Automated Irrigation System

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Abstract— This research paper tackles the issue of irrigation systems in the Gulf Cooperation Council (GCC), such as large consumption of water. It presents a contemporary model for an automated irrigation system controlled directly from a mobile application. The aim behind such a project is to minimize the use of resources (i.e., workers, water, and electricity) and manual intervention, maximize the operational speed and the agriculture production while preserving plants from fungi. All the above highly contribute to the sustainability of the proposed model and make it an exceptional option to be considered to improve the agriculture sector from an irrigation efficiency standpoint. The result of the analysis shows that the automated irrigation system is able to control and monitor three types of plants; we also found that the mint plant consumes the least resources when compared to the mango and lemon plants.

Keywords— Irrigation, Smart systems, Embedded System, Automated System, Agriculture.

I. INTRODUCTION

Over the past decades, quick advancements in smart agricultural systems were noted [1]. This showcases the great importance of the agriculture industry worldwide. In India, for instance, about 70% of the people rely on agriculture [1]. In the past, irrigation systems used to fully depend on the mills to irrigate farms by conventional methods without a thorough understanding of the appropriate quantities of these crops. Such systems contribute to the water waste problem, which, in turn, contributes to the destruction of crops as there is no understanding of adequate quantities of water. However, with the recent technological advancements, new innovative systems for irrigation without the farmer interfering in the irrigation process have seen light [2]. Furthermore, because of the geographical region where the Sultanate of Oman is located, it suffers from the lack of rain throughout the year and lack of groundwater, this modern irrigation system will reduce these two main issues. Indeed, smart systems have proven their capability to regulate the irrigation of crops while minimizing the water-waste and the number of resources, which, in turn, will reduce costs. This research paper intends to solve irrigation issues, such as the consumption of large quantities of water and the human-errors that affect trees and their fungi. The farmers experience is an important factor to be taken into account to achieve a high efficiency of modern irrigation systems. With the increase of the world population, the need for farming yields is increasing exponentially. Further, the farmers' potential and abilities in the agriculture filed are reduced due to different enterprises that attract workers away from the farming zone. For example, 28% of farmers in Japan are over 65 years old [3].The expected outcomes of this project are as follows: to facilitate the irrigation system by installing and designing an automatic system to increase crop performance, and to reduce overwatering a saturated soil. This system will also prevent irrigation happening at the wrong time by switching the engine ON or OFF by utilizing the irrigation system data. The system controller will be responsible for switching the engine ON or OFF depending on what is needed. This process is all automated and does not need any human interaction, which is the contribution of this project. This will help reduce human errors and preserve resources from waste. The rest of the paper is structured as follows. In Section 2, we present the literature review. In Section 3, we discuss the research objectives followed by design and implementation of the system. In the last section we present the results of implementing this system.

II. LITERATURE REVIEW

Several studies that address irrigation issues are found in literature, as follows:

1) Automated irrigation system using solar power in Bangladesh. This study was applied in the rice field in Bangladesh. The primary goal of this gadget is to balance out the level of water in agricultural fields to avoid losing the merchandise due to floods. The sensor sends a message from the field to an operator mentioning the level of water within the area and mentions whether it is expected to increase or decreases. The operator, then, controls the pump to regulate the water level accordingly [4].

2) Design and implementation of an Automatic irrigation system in Nigeria. The basic idea is to rely on the type of soil and the amount of water needed by each one. This process is carried out by measuring the level of moisture in each type and using the pump to supply water. The result indicates that sandy soil requires less water than clay soil [5].

3) Automated Irrigation System based on GSM for use of resource and crop planning in India. This device is placed on agricultural lands and works by using Bluetooth or GSM signal. The goal of this device is to monitor the humidity and temperature in the agricultural land in addition to monitoring the state of the climate through the weather

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temperature, humidity, and dew drops. It, then, sends a text message to the user's machine [6].

III. RESEARCH OBJECTIVES

The main objective of this project is to develop an automated system that solves problems related to irrigation and agriculture, such as controlling and saving resources (water mainly), increasing the agricultural production using small quantities of water, minimizing manual interventions in watering operations while increasing the watering speed, and preserving plants from fungi. All these features make the automated system a sustainable option to be considered to improve the agriculture and irrigation efficiency. The goal of this study is to discover the excellent automation technique for irrigation system automatically controlled through software in a way that allows the user to monitor all information and manage the device immediately from a mobile device. The objectives to consider are: Simplify the irrigation system by installing and designing the whole irrigation system, Optimize the water consumption, Fully automate the system, Decrease the cost of operation, and Make the system user-friendly. The system method includes the implementation of a prototype device that works robotically and is controlled through a mobile application. Reading the related works and drawing the timeline of the project constitutes step one of this project. After looking into the benefits and drawbacks of the previous studies on the matter, the implementation starts with the layout and the automation method for the executable. To implement this project, we start by describing the idea. Next, we identify the objects of this project, such as why this project is important, and what is the exact object of this project. The second step is to read related studies to know if there is such idea and how they implemented in different way. Then, comes the choice of materials; this step takes more time because the materials should be of certain specification. Following that, we started building a small version of the project to try the scenario and test materials. We write the code of each item and then combine all codes together. Next, we build the prototype and test the code, followed by the implementation of a mobile application for the system. The main idea of building a mobile application was to be able to control the system remotely. The last step is to review and test.

IV. DESIGN AND IMPLEMENTATION

To achieve the exact project objectives, using Arduino as the operating system seems to be the best choice as it contains a number of open supply hardware and software as well as it is cheap and available in our country. Choice of materials: The first step of this process of building the prototype of the automated irrigation system was the choice of materials. Field Control System: This step depends on the working of different sensors used in this project which are (moisture, temperature, light, and rain). First of all, we choose an open source operating system which is Arduino. Then, we programmed every sensor separately. We started with the moisture sensor, and so on, and then combined all nine sensors, including the rain, temperature, light and flow meter sensors. We included in our code pump and valve and tested. Project Preparation: For the purpose of building the structure of this project, two tables were used to make parts more stable. However, to create a perfect structure, the size was measured for each part that will be used in the project later on: the types of sensors based on the environment that they will work on, two 12 volt batteries, a small plastic tank, an LCD screen for monitoring, the different type of connecting wires, and controller (Arduino type AT mega 328V). Mechanical Design: In the beginning, a sketch design for the project was made, then the measurements were taken. Two wood tables (1.6-meter x 1.6 meter) have been chosen as a base and stand for this project. The first step of designing the system was to draw the sketch of the system to know the exact materials and measurements needed.

A. Design Process

As shown in Figures 1 and 2, three pieces of foam were used for the area below the grass mat and the area where all wires, flowmeter, and valves are located. The size of the grass mat was cut to make nine holes to set the plastic plates. A special cutter was used to cut the grass into nine equal squares. The plastic water tank was chosen in a way that it is large in size, but light in weight. Moreover, nine moisture sensors, one temperature sensor, four solenoid valves, one water pump, one breadboard, two (12 volts' batteries), wires and an LCD screen are the main parts that were used to implement this project. There were difficulties in choosing the type of pipes for this project since it should be easy to connect as well as easy in the cutting process. Thus, two types of connection joints (T-joint and L–joint) were needed to simplify the installation process. The Arduino controller has been chosen as the processor since it is an open source, simple program that combines three models at once, which are: a digital input, an analog input, and a processor. Every sensor and tool have been tested individually before being connected to a large-scale project, as shown in Figures 1 and 2. Tests were run for every part of the system to make sure it works as expected.

Figure 1. Control Tools and Wiring

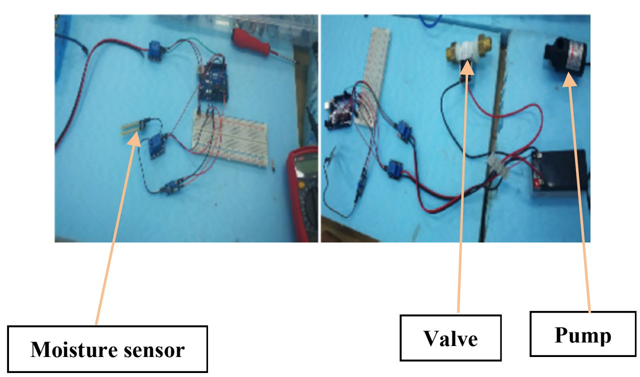

Figure 2. Valve Testing and Connection

Figure 3. Whole system

The last step was to assemble all parts together to finalize the project construction, as shown in Figure 3. The last step in the coding process was to gather all codes in one single program and run it in a large-scale project to make sure that everything is working perfectly. Figure 4 showcases the circuit design of the whole system with the wiring.

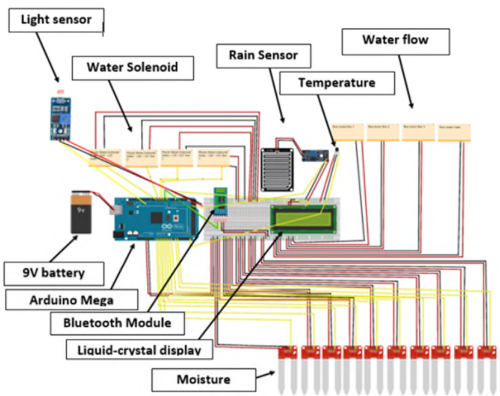

Figure 4. Circuit design

B. Sequence scenario of the system

As shown in Figure 3, the project was divided into 3 fields, namely: field A, field B, and field C. Each field will have one valve and one flow meter sensor in order to measure and monitor the amount of consumed water in each field. Field A has valve_1 and flow meter 1, field B has valve_2 and flow meter_2, field C has valve_3 and flow meter_3 in addition to valve_4 with flow meter that will be located near the tank in order to measure and monitor the total amount of consumed water. As it shows in the flow chart (Figure 5), if two or more moisture sensors are active, the system will automatically work. In addition, the temperature sensor and the light sensor work together. For example, when the temperature is more than 40°C and the light sensor is active, then the system will be switched OFF because the heat of the sun works to evaporate the water. This system was configured to stop the process and schedule it. Moreover, the purpose behind such a system is to work in a smart way; therefore, if it rains, the system will automatically be OFF. One should keep in mind that the main water tank will be monitored carefully so that it does not go below the level where the pump cannot suck the water. The system will not work if the water level is low.

C. Implementation

Figure 5 presents the start of the process where two or three moisture sensors of field B must be activated to move to the next step. Next, the rain sensor must be dry to continue the process and the weather temperature sensors should not exceed 40°C to enable the process to move to the next step. If the water tank level is not low, the pump will run, valve_2 and 4 will open and the flow meter_2 and 4 will have the same reading. If two or three moisture sensors of all fields (A, B, C) are active at the same time and the rain sensor is dry while the temperature sensor remains under 40°C and the light sensor is not active, then the system proceeds to the next step. Also, if the water level sensor is not below the threshold, then the pump will be ON and valves_1, 2, 3 and 4 will open and the flow meter (1,2,3, 4) will have the same readings.

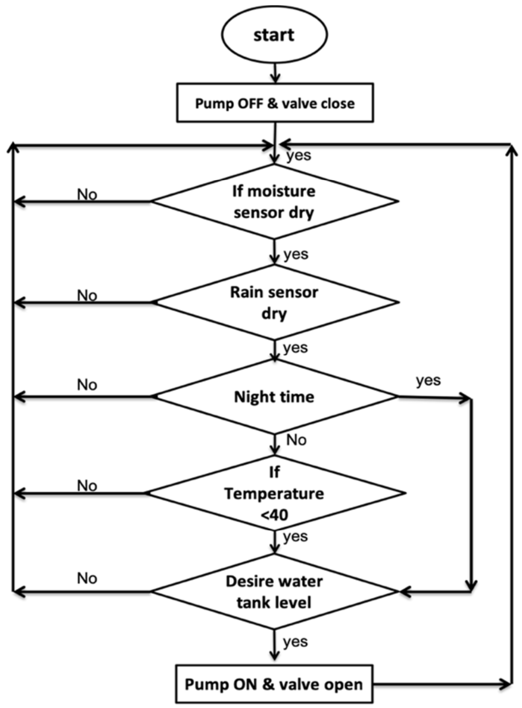

Figure 5. Flow chart of implementation process

D. Mobile Application

Figure 6 presents the application process of the mobile application. It starts with the app installation on a phone and opening it. First of all, the main screen (Figure 7) of the app will be loaded when the user will choose the device to be connected to Bluetooth. The system will check whether or not the device is connected and notify the user in either case. On the main screen, the user can directly switch ON /OFF the entire system. Moreover, if the “Details Button” is pressed, it will load the details screen (Figure 7). In this screen, the user will be able to see all details related to the whole system. For instance, if he pressed on the “plant 1 button”, he will be able to see the amount of water, the soil moisture, and the temperature. Further, if a problem occurs in this line, the user has the option to switch it ON /OFF. The app inventor is an open source tool provided by Google. This program allows beginners to create programs that can run under Android. It uses a graphical user interface such as Scratch [8].

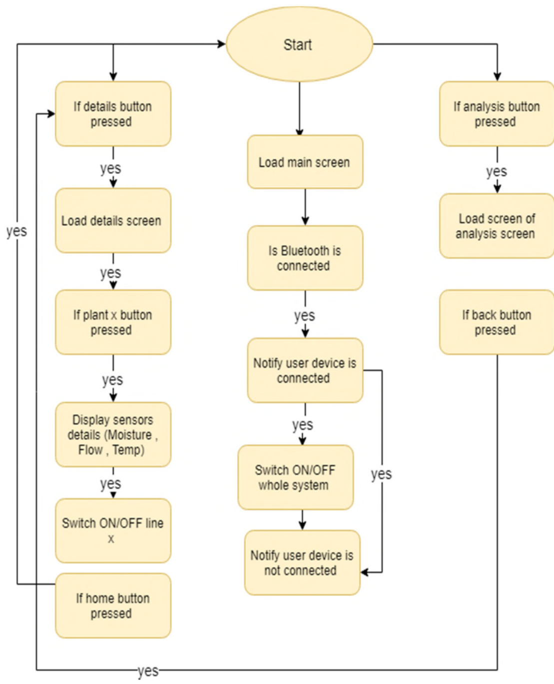

Figure 6. Flow chart of application process

In Figure 7:

1- If “Button 1”is pressed, it send the user to About Page, which provides app information.

2- If “Button 2” is pressed, the user gets directed to the Help Page.

3- When the List Picker is clicked, it shows a list of all connected Bluetooth devices When a Bluetooth device is clicked.

4- Regarding the connection, if the device is connected, the text colour changes to green for feedback and writes ‘Connected'.

5- The “ON /OFF buttons” allow the user to switch on or off the system.

6- When the “Details button "is pressed, it takes the end user to a details page that shows all the information and let user control the system line by line.

7- When the “List Picker” is pressed, it shows a list of all connected Bluetooth devices.

8- The two labels show the temperature and amount of water going from tank flow 4 is the main one.

9- The “Plant” button shows the user a list of details about a plant, such as name of the plant, humidity and amount of water.

10- The three labels are not visible unless the user clicks on the plant button.

11- The “Responsive” button takes the user to the Home page.

12- The “ON/OFF” button in each line allows a user to switch on or off each line individually.

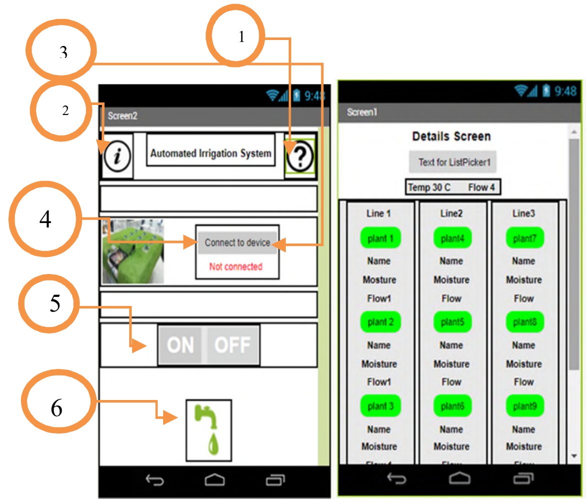

Figure 7. App Screenshot

V. RESULTS

The process of manual irrigation involving one user to control the irrigation process has been done in real world environment for three types of plants (lemon, mint, and mango) for one month and the results were recorded. The irrigation process takes place twice a week in the morning and the remaining days in the evening because the manual irrigation process is usually done at that time. For data analysis purposes, data of a chosen plant twice a day, once between 9 am - 5 pm and the second one between 6 pm-11pm, was taken. The line graph in Figure 8 depicts the humidity data of the mint. The y-axis represents the humidity rate while the x-axis represents the day and time. We notice that Sunday and Wednesday have the largest humidity rate, which is 900-800. When the humidity is more than 800, it means that the plant is dry and needs to be irrigated. The humidity rate decreases on Monday evening and Thursday morning and reaches 200-120. This means that the plant is not dry and does not need watering. From this data, we can say that the mint gradually dries up and it retains water more than other plants.

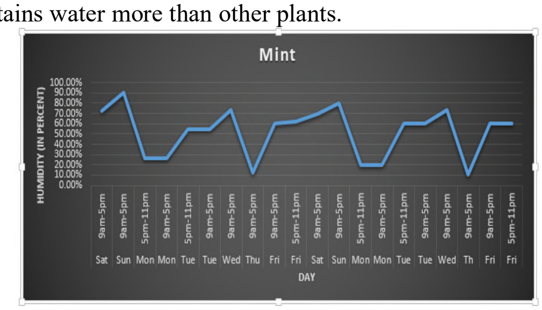

Figure 8. Humidity data of mint

The line graph in Figure 9 presents the humidity data of the lemon plant. The y-axis shows the humidity rate while the x-axis shows the day and time. Sunday and Wednesday have the largest humidity rate (1000); which means that the plant is very dry and needs to be irrigated as soon as possible. On Monday and Thursday, the humidity decreased; however, it is noticed from the graph and the data that the lemon needs to be irrigated more than twice a week because it loses water fast. Therefore, we conclude that lemon needs water more than mint.

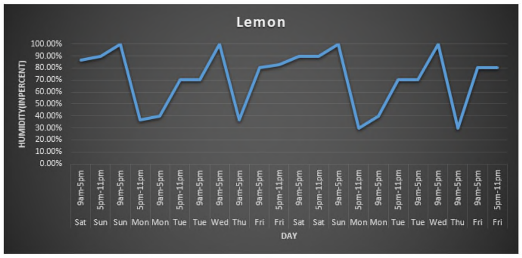

Figure 9. Humidity data of lemon

The line graph in Figure 10 shows the humidity data of the mango plant. Sunday, Thursday, and Saturday have the largest humidity rate; this means that the plant is very dry. We also notice a rapid decrease and a rapid increase in the amount of moisture; this means that mango loses water very fast and needs to be irrigated more than twice a week.

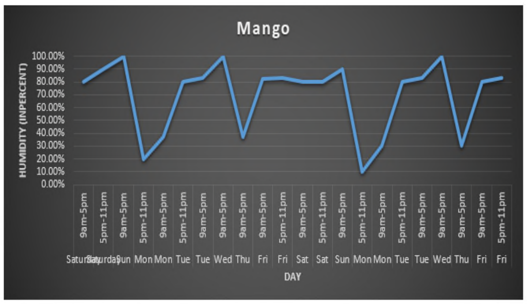

Figure 10. Humidity data of mango

Based on the data above, we observe the following in Figure 11. All the plants were watered at one time and in equal quantities almost twice a week, but after comparing the results, we found that the lemon and mango needed to be watered more than twice a week because the humidity ratio is significantly reduced (taking into account the temperature and the time of irrigation). When they are irrigated in the morning, the plants lose humidity quickly and very significantly because the irrigation is at the wrong time; the sun evaporates the water much faster. As for the mint plant, through the results, we found that this plant does not lose moisture quickly as it can withstand a longer period compared to the mango and the lemon. Hence, we conclude that using an automatic irrigation system is much more efficient because it solves almost all the problems of using a manual system. The automatic irrigation system works based on the needs of plants, so it solves the problem of irrigation at the wrong time by using light and temperature sensors together.

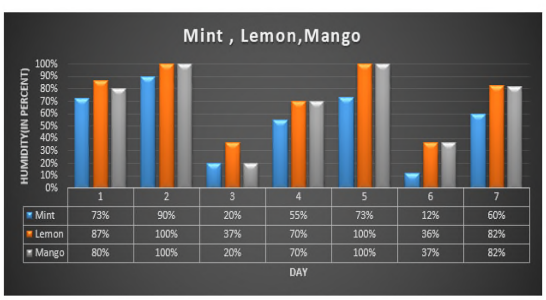

Figure 11. Humidity data of all plants

In Figure 12, the result of the flow meter sensor is presented. As shown in Figure 12, the amount of water using manual irrigation system is equal for all plants and administered at the same time. Because all plants do not need the same amount of water, using a moisture sensor connected to a flow meter gives better results.

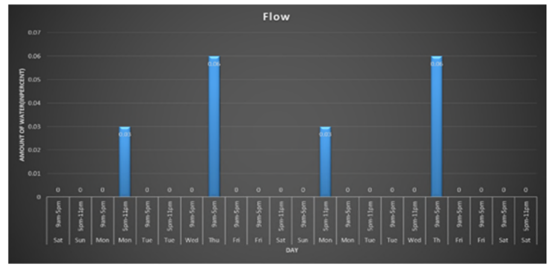

Figure 12. Flow meter data

VI. Discussion

After we completed the project and all the requirements were implemented, in order to finish this smart irrigation, system testing was the next step. In fact, the system will not work until two or three of the moisture sensors from any line of the 3 fields sends a signal to the Arduino that the soil is dry and the crop needs water. After the signal reaches the Arduino, it will send a command to the relay of that specific line field valve to be energized to open the valve and a command to the relay of the pump to exchange it directly to irrigate that field. Moreover, all 3 fields can be irrigated at the same time if a minimum of 2 of all 3 plants moisture sensors are activated. Thus, all solenoid valve relays may be energized to open all valves and the pump runs to irrigate all 3 plants. There has been a problem at the beginning to choose a suitable pump to irrigate all plants at the same time. The program of the system has been configured and the system will no longer operate unless two or three moisture sensors are activated. But, if one sensor is activated of any line, the system will no longer perform because that sensor can also be defective. If the water tank level is low, the system will not operate even if all plant sensors are activated to protect the water pump. Furthermore, this smart irrigation system has been configured in a way that, if it rains, it will not work. This is because the rain sensor will be activated and will send a signal to Arduino to stop the water pump and to close all valves as well. Further, during daytime, the system will no longer work due to the mild sensor that will be activated and that will close the plant's valve as well as switch OFF the pump. Concerning the system programming, it has been precisely chosen, as stated in the previous sections, to apply UNO Arduino. The wire connections from the controllers to the Arduino have been difficult to implement, as a single mistake can damage any electric element. It was not easy to program the smart irrigation system and upload it in Arduino to run the water pump and starting valves with eighteen sensors, but with the assistance of Arduino library, this system was completed. Connecting the wires can become complicated, but by using the plastic breadboard, it became easier to connect the wires. For designing the plant, special flexible pipes were used to facilitate the connection from the water tank to the plant. However, we faced the problem of connecting the pipes together. So, two types of

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pipe joints (T-joint and L-joint) were used to solve this issue.

VII. Conclusion

With this project, we achieved successful results. The purpose of the smart irrigation system for large or small scale is to make it the process more effective. Different sensors (soil moisture, light, temperature, level, rain, flow) together with other devices (water pump, battery, LCD screen, solenoid valve) have been used in this project. Using Arduino proved profitable, as it is able to serve a number of different sensors of various types and sizes. Arduino boards are other devices. Furthermore, two wood tables and three sheets of foam have been used in the project. Several design criteria have used in this system. The sensors used were suitable for detecting and sending signals to Arduino, to control the water pump and to open the solenoid valve. The system was tasted in indoor conditions similar to the ones on the farm. The purpose of the screen monitor is to show the flow for each line, which shows if there is any passing of water in pipes. Also, if it is raining, the system will not work in order to save the water. The mobile application is to control the system remotely. It allows a user to monitor the whole system and, if there is any problem or passing of water, the user can switch off the system through this application. Finally, results analysis proves that the proposed automated irrigation system is able to control and monitor three types of plants. We found that the mint plant consumes the least resources. Following what has been done for this project, in the future works, we intend to transfer the system to a larger scale. Furthermore, controlling the system via Zig Bee instead of using wire connections could be a great addition. Moreover, creating a more responsive mobile application would provide more controlled data. We can also think of developing this system by using renewable energy, which is solar power instead of batteries using solar energy, in an effort to help reduce future costs.

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