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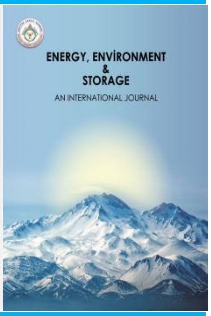

Novel Optimal Perennial Calendar Systems vs Gregorian Calendar and Their Impact on the Energy Demand and the Environment

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ABSTRACT. Have you ever missed an event because you were confused about days and dates? Do you remember the date of any specific day without looking at the calendar? Is the current Gregorian Calendar efficient enough for usage, and does it facilitate our life or make it more complicated? Have you ever thought about a simpler way to calculate days and dates in a year without using a calendar? All these questions are answered in this paper, in which authors propose two contributions, (a) a new mathematical formula that calculates the number of days in any month in the Gregorian calendar for any year, including the leap years, (b) an original optimization method that creates optimal perennial calendars. Results show that there is more than one way to create a perennial calendar using the proposed optimization model, in which the number of days in each month does not change, neither the dates. Hence, all months have the same sequence of days and dates. In other meaning, Monday becomes the first day of every month, and Sunday becomes the last day. Consequently, the calendars become much easier to memorize, and it becomes simpler to predict the days and dates in any year. In addition, the proposed optimal perennial calendar system reduces the energy demand and pollution worldwide, in which it has less impact on the environment and climate change compared to the Gregorian calendar. This is due to the fact that less printed-out calendars are produced, and less time is spent on the digital calendars to check the dates and days.

Keywords: Gregorian Calendar; Weekly-based Calendar; Original Calendar; Optimization algorithm; Energy saving.

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NOMENCLATURE

GC	Gregorian Calendar
IFC	International Fixed Calendar
JC	Julian Calendar
OPC	Optimal Perennial Calendar (Proposed in this paper)
PC	Perennial Calendar

1. INTRODUCTION

1.1 Background and motivation

From the early beginning of human civilizations, people realized the importance of organizing their daily life [1]. Many cultures created their calendars and dating systems that helped them to save religious and social activities and events [1]. The most recognized calendars in the ancient time include but are not limited to, Roman calendar [2], [3], Sumerian calendars [4], [5], Babylonian calendar [6], Zoroastrian calendar [7], Hebrew calendar [8], Hellenic calendars [9] and Julian calendar [10]. In the late sixteenth century, the Gregorian calendar (GC) was introduced by Pope Gregory XIII on October 15, and was later adopted worldwide [11]. In the Gregorian calendar, a year is composed of 12 months. Each month has a different number of days. For example, January has 31 days, February has 28 days, and 29 in a leap year, April has 30 days, and so on. One of the main critics of the Gregorian calendar is that it is very difficult to find a simple relationship between dates and days [12]. Sometimes, the dates become confusing especially when a particular day like Monday, is the first day in a month, and the second or even the seventh in another month; sometimes holidays which are on a specific date, such as December 24, could be located during the weekdays (e.g., Tuesday 24, 2019), while it can be in weekends in another year (e.g., Saturday 24, 2022). Hence, calculating days and dates is a difficult task, because of the irregularities in the Gregorian calendar. It appears that the existing calendar system becomes a little bit confusing for most of the people, and a much simpler calendar is needed. In addition, billions of calendars are printed every year worldwide, in which millions of trees are used every year to supply the demand. The emission of CO2, the pollution, the waste, and the energy used to print out Gregorian calendar cannot be neglected especially when around billions of calendars are thrown every year. Therefore, Gregorian calendar imposes negative impact on the society, the economy, and the environment, in which a solution should be proposed to facilitate the life of people and create a more sustainable and greener society.

Some questions may arise. What happens if we create a more organized calendar in which the days and dates in a month do not change? For example, Monday will always be the first day of any month. The holidays will have the same dates and days in any year, including leap years. For example, December 24, will always be on Wednesday, whatever is the year. Can we create an eco-friendly calendar, which is very easy to memorize without printing a hard copy to reduce pollution? Moreover, human beings always tend to develop and invent new things every day in order to facilitate their lives. So why do we not develop an easier way to count days, weeks, and months in a year?

1.2 Gregorian vs. Julian Calendars

A year is the time a given celestial object (e.g., Earth, Mars, etc.) takes to complete one orbit around another celestial object (e.g., Sun), also called the orbital period. However, astronomical years do not have integer numbers of days; for example, the Earth orbits the Sun in about 365.2425 days; therefore, it is necessary to introduce the intercalation system such as leap years. Julian and Gregorian calendars are the most common ones these days. A Julian calendar counts 365.25 days in a year, while 365.2425 days are considered in the Gregorian calendar. In total, a leap year occurs every four years in the Julian calendar, in which one day is added to the month of February. The Gregorian calendar follows almost the same concept; however, some new rules were added to reduce the gap with the reference (365.2422 days per year). These new rules are cited as follows:

> *"Every year that is exactly divisible by four is a leap year, except for years that are exactly divisible by 100, but these centurial years are leap years if they are exactly divisible by 400. For example, the years 1700, 1800, and 1900 are not leap years, but the years 1600 and 2000 are [13]."*

These new rules reduce the error by 1.2 days every 4,000 years, as shown in Table 1, while the Julian calendar shows an error of 31.2 days. From this place, the Gregorian calendar was adopted until this time.

Table 1. Accuracy comparison between Julian calendar and Gregorian calendar over a period of 4000 years.

Calendar	Number of days in a year	Number of days in 4 years	Number of days in 400 years	Number of days in 4,000 years	Error per 400 years with respect to the reference	Error per 4,000 years with respect to the reference
Julian	365.25	1,461	146,100	1,461,000	3.12	31.2
Gregorian	365.2425	1,460.97	146,097	1,460,970	0.12	1.2
Reference	**365.2422**	**1460.9688**	**146096.88**	**1,460,968.8**	**-**	**-**

1.3 International Fixed Calendar

The Gregorian calendar has serious problems and flaws. The main problem of the Gregorian calendar is that the number of days in months is not fixed, and it may vary between 28 and 31 days per month. Moreover, a month can start on Monday (June 1, 2020) and the next one on Wednesday (July 1, 2020). Therefore, there is no consistency between days and dates. The date of February 29 occurs every four years, which seems unpleasant to some people. Moreover, a year is divided into four quarters (3 months each quarter). If the number of days is counted in each quarter, it appears that the first quarter has 90 days, the second one has 91 days, and the third and fourth one has 92 days. The quarters are not symmetrically distributed. Therefore, two additional working days in a quarter can make a difference in the statistics for a big company. In addition, holidays are not stable during the year. For example, Christmas on December 24 is on Thursday in 2020, while it is on Saturday in 2022.

In conclusion, the Gregorian calendar is difficult to handle and memorize. To solve the problem, other sophisticated calendars were proposed to facilitate our lives. The most famous calendar is called International Fixed Calendar (IFC) and also called Cotsworth calendar, which was introduced by Moses Cotsworth in 1902 [14]. The calendar divides the solar year into 13 months of 28 days each. This kind of calendar is defined as a perennial calendar, in which every weekday has a fixed date every year. The IFC has some rules to follow, as described below [14]:

- One year has 13 months,
- Each month has exactly 4 weeks,
- Each week has 7 days. Therefore, the total number of days in a year becomes equal to 364 (7 days x 4 weeks x 13 months),
- An extra day is added as a holiday at the end of the year, and it is called Year Day,
- The Year Day does not belong to any week. Therefore, the total number of days, including the Year day in a year, becomes equal to 365 days,
- The Cotsworth calendar is correlated to the Gregorian calendar in which it has the same number of days, and each year starts on the same date, which is January 1,
- Cotsworth calendar has the same month's names and order as the Gregorian calendar, except the extra month (called Sol), which is inserted between June and July [15],
- A leap year has 366 days, and its occurrence follows the Gregorian rules,
- The Leap-Day is inserted on June 29 (between Saturday, June 28, and Sunday, Sol 1),
- Each month starts on a Sunday and ends on a Saturday,
- Both Year-Day and Leap-Day do not belong to any week. They are preceded and followed by a Saturday and a Sunday, respectively.

Table 2 presents the IFC, in which the Leap-Day and the Year-Day are added to the end of months June and December. Despite the success of this calendar, it received many critics, and it has some drawbacks. The most common critics can be presented as follows:

a. The calendar claimed to have exactly 28 days in each month. However, when the leap day is added, June month will contain 29 days and not 28. The same for the leap year, in which it is added to the month of December. Hence, the total number of days becomes equal to 29.
b. The calendar has 13 months, which is a prime number and cannot be divided by 2, nor by 3, neither by 4. Therefore, it becomes difficult to categorize activities based on a biannually, triannually, or quarterly basis. Thus, activities will be out of alignment with months.
c. The week starts with a Sunday. Hence, the calendar disagrees with ISO 8601, in which the first day is Monday and not Sunday.
d. Adding a day between Saturday and Sunday is considered confusing, especially when leap-day and year-day are added to the month of June and December.
e. Some people are pessimistic about the date Friday 13th.
f. The weekday starts on the second of each month and not on the first.

Table 2. International Fixed Calendar.

International Fixed Calendar

Proposed by Moses Cotsworth in 1908

January

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

February

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

March

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

April

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

May

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

June

S	M	T	W	T	F	S	Leap-Day
1	2	3	4	5	6	7	
8	9	10	11	12	13	14	
15	16	17	18	19	20	21	
22	23	24	25	26	27	28	29

Sol

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

July

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

August

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

September

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

October

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

November

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

December

S	M	T	W	T	F	S	Year-Day
1	2	3	4	5	6	7	
8	9	10	11	12	13	14	
15	16	17	18	19	20	21	
22	23	24	25	26	27	28	29

1.4 Does the Gregorian calendar have an impact on the environment and energy demand?

There has been a high awareness of global warming and climate change in recent years, where the average global atmosphere temperature has exceeded 1.2°C above the pre-industrial level. Many countries and regions have started to shift from fossil fuel-based power plants to renewable energy-based power plants in order to reduce the Carbon footprint and the emission of CO_2 and other harmful gases [16, 17].

Fossil fuel-based power production is not the only cause of global warming and climate change. Inadequate consumption, excess of unnecessary production, and bad waste management also play an important role in increasing pollution and negatively affecting the whole planet [17, 18]. In addition, the competition between countries to increase their economic growth has also a huge impact on the Carbon footprint and the emission of harmful gases, which threaten the whole life on Earth [19]. From this place, any kind of production, whether it is energy or material, has a direct impact on the environment and climate change. More specifically, the excessive production of Gregorian calendars every year is energy-consuming and polluting at the same time since the whole process of production and distribution of the products consumes lots of energy and primary materials. According to The New York Times [20], the average number of printed calendars in households was 3.12 in 2011 compared to 3.98 in 1981 in the United States. Most of the countries still rely heavily on paper-based calendars.

With the advancement of technologies, digital calendars are presented everywhere, such as on smartphones, smart televisions, smartwatches, computers, laptops, etc. Even with the usage of these digital calendars, the time spent on surfing the calendars and looking for days and dates is considerably high. If the time used on such devices to check the calendar is summed up during a year for the whole world, the energy wasted is high enough to power a complete village for a complete year.

According to [21], and according to the standards ISO 14040/14044, the average carbon footprint of an office paper during its lifecycle is around 4.64gCO_2eq per A4 sheet. In this case, the weight of the sheet will be around 80g/m2. Therefore, a paper-based calendar which approximately has (200 A4 sheets or 400 A5 sheets) can produce about 928 gCO_2eq (or 0.928 kgCO_2eq).

Based on a survey released by a leading calendar communications platform in Australia in 2018, ECAL [22], 47% of participants rely on mobile calendars, 23.4% rely on a desktop calendar, 27.8% rely on paper calendars (including diary, journal, and planner), while 1.8% used other scheduling tools, as presented in Figure 1.

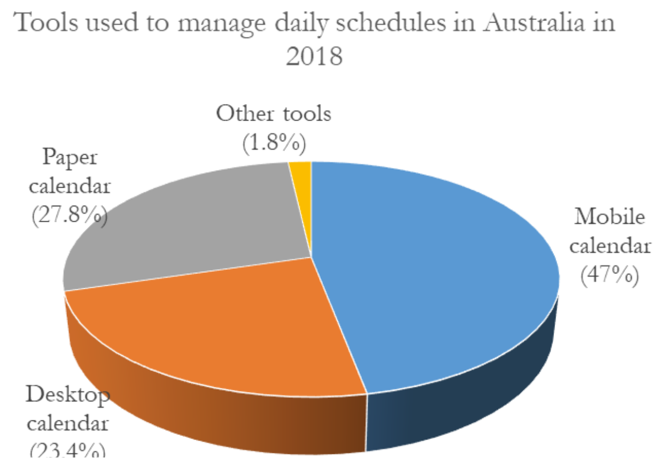

Figure 1. Tools used to manage daily schedules in Australia, 2018.

If these percentages are generalized on the total population on Earth (7.9 billion in 2021), just for approximation. It can be found that the number of produced paper-based calendars in a single year reaches about 2.2 billion paper-based calendars per year. Since the Carbon footprint of one paper-based calendar is about 0.928 kgCO_2eq, producing only paper-based calendars per year will be about 2.04 Mt CO_2eq (Mega tonne), which is a considerable amount. A more detailed calculation will be provided in this paper in the result section.

1.5 Contributions

The main contributions in this paper are stated as follows:

- A new mathematical formula is developed to describe the number of days in any month for any year (including leap year) for the Gregorian calendar. This formula eliminates the mistakes in counting the number of days in any month,
- Original perennial calendar systems are proposed, in which they respond to the critics mentioned in section 1.3 for the IFC. The proposed perennial calendar systems have the same number of days in any months, and the dates of days never change. For example, Monday will be always the first day of a week, a month and a year, and it will always have the same date (such as 1st January, 1st February, 1st March, etc.),
- A perfect calendar is newly introduced and defined as a calendar that can be divided into equal intervals during a year (e.g., 2 "biannual", 3 "triannual", 4 "quarter", 5 "quinnanual", and 6 "sexannual"), and each interval has exactly the same number of weeks and days.
- An original optimization algorithm that generates perennial calendars is proposed. An objective function and some constraints are defined for this purpose. The algorithm is solved with Mixed Integer Genetic Algorithm.

To validate our concept, one of the proposed perennial calendar systems is compared to the Gregorian calendar and the International Fixed Calendar, and different aspects are considered in the comparison, such as technical, economic, environmental, individual, and social aspects. Moreover, a deeper analysis is conducted to study their impact on energy consumption, energy and production waste, and the carbon footprint.

2. NEW MATHEMATICAL FORMULA DESCRIBES THE NUMBER OF DAYS IN ANY MONTH

Gregorian calendar is an irregular calendar in which the number of days is not the same for all months. Some months have 30 days, and others have 31. The month of February has 28 days, and a day is added in a leap year in which the total number of days becomes equal to 29. Sometimes, it is confusing for some people to remember the number of days for each month, and even it becomes embarrassing for others on social media to post wrong dates and days, such as in Figure 2.

Figure 2. Wrong date and day on a weather forecast show.

There is a traditional way to calculate the number of days in a month using the fist as in Figure 3. The knuckles of the four fingers of one's hand and the spaces between them can be used to remember the lengths of the months. By making a fist, each month will be listed as one proceeds across the hand. All months landing on a knuckle are 31 days long, and those landing between them are 30 days long, with variable February being the remembered exception. When the knuckle of the index finger is reached (July), go over to the first knuckle on the other fist, held next to the first (or go back to the first knuckle), and continue with August. This physical mnemonic has been taught to primary school students for many decades, if not centuries [23].

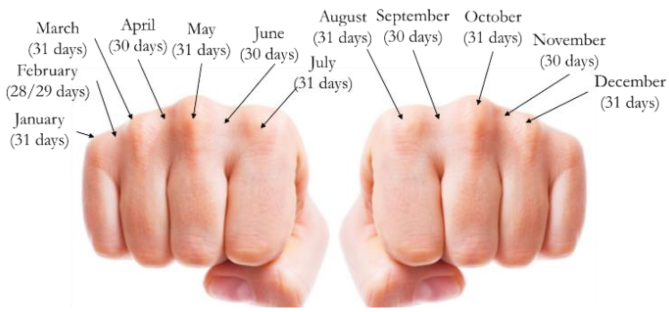

Figure 3. Traditional method uses the fist to count the number of days in a month.

Another method using the keyboard/piano is also popular, as presented in Figure 4. The cyclical pattern of month lengths matches the musical keyboard/piano alternation of wide white keys (31 days) and narrow black keys (30 days). The note F corresponds to January, and the diabolis in musica note F♯ corresponds to February, the exceptional 28-29 day month.

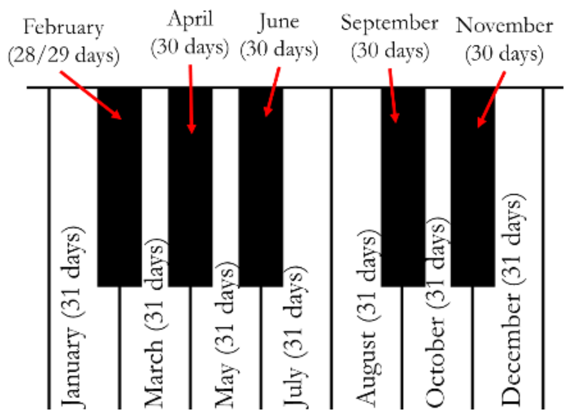

Figure 4. Traditional method uses the keyboard/piano to count the number of days in a month.

The disadvantages of the traditional methods are, (i) they are not based on mathematical proof, (ii) the number of days of February is not determined since they don't take into account the leap year. Although with these disadvantages, they are the simplest methods for counting the number of days in a month and have been taught for hundreds of years.

In the literature, there are various methods to calculate the day of the week for any particular date in the past or future [24, 25]. These methods rely on algorithms to determine the day of the week for any given date, including those based solely on tables as found in perpetual calendars that require no calculations to be performed by the user. A typical application is to calculate the day of the week on which someone was born or any other specific event occurred. Even by using the Gauss calendar formula, there are some parameters that should be predefined in order to calculate the number of days in a month.

In this paper, a new mathematical formula is proposed that calculates the number of days for each month even during a leap year, as presented in Eq. (1).

$$N_{days} = \left(\begin{array}{c} 30 + \dfrac{\cos(\pi(m-1+U(m-8)))+1}{2} \\ + rect_{0.2}(m-2)\left[rect_{0.2}\big(Mod(y,4)\big)-2\right] \end{array} \right) \quad (1)$$

Where,

- N is the number of days in a month, i.e., 31 in January, 28 in February (in a non-leap year and 29 in a leap year), etc.,
- m is the month number, e.g., $m = 2$ for February,
- $U(x)$ is a unity step function defined in Eq. (2),
- $rect_T(x)$ is a rectangular function defined in Eq. (3),
- y is the year, e.g., $y = 2021$,
- Mod($number$, $divisor$) returns the remainder after a number is divided by a divisor. The result has the same sign as the divisor. Number: is the number for which you want to find the remainder, e.g, 2021. Divisor: is the number by which you want to divide the number, e.g, 4. For example, $Mod(1,4) = 1$, $Mod(2,4) = 2$, $Mod(4,4) = 0$, etc.

$$U(m-8) = \begin{cases} 1 \; if \; m \geq 8 \\ 0 \; if \; m < 8 \end{cases} \quad (2)$$

$$rect_T(x) = \begin{cases} 1 \; for \; -\dfrac{T}{2} < x < \dfrac{T}{2} \\ \dfrac{1}{2} for \; x = \pm\dfrac{T}{2} \\ 0 \; for \; -\dfrac{T}{2} > x > \dfrac{T}{2} \end{cases} \quad (3)$$

A step-by-step calculation is made in Table 3 to determine the number of days in any month of a year, including the leap year.

Table 3. Step by step calculation to determine the number of days in any month.

	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Month (m)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Number of days	31	28 29	31	30	31	30	31	31	30	31	30	31
$U(m-8)$	0	0	0	0	0	0	0	1	1	1	1	1
$\cos(\pi(m-1+U(m-8)))$	1	-1	1	-1	1	-1	1	1	-1	1	-1	1
$\frac{\cos(\pi(m-1+U(m-8)))+1}{2}$	1	0	1	0	1	0	1	1	0	1	0	1
$30+\frac{\cos(\pi(m-1+U(m-8)))+1}{2}$	31	30	31	30	31	30	31	31	30	31	30	31
$rect_{0.2}(m-2)$	0	1	0	0	0	0	0	0	0	0	0	0
$rect_{0.2}(m-2)[rect_{0.2}(Mod(y,4))-2]$	0	-2 -1	0	0	0	0	0	0	0	0	0	0
$\left(30+\frac{\cos(\pi(m-1+U(m-8)))+1}{2}+ rect_{0.2}(m-2)[rect_{0.2}(Mod(y,4))-2]\right)$	31	28 29	31	30	31	30	31	31	30	31	30	31

Remark: the number of days for the month of February in the table is 28 for non-leap year, and 29 for leap year.

Eq. (1) can be also programmed which makes it easier for the user to determine the number of days in each month for any year. The code is written in Scilab 6.1.1.

3. PROPOSED PERENNIAL CALENDAR

The idea of creating a perennial calendar, such as the International Fixed Calendar (IFC), was to make our life easier. Its main advantages are as follows: (a) the calendar never expires, and it is always relevant, (b) it becomes easier to memorize and remember events and dates, (c) there is no need to change the calendar or by a new one every year, (d) adding new events is easy and can be done once, etc. However, the IFC has many drawbacks, as mentioned previously. To address these drawbacks, new perennial calendar systems are proposed based on the idea of the IFC, the Gregorian calendar, and using optimization. To do so, a new annotation will be used in this paper to refer to a specific calendar. The annotation is "MWD+R", or simply the mathematical formula can be written as in Eq. (4), and explained in Figure 5.

Code on Scilab:

```
//Calculate the number of days in each month for any year

clear;clc;close;//Clear all previous data

repeat=1;//Initial value to enter the while loop

while repeat==1
    disp("Enter the year that you would like to check the
          number of days for each month");

    year=input("Year= ");

    for m=1:12 //m is the month number

        //convert a sign into a unit step function
        U=(sign(m-7.9)+1)/2;

        //convert a sign into a rectagular pulse function
        rect=(sign(m-2+0.2)+1)/2-(sign(m-2-0.2)+1)/2;

        rect_mod=(sign(modulo(year,4)+0.2)+1)/2-
                 (sign(modulo(year,4)-0.2)+1)/2;

        //Number of days for each month "m"
        N_days(m)=30+(cos(%pi*(m-1+U))+1)/2 + rect*
                      (rect_mod-2);
    end

    //Write the month number and the number of days in
     each month in the same matrix
    Number_of_Days_per_Month(1,:)=1:12;
    Number_of_Days_per_Month(2,:)=N_days';

    disp("Month Number:              ");
    disp("Number of days per month: ");
    disp(Number_of_Days_per_Month);

    disp("Would you like to repeat?");
    repeat=input("Press ""1"" for YES or any key for NO:
             ");
end

disp("Thanks for using this application!  ");
disp("************************************");
disp("Copyrighted (C) Claude Ziad El-Bayeh");
disp("************************************");
```

Output on the Console window

```
"Enter the year that you would like to check the number
of days for each month"

Year= 1987

"Month Number:              "
"Number of days per month: "

1.  2.  3.  4.  5.  6.  7.  8.  9.  10. 11.  12.
31. 28. 31. 30. 31. 30. 31. 31. 30. 31. 30.  31.

"Would you like to repeat?"

Press "1" for YES or any key for NO: 1



"Enter the year that you would like to check the number
of days for each month"

Year= 1988

"Month Number:              "
"Number of days per month: "

1.  2.  3.  4.  5.  6.  7.  8.  9.  10. 11.  12.
31. 29. 31. 30. 31. 30. 31. 31. 30. 31. 30.  31.

"Would you like to repeat?"

Press "1" for YES or any key for NO: 2



"Thanks for using this application!  "
"************************************"
"Copyrighted (C) Claude Ziad El-Bayeh"
"************************************"
```

$$M \times W \times D + R = 366 \text{ days in a leap year} \quad (4)$$

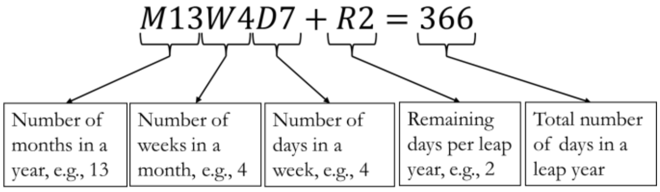

Figure 5. Example of annotating a calendar with the name M13W4D7+R2, which means there are 13 months a year, 4 weeks a month, 7 days a week, and 2 remaining days in a leap year.

M presents the number of months in a year (e.g., M = 12 months in a year). W shows the number of weeks in a month (e.g., W = 4 weeks in a month). D stands for the number of days in a week (e.g., D = 7 days in a week). R describes the number of remaining days that fill the gap between a perennial calendar and the actual number of days in a leap year (366). For example, calculate R if there are 12 months a year, 4 weeks a month, and 7 days a week. In this case, M=12, W=4, D=7. Hence,

M x W x D + R = 12 months/year x 4 weeks/month x 7 days/week + R = 366

⇒R = 366 – 12 x 4 x 7 = 30 remaining days per leap year

Based on the above-mentioned example, the number of remaining days per year is almost equal to one month for the Gregorian calendar. Therefore, the Gregorian calendar cannot be considered a good example of a perennial calendar. From this place, the real number of months in a year should be equal to 13 in the above case. An ideal perennial calendar is when the remaining number of days in a year will be equal to zero, hence R = 0. However, this is not possible for the Earth because the number of days in a year does not have an integer value, and it is equal almost to 365.2422. Therefore, it is necessary to rearrange the number of days, weeks, and months in order to minimize R. Thus, it becomes an optimization problem in which we need to recalculate the number of months, weeks, and days in a way to minimize R.

3.1 Optimization Model

As discussed previously, to minimize the number of remaining days in a year, an optimization model should be created. The objective function is described in Eq. (5), and the constraints are shown in Equations (6) to (10). Where, R_{min} and R_{max} describe the lower and upper bound of the number of remaining days in a perennial calendar. M_{min} and M_{max} are the lower and upper bound of the number of months per year. W_{min} and W_{max} represent the lower and upper bound of the number of weeks per month. D_{min} and D_{max} show the lower and upper bound of the number of days per week. It is obvious that the optimization problem is mixed-integer nonlinear programming in which M, W, D, and R should be integers. To solve the problem, the Mixed-Integer Genetic Algorithm (MIGA) is used in this paper.

Objective function:

$$\text{Minimize } R = Y - M * W * D \quad (5)$$

Subject to :

$$R_{Min} \leq Y - M * Y * D \leq R_{Max} \quad (6)$$

$$M_{Min} \leq M \leq M_{Max} \quad (7)$$

$$W_{Min} \leq W \leq W_{Max} \quad (8)$$

$$D_{Min} \leq D \leq D_{Max} \quad (9)$$

$$[r, M, W, D] \in \mathbb{N} \quad (10)$$

3.2 Optimization Algorithm

To solve the above problem, Algorithm 1 is proposed and written in MATLAB 2018b. The initial values (such as Mmin, Mmax, etc.) can be changed according to the needs of the user. Mixed Integer Genetic Algorithm (MIGA) is used as an optimization technique to solve the problem. The initial values of the input are stated in Table 4.

4. RESULTS AND DISCUSSIONS

4.1 Assumptions

After defining the optimization model and algorithm, it is necessary to present the assumptions that are considered in this paper. The optimization model requires the user to set the boundaries of the constraints. For this purpose, the limits are defined as follows:

- The remaining number of days in a year: Rmin=0 and Rmax=10. By increasing the range, more options appear to the user to choose the best calendar that fits his needs.

- The number of months in a year: Mmin=10 and Mmax=20. We do not want a number of months less than 10 because they become very long.

- Number of Weeks in a month: Wmin=0 and Wmax=20. We set the number of weeks flexible in order to get more options.
- Number of Days in a week: Dmin=5 and Dmax=8. A number less than 5 represents a too-short week, and a number greater than 8 is considered too long for a week.

4.2 Output results of the algorithm

Table 5 presents a selected list of options with their input and output results for the number of months, weeks, days, and remaining days per year for the proposed perennial calendars. The values can change when the boundaries of the constraints change.

Table 4. Input of the optimization model.

Input								
Y	**Rmin**	**Rmax**	**Mmin**	**Mmax**	**Wmin**	**Wmax**	**Dmin**	**Dmax**
366	0	10	10	20	0	20	5	8

Algorithm 1. Optimization model of the proposed original perennial calendar.

```
%% An Original Optimal Perennial Calendar

clc;clear;close all;%Clear all previous data on MATLAB


%% Optimization Model-------------------------------
for section1=1:1%Initial Values
    Y=366; %Number of days in a leap year
    Mmin=0; Mmax=20; %minimum and maximum number of
           months in a year
    Wmin=0; Wmax=20; %minimum and maximum number of
           Weeks in a Month
    Dmin=5; Dmax=8; %minimum and maximum number of
           Days in a Week
    Rmin=0; Rmax=10; %minimum and maximum number of
           remaining Days in a Year
End


for section1=1:1%Optimization Model
    %Decision variable: X, X(1)=Month, X(2)=Week,
      X(3)=Day
    OF=@(X)(Y-X(1).*X(2).*X(3)); %Objective Function

    %Constraints of the Form A*x<=B
    A=[1 0 0 ; 0 1 0 ; 0 0 1]; B=[Mmax, Wmax, Dmax]';

    %Constraints of the Form Aeq*x=Beq
    Aeq=[]; Beq=[];

    %Constraints of the Form lb<=x<=ub
    LB=[Mmin Wmin Dmin]'; %Lower Bound
    UB=[Mmax Wmax Dmax]'; %Upper Bound

    X0=zeros(3,1);%Starting point

    %Solution of the Optimization
    nvar=3; %Number of studied variables
    IntCon=[1,2,3]; %Variable that should be integer

    [X,Value,exitflag,output]=ga(OF,nvar,A,B,Aeq,Beq,
      LB, UB,@C_Matrix,IntCon);

    X %Show the number of Variable

    R=Value %Show the remaining number of days

    MWD=X(1).*X(2).*X(3) %Show total number of days in
          a year except the remaining days

    fprintf('M=%2.0f , W=%2.0f, D=%2.0f, R= %2.0f ,
          MWD= %2.0f \n',X,R,MWD)
end


function [C,Ceq] = C_Matrix(X)
    Y=366;
    Rmin=0; Rmax=10;
    C(1)= X(1).*X(2).*X(3)-Y+Rmin;
    C(2)= Y-X(1).*X(2).*X(3)-Rmax;
    Ceq=[];
end
```

Table 5. Input and Output Results of the Optimization Model.

	Input								Output							
Options	**Rmin**	**Rmax**	**Mmin**	**Mmax**	**Wmin**	**Wmax**	**Dmin**	**Dmax**	**M**	**W**	**D**	**R**	**MWD**	**Nb of weeks in a year**	**Perfect Calendar**	**Semi-Perfect Calendar**
1	0	10	10	20	0	20	5	8	10	6	6	6	360	**60**	**Yes**	-
2	0	10	10	20	0	20	5	8	12	6	5	6	360	72	No	Yes
3	0	10	10	20	0	20	5	8	12	5	6	6	360	**60**	**Yes**	-
4	0	10	10	20	0	20	5	8	12	3	10	6	360	36	No	Yes
5	0	10	10	20	0	20	5	8	13	4	7	2	364	52	No	No
6	0	10	10	20	0	20	5	8	15	4	6	6	360	**60**	**Yes**	-
7	0	10	10	20	0	20	5	8	15	3	8	6	360	45	No	No
8	0	10	10	20	0	20	5	8	18	4	5	6	360	72	No	Yes
9	0	10	10	20	0	20	5	8	20	3	6	6	360	**60**	**Yes**	-

A calendar that has 13 months, such as some of the proposed Optimal Perennial Calendars in this paper, has a prime number "13" which cannot be divided by 2, nor by 3 neither by 4. Therefore, it becomes difficult to categorize activities based on a biannually, triannually, or quarterly basis. In order to solve the problem, dividing the year into many intervals can be done on a weekly basis in which the total number of weeks in a 13 months calendar system is equal to 52 (13x4).

In this paper, a perfect calendar is defined as a calendar which can be divided into many equal intervals (particularly 2 (biannually), 3 (triannually), 4 (quarterly), 5 (quinannually), and 6 (sexannually) with the exact number of weeks in each interval. A semi-perfect calendar is defined as a calendar that can satisfy at least 4 of the previously mentioned intervals (2, 3, 4, 5, and 6), as presented in Table 6.

Table 6. Example of dividing a year into intervals with the same number of weeks for different perennial calendars.

Proposed optimal perennial calendar systems		**M12W3D10+R6**	**M15W3D8+R6**	**M15W3D8+R6**	**M13W4D7+R2**	**M12W5D6+R6**	**M10W6D6+R6**	**M12W6D5+R6**	**M18W4D5+R6**
Number of Weeks		**36**	**45**	**45**	**52**	**60**	**60**	**72**	**72**
Interval per year	2	18	22.50	22.50	26	30	30	36	36
	3	12	15	15	17.33	20	20	24	24
	4	9	11.25	11.25	13	15	15	18	18
	5	7.20	9	9	10.40	12	12	14.40	14.40
	6	6	7.50	7.50	8.67	10	10	12	12
Perfect Calendar		**No**	No	No	No	**Yes**	**Yes**	No	No
Semi-Perfect Calendar		**Yes**	No	No	No	-	-	**Yes**	**Yes**

4.3 Case Study of a Calendar with 13 Months, 4 Weeks and 7 days (M13W4D7+R2)

In this paper, only the perennial calendar "M13W4D7+R2" (option 5) is discussed, while others can be interpreted in the same way. Table 7 presents the proposed perennial calendar "M13W4D7+R2" based on some new rules, as stated below:

- One year has 13 months with an exact number of days and weeks. No days are added to any month nor to any week. Hence, the drawback (a) mentioned in section 1.3 is resolved,
- Each month has exactly 4 weeks,
- Each week has exactly 7 days. Therefore, the total number of days in a year becomes equal to 364 (7 days x 4 weeks x 13 months),
- A new month is added to the list, which is called "Month Zero", in which it contains the remaining days (Year-day and the Leap-day). The reason for adding this month is to separate the remaining days from the normal days, which is not the case with IFC. In addition, it respects the international standard ISO 8601, in which the dates are expressed. For example, 2020-00-01 is the Year-day, 2020-00-02 is the leap-day in a leap year, 2020-01-01 is the first official day of the year 2020, which is Monday, etc. Therefore, there is a consistency in numbering the days, dates, and their expressions,
- We do not celebrate the end of a year as other existing calendars do, such as the GC, JC, and IFC. On the contrary, we celebrate the beginning of a new year. That is why Month Zero is added at the beginning, which represents a new start and a happy month in our lives. This method has a positive impact on the psychology of the people in which the end is not important as the beginning of a new thing in their life,
- Friday will never occur on the 13th of any month. Therefore, some people who feel pessimistic about this date will be satisfied with the new calendar. Hence, the problem (e) in section 1.3 is solved,
- The Year-Day and Leap-Day only belong to the "Month Zero". Therefore, months still have the same number of days and will never change. Therefore, the problem (d) in section 1.3 is solved,
- A leap year has 366 days, and its occurrence follows the Gregorian rules,
- Each week starts on Monday and ends on Sunday, which agrees with the international standard ISO 8601. Therefore, the problems (c) and (f) in section 1.3 are addressed,
- Each month starts on Monday and ends on a Sunday,
- Every year starts on Monday and ends on Sunday. Therefore, Month Zero is considered as a fictive month with a maximum of 2 days, which are feast days that celebrate the beginning of a new year.
- For business purposes, instead of dividing the year into quarters or triannuals, it is recommended to consider weeks that give more accurate results. For example, if we want to divide a year into 4 quarters, in the proposed

calendar, each quarter is exactly 13 weeks. For a triannual year, 17 weeks are considered for the first two triannually -based year, and 18 weeks are considered for the third period. Therefore, problem (b) mentioned in section 1.3 is solved.

Table 7. Proposed perennial calendar M13W4D7+R2.

The proposed Perennial Calendar M13W4D7+R2	
Year: Any year has the same sequence of days and dates	

Month Zero	
Year-day	Leap-day
1	2
# of Working Days:	260
# of Off Days:	105

Month 1 (January)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 2 (February)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 3 (March)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 4 (April)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 5 (May)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 6 (June)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 7 (July)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 8 (August)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 9 (September)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 10 (October)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 11 (November)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 12 (December)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 13 (Undecember)						
M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Based on Table 7, it is clear that the proposed Calendar has a more systematic organization of days and months in a year compared to the Gregorian calendar. The first day of a month always starts on Monday, and the last day of each month is always Sunday. Therefore, counting days becomes an easy task, and there is no need for complex algorithms to predict the days and dates in previous years. The days and dates in the proposed Calendar have strong and correlated relationships, which can be described by simple mathematical equations as in Eq.(11).

$$\begin{cases} Monday = 1 + 7(w-1) \\ Tuesday = 2 + 7(w-1) \\ Wednesday = 3 + 7(w-1) \\ Thursday = 4 + 7(w-1) \\ Friday = 5 + 7(w-1) \\ Saturday = 6 + 7(w-1) \\ Sunday = 7 + 7(w-1) \\ Yearday = 365 \\ Leap\ day = 366\ (in\ a\ leap\ year) \end{cases} \quad (11)$$

$$Where\ w\ is\ the\ week\ number\ in\ a \begin{cases} month: w \in [1,4] \\ year: w \in [1,52] \end{cases}$$

As an example, calculate the date of Monday in the third week of a month.

Answer: Monday $= 1 + 7(3-1) = 15$

March						
Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Another example, calculate the day number of Wednesday located on the 36th week of the year.

Answer: Wednesday $= 3 + 7(w-1) = 3 + 7(36-1) = 248$

July						
Mon	Tue	Wed	Thu	Fri	Sat	Sun
169	170	171	172	173	174	175
176	177	178	179	180	181	182
183	184	185	186	187	188	189
190	191	192	193	194	195	196

August						
Mon	Tue	Wed	Thu	Fri	Sat	Sun
197	198	199	200	201	202	203
204	205	206	207	208	209	210
211	212	213	214	215	216	217
218	219	220	221	222	223	224

September						
Mon	Tue	Wed	Thu	Fri	Sat	Sun
225	226	227	228	229	230	231
232	233	234	235	236	237	238
239	240	241	242	243	244	245
246	247	248	249	250	251	252

October						
Mon	Tue	Wed	Thu	Fri	Sat	Sun
253	254	255	256	257	258	259
260	261	262	263	264	265	266
267	268	269	270	271	272	273
274	275	276	277	278	279	280

4.4 Comparison between the proposed calendar and the Gregorian calendar

In this subsection, a comparison between the proposed and Gregorian calendars is presented. Table 8 shows both calendars, in which it is obvious that the proposed one is much easier to memorize because all months look the same. A more detailed comparison is presented in Table 9.

Table 8: Comparison between the proposed and Gregorian calendars.

The proposed Perennial Calendar M13W4D7+R2	Gregorian Calendar
Year: Any year has the same sequence of days and dates	Only for the year 2020, the dispalcement of dates and days change

The proposed Perennial Calendar M13W4D7+R2

Month Zero

Year-day	Leap-day
1	2

Month 1 (January)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 2 (February)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 3 (March)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 4 (April)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 5 (May)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 6 (June)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 7 (July)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 8 (August)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 9 (September)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 10 (October)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 11 (November)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 12 (December)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 13 (Undecember)

M	T	W	T	F	S	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Gregorian Calendar

January 2020

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

February 2020

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

March 2020

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

April 2020

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

May 2020

S	M	T	W	T	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

June 2020

S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

July 2020

S	M	T	W	T	F	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

August 2020

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

September 2020

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

October 2020

S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

November 2020

S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

December 2020

S	M	T	W	T	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Table 9: Comparison between three calendars, the proposed one (M13W4D7+R2), Gregorian, and IFC.

Aspects	**Description**	**Proposed Calendar**	**GC**	**IFC**
Technical	Number of weekends in a year	**Up to 106**	Up to 104	**Up to 106**
	Complexity of the system	**Very easy**	Complex	Easy
	Computation time	**Very low**	Very high [26]	Low
	Reduce wasted time to check days and dates on a calendar	**Very low**	Very high	Low
	Do we need a Calendar to check the dates	**No**	Yes	**No**
	Considered as Perennial Calendar	**Yes**	No	**Yes**
	The date of days does not change (e.g., the 17th always falls on a Tuesday)	**Yes**	No	**Yes**
	Calendar respects international standards	**Yes**	No	No
Economic	Number of payable months	**13**	12	**13**
	Easy scheduling for institutions and industries with extended production cycles	**Yes**	No	**Yes**
	Accurate statistical comparisons by months, since all months have exactly the same number of business days and weekends	**Yes**	No	**Yes**
	Possibility of error in printing the calendar and calculating the dates	**No**	Yes [27]	**No**
	Can be considered as a financial calendar in which years can be divided into quarters, triannuals, and biannuals	**Yes (based on weeks instead of months)**	**Yes**	No
Environ-mental	Eco-friendly	**Yes**	No	**Yes**
	Reduce the number of printed hard-copies	**Yes**	No	**Yes**
	Reduce pollution and waste from printing the calendars	**Yes**	No	**Yes**
	Reduce energy consumption	**Yes**	No	**Yes**
Indivi-dual	Better organization of personal life	**Yes**	No	**Yes**
	Accurate appointments and events	**Yes**	No	**Yes**
Social	Movable holidays celebrated on the *n*th certain weekday of a month, (e.g., Thanksgiving Day), would be able to have a fixed date while keeping their traditional weekday	**Yes**	No	**Yes**
	Better organization of social activities	**Yes**	No	**Yes**
	Less conflict because of missing some events, meetings, and appointments	**Yes**	No	**Yes**

4.5 Other proposed Calendars

In the previous subsection, the proposed calendar "M13W4D7+R2" is discussed. However, Table 5 shows other possible solutions, in which some of them will be presented briefly in this subsection. In Tables 10 to 13, only 4 calendars are presented, which come from Table 5. The yellow boxes represent the weekends and the day offs, and the white boxes are for the working days.

Table 10. Proposed calendar: M12W5D6+R6.

The proposed Calendar M12W5D6+R6

Year: Any year has the same sequence of days and dates

Month 01

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 02

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 03

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 04

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 05

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 06

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 07

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 08

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 09

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 10

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 11

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 12

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30

Month 13 (Year-Month)

YD1	YD2	YD3	YD4	YD5	YD6	
1	2	3	4	5	6	← For the day 366 in a leap year
For days 361 to 365						

# of Working Days: 264

# of Off Days: 102

This calendar has 12 official months. Each month has 5 weeks of 6 days each. At the end of the year, an additional Month is added with only 5 days (+1 leap day in a leap year). These days are called Yeardays, in which they are different from the normal days, and can be considered as holidays or day off for employees.

Table 11. Proposed calendar: M12W6D5+R6.

The proposed Calendar M12W6D5+R6

Year: Any year has the same sequence of days and dates

Month 01

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 02

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 03

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 04

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 05

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 06

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 07

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 08

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 09

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 10

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 11

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 12

D1	D2	D3	D4	D5
1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25
26	27	28	29	30

Month 13 (Year-Month)

YD1	YD2	YD3	YD4	YD5	YD6	
1	2	3	4	5	6	← For the day 366 in a leap year
For day 365						

# of Working Days: 264

# of Off Days: 102

This calendar has 12 official months. Each month has 6 weeks of 5 days each. At the end of the year, an additional Month is added with only 5 days (+1 leap day in a leap year). These days are called Yeardays, in which they are different from the normal days, and can be considered as holidays or day off for employees.

Table 12. Proposed calendar: M10W6D6+R6.

The proposed Calendar M10W6D6+R6

Year: Any year has the same sequence of days and dates

Month 01

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 02

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 03

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 04

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 05

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 06

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 07

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 08

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 09

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 10

D1	D2	D3	D4	D5	D6
1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Month 11 (Year-Month)

YD1	YD2	YD3	YD4	YD5	YD6	
1	2	3	4	5	6	← For the day 366 in a leap year
For days 361 to 365						

# of Working Days: 260

# of Off Days: 106

This calendar has 10 official months. Each month has 6 weeks of 6 days each. At the end of the year, an additional Month is added with only 5 days (+1 leap day in a leap year). These days are called Yeardays, in which they are different from the normal days, and can be considered as holidays or day off for employees.

Table13. Proposed calendar: M15W3D8+R6.

The proposed Calendar M15W3D8+R6

Year: Any year has the same sequence of days and dates

Month 01

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 02

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 03

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 04

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 05

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 06

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 07

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 08

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 09

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 10

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 11

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 12

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 13

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 14

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

Month 15

D1	D2	D3	D4	D5	D6	D7	D8
1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24

This calendar has 15 official months. Each month has 3 weeks of 8 days each. At the end of the year, an additional Month is added with only 5 days (+1 leap day in a leap year). These days are called Yeardays that they are different from the normal days, and can be considered as holidays or day off for employees

Month 11 (Year-Month)

YD1	YD2	YD3	YD4	YD5	YD6	
1	2	3	4	5	6	←For the day 366 in a leap year
For days 361 to 365						

# of Working Days: 255

# of Off Days: 111

4.6 Impact on the Environment and Energy Demand

The rotation of the Earth around the Sun takes almost 365.2422 days which is neither an even number nor an integer and cannot be divided into equal intervals. Therefore, it was challenging to create a user-friendly and easy to memorize calendar in which the number of days, weeks, and months are distributed equally along the year. Gregorian calendar was one of many attempts to create an accurate calendar that reduces the calculation error in counting the number of days on a long period, as mentioned in Table 1. Despite the accuracy of the Gregorian calendar, it has lots of drawbacks. It is not a user-friendly calendar, and it is not easy to memorize the days and their corresponding dates. Therefore, it was necessary to print out the calendar on paper, which will increase the pollution and the emission of Green House Gases (GHG) such as CO_2. In addition, lots of energy is consumed to produce and distribute these paper-based calendars. In modern times, computers, cell phones, and smartwatches are mostly used to check the days and dates and save events. They do not consume paper; however, they still consume lots of energy, as will be calculated in the following subsections.

4.6.1 Impact on the energy demand

In order to proceed in the calculation, it is important to select the most pertinent data set for the problem. In this subsection, we intend to collect data of mobile and computer users in order to calculate the impact of using digital calendars on total energy consumption worldwide. In other meaning, we will calculate the wasted energy by checking the dates and days using digital calendars. Input data are presented as follows:

- Current world population 7.9 billion people (2021),
- Number of mobile phone users: 5.27 billion [28],
- Number of computer users: 2 billion [29],
- Average time spent to check the days and dates on the calendar per user per day: 5 minutes,
- Efficiency from power generation to consumption: 0.88 considering losses on transmission/distribution lines,
- Average energy consumption of a mobile per day: 12Wh,
- Average power consumption of a mobile: 1.8W average,
- Charging efficiency: 0.9,
- Average power consumption of a computer: 60W (considering desktops, and laptops).

Table 14. Average computer energy consumption [30].

Computer Type	Energy Consumption
Desktop Computer	60-250 Watts
Computer with Active Screen Saver	60-250 Watts
Computer on Sleep or Standby	1-6 Watts
Laptop	15-45 Watts

Table 15 presents the calculation made to find out the wasted energy to check the days and dates on a calendar for all users across the globe per year using computers and mobile phones. It was found that almost 293 GWh/year are wasted just to check the Gregorian calendar, while it is about 23.4 GWh/year for the proposed Optimal Perennial Calendar (M13W4D7+R2) in the worst-case scenario. Therefore, the proposed optimal perennial calendar system has reduced the energy demand by at least 12.5 times compared to the Gregorian calendar.

Table 15. Wasted energy to check dates & days using GC and OPC (M13W4D7+R2).

Description	**Value**		**Unit**	**Equation**
Population	7.90E+09		-	A
Number of mobile users	5.27E+09		-	B
Number of computer users	2.00E+09		-	C
Average time spent to check the days and dates on the calendar per user per day	3.47E-03	2.78E-04	[hour/day]	D=(5/60)min / 24h
Mobile phone	**GC**	**OPC**	**Unit**	**Equation**
Average energy consumption of a mobile per day	12	12	[Wh/day]	E
Average energy consumption of a mobile per day from the generation side (considering losses of the charger (10%), distribution and transmission lines (12%))	15.152	15.152	[Wh/day]	F=E/(0.9*0.88)
Average energy consumption of a mobile per day to check the days and dates on the calendar from the generation side (considering losses of the charger (10%), distribution and transmission lines (12%))	0.0526	0.0042	[Wh/day]	G=F*D
Average energy consumption of all mobile phones for all users to check the days and dates on the calendar from the generation side	277,252	22,180	[kWh/day]	H=G*B/1000
	277.252	22.180	[MWh/day]	I=H/1000
	101.197	**8.096**	**[GWh/year]**	**J=I*365/1000**
Computer	**GC**	**OPC**	**Unit**	**Equation**
Average power consumption of a computer/laptop	60	60	[W]	K
Average energy consumption of a computer per day to check the days and dates on the calendar	0.2083	0.0167	[Wh/day]	L=K*D
Average energy consumption of a computer per day to check the days and dates on the calendar from the generation side	0.2630	0.0210	[Wh/day]	M=L/(0.9*0.88)
Average energy consumption of all computers for all users to check the days and dates on the calendar from the generation side	526,094	42,088	[kWh/day]	N=M*C/1000
	526.094	42.088	[MWh/day]	O=N/1000
	192.024	**15.362**	**[GWh/year]**	**P=O*365/1000**
Total energy demand to check the calendar per year for all users	**293.221**	**23.458**	**[GWh/year]**	**Q=P+J**

4.6.2 Impact on the CO_2 emission and pollution

The production of paper-based calendars every year does not only increase the energy waste but also increases the CO_2 emission and the waste, as presented in Table 16. It can be remarked that the CO_2 emission by producing only paper-based calendars may exceed 3.8 million tons per year and yield about 1.9 million tons of waste. Of course, we did not consider the pollution from the power plant sources since we assume that the energy production comes from renewable energy sources such as photovoltaics and wind turbines, using storage systems such as batteries. In the case when fuel-based power plants are used, the figures could be tripled since the average efficiency of most of the fuel-based power plants does not exceed 33%.

Table16. CO_2 emission and waste production using GC and OPC(M13W4D7+R2).

Calendar	**GC**	**OPC**		
Description	**Value**	**Value**	**Unit**	**Equation**
Population	7.90E+09	7.90E+09	-	A
Sold calendars per year (including wall calendars, and paper calendars)	1.90E+09	1.90E+09	-	B
Average number of sheets per calendar	200	0.1	-	C
Number of sheets produced each year to create paper-based calendars	3.80E+11	1.90E+08	sheet/year	D=C*B
CO2 emission per paper sheet	5	5	g of CO2/sheet	E
CO2 emission per printed paper sheet	10	10	g of CO2/sheet	F
Total CO2 emission per year	3.80E+09	1.90E+06	kg/year	G=D*F/1000
	3.80E+06	**1.90E+03**	**Ton/year**	**H=G/1000**
CO2 reduction ratio (GC/OPC)		**2000**	**Ton/year**	H(GC)/H(OPC)
Weight of a sheet letter	5	5	g	I
Total weight of used papers	**1.90E+06**	**9.50E+02**	**Ton**	**J=I*D/1e6**
CO2 reduction ratio (GC/OPC)		**2000**	**Ton/year**	J(GC)/J(OPC)

From this place, it is time to rethink again about changing our calendar system to a more efficient, user-friendly, easier to memorize, eco-friendly, and sustainable calendar system using one of the proposed OPC systems in this paper. The massive production of calendars every year is energy-consuming and material-consuming. Thus, the carbon footprint of the Gregorian calendar is high and should be reduced by any means.

5. CONCLUSION

The Gregorian calendar has been used for several centuries, in which it was introduced to correct the Julian calendar. Despite the success of the Gregorian calendar worldwide, and despite its accuracy, it is not easy to deal with the dates and days; hence sophisticated software is needed to calculate the dates of corresponding days. Billions of hard copies of the calendar are printed every year to help people organize better their life. Thus, millions of trees are cut every year to produce calendars and planners, which increases pollution and the emission of CO2. To minimize pollution and to go a further step toward a more sustainable society, this paper proposes an original perennial calendar system that is user- and eco-friendly. The proposed calendar system is very easy to interpret and memorize. Thus, there is no need to print hard copies of the calendar; therefore, millions of trees can be saved every year, and less pollution is emitted. For instance, we found that by using the Gregorian calendar system, the wasted energy used to check the dates and days on the calendar is almost 293 GWh/year. In addition, the CO2 emission and waste by producing paper-based calendars are 3.8 and 1.9 million tons per year, respectively, which are considered non-negligible numbers. From this place, the proposed calendar system uses optimization algorithms and mathematical modeling in order to obtain the optimal distribution of days, weeks, and months in a year. This paper compared the proposed calendar system with the Gregorian calendar and the International Fixed Calendar. Results show that the proposed one has more advantages compared to the other calendars, in which it reduces the energy demand and carbon footprint by 200 and 2000 times, respectively, compared to the Gregorian calendar. Further statistical analysis is required to see how people react regarding the idea of changing the calendar system and what will be the next step to do in order to implement it.

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