Problem Chosen	2025 MCM/ICM Summary Sheet	Team Control Number
C		2515374

Foresting Greatness: Olympic Medal Predictions based on PRE Model

Summary

The Olympic Games, inspired by the ancient Greek Games, is the world's premier international multi - sport event. Held every four years, it features summer and winter editions, bringing together athletes from around the globe to compete in a wide range of sports. For every sports lover, the Stimulation of Olympic Medals is a very interesting topic, while it's crucial for countries to adjust their strategy. **In this paper, we will analyze the data of the Summer Olympic Games from 1896 to 2024, and use the data to simulate the results of the 2028 and 2032 Olympics using different methods from 'NAME' model mostly based on machine learning.**

First, we've examined, cleaned and transformed the raw data, setting the ice sports aside, combining various teams of one country, and mapping the countries which no longer exist to the current existing country so as to provide a better stimulation model. Then, we tried to use linear regression methods like Multicollinearity and Ridge regression, only to find that for some countries, especially Russia,'year' have a completely non-linear relationship with the number of medals they win. As a result, we turn to machine learning, selected the independent variables to use by **Correlation Coefficient Matrix** and **Principal Component Analysis**, split the data into training and testing parts, and use **EXtreme Gradient Boosting** methods to train features and target matrix. **Kolmogorov-Smirnov Test** is used to ensure the effectiveness of the model, while history data are reprocessed using feature importance and data in recent years are given higher weights to improve the accuracy of the model. In the end, we use the model to predict the results of the 2028 and 2032 Olympics, and the results are shown in multiple forms(**write more specific IN the following chapters!!!**).

After that, we encode country labels, create feature dataset of each country,and filter out data for countries that won medals in 1896 to construct training and testing datasets of the feature of 'First Win Country'.**Random Forest** is used to train the model, and the results of the top ten countries most likely to win their first medal in 2028 are shown in the form of a bar chart.

Events: By analyzing the data given, we've found that some specific sports and events play a significant role in the medal tally of some specific countries, for example, long distance race for Kenya. We calculate the **proportion** of medals from these events, further estimate their importance, and finally come to the result of the extent to which choosing these events impact countries performance in the medal list.

Finally, we combined methods used above and created a comprehensive prediction model called **'PRE'** model, naming after the primary methods we use. The model is specifically-tuned to calculate **Legendary Index** so as to detect **Legendary Couch Effect** using data of US gymnastics team coached by Bela Karolyi and Marta Karolyi. Lang Ping is successfully detected as a legendary coach, and we've found many more great teams and athletes, even controversial results(2024 Male Fencing,Italy) and decline of the great ranks(2024 Tennis,China).

Greatness is not born, but made. We hope that our model may help countries' Olympic committes to accommodate strategies and achieve better results in the future Olympic Games.

Keywords: Olympic Games; Data Analysis; Stimulation; Machine Learning;

Contents

1 Introduction

1.1 Background and Literature Review

1.2 Restatement of the Problem

Considering the background, in this paper we are required to solvye the following problems:

Task 1: Develop a model for medal counts for each country, both **Gold** and **Total**, and use the model to predict various countries' performance in the 2028 and 2032 Olympics. The model also include estimates of the precision and measures of how well the model performs.

Task 2: Develop a model for prediciton of when a country will win its **first** medal in the Olympics, and the probabililty of winning it in the coming next LA Olympics. Also, we will evaluate this model.

Task 3: Develop a model for estimation of the **"great coach"** effect, and further using this model to identify three countries suitable for imitating this strategy.

Task 4: Calculating the **"great athlete"** effect, referring to the phenomenon that some great athletes won a large number of the (Gold) medals of a certain sport or event, and sometimes his/her country's medal tally greatly depend on him/her during his/her athlete career. We will also explain how this can inform country Olympic committees.

In order to solve those problems, we will proceed as follows:

- **Stating assumptions**. By stating our assumptions, we will narrow the focus of our approach towards the problems and provide some insight into bathtub water temperature issues.
- **Making notations**. We will give some notations which are important for us to clarify our models.
- **Presenting our model**. In order to investigate the problem deeper, we divide our model into two sub-models. One is a steady convection heat transfer sub-model in which hot water is added constantly. The other one is an unsteady convection heat transfer sub-model where hot water is added discontinuously.
- Defining evaluation criteria and comparing sub-models. We define two main criteria to evaluate our model: the mean temperature of bath water and the amount of inflow water.
- **Analysis of influencing factors**. In term of the impact of different factors on our model, we take those into consideration: the shape and volume of the tub, the shape/volume/temperature of the person in the bathtub, the motions made by the person in the bathtub and adding a bubble bath additive initially.
- **Model testing and sensitivity analysis**. With the criteria defined before, we evaluate the reliability of our model and do the sensitivity analysis.
- **Further discussion**. We discuss about different ways to arrange inflow faucets. Then we improve our model to apply them in reality.
- **Evaluating the model**. We discuss about the strengths and weaknesses of our model:

1) ...
2) ...
3) ...
4) ...

1.3 Our Work

2 Assumptions and Justification

To simplify the problem, make it convenient for us to construct simulation model and ensure the effectiveness of the model, we make the following basic assumptions, each of which is properly justified.

- **Data preprocess**. We've examined that most of the data provided by the problem is accurate and reliable, although some may not be the same as other data. However, in order to provide an effective and accurate model, we will preprocess the data to make it more suitable.We set the ice sports aside, combine various teams of one country, and map the countries which no longer exist to the current existing country
- **All the physical properties of bath water, bathtub and air are assumed to be stable**. The change of those properties like specific heat, thermal conductivity and density is rather small according to some studies [5]. It is complicated and unnecessary to consider these little change so we ignore them.
- **There is no internal heat source in the system consisting of bathtub, hot water and air**. Before the person lies in the bathtub, no internal heat source exist except the system components. The circumstance where the person is in the bathtub will be investigated in our later discussion.
- **We ignore radiative thermal exchange**. According to Stefan-Boltzmann's law, the radiative thermal exchange can be ignored when the temperature is low. Refer to industrial standard [3], the temperature in bathroom is lower than 100 °C, so it is reasonable for us to make this assumption.
- **The temperature of the adding hot water from the faucet is stable**. This hypothesis can be easily achieved in reality and will simplify our process of solving the problem.

3 Notations

Symbols	Description	Unit
h	Convection heat transfer coefficient	W/(m^2· K)
k	Thermal conductivity	W/(m · K)
c_p	Specific heat	J/(kg · K)
ρ	Density	kg/m^2
δ	Thickness	m
t	Temperature	°C, K
τ	Time	s, min, h
q_m	Mass flow	kg/s
Φ	Heat transfer power	W
T	A period of time	s, min, h
V	Volume	m^3, L
M, m	Mass	kg
A	Aera	m^2
a, b, c	The size of a bathtub	m^3

where we define the main parameters while specific value of those parameters will be given later.

4 Model Overview

In our basic model, we aim at three goals: keeping the temperature as even as possible, making it close to the initial temperature and decreasing the water consumption.

We start with the simple sub-model where hot water is added constantly. At first we introduce convection heat transfer control equations in rectangular coordinate system. Then we define the mean temperature of bath water.

Afterwards, we introduce Newton cooling formula to determine heat transfer capacity. After deriving the value of parameters, we get calculating results via formula deduction and simulating results via CFD.

Secondly, we present the complicated sub-model in which hot water is added discontinuously. We define an iteration consisting of two process: heating and standby. As for heating process, we derive control equations and boundary conditions. As for standby process, considering energy conservation law, we deduce the relationship of total heat dissipating capacity and time.

Then we determine the time and amount of added hot water. After deriving the value of parameters, we get calculating results via formula deduction and simulating results via CFD.

At last, we define two criteria to evaluate those two ways of adding hot water. Then we propose optimal strategy for the user in a bathtub. The whole modeling process can be shown as follows.

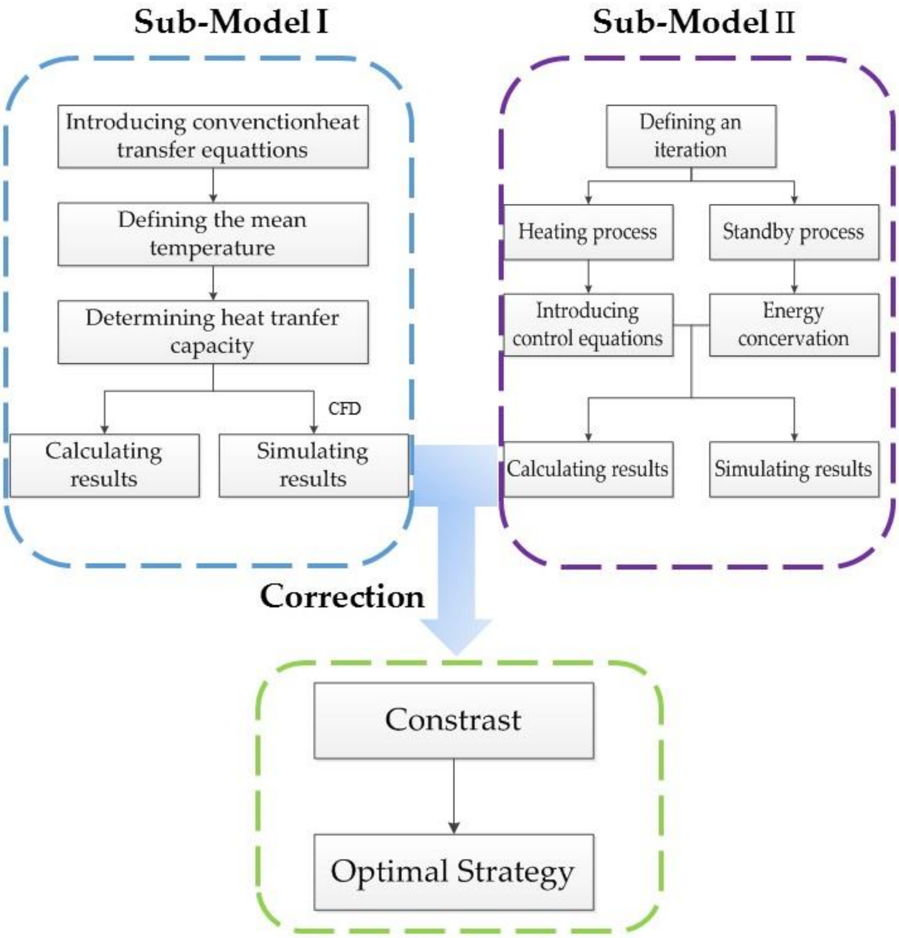


Figure 1: Modeling process

5 Task I : Predicting the Medal of the 2028 LA Olympics

We first establish the sub-model based on the condition that a person add water continuously to reheat the bathing water. Then we use Computational Fluid Dynamics (CFD) to simulate the change of water temperature in the bathtub. At last, we evaluate the model with the criteria which have been defined before.

5.1 Model Establishment

Since we try to keep the temperature of the hot water in bathtub to be even, we have to derive the amount of inflow water and the energy dissipated by the hot water into the air.

We derive the basic convection heat transfer control equations based on the former scientists' achievement. Then, we define the mean temperature of bath water. Afterwards, we determine two types of heat transfer: the boundary heat transfer and the evaporation heat transfer. Combining thermodynamic formulas, we derive calculating results. Via Fluent software, we get simulation results.

5.1.1 Control Equations and Boundary Conditions

According to thermodynamics knowledge, we recall on basic convection heat transfer control equations in rectangular coordinate system. Those equations show the relationship of the temperature of the bathtub water in space.

We assume the hot water in the bathtub as a cube. Then we put it into a rectangular coordinate system. The length, width, and height of it is a, b and c.

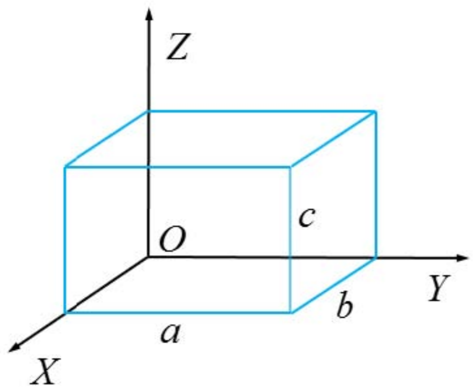


Figure 2: Modeling process

In the basis of this, we introduce the following equations [5]:

- **Continuity equation:**

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{1}$$

where the first component is the change of fluid mass along the X-ray. The second component is the change of fluid mass along the Y-ray. And the third component is the change of fluid mass along the Z-ray. The sum of the change in mass along those three directions is zero.

- **Moment differential equation (N-S equations):**

$$\begin{cases} \rho\Big(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\Big) = -\frac{\partial p}{\partial x} + \eta\Big(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\Big) \\ \rho\Big(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\Big) = -\frac{\partial p}{\partial y} + \eta\Big(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\Big) \\ \rho\Big(u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\Big) = -g - \frac{\partial p}{\partial z} + \eta\Big(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\Big) \end{cases} \tag{2}$$

- **Energy differential equation:**

$$\rho c_p\Big(u\frac{\partial t}{\partial x} + v\frac{\partial t}{\partial y} + w\frac{\partial t}{\partial z}\Big) = \lambda\Big(\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} + \frac{\partial^2 t}{\partial z^2}\Big) \tag{3}$$

where the left three components are convection terms while the right three components are conduction terms.

By Equation (3), we have ......

......

On the right surface in Fig. 2, the water also transfers heat firstly with bathtub inner surfaces and then the heat comes into air. The boundary condition here is ......

5.1.2 Definition of the Mean Temperature

......

5.1.3 Determination of Heat Transfer Capacity

......

6 Sub-model II: Adding Water Discontinuously

In order to establish the unsteady sub-model, we recall on the working principle of air conditioners. The heating performance of air conditions consist of two processes: heating and standby. After the user set a temperature, the air conditioner will begin to heat until the expected temperature is reached. Then it will go standby. When the temperature get below the expected temperature, the air conditioner begin to work again. As it works in this circle, the temperature remains the expected one.

Inspired by this, we divide the bathtub working into two processes: adding hot water until the expected temperature is reached, then keeping this condition for a while unless the temperature is lower than a specific value. Iterating this circle ceaselessly will ensure the temperature kept relatively stable.

6.1 Heating Model

6.1.1 Control Equations and Boundary Conditions

6.1.2 Determination of Inflow Time and Amount

6.2 Standby Model

6.3 Results

We first give the value of parameters based on others' studies. Then we get the calculation results and simulating results via those data.

6.3.1 Determination of Parameters

After establishing the model, we have to determine the value of some important parameters.

As scholar Beum Kim points out, the optimal temperature for bath is between 41 and 45°C [1]. Meanwhile, according to Shimodozono's study, 41°C warm water bath is the perfect choice for individual health [2]. So it is reasonable for us to focus on $41°\text{C} \sim 45°\text{C}$. Because adding hot water continuously is a steady process, so the mean temperature of bath water is supposed to be constant. We value the temperature of inflow and outflow water with the maximum and minimum temperature respectively.

The values of all parameters needed are shown as follows:

.....

6.3.2 Calculating Results

Putting the above value of parameters into the equations we derived before, we can get the some data as follows:

Table 1: The calculating results

Variables	Values	Unit
A_1	1.05	m^2
A_2	2.24	m^2
Φ_1	189.00	W
Φ_2	43.47	W
Φ	232.47	W
q_m	0.014	g/s

From Table 1, ...

......

7 Correction and Contrast of Sub-Models

After establishing two basic sub-models, we have to correct them in consideration of evaporation heat transfer. Then we define two evaluation criteria to compare the two sub-models in order to determine the optimal bath strategy.

7.1 Correction with Evaporation Heat Transfer

Someone may confuse about the above results: why the mass flow in the first sub-model is so small? Why the standby time is so long? Actually, the above two sub-models are based on ideal conditions without consideration of the change of boundary conditions, the motions made by the person in bathtub and the evaporation of bath water, etc. The influence of personal motions will be discussed later. Here we introducing the evaporation of bath water to correct sub-models.

7.2 Contrast of Two Sub-Models

Firstly we define two evaluation criteria. Then we contrast the two submodels via these two criteria. Thus we can derive the best strategy for the person in the bathtub to adopt.

8 Model Analysis and Sensitivity Analysis

8.1 The Influence of Different Bathtubs

Definitely, the difference in shape and volume of the tub affects the convection heat transfer. Examining the relationship between them can help people choose optimal bathtubs.

8.1.1 Different Volumes of Bathtubs

In reality, a cup of water will be cooled down rapidly. However, it takes quite long time for a bucket of water to become cool. That is because their volume is different and the specific heat of water is very large. So that the decrease of temperature is not obvious if the volume of water is huge. That also explains why it takes 45 min for 320 L water to be cooled by 1°C.

In order to examine the influence of volume, we analyze our sub-models by conducting sensitivity Analysis to them.

We assume the initial volume to be 280 L and change it by $\pm 5\%$, $\pm 8\%$, $\pm 12\%$ and $\pm 15\%$. With the aid of sub-models we established before, the variation of some parameters turns out to be as follows

Table 2: Variation of some parameters

V	A_1	A_2	T_2	q_{m1}	q_{m2}	Φ_q
-15.00%	-5.06%	-9.31%	-12.67%	-2.67%	-14.14%	-5.80%
-12.00%	-4.04%	-7.43%	-10.09%	-2.13%	-11.31%	-4.63%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%
-8.00%	-2.68%	-4.94%	-6.68%	-1.41%	-7.54%	-3.07%

9 Strength and Weakness

9.1 Strength

- We analyze the problem based on thermodynamic formulas and laws, so that the model we established is of great validity.
- Our model is fairly robust due to our careful corrections in consideration of real-life situations and detailed sensitivity analysis.
- Via Fluent software, we simulate the time field of different areas throughout the bathtub. The outcome is vivid for us to understand the changing process.
- We come up with various criteria to compare different situations, like water consumption and the time of adding hot water. Hence an overall comparison can be made according to these criteria.
- Besides common factors, we still consider other factors, such as evaporation and radiation heat transfer. The evaporation turns out to be the main reason of heat loss, which corresponds with other scientist's experimental outcome.

9.2 Weakness

- Having knowing the range of some parameters from others' essays, we choose a value from them to apply in our model. Those values may not be reasonable in reality.
- Although we investigate a lot in the influence of personal motions, they are so complicated that need to be studied further.
- Limited to time, we do not conduct sensitivity analysis for the influence of personal surface area.

10 Further Discussion

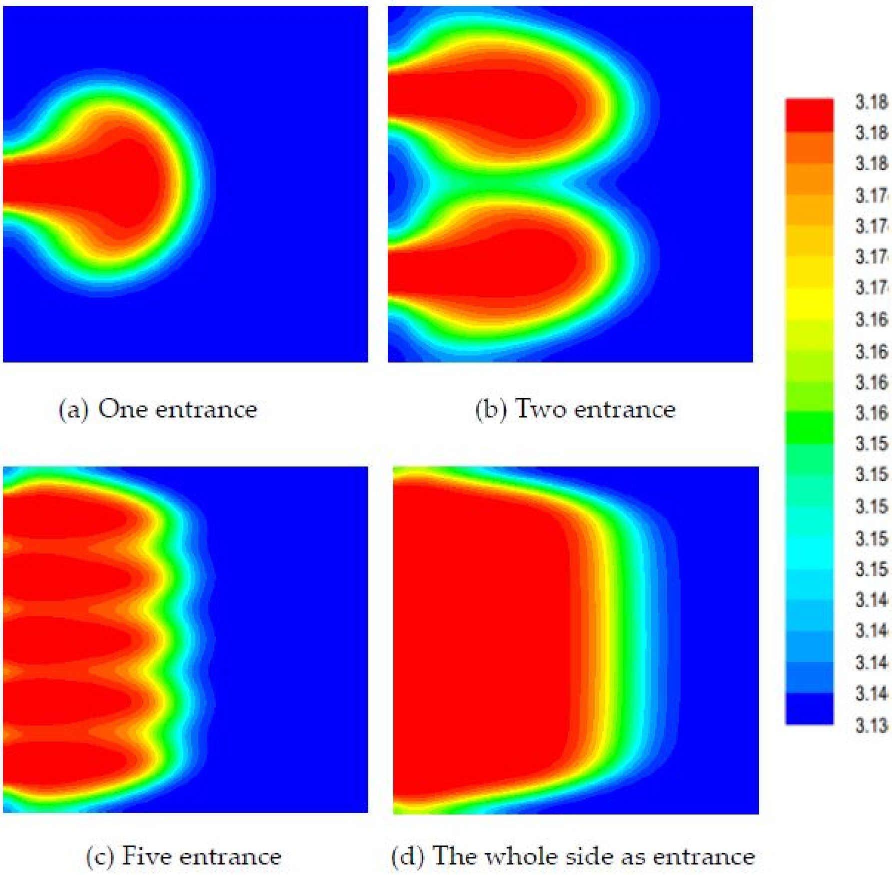
In this part, we will focus on different distribution of inflow faucets. Then we discuss about the real-life application of our model.

- Different Distribution of Inflow Faucets

  In our before discussion, we assume there being just one entrance of inflow.

  From the simulating outcome, we find the temperature of bath water is hardly even. So we come up with the idea of adding more entrances.

  The simulation turns out to be as follows



(a) One entrance

(b) Two entrance

(c) Five entrance

(d) The whole side as entrance

Figure 3: The simulation results of different ways of arranging entrances

From the above figure, the more the entrances are, the evener the temperature will be. Recalling on the before simulation outcome, when there is only one entrance for inflow, the temperature of corners is quietly lower than the middle area.

In conclusion, if we design more entrances, it will be easier to realize the goal to keep temperature even throughout the bathtub.

- Model Application

  Our before discussion is based on ideal assumptions. In reality, we have to make some corrections and improvement.

  1) Adding hot water continually with the mass flow of 0.16 kg/s. This way can ensure even mean temperature throughout the bathtub and waste less water.
  2) The manufacturers can design an intelligent control system to monitor the temperature so that users can get more enjoyable bath experience.
  3) We recommend users to add bubble additives to slow down the water being cooler and help cleanse. The additives with lower thermal conductivity are optimal.
  4) The study method of our establishing model can be applied in other area relative to convection heat transfer, such as air conditioners.

References

[1] Jane Doe. *An example book*. Example Publisher, 2022.

[2] Emily Johnson. "An example conference paper". In: *Proceedings of the Example Conference*. 2021, pp. 56–67.

[3] Sarah Lee. *An example technical report*. Tech. rep. Example Institute, 2018.

[4] John Smith. "An example article". In: *Journal of Examples* 10.2 (2023), pp. 123–134.

[5] Michael Thompson. "An example thesis". PhD thesis. Example University, 2019.

[6] Example Webmaster. *An example website*. `http://www.example.com`. 2020.

Enjoy Your Bath Time!

From simulation results of real-life situations, we find it takes a period of time for the inflow hot water to spread throughout the bathtub. During this process, the bath water continues transferring heat into air, bathtub and the person in bathtub. The difference between heat transfer capacity makes the temperature of various areas to be different. So that it is difficult to get an evenly maintained temperature throughout the bath water.

In order to enjoy a comfortable bath with even temperature of bath water and without wasting too much water, we propose the following suggestions.

- Adding hot water consistently
- Using smaller bathtub if possible
- Decreasing motions during bath
- Using bubble bath additives
- Arranging more faucets of inflow

Sincerely yours,

Your friends

Appendices

Appendix A First appendix

In addition, your report must include a letter to the Chief Financial Officer (CFO) of the Goodgrant Foundation, Mr. Alpha Chiang, that describes the optimal investment strategy, your modeling approach and major results, and a brief discussion of your proposed concept of a return-on-investment (ROI). This letter should be no more than two pages in length.

Here are simulation programmes we used in our model as follow.

Input matlab source:

```
function [t,seat,aisle]=OI6Sim(n,target,seated)
pab=rand(1,n);
for i=1:n
    if pab(i)<0.4
       aisleTime(i)=0;
    else
        aisleTime(i)=trirnd(3.2,7.1,38.7);
    end
end
```

Appendix B Second appendix

some more text **Input C++ source:**

```
//===============================================================================
// Name         : Sudoku.cpp
// Author       : wzlf11
// Version      : a.0
// Copyright    : Your copyright notice
// Description : Sudoku in C++.
//===============================================================================

#include <iostream>
#include <cstdlib>
#include <ctime>

using namespace std;

int table[9][9];

int main() {

    for(int i = 0; i < 9; i++){
        table[0][i] = i + 1;
    }

    srand((unsigned int)time(NULL));

    shuffle((int *)&table[0], 9);

    while(!put_line(1))
```

```
    {
        shuffle((int *)&table[0], 9);
    }

    for(int x = 0; x < 9; x++){
        for(int y = 0; y < 9; y++){
            cout << table[x][y] << " ";
        }

        cout << endl;
    }

    return 0;
}
```

Report on Use of AI

1. OpenAI ChatGPT (Nov 5, 2023 version, ChatGPT-4,)

   Query1: <insert the exact wording you input into the AI tool>

   Output: <insert the complete output from the AI tool>

2. OpenAI Ernie (Nov 5, 2023 version, Ernie 4.0)

   Query1: <insert the exact wording of any subsequent input into the AI tool>

   Output: <insert the complete output from the second query>

3. Github CoPilot (Feb 3, 2024 version)

   Query1: <insert the exact wording you input into the AI tool>

   Output: <insert the complete output from the AI tool>

4. Google Bard (Feb 2, 2024 version)

   Query1: <insert the exact wording of your query>

   Output: <insert the complete output from the AI tool>