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Simulation Based Design and Optimization of Effluent Storage System for E-Toilet in Train Coaches

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Abstract - Indian Railways was being roundly criticized for creating an environment hazard by discharging toilet waste on tracks. Irrespective of the type of train or class they need improvement in cleanliness of toilets. In order to make cleaning more effective and environment friendly, simulator has been designed to find optimum storage capacity of tank and to find minimum failures in overflow of tank.

Keywords - Simulation, Storage Tank, Controlled Discharge System, E-toilet.

I. INTRODUCTION

The traditional method of disposing human waste from trains is merely to deposit the waste onto the tracks using what is known as a 'Hopper Toilet'. A recent Comptroller and Auditor General of India (CAG) report observed, "Passenger amenities like toilets and urinals at stations are not commensurate with the quantum of passengers using them and are poorly maintained at many stations, thereby straining existing facilities and hampering cleanliness efforts with passengers overcrowding the station premises. This is further complicated by the failure to prevent unauthorized persons from entering station premises"[1].

So, the Indian Railways (IR) is continuing the experiment with three types of toilets in trains: 1.Modular Toilets 2.Vacuum Toilets 3.Chemical Toilets. **Modular toilet** is a controlled discharge toilet system, which stores toilet discharge in a sealed tank in stationary condition and avoids littering stations. The tank is emptied slowly when speed of train exceeds predetermined limit of 40 kms per hour using speed sensor. **Vacuum toilet** system provides a sealed commode with an efficient flushing system and provide odour free interior of the toilets applicable to Western and Indian style toilets of mainline broad gauge (BG) coaches of IR. **Chemical toilet** is a toilet using chemicals to disinfect the waste instead of simply storing it in a hole, or piping it away to a sewage treatment plant. These toilets are most commonly found on airplanes and trains, identified with a blue colored dye in the bowl water [1]. The concept of modular toilets has been adopted to overcome the limitations of Controlled Discharge System (CDS).

The toilets discussed above use the concept of E-toilet system. **E-toilet (Electronic-toilet)** system offers utmost cleanliness, sustainability, ease of maintenance and better sanitation [2].There are various features of E-toilet system i.e. alert to users, automatic payment collection & access controls, automatic door opening, sensor-based interior facilities, water tank, touch free cleaning, SMS alerts to control room, safety to women & children and biological treatment of sewage.

As all the toilets need the storage tank and for the designing of such tank there is a powerful tool called 'Simulation'. Simulation is a process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and evaluating various strategies for the operation of the system [3]. Design of tank may consider many factors such as cost, quality etc. The key to find out a capacity of tank is to analyses that how many times a human take in toilet and on the basis of this data a model is developed.

The most common method of determining the capacity of tank is to simulate the project by iterating or running it hundreds or thousands of times with simulation. The most commonly used simulation technique is Monte-Carlo simulation. Monte Carlo simulation is an important technique for finding the tank capacity, specifically those related to cost. The research mainly alleged on the analysis of capacity of tank in toilets in trains.

II. DESIGN OF STORAGE TANK-SIMULATION BASED APPROACH

C++ language has been used for designing the simulator to find the optimum size of storage tank. Simulation is very helpful in solving the realistic and complex problems. Owing to the deterministic nature of usage patterns of toilets and hence storage tanks, it is very difficult to compute a tank size that would not fail to meet the requirements of toilet users. In fact, it would take a tank of infinite size to ensure failure free toilet operations. Below algorithm is used to find out the optimum size of storage tank.

Algorithm: TANKSIZE_SIM (WATER_P1, SLOW_TIME, MEAN, STD_DEV, TANK_VOL)

Step -1: *Read input data.*

[T_RUNS, TANK_VOL, STEP_SIZE, FAILURE_COUNT, SLOW_TIME, MEAN, STD_DEV]

***Step-2**: Perform initialization.*

[SET N=0, SIZE=0, TOTAL_T=0, TOTAL_W =0, I=0, WATER_P1=2500, FAILURE_COUNT = 0]

***Step-3:** Generate random input data.*

[Invoking random number generator, for generating random samples of waste per person WASTE_P1's, (Using Gaussian distribution), generating S_TIME's and I_TIME's for all users from exponential distribution, MAXS_TIME by applying Gaussian distribution on MEAN and STD_DEV]

***Step-4:** Perform computations for calculating total waste.*

```
    IF TOTAL_T < (MAXS_TIME + SLOW_TIME)   THEN
            TOTAL_T = TOTAL_T + S_TIME(i)+I_TIME(i)
            TOTAL_W = TOTAL_W + WASTE(i)
            Update and increment i
else
            N = i
```

***Step-5:** Compute the size of waste and no. of users.*

*[SIZE = TOTAL_W + N * WATER_P1*

Where N is the no. of users and SIZE is the size of waste]

***Step-6**: Compare the volume of tank with size of waste.*

```
    Repeat for i = 1 to T_RUNS
            STVAL[i] = Tank_Vol + i * StepSize;
    [End of loop]
    IF STVAL[j]  < SIZE THEN
            PRINT "Failure"
            FailureCount++              [Update]
```

***Step-7:** Compare failure with number of acceptable FAILURES.*

```
   IF Number of FAILURES<= FAILURE_COUNT Then
            Print Number of FAILURES with Volume of the tank
```

***Step-8**: End.*

III. RESULTS AND DISCUSSION

The maximum stoppage time during the train's journey for one month of the train is given in Table 1. On the first day of the month, the train stoppage time is 38 minutes, second day, it is 36. Similarly, in the last day of the month, i.e. thirtieth day, it is 33 minutes. The mean time of the month is 36 minutes and standard deviation is 4.62.

Table 1 Maximum stoppage time of the train at a particular railway station for thirty days

Days	Stoppage time	Days	Stoppage Time
1	38	16	38
2	36	17	38
3	41	18	36
4	42	19	43
5	30	20	38
6	35	21	36
7	43	22	30
8	36	23	35
9	43	24	42
10	36	25	39
11	40	26	43
12	34	27	42
13	32	28	38
14	30	29	44
15	40	30	33

,

The program is run for 1000 times. The maximum stoppage time for 1000 runs has been generated using Gaussian distribution from the above mentioned data. The input of the tank is volume of human waste and water used by the user of the tank. In reality, no reasonable finite sized storage tank can provide an absolute guarantee of meeting the demand 100% because the human waste and water, inter arrival and using toilet time, all are random variables. To build such a tank, which will never fail through its entire life will, generally, be uneconomical. Here, the tank size is calculated using simulation which will meet the demand with a minimum number of failures. The Fig. 1 shows a graph between a particular day and maximum stoppage time at a particular station on the way.

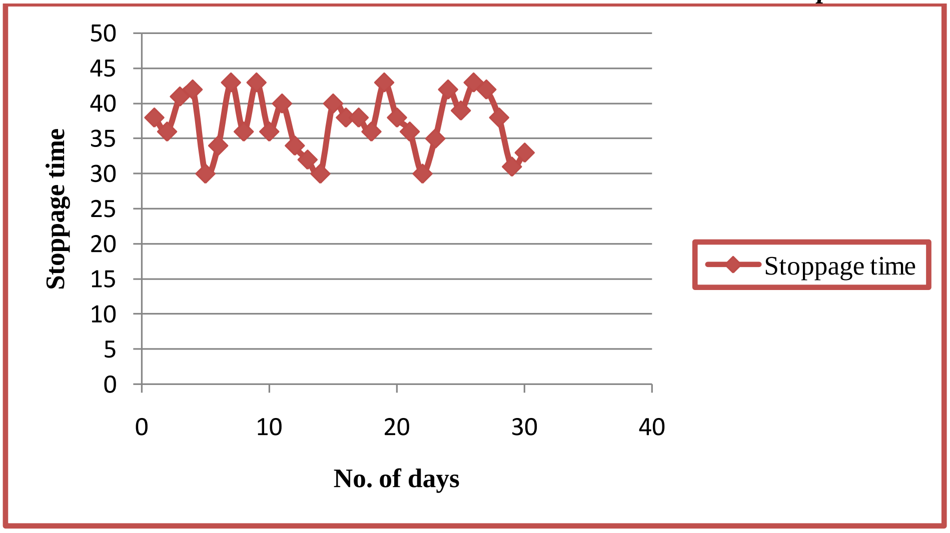

Fig. 1 One month stoppage schedule of single specific train

Fig. 2 shows the relationship between no. of failures v/s size of tank. Table 2 shows the different sizes of the tank during 1000 runs with failures less than equal to 5.

Table 2 Tank size and no. of failures

Sr. No.	Tank Size(ml)	Failures	Sr. No.	Tank Size(ml)	Failures
1	28600	4	46	37600	0
2	28800	2	47	37800	0
3	29000	2	48	38000	0
4	29200	2	49	38200	0
5	29400	2	50	38400	0
6	29600	2	51	38600	0
7	29800	2	52	38800	0
8	30000	2	53	39000	0
9	30200	2	54	39200	0
10	30400	2	55	39400	0
11	30600	2	56	39600	0
12	30800	2	57	39800	0
13	31000	2	58	40000	0
14	31200	2	59	40200	0
15	31400	2	60	40400	0
16	31600	0	61	40600	0
17	31800	0	62	40800	0
18	32000	0	63	41000	0
19	32200	0	64	41200	0
20	32400	0	65	41400	0
21	32600	0	66	41600	0
22	32800	0	67	41800	0
23	33000	0	68	42000	0
24	33200	0	69	42200	0
25	33400	0	70	42400	0
26	33600	0	71	42600	0
27	33800	0	72	42800	0
28	34000	0	73	43000	0
29	34200	0	74	43200	0
30	34400	0	75	43400	0
31	34600	0	76	43600	0
32	34800	0	77	43800	0

33	35000	0	78	44000	0
34	35200	0	79	44200	0
35	35400	0	80	44400	0
36	35600	0	81	44600	0
37	35800	0	82	44800	0
38	36000	0	83	45000	0
39	36200	0	84	45200	0
40	36400	0	85	45400	0
41	36600	0	86	45600	0
42	36800	0	87	45800	0
43	37000	0	88	46000	0
44	37200	0	89	46200	0
45	37400	0	90	46400	0

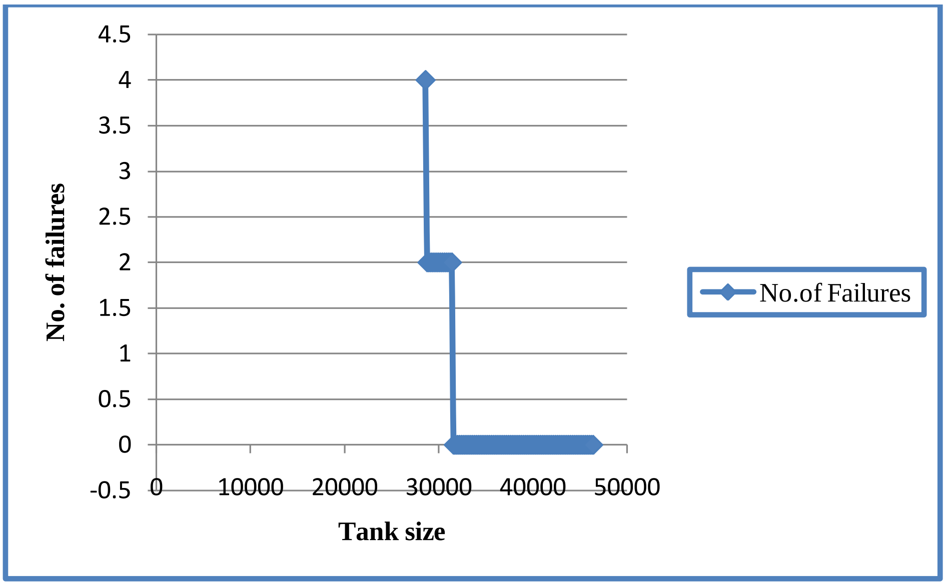

Figure 2: No. of failures v/s tank size

From the above mentioned parameters, the optimum size of the tank is 28,000 milliliter i.e. 28 liter(Figure 2) and number of passengers, in the given time, is 9, if service rate (mu) = 4; inter arrival rate(lamda) = 8 and water per person is 2500 ml. By taking the size 28,000 milliliter, the risk of failure is reduced to 1 per 1000 which means roughly one failure in a year (when the tank would overflow).

IV. CONCLUSIONS

Sanitation in railways has become a need of time and an important aspect for Indian railways to catch the height of success. So, to overcome this drawback we have a simulation based design to determine a tank size. By using the tank size of 28,000 the chances of overflow of the tank should be minimized. There is minimum chance of failure in the tank size of 28,000 ml. This work can make the railway platform more hygienic and clean. In the train each coach contains 3-4 toilets and in each toilet bowl there is a storage tank, so the proposal of storage tank is costly. Hence by using the optimum size retention tank the cost should be minimized. In future, there is possibility to recycle the waste after cleaning the storage tank

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