A Homemade Air Quality Sensor: Is it viable?

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ABSTRACT

The fact that indoor air quality is a very important topic has already been proven by Wybon back in 2014 [1]. Although more and more commercial sensors become available to start collecting your own data, these sensors often turn out to be very expensive due to mandatory services being involved. This project measures indoor air quality by means of a homemade sensor. Goal is to check whether it is viable to come up with your own IOT device and to use it for empirical research.

Keywords

Indoor air quality, Homemade sensor, End-user experience, Wifi data, FeedbackNow, Empirical research, IOT

1. INTRODUCTION

The number of IOT devices has made a huge increase during the past few years [2]. A high amount of sensors are being placed on a daily basis, creating even more data. Air quality sensors are no exception. When searching on the internet, lots of those sensors can be found in whatever size and shape you prefer. However, almost all of the commercial sensors share one common factor: they are expensive. This gives rise to the interesting question whether or not it is viable to come up with your own sensor. Since lots of different sensors exist for lots of different purposes, this does not just hold for air quality sensors. All disciplines that make use of sensors should consider the question whether it is possible to simply buy the components needed, put it all together and just start using it for empirical research whilst in the meantime guarantee reliability. Before answering this question, we will first take a closer look at the costs of time, money and effort that are needed. Next, the sensor will be compared to a commercial sensor in order to find out how reliable the homemade sensor and therefore the data is. Also the sensor will be used to collect empirical data about the air quality in the library of the University of Twente. This data will then be used to check for potential correlations with other data sources.

1.1 Case study Asito

Asito is currently one of the largest cleaning companies in the Netherlands [3]. In order to not fall behind on their competitors, innovation is of great importance [4].

One of the high-potential services that Asito currently explores is increasing the end-user experience. The ongoing issue is that facility managements put the responsibility for this end-user experience by Asito without questioning if Asito is capable of changing this at all. Martine Drewes, campus & facility management UT, mentioned in an expert interview that in their current contract with Asito the end-user experience needs to improve on a yearly basis or else they will contact a competitor [5]. Asito therefor has no other choice than to dive into the world of end-user experience.
This specific project is part of the larger exploration to end-user experience and focuses on the possible influence of air quality on this experience. Rather than buying expensive existing sensors, Asito is doing research on the option to start producing IOT themselves. During a previous project at Asito, three Business & IT students came up with their own air quality sensor. Now Asito wants to know if this sensor is reliable by running a project in which the sensor is being validated and used for empirical research.

1.2 Case study UB

Next to Asito, there is another party involved in the project. The UB is the library of the University of Twente. Lots of students visit this place to study or work on projects. Especially during the end of the semesters when exams are taking place the UB is crowded. The head of operations & learning services, Olga Steen, mentioned in an interview that her goal is to create the best study landscape in the world [6]. One of the most important factors that contribute to reaching this goal is the level of air quality since it has a huge effect on productivity and health [7][1]. More and more people nowadays get infected with the sick building syndrome. Meaning people who enter a 'sick' building get infected and show symptoms like eye irritation, dry throats and headaches. Poor indoor air quality is stated as the main cause behind the SBS [8]. Besides solving the SBS problem, also the productivity can be significantly increased. Improving the air quality by means of doubling the ventilation can cause an efficiency increase of 14.5%. Also every $1^{o}C$ increase of temperature results in a productivity reduction of 3.5% [9].

In order to gather data-based information about the air quality situation inside the UB, sensors need to be placed. Currently, no real air quality sensors are running in the UB. The Facility Management (FM) does have some info about the level of CO2 and temperature though. This data is gathered by means of the ventilation system, which does include sensors. However, the employees working at the library are not satisfied with the current state of the air quality. The homemade sensor needs, together with upcoming projects, to first provide proof before changes are being made. Since the sensor is not validated yet, a commercial sensor will be placed at the exact same location in order to be able to validate the data.

By combining the two interested parties the goal is to create a win-win situation. Both Asito and the UB should take advantage from the experiment. Since both parties are only in the exploration stage this experiment is to be considered a first step in the right direction.

1.3 Problem statement

The topic of air quality is getting more and more important. Lots of research has lately been done about the consequences on health and efficiency. However, barely any of this research mentions end-user experience. Asito is held responsible for this end-user experience and therefore needs information about the factors that influence the experience. Since this information is lacking in current literature, the decision was made to start own research.
Since air quality is an important factor in both end-user experience and cleaning, a sensor is needed to be able to collect data about the air quality. Existing sensors turned out to be very expensive, which left the question whether creating an own sensor would be more viable.

After coming up with the homemade sensor, validation is needed in order to get knowledge about its reliability. A first prototype was made to be able to start collecting data, but research has to be done first to find out how reliable and therefore valuable the actual data would be [10].
The UB is looking to improve their study landscape. The library offers place on a daily basis to lots of students who need to be very focussed whilst studying. Air quality is one very important factor that influences both health as well as productivity [7][11][1]. The better the air quality, the better the student can study. Current situation is that the library has done almost no research about this topic yet which means the time has come to start experimenting.
According to the Head of Operations & Learning Service UB: "Especially during busy weeks the air quality does not feel good. Busy weeks are the two weeks before the start of the exams and the two weeks in which the exams take place. When entering the UB at the end of the exam period, you simply can smell that a lot of people have been inside". Sensors are useful to provide data about the air quality inside the UB. Of course there needs to be checked if indeed lots of people have been inside the UB during these busy weeks. Last step is to correlate this data with end-user experience.

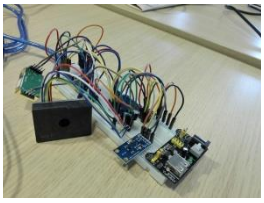
2. CORE COMPONENTS

2.1 The sensors

During a previous project at Asito Tibor Casteleijn, Lieke Hamelers and the author of this paper came up with their own air quality sensor. The project was set to be up and running for just 10 weeks total. During those ten weeks, research was done for what hardware and software to use. In the end all the parts were ordered and combined in order to create the current sensor, of course being just a first prototype. For more information about the construction of the sensor see appendix B.2. The sensor consists of the following measurement components:

- CO2 sensor MH-Z19
- Temperature/humidity/Barometric sensor BME280
- Dust sensor GP2Y10
- Light intensity sensor BH1750
- Een motion detection sensor HC-SR505
- Een WEMUS D1 mini

Since a wifi chip is included, a connection with the database can be set up fairly easy. This is a live connection, meaning that the database (currently running in Azure) will receive data from the sensor every 10 minutes. The sensor itself obviously needs power, currently being a socket. However, in a short period of time this will be changed into (low energy) batteries.



None of the components have been put to real use yet, which means they are not validated whatsoever. Consequence is that the output values cannot be assumed to be exactly true, instead the global trends will be used. For further details about the hardware costs of the homemade sensor see Appendix B.1.

The commercial sensor on the other hand has been in use for multiple years already by the University of Twente. Before its appearance on the market, lots of testing and validation has been done in order to guarantee its values are indeed true. Also since the University has been using them for almost four years now, lots of projects have taken place testing those sensors even more. Therefore this specific sensor is well suited for the task of validating the homemade sensor. The commercial sensor keeps track of the temperature, humidity, CO2, light intensity and movement.

2.2 Other data sources

Setting up empirical research at the UB also opens up various other possibilities since they really do stimulate researches like these. After having conducted some more interviews it became clear that two more interesting and relevant data sources were accessible: the wifi access points and the feedbackNow system.

2.2.1 Wifi data

The wifi access points were already being used for extracting wifi data. The data is stored in a database which is accessible to only a few people due to privacy issues. This data is very useful for wifi tracking. Wifi tracking can estimate fairly accurate how many people are present in a room [12]. All people that have their wifi turned on at any of their devices are located. Their locations stay up to date which makes things very privacy sensitive, especially when creating a heat map of all located devices. According to Jeroen van Ingen, network engineer at the UT, the data provided for this project is however already anonymized and therefore ready to be used [13]. This is done by copying parts of the original database into another database. This new database is created in order to still be able to provide data for projects like these. The data in this new database is encrypted on a daily basis which means devices can be tracked for a time period of just one day. However, for this project it is not important who was present in the room nor the locations or path that was followed. In fact, just the number of devices will be sufficient in order to define a trend. This process does therefore not require privacy sensitive data.

2.2.2 FeedbackNow data

The other interesting data source is the feedbackNow system. This system consists of multiple boxes, each containing one very specific question of your own choice. The users can provide their input by either pressing the unhappy, neutral or happy smiley. All the boxes are connected to a database. Every time a smiley is pressed on one of the boxes, the database will be updated. All elements that might be of any importance are stored as well. These elements include the number of the box, the time and what smiley is pressed. Disadvantage is that the location of the box as well as what question is currently on the box cannot be stored and therefore need to be taken care of manually. When the angry smiley on one of the boxes is pressed three times in a row, an alert will be send so that the person in charge can immediately take a look if there is an emergency. Of course situations in which users are spamming a smiley just for fun are taken care of. The aspect that makes this system so interesting, is that it collects feedback directly from the end-user.

3. RESEARCH QUESTIONS

From the problem statement mentioned above, the following research questions have been conducted:

Main research question: *How viable is it to come up with a homemade sensor for academic/empirical research?*

This question will be answered with the help of multiple sub questions:

- What are the costs of coming up with a homemade sensor?
- How does the sensor compare to a commercial sensor?
- Is there a difference in the data extracted from the sensor during the start of the busy weeks (week 23/24) and the end of the busy weeks (week 25/26)?
- Is there a correlation between the sensor data and the wifi/feedbackNow data?
  A. Is there a correlation between the sensor data and the wifi data?
  B. Is there a correlation between the sensor data and the feedbackNow data regarding temperature?

4. METHODOLOGY

4.1 Expert interviews

In order to get a better understanding of their expectations regarding the purpose of the sensor, interviews with multiple managers at Asito have taken place. Innovations should be made to come up with and adopt new technology. The CIO states this new technology should open up for new potential services. Rather than simply buying expensive existing technology, the Business Development Managers state they want to come up with their own (air-quality) sensor in order to bypass the unnecessary and expensive services. Starting off with creating a prototype, goal is to monitor the costs of time, money and effort. Once the prototype is up and running, it first needs to be validated and tested thoroughly before being able to use it as a commercial sensor. Consequence is that multiple projects are started to validate the sensor and to use it for empirical research. According to the Business Development Managers, this project is considered to be the first step in the right direction.

For the technical challenge of getting the sensor ready for use, several session took place with both an employee of Asito (the same as who contributed to constructing the sensor) and a network engineer at the university of Twente. Firmware had to be updated first before connection with the database could be established. Once that was all in place, the sensor was connected to the university network.

In order to get the best location possible for the sensor to be placed, advice was given by the Head of Operations & learning services, the Campus and Facility management as well as a project leader who has lots of experience with sensor projects.
Furthermore, the network engineer provided accessibility to the wifi data. He first has made sure that the data was anonymized in such a way it is usable for this research project. Regarding the feedbackNow data, meetings with the Head of Operations & Learning Services and an expert on the feedbackNow system gave clear insight into what data was being collected and how to interpret those data.

4.2 Measurement environment

Both of the sensors are placed at the exact same location inside the UB. The UB is the library at the university of Twente, a place where lots of students study. The building contains both small rooms and open areas. The sensors are placed in such an open area where students can sit down to study, relatively close to the service desk. Advantage of this placement is that employees of the service desk can keep an eye on the sensor. At the other side of the open space are a lot of computers. These tend to have quite an influence on the air quality. No research has been done on that specific subject, therefore the sensors were intentionally not placed anywhere close to those computers.
The location is chosen to be not in range of at least 3 meters of the entrance. Furthermore the sensors are not placed close to a corner or perimeter wall. Sufficient ventilation is in place and there is no risk of people breathing out right on top of the sensor [14].

The height is chosen to be just above eye level. Eye level would be more optimal, but risks are that students start playing around with the sensor and damaging it by doing so. Placing the sensor just above eye level however, means it is more out of sight and therefore safer.

5. RESULTS

During the project, multiple data sources have been used. First of all did the homemade sensor provide data about the temperature, humidity and level of CO2 inside the UB. A commercial sensor was put next to the homemade sensor. The data extracted from the commercial sensor is regarded as reliable, and therefore usable for validation of the homemade sensor. Data from the wifi access points closely located to the sensors will tell how many devices approximately have been in the room. The feedbackNow system has been collecting end-user feedback about the temperature. All the results of these data sources will be both provided and discussed below.

5.1 Homemade sensor

The CO2 component of the homemade sensor was not working well during the first week of the measurements. It has been fixed before the second week started. This issue caused the absence of PPM data during week 23. Dust refers to the number of dust particles measured. PPM is the value in which CO2 is being expressed. Temp. is an abbreviation of temperature, values being in degrees of Celsius. The values of Humidity are given in percentages.

Table 1. Average values per day during week 23

Date	Dust	PPM	Temp.	Humidity
4	1167,813		24,304	52,429
5	1255,285		24,099	47,928
6	1098,616		24,272	47,092
7	1105,413		24,465	49,331
8	1135,333		24,416	54,465
9	1163,714		24,178	55,192
10	1148,827		24,115	53,779
Total	1153,572		24,264	51,459

As can be seen in the data of week 24, the dust values are significant lower than during the previous week. The extremely high value for the 11th of June cannot be fully explained. The significant higher values for June 4th – June 11th are caused by the remodelling of the open space that took place during that period. The extreme low value of PPM on June 11th can be explained by the absence of data during the first few hours of the day providing a 0 value as input. This should be taken into account when using the data.

Table 2. Average values per day during week 24

Date	Dust	PPM	Temp.	Humidity
11	1641,110	399,540	24,290	46,909
12	461,724	601,296	24,201	43,357
13	506,730	581,107	24,102	41,000
14	475,957	570,270	24,090	42,793
15	507,699	526,931	24,006	48,392
16	495,629	505,305	24,013	46,162
17	482,106	544,906	24,089	43,905
Total	652,994	532,765	24,113	44,645

As can be concluded from table 3, there is no data collected on June 19th until June 21st. This is due to a firmware crash, causing the data to not be transferred into the database. The crash happened on June 18th, 14:41. It was fixed on June 22nd, 15:45. This should be taken into account when analysing the data of these two days.

Table 3. Average values per day during week 25

Date	Dust	PPM	Temp.	Humidity
18	534,441	535,081	24,072	46,108
22	710,565	620,959	24,360	40,104
23	1033.275	552,079	24,154	39,713
24	683,290	625,679	24,158	43,309
Total	740,393	583,450	24,186	42,309

The connection with the database got lost again on June 27th. It happened early morning, meaning the values for date 27 represent only the data from 00:00 until 08:01.

Table 4. Average values per day during week 26

Date	Dust	PPM	Temp.	Humidity
25	543,707	660,880	24,087	46,345
26	558,153	635,727	24,056	43,638
27	599,409	438,587	23,796	45,174
Total	560.090	578,398	23,980	45,052

5.2 Commercial sensor

During week 23 no measurements have taken place by the commercial sensor due to logistical issues. The initial sensor that was used for validating the homemade sensor did not contain a CO2 sensor. Only in week 25 a sensor with a CO2 component became available.

Table 5. Average values per day during week 24

Date	Temperature	Humidity
11	23,721	47,632
12	23,535	44,448
13	23,230	41,728
14	23,371	45,887
15	23,220	50,454
16	23,296	47,096
17	23,336	45,174
Total	23,387	46,060

Table 6. Average values per day during week 25

Date	PPM	Temperature	Humidity
18		23,284	48,634
19		23,373	52,178
20		23,550	54,360
21		23,477	51,368
22		23,470	42,172
23	618,500	23,375	40,853
24	603,708	23,301	43,294
Total	611,104	23,404	47,551

Table 7. Average values per day during week 26

Date	PPM	Temperature	Humidity
25	677,130	23,331	47,741
26	710,053	23,359	45,152
27	639,396	23,311	46,790
28	628,982	23,645	46,475
Total	663,890	23,412	46,540

5.3 Wifi data

The values in the tables down below represent the # of devices that were tracked by the wifi access points close to the location of the sensors. These devices have not been converted into real people. This project focusses on trends meaning no exact numbers need to be used. By using high numbers of devices though, it is safe to say that an increase in the # of devices also means an increase in the # of people.

Table 8. Amount of #devices per day during week 24

Date	#Devices
11	2734
12	2782
13	2343
14	2831
15	2003
16	904
17	1492
Total	2156

Table 9. Amount of #devices per day during week 25

Date	#Devices
18	2539
19	3226
20	3799
21	3478
22	2371
23	1743
24	1910
Total	2724

Table 10. Amount of #devices per day during week 25

Date	#Devices
25	4186
26	4441
27	3346
28	3431
Total	3851

5.4 FeedbackNow data

Before taking a look at the actual feedbackNow data, it should be noted that the system has been in use for almost two years now. This is important to realize for the following two reasons. First of all, this means the UB is past the first trial period in which they had to find out how exactly to put this system to good use. Next however, this also means that the users have been getting used to the system being around. According to Olga Steen, who is in charge of the system, a significant decrease can be seen in the amount of feedback given. During the first few months after putting the system into practice, lots of users were willing to give their feedback. After two years however, users are only willing to give their feedback when something is wrong. This is an important factor to take into account when analysing the data.

The specific question that was asked to the users was: Temperature in here ok? In total, three boxes containing this question were placed across the library. One of these boxes (box #8) was placed close to the location of the sensors and is therefore most relevant. The remaining two boxes will be added in order to create an overview of the total feedback given.

Below an overview is given of both box #8 as well as the total of all three boxes. Week 26 contains the data from Monday (25th) until Thursday (28th).

Table 11. Box #8

Week #	Green	Yellow	Red
Week 21	38%	25%	38%
Week 22	100%	0%	0%
Week 23	71%	0%	29%
Week 24	33%	0%	67%
Week 25	86%	14%	0%
Week 26	100%	0%	0%

Table 12. Total

Week #	Green	Yellow	Red
Week 21	48%	22%	30%
Week 22	62%	4%	34%
Week 23	50%	21%	29%
Week 24	40%	20%	40%
Week 25	86%	7%	7%
Week 26	33%	17%	50%

The goal of collecting this feedback is to get an insight in the end-user experience. Important factor therefore are the moments the red smiley is being pressed. These indicate an unhappy user. Down below a list is given of these specific moments in time for the most relevant smiley box.

Table 13. Red smileys box #8

Date	Time
24/5	12:14
26/5	11:36
06/6	21:57
10/6	15:45
13/6	19:39
15/6	14:41

6. DISCUSSION

6.1 Sensor costs

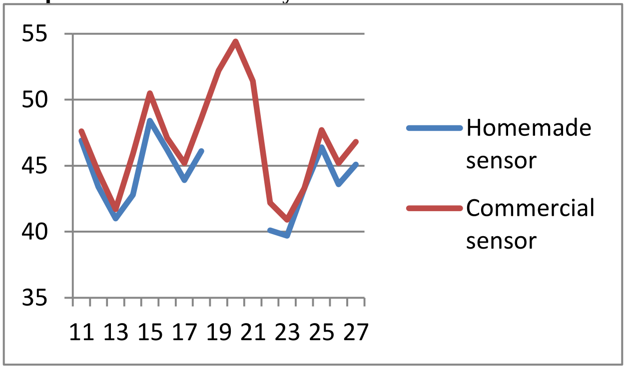
As mentioned in part 2.1, the sensor was created during a previous project. This project took place from February until April on behalf of the cleaning company Asito. The project team consisted of three Business & IT students of which only one had some experience with the technology. According to planning, the project took only ten weeks in total. During this time research was done, the components were ordered and the sensor was constructed. During the last two phases, the students got assisted by an employee who got some more experience on the technology. As can be found in appendix B.1, the total costs of one sensor are just €85,51. It should be noted that none of the project members spent all of their time on the project. Instead, the students only spent 2 à 3 days a week working on the project, whereas the employee of Asito was needed for just a couple of hours a week. Combining all factors of time, money and effort, it is safe to say this homemade sensor is very easy to come up with.

6.2 Sensors comparison

In general, during summer time the recommended indoor temperatures are between 22.7° and 25.5° Celsius [15]. Even though a difference exist in values between the homemade sensor and the commercial sensor, all data collected is inside this range. The homemade sensor appears to always measure higher values compared to the commercial sensor. However, this difference is very constant in a range of 0.7 – 0.9 degrees Celsius. Thus, even though the absolute values provided by the homemade sensor are not fully correct, the temperature measurement component (BME280) turns out to be reliable. Next time however, the component should be calibrated first before putting it to use.

Humidity level should be between 40% and 50%, whilst during winter time it might have to drop somewhat below 40% to prevent condensation on windows [16]. Most of the data collected by both the homemade sensor as well as the commercial sensor turns out to be inside this range, despite some values being just above 50%. Even though the humidity level seems to fluctuate a lot at the measurement location, there is not a huge difference between both sensors (see graph 1). Thus, although the values of the homemade sensor appear to be a little lower, the humidity measurement component (also BME280) proves itself reliable as well.

Graph 1. Level of humidity



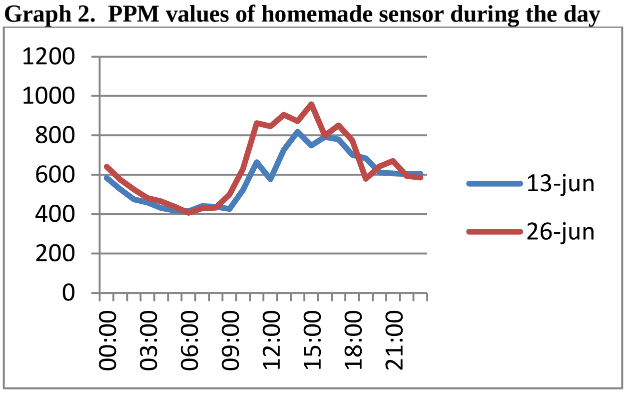
According to general guidelines on indoor health quality, the indoor CO2 level should stay below 1000ppm [17]. When analysing the data extracted from both sensors this appears to be the case at the measurement location. Values extracted from the homemade sensor tend to be lower compared to the commercial sensor (as well as the FM data). Furthermore the same pattern can be observed in all data sources: during night time the CO2 level always decreases till it reaches a certain level. It will then remain constant at this level until people start entering the area. More research should be done in order to further validate the CO2 measurement component (MH-Z19).

6.3 Busy weeks analysis

As mentioned above, the dust values started of very high due to remodelling of the measurement location. Once the remodelling was done, the dust values seem to overall increase over time. However, the values differ a lot from day to day. More and longer measurements are needed in order to come up with conclusions.

The PPM values visualise best the difference between the first two busy weeks and the last two busy weeks. An overall steady increase can be found when analysing the data. However, during night time the PPM values always get reduced to the same level, just above 400. Meaning every morning, the PPM values start at the same level. It should be mentioned however, that in the last two weeks it takes the ventilation system more time to reduce the PPM level compared to the first two weeks. The red line only comes close to the 400-level at some point early in the morning whereas the blue line reaches that level way earlier and remains at that level for a longer period (see graph 2).

Graph 2. PPM values of homemade sensor during the day



Both the temperature and the humidity are not influenced by the increase of visitors of the measurement location. The temperature remains constant at the same level over the weeks, whereas the humidity differs per day without representing any increase or decrease trend whatsoever.

6.4 Sensor data vs other data sources

After analysing both the wifi data and the sensor data, one potential correlation can be found. When the number of devices increases, also the level of PPM increases. Graph 2 shows a higher value of PPM during the day at the 26th of June (average: 636) compared to the 13th of June (average: 581). When comparing two days, both the absolute as well as the average PPM values will be higher for the day during which most devices were tracked. But also when zooming in on one specific day, the level of PPM increases when the number of devices increases. Below are three tables of representative moments during June 26th, showing the correlation between the number of devices and the PPM level.

Table 14. Correlation #devices and PPM June 16th #1

Time	#Devices	PPM
08:35	6	438
08:45	10	463

Table 15. Correlation #devices and PPM June 16th #2

Time	#Devices	PPM
08:45	8	557
09:55	15	631

Table 15. Correlation #devices and PPM June 16th #3

Time	#Devices	PPM
15:40	49	935
16:10	35	660
16:25	41	864

The temperature remained very constant during day time. All values measured were inside the range of 23.8 and 24.5 degrees Celsius. Furthermore, neither humidity nor dust values showed any sign of a potential correlation with the wifi data.

After analysing both the sensor data and the feedbackNow data, no correlation was to be found. During the moments at which the red smiley was pressed, no extraordinary temperatures (or PPM values) were measured. As mentioned above, the temperature remained at a very constant rate. Therefore it can be concluded that the feedbackNow data turns out to be subjective. Users do differ in preference for indoor temperature, consequence is that some users are not happy with the current indoor temperature.

7. CONCLUSIONS

Constructing a homemade sensor is very easy. Getting it to the point of using it for empirical research takes a lot more time though. In order to build a first reliable prototype, only basic knowledge of the technology together with some time and money are needed. Upgrading the sensor to be fully validated and reliable needs a lot more projects, meaning more time and skill. However, once the process is over it offers a lot of potential for new business cases. Given the low costs and the level of reliability and validity achieved with the first prototype, it is definitely worth giving it a shot if in possession of the basic knowledge.

The construction of a basic homemade sensor can be very cheap. In just one project of about ten weeks, with a total construction cost of 85 euros, research as well as the construction itself can be accomplished. However, before putting it to commercial use lots of projects need to be run in order to further improve the sensor by validating the components together with gaining further information about the data collected. Also the firmware needs to be updated frequently in order to assure a more reliable connection with the database. Therefore it can be concluded that a working prototype can be constructed fairly easy whereas a fully reliable and validated sensor takes a lot more time and skill to establish.

Even though the absolute values of the data collected differ between the homemade sensor compared to the commercial sensor, the data shows the same trends. Meaning although the temperature/humidity measurement component (BME280) is not fully valid, it is reliable. Given the fact that the same trends are detected when analysing the data of the homemade sensor compared to the other data sources, the CO2 measurement component (MH-Z19) can be marked as reliable as well. However, further research has to be done about its validity.

A real difference between the busy weeks can only be noticed when comparing the PPM data of both periods. During day time the PPM values are much higher during the last two busy weeks. However, during night time the ventilation system (barely) manages to reduce the PPM values to the same level of just above 400. Meaning if even more visitors are expected, the ventilation system needs a boost in order to keep control of the CO2 level.

The cause for the higher CO2 level in the last two weeks compared to the first two weeks is the increase in the amount of visitors. Whenever a significant increase in the number of devices tracked is detected, the PPM values rise as well and vice versa. Meaning if a busy period is coming up, the ventilation system can be pre adjusted reckoning with an expected increase in PPM.
When analysing both the feedbackNow data and the homemade sensor temperature data, no correlation was to be found. The feedbackNow data being subjective decreases its functionality. In order to become useful for exploring potential correlations, more end-user input is needed.

7.1 Limitations and future work

Due to limited time, the project could not cover every single aspect. Data could only be measured for a couple of weeks, whereas a longer time period would be desirable. Also just one sensor was available. This means only one location could be measured. In order to get a better insight in the level of indoor air quality, it is recommended to make use of multiple sensors across the room. Furthermore a first prototype of the homemade sensor was used. Since none of the components have been validated yet, the reliability of the data extracted cannot be guaranteed. In the future these components should be validated more thoroughly. The wifi data used during this project contains the # of devices instead of the # of people. This means no analysis can be done based on a potential correlation between the # of people and the values of the air quality.

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6. APPENDIX

APPENDIX A: Experts Interviews

NAME	FUNCTION	DATE
Mert Alberts	CIO at Asito	02-05-2018
Roy Tibben	Business Development Manager at Asito	14-05-2018
Arjan Geurtsen	Business Development Manager at Asito	07-05-2018
Olga Steen	Head of Operations & Learning Services at UB	18-05-2018
Jeroen van Ingen	Network Engineer at UT	04-06-2018
Sander Smit	Project Leader at UT	31-05-2018
Andries Klijnstra	Campus & Facility Management at UT	04-06-2018

APPENDIX B: Homemade Sensor

B.1 Hardware Costs

Component	Price in €
Wemos D1 mini	6,50
Dupont wires (3x)	1,50
5V adapter	8,00
Breadboard	4,00
Pushbutton	0,15
Sharp GP2Y10	10,00
OLED display	7,00
HC-SR505	3,50
BME280	4,50
BH1750	3,50
USB cable	1,50
MH-Z19	35,36
Total	85,51

B.2 Construction

Down below an overview of the construction of the sensor is given. Furthermore is shown how the components are connected.