	**Concentration Range of Sensors**	**Accuracy of Sensors**	**Volumetric Flowrate**	**Noise Level**	**Daily Energy Consumption**	**Volume of Device**	**Reaction Time of Hardware Components**	**Minimum Diameter of Particles the Device Will Filter**
Monitor Air Quality	**7**	9	9					3	
Portable	**2**					1	9		
No Noise	**2**			1	9				
No Heat	**0**								
Reduces Contamination	**6**	3	9	9				3	9
Internal Power Source	**2**					3	1		
Compatiable with Honeywell Products	**4**	1	1						
Doesn't Interfere with Existing Infrastructure	**5**						1		
Raw Score (406)		85	121	56	18	8	25	39	54
Relative Weight %		20.94	29.80	13.79	4.43	1.97	6.16	9.61	13.30
Rank Order		2	1	3	7	8	6	5	4

The values in Table 2 were then used to determine weights for each engineering characteristic which allowed the importance of the characteristics to be ranked. The accuracy of the sensors was the highest ranked characteristic. It is the most important because it heavily impacts the ability of the device to effectively monitor air quality and reduce contamination, which were the two most important needs from Table 1. The least important characteristic is the daily energy consumption of the device, since it only slightly affects portability and the usage of an internal power source, two relatively unimportant customer requirements.

We then compared the important characteristics determined in Table 2 to the five medium and three high fidelity designs described in section 1.6 of this evidence manual. The types of filters and fans used in each concept are very similar, so all designs were thought to perform the same in relation to the volumetric flowrate, noise level, volume of device, reaction time of hardware, and minimum diameter of filterable particles characteristics. Concepts 13, 14, and 47, 48 all possess air quality sensors so can fulfil the needs of the two most highly ranked engineering characteristics, concentration range of sensors and accuracy of sensors. Therefore, at this stage in the concept selection process, these four design concepts were the frontrunners.

Pugh Chart

A Pugh chart was then created for the medium and high-fidelity concepts that were generated. Each concept was compared against a datum concept to determine whether the concept performed better, worse, or the same for each characteristic. Table 3 shows our eight medium and high-fidelity concepts being compared against a standard air purifier as the datum.

Using Table 6, Concepts 36, 38, 46, and 47 were be eliminated because of their low performance relative to other concepts. These concepts had the highest number of minuses compared to a relatively small number of plusses. A second Pugh chart was created using the top four concepts, 13, 14, 43, and 48. Concept 34 was chosen as the datum for this Pugh chart because it performed moderately well in Table 3. The second Pugh chart can be seen in Table 4.

Table 3: Initial Pugh chart using a standard air purifier as the datum

Pugh Chart									
Engineering Characterisitcs	Datum: Air Purifier	Concept 13: Single mobile cart	Concept 14: double mobile cart	Concept 34: Air purifier on cart	Concept 36: Stationary air purifier	Concept 38: Air purifier with UV cleaning	Concept 46: rotating air furifier	Concept 47: Light-up air purifier	Concept 48: Wall mounted sensors
ability to circulate air	Datum	+	S	+	+	S	S	-	+
ability to purify air		+	+	S	+	+	+	+	S
ability to filter particulates		+	+	+	+	S	S	+	S
ability to humidify and dehumidify air		+	+	+	+	-	-	-	+
utilizes control systems		+	+	+	-	-	-	S	+
portable		S	+	+	-	-	-	+	-
utilizes proprietary power source		S	S	S	-	-	-	S	+
utilizes multiple sensors		S	S	-	-	-	-	+	S
Plusses		5	5	5	4	1	1	4	4
Minuses		0	0	1	4	5	5	2	1
Satisfactory		3	3	2	0	2	2	2	3

Table 4: Secondary Pugh chart with concept 34 as the datum

Pugh Chart				
Engineering Characterisitcs	Concept 34: Air purifier on cart	Concept 13: Single mobile cart	Concept 14: double mobile cart	Concept 48: wall mounted sensors
Ability to circulate air	Datum	+	S	S
ability to purify air		+	+	+
ability to filter particulates		+	+	+
ability to humidify and dehumidify air		+	+	+
utilizes control systems		S	S	+
utilizes mobility		S	+	-
utilizes proprietary power source		S	S	-
utilizes multiple sensors		S	S	S
Plusses		4	4	4
Minuses		0	0	2
Satisfactory		4	4	2

Concept 48 was the worst performing design in the second Pugh chart, as shown in Table 4, leading to its elimination. Concepts 13 and 14 tied as the best designs with four plusses and no minuses. They performed the same as or better than concept 34 in all categories, which led us to eliminate concept 34 as a prospective design. Concepts 13 and 14 performed equally well in both the HoQ and Pugh chart selection techniques, leading us to use the Analytical Hierarchy Process (AHP) to make the final decision.

Analytical Hierarchy Process (AHP)

The functions determined through the updated functional decomposition, shown in section 1.4 of this manual, were used to create the AHP. The full catalogue of tables generated during this process are shown in Appendix A. The criteria weights found in Table 5, were used to determine the importance of each function.

Table 5: Normalized Criteria Comparison Matrix

Development of Candidate Set of Criteria Weights {W}													
Normalized Criteria Comparison Matrix [NormC]													
Engineering Characteristics	**Portability**	**Sense air Quality**	**Propeller Activation**	**Propeller Modulation**	**Purifier Activation**	**Purifier Modulation**	**Air Propulsion**	**Air Purification**	**Air Treatment**	**Filter Particulates**	**Humidify**	**Sanitize**	**Criteria Weight {W}**
Portability	0.0183	0.0564	0.0037	0.0027	0.0041	0.0037	0.0092	0.0140	0.0284	0.0606	0.0171	0.1554	0.0311
Sense air Quality	0.0061	0.0188	0.0037	0.0038	0.0058	0.0052	0.0092	0.0100	0.0203	0.0433	0.0284	0.2591	0.0345
Propeller Activation	0.1280	0.0940	0.0258	0.1337	0.0288	0.0782	0.0153	0.0100	0.0203	0.0433	0.0171	0.0074	0.0502
Propeller Modulation	0.1280	0.0940	0.0037	0.0191	0.0041	0.0261	0.0153	0.0100	0.0203	0.0433	0.0171	0.0074	0.0324
Purifier Activation	0.1280	0.0940	0.0258	0.1337	0.0288	0.1304	0.0153	0.0100	0.0284	0.0606	0.0171	0.0074	0.0566
Purifier Modulation	0.1280	0.0940	0.0086	0.0191	0.0058	0.0261	0.0153	0.0140	0.0284	0.0606	0.0171	0.0104	0.0356
Air Propulsion	0.0915	0.0940	0.0774	0.0573	0.0865	0.0782	0.0460	0.0233	0.0474	0.0606	0.0171	0.0173	0.0580
Air Purification	0.0915	0.1316	0.1806	0.1337	0.2018	0.1304	0.1381	0.0699	0.1422	0.1010	0.0171	0.0173	0.1129
Air Treatment	0.0915	0.1316	0.1806	0.1337	0.1441	0.1304	0.1381	0.0699	0.1422	0.1010	0.2558	0.1554	0.1395
Filter Particulates	0.0915	0.1316	0.1806	0.1337	0.1441	0.1304	0.2301	0.2098	0.4267	0.3030	0.4263	0.2591	0.2222
Humidify	0.0915	0.0564	0.1290	0.0955	0.1441	0.1304	0.2301	0.3497	0.0474	0.0606	0.0853	0.0518	0.1226
Sanitize	0.0061	0.0038	0.1806	0.1337	0.2018	0.1304	0.1381	0.2098	0.0474	0.0606	0.0853	0.0518	0.1041
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The criteria weight shown in Table 5 provides a different perspective on what is important for device functionality compared to the HoQ discussed earlier. The criteria weights of functions related to cleaning air had higher criteria weights than other functions. The table shows that filtering particulates is the most important characteristic, whilst portability is the least important. This was found because the device will not be able to fulfil the project brief of improving air quality if it cannot clean air. However, it can fulfil this brief if it does not possess other characteristics, such as portability.

Concept 14 utilizes two carts, one for sensors to monitor air quality, and another containing equipment to clean the air if the sensors determine it to be bad quality. Concept 13 is comprised of a single cart containing both sensing and cleaning equipment. The two-cart model used in design 14 provides space for more cleaning equipment to mounted to the cart. The ability to use more equipment and have greater flexibility of where it is placed on the cart is an advantage over the one-cart model. Therefore, Concept 14 is better equipped to fulfil the design requirements deemed important in the AHP.

Final Selection

From the Pugh chart in Table 4, all concepts but Concept 13: Single Mobile Cart and Concept 14: Double Mobile Cart were eliminated. The other high-fidelity design, Concept 48: Wall Mounted Sensors, can further be eliminated since it is completely fixed in place, which is directly in opposition to the customer need of portability. The fixed nature of this design also prevents us from moving the devices to hotspots where air quality is a particular risk.

Concepts 13 and 14 are quite similar, both placing the cleaning and sensing equipment on battery powered carts that can be moved around the FAMU-FSU College of Engineering, the primary difference being that Concept 14 places the sensing equipment on one cart to be used to check air quality, only bringing in the second cart with cleaning equipment when the air quality is poor. Concept 14 allows for more flexibility in both sensing and cleansing equipment as their size constraints no longer affect each other. For this reason, Concept 14 was ultimately chosen for this project.

Appendix A

Table A1: Development of Candidate Set of Criteria Weights {W}

Development of Candidate Set of Criteria Weights {W}												
Criteria Comparison Matrix [C]												
Engineering Characteristics	**Portability**	**Sense air Quality**	**Propeller Activation**	**Propeller Modulation**	**Purifier Activation**	**Purifier Modulation**	**Air Propulsion**	**Air Purification**	**Air Treatment**	**Filter Particulates**	**Humidify**	**Sanitize**
Portability	1.00	3.00	0.14	0.14	0.14	0.14	0.20	0.20	0.20	0.20	0.20	3.00
Sense air Quality	0.33	1.00	0.14	0.20	0.20	0.20	0.20	0.14	0.14	0.14	0.33	5.00
Propeller Activation	7.00	5.00	1.00	7.00	1.00	3.00	0.33	0.14	0.14	0.14	0.20	0.14
Propeller Modulation	7.00	5.00	0.14	1.00	0.14	1.00	0.33	0.14	0.14	0.14	0.20	0.14
Purifier Activation	7.00	5.00	1.00	7.00	1.00	5.00	0.33	0.14	0.20	0.20	0.20	0.14
Purifier Modulation	7.00	5.00	0.33	1.00	0.20	1.00	0.33	0.20	0.20	0.20	0.20	0.20
Air Propulsion	5.00	5.00	3.00	3.00	3.00	3.00	1.00	0.33	0.33	0.20	0.20	0.33
Air Purification	5.00	7.00	7.00	7.00	7.00	5.00	3.00	1.00	1.00	0.33	0.20	0.33
Air Treatment	5.00	7.00	7.00	7.00	5.00	5.00	3.00	1.00	1.00	0.33	3.00	3.00
Filter Particulates	5.00	7.00	7.00	7.00	5.00	5.00	5.00	3.00	3.00	1.00	5.00	5.00
Humidify	5.00	3.00	5.00	5.00	5.00	5.00	5.00	5.00	0.33	0.20	1.00	1.00
Sanitize	0.33	0.20	7.00	7.00	7.00	5.00	3.00	3.00	0.33	0.20	1.00	1.00
Sum	54.67	53.20	38.76	52.34	34.69	38.34	21.73	14.30	7.03	3.30	11.73	19.30

Table A2: Further Development of Candidate Set of Criteria Weights {W}

Development of Candidate Set of Criteria Weights {W}													
Normalized Criteria Comparison Matrix [NormC]													
Engineering Characteristics	**Portability**	**Sense air Quality**	**Propeller Activation**	**Propeller Modulation**	**Purifier Activation**	**Purifier Modulation**	**Air Propulsion**	**Air Purification**	**Air Treatment**	**Filter Particulates**	**Humidify**	**Sanitize**	**Criteria Weight {W}**
Portability	0.0183	0.0564	0.0037	0.0027	0.0041	0.0037	0.0092	0.0140	0.0284	0.0606	0.0171	0.1554	0.0311
Sense air Quality	0.0061	0.0188	0.0037	0.0038	0.0058	0.0052	0.0092	0.0100	0.0203	0.0433	0.0284	0.2591	0.0345
Propeller Activation	0.1280	0.0940	0.0258	0.1337	0.0288	0.0782	0.0153	0.0100	0.0203	0.0433	0.0171	0.0074	0.0502
Propeller Modulation	0.1280	0.0940	0.0037	0.0191	0.0041	0.0261	0.0153	0.0100	0.0203	0.0433	0.0171	0.0074	0.0324
Purifier Activation	0.1280	0.0940	0.0258	0.1337	0.0288	0.1304	0.0153	0.0100	0.0284	0.0606	0.0171	0.0074	0.0566
Purifier Modulation	0.1280	0.0940	0.0086	0.0191	0.0058	0.0261	0.0153	0.0140	0.0284	0.0606	0.0171	0.0104	0.0356
Air Propulsion	0.0915	0.0940	0.0774	0.0573	0.0865	0.0782	0.0460	0.0233	0.0474	0.0606	0.0171	0.0173	0.0580
Air Purification	0.0915	0.1316	0.1806	0.1337	0.2018	0.1304	0.1381	0.0699	0.1422	0.1010	0.0171	0.0173	0.1129
Air Treatment	0.0915	0.1316	0.1806	0.1337	0.1441	0.1304	0.1381	0.0699	0.1422	0.1010	0.2558	0.1554	0.1395
Filter Particulates	0.0915	0.1316	0.1806	0.1337	0.1441	0.1304	0.2301	0.2098	0.4267	0.3030	0.4263	0.2591	0.2222
Humidify	0.0915	0.0564	0.1290	0.0955	0.1441	0.1304	0.2301	0.3497	0.0474	0.0606	0.0853	0.0518	0.1226
Sanitize	0.0061	0.0038	0.1806	0.1337	0.2018	0.1304	0.1381	0.2098	0.0474	0.0606	0.0853	0.0518	0.1041
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A3: Development of Weighted Sum Vectors {Ws}

Development of Weighted Sum Vectors {Ws}													
Engineering Characteristics	**Portability**	**Sense air Quality**	**Propeller Activation**	**Propeller Modulation**	**Purifier Activation**	**Purifier Modulation**	**Air Propulsion**	**Air Purification**	**Air Treatment**	**Filter Particulates**	**Air Humidific ation**	**Sanitize Contamin ants**	**Weighte d Sum {Ws}**
Portability	0.0311	0.1034	0.0072	0.0046	0.0081	0.0051	0.0116	0.0226	0.0279	0.0444	0.0245	0.0312	0.3218
Sense air Quality	0.0104	0.0345	0.0072	0.0065	0.0113	0.0071	0.0116	0.0161	0.0199	0.0317	0.0409	0.0521	0.2493
Propeller Activation	0.2177	0.1724	0.0502	0.2266	0.0566	0.1068	0.0194	0.0161	0.0199	0.0317	0.0245	0.0015	0.9435
Propeller Modulation	0.2177	0.1724	0.0072	0.0324	0.0081	0.0356	0.0194	0.0161	0.0199	0.0317	0.0245	0.0015	0.5865
Purifier Activation	0.2177	0.1724	0.0502	0.2266	0.0566	0.1781	0.0194	0.0161	0.0279	0.0444	0.0245	0.0015	1.0354
Purifier Modulation	0.2177	0.1724	0.0167	0.0324	0.0113	0.0356	0.0194	0.0226	0.0279	0.0444	0.0245	0.0021	0.6270
Air Propulsion	0.1555	0.1724	0.1506	0.0971	0.1699	0.1068	0.0581	0.0376	0.0465	0.0444	0.0245	0.0035	1.0670
Air Purification	0.1555	0.2413	0.3514	0.2266	0.3965	0.1781	0.1742	0.1129	0.1395	0.0741	0.0245	0.0035	2.0780
Air Treatment	0.1555	0.2413	0.3514	0.2266	0.2832	0.1781	0.1742	0.1129	0.1395	0.0741	0.3680	0.0312	2.3359
Filter Particulates	0.1555	0.2413	0.3514	0.2266	0.2832	0.1781	0.2903	0.3388	0.4186	0.2222	0.6133	0.0521	3.3712
Air Humidification	0.1555	0.1034	0.2510	0.1619	0.2832	0.1781	0.2903	0.5647	0.0465	0.0444	0.1227	0.0104	2.2119
Sanitize Contaminants	0.0104	0.0069	0.3514	0.2266	0.3965	0.1781	0.1742	0.3388	0.0465	0.0444	0.1227	0.0104	1.9067
Sum	1.70	1.83	1.95	1.69	1.96	1.37	1.26	1.62	0.98	0.73	1.44	0.20	16.73