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Icon of the Mobile App Named "Smart Water"

Monitoring of Household Water Use and Controll of Pressure with Internet of Things and Cloud Database

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Content

Abstract

Parallel to the rapid population growth, the worldwide demand for water is increasing while the accessible water resources do not increase and even decrease as a result of pollution. For this reason, the emerging water scarcity situation is becoming a bigger problem day by day. The concept of water literacy is gaining more importance today when the conscious use of water has become more necessary than ever before. Turkey is among the countries experiencing water stress with a usable water amount of 1500 $m3$ per capita. It is known that this value will continue to decrease in the coming years due to the increasing water demand. In this case, the only way to meet the increasing demand with the current water resources we have is to increase the efficiency of water use and make changes in our consumption habits. Water resources in the world are used in 3 areas: agriculture, industry and households. Although there are technology-integrated studies aiming to reduce agricultural and industrial water consumption in the literature, no studies have been found that are integrated with the Internet of Things and cloud database targeting household water consumption. In this project, a model was created that will contribute to increasing awareness and control of water use by ensuring that households have access to detailed water consumption information and have a water use limitation system. In this model; there are smart water meters that create usage data, a mobile application integrated with the internet of things and cloud database that provides a detailed display of this usage (instant display of usage in liters, instant display of water bill, monthly display and categorised display according to usage areas in the home) and a pressure reducing system which works under the control of this mobile application and supports the household to limit water use. As a result of testing the model, the functions of the mobile app work as desired. Moreover, when the pressure reducer is activated, it creates a stimulating effect and provides a 12.5% water usage reduction. It is thought that if the model is put into widespread use, it will increase awareness and decrease water use.

Keywords: Water literacy, mobile application, internet of things, cloud database, smart pressure reducer, smart water meters

1.Project Purpose

It has become a necessity to replace traditional water consumption models that cause great waste to economical and conscious water consumption models.

Therefore, the purpose of the project created is to develop a new model that;

1- Presents the water usage information obtained from various sensors to the user by putting them into consumption categories and consumption amount via a real-time cloud database;
2- Provides instant access to the city-based pricing of consumption;
3- Delivers information about consumption to the user with various graphics, indicators and user-friendly interface in the mobile application;
4- Contains a pressure reducing system aiming to provide concrete limitation of water usage;
5- Controls the water consumption in the house by using the internet of things technology connected to the cloud database.

2. Introduction

2.1. Water in the World

Imbalance between water resources and water demand form the basis of water problems.

2.1.1. World Water Resources

“If you look at the world map, it is seen that 75% of the earth is covered with water. However, only 2.5% of these waters correspond to fresh water resources. Considering that 70% of these freshwater resources are hidden in glaciers, the accessible freshwater resource is less than 1% of the total water amount. (“Türkiye’nin Su Riskleri Raporu”, 2014, p. 7).

2.1.2. Distributions of Water Consumption and Water Footprint in the World

Three main areas where water resources are used can be counted: agriculture, industry and household consumption. Worldwide, 70% of the total water is consumed in agriculture, 22% in industry and 8% in homes. (“On Birinci Kalkınma Planı”, (2019-2023) Su Kaynakları Yönetimi Ve Güvenliği Özel İhtisas Komisyonu Raporu”, 2018, p.40).

A general trend is that industrialized countries have a larger water footprint associated with the consumption of industrial products than developing countries. In addition to the effect of consumption model, production efficiency is also effective in this distribution (Hoekstra and Mekonnen, 2012, p.3)

2.1.3. Future Foresights

According to Boretti and Rosa (2019), the extending gap between water demand and capacity brings with it certain predictions: By 2050, 6 billion people (40 % of the world population) will face clean water shortage. If adequate measures are not taken to meet the basic needs, conflicts will arise, examples of which can be seen even today in areas suffering from water scarcity.

2.3.Water in Turkey

“Turkey is among the countries experiencing water stress with a usable water amount of 1500 $m3$ per capita. For this reason, the protection of existing water resources, the development of alternative water resources, the use and dissemination of technologies compatible with the ecological environment, the creation of sustainable water policies which are considered to be parameters to sustainable development have an important place in the country's agenda. (“Su Kaynakları Yönetimi Ve Güvenliği Özel İhtisas Komisyonu Raporu”, 2018, p.9).

If the Falkenmark Indicator values are analyzed in terms of whole Turkey and by years, it is realized as 1,422.23 m^3/person in 2015 and this has made Turkey a country with "water stress". In 2017, this value decreased to 1386 m^3/person. The water potential of water-stressed Turkey will be around 1.289 m^3/person with a population of 87 million expected in 2023, and around 1100 m^3/person with a population of 100 million expected in 2030 (Hakyemez, 2019, p.11-27).

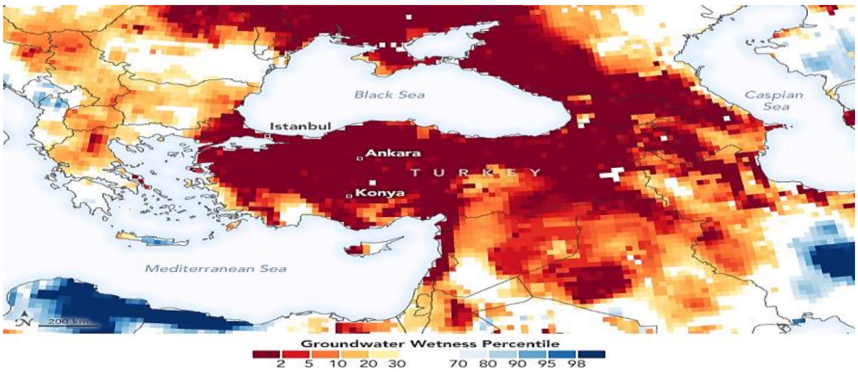

Figure 1. Shallow Groundwater Storage in Turkey as of January 11, 2021 (Patel, 2020)

The map in Figure 1 shows shallow groundwater by the Gravity Recovery and Climate Experiment Monitoring (GRACE-FO) satellites. The colors show how the percentage of wetness or the amount of groundwater compares to long-term records (1948-2010). Blue areas have more water than normal while orange and red areas have less water (Patel, 2020). As can be seen, Turkey is a country that loses its water resources day by day.

2.4. Household Water Consumption

Household consumption, which is the main focus of the project, is one of the 3 pillars of water consumption worldwide. "54% of the world population lives in cities. By 2050, the urban population is expected to increase to 66%. Growing cities with their increasing populations are an important pressure factor on the water resources and ecosystems that develop water (forested areas, pastures, etc.). Domestic water use is evaluated on the basis of daily water consumption per capita. In developed countries, the average daily water consumption per capita (500-800 m^3) is about ten times the water consumption in developing countries. In regions with water scarcity, this rate drops to 20-60 m^3 per person per day. In 2025, agricultural water use is expected to increase by 1.3 times, industrial water use by 1.5 times, and domestic water use by 1.8 times. 18% of the total increase is expected to be in developed countries and 50% in developing countries."(https://sutema.org)

This situation shows that the role of household consumption in total consumption will increase significantly. With the help of this study, we aim to increase the awareness on the water problem, which has become a global issue, and change the consumption habits of the households.

2.4.1 Uses of Water at Homes and What can be done to Reduce Consumption

Studies have shown that "About 26% of the water used at home is used in toilets, 22% in washing machines, 17% in showers, 16% in taps, 2% in bath tubs and 3% in other areas; 14% of it is lost in leakages in domestic installations."(https://sutema.org/gelecekin-suyu/evsel-su-tuketimi.18.aspx) In addition to their daily water use, citizens see how much water is used to produce the products they consume. They should be able to recognize and establish the link between their consumption habits and water scarcity and deteriorating water quality. This is the first step of a total action in terms of the future and sustainablity of not only the province, region or country we live in, but also the whole world and all living things. Apart from this, they can both contribute to their own budgets and show sensitivity on behalf of future generations in terms of water saving with simple but effective efforts (Özkan, M. 2019). In the light of all these, awareness regarding water consumption should be increased by taking the problem awaiting our world into account .

With this study, it is desired to develop a software that can be easily adapted to homes and reduce water consumption with a mobile application, rather than due diligence.

2.5. Internet of Things

The concept of "internet of things", first used by Kevin Ashton in 1999 when he introduced a new supply chain model, has grown in popularity ever since and its usage areas have diversified considerably. It is used in many areas from industrial production areas to smart home systems, from wearable technologies to the entertainment industry. (Ashton, 2009).

The reason why we chose to work with the internet of things is that it has very effective features such as working with wireless connection systems, providing simultaneous or very close to simultaneous viewing through the designed software and having no physical boundaries in the field of activity. Besides, it is very suitable for development.

2.6. Previous Studies

Mario A. Paredes-Valverde et al. have created an IoT-based support tool for home energy saving, which they call IntelliHome, based on large amounts of data from the home network. This system was able to reduce electricity consumption between 7.9% and 13.9%. (https://doi.org/10.1111/coin.12252)

Peng Zhang et al.'s work builds an intelligent irrigation system platform that can realize real-time monitoring of crop growth environment information, providing visualization based on the internet of things and big data. (https://doi.org/10.1109/CSE-EUC.2017.258)

Although IoT technologies are used in electrical appliances in smart home systems and in the agricultural industry, no similar study has been found in the literature with an integrated IoT and cloud database targeting household water consumption.

Using the internet of things, cloud database technologies and specially designed pressure reducer with a focus on reducing household water consumption is the unique aspect of this project.

2.7. Research Question

In order to reveal the problem, a sample group was taken from the household, which is the main target group of the project, and a questionnaire was applied. The survey was prepared and applied using Google Forms as an online survey instead of the traditional physical survey due to the restrictions caused by covid-19. The questionnaire was sent to the people in Aydın, the province. The questionnaire was applied to 673 men and women with 4 different income levels, 6 different education levels and working in 12 different business areas.

85% of the participants said that they are conscious about the use of water. Of those who gave these answers, 42% stated that they did not know the billing in their city, 55% did not know how many tons of water they used as a household, 62% stated that the time they spent in the shower was more than 10 minutes, and 31% used the dishwasher every day. 50% of them did not know the true value of Turkey on the Falkenmark scale.

These results suggest that the actual level of consciousness of people who consider themselves conscious about water is lower than they stated or that they do not fully reflect this level of consciousness to their daily consumption habits.

The availability of a mobile application and pressure reducing system based on Internet of Things and cloud database technologies was investigated in order to increase the awareness of individuals and water control in their households.

3.Method

3.1. Main Scheme

Model consists of 3 main components: Water metering system, mobile app and pressure reducing system.(Figure 2) The water measurement systems, which are planned to be installed on the water inlet pipes of the sections such as sinks, showers, dishwashers, where the amount of water used is intended to be measured, creates the data and sends it to the appropriately designed database. Firebase, a real-time cloud database developed by Google, was used as the database. The mobile application draws and processes data from Firebase and presents water usage data to the user with indicators, graphics and a user-friendly interface. A specially designed pressure reducing system, which will be controlled by the mobile application, has been added to support usage limitation and create a stimulating effect for users. This system constantly checks the pressure reducer status in the Firebase database and reduces the pressure in the pipe it is connected to if an activation command is received.

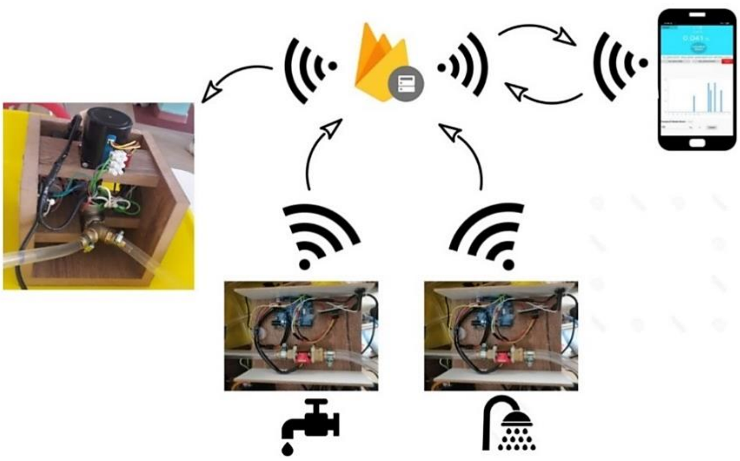

Figure 2. Main Scheme of the Model

3.2. Smart Water Meter

YF-B2 Flow Meter was used in the design of water measurement systems. Arduino Uno was used as the development board and NodeMCU was used to transmit water usage data to Firebase database. The power input of the system is provided with a 12V 2A DC adapter. (Figure 3)

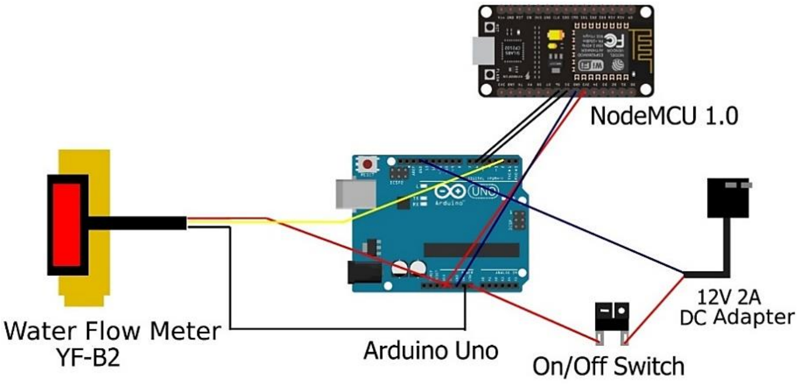

Figure 3. Circuit Diagram of Smart Water Meter

Arduino programming is done in Arduino IDE with Arduino Programming Language. Communication with Firebase database is established with NodeMCU Wifi card.

An open source code has been added to enable the YF-B2 Flowmeter to work, connected to the pipe where the water flow amount is wanted to be measured. (https://www.instructables.com/How-to-Use-Water-Flow-Sensor-Arduino-Tutorial/) Then, the NodeMCU code was written, which received the translated flow data from Arduino. In this code, the flow data has been converted to the average liter per minute data and finally this data has been transferred to the Firebase database.

3.3. The Mobile App Named "Smart Water"

The mobile application was created on Android Studio using the Java programming language.

3.3.3.1. Features That Give Instant Display of Water Usage in Liters and Water Bill

For this function, variables are assigned to separately extract the total usage data in milliliters from the 1st and 2nd smart water meters from Firebase. Then, using these data, a variable that will give the total amount of water consumed in liters is assigned (Figure 4).

A code has been written to send the total water usage data in the form of continuous notification.

The amount charged for water per m^3 for 7 capitals of 7 selected countries as an example were taken from official websites and assigned to the relevant variables. (If current prices cannot be found on official sites, the values on the site are accepted: http://waterstatistics.iwa-network.org/graph/16) Then, the VAT was also included in this account, and the total amount to be paid for the amount of water was obtained (Figure 5). The value based on that country's currency was created.

```java
ref.addValueEventListener(new ValueEventListener() {
    @Override
    public void onDataChange(@NonNull DataSnapshot snapshot) {
        total1=snapshot.child("Total1").getValue().toString();
        total2=snapshot.child("Total2").getValue().toString();

        total3 = (Float.valueOf(total1)+Float.valueOf(total2))/1000;

        total1int = snapshot.child("Total1").getValue(Integer.class);
        total2int = snapshot.child("Total2").getValue(Integer.class);

        total1day = snapshot.child("Total1day").getValue(Integer.class);
        total2day = snapshot.child("Total2day").getValue(Integer.class);

        total3day = (Float.valueOf(total1day)+Float.valueOf(total2day))/1000;
```

Figure 4. Data Extraction from Firebase

```java
//Japan 218¥/m3 tax included
public void japan(){
    double japanSuTL = total3*0.218;
    double japanTotalTL = japanSuTL;
    TL = japanTotalTL;
    strTL = Double.toString(TL);
    b.setText(strTL);
    f.setText("¥");
}
//Sweden 36.24kr/m3
public void sweden(){
    double swedenSuTL = total3*0.03624;
    double swedenTotalTL = swedenSuTL;
    TL = swedenTotalTL;
    strTL = Double.toString(TL);
    b.setText(strTL);
    f.setText("kr");
}
//Turkey 3,33TL/m3
public void turkey(){
    double turkeySuTL = total3*0.00333;
    double turkeyKDV= (turkeySuTL*8)/100;
    double turkeyTotalTL = turkeySuTL+turkeyKDV;
    TL = turkeyTotalTL;
    strTL = Double.toString(TL);
    b.setText(strTL);
    f.setText("₺");
}
//USA 1.28$/m3
public void usa(){
    double usaSuTL = total3*0.00128;
    double usaKDV= (usaSuTL*15)/100;
    double usaTotalTL = usaSuTL+usaKDV;
    TL = usaTotalTL;
    strTL = Double.toString(TL);
    b.setText(strTL);
    f.setText("$");
}
```

Figure 5. City-specific calculation of the invoice to be paid for the water used

3.3.3.3. The Feature That Creates the Distribution Of Water Usage in the Month and Shows It in Graphical Form

For this graph, a variable that states the information as to what day of the month it is (date variable), is assigned first. Then, a database and name list were created with the help of the AnyChart library (Figure 6). Then the date variables in the Firebase library were assigned to the date variables in Android Studio. (Figure 7) These created date variables were added to the database created with

AnyChart (Figure 8, Figure 10) . In order to control these variables day by day and reset them at the beginning of each month, the control functions structure was created (Figure 9).

```java
Calendar calendar = Calendar.getInstance();
int day = calendar.get(Calendar.DAY_OF_MONTH);

Cartesian kartezyen = AnyChart.column();

List<DataEntry> data = new ArrayList<>();
```

Figure 6. Creating a Monthly Usage Graph

```java
day1=Float.valueOf(snapshot.child("zday1").getValue().toString());
day2=Float.valueOf(snapshot.child("zday2").getValue().toString());
day3=Float.valueOf(snapshot.child("zday3").getValue().toString());
day4=Float.valueOf(snapshot.child("zday4").getValue().toString());
day5=Float.valueOf(snapshot.child("zday5").getValue().toString());
day6=Float.valueOf(snapshot.child("zday6").getValue().toString());
day7=Float.valueOf(snapshot.child("zday7").getValue().toString());
```

Figure 7. Assigning Day Variables to Firebase

```java
data.add(new ValueDataEntry( x: 1,day1));
data.add(new ValueDataEntry( x: 2,day2));
data.add(new ValueDataEntry( x: 3,day3));
data.add(new ValueDataEntry( x: 4,day4));
data.add(new ValueDataEntry( x: 5,day5));
data.add(new ValueDataEntry( x: 6,day6));
data.add(new ValueDataEntry( x: 7,day7));
```

Figure 8. Defining Generated Variables to Graph Database

```java
if (day==1){
    if(dayC!=1){
        database.getReference( path: "Total1day").setValue(0);
        database.getReference( path: "Total2day").setValue(0);
    }
    database.getReference( path: "zday1").setValue(0);
    database.getReference( path: "zday2").setValue(0);
    database.getReference( path: "zday3").setValue(0);
    database.getReference( path: "zday4").setValue(0);
    database.getReference( path: "zday5").setValue(0);
    database.getReference( path: "zday6").setValue(0);
    database.getReference( path: "zday7").setValue(0);
```

Figure 9. Day Control Functions Structure

```java
else if (day==2){
    if(dayC!=2){
        database.getReference( path: "Total1day").setValue(0);
        database.getReference( path: "Total2day").setValue(0);
    }
    dayC=2;
    database.getReference( path: "zday2").setValue(total3day);
    data.add(new ValueDataEntry( x: 2,day2));
}
else if (day==3){
    if(dayC!=3){
        database.getReference( path: "Total1day").setValue(0);
        database.getReference( path: "Total2day").setValue(0);
    }
    dayC=3;
    database.getReference( path: "zday3").setValue(total3day);
    data.add(new ValueDataEntry( x: 3,day3));
}
else if (day==4){
    if(dayC!=4){
        database.getReference( path: "Total1day").setValue(0);
        database.getReference( path: "Total2day").setValue(0);
    }
    dayC=4;
    database.getReference( path: "zday4").setValue(total3day);
    data.add(new ValueDataEntry( x: 4,day4));
}
else if (day==5){
    if(dayC!=5){
        database.getReference( path: "Total1day").setValue(0);
        database.getReference( path: "Total2day").setValue(0);
    }
    dayC=5;
    database.getReference( path: "zday5").setValue(total3day);
    data.add(new ValueDataEntry( x: 5,day5));
}
```

Figure 10. Adding Generated Variables to Graph Database

3.3.3.4. The Feature That Categorizes and Graphically Displays Water Use

For this function, a database and a list of names were created with the help of the MPAndroidChart library. The data from the 1st and 2nd water meters were labeled with the names of “bathroom” and “kitchen”. The function that will allow these labels to be displayed as a pie chart on the application was created using the graphic library (Figure 11)

```
List<PieEntry> kategoriEntries = new ArrayList<>();
kategoriEntries.add(new PieEntry(total1int, label: "Bathroom"));
kategoriEntries.add(new PieEntry(total2int, label: "Kitchen"));
PieDataSet kategoriDataSet = new PieDataSet(kategoriEntries, label: "");
PieData kategoriData = new PieData(kategoriDataSet);
int[] colorClassArray = new int[]{Color.BLUE,Color.CYAN,Color.RED,Color.DKGRAY};
kategoriDataSet.setColors(colorClassArray);

PieChart kategoriChart = (PieChart)  findViewById(R.id.kategoriChart);
kategoriChart.getDescription().setEnabled(false);
kategoriChart.setData(kategoriData);
kategoriChart.invalidate();
```

Figure 11. Creating the Category Chart

3.3.3.5. Features that Manually and Automatically Control the Operation of the Pressure Reducer

For automatic operation, a text box has been created where the savings limit will be written first. Afterwards, an indicator that will receive information on whether the water usage will be controlled according to water bill or Liter type through the application was created. According to this information received, the relevant value is changed. If the specified saving limit is reached, the value indicating the status of the smart pressure reducer in Firebase is changed to activate the pressure reducer.(Figure 12)

"Open Saving" and "Close Saving" buttons have been created in the application for manual work. Then, the functions that are triggered when these buttons are tapped were created. If one of the buttons is tapped, the relevant function changes the variable containing the pressure reducer status information in Firebase to activate or deactivate the pressure reducer. (Figure13)

```java
if (edittextN==1){
    if (edittextNC==1){
        EditText sinirsayiET = (EditText) findViewById(R.id.editTextNumber);
        if (TL>=Integer.valueOf(sinirsayiET.getText().toString())){
            FirebaseDatabase database = FirebaseDatabase.getInstance();
            ref = database.getReference( path: "PressureChamber");

            ref.setValue(1);
            sinirOff();


        }
    }
}
else if (edittextN==2){
    if (edittextNC==1) {
        EditText sinirsayiET = (EditText) findViewById(R.id.editTextNumber);
        if (total3 >= Integer.valueOf(sinirsayiET.getText().toString())) {
            FirebaseDatabase database = FirebaseDatabase.getInstance();
            ref = database.getReference( path: "PressureChamber");

            ref.setValue(1);

        }
    }
}
```

Figure 12. Auto Save Mode

```java
public void PCOn() {
    FirebaseDatabase database = FirebaseDatabase.getInstance();
    ref = database.getReference( path: "PressureChamber");

    ref.setValue(1);
    Toast.makeText(getApplicationContext(),  text: "Inserted", Toast.LENGTH_SHORT).show();
}
public void PCOff() {
    FirebaseDatabase database = FirebaseDatabase.getInstance();
    ref = database.getReference( path: "PressureChamber");

    ref.setValue(2);
    Toast.makeText(getApplicationContext(),  text: "Inserted", Toast.LENGTH_SHORT).show();
}
```

Figure 13. Pressure Reducer Manually Managed Code

3.4. Smart Pressure Reducer

In the design of the smart pressure reducer, a pressure regulator that reduces the pressure by reducing the diameter of the pipe it is attached to was used. A 230V motor was used by making special modifications for the automatic operation of the regulator, whose setting is normally adjusted manually by means of an allen key. Arduino Uno was used as the development board and NodeMCU was used to control the pressure reducer status information in the Firebase database. Since Arduino can work with a maximum of 5 volts, a system was prepared with 5V relays. The power input of the system is provided by a 12V 3A DC adapter connected to the Arduino. (Figure 14)

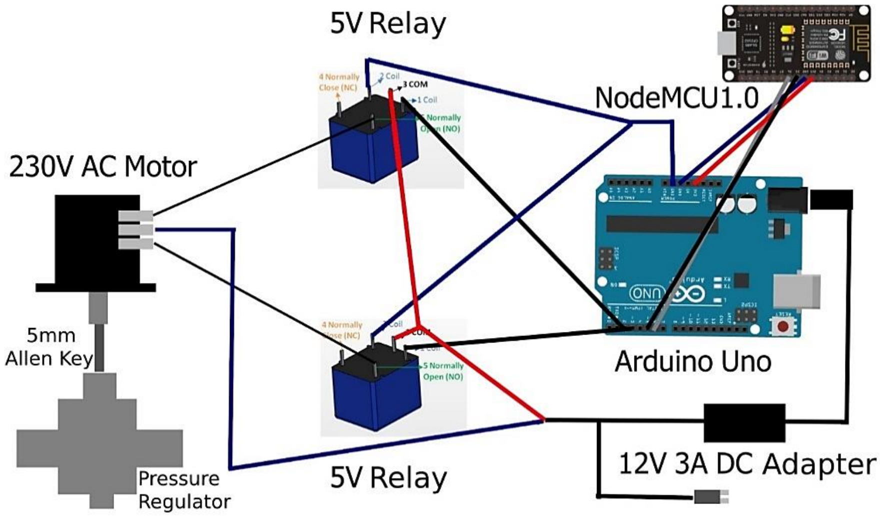

Figure 14. Circuit Diagram of Smart Pressure Reducer

Arduino and NodeMCU in the pressure reducing system are coded in Arduino IDE using Arduino Programming Language.

NodeMCU code has been written that will enable it to transfer the data it receives to Arduino for a certain period of time (1.15 minutes). In this code, a control function has been added to the code so that it does not send the same status information when the pressure is reduced or increased.

According to the data coming to the Arduino, the code was written to enable the regulator to be tightened or loosened by rotating the motor. When the regulator is tightened, the pressure decreases and thus the amount of water used is reduced.

3.5 Testing the Model

A tap was used to represent the kitchen, a shower head to represent the bathroom, water hoses to represent the water pipes in the houses, an aquarium engine to represent the water pressure in the houses, and a water engine for support. A bucket full of water was placed as a water source. Aquarium and water engine were placed in this bucket. the main hose which was connected to the water motor initially came to the pressure reducer. (Figure 15) 2 hose outlets were provided from the smart pressure reducer. These hoses passed through smart water measuring devices, one of them was connected to the tap and the other to the shower head. (Figure 16) Measured buckets were placed to collect the water ran from the tap and shower. (Figure 17)

Figure 15. Smart Pressure Reducer System

Figure 16. Smart Water Meter System

Figure 17. Prototype Overview

The created system was run for 1, 5, 10 and 20 minutes. In this way, it was tested if the water meters worked properly, processed the data correctly, sent the data to the Firebase center; the mobile application pulled this data from the Firebase database and finally if the mobile application features worked properly.

While the pressure reducer was active, the system was operated again for 1, 5, 10, 20 minutes. The water in metered buckets was measured. This measurement was compared to the first time measurement. In this way, it was tested how much savings the pressure reducer provided.

4. Results

The water metering system sends the data to the Firebase database and the mobile application pulls the data from the Firebase database.

During the run of the model, screenshots were taken that allow to examine the different features of the mobile application. (Figure 18-22)

Figure 18. USA/Washington **Figure19.** Turkey/Ankara **Figure 20.** Germany/Berlin **Figure 21.** Sweden/Stockholm

Figure 22. Notification

According to the mobile application reviews made after model was run for 1, 5, 10 and 20 minutes, instant water consumption in litters and water bill display and categorization features worked as predicted.

The total water data in the metered buckets obtained as a result of the test and the display data in liters of the total water used on the application have been tabulated. (Table 1).

Table 1. Water measurement success of the model

	Total water (liter) in metered buckets	Total water usage (liter) displayed in the application	Deviation margin
After 1 min	6.5	6.6	%2<
After 5 min	30.5	31.1	%2<
After 10 min	68.8	70.1	%2<
After 20 min	145.0	147.0	%2<

Table values are interpreted as a column chart. (Figure 23)

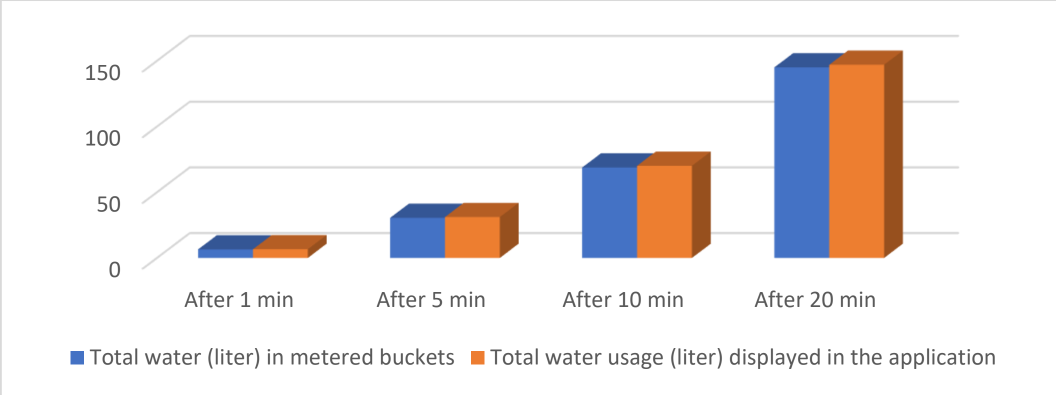

Figure 23. Comparison of Water Amount in Measured Buckets and Water Usage in Practice

Manual and automatic activation of the pressure reducer took place in 75 seconds as predicted. The total amount of water in the metered buckets after the pressure reducing system was run for 1, 5, 10 and 20 minutes and the total amount of water in the metered buckets in the first measurement made when the pressure reducer was closed were tabulated. (Table 2)

Table 2. Percentage of profit provided by the pressure reducer

	Total water (liter) in buckets when Pressure Reducer is not active	Total water (liter) in buckets when Pressure Reducer is active	Profit %
After 1 min	6.5	5.7	%13
After 5 min	30.5	26.8	%12
After 10 min	68.8	59.8	%13
After 20 min	145.0	127.6	%12

Table values are interpreted as a column chart. (Figure 24)

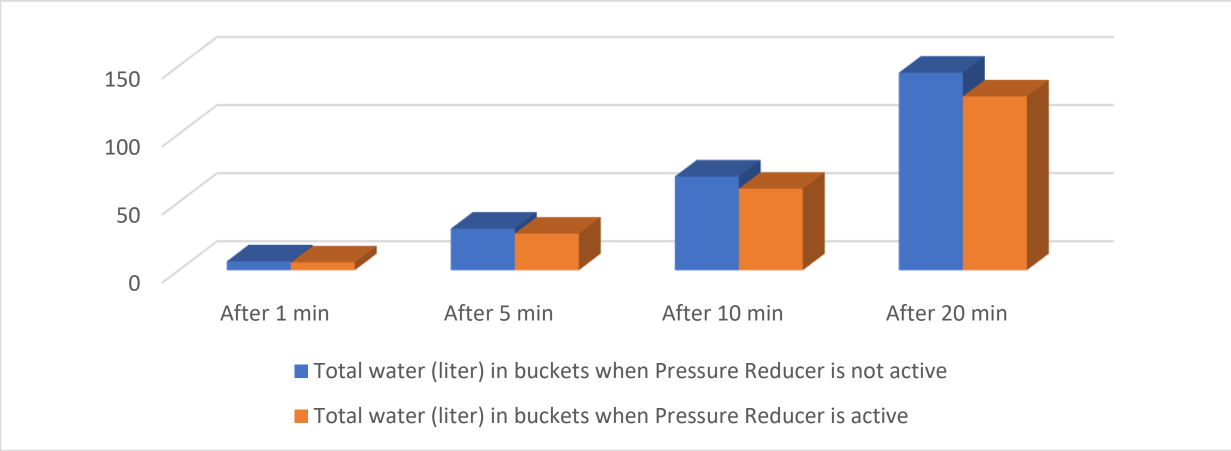

Figure 24. Comparison of Measured Amount of Water While Pressure Reducer is active and not active

The process of turning off the saving mode via the application took place as predicted.

5. Conclusion and Discussion

- According to Figure 18-21, It has been observed that the processes of collecting water measurement data of water meters, processing these data, transferring them to Firebase, and presenting these data to be displayed on the screen by the mobile application worked as aimed.
- According to Figures 18-21, it has been observed that the instant liter display feature in the mobile application works successfully. With this feature, it is believed that users who access household water usage information before the billing date will become conscious about water use and will reduce their water usage.
- According to Figures 18-21, it has been observed that the instant display of water bill feature in the mobile application works successfully. It is possible that the representation of the water used in liters will be meaningless for those who encounter these data for the first time. The display of the amount that will be reflected on the bill, as well as the display of liters, may enable users to establish the connection between water usage and its pricing more easily.
- According to Figures 20-21, it has been observed that the monthly usage display feature in the mobile application works successfully. Although the monthly total usage can be seen with the water bill, the distribution of this usage within the month is not known. It is aimed to solve this problem with the monthly display feature. Thus, it is thought that it will be easier for users to take steps towards reducing usage by seeing when they consume the most.
- According to Figures 18-19, it has been observed that the categorization feature in the mobile application works successfully. It is thought that categorising the use of water in the home,

which is one of the main starting points of the project, and showing it to the user, will have three main benefits:

1. Users have information about their own water consumption habits.
2. it will help users to decide to consume water more efficiently.
3. It will help users to observe the usefulness of the decisions taken.

- As seen in Figure 22, the notification feature worked as desired. Thanks to this feature, users will be able to access their total water usage data without having to enter the application.
- According to Figure 23, it has been observed that the measured value on the application is slightly higher than that accumulated in the metered buckets in all four measurement periods.
- Percentage deviation according to Table 1 has been measured as less than 2% at all four measurement periods. It is estimated that this deviation may have been caused by the water remaining in the hoses in the prototype, and the human related measurement errors during the test. It is thought that this margin of deviation will decrease if higher quality water measuring devices are used.
- The amount of water measured according to Figure 24 decreased after the pressure reducer was activated in all four measurement periods.
- According to Table 2, when the pressure reducer is used, a water usage reduction in the range of 12-13% is achieved. It is thought that the fact that the flexible water hoses, which are used to represent the fixed pipes in home plumbing systems, cannot be kept fixed in their initial position reduces the savings value. It is suggessted that this problem can be solved by designing a prototype more similar to the real one. In other words, the pressure reducer can provide a higher water usage drop in real conditions.
- The pressure reducer will help people reduce their water use. Withal, these profit rates may reach higher values when it is assumed that individuals who see the water usage data in the application will become more conscious water consumers.
- When looked at individually, it can be said that the decrease in the money spent for water will contribute to the household economy. On the country level, the budget spent for water supply might decrease due to the decrease in water waste.
- It is thought that the use of the model will contribute to the prevention of unnecessary water use in today's world, where conscious water consumption is more important than ever since water resources are gradually decreasing and water demand is increasing.
- It is aimed to design the developed mobile application as much user-friendly for all ages as possible for it to be used widely in a short while.

- It is foreseen that if the developed model is widely used, mass awareness can be achieved and a massive decrease in water use can be experienced.

As a result:

- This model could set an example for future internet of things and cloud database integrated studies.
- It is believed that the model will increase awareness about water literacy.
- Creating a model for reducing household water consumption with a mobile application integrated with internet of things and cloud database technologies; the creation of a warning and water usage reduction system by using a specially designed smart pressure reducing system are the unique aspects of this project.

6. Suggestions

- By using high quality measuring devices in model design, the water consumption data gathered can be closer to the truth.
- By adding new features to the mobile application, it can be ensured that the amount of water usage control in the households of the users can be increased. For example, showing general water usage statistics in the world, country, city; giving personalized water usage recommendations…
- The model was created to control household water use. However, the model can be developed to be used in industry and agriculture, which are the other two major pillars of world water use, by making adaptations.

7. References

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