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AGH; An Ant Genetic Hybrid Solution to Solve the Multi-model Traveling Salesmen Problem

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ABSTRACT The concept of multi-model optimization brings the idea of finding all or most of the existing high quality solutions. Recent research on multi-model optimization (MMO) seemed to be using nature inspired algorithms in solving such interesting problems. Multi-model traveling salesman problem is an important but rarely addressed discrete MMO problem. This paper proposes a hybrid algorithm combining the Ant Colony Systems algorithm (ACS) with a modified genetic algorithm (MODGA) to solve multi-model traveling salesman problems (MMTSPs). The concept of the hybrid algorithm divides the solution into two parts where ACS is used to find an average quality solution which is then provided as a threshold to the MODGA to find other quality solutions as much as possible. Benchmark multi-model TSP problems have been used on the new algorithm to test its capability. 70% of the success PR and 0.6% of success SR values indicates the capability of the method solving MMTSPs. The results compared with several state of the art multi-model optimization algorithms showed that the proposed hybrid algorithm performs competitively with these algorithms. As the first approach to solve MMTSPs without niching strategies, improvements will lead the current algorithm to a greater place.

KEYWORDS: Multi-model Optimization, GA, ACS, Traveling salesmen problem

I Introduction

There are many situations in the real world where we need to come up with multiple different good solutions than one. Particular advantages are when various practical constraints involve with the solutions. In applied mathematics, such problems are called multi-model optimization problems (MMOP) [1]. Multi-model optimization discusses finding several optimum solutions in a single run of an algorithm. When it comes to solving such MMO problems there are many approaches discussed in the literature. One way of achieving these optimal solutions is to run a particular algorithm many times by approaching different areas in the search space of the problem. In many of these cases there is no guarantee to find all or most of all the solutions by such a method. When the problem is in the discrete domain, the complexity of achieving multiple solutions is doubled.

In the research literature on solving such multi-model optimization problems, continuous domain is highly touched and the discrete problems are less addressed [2]–[5]. To date, traveling salesman problem (TSP) is one of the most popular and intensively studied problems in optimization [6]–[8]. In many practical applications related to TSP, several better solutions are required than obtaining a single best solution. For example, it is always recommended for route planning applications to provide several acceptable routes so that the driver can choose the cheapest route based on his own knowledge. Since the road condition changes dynamically, a route can become invalid due to traffic jam or road maintenance. In these cases, drivers want to quickly switch to a candidate route of the same quality in order to get their job done on time. This is where the importance of multimodal TSP (MMTSP) comes to the stage. Among different approaches used to solve both continuous and discrete multi-model optimization problems, use of meta-heuristics such as evolutionary computing or swarm intelligence algorithms are undoubtedly popular due to their population behavior [9]–[12]. In this kind of research work where MMOPs were addressed using meta-heuristics, use of niching strategies is popular [2], [5], and [13]–[15]. Niching brings the idea of dividing the population of solutions into disjoint sets, with the intension of having at least one member in each region of the objective function. Drawbacks of such niching methods can be pointed out as problems with maintaining found solutions, difficulties in scalability and performance measuring, and problems arise with niching parameters. Hence the aim of this paper is twofold; to address discrete multi-model optimization problems; particularly MMTSP, and to use meta-heuristics to solve MMTSP without using niching methods.

Population based stochastic meta-heuristics such as Evolutionary Algorithms (EA) and Swarm Intelligence (SI) algorithms are advantages for solving many real world optimization problems especially when they are with the NP hard characteristics. These algorithms have the anytime behavior by giving a feasible solution at any given time and dealing with multiple solutions at a given time in the predefined solution space. Exploration and exploitation properties embedded in these algorithms allow them to search the reliable solutions in the solution space. This study is consisting of two popular nature inspired algorithms; ant colony systems (ACS) and genetic algorithms (GA). ACS is hybridized with a modified version of GA to find multiple solutions.

We structured the remainder of the paper as follows. The

literature related to the multi-model traveling salesmen problem is discussed in Section II. Section III is dedicated to introduce the AGH; the ant genetic hybrid solution we propose and its capabilities. In Section IV, we points out the numerical examples, the information on parameters used in the study and the results obtained. A statistical comparison with existing methods is also included. Finally, we draw conclusions briefly in Section V.

II Solving Discrete Multi-Model Optimization Problems – Summarizing Similar Studies

The research problem discussed in this paper mainly focuses on discrete multi-model optimization, specifically multi-model traveling salesman problem. Multi-model optimization can be defined as an optimization which focuses on finding more than one global and local solutions. Let's say there is a problem to be solved to find minimum/maximum $f(x)$, and the optimum solution is R. Then if there is a possibility of finding several x values which gives you R or there exist only x which is unique but there exist several local optimums (optimal in a certain neighborhood) is then can be stated as a multi-model solution. Therefore you may obtain local or global optimum values by solving a multi-model optimization problem. The problem that we address here belongs to the discrete domain which is the famous traveling salesmen problem having many global optimum routes. The main aim of the hybrid algorithm proposed in this paper is to catch all the global optima in a multi-model traveling salesmen problem.

In practice, there are often problems with multiple solutions. In particular, the traveling salesman problem (TSP) can have several shortest tours from which travelers can choose one, depending on their specific requirements. The travelling salesman problem (TSP) is an NP-hard problem in combinatorial optimization studied in operations research and theoretical computer science. Given a collection of cities and the cost of travel between each pair of them, the traveling salesman problem, is to find the cheapest way of visiting all of the cities and returning to the starting point. In the standard version, the travel costs are symmetric in the sense that traveling from city X to city Y costs just as much as traveling from Y to X. This problem was first formulated as a mathematical problem in 1930 and is one of the most intensively studied problems in optimization. It is used as a benchmark for many optimization methods. There can be many studies related to finding optimal ways to solve single objective and multi-objective TSPs [16]–[20].

Multi-model TSPs is a topic which has been rarely addressed in the world of optimization research. Only handful of research can be found on the specific topic. Here we discuss some findings on multi-model optimization over discrete domains including the MMTSP.

The very first published work on the matter of finding multiple optimum solutions in the discrete domain is dated back to 1995 [21]. The authors addressed the same problem of MMTSP and attempted to solve it using genetic algorithms; what we are adapting in this research as well. As what we concern in the present research, they have also paid attention on finding a way that will get the help of niching strategies at its minimum. Representation method, fitness measures and the evolving mechanisms were presented with a novel idea to solve a MMTSP and a TSP problem was constructed on testing purpose. One disadvantage; although should not mention as such since the time this research has been carried out is more than two decades back, is the prior definition of the number of solutions that expect from the algorithm. Another important fact is that in there, the solutions were obtained in different runs where our approach tries to make it simultaneously which are obviously advantageous. Niching is common in stage when it is about multi-model optimization; no matter the type of the domain. Simply put, niching is a class of methods that try to converge to more than one solution during a single run. Niching is a general class of techniques intended to end up with roughly half the population converging in each minima/maxima. The idea here is that you discourage convergence to a single region of the fitness function by pretending there are limited resources there. The more individuals try to move in, the worse off they all are. The result is that as the GA converges to a single local optimum somewhere, the fitness of that optimum decreases because of the increased competition within the niche. Eventually, another region of the fitness landscape becomes more attractive, and individuals migrate over there. The idea is to reach a steady state - a fixed point in the dynamics - where an appropriate representation of each niche is maintained. This is the most common approach that has been adopted by many of the research conducted on multi-model optimization [5], [15], [22].

In 2006, a research has been carried out to find out how the niching strategies can be adopted to the ant colony optimization algorithms where the initial works of niching strategies can be found with evolutionary algorithms [23]. The TSP known as 'crown' problem was tested with the proposed algorithm. Later in 2018 solving MMTSP problems were addressed with another ant colony system algorithm incorporated with niching methods [24]. One important fact is that in that study, they have designed a test suite for multi-model TSPs which is useful and has been used in our study as well. In a similar study which was carried out at the same time, genetic algorithm has been used incorporating niching methods titled as "neighborhood based genetic algorithm" [25]. The same research group, later in 2020 has published their work of solving multi-model TSPs using a niching memetic algorithm. The test suite with 25 test problems that they have designed in previous study has been used for the testing purposes [26].

The literature points out following important facts on solving a discrete multi-model optimization problem.

- TSP is the most common discrete problem that has been solved as a discrete multi-model optimization problem.
- Very limited approaches can be seen on solving discrete multi-model optimization problems.
- In almost all the studies, a kind of niching strategy has been carried out to find the multiple solutions.

For the convenience, the summary of the findings regarding discrete multi-model optimization are listed in Table 1.

Tab. 1: Summary of the findings regarding discrete multi-model optimization

Year	Paper	Used Algorithm and/ or technique	Niching (Yes/ No)
1995	[21]	Genetic Algorithms + Multiple Solution Technique	Yes
2006	[23]	Ant Colony Optimization algorithm + Fitness Sharing / Simple Crowding	Yes
2018	[25]	Genetic Algorithms + neighborhood-based strategy	Yes
2018	[24]	Ant Colony System + niching strategy and multiple pheromone matrices	Yes
2020	[26]	Memetic Algorithms + niche preservation technique	Yes

However researchers have pointed out some drawbacks of using niching methods on solving multi-model optimization problems such as difficulties in maintaining found solutions, specifying niching parameters, scalability and performance measuring [27]. These findings motivated to carry out the present work to find multiple optimum solutions simultaneously in MMTSPs without using existing niching strategies. We were interested to use latest trends in the field of meta-heuristics; use of hybrid algorithms to solve MMTSPs. We used a crossed version of two famous nature inspired algorithms; ant colony systems algorithm and the genetic algorithm.

III AGH; The ant genetic hybrid solution to solve MMTSPs

Here we discuss the outline of the hybrid algorithm and the full explanation on what we propose for solving multi-model traveling salesman problem. First sections will briefly introduce the two algorithms used; ACS and GA, and the modifications. The latter half presents the detailed description of the new hybrid algorithm that has been proposed with the modifications.

A Ant colony system algorithm (ACS)

Being among the three major extensions of ant colony optimization algorithms, the ant colony system algorithm is one of the most popular and most widely used metaheuristic algorithms in the field of Swarm Intelligence. It is the most recommended and widely used meta-heuristic for the route finding problems [16]. The ACS algorithm is inspired by the optimized routing process from food source to the destination of most ant species, aiming the pheromone communication technique between them. The purpose is to find a good path between the colony and a food source. In the standard ant colony system, this good path refers to the shortest path.

As going along the natural concept, the ACS works as follows. The primary step of the algorithm is to position the artificial ants on random starting points. While they are traveling among the nodes, the route they follow is stored for future usage. For a particular ant, to select the next city from where it is now is decided considering the amount of pheromone deposited in the nodes by the other ants (known as state transition). Each ant, upon visiting a city is responsible for laying some amount of pheromone according to the rule of local pheromone updating. Once all ants complete the tours, the cities followed by the best ant in the population will also benefited with some extra pheromone amount; according to the rule of global pheromone updating. The pseudo code of the algorithm is given in Algorithm 1.

State transition rule is responsible for an ant to find its next visiting city. Assume the ant is in the node r. Its next city s is determined by the equation 1.

$$s = \begin{cases} arg \ \ max_{u \in J_k(r)}\{[\tau(r,u)^{\theta}].[\eta(r,u)]^{\beta}\} & q \leq q_0 \\ S & Otherwise \end{cases} \quad (1)$$

Where, $\tau(r,u)$ is the pheromone density of an edge (r,u), $\eta(r,u)$ is [1/distance(r,u)] for TSP. $J_k(r)$ is the set of cities that remain to be visited by ant k positioned on city r. The relative importance of the pheromone trail and the heuristic information are represented by the parameters θ and β $(\theta, \beta \geq 0)$. q is a random number uniformly distributed in [0, 1], q_0 is a parameter$(0 \leq q_0 \leq 1)$, and S is a random variable from the probability distribution given by the equation 2.

$$P_k(r,s) = \begin{cases} \dfrac{[\tau(r,u)]^{\theta}.[\eta(r,u)]^{\beta}}{\sum_{u \in J_k(r)}[\tau(r,u)]^{\theta}.[\eta(r,u)]^{\beta}} & if s \in J_k(r) \\ 0 & Otherwise \end{cases} \quad (2)$$

ACS local and global updating happens according to the equation 3 and equation 4 respectively.

$$\tau(r,s) \leftarrow (1-\rho).\tau(r,s) + \rho.\Delta\tau(r,s) \quad (3)$$

Where $0 < \rho < 1$ is a parameter.

$$\tau(r,s) \leftarrow (1-\alpha).\tau(r,s) + \alpha.\Delta\tau(r,s) \quad (4)$$

Where

$$\Delta\tau(r,s) = \begin{cases} (L_{gb})^{-1} & if (r,s) \in global \ \ best \ \ tour \\ 0 & Otherwise \end{cases} \quad (5)$$

$0 < \alpha < 1$ is the pheromone decay parameter and L_{gb} is the length of the globally best tour.

Algorithm 1 : Pseudo code of the ACS Algorithm

```
Begin;
Initialize parameter values
Define the objective function
while End condition do
    Position ants on starting nodes
  for i = 1 : n (for each ant i in the population) do
      Build the tour while local pheromone update
    (Equations 1, 2, 3)
  end for
  Do global pheromone update to the globally best ant.
  (Equation 4)
end while
Post process results and visualization;
End
```

In the AGH, the ACS works as the initializer by giving a single promising solution to a given MMTSP instance.

B Genetic Algorithms (GA)

GA seems to be the most significant and widely used evolutionary algorithm since its inception. Its flexibility over different domains makes it easy to use and as a result many NP hard problems have their GA version of solutions [28] – [32]. An individual in GA is known as a chromosome which is typically a feasible solution to the problem to be solved. With GA, it can be stated that the binary encoded GA is the most popular version, however many other representations including real value, integer and permutation are also being used. Fitness of a population is calculated and the fitter individuals are then selected probabilistically to be parents to mate and produce offspring. Crossover and mutation are mainly used to generate offspring from the parents providing exploitation and exploration capabilities to the algorithm. Over time, as results of successful research, various crossover and mutation operators for different representations have been presented.

Crossover basically allows new individuals to have blocks of genes from its parents representing the crossover happens in the natural genes. It is mutation that handles the part that cannot be done by this inheritance, allowing the new offspring to be slightly differing from their parents in a probabilistic manner. It further works on the solutions to get out without being trapped in local optimum solutions. The algorithm will be repeated until a predefined termination criterion is satisfied. The general framework of the genetic algorithm is given in Algorithm 2.

Algorithm 2 : Pseudo code of the GA Algorithm

```
Begin;
Initialize algorithm parameters:
Define the objective function
Generate random population of chromosomes
while End Condition do
    [Fitness] Evaluate the fitness of each chromosome
    while new population is complete do
        [Selection] Select parent chromosomes
        [Crossover] Perform crossover to form a new off-
        spring
        [Mutation] Perform mutation on new offspring
        [Accepting] Place new offspring in a new popula-
        tion
        [Replace] Use new generated population
    end while
    Go to step 6
end while
[Test] Upon completion, return the best solution in cur-
rent population
End;
```

C AGH; The ant, genetic hybrid solution to solve MMTSPs

In order to implement the proposed hybrid, several modifications were implemented on the standard genetic algorithm. The GA with proposed modifications is named as MODGA. The modifications are proposed in order to enhance the exploration capability of the standard genetic algorithm. By adopting the concept of hybridization, we divide the solution into two parts where ACS finds one optimum tour of a TSP and taking that as a threshold, the MODGA finds other
Optimal tours as much as possible. We proposed two modifications to the standard GA, which has been introduced in a previous study for the continuous domain [33]. The concept of archiving and the use of counter variable are included in the modification. The hybrid AGH will work as follows.

- Initially n ants are placed on starting nodes.
- Ants will build tours with local and global pheromone updating rules.
- At the termination, best ant tour with the optimal tour length is selected. (Let K be the optimal tour length given by the ACS).

Using the K (threshold), MODGA algorithm operates as follows.

- Each chromosome (a permutation) in the GA represents a possible solution to the TSP problem.
- Fitness of a chromosome is calculated using the objective function. We used the distance of the route given by the solution as the objective function.

- Then selection, crossover and mutation will perform on the population to generate offspring. We have used 'generational' population model where we generate 'N' offspring, where 'N' is the population size, and the entire population is replaced by the new one at the end of the iteration.

- From the new generation, the better chromosomes were identified (chromosomes whose fitness is ≤ to K), and the archiving concept is used to collect them. The empty positions in the population are then filled with random chromosomes.

- **A counting variable** is located to identify the poor iterations (iterations which are not contributed to the archive for a specified period (Holt)) and new chromosomes are introduced to the population in a random manner. In the standard GA, crossover and mutation updates a solution using both exploitation and exploration properties. Since our concern lies on enhancing the random replacements when significant performance cannot be seen, this modification further tries to enhance the exploration capability.

- Finally, after a fixed number of iterations, the output of the AGH is the possible optimal routes for the MMTSP which are located in the archive.

For further clarification of the proposed approach, the pseudo-code of the AGH (ACS MODGA Hybrid) to solve MMTSPs is given in Algorithm 3.

It is important to investigate the features of AGH which have contributed to the capability of the algorithm in solving MMTSPs. One of the major decisions that have to be taken is how to identify the global optimum when it is unknown. It is achieved via an approximation done by the ACS algorithm. Once we have an approximation we used it as a threshold to find other possible routes having same, closer or better route distances with the enhanced genetic algorithm. By introducing an archive and the mechanism to identify poor iteration circles, we tried to improve the exploration capability of the algorithm to find multiple solutions as much as possible. Once a solution is found we put it to the archive and replace its position with a random solution in order to change the direction of the search (searching towards the same solution is discouraged). The speed of the algorithm is enhanced with the random replacements introduced for the poor iteration circles (when no improvement can be seen in iterations for a predefined number). These modifications to the standard GA gave acceptable solutions to the MMTSPs.

The significant features of this hybrid can be stated as it uses no niching strategy that has been used in almost all the approaches we have seen to solve multi-model optimization problems. This can be considered as a milestone in the discrete multi-model research where the opportunities are revealed apart the traditional niching methods. The algorithms used in this study are very simple and user friendly and the modifications are simple but precious. The concepts adapted enhance the algorithm by giving more exploration ability and the early identification of poor iterations support to acquire the maximum benefits.

Algorithm 3 : Pseudo code of the AGH Algorithm

```
Begin;
Initialize algorithm parameters of ACS
Define the objective function
while End Condition do
    Position ants on starting nodes
    for i = 1 : n for each ant i in the population)) do
        Build the tour while local pheromone update
    end for
    Do global pheromone update to the edges of globally best ant.
end while
Post process results and visualization;
Take the best TSP route distance as K for further processing

Generate the initial population of chromosomes
while End Condition do
    [Fitness] Evaluate the fitness of each chromosome
    while new population is complete do
        [Selection] Select two parent chromosomes from a population according
        to their fitness
        [Crossover] Cross the parents to form a new offspring
        [Mutation] Mutate new offspring
        [Accepting] Place new offspring in a new population
        [Replace] Use new generated population
    end while
    Find chromosome with suitable fitness I ≤ K (consider minimizing)
    Update the archive and replace the positions with random chromosomes;
    if No chromosomes in the population to the archive then
        set CountVal = CountVal+1;
    end if
    if No chromosomes in the population to the archive and CountVal = Hol
    then
        CountVal = 1;
        size = random integer between (popSize/2) and popSize;
        Create random chromosomes up to size and replace the population;
    end if
end while
Post-process chromosomes in the archive and get multiple optimum solutions
for the MMTSP.
End;
```

IV Experimentation

AGH can be considered as the very first attempt of using swarm intelligence and evolutionary algorithms to solve a discrete multi-model traveling salesman problem without using a niching method. This section details the test problems and the obtained results of the suggested hybrid.

This research work is carried out on an Intel Core i7 laptop with a RAM of 4GB. Program is developed in MATLAB. Parameter settings of the algorithms are presented in the Table 2.

Tab. 2: Parameter values used in the AGH Algorithm

ACS		MODGA	
Parameter	Value	Parameter	Value
α, ρ (Pheromone decay parameter)	0.1	P_C (Partially Mapped Crossover)	0.85- 0.95
q_0, β	0.9, 2	P_m (Swap mutation)	0.01- 0.25
Population Size	50	PopulationSize	50- 200
Iterations	200	Iterations	500- 2000

A Summary of Benchmark MMTSPs used

Set of MMTSP problems were selected from different studies as well as from the TSPLIB [21], [23]–[26], [34]. Details of the twenty (20) benchmark MMTSPs used are given below.

- **T1**: The TI test problem was devised by selecting towns on the Euclidean plane in such a way that two very different global optima were expected. This MMTSP was originally proposed in [21] and they have found two different global optimum / maximum routes.
- **T2**: The 'crown' problem- The 'crown' problem is a symmetric, 2-Dimensional Euclidean TSP containing 6 cities used in [23]. They were able to locate two different optimum routes.
- The 06 MMSTPs given in Table 3 were taken from [24].

Tab. 3:

Problem	No of cities	Optimal length	# of solutions according to [24]
self8-1	8	187.444	3
self8-2	8	309.436	2
self10-1	10	225.133	2
self10-2	10	236.212	2
test16	16	918.353	9
ulysses16	16	73.9876	10

- The 12 MMSTPs given in Table 4 were taken from [26].

Tab. 4:

Problem	Noof cities	Optimal length	# of solutions according to the standard repository mentioned in[26]
Simple 9	9	680.8311	3
simple2 10	10	1264.4	4
simple3 10	10	832.2031	13
simple4 11	11	803	4
simple5 12	12	754	2
simple6 12	12	845	4
geometry1 10	10	130.821	56
geometry2 12	12	1344	110
geometry3 10	10	72.4033	4
geometry4 10	10	72	4
geometry5 10	10	78.3758	14
geometry6 15	15	130	196

B Results

The Table 5 shows number of multiple optimum routes obtained by the AGH algorithm for the benchmark MMTSP problems. For 5 MMTSP instances, the AGH algorithm has given outstanding number of solutions where other methods have not given. But it should be noted that, for some complicated problems, AGH algorithm has not performed as some of the other methods with niching strategies.

Tab. 5: Number of different optimum solutions obtained

MMTSP Instance	# of different solutions form previous studies and bench- mark details	# of different solutions from AGH algorithm
T1	2	**6**
T2 – CrownProblem	2	**2**
self8-1	3	**5**
self8-2	2	**2**
self10-1	2	**2**
self10-2	2	**4**
test16	9	**10**
ulysses16	10	9
Simple 9	3	**3**
simple2 10	4	**4**
simple3 10	13	**13**
simple4 11	4	**4**
simple5 12	2	**2**
simple6 12	4	**4**
geometry1 10	56	36
geometry2 12	110	3
geometry3 10	4	**6**

geometry4 10	4	3
geometry5 10	14	13
geometry6 15	196	25

PR and **SR** are standard measures proposed by [35] to evaluate the performance of multi-model optimization problems. We have measured the values for the 20 MMTSPs used (see Table 6).

PR is a measurement that calculates the average percentage of the optimums given by an algorithm over all the runs (here we used 50 runs), and **SR** calculates the average percentage of the runs where all global optimum are given by the algorithm. Equation 6 and 7 show the formulas.

$$PR = \frac{\sum_{i=1}^{NR} NPF_i}{NKP * NR} \quad (6)$$

Where NPF_i denotes the number of global optima found at the end of the i-th run, NKP the number of known global optima, and NR the number of runs.

$$SR = \frac{NSR}{NR} \quad (7)$$

SR measures the percentage of best runs (a best run is defined as a run where all known global optima tours are found) out of all runs.

Tab.6: PR AND SR VALUES OF ACS-MODGA FORTHE 20 BENCHMARK PROBLEMS

MMTSP Instance	PR Value	SR Value
T1	1	1
T2 – Crown Problem	1	1
self8-1	1	1
self8-2	1	1
self10-1	1	1
self10-2	1	1
test16	0.8888	0.5
ulysses16	0.35	0
Simple 9	1	1
simple2 10	1	1
simple3 10	0.6923	0
simple4 11	1	1
simple5 12	1	1
simple6 12	0.85	0.6
geometry1 10	0.4125	0
geometry2 12	0.0427	0
geometry3 10	1	1
geometry4 10	0.5	0
geometry5 10	0.7857	0
geometry6 15	0.0648	0

70% of better **PR** values and 60% of better **SR** values indicate the success and the capability of the proposed algorithm. It should be admitting that for some complicated problems, zero **SR** indicated that improvements of the **AGH** are essential to find the all possible routes. Improvements to the algorithm and the parameter values is essential and possibilities will give a good impact as AGH is the first algorithm to solve **MMTSP**s without complicated niching strategies.

Graphical representations of some of the solutions obtained can be seen in Figures 1, 2.

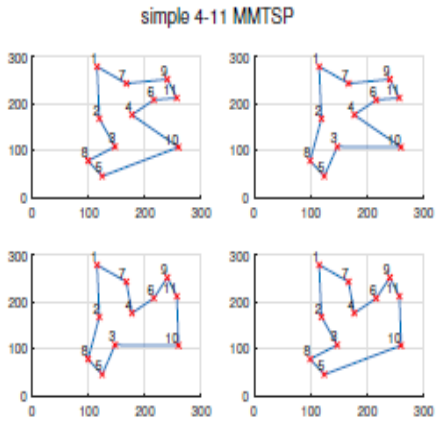

Fig. 1: The four routes obtained by AGH for the 'simple 4-11' MMTSP instance

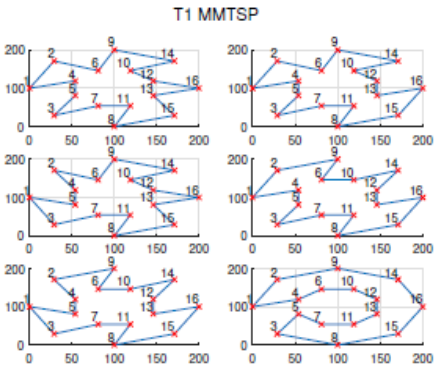

Fig. 2: The six routes obtained by AGH for the 'T1' MMTSP instance

The graphs on the improvement of the fitness during iterations indicate the viability of the algorithm in optimizing the solutions (see Figure 3).

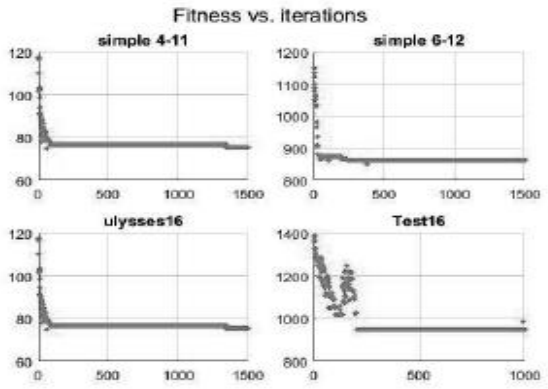

Fig. 3: Fitness changes over iterations of 4 MMTSP instances

For the 12 composite MMTSP problems which includes complicated MMTSPs as well (Table 4), the obtained average distances are as follows (Table 7).

Tab. 7: Average distances obtained by the AGH algorithm

MMTSP Instance	Published Distance	Avg distance from AGH
Simple1 9	680	680.8311
simple2 10	1265	1264.4
simple3 10	832	832.2031
simple4 11	803	803
simple5 12	754	754
simple6 12	845	845
geometry1 10	130	130.821
geometry2 12	1344	1344
geometry3 10	72	72.4033
geometry4 10	72	72
geometry5 10	78	78.3758
geometry6 15	130	130

C Statistical Analysis

A statistical analysis has been done to compare the performance of the **AGH** algorithm with number of solutions given in the standard **MMTSP** repository mentioned in [26]. We used Wilcoxon signed-rank test; a non-parametric test which applies to two related samples [36]. It is an alternative test for the paired Student's t-test or the t-test for dependent samples when the population cannot assume to be normally distributed [37]. It uses the standard normal distributed z value to test of significance. We used results (number of different alternative roots) from **AGH** algorithm with number of solutions given in the standard **MMTSP** repository [26] for the set of 12 **MMTSP**s as two related samples. We conducted the test using **SPSS** statistical software, to test the following hypothesis.

H_0: There is no significant difference between number of solutions given by **AGH** and the standard **MMTSP** repository [26]

H_1: There is a significant difference between number of solutions given by **AGH** and the standard **MMTSP** repository [26]

We received the following output. The SPSS output has given both a W-value and z-value. Since the size of N is low (different values), and particularly it's below 10, we used the W-value to evaluate the hypothesis.

```
Result Details

W-value:  3
Mean Difference:  61
Sum of pos.  ranks:  18
Sum of neg.  ranks:  3

Z-value:  -1.5724
Sample Size (N): 6
```

The value of W is 3. The critical value for W at N = 6 ($p < 0.05$) is 0. So we do not reject H0; that is we accept that there is no significant difference between the number of solutions given by AGH and the standard MMTSP repository [26].

As a final supposition, we can state that with the conducted statistical analysis, the AGH is performing well for the MMTSPs given in the standard MMTSP repository mentioned in [26]. However, the improvements are significant for most cases. For this reason, we say that the presented AGH is capable in solving MMTSPs, meeting, in this respect, the main objective of this study which is to find a hazel free approach to deal with discrete multi-model optimization problems. It should be noted that AGH is unable to perform well with MMTSPs which have large number of multiple solutions. We suppose that the reason is the less exploration power of MODGA due to the lacking of niching strategies. But with careful modifications, in future we hope to improve AGH; without complicated niching work, to be suitable for such MMTSPs as well.

V Conclusions and further work

Here we presented a hybrid algorithm (AGH) implemented using ACS and GA, to solve multi-model traveling salesmen problem. The proposed algorithm is two phased. ACS finds the initial optimum value for a tour which works as a threshold in the second half. The MODGA which uses an archive and a flag/counter variable runs in the second half with the given threshold to find the multiple optimum solutions/routes for the MMTSP. The algorithm does not relay on niching strategies as all the other algorithms that has been used in the literature to solve MMTSPs. This can be stated as the most significant feature of this algorithm that provides a less complicated approach to solve MMTSPs.

In order to prove the capability of the proposed AGH algorithm, we have compared the performance on more than 20 MMTSPs with the existing methods. A statistical analysis has been carried out on the obtained results using Wilcoxon signed-rank test. Overall, the AGH algorithm performs equally well

for many MMTSP instances. However for the instances having large number of different optimum routes, AGH was unable to perform well. We believe that as further enhancements, amplifying the exploration ability of the algorithm will provide better solutions. Here, it is important to highlight that the main goal of this study is not to find an accurate algorithm for MMTSPs, rather to find the capability of implementing a flexible, less complicated algorithm which can handle discrete multi-model optimization problems.

We also expect to consider the parameter tuning of the two algorithms used. As we know, especially in swarm intelligence algorithms, there are many algorithm specific parameters to be fixed by the user. This will directly affect the performance of the algorithm. To popularize the usage of these algorithms, parameter tuning techniques are essential to find the proper parameter values without the involvement of the user. Further, inspired by the results obtained from our experiment; we are planning to expand the study on solving other discrete multi-model optimization problems.

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Optimizing Smart Agriculture by Integrating Artificial Cognition: A Review, Current Challenges and Future Trends

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ABSTRACT Agriculture is one of the most influential sectors for human existence given the fact that all human beings depend on food for survival. Hence there is continuous research for efficiency and effectiveness improvements in agricultural activities to yield a quality harvest with increased volumes. Rapid advancements in technologies have paved the way for smart agriculture to improve the agricultural process. Thus, many smart artifacts have been introduced to the agriculture field including autonomous robots. As a result, the agricultural aspects such as soil management, seeding, harvesting and plant disease management have been focused highly with the aim of upheaving each of these agricultural sectors. Since none of these systems are integrated with cognitive capabilities, they cannot operate in an optimal manner by taking rational decisions as humans on contemporary issues related to agriculture. Hence, these systems are less efficient and adaptive and become vulnerable in difficult conditions. Therefore, integration of cognition is vital to agricultural artifacts including robots and is a research challenge. A critical literature review has been carried out in this research to identify the existing limitations and challenges in smart agriculture and it was extensively discussed how cognition can be integrated in this regard. A hybrid cognitive architecture has been identified as a mechanism for integrating cognition into agricultural artifacts. Finally, the paper discusses several possible real-world applications with few case studies and provides insights for integrating cognition into agricultural artifacts.

KEYWORDS: Artificial Intelligence, Artificial Cognition, Cognitive Architectures, Smart Agriculture.

I. Introduction

Cognitive computing is a widely discussed and researched topic in Artificial Intelligence (AI) which is inspired from human cognition [1]. Cognitive computing is considered as the ability of computers to imitate the complex human thought process [2]. The term cognition comes from the notion of human cognition where human cognition is defined as the capacity of people to employ their five senses, vision, sound, smell, taste, and touch and respond appropriately. Moreover, the ability of human beings for self-reliance, figuring things out for independent, adaptive, and anticipatory actions are referred to as cognition [3]. According to Britannica, 'Cognition includes all conscious and unconscious processes by which knowledge is accumulated, such as perceiving, recognizing, conceiving, and reasoning' [4]. Currently, the advancements in Artificial Intelligence have enhanced the aspects of embedding cognition into systems. Although there exist advanced tools, technologies, and theories in the field of computer science and artificial intelligence, there is a gap in embedding cognition into these artifacts [5].

The process of embedding human level cognition into hardware or software systems to obtain human level capabilities is referred to as artificial cognition. Cognitive neuroscience, and development psychology etc. are the fields that contribute to the field of artificial cognitive systems. Nevertheless, embedding human level cognition into systems artificially is a painstaking process since human cognition is also not yet fully understandable and there are currently no known techniques that can fully embed cognition into systems [6]. Furthermore, human level thinking is not achievable yet via a system although human knowledge can be embedded to a greater extent. Hence it is evident that human cognitive tasks are not fully achievable up to now and extensive research is being carried out [7] [8] at present as this would be one of the greatest achievements in AI, if achieved. Furthermore, psychological science and AI fields mutually benefit each other as the studies related to these two fields invent and uncover new theories [9]. Artificial cognition has headed its way towards many industries and agriculture is one such prominent domain that is being investigated.

As all living creatures completely depend on food for survival, improving the agricultural sector is one of the utmost priorities in the world. In the past, all agricultural activities were done with manual systems based on the experiences of farmers. Throughout human history, significant advances have been made to boost agricultural productivity with fewer resources and labor demands. With the rapid improvements in the technology some of these manual systems were automated and AI has been integrated [10] to boost the productivity and

efficiency, in selected narrow segments in agriculture. In addition, for some countries agriculture is one of the main revenues generating sectors thus pushing the boundaries to adopt more and smarter agricultural systems to achieve excellence.

Some of the automated systems/robots employed in the agriculture sector can operate autonomously in pre-defined contexts. Yet none of these are integrated with cognitive abilities to achieve human level expertise [11]. Among the various AI and cognitive aspects that are being examined for integration in smart agriculture cognitive ergonomics is one such. Improved work efficiency, reduced human error, and strengthening the knowledge available in how humans process information are some significant aspects of cognitive ergonomics that relates to smart agriculture [11].

With the identified importance of integrating cognitive aspects to smart agricultural artifacts, this research is aimed to provide a critical analysis on how the agricultural aspects have been influenced with the concept of smart agriculture, the challenges faced in adopting smart agriculture, and methods of integrating artificial cognitive systems in smart agriculture.

To achieve this, a systematic literature review was conducted based on the following three research questions.

RQ1: How has the agriculture field been affected by the concept of smart agriculture?

RQ2: What are the challenges faced by the smart agricultural paradigm?

RQ3: How artificial cognitive systems can be integrated into smart agriculture for further enhancements?

The rest of the paper is structured as follows. Section 2 describes the methodology of the research while section 3 briefly discusses different aspects in agriculture that utilize smart techniques. The section 4 discusses the challenges to the concept of smart agriculture while section 5 includes few scenarios where cognition can be embedded artificially to smart agricultural systems. Final section discusses the overall approach taken in the paper and concludes with research findings.

II. Methodology

To identify the existing landscape of smart agriculture a thorough literature review was conducted. In doing so the objectives of this research have been formulated as research questions and were stated in the Introduction section.

This work applied a Systematic Literature Review (SLR) in answering the formulated research questions. Searching for literature was done using multiple databases such as IEEEXplore, Google Scholar, Science Direct and Web of Science. The keywords used in searching for literature in the above databases are “Smart Agriculture”, “Artificial cognition" AND “Agriculture”, “Cognition" AND “Agriculture”, “Artificial cognition" AND “Smart agriculture”, “Smart Agriculture” AND “Challenges", “Artificial Cognition” AND “Agriculture” AND “Challenges”. The resulted literature was further filtered based on the inclusion criteria of research being published after 2015, ensuring latest research work. For further filtering, literature that relates to the research questions of this research, title, abstracts and keywords of the publications were screened. The above stated systematic approach resulted in 47 publications that identified as most suitable publications for the literature review to be conducted in this research.

Then as the next step, 3 Quality Assessment Criteria (QAC) were considered to evaluate the quality of the selected 47 publications. The QAC were scored from the range of 0 to 1.

QAC1: Has the study employed the established standards in conducting the research?

QAC2: Has the study performed a literature review pertaining to contemporary research and taken insights from them?

QAC3: Has the work been published in a refereed international journal or in an international conference?

The above 3 QAC were fulfilled with the maximum total score of 3 by all the 47 publications and therefore, can be proved as suitable for the literature review work conducted in this research.

Then, the data from those 47 publications were extracted and interpreted in the rest of the sections of the paper. Finally, few case studies were considered and some recommendations were given for future research work.

III. Related work

This section comprehensively discusses the landscape of smart systems in soil management, seeding, harvesting, and in plant diseases.

A. Soil Management

Soil is the crucial ingredient of agricultural operations since most agricultural crops are grown in soil hence agriculture and soil are inseparable. Nevertheless, due to the growth in world's population and increased urbanization and industrialization the agricultural land areas are shrinking [12]. Crop production needs to be improved and soil resources need to be conserved with a thorough understanding of diverse soil types and conditions. Therefore, soil testing is critical in modern agriculture to optimize productivity and protect the environment from overuse of fertilizers [13]. A six wheeled soil sampling mobile robot has been developed, to increase the efficiency and productivity in agriculture [13].

The information of soil fertilization has also been a concern of many researchers in the field of smart agriculture. An Internet of Things (IoT) sensor integrated smart system has been developed in [14] for collecting information on soil and use of fertilizer in agricultural fields. A four-wheeled agricultural robot has been implemented to collect information about soil and crop in open fields in [15]. This robot utilizes a touch screen for the generation of control commands and the mobility of the robot is achieved using six motors. Nevertheless, the researchers have not specifically stated a procedure for the collection of soil or crop information.

Augmented Reality (AR) concept too has been integrated into soil sampling for efficiency and effectiveness. Wearable AR technology has been used to direct users to identify soil sampling spots for data collection [16]. This research employs an algorithm to automatically decide the locations for soil sample collection based on a soil map built from drone photography after ploughing. This is a major step in the field of smart agriculture where the AR concept is being utilized for the traditional farming process. Soil salinity also has adverse effects on the degradation of soil that inhibits the sustainable development of the irrigated farmlands. The research work in [17] utilizes satellite remote sensing along with soil sampling for predicting the salinity of soil with the use of machine learning techniques. Further the research in [17] can identify the desired salinity level of soil based on the vegetation that suits best for the crops.

Soil monitoring systems need to be capable of responding quickly to adverse circumstances, such as extreme weather or chronic drought, based on soil conditions. An autonomous soil monitoring robot has been implemented in [18] that collects data on soil moisture and temperature at specified points in the field. Nevertheless, the autonomous robot is not able to act on collected information of soil, whereas the collected data from the field must be forwarded to the farm manager for investigation. The research work in [19] concerns controlling the soil condition using the ESP-NOW protocol that works in real time to monitor the humidity of soil as well as the temperature and humidity of the air. This autonomous robot can both monitor the soil condition and act accordingly to water the crops. The protocol utilized in this autonomous robot allows the operation without connecting to Wi-Fi. The autonomous robot developed in [20] can move to any specific location within the field and water the plants without any human intervention, according to a specified schedule to retain the moisture of the soil in the field. RoSS, is a robot that can penetrate the soil to send a sensor probe to detect the moisture level of soil [21]. It is a low-cost robot that analyses the soil health based on the collected samples and sends the data to a cloud for storage thus eliminating the human dependency in soil sampling. Further works of this research includes integration of a GPS, camera, and a LIDAR unit.
The standard approaches to generating agricultural suggestions such as seed spreading, watering, fertilizing, etc. can be enhanced by sensors. For example, complex laboratory experiments of soil testing can be overcome by integrating IoT sensors to monitor soil conditions. Thus, more efficient equipment can be developed using sensors for strategic on-farm testing [22]. The use of an EM38 sensor that employs electromagnetic induction in characterizing the soil samples has been widely used in research related to agriculture. The research in [23] provides further insights into the applicability of the EM38 sensor in agricultural fields due to its ability in evaluating soil parameters and identifying the locations for soil sampling. According to the research [23], the EM38 sensor can be used to assess the soil salinity, water level, soil types along with boundaries, nutrients, N-turnover etc. that assures the widespread usage of this sensor in agricultural fields. Therefore, it is clearly evident that this type of sensor is much valuable in the agricultural field to have a broader view on the soil being concerned.

Autonomous fertilizing is another aspect considered in the field of smart agriculture. The robot developed in the research work in [24] can fertilize the soil autonomously and this system is more efficient and effective because it can be used in gardens, agricultural, and horticultural fields as well. The robot named ‘Agrobot Lala’ is one of the latest developments in smart agriculture [25]. This robot can perform real time soil sampling and can analyse the amount of nitrate in the soil. Satellite images along with machine learning algorithms are used in this research for partitioning the target agricultural fields into representative regions where the robot is capable of automatically sampling soil at the relevant regions. Therefore, it reduces the number of samples collected and optimizes the location of the soil samples that makes this research unique.

B. Seeding

Seed spreading is also an integral part of crop management where the farmer engagement is extensive if the agricultural area is large. The primary goal of automating the seeding process is to make it more efficient and precise than traditional seed sowing methods. Therefore, many researchers have worked on seed spreading robots that upheaves the smart agriculture concept. A seed spreading robot has been designed to perform seeding on a predefined fixed distance in the agricultural field [26]. Authors have indicated embedding intelligence to pick weeds as future work.

An Agribot has been designed for the seeding process with the use of precision agriculture concept where each crop is treated independently [27]. Furthermore, the researchers have utilized the concept of optimal depth and distance in the seeding task. This Agribot can navigate easily in more compact areas using IR sensors, which is an advantage over the existing agricultural robots. Nevertheless, one of the main constraints of this agricultural robot is the limited coverage area that it can navigate due to its reliance on a DC battery. As further work, the researchers have stated the requirement of integrating weeding and spraying activities to make the robot usable in multiple scenarios. The work carried out in [28] addresses the limitations in existing seeding robots and highlights some of the constraints that exist in real agricultural fields. This seeding

agricultural robot incorporates a seed selector in the seeding process with multiple other features such as keeping track of the lanes, automatically following the path, and establishing wireless communication with the owner in an emergency etc. In addition, the robot is designed with DC components and is battery operated. As future work researchers have indicated the use of solar panels where there are electricity issues.

A four-wheel robot has been developed in [29] which can carry out the seeding process in similar intervals based on the parameters given. Some of the inputs are length and breadth of the agricultural land where the seeding is to be performed, and the seed spacing intervals. This robot has been able to increase the number of seeding locations and to reduce the seed wastage. As further works, it is being indicated the possibility of integrating IOT based equipment and sophisticated components for wheels and sensors to ensure the operation of the robot in harsh environmental conditions, and to integrate other agricultural tasks to the same robot.

In the recent past much focus has been paid to developing robot communities that work towards a common goal. Mobile Agricultural Robot Swarms (MARS) is the paradigm of smart agriculture that explores the possibility of using multiple robots that perform individual tasks delegated and coordinated by a central robot system that are working towards achieving a single goal [30]. These robot swarms use minimum sensor technology to obtain a lower cost and efficiency in terms of energy consumption that provides reliability and scalability. For the seeding process, a MARS system has been used in [30], which is a novel step towards smart agriculture.

The Agribot [31] makes use of both the sensor and vision technologies in the seeding process for achieving the navigation and localization tasks. The robot's position is identified by a Global Positioning System (GPS) with an on-board vision mechanism. In addition, this robot consists of a suspension mechanism to prevent the robot from toppling while navigating in agricultural fields that makes this research stand out from other research work. According to the authors, this suspension system can handle bumps up to 3cm. Moreover, the researchers propose to use the swarm technology to reduce the sowing time.

C. Harvesting

Crop production is confronted with enormous difficulties mainly due to reasons such as diseases, low yield, damage from animals and natural disasters etc. Therefore, to ensure the security of food and ecosystem, future crops must be developed for sustainable agriculture by boosting net production while minimizing negative environmental impacts. In the research [32] drones were used for distinguishing between different techniques used for ploughing in fields with the use of an RGB-D sensor. Generally, image acquisition, analysis and reasoning in smart agriculture is a tedious, time-consuming work in large agricultural farms. Therefore, use of new sensors has been indicated as further work in [32] to achieve high resolution. Identification of crop rows is also an essential task for almost all the activities in the agricultural sector. Both the tasks of crop row identification and navigation between the crop rows have been achieved successfully with the use of a clustering algorithm in the mobile robot [33].

Crop harvesting robots are also gaining much attention in mass scale agriculture. With the use of NI RoboRIO controller, a harvesting robot has been implemented targeting small and medium sized low hanging crops [34]. Since the fields are not even, image acquisition without the background is a challenge. The robot developed in [35] for image acquisition can be configured remotely and provide scalable solutions to minimize the challenges encountered in using traditional image gathering techniques with the use of cloud computing and wireless network technology. Harvey [36] is a robotic harvester that aims on harvesting sweet pepper, based on vision algorithms. The results demonstrate that better grasping techniques lead to significantly better harvesting.

The development of an agricultural humanoid robot based on natural human harvesting behavior has been the goal of the research in [37]. The humanoid robot utilizes a vision-based approach with two RGB-D sensors fixed in the head and the hand. The humanoid robot consists of grippers to achieve the natural human grasping in harvesting and the system has been deployed successfully in tomato agricultural fields. A robot integrated with a sac with constant air pressure for grasping the fruit is deployed in tomato harvesting and shows much higher success rate and can prevent the fruit being damaged [38]. A rotational plucking gripper has been utilized in the research [39] to efficiently pluck tomato that makes the gripper rotate using an infinity rotational joint. An apple harvesting robot implemented by the researchers in [40] can perform real-time apple detection and picking up the apples with a success rate of 0.8.

In the recent past it has been researched to use the same harvesting robot in multiple cultivation fields, mainly due to economic reasons. A novel low-cost gripper [41] has been developed using a 3D sensor for harvesting fruits and vegetables. The gripper can detect the cutting point of the fruit or the vegetable without affecting the flesh that makes this a viable approach in agricultural fields.

Integrating smart agriculture into paddy cultivation is a challenge as there is no shape or a fixed position for the paddy harvest (Vee Karala) to capture an image in a simple manner. Rice harvesting has been the concern of the study [42] and it has developed an automated procedure to account for each step in the harvesting process. This includes steps such as loading/unloading and restarting the robot to harvest the rest after a small break where the robot has the capability to cooperate with the farmers in the harvesting process. Therefore, it is apparent that the process of harvesting rice involves a complex process that must be focused on many angles.

Other than wide agricultural lands, the concern has also shifted towards small agricultural areas where the environment is cluttered and unstructured. A robot [43] has been developed to harvest strawberries in a polytunnel that includes some complex processes due to the environmental constraints. This robot can successfully pick strawberries from clusters of strawberries which makes this research stand out from other strawberry picking systems. The algorithm named 'obstacle-separation path planning' has been introduced in this research where the robot uses a gripper to push away any exterior obstacles to reach the goal to be picked up. In another research a robot [44] has been developed for harvesting strawberries in a greenhouse where it was stated that the average picking time of a strawberry is about only 4 seconds. This fully autonomous robot can detect ripe fruits, pick them up and place the fruits in a box without any damage. According to the researchers, this is a cost-effective complete solution for the scarcity of expensive human pickers.

In addition to the vegetables and fruits to be harvested, some researchers have focused on the greenhouse horticultural domain as well. A mobile robot has been designed in [45] to support harvesting flowers inside a greenhouse. The developed robot can follow a person by 3D mapping and assist in harvesting flowers and has been tested in a real greenhouse.

D. Plant Diseases

Plant diseases pose a serious threat to the agricultural process. As a result, it is critical for farmers to adequately deal with diseases and monitor them using prompt prevention methods. Crop diseases have been generally divided into two categories: abiotic (also known as non-infectious) and biotic (also known as infectious) [46]. Plant production and the minimization of both qualitative and quantitative losses in crop productivity depend on the early and effective diagnosis and identification of plant diseases. Optical techniques have proven effective results in plant disease detection in early stages. Among the optical techniques that are being used, RGB imaging, thermography, 3D scanning, etc. are more prominent [47]. Nevertheless, according to study [48], detecting plant diseases continues to be a challenging issue for both biotic and abiotic categories. This study also brings out the fact that although there are many successful attempts in detecting plant diseases, most of them require a controlled environment for the acquisition of data to prevent false positives. In addition, the advancements in mechatronics and robotic systems for plant disease management should be driven by the challenge that diagnostic specificity poses for microorganism control.
A plant health monitoring system with an 83% accuracy level was implemented in [49] for early detection of plant health based on images of the crop. This system enables early detection of malnutrition conditions and classifies the plants as healthy or unhealthy and the system can sprinkle pesticides accordingly. A robot operated with a mobile phone has been developed by the researchers in [50] for the purpose of spraying pesticides. This system comprises three units, namely, input, spray and control processing, and output. Nevertheless, this system is not fully autonomous since the farmer needs to manually operate the robot functions, movements, spraying, and stop spraying functions with the use of the mobile interface. The autonomous robot that has been implemented by [51] is capable of autonomously spraying pesticides and is based on image processing for detecting plant disease. The work done in [52] is much like the previous work, however the concern was only towards leaf disease detection.

The leaf disease detecting robot developed in [53] is voice controllable and can alert the user with the measures that can be taken to address the identified disease. Another approach taken by researchers in preventing plant diseases is removing the unwanted part of the plant once the disease is detected. The research work [54] focuses on the automatic detection of the plant diseases and can cut the stem where the leaves are affected and has reported an accuracy level of 79%. Deep learning techniques have been applied for building models to detect plant diseases in [55].

Furthermore, the concern on plant disease detection has also directed towards handling multiple issues of a single plant giving an all-in-one solution. The research [56] attempts to address the issue of automated identification and classification of diseases in the rice plant using machine learning and image processing approaches. Nevertheless, it has been indicated in the study that with the passage of time, plant diseases get more severe and to understand the parameters that affect the detection of plant diseases at a maturity level needs more in-depth research. Durmus et.al, 2017 have integrated the ability of tomato plant leaf disease detection to a robot which already had the capability of navigating, controlling, and collecting data [57]. The authors have utilized two deep learning architectures namely, AlexNet and SqueezeNet in PlantVillage dataset of tomato leaf images. As further work, it was indicated to improve the system to extract leaves from complex backgrounds.

All the above discussed methods and technologies in smart agriculture have mainly focused on automating a very specific task. Yet, none of those methods and techniques are capable enough of embedding general cognition into any of these systems. For example, none of the robots/systems described earlier can adapt to changing situations such as in the absence of a particular nutrient substituting it with a local similar nutrient. In addition, none of the agricultural robots at existing present can perform all the agricultural tasks on their own without any human intervention.

IV. Challenges to smart agriculture

This section discusses the challenges and limitations in smart agriculture in a more concise manner. The developments in Artificial Intelligence and related fields have enabled farmers to adopt autonomous farming technology and make use of predictions based on past and current conditions. All these strategies make use of numerous hardware components that

require connectivity and electricity to operate. The challenges to the concept of smart agriculture have been the focus of many researchers [58], [59]. Figure 1 illustrates the challenges identified, to smart agriculture based on the literature reviewed in this research.

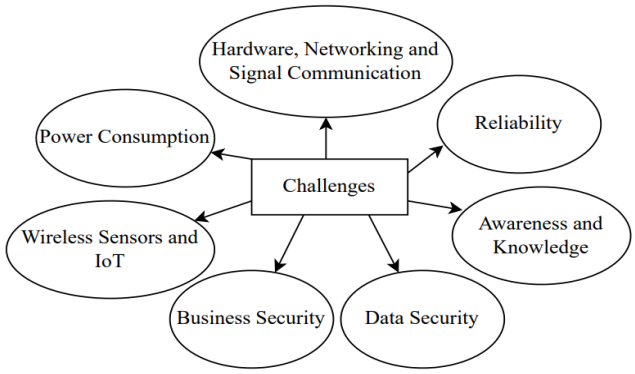

Figure 1. Challenges to Smart Agriculture

When the extent of the farming area is large, continuous operation of these robots only with battery power is a challenge due to high power consumption. Therefore, it is essential to either reduce the power usage or to improve the battery life for continuous, uninterrupted usage by these machines. Hence there are some ongoing research works that investigate the possibility of integrating solar power and wireless sensors to increase the lifetime. Nevertheless, there are some challenges such as exposure to solar energy, efficiency of the solar panel conversion etc. With the expansion of the cultivation fields the scalability of existing systems is a major concern without re-engineering the whole process.

Autonomous systems in smart agriculture tend to face numerous hardware related difficulties when in operation due tough climatic conditions such as exposure to bad weather, traversing uneven terrain, deliberate attacks, and harm from animals, etc. Still there are no fully integrated systems that can mitigate all these limitations.

Additionally, these autonomous systems face various networking related issues especially in connecting IoT devices dispersed in agricultural fields including device malfunctions as well. The quality and reliability of real time data transmitted by the IoT devices become questionable due to these network related issues. The infrastructure in autonomous systems in agricultural fields are highly complex and, in rural areas, in most countries, the network communications are very slow or not present at all. This hampers the continuous real time data streaming and accessing essential knowledge for farming.

Nevertheless, it is understood that most of the farmers are lacking the essential knowledge to operate in the wake of smart agriculture. Hence there needs to be carefully designed knowledge dissemination events to equip the farmers and update their knowledge. Data security and maintaining integrity of specific business processes are also crucial while implementing such systems.

Furthermore, none of the present smart agricultural systems are integrated with cognition where these systems can evaluate the current internal and external conditions and reason out, adapt to changing situations and take informed decisions over anticipated situations. Adaption of proper cognitive architectures in smart agriculture is yet a research challenge. In addition to the above limitations the knowledge gap in identifying and modelling of human level cognition is a challenging task that limits embedding of cognition into these smart agricultural systems. Other than the challenges identified with the literature review conducted, authors would like to add cultural aspects also to the list of challenges to the smart agricultural paradigm. Still farmers in some rural areas in some parts of the world are using traditional approaches combined with non-scientific belief systems for farming and some are very reluctant to embrace the change. This has posed a barrier to the usage of smart agricultural systems in day to day agricultural activities.

V. Integrating artificial cognition into smart agriculture

A. Real –world scenarios

The real-world examples given next, discusses how cognition can be integrated in smart agriculture. None of the soil sample collecting robots can decide whether the designated place is the most suitable place for collecting the sample. For example, if the designated place is trampled and damaged by wild animals, then that soil could be contaminated with animal waste. By integrating cognition through common sense knowledge and the ability of context-based reasoning mechanisms these systems will be able to avoid such places that will enable avoiding making erroneous decisions. When sprinkling water if the system can identify the weather condition and decides whether watering is required or not is a step forward in smart agriculture. Additionally, if the system noted that the plants or crops do not look healthy and if the system can decide the next set of steps such as watering or watering with added nutrients will yield better harvest. The process of autonomous fertilizing can also be uplifted if the soil fertility can be predicted and fertilized accordingly. Another agricultural process that can be embedded with cognition is the cultivation phase where the robot can be made to identify the relevant places in the agricultural field to cultivate or a particular plant type in the seeding process. Spraying pesticides can be stated as an agricultural activity where farmers tend to be more careful, and therefore, the full control has not been given to the agricultural robots yet.

In Sri Lankan context, tea, rubber, and coconut are the plantations that are widely of concern. Deploying smart agricultural systems integrated with artificial cognition will elevate these agricultural sectors into the next level that could

bring much needed foreign exchange. All these three sectors are facing a severe scarcity in finding capable human labor.

Developing autonomous cognitive systems for tea leaves plucking will be an extreme research challenge because of ground conditions and the difficulty of identifying the rightly matured tea leaves for plucking. Any autonomous cognitive system developed for the tea agricultural sector will not be only a research achievement but will be a sustainable support for the industry. Rubber agricultural sector is faced with a dearth of skilled workers for rubber tapping. Autonomous cognitive rubber tapping machines are a requirement of the hour which is not fulfilled yet. The autonomous rubber tapping machines should be capable of identifying the suitable rubber trees and their height for tapping. Navigating among the trees and identification of weather conditions and acting accordingly are two aspects that need to be considered. Coconut agricultural sector too is another area hardly hit due to scarcity of skilled workers. Autonomous cognitive coconut plucking machines will be an ideal solution to the problem, which is not yet realized. The ability of the machine to identify the matured coconut for plucking, monitoring the healthiness of the tree top and identification and treating for any insects or diseases that might be at the top of the tree are few cognitive aspects that need to be considered.

Irrespective of the agricultural sector any autonomous cognitive machine deployed in the agricultural fields needs to be able to assess the environmental conditions, healthiness of the plants and requirement of fertilizer and nutrients and take decisions accordingly.

B. Cognitive Architectures in Smart Agriculture

Artificial cognitive systems are embedded with the ability of learning, reasoning, and anticipation as fundamental capabilities. Thus, these capabilities can be harnessed into smart agriculture for developing cognitively able autonomous systems. Furthermore, farmers will be able to deploy autonomous farming technology and make better predictions of the future, based on current and past conditions, reducing crop diseases and pest invasions, by harnessing the power of Artificial Intelligence.

Identifying the correct architecture to integrate cognition is a much-researched area at present. Cognitivist architecture and Emergent architecture are two possible architectures that can be used for developing cognitive systems for smart agriculture. A cognitivist architecture supports embedding of static knowledge to the system where the system/robot will work according to the predefined knowledge. Emergent architecture concerns on learning by experience with the interactions with the environment. The system learns and builds its own knowledge repository. Thus, it is proposed here to use a hybrid cognitive architecture that combines cognitivist and emergent architectures in building autonomous cognitive systems for smart agriculture.

The hybrid architecture will be a good approach for smart agriculture as it allows the leverage to utilize the inherent and integrated knowledge while accounting for emerging situations. Thus, the system will be able to utilize the explicit knowledge provided to the system and will be able to adjust according to the inputs taken from the environment. This approach facilitates integrating the basic knowledge of farmers as well as the knowledge that is being gathered by them through experience.

VI. Discussion and conclusion

Through this research, it was identified that the concept of smart agriculture is strongly based on automating the routine steps of agriculture to enhance efficiency and effectiveness. Integration of AI and IoT have further improved and accelerated the adaptation. Yet it was noted that no cognitive abilities are integrated to any of these systems to a significant extent. This was clear based on the literature review done with respect to soil management, seeding, harvesting, and plant diseases. Therefore, it can be stated that although there are partially/fully automated systems in the smart agricultural paradigm, cognitively able systems are scarcely noted in the agricultural process. In addition, embedding cognition completely into a system is a very complex process because there is a knowledge gap in fully understanding how the human cognition process works. Additionally, techniques and tools are also not yet fully known and readily available. In addition, there exists a wide range of challenges to the concept of smart agriculture where the authors have broadly discussed those challenges previously. Furthermore, to achieve the right level of cognition, it is required to integrate the proper cognitive architecture into systems that are deployed in smart agriculture. Hence, a hybrid architecture is proposed which is a combination of the cognitivist and emergent architectures. Yet this poses a great challenge since complete knowledge on how human cognition gained and works is not completely understood at present. Nevertheless, the authors highly urge the need of concerning actual requirements when developing fully autonomous cognitive systems since identifying the real need of farmers will drive the implemented system to a success. Moreover, the research gap in how humans process information with the use of their conscious mental processes and the knowledge in embedding cognition artificially to systems is a research challenge at present. Nevertheless, research in both cognitive computing and smart agriculture will further enhance the cognitive facet of smart agriculture in future.

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Performance Analysis of Docker-based Database Management Systems Compared to Virtual Machine-based Systems: A Comparative Study

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ABSTRACT Computer virtualization is a very old technology. Due to a lot of technical barriers, computer containerization has been introduced recently. Nowadays, computer containerization is playing a major role in information technology and containerization is a trending topic. Among the practitioner of information technology, a lot of software services are moving to containerization instead of traditional virtual machines. Among the most famous software services: database management systems are a leading service. Among most computer containerization technologies, Docker is the most popular and trending container vendor. Therefore, identification of the performance of database management systems on the Docker-based platform is an essential task for the practitioner. This research study aims to identify the practical aspects of each database management system on the Docker-based infrastructure for main database management system operations. For the study: Ubuntu 18.04 Long Term Support (used package with architecture: GNU/Linux 4.15.0-112-generic x86_64) cloud-based operating system was used and on that operating system the Docker infrastructure was launched. Docker version 19.03.9 was launched for the study. On Docker: MySQL, PostgreSQL, and MongoDB database management system containers were launched separately. SELECT, DELETE, UPDATE, and INSERT operations were used for the performance evaluations of database management system response times. This research identified that there was an increase in the performance of the Docker platform with a 95% confidence interval level for all data records to virtual machine-based platforms. Finally, the research study identified that Docker-based database management system has a quick response time than virtual machine-based database management systems.

KEYWORDS: Containers, Database Management Systems, Docker, MongoDB, MySQL, PostgreSQL

I. Introduction

Computer containerization is a trending technology that brings the computing environment as a logically packaged mechanism. Packaged containers consist of all required environments with essential binaries, dependencies, libraries, and configuration files to execute any such kind of software application and/or service. Containers can be deployed in any computer environment such as a public cloud centre, private cloud centre, or any personal computer.

Within the practitioner of containers, Docker is one of the trending container management technologies. Other than Docker: Rkt and Linux containers are available as container technologies.

As mentioned in the official Docker documentation, most of the widely used computing tools are engaged with Docker containerization. A few of them are Bitbucket, GitLab, GitHub, NGINX, Redis, Jenkins, JFrog, MongoDB, Visual Studio Code, etc. [3].

Relational Database Management Systems (RDBMS) is a specific database management system specification, which is based on the relational model and Structured Query Language (SQL). Most modern database systems are RDBMSs. MySQL, PostgreSQL, IBM DB2, MS SQL Server, and Oracle are the best examples of RDBMSs [6].

Within the existing research studies, the authors have evaluated the database management systems by considering the taken time to particular SQL queries and response time commonly.

This research study aims to identify the practical aspects of each database management system on the Docker-based infrastructure for main database management system operations. By considering the response time, practically, information technology academics and practitioners will be able to select suitable database management system technology for the applications.

The overall research study provides answers to the below research questions.

RQ1: *How are the performances of relational database management system Docker containers over virtual machine-based database management systems?*

RQ2: *How are the performances of the no-SQL database management system Docker containers over virtual machine-based database management systems?*

RQ3: *How to launch no-SQL and relational database management systems on Docker and virtual machine-based infrastructures?*

II. Literature review

Server containerization has emerged with various reviews here and there. Practically, the vulnerability of data, complex criteria for resources, and network problems are often cited as drawbacks. Nevertheless, the usage of containerization has increased, since most applications are running with containerized databases which are migrated from traditional virtual machines. Software development and software infrastructure-providing organizations of all sizes (from small start-ups to multinational, proven microservices companies) are using containers. Even the containerization has been taken over by well-known companies including Google, Amazon, Oracle, and Microsoft, databases are playing a major role.

In addition to the database operating environment, the containerization of the database involves databases inside a container to allow data to be loaded onto a virtual machine and executed separately. The article [14] has mentioned four special factors that support the usage of the database in containers. Those are the usage of the same configurations or ports for all containers, resilience, resource, and storage, cluster upscale or downscale, and data locality and networking.

According to the above first factor, the containerized architecture removes some of the overhead associated with a distributed system that supports various node types. This kind of distributed applications and systems required the management of separate containers that also require multiple configurations. One kind of configuration type is supported for database containerization. As well as, resilience, resources, and storage are considered as the second factor. But containerization should not be left with data inside them. According to typical database scenarios, it is often important to have database replications or export data from a central storage system. This process makes more cost and significantly slows down the performance. Database Management Systems are executing like any other sever-side applications but they are consuming more CPU-intensive and memory-intensive, have high status, and occupy storage space. The article [14] has expressed that all principle functions are in same for containers as well. In addition to that, the states of the database engine can be controlled, resources can be limited and access to the network can be restricted.

According to the third factor, the practice expresses the ambiguity as to how effective the application will be and the volume needed by enhancing the elasticity of the network. Database containerization takes into account the elasticity of the software applications. As well as by growing and shrinking most suitable infrastructure is provided. The article [14] has presented that data can be replicated in the background by adding extra nodes to the container cluster. According to the last factor, network scaling was a major challenge within the modern virtualized infrastructure. Load balancers typically take all traffic on the first run and then distribute it to the application containers. Thereafter, application containers interact with databases that produce more traffic. Hence containerization puts the database and the application back together, by removing any network troubles.

As presented in the white paper [15], databases may be available on standard stand-alone servers, on-premise clusters, or in PaaS (Platform as a Service) cloud services such as Azure SQL databases. For the development and test environments, however, it is practical to run the databases as containers, since no external dependencies are required and the entire application is started by simply executing the docker-compose-up command. The existence of these databases as containers is also ideal for integration tests since the database is started in the container and is always filled with the same data so that tests are more predictable.

Commonly, NoSQL database management systems are suitable for geospatial data and big data environments. The authors of [16] have mentioned that MySQL is a very mature RDBMS, a popular and inexpensive option. Furthermore, MySQL is an open-source RDBMS that is distributed, developed, and supported by Oracle Corporation. RDBMSs have identified that they are with remarkable features to reform transactional updates and handle the underlying consistency issues considerably well.

III. Methodology

To evaluate and make the comparison for Docker container-based database management systems, the Docker containerized

infrastructure was launched on Ubuntu 18.04 Long Term Support (used package with architecture: GNU/Linux 4.15.0-112-generic x86_64) cloud-based operating system. The host computer was with 15 GB memory capacity and 1 Gbps network bandwidth. On that host computer infrastructure, Docker version 19.03.9 was launched. Both Docker client and server engine communities are version 19.03.9. Docker API (Application Program Interface) version was 1.40 [17].

For the experimental evaluation: 5, 50, 500, 5000, and 50000 data records were used for each database management system. For the evaluation: MySQL and PostgreSQL database management systems were used as relational database management systems. MongoDB was used as the no-SQL database management system. To access each database management system remotely, MySQL Workbench, pgadmin, and Robo 3T (formerly Robomongo) were used respectively for the MySQL, PostgreSQL, and MongoDB database management systems.

The used database schema is as follows. For the queries, join based queries were used by considering the tables *oderdetails*, *orders*, and *customers*.

```
Table "customers" {
  "customerNumber" int(11) [pk, not null]
  "customerName" varchar(50) [not null]
  "contactLastName" varchar(50) [not null]
  "contactFirstName" varchar(50) [not null]
  "phone" varchar(50) [not null]
  "addressLine1" varchar(50) [not null]
  "addressLine2" varchar(50) [default: NULL]
  "city" varchar(50) [not null]
  "state" varchar(50) [default: NULL]
  "postalCode" varchar(15) [default: NULL]
  "country" varchar(50) [not null]
  "salesRepEmployeeNumber" int(11) [default: NULL]
  "creditLimit" decimal(10,2) [default: NULL]


Indexes {
  salesRepEmployeeNumber [name: "salesRepEmployeeNumber"]
}
}


Table "employees" {
  "employeeNumber" int(11) [pk, not null]
  "lastName" varchar(50) [not null]
  "firstName" varchar(50) [not null]
  "extension" varchar(10) [not null]
  "email" varchar(100) [not null]
  "officeCode" varchar(10) [not null]
  "reportsTo" int(11) [default: NULL]
  "jobTitle" varchar(50) [not null]

Indexes {
  reportsTo [name: "reportsTo"]
  officeCode [name: "officeCode"]
}
}


Table "offices" {
  "officeCode" varchar(10) [pk, not null]
  "city" varchar(50) [not null]
  "phone" varchar(50) [not null]
  "addressLine1" varchar(50) [not null]
  "addressLine2" varchar(50) [default: NULL]
  "state" varchar(50) [default: NULL]
  "country" varchar(50) [not null]
  "postalCode" varchar(15) [not null]
  "territory" varchar(10) [not null]
}

Table "orderdetails" {
  "orderNumber" int(11) [not null]
  "productCode" varchar(15) [not null]
  "quantityOrdered" int(11) [not null]
  "priceEach" decimal(10,2) [not null]
  "orderLineNumber" smallint(6) [not null]

Indexes {
  productCode [name: "productCode"]
  (orderNumber, productCode) [pk]
}
}


Table "orders" {
  "orderNumber" int(11) [pk, not null]
  "orderDate" date [not null]
  "requiredDate" date [not null]
  "shippedDate" date [default: NULL]
  "status" varchar(15) [not null]
  "comments" text
  "customerNumber" int(11) [not null]

Indexes {
  customerNumber [name: "customerNumber"]
}
}

Table "payments" {
  "customerNumber" int(11) [not null]
  "checkNumber" varchar(50) [not null]
  "paymentDate" date [not null]
  "amount" decimal(10,2) [not null]

Indexes {
  (customerNumber, checkNumber) [pk]
}
}


Table "productlines" {
  "productLine" varchar(50) [pk, not null]
  "textDescription" varchar(4000) [default: NULL]
  "htmlDescription" mediumtext
  "image" mediumblob
}

Table "products" {
  "productCode" varchar(15) [pk, not null]
  "productName" varchar(70) [not null]
  "productLine" varchar(50) [not null]
  "productScale" varchar(10) [not null]
  "productVendor" varchar(50) [not null]
  "productDescription" text [not null]
  "quantityInStock" smallint(6) [not null]
  "buyPrice" decimal(10,2) [not null]
  "MSRP" decimal(10,2) [not null]

Indexes {
  productLine [name: "productLine"]
}
}

Ref "customers_ibfk_1":"employees"."employeeNumber" < "customers"."salesRepEmployeeNumber"

Ref "employees_ibfk_1":"employees"."employeeNumber" < "employees"."reportsTo"

Ref "employees_ibfk_2":"offices"."officeCode" < "employees"."officeCode"

Ref "orderdetails_ibfk_1":"orders"."orderNumber" < "orderdetails"."orderNumber"
```

Ref "orderdetails_ibfk_2":"products"."productCode" < "orderdetails"."productCode"

Ref "orders_ibfk_1":"customers"."customerNumber" < "orders"."customerNumber"

Ref "payments_ibfk_1":"customers"."customerNumber" < "payments"."customerNumber"

Ref "products_ibfk_1":"productlines"."productLine" < "products"."productLine"

After launching the Docker-based database management system containers, the same database management systems were launched on a virtual machine-based environment. For that, the host computer was with the same configurations as the Docker infrastructure host computer.

Applied computational steps to evaluate the performance are mentioned below pseudocode.

[Pseudocode]

```
(1)  INPUT: EXECUTED_QUERY
(2)  OUTPUT: QUERY_EXECUTION_TIME
(3)  BEGIN
(4)       ESTABLISH the Database Connection
(5)       CHECK the Database Connection
(6)       IF (Connection == Success)
(7)       SELECT the Option

(8)       IF (Option == Selection)
(9)       SELECT the Number of Records to Be Selected
(10)      PASS the Value to Proceed to DBMS
(11)      MEASURE the execution time

(12)      ELSE IF (Option == Deletion)
(13)      SELECT the Number of Records to Be Deleted
(14)      PASS the Value to Proceed to DBMS
(15)      MEASURE the execution time

(16)      ELSE IF (Option == Updating)
(17)      SELECT the Number of Records to Be Updated
(18)      PASS the Value to Be Proceed to DBMS
(19)      MEASURE the execution time

(20)      ELSE IF (Option == Insertion)
(21)      SELECT the Number of Records to Be Inserted
(22)      PASS the Value to Proceed to DBMS
(23)      MEASURE the execution time

(24)                DISCONNECT the Database Connection
(25)      ELSE
(26)                DISPLAY the connection error
(27) FINISH
```

For the experiment, MySQL version 8.0.31, PostgreSQL version 14.5, and MongoDB version 5.0 were used. Between the cloud-hosted Docker infrastructure and local remote computer a strong internet connection [upload speed 93.10 Mbps and download speed 94.41 Mbps] was established to eliminate all kinds of external traffics and omit all kinds of external effects during the experimental study.

IV. Results and discussion

After launching the Docker-based database management system containers, the respective database management systems were evaluated at the next stage. Any software application engages with a database management system for the basic CRUD (Create/Insert, Read/Select, Update, and Delete) operations as a thumb rule. Hence to evaluate the database engine responses, the response time for each SQL operation was measured. For the study, the most popular and open-source two relational database management systems and one no-SQL database management system were used. The response time was measured for the SELECT, UPDATE, INSERT, and DELETE operations.

A. SELECT Operation

The SELECT statement is used to select data from a database. The SELECT operation was executed for the selected three database management systems for the Docker-hosted and virtual machine-based infrastructures. The corresponding response time/query execution time was presented below in Table 1 for all infrastructures.

Table 1: Response time for SELECT operation

Data Records	Response Time (s)					
	MySQL		PostgreSQL		MongoDB	
	Docker	Virtual Machine	Docker	Virtual Machine	Docker	Virtual Machine
5	0.3	0.32	0.37	0.3	0.014	0.015
50	0.3064	0.35	0.4284	0.4147	0.087	0.092
500	0.6684	0.8172	1.6137	1.8835	0.1681	0.1763
5000	1.476	2.3146	1.9478	2.0250	0.4274	0.4431
50,000	3.5891	7.5341	4.8790	3.6941	1.0654	1.4145

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Figure 1 given below, presents the graphical representation of the SELECT query response time (execution time) for Docker-hosted and virtual machine-based MySQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MySQL database management system engine and the red-coloured line is presenting the virtual machine-based MySQL database management system engines.

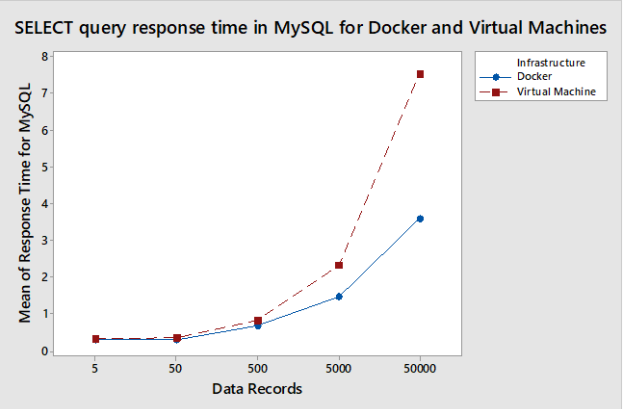

Figure 1: SELECT query response time for MySQL

The above figure 1 presents that the Docker-based MySQL database management system engine has a lower response time for the particular SELECT query than the corresponding virtual machine-based MySQL database management system engine. For the lower data records, both MySQL database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based MySQL database management system engine infrastructure has a lower query response time than the virtual machine-based MySQL database management system engine.

A dependent t-test was steered to assess the performance of MySQL DBMS for 50000 data records for SELECT query execution. The results showed a significant performance improvement in query execution time on Docker (Mean=3.5891, Standard Deviation=0.00008) to query execution time on VM(Mean=7.53407, Standard Deviation=0.00007), t(9)=107590.09, p-value=0.000(two-tailed). This means the increase in the performance of Docker was 3.94489 with a 95% confidence interval level.

Figure 2 below, presents the graphical representation of the SELECT query response time (execution time) for Docker-hosted and virtual machine-based PostgreSQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted PostgreSQL database management system engine and the red coloured line is presenting the virtual machine-based PostgreSQL database management system engines.

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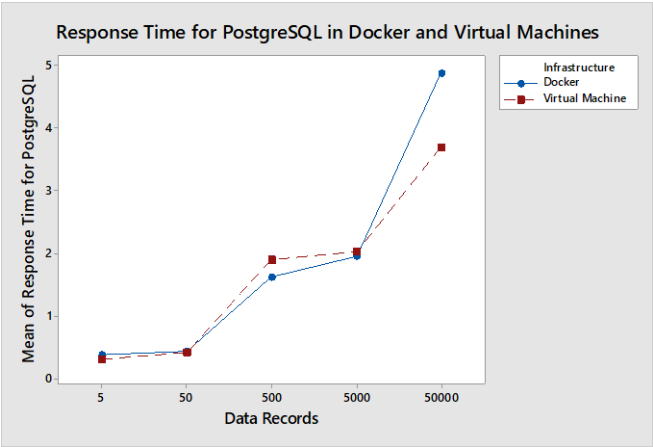

Figure 2: SELECT query response time for PostgreSQL

The above figure 2 presents that the Docker-based PostgreSQL database management system engine has a higher response time for the particular SELECT query than the corresponding virtual machine-based PostgreSQL database management system engine. For the lower data records, both PostgreSQL database management system engine infrastructures present approximately the same response time but for the 500 data records, the Docker-based PostgreSQL database management system engine has a lower response time than the virtual machine-based PostgreSQL database management system engine.

A dependent t-test was steered to assess the performance of PostgreSQL DBMS for 5000 data records for SELECT query execution. The results showed a significant performance improvement in query execution time on Docker (Mean=1.9478, Standard Deviation=0.00005) to query execution time on VM(Mean=2.025, Standard Deviation=0.00008), t(9)=3661.92, p-value=0.000(two-tailed). This means the increase in the performance of Docker was 0.077152 with a 95% confidence interval level for 5000 data records.

Figure 3 below, presents the graphical representation of the SELECT query response time (execution time) for Docker-hosted and virtual machine-based MongoDB database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MongoDB database management system engine and the red-coloured line is presenting the virtual machine-based MongoDB database management system engines.

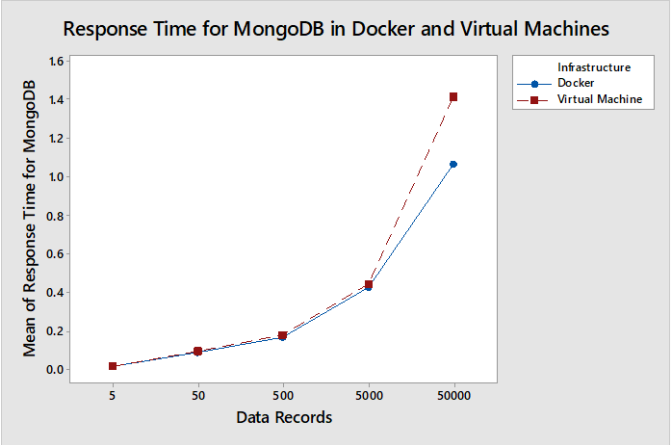

Figure 3: SELECT query response time for MongoDB

The above figure 3 presents that the Docker-based MongoDB database management system engine has a lower response time for the particular SELECT query than the corresponding virtual machine-based MongoDB database management system engine. For the lower data records, both MongoDB database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based MongoDB database management system engine infrastructure has a lower query response time than the virtual machine-based MongoDB database management system engine.

A dependent t-test was steered to assess the performance of MongoDB DBMS for 50000 data records for SELECT query

execution. The results showed a significant performance improvement in query execution time on Docker (Mean=1.06540, Standard Deviation=0.00005) to query execution time on VM(Mean=1.41450, Standard Deviation=0.00009), t(9)=8851.30, p-value=0.000(two-tailed). This means the increase in the performance of Docker was 0.349011 with a 95% confidence interval level.

Overall, Docker-based database management systems are presenting better performance than the virtual machine-based approach on the query execution time.

B. DELETE Operation

The DELETE statement is used to delete data from a database. The DELETE operation was executed for the selected three database management systems for the Docker-hosted and virtual machine-based infrastructures. The corresponding response time/query execution time was presented below in Table 2 for all infrastructures.

Table 2:Response time for DELETE operation

Data Records	**Response Time (s)**					
	MySQL		**PostgreSQL**		**MongoDB**	
	Docker	**Virtual Machine**	**Docker**	**Virtual Machine**	**Docker**	**Virtual Machine**
5	0.4	0.43	0.39	0.432	0.063	0.063
50	0.4157	0.494	0.4198	0.4277	0.088	0.097
500	0.6891	0.9641	0.7642	0.9471	0.1170	0.1287
5000	1.561	2.5873	1.7341	1.7753	0.2197	0.2947
50,000	3.9172	7.8973	5.6917	8.4782	0.9784	1.6810

Figure 4 below, presents the graphical representation of the DELETE query response time (execution time) for Docker-hosted and virtual machine-based MySQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MySQL database management system engine and the red-coloured line is presenting the virtual machine-based MySQL database management system engines.

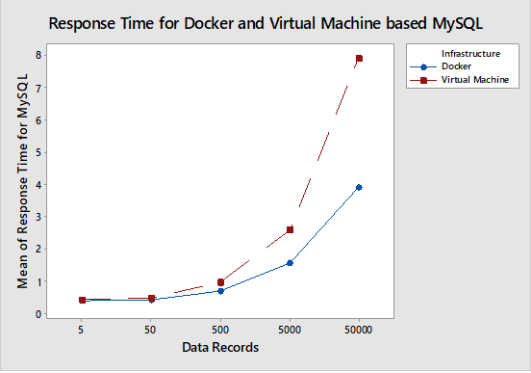

Figure 4: DELETE query response time for MYSQL

Figure 4 above, presents that the Docker-based MySQL database management system engine has a lower response time for the particular DELETE query than the corresponding virtual machine-based MySQL database management system engine. For the lower data records, both MySQL database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based MySQL database management system engine infrastructure has a lower query response time than the virtual machine-based MySQL database management system engine.

A dependent t-test was steered to assess the performance of MySQL DBMS for 50000 data records for DELETE query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=3.9172, Standard Deviation=0.00014) to query execution time on VM(Mean=7.8973, Standard Deviation=0.00005), t(9)=94396.36, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker platform was 3.98 with a 95% confidence interval level.

Figure 5 below, presents the graphical representation of the DELETE query response time (execution time) for Docker-hosted and virtual machine-based PostgreSQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted PostgreSQL database management system engine and the red coloured line is presenting the virtual machine-based PostgreSQL database management system engines.

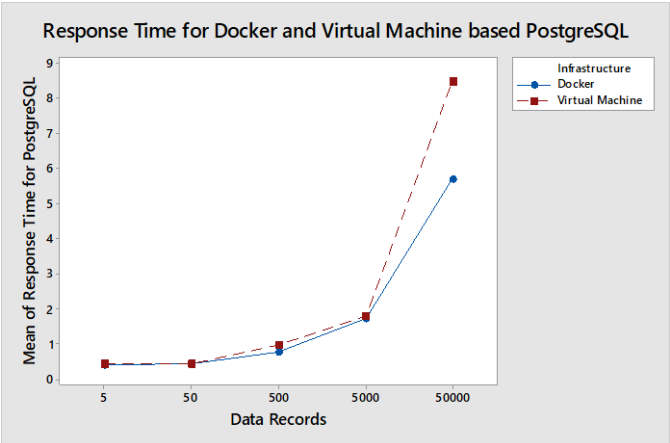

Figure 5: DELETE query response time for PostgreSQL

The above figure 5 presents that the Docker-based PostgreSQL database management system engine has a lower response time for the particular DELETE query than the corresponding virtual machine-based MySQL database management system engine. For the lower data records, both PostgreSQL database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based PostgreSQL database management

system engine infrastructure has a lower query response time than the virtual machine-based PostgreSQL database management system engine.

A dependent t-test was steered to assess the performance of PostgreSQL DBMS for 50000 data records for DELETE query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=5.6917, Standard Deviation=0.00015) to query execution time on VM(Mean=8.4782, Standard Deviation=0.00007), t(9)=59110.59, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker infrastructure was 2.78639 with a 95% confidence interval level.

Below figure 6 presents the graphical representation of the DELETE query response time (execution time) for Docker-hosted and virtual machine-based MongoDB database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MongoDB database management system engine and the red-coloured line is presenting the virtual machine-based MongoDB database management system engines.

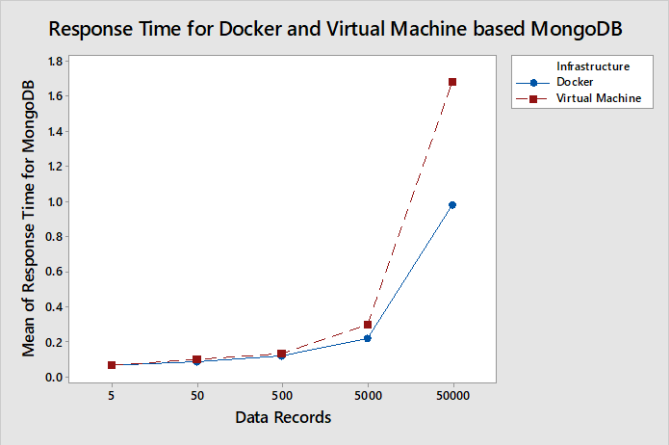

Figure 6: DELETE query response time for MongoDB

The above figure 6 presents that the Docker-based MongoDB database management system engine has a lower response time for the particular DELETE query than the corresponding virtual machine-based MongoDB database management system engine. For the lower data records, both MongoDB database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based MongoDB database management system engine infrastructure has a lower query response time than the virtual machine-based MongoDB database management system engine.

A dependent t-test was steered to assess the performance of MongoDB DBMS for 50000 data records for DELETE query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=0.9784, Standard Deviation=0.00005) to query execution time on VM(Mean=1.68100, Standard Deviation=0.00007), t(9)=21078.00, p-value=0.000(two-tailed). This means the increase in the performance of Docker was 0.702525 with a 95% confidence interval level.

Overall, the Docker-based PostgreSQL database management system engine has a higher response time than the Docker-based MySQL database management system engines for the particular DELETE query.

C. UPDATE Operation

The UPDATE statement is used to update data from a database. The UPDATE operation was executed for the selected three database management systems for the Docker-hosted and virtual machine-based infrastructures. The corresponding response time/query execution time was presented in below table 3 for all infrastructures.

Table 3: Response time for UPDATE operation

Data Records	**Response Time (s)**					
	MySQL		**PostgreSQL**		**MongoDB**	
	Docker	**Virtual Machine**	**Docker**	**Virtual Machine**	**Docker**	**Virtual Machine**
5	0.4961	0.5084	0.5149	0.5331	0.0743	0.087
50	0.5618	0.6347	0.7841	0.8146	0.0971	0.0991
500	0.7156	1.1433	0.7547	0.9947	0.0997	0.1973
5000	1.7891	1.8216	1.8759	1.1724	1.1679	1.2640
50,000	4.0870	8.1735	5.1157	8.8875	1.5441	1.9718

Below figure 7 presents the graphical representation of the UPDATE query response time (execution time) for Docker-hosted and virtual machine-based MySQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MySQL database management system engine and the red-coloured line is presenting the virtual machine-based MySQL database management system engines.

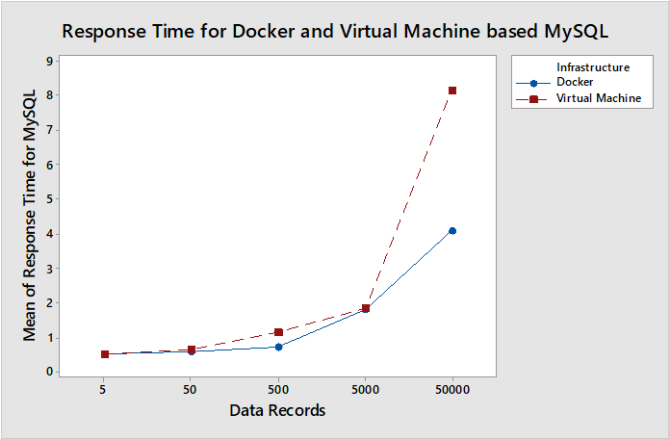

Figure 7: UPDATE query response time for MySQL

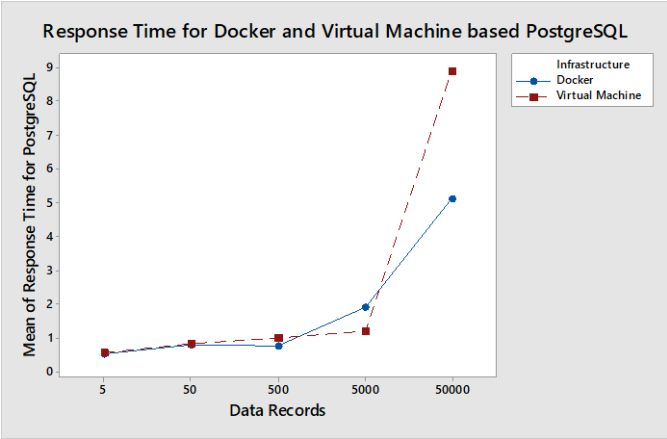

Figure 8: UPDATE query response time for PostgreSQL

The above figure 7 presents that the Docker-based MySQL database management system engine has a lower response time for the particular UPDATE query than the corresponding virtual machine-based MySQL database management system engine. For the lower data records, both MySQL database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based MySQL database management system engine infrastructure has a lower query response time than the virtual machine-based MySQL database management system engine.

A dependent t-test was steered to assess the performance of MySQL DBMS for 50000 data records for UPDATE query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=4.087, Standard Deviation=0.00007) to query execution time on VM(Mean=8.1735, Standard Deviation=0.00013), t(9)=137065.38, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker was 4.08643 with a 95% confidence interval level.

Below figure 8 presents the graphical representation of the UPDATE query response time (execution time) for Docker-hosted and virtual machine-based PostgreSQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted PostgreSQL database management system engine and the red coloured line is presenting the virtual machine-based PostgreSQL database management system engines.

The above figure 8 presents that the Docker-based PostgreSQL database management system engine has a lower response time for the particular UPDATE query than the corresponding virtual machine-based PostgreSQL database management system engine. For the lower data records, both PostgreSQL database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based PostgreSQL database management system engine infrastructure has a lower query response time than the virtual machine-based PostgreSQL database management system engine. But for the 5000 data records, the Docker-based PostgreSQL database management system engine has presented a higher response time than the virtual machine-based PostgreSQL database management system engine.

A dependent t-test was steered to assess the performance of PostgreSQL DBMS for 50000 data records for UPDATE query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=5.1157, Standard Deviation=0.00020) to query execution time on VM(Mean=8.8875, Standard Deviation=0.00022), t(9)=31877.53, p-value=0.000(two-tailed). This means the increase in the performance of Docker was 3.77153 with a 95% confidence interval level.

Below figure 9 presents the graphical representation of the UPDATE query response time (execution time) for Docker-hosted and virtual machine-based MongoDB database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MongoDB database management system engine and the red-coloured line is presenting the virtual machine-based MongoDB database management system engines.

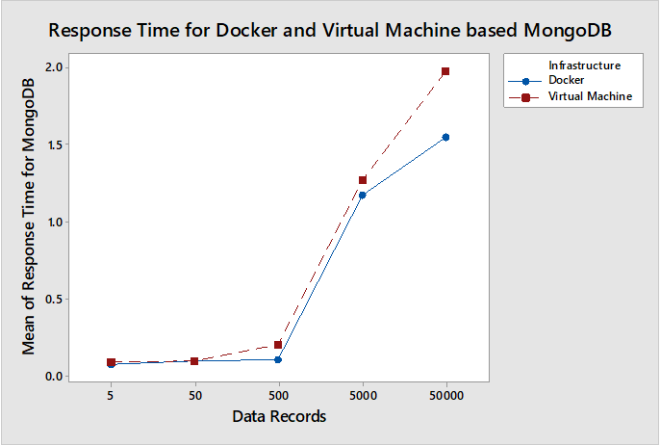

Figure 9: Update query response time for MongoDB

The above figure 9 presents that the Docker-based MongoDB database management system engine has a lower response time for the particular UPDATE query than the corresponding virtual machine-based MongoDB database management system engine. For the lower data records, both PostgreSQL database management system engine infrastructures present approximately the same response time. But for the higher data records, the Docker-based PostgreSQL database management system engine infrastructure has a lower query response time than the virtual machine-based MySQL database management system engine. But, the above figure is presenting a special behaviour for the 5000 data records. That is, the response time has a massive increment for the 5000 data records than other all scenarios.

A dependent t-test was steered to assess the performance of MongoDB DBMS for 50000 data records for UPDATE query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=1.5441, Standard Deviation=0.00011) to query execution time on VM(Mean=1.9718, Standard Deviation=0.00005), t(9)=10844.17, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker infrastructure was 0.427611 with a 95% confidence interval level.

The MySQL, PostgreSQL, and MongoDB database management system engines have lower response times for the Docker-based infrastructure than the virtual machine-based infrastructure. The Docker-based PostgreSQL database management system engine has a higher response time than Docker-based MySQL database management system engines for the particular UPDATE query.

D. INSERT Operation

The INSERT statement is used to insert or create data into a database. The INSERT operation was executed for the selected three database management systems for the Docker-hosted and virtual machine-based infrastructures. The corresponding response time/query execution time was presented below in Table 4 for all infrastructures.

Table 4:Response time for INSERT query

Data Records	Response Time (s)					
	MySQL		PostgreSQL		MongoDB	
	Docker	Virtual Machine	Docker	Virtual Machine	Docker	Virtual Machine
5	0.6482	0.6641	0.7244	0.7573	0.1157	0.2748
50	0.7137	0.7237	0.7784	0.8104	0.2649	0.3113
500	0.8232	1.2424	1.1607	1.2115	0.4381	0.5719
5000	1.8716	2.4104	2.4467	2.5491	1.0816	1.1670
50,000	6.7360	10.1133	6.9818	10.6970	2.7366	3.4108

Below figure 10 presents the graphical representation of the INSERT query response time (execution time) for Docker-hosted and virtual machine-based MySQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MySQL database management system engine and the red-coloured line is presenting the virtual machine-based MySQL database management system engines.

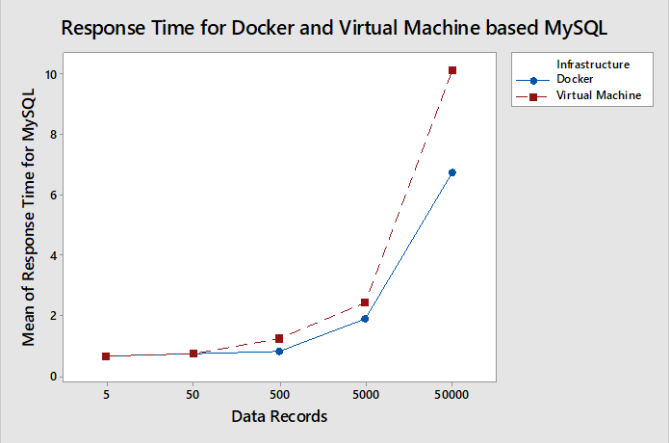

Figure 10: INSERT query response time for MySQL

The above figure 10 presents that the Docker-based MySQL database management system engine has a lower response time for the particular INSERT query than the corresponding virtual machine-based MySQL database management system engine. For the lower data records (less than 50), both MySQL database management system engine infrastructures present approximately the same response time. But for the higher data records (more than 50), the Docker-based MySQL database management system engine infrastructure has a lower query response time than the virtual machine-based MySQL database management system engine.

A dependent t-test was steered to assess the performance of MySQL DBMS for 50000 data records for INSERT query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=6.7360, Standard Deviation=0.0002) to query execution time on VM(Mean=10.1133, Standard Deviation=0.0001), t(9)=75518.72, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker was 3.7720 with a 95% confidence interval level.

Below figure 11 presents the graphical representation of the INSERT query response time (execution time) for Docker-hosted and virtual machine-based PostgreSQL database management system engines. The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted PostgreSQL database management system engine and the red coloured line is presenting the virtual machine-based PostgreSQL database management system engines.

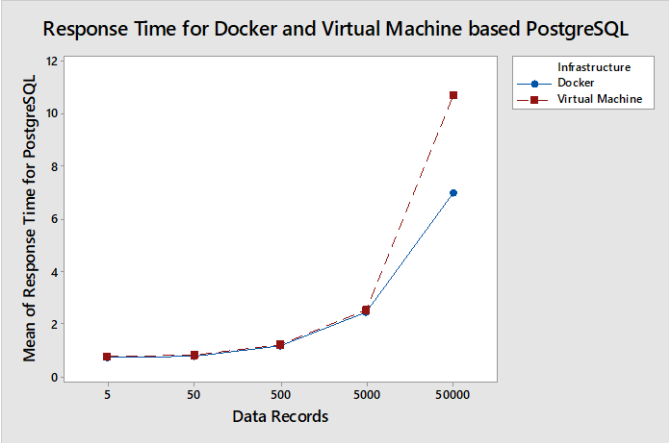

Figure 11:INSERT query response time for PostgreSQL

The above figure 11 presents that the Docker-based PostgreSQL database management system engine has a lower response time for the particular INSERT query than the corresponding virtual machine-based PostgreSQL database management system engine for the higher data records. For the lower data records 5-5000, both PostgreSQL database management system engine infrastructures present approximately the same response time.

A dependent t-test was steered to assess the performance of PostgreSQL DBMS for 50000 data records for INSERT query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=6.6918, Standard Deviation=0.0000) to query execution time on VM(Mean=10.6970, Standard Deviation=0.0002), t(9)=71944.54, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker was 3.71508 with a 95% confidence interval level.

Below figure 12 presents the graphical representation of the INSERT query response time (execution time) for Docker-hosted and virtual machine-based MongoDB database management system engines.

The y-axis is denoting the response time and the x-axis is denoting the number of data records. The blue-coloured line is presenting the Docker-hosted MongoDB database management system engine and the red-coloured line is presenting the virtual machine-based MongoDB database management system engines.

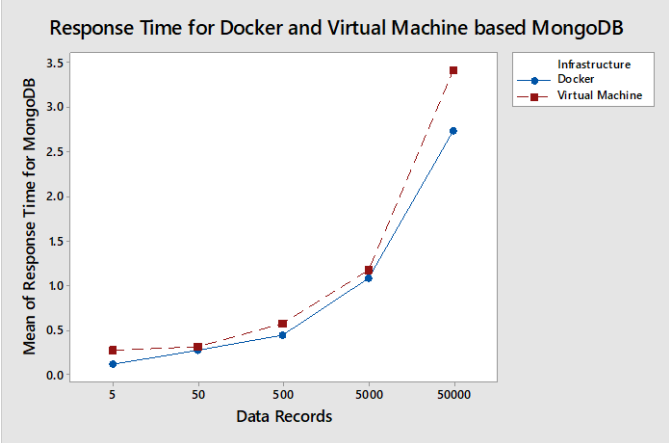

Figure 12: INSERT query response time for MongoDB

The above figure 12 presents that the Docker-based MongoDB database management system engine has a lower response time for the particular INSERT query than the corresponding virtual machine-based MongoDB database management system engine.

A dependent t-test was steered to assess the performance of MongoDB DBMS for 50000 data records for INSERT query execution time. The results showed a significant improvement in the query execution time on Docker (Mean=2.7366, Standard Deviation=0.00034) to query execution time on VM(Mean=3.4108, Standard Deviation=0.00005), t(9)=6333.01, p-value=0.000(two-tailed). This means the increase in the performance of the proposed Docker infrastructure was 0.673959 with a 95% confidence interval level.

The MySQL, PostgreSQL, and MongoDB database management system engines have lower response times for the Docker-based infrastructure than the virtual machine-based infrastructure.

V. Conclusions

After the initial launch of the Docker engine, on the host computer infrastructure: MySQL, PostgreSQL, and MongoDB database management system containers were launched. The

particular queries were executed through the remote database client software.

According to the experimental evaluation: Docker-based relational database management system containers presented the quickest response time for each query than traditional virtual machine-based database management systems. As well for the no-SQL database management systems also, Docker-based containers presented the quickest response time than traditional virtual machine-based database management systems. Furthermore, overall no-SQL database management system containers presented quicker response time than relational database management system containers.

Shortly, Docker containers will play a major role in practical information technology. As well the cloud computing, image processing, artificial intelligence, and data science domains will have oriented to the Docker container-based infrastructure.

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Social Media Platform for the Travel and Tourism Industry in Sri Lanka

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ABSTRACT As the industrial society of the twentieth century gives way to the information society of the twenty-first century, the modern world is undergoing a major transition. This dynamic process has the potential to fundamentally alterall parts of our life, including knowledge distribution, social interaction, business practices, political activity, media, education, health, leisure, and entertainment. Travel industry software applications play a significant role intourism and travel industry by contributing to a large volume of transactions and revenue. Many studies have evaluated tourism websites through different research methods. Website usability, in general, has improved dramatically but problems are still remaining. Very few studies focus on the use of software applications and features of need to develop in the Sri Lankan context. This research uses a mixed-methods approach. The survey results show that tourism and travel industry software applications search is regularly utilitarian in nature; the complex interface and not having one platform includingmore features either obscure or were ignored by most tourists while decreasing the satisfaction of that travel industry software applications. This research paper discusses the existing systems and their software applications, additional features, and satisfaction rates of these software applications, and suggest modern software application for that industry in Sri Lanka.

KEYWORDS: Features, Modern social media platform, Satisfaction, Software application, Sri Lanka, Tourism and travel industry

I. Introduction

The travel and tourism industry represents one of the most important sectors of the world's financial system. Travel has become a normal activity in our lives. The tourism industry itself is made up of parts of transportation, accommodation, food and beverage, retail trade, entertainment, and other industries. Tourism is one of the fastest-growing industries around the world. It contributes approximately 9% to the global GDP and has created millions of employment opportunities. Sri Lanka too is striving to get the maximum benefit from this growing business. But it is obvious that there was no clear national policy to develop the tourism industry in the country even after gaining independence from the British in 1948. Recently, Sri Lanka has had some automated systems, but these are not successful because tourists use the manual processes of tourist travel plans and guides.

Mostly the internet has become a valuable part of people's lives because of the current pandemic situation. Most people now are adopting the software application aspect. The benefit of technology is that it has facilitated globalization. The globe hasbeen constricted into one small village. People are linked together via internet networks and social media. With a single mouse click, information is sent at a quicker rate. Software applications are given many benefits. Making all bookings easily at one application, the most attractive rebates, and Customized Services, give more benefits like effective marketing tools, decreasing paperwork, getting a real view of tour destinations, and Simplify Transactions are the main target benefits of travel software applications in the tourism industry. The main objectives of the research were,

- Analyzing the challenges faced by tourists while in Sri Lanka.
- Examine the feedbacks and comments of the current and existing developments.
- Analyzing the opinion on modern social media applications and designing architecture for implementing a mobile application.

The research will highlight the multifaceted development of tour travel for improving an automated travel planning system for tourists. The sections that follow will look into how it could be enforced, the suitability of such a system in Sri Lanka, and the technical specifications of just such a system that will be developed. The further aim of the research paper is to analyze the software application success rate in the travel and tourism industry and implement a suitableapplication for that industry in Sri Lanka.

This will not only ease the commuters but also the government

due to database management in the system. The survey conducted in this paper reveals the problems in the traditional tour guide system in Sri Lanka. The research questions are: what are the currently existing solutions and technologies?, what is the customer feedback and satisfaction about current existing solutions?, what are the drawbacks in existing solutions?, and what are the recommendations by customers for further developments? After analyzing that and implementing the application. The review paper section identifies what kind of applications that are currently in existence and the relationship between social media and the impact of that researcher implementing the application.

This study also illustrates the existing problems of the tourism systems, customer satisfaction rate, development features,and further improvements.

II. Literature review

A Current situation in tourism

According to this research, the researcher has found that the Tourist nights spent in Tourist Hotels are gradually declining while tourist nights spent in supplementary establishments and unregistered accommodation units and private houses is increasing, which indicates the change of preferences in terms of tourist accommodation. [1]

According to this research, the researcher presented a comprehensive historical narrative of Sri Lankan tourism and discusses how Sri Lanka has lost chances in the past, as well as an introduction to Sri Lanka, including its location and natural features. The second section addressed creating a Computable General Equilibrium (CGE) model concentrating on tourism and building a database with a tourist focus. More introductions to Sri Lanka, including its location and natural wonders the historical study emphasizes future tourist aspirations and potentials in Sri Lanka. The third segment looked at the long-term economic implications of Sri Lanka's post-war tourist boom [2].

As reported by this research article, the researcher shows that e-tourism information search is primarily utilitarian in character, with most users being confused or ignoring the complicated interface and advertising messages. Highlighted the advantages and disadvantages of both traditional and internet travel companies furthermore, there are when deciding on the ideal choice, it is critical to consider which ones provide the discounts, products, and services that a traveler seeks as the agents of travel. Finally, consider how to become more competitive through more effective use of information technology, as well as discuss how customer decisions may be influenced by the perceived value of the services required [3].

This research prioritizes covers the arrival of new technology utilized in travel communication tools, as well as fresh ideas on how to use them in Sri Lanka. Further, this researcher intends to introduce a number of subjects in the development of this smartphone application model. This research was made possible by Sri Lanka tourism, smart travel & e-tourism, tourism promotion, and mobile phone applications [4].

This article examined the factors that contributed to the positive perception of the travel destination and the relationship between tourist perception and satisfaction with the Nuwaraeliya holidays. Furthermore, the empirical results provided reliable evidence that tourist perception influences tourist satisfaction. Tourists choose a specific destination based on their travel expectations and other expected tangible and intangible benefits. After reaching the destinations, tourists as consumers experience many different products and services.

That research examines the push and pulls variables that impact tourists' decisions to visit Sri Lanka and categorizes them as primary, secondary, moderately influenced and least influenced factors. Rest and relaxation, escape from a demanding job, being away from a monotonous life, experiencing new living styles, seeking information, and so on are among the most impacted push motives, according to the author. Natural beauty, diversity of flora and fauna/diversity of attractions, Sri Lankan culture, Buddhism, archaeological and historical monuments, and sandy beaches, according to the author, are very important in people choosing Sri Lanka as their vacation destination [6].

This research prioritizes travel agents are specialists who can assist travelers with all of their travel arrangements. Despite the widespread usage of the internet for travel-related services, travel agents are still required in some situations. People who wanted to travel engaged travel agencies or travel agents to help them prepare for their planned journey years ago when the internet had not yet reached its current state and condition [7].

The people that organize and plan vacations for their clients are known as travel agents. They are quite beneficial to travelers. These days, a lot of tour and travel businesses are giving attractive packages to passengers. Travel agents are those that organize all forms of transportation and lodging for travelers. A tours and travels agency arranges the selling and buying of travel and other associated services [8].

According to this research, the researcher gives an evaluation of how consumers use mobile tourism apps and how they use those apps to guide customer intentions to visit tourist places. This research proposes a model for a novel travel communication mobile application that combines virtual reality and augmented reality technologies with multimedia information techniques to create a tourism mobile phone game. The various management consequences, such as apps as different marketing tools, increasing attitudes toward using tourism applications, and segmenting clients to build marketing strategies, are all taken into consideration [9].

B Applications of social media in the Tourism Sector

Social networks' position has been gradually explained and studied as an emerging topic in the tourist sector. The phrase "Travel 2.0" refers to a novel idea that highlights the growth of social media's relevance in travel and current investments in thetravel sector [17]. Social media is fetching more and more vital inseveral facets of travel and tourism, particularly when gatheringmaterial, providing decisions, and marketing travel, with animportance on the finest tools for connecting with users on socialmedia platforms [18]. In addition to having an impact on visitorconsumption patterns, social media's development has had animpact on the field of tourism and hospitality research. Researchers have acknowledged for the past 20 years that, social media is crucial for travelers to choose and organize their vacation [19]. In current, an admirable method has been proven to feature social media to offer tourism services. Social media is seen as a key instrument by many nations and governments to boost their vacationer's economies. The social media advertising approach of a company outlines how it uses social media platforms to achieve its marketing objectives. The company's business plan may be built upon and changed as a result of the market and customer insights provided by the social media strategy. The tourism businesses case study on the application of social media advertising indicates that the commercial idea is currently not completely executed. Based on their studied plan for using social media providing to sell their business, the corporation has to make further decisions about how to best utilize the marketing tools at their disposal to attract new clients. Social media can act as a promotional tool, and individuals and industries use it to reachpotential tourists [20]. Social media raises awareness of destinations, reaches the masses, encourages travelers to plan their trips, enhances the image of destinations as selected destinations, and targets new/specific markets, and visitors. Increase the number of Facebook likes has become the goal, which can be used to spread the number of positive reviews that generate a buzz [21].

C Relationship between Tourism and social media

Marketers can analyze customer satisfaction. The impact of traveler-generated gratification via social media influences traveler travel planning. Many conference papers have also shown the impact of social media on the sector. The proposal reveals that traveler reviews on social media sites can help make the customer's travel plan-making process more enjoyable [22]. In addition, it works by growing confidence in the decisions of individuals, especially travelers, and reducing the risk of unknowns or uncertainties. According to this researcher[23], social media facilitates satisfying customers. In addition, the state came from a way to share customer feedback with lots ofpeople, with importance on positive reviews. This is established as "the best ad you can buy with money". A researcher reported that 82% of US customers searching for travel site reviews online are searching for travel related to the travel-planning process. However, publications on applications such as Facebook do provide a star rating based on the overall understanding. In addition, organizations need to analyze the words their customers use [24]. Online reviews not only attract and repel people but also provide knowledge and help you imagine your goals [25].

Social media and social networks behave like important advertising tools and carry out several areas. These tools typically deliver users with a platform for getting guidance on products and services. In addition, customers can raise awareness; think about travel experiences, and share travel accounts. Similarly, the benefit to a company is to market its objective, increase brand loyalty, and provide opportunities to augment long-term relations [26]. Making use of social media as an advertising tool is extremely valuable as it gives your organization a competitive advantage over its competitors.

When the researcher before writing a paper collects the related others titled also. Then researcher identified some critical relationship points between social media and the travel and tourism industry.

D Impact of social media in the Tourism Sector

The point, Facebook has a substantial impact on traveler choices, particularly in the travel industry. According to research done in 2012, more than 90% of consumers' worldwide claim to trust and believe suggestions made by colleagues, such as word-of-mouth. In addition, the potential client will be impacted by ideas and reports made on social media [27].

According to research, businesses that partner with customers who leave online reviews see an increase in customer loyalty [28], and social media improves client satisfaction [23]. Researcher define businesses that partner withcustomers who leave online evaluations increase client churn [29]. Companies that hire people who leave online evaluationsget a competitive advantage [30]. In further studies, eWOM and reviews influence customers' booking decisions. The decision to reserve a room is influenced by the majority of favorable evaluations [31]. It is believes that businesses that use social media build lasting ties with both current and potential customers [32].

Social media affect travel in various aspects. Positive remarks will highlight consumer satisfaction and positive experiences, and negative remarks will highlight negative experiences and disappointments. Therefore, it is crucial to examine the impact of unfavorable remarks on the destination's reputation and traveler choices. Travel selections are significantly influenced by social media. Additionally, the remarks and opinions made in the tourism industry on social media will be tied to the potential customer.

Social media also affected customer service, which resultedin happy customers. Social media presence helps businesses respond to client complaints and issues. Additionally,

responding to consumer complaints aids in building brand loyalty for businesses. The core of customer service is this. In order to improve consumers' perspectives, one technique is to underline how important they are. Additionally, this social media format, which is classed as a single piece of material, turns into a topic of conversation amongst many users. However, negative connections will occur if social interactions, as seen in social media relations like shares, likes, and comments, are the norm. This unfavorable information will reach potential buyers in addition to followers. As a result, social media has a "called effect" on certain travel-related industries. As a result, over-tourism and grant to overcrowding. The addressing issue of over-tourism through careful further planning and a multi-activity, multi-sponsor style appears to be the best course of action [33]. Therefore, the tourism and travel industry need specific social media for theirs.

E Feature comparison

Sri Lanka currently has no specific social media platform forthe travel and tourism industry. But that industry has some applications. Those applications have some feature problems. The proposed system has some main features in one application.

Table 1-Summary of Feature Comparison

	Official website of Sri Lanka tourism [1]	Sri Lanka Travel Guide [2]	Trivago [5]	Viator [6]	Eco Sri Lanka [7]	Tourpal Travel Guide & Tours on	Tripoto [11]	Goibibo [13]	PickMe [14]	TripAdvisor [15]	Booking.com [16]	Google Map [17]	Travel Guide [18]	Telegram [19]	You tube [20]	**Traveller [Project**
Ability to download the mobile application				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ability to read Guidelines													Have			✓
Ability to check the guide with high accuracy										✓			only			✓
Ability to rate services or places				✓	✓			✓	✓	✓	✓		read			✓
Ability to add comments about places or services			✓	✓	✓		✓	✓					option			✓
Ability to find top-rated places with ease			✓							✓	✓		travel			✓
Ability to book services			✓	✓		✓	✓	✓	✓	✓	✓		places			✓
Ability to get transportation services	✓	difficult		✓			✓	✓			✓					✓
Ability to watch travel-related videos		✓													✓	✓
Ability to connect with service providers directly	✓				✓				driver only							✓
Ability to chat with others														✓		✓
Ability to get travel plans										✓						✓
Ability to connect with Guiders	✓	✓														✓
Ability to get rent vehicles accommodations																✓
Ability to search location	✓	✓		✓		✓	✓	✓		✓	✓	✓				✓

Table 1-Summary of Feature Comparison

III. Methodology

With a mixed-methodology approach, this study combined interviews, surveys, and reviews and presents them as an analysis. As methodology researchers used a survey to collect data. The data has been gathered from a sample of 95 foreigners and the survey contains questions that asked about whether tourists are satisfied or not with current travel planning systems in Sri Lanka. And suggested a suitable platform for that using a research paper review. Researchers asked questions to take information about current systems problems in Sri Lanka. Researchers also gathered data by observing how current systems work with Sri Lankan tourists and problems have existing systems by doing interviews with current application builders. The interviews were guided by a set of pre-determined questions about the tourist and travel software applications, both negative and positive on software applications in SriLanka. The purpose of the interviews was to identify the benefits and problems of software applications and to identify the stakeholder attitudes on the impacts.

The researchers used several kinds of research strategies such as conducting surveys on the identified audience, understanding the grounded theories and algorithms which were used, clearly understanding the current scenario, and focusing on the best solution for recovering the problems in the current situation. This study considers prime information collected from common people from tourist countries which comprises both males and females, with a survey comprising both closed-ended and open-ended questions. At the same time information was collected from Sri Lankan, popular sites moreover utilized in this investigation. Further, the researcher suggests a useful platform for implementation using reviewing research papers.

The system is developed using android studio. The server side language is Java, and the database is based on firebase. The Google play store sells android apps and researchers use the google play API to integrate them.

The developer event set it up to customize travel plan suggestions using filters. Further, use Google Maps APIs to develop map features. Iterative waterfall methodology is used during the development of the system as it reduces the developers' effort and time required to detect and correct the errors.

A. Data Gathering

The survey data for this study was gathered through a questionnaire, and literature reviews. The survey was conducted by delivering a questionnaire. This was done to collect 95 tourists and a literature review and review paper findings were completed by consulting 33 research data extremely precisely to improve the effectiveness of the research outcomes.

B. Data Analysis

In this study, many forms of analysis were carried out. Mainly analysis of data under the questionnaire. And secondly using conference papers. To pinpoint the chosen papers' research focuses, qualitative analysis was used. Frequency analysis was

used to examine the social media applications in tourism, social media and tourism's relationship, and the impact of social media on tourism. Finally, the researcher chooses a suitable application or platform in that industry in Sri Lanka.

C. Proposed System Background

Here the researcher specifies the software requirements which were needed to build the project, the concepts which could be applied, and a brief explanation of the overall outcome of the procedure of the project.

i. Android SDK

Important implications for developing applications for the Android Platform are provided by the Android SDK (Software Development Kit). The following are some of the Android SDK's key elements:

a) SDK Build Tools: This is a combination of all the tools needed to build every individual application component.

b) Android Emulator: This is a virtual device used to test theandroid application in the development environment itself.

c) Platform Tools: These are the tools that offer assistance for using the current Android API with an application.

d) SDK Platform: The application's intended API level (Android level)

e) Google APIs - By offering APIs which were supporting the building interfaces which is important in simplifying the app implementation.

ii. Firestore

Cloud Firestore is the name of the most recent database for Firebase's mobile app development. It builds on the benefits of the Real-time Database with a new, easier to understand data schema. In comparison to Real-time Database, Cloud, Firestore scales are larger and enable deeper faster searches. Each document has an assortment of key-value pairs. Large numbers of small documents should ideally be stored in the Cloud Firestore. All papers must be stored in collections. Documents can contain sub collections and nested objects, both of which may contain straightforward objects like lists or complex ones like lists. Collections and documents are generated automatically in Cloud Firestore, by simply applying data to a collection of papers. If one or both are absent, Cloud Firestore creates the collection or document.

iii. FCM

Using Cloud Messaging (FCM) users can transmit messages consistently and cost-free using a service for cross-platform messaging called Firebase Cloud Messaging (FCM). Using FCM, you may notify a client app when a new email or other data is available for syncing. Notification messages can be sent to encourage user re-engagement and retention. Mainly this provides a wide range of communication possibilities and skills. Push notifications are distributed using the Firebase Cloud Messaging service to android, iOS, and the web.

iv. Maps SDK for Android

Use the Maps SDK for Android to integrate google maps data, map displays, and gesture responses into your Android app, including Wear OS apps. Users may enhance the places on your map and encourage user involvement by addingmarkers, polygons, and overlays. The Kotlin and Java programming languages are also supported by the SDK, which also offers extra libraries and extensions for cutting- edge features and programming methods.

IV. Analysis

Data analysis, according to Yin (1994), includes evaluating, classifying, tabulating, or else recombining the data. Every study should have a broad analytical technique that treatsdata objectively, generates persuasive analytic findings, and eliminates alternative interpretations. This analytical approach should assist the researcher in selecting a technique that completes the study analysis. This analyses all of the main data acquired from the questionnaire distributed to tourists' visitors, conversations with app developers, and survey outcomes.

A. Age

The survey was conducted among foreign tourists which travel to Sri Lanka. That included 95 respondents. They are divided into groups with respect to their age limits. Among the sample users, 21.1% of them belong to the 10-25 age limits. When compared with the 26- 35 age limit that age limit percentage is low because 26-35 age limit tourists have some better experience in this topic area. 41.1% of users under the age 26-35 age limit as this survey is mainly targeted through Sri Lanka tourists' board registered people. 25.3% of users under 36-49 and 12.6% of respondents belong to the age above 50. Because of a lack of awareness about technology and the lack of usage of social media marketing the responses that came from the survey are very low from the above 50 age limit students. The following pie chart describes the sample sizes of respondents in each age limit category. Figure 1 shows the overall distribution selected respondents in terms of belonging to each category.

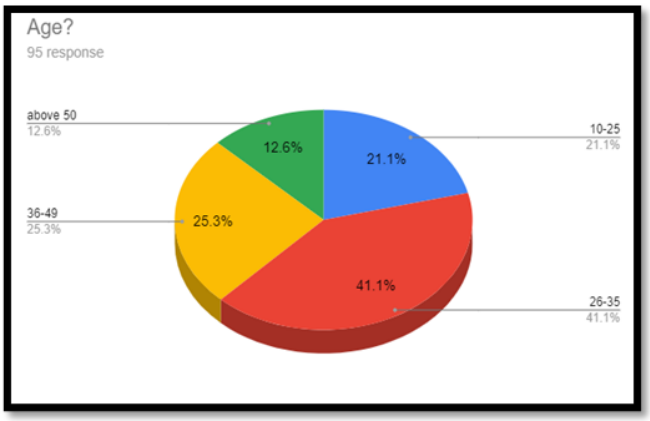


Figure 1: Age

B. Country

The survey received responses from 22 countries and 95 people. Accordingly, 7.4% from France, India, Russia, 6.3% from Thailand, and Switzerland tourist added their responses. Also, 5.3% from America, Canada, England, and Poland, and 4.2% from Australia, Denmark, Germany, Italy, and Japan tourists mark their responses. 3.2% from Belgium, Malaysia, Mali, and Nepal, and 2.1% from Bangladesh, China, Pakistan, Philippines, and Pakistan tourist people added their responses. This survey was shared through the people on the tourism board, and this was shared in almost every country people, but the number of responses decreased due to their inadequate knowledge of English.

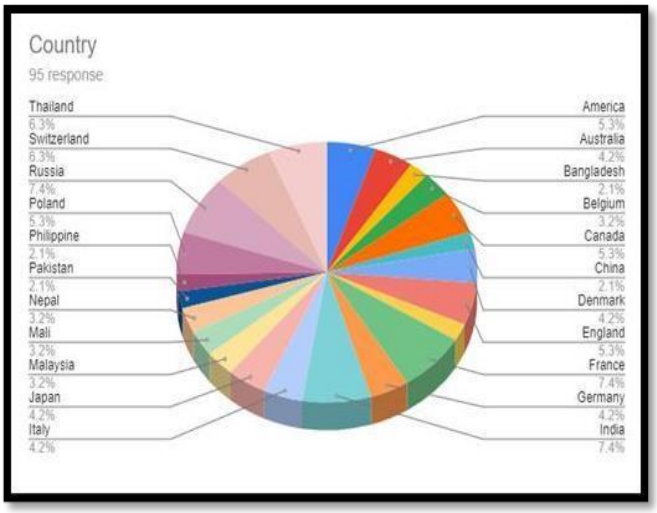


Figure 2-Country

C. Do you think you had a better travel experience in Sri Lanka?

According to the survey done by the researcher this question was also asked to know about their satisfaction in travelling experiences. Sri Lanka has thus achieved an important stage in comparison to the others of the world. 53.7% of tourists say they had a better travel experience in Sri Lanka. That is the most important point, because if someone gets a better experience at one time, they will be willing to travel to Sri Lanka again. But there were some unfortunate incidents that tourists could not enjoy or get a good experience during their travel. 6.3% of guests think they were not able to get a better travel experience as they were not having a good travel plan, had time limitations, or faced some bitter experiences. 40.0% gave the maybe answer because the overall experience they had was a mixed satisfaction with good and bad experiences in and out. Tourist satisfaction is a sensation produced by both cognitive and emotional components of tourist activities, as well as a cumulative perceptual appraisal of the many items and services consumed throughout the stay at the location. Tourist happiness is determined by a variety of elements, including travel motivations, tourist expectations, perceived quality, and ease of use, perceived value, and destination image. Tourist pleasure is highly tied to their post-purchase behavior. If the tourists are happy, they will return and suggest the place to others. Similarly, unsatisfied visitors act in a negative manner.

Figure 3-Experience rate

D. Were you able to see all the beautiful places in Sri Lanka as you thought?

Sri Lanka have multiple beautiful places to visit, but some tourists were not have been able to see those beautiful places. 24.2% marked answer as “No” because they were not able to visit many good places. Most of the guests gave their result as “maybe”. That is 52.6% in figures and it was because the people guessed could have seen some more places. 23.2% give a “yes” answer. Those guests were fully satisfied during the Sri Lanka's travel.

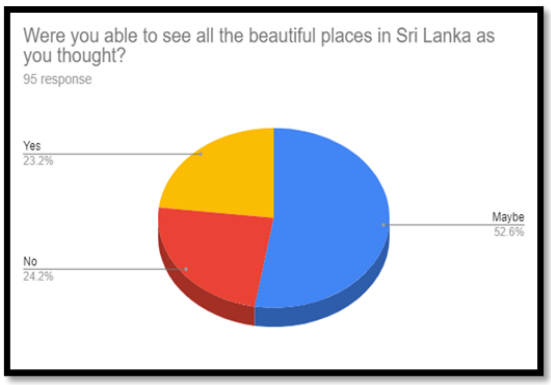


Figure 4-Satisfation I

E. What were the platforms you used to find instructions while traveling inside Sri Lanka?

Tourism is a very dynamic and competitive sector that demands the capacity to constantly adapt to travelers' quickly changing requirements and wishes, since the pleasure, safety, and happiness of tourists are the primary emphasis of the travel and tourism industry. To make Sri Lanka competitive in the global travel and tourism sector and to fully use the industry's economic potential, appropriate regulations and investment decisions are required. 27.7% of guests get others' help to travel inside Sri Lanka. Anyone willingly offering help such as vehicle drivers, agency workers, shop owners, and other people give instructions to foreigners to enjoy their Sri Lanka travel correctly and better. That is the manual system. The modern-day world is going with the technology side. At that time, decrease in the use of books. 12.9% of guests use books. Mobile apps and websites both get equal responses. That is 24.6% out of the full response. Technology is the modern trend in the world. Sri Lanka also must be important to follow this technology. 9.8% Use some other platforms to get some instruction for travel inside Sri Lanka.

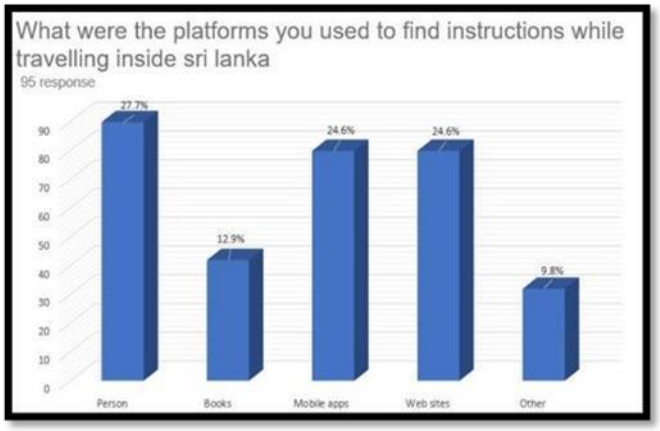


Figure 5-Platforms

F. If other, please specify a used platform.

In the above 9.8%, people say some used other platforms. Accordingly, out of 32 responses 4 people used Facebook, 2 guests used videos, and 6 responses used YouTube to get some instruction while traveling in Sri Lanka. Facebook and YouTube both platforms used 10 guests and social media platforms also used 10 people. Every time social media platforms are helping to get more instruction in any area. That is the importance of this but sometimes that has worn information. That is the dangerous thing.

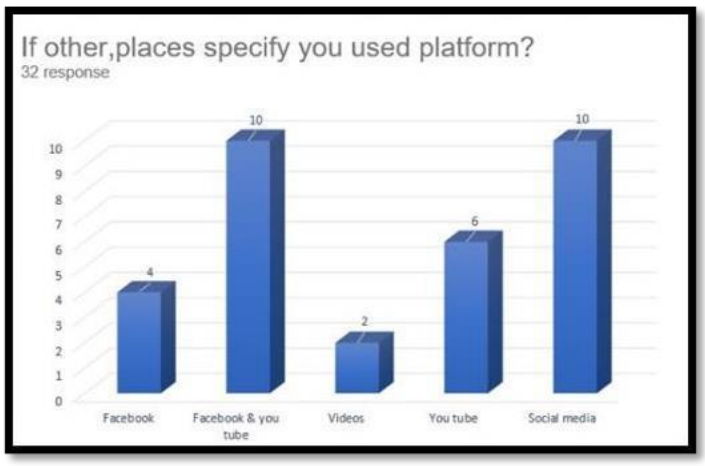


Figure 6-Other platforms

G. What are the names of apps and websites you used?

Sri Lanka has risen to prominence in contrast to the rest of the globe. From this perspective, the current state of the tourist business in Sri Lanka provides optimum comfort to the passenger. They are, respectively, fraud information, and inaccurate information added to the travel book. As a result of all of this, the country's attitude toward the tourist business has deteriorated. Similarly, there is no up-to-date information system elsewhere in the globe for a visitor intending to visit Sri Lanka and a local tourist before making their journey. There is no assistance in picking new software to enter Sri Lanka, other than current travel support software such as Google Maps, TripAdvisor, and Booking.com. It is critical that a traveler with a mobile phone has access to essential mobile phone software. Sri Lanka's tourist infrastructures, as well as the utilization of technology and new information, all need to be improved as a result of the above. Using more mobile applications or E-tourism is one of the world's most popular and investigated industries. 10 tourists said they use Google Maps for success in their travel. Google Maps is a worldwide app, hence it will be highly supportive. 12 of the guest mark they used trip advisor. That is both mobile and web applications. Trip advisor is one of the useful and popular applications for all countries because that has some new and easy-to-handle features. Out of 70 responses 8 guests said they use the booking.com app. which is one side of the travel and tourism industry. The PickMe app and the Sri Lanka tourism web page were used equally by 7 guests each. PickMe also is one side basic application and the tourism Sri Lanka tourism page is the most suitable application to get important and reliable information. 5 people used YouTube for getting more travel information. Today's one of the most common platforms has become YouTube because it has video and audio multitask features. Moreover, the Google travel page was also used by 5 guests. 6 tourists were giving responses using the "Travel Sri Lanka" page and 4 people were using the "Sri Lanka travel guide" page. Google earth and stray boots were used by 3 guests each.

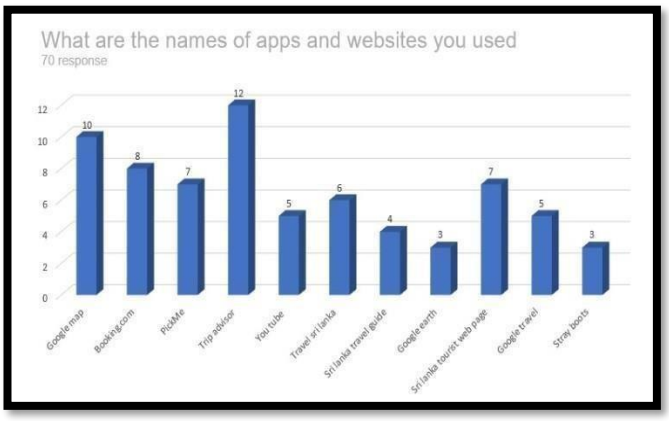


Figure 7- Names of software applications

H. Have you found one platform where you can make a good travel plan and know the guidelines exactly after coming to SriLanka?

In today's information-technology environment, computers, IT systems, and the Internet are becoming indispensable for many ofour daily jobs. As a result, having an online presence has become essential for remaining competitive in the tourism industry. The use of software applications has also become vital to ensure that you compete with the rest of the globe. 82.6% of respondents say current Sri Lanka does have not one platform for making a good travel plan, with better features including correct guidance and multitasking activities. Inside Sri Lanka has tourism and travel industry- related more software applications but no one platform all featured are included. 17.4% of guests say found one platform. When getting that one platform, have more advantages. Such as decreasing time and money waste, getting correct information and guides, enjoy travel.

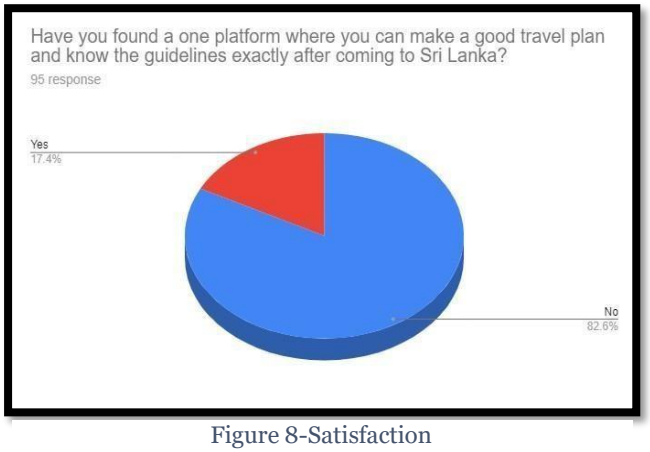


Figure 8-Satisfaction

I. How much support did you get from the existing app and website systems in Sri Lanka?

This survey can identify the success of software applications in the tourism and travel industry in Sri Lanka. In this chart number1 is the lowest support get software applications and number 5 is the highest mark that gets software applications.11% responses from number 1(lowest mark), 21% responses of number 2 (mid- lower mark), 32% response from number 3(middle), 28% responses of number 4(mid-highest mark), and 8% responses ofnumber 5(highest mark). Number 5 has fewer responses, which mainly affects the user satisfaction rate. Number 3 and 4 have more responses which mean tourists get software application support moderately. When adding other features users or guests can get the highest support from that software application.

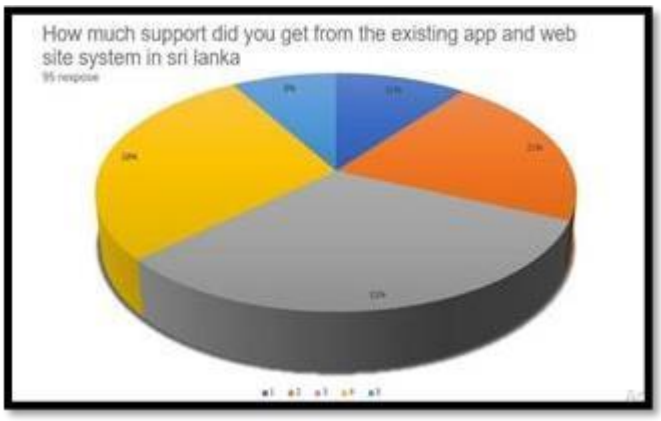


Figure 10-Support rate

J. Are you satisfied with the software application features available in Sri Lanka to make a travel plan and get things done properly?

Local government institutions and communities should concentrate on tourist satisfaction to ensure better travel services regarding the tourism industry. It is essential to take steps to make sure the quality of tourist services in both national and international markets. The categorization requirements for tourists' likeness were found in a survey of consumer satisfaction. It is obvious that quality is the most important necessity of tourism including the travel industry. To provide better travel services in the tourism industry, local government institutions and communities should focus on visitor satisfaction. It is critical to take measures to ensure the quality of tourism services in both domestic and international markets. A survey of customer satisfaction revealed the classification needs for tourists' similarity. Quality isthe most crucial need of the tourist industry, including the travel industry. When serving a good service, guests are satisfied more but Sri Lanka does not have better software applications. Therefore, difficult to travel inside Sri Lanka. when introducing better mobile or web applications, the satisfaction rate also increases.4.3% of respondents say satisfied with existing software applications in the travel and tourism industry because sometimes some people do not need more features to use applications. Most people's response is not satisfied with Sri Lanka's existing software applications in the travel industry. 45.7% of guests gave "maybe" as the answer.

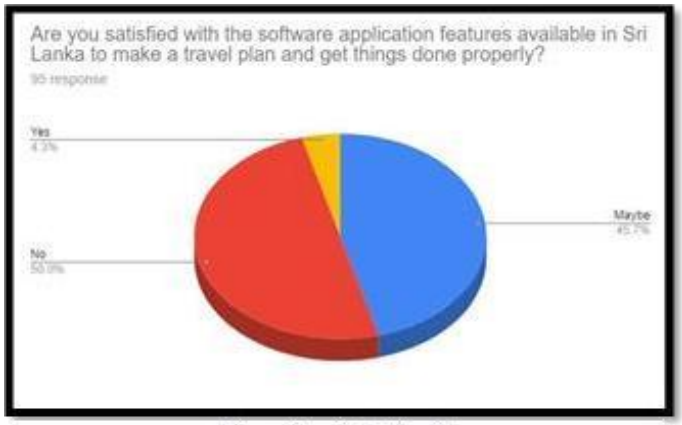


Figure 9-satisfaction III

K. Do you think those systems need to be further developed?

From this survey, it was found that the most needed features are required to be added for existing software applications. Such as 22.6% like to add interactive interface features to existing applications. That is the most important point to get the attraction. 18.9% say need tourist guidelines and 9.9% like to add a geo-tracking service. That represents the security area of the travel and tourism industry.8.7% of respondents need a world clock because they need to know other countries' family members' time for contact with them. 20.1% like to add location-based shops, restaurants, and hospitals. Sometimes it is difficult to search for good places not using software applications to help. Every people cannot verbalize in English.14.1% highlighted the need a language translation option and 5.3% of respondents mention having more features to develop in the Sri Lanka tourism and travel industry technology field.

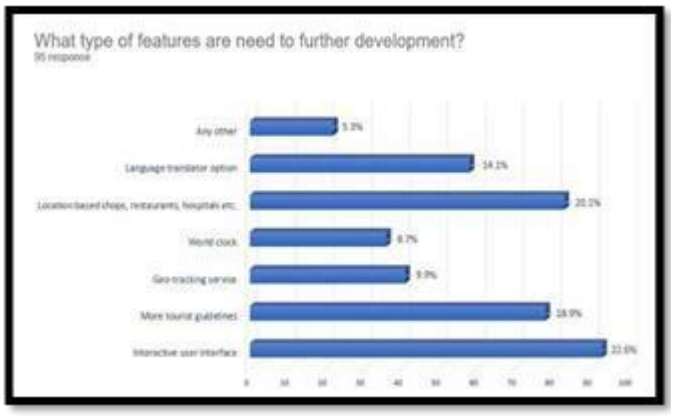


Figure 11-Features

L. What type of features are needed for further development?

The mobile application concept is a key influence in the tourist business in Sri Lanka, providing travelers with informationsuch as travel, transit data, lodging, bungalows, and food. Forpeople who want to read and listen to audio and videoinformation, video and radio reports about each tourist location are now accessible. The objective is to develop such a user-friendly application to cater to the world's preferred languages.Throughout this process, Sri Lanka's tourist sector is developing a strong multi-media travel communications mobile application. It allows a traveler to participate in a multi-purpose multimedia application that offers essential conveniences aswell as entertainment and data. Here are considered the tourists'ideas about some of the new features need to add currentapplications fields specifically explored in this research. Suchas, Easy to handle interface, Easy payment options, and apackage system, Sri Lanka places description video blogs, booking services, need correct country rule updates, indicatesEmergency phone numbers, change our reservation on the go,makes an application that can give the guidelines with voice recognition, quick response, Correct descriptions about hotels,restaurant, newly updated news, Vehicle rent locations, and prices and instructions of theirs. When these requested featuresare added can get superb software applications because thatresponse people have experience using other countries' software applications.

M. Ideas of app developers

Despite several challenges and small size, the software and telecom sectors of Sri Lanka's ICT economy are flourishing. Nonetheless, the business is confronted with a number of important issues. They include a lack of openness in government acquisitions, a lack of reasonably priced international bandwidth, a dearth of qualified modern technology experts and a management- classknowledgeable about modern technology, and a tax framework that does not promote local sales. In general, the usage of modern technology in the tourist sector is sporadic. Some financial institutions have made significant investments in modern technology, and as a result, they are technological leaders in their respective countries. Other industries lag far behind, and their usage of modern technology is patchy at best. Even organizations that have invested in modern technology frequently do so in limited ways that are inadequately integrated into their operations. The same may be said about Internet use. Part of this is due to the tiny fraction of Sri Lankans who have access to the Internet, but the primary cause is, without a doubt, a lack of managerial understanding about the modern technology capabilities in their company sector.

In addition to this, Sri Lanka lags behind the rest of the world due to the fact that there are still those who do not have much experience in the tourism industry. It can be seen that the features of the existing apps in Sri Lanka need to be further improved by comparing them with the apps in other countries. Add new features, make them easy to use and bring booking, planning, and paying all sides on one platform. For that, you can use modern technology.

V. Requirement analysis

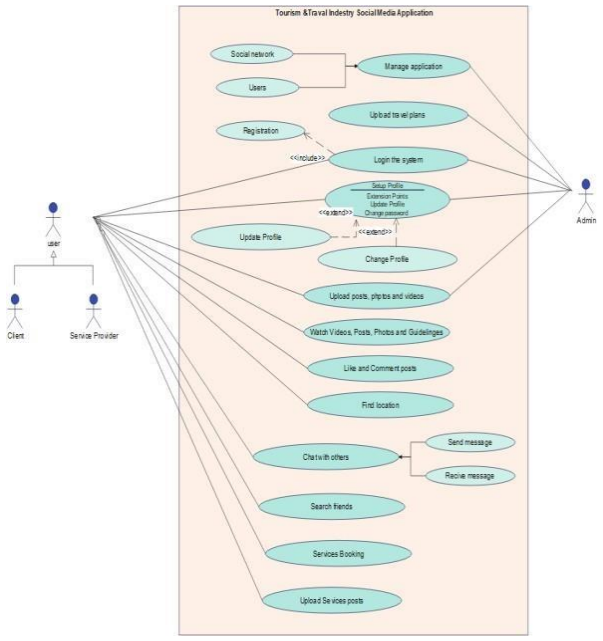
There are two main user types in this system. This proposed system may be accessed by mainly theadministrator and user. Secondary users divide into two subcategories such as client and service provider. Furthermore, each user has a unique username and password provided by the system when they register. There are major functional requirements listed below. Admin should be able to,

- Perform CRUD operations in the system.
- Manage accounts

- View the number of accounts and related details.

The user should be able to,

- Upload posts, pictures, and videos.
- Like and comment on a post.
- Share servicers.
- Watch videos related to travel places.
- Chat with others.
- Read guidelines and contact the travel guide.
- Services booking.
- Select tour plans.
- Account management.
- Search for places using the map.



VI. Design approach

The modern social media platform in the travel and tourism industry in Sri Lanka mainly consists of eight main modules. Interactive mobile prototypes were created for each module for efficient tasks of implementation.

A. Registration and login module

Users should register for this system by themselves by entering their username and password as preferred. Those usernames andpasswords are used to log into the system. If required users can change their passwords after login into their account. The login function should be used to access the system used to log into thesystem. Users should already be with their usernames and passwords.

Figure12-Mobile Prototype for Login and Registration Module

B. Administrator module

The administrator also has to log in and register and the further administrator has the authority to access all the account details, upload image details, and travel plan details. Admin can access the system by adding, editing, and deleting some uploads.

C. Post-uploading module

Post-uploading is one of the main functions of a social media platform. Clients can upload their feedback, experience or recommended posts, adventure videos, and posts. Post ID is auto generated when uploading a post. Clients also can write small descriptions of posts. Mainly users can capture images of trips using a camera during the travel and others can like and comment on these posts. Those pictures and posts can be uploaded with descriptions to share a live experience of the trip. When reading descriptions and comments the implementercan understand what type of travel plans need to be further.

Figure12-Mobile Prototype for Post uploading and Map Module

D. Services uploading module

Service uploading is one of the main functions of a social media platform. Service providers can upload an advertisement to display their services. The service providers can upload their service detail advertisement posts. Post ID is auto-generated when uploading a post. Mainly service providers can upload details including created posts and others can like and comment on these posts. A small description also can write above posts. Those pictures and posts can be uploaded with descriptions to

share a live experience of the service providers.

E. Guideline module

The administrator should upload guideline details PDFs to the system related Sri Lanka travel and tourism industry. Clients and service providers both of users can go through the relevant guideline category, and they can find guides who can advise more details about Sri Lankan guidelines.

F. Travel plan module

The main function given by the application is the client can add their tour details to the system on their own and after submitting system expresses some travel plans related to the client's details. After the client can choose a travel plan and the like. The travel plans are uploaded by the administrator. Administrators have created a set of imaging travel plans. The administrator that plans build by their search details google websites review and based on administrator experiences. The client who selects a travel plan will be can search places using the google map feature.

G. Image and Videos gallery module

The administrator should upload travel places-related images and videos to the system and users can watch that and can get some idea of Sri Lankan travel places. Clients can get ideas about travel places before traveling.

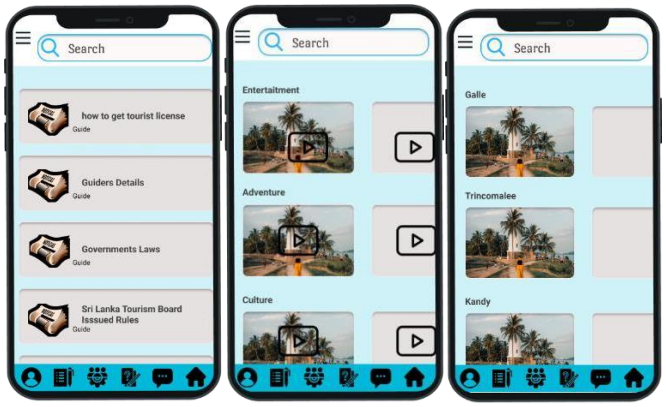


Figure12-Mobile Prototype for gallery and guideline Module

H. Chat module

Clients and service providers can chat and share details andget some knowledge about Sri Lanka travel places, and service providers' guideline details using one platform.

VII. Implementation

This furniture application is deployed in 3 states as explained below.

A. Travel Plan Collection

The developer should collect the most popular travel plans for related travel and tourism industries in Sri Lanka. For the creation of the travel plans developer used the using websites.

B. User Interface Creation

The main pages of the traveling application are the Login page, registration page, home page, gallery page, services page, and payment details page. The main pages of the social media application are the post-reading and upload page and chat page. All the UI should be simply designed and developed according to the basic requirements of the clients. The process of this application is somewhat new for all Sri Lankans. Therefore, for easy acknowledgment of all the people, the developer used many techniques in developing UIs by showing the process of the application.

C. Insertion of products into the categories and backend

After an assortment of industry knowledge, an interfacewas created to change the process of uploading the info to the base database. Furthermore, the user can upload posts, view uploaded posts, and like and comment on posts. Administrator, whose credentials are often created on the server aspect of the base, the administrator is ready to log in through a separate login page and then the user login page. Upon thriving authentication and login, the administrator is ready to feature the merchandise information to the information through the add gallery and information document pages.

VIII. Results and evaluation

For the evaluation of the accuracy of the system, theresearcher has tested the posts, images, and videos in real-time preview by keeping the mobile phone in every environment. Users can upload posts using gallery imagesor using the camera in a mini-second.

The researcher has done the evaluation process indifferent ways. The researcher has compared the developed system with a set of related real-world scenarios' functional and non-functional requirements. The researcher has shared the above-implemented system with the foreign travelers which were used to gather the requirements in the requirement analysis process. The complete system evaluation results are mentioned below. Here the system has been given to a set of Sri Lankan service providers and foreign travelers who are engaging in travel using the applications. Here the sample population was eight travel agencies.

Note: the mean score is calculated from respondents' feedback on the Five-scale questionnaire: 1 (Strongly Disagree), 2, 3, 4, and 5 (Strongly Agree).

The functionality of the system	**Mean Score**
Customer account management	4.6
Admin account management	4.7
Service provider advertisement management	4.5
Post Upload management	4.8
Gallery and guideline category management	4.8
Chat management	4.6

Travel plan management	4.8
Analysis management	4.2
Service booking management	4.1

Table 2-System Evaluation Result

IX. Conclusion and further work

The study researched tourists' perceptions and satisfaction with Sri Lanka's tourism and travel sector software application. Age, country, support rate of software programs, features more likely to be needed in the future, tourist attractions, price levels, and used platforms for travel and experiences were all used to gauge how tourists felt about their trip. As tourists, they are very much fond of new technologies, therefore, interactive mobile technologies and the internet are carving new faces in customer services for the tourism and travel industry. Through a mobile, tourists can be guided through cultural heritage through multi-language voice, text, or images. Further, this research paper confirms all age ranges of tourists are interested in travelling to Sri Lanka and most guests have better experiences in Sri Lanka travel. Have many platforms to get helped during the travel, and mostly used mobile and web applications names are discussed. Guests are not satisfied with current app features and additional features need to be added to existing systems. Those features that should be taken as improvements were also identified through a survey. Additionally, app developers also share their ideas that existing systems have problems and that may have to be further developed. Accordingly, the features and shortcomings in the software applications in the tourism and travel industry have contributed to a decrease in satisfaction. Then researcher implements the modern social media platform for the tourism and travel industry in Sri Lanka. As the mobile phone is an essential device for people these days, social media platforms are the most popular application these days. For further work, researchers would recommend improving this social media application with many more options. Further, this system can be improved by using this application in many languages.

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Bin- Eazy: The Tracking-Based Solid Waste Collection System

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ABSTRACT The majority of developing countries, including Sri Lanka, are still struggling to manage solid waste, resulting in a slew of social, environmental, and health issues. In Sri Lanka, as in the majority of other nations, the responsibility for waste management is delegated to Local Authorities (LAs). With rising solid waste quantities, Sri Lanka is now struggling to manage trash. This research, aims to develop an automated solid waste management collection mobile application named as "Bin-Eazy" and a web application to address the above situation in Sri Lanka. These applications facilitate both the municipal council and the citizens to avoid the problems that arise during waste collection. The methodology for the improvement of the waste collection and transportation system was devised based on Google Map API. This system includes a mobile application to organize garbage in various locations. We can communicate directly with the municipal council and provide information on the location of the garbage bins or dump with this mobile application. Python, Image Processing, Flutter, SQLite, and React are technologies that were used in this project. Image processing is the technical analysis of images using complex algorithms. The municipality uses image processing to check whether the citizens have correctly classified the garbage. This system mainly focuses on household solid waste. In a country like Sri Lanka, both residents and municipal councils may save time and money by using this mobile application to collect solid waste. Those are the expected primary goal of this paper.

KEYWORDS: Image Processing, Location tracking, Solid waste disposal

I. Introduction

In today's world, waste collection has become a serious issue. Garbage has become one of the primary problems in a country like Sri Lanka as the population grows.

Municipal Councils		Population (2001)	Daily waste generation (Tons)
1	Colombo	642,163	675
2	Dehiwala	209,787	272
3	Moratuwa	177,190	150
4	Kotte	115,826	125
5	Negombo	121,933	110
6	Galle	90,934	50
7	Gampaha	9,438	20
8	Kandy	110,049	80
9	Matale	36,352	26
10	NuwaraEliya	25,049	20
11	Badulla	40,920	20
12	Jaffna	78,781	NA
13	Rathnapura	46,309	30
14	Kalmunei	105,000	50
15	Kurunegala	38,337	38
16	Kaduwela	270,000	35
17	Dambulla	66,727	67
18	Batticaloa	88,459	60
19	Anuradapura	81,522	37

Figure 1. Municipal waste generation in Sri Lanka Source:

There are no suitable facilities for the disposal of waste produced by households and industries in a country like Sri Lanka. Furthermore, relevant authorities pay less attention to this situation. As a result, people are used to dump garbage alongside the roads. In countries like Sri Lanka, daily life can generate many kilograms of solid trash from homes, industries, businesses, and other locations. The lack of proper management has led to many problems. In Sri Lanka, this garbage collection is usually done under the control of the Municipal Council.

For residents living within the municipal area, garbage should be kept outside their premises on relevant day. But in this process, the municipal council, as well as the citizens, face various problems as Sri Lanka develops, more people are moving to cities for their benefit, due to the increase in garbage production. As a result of these factors, the garbage problem has become a major issue for the wider populace. Various waste collection and management methods can be found all over the world. However, no proper computer based waste collection system has yet been built in Sri Lanka.

A. Objectives

This project aimed to develop an automated solid waste Collection & Management System as a solution to the disposal of garbage in Sri Lanka. This system will create a web application and a mobile application. We named our mobile application "Bin -Easy". It supports both Sinhala & English languages.

The following objectives have been identified with the aim of growing an Automated Solid Waste Collection and Management System.

- To conduct a critical examination of Sri Lanka's current garbage collecting difficulties.
- To analyze the current computer-based systems critically and to suggest an effective waste collection solution.
- To make a project prototype of the system.
- To determine the effectiveness of the new Automated Solid Waste Collection and Management System

B. Resource Requirements

- The development of the mobile application is assured by its compatibility with all other mobile devices running Android, iOS, and Windows.
- The database will be implemented by using DB forge studio for SQLite.
- The web server will be created such that it works with all Windows 7, Windows 8.1, and Windows 10 computers.
- Android Studio and Dart will be used to implement the mobile application.
- The Django framework and the Python programming language will be used to create the administrative interface.

II. Literature review

The amount of waste produced increases as the population grows. The more people a city has, the more complicated its activities and companies become. Industrial, biological, and domestic garbage are all dealt with via waste management. Waste can, in some situations, be harmful to human health. Waste management is also carried out for the purpose of gaining advantages, particularly for people. Based on the belief that rubbish is a resource that may be utilized and even has financial value [7].

A healthy and happy community requires a healthy environment. The process has been prone to human mistakes and neglect with the age-old system of hiring employees to periodically check and clear overflowing dustbins. Furthermore, due to the varying rates of trashcan usage in different places, routine checks based on time services are wasteful because a dustbin may fill early and require rapid attention, or there may be no need for a routine check for a long time. As a result, the current system becomes more of a problem than a solution, as overflowing, smelly trash cans become an issue rather than a solution [4].

A. Existing systems

According to the research done by R. Zade et.al, [8] they had this study introduces a novel system that will aid in keeping cities clean. This system monitors the garbage bins and notifies users via a web page of the amount of waste collected in the bins, as well as alerts users via a buzzer and LEDs. The ultrasonic sensors (HC-SR04) in the system are utilized to detect the rubbish level over the bins. The depth of the waste bins is then compared. The system's hardware architecture includes an Arduino module, an LCD, a sensor, and a buzzer. On the LCD panel, the level of rubbish collected in the bins is indicated. The system is remotely monitored via a web page created in LabVIEW using the VISA tool. When the amount of garbage collected exceeds the stated limit, the buzzer indicator goes off. As a result, by informing the public about the rubbish levels in the bins, this system contributes to keeping the city clean.

It handles with a real time trash bin observing scheme by using various identifying equipment and new technologies to the research paper "GARBAGE MONITORING AND CLEARANCE USING ROBOTS" [3] studied garbage disposal that isn't done properly pollutes the atmosphere, endangering living organisms. Recent technological advancements are proving to be more beneficial to humans, and their recommended approach for waste collection is excellent. An ultrasonic sensor attached to the bin lid shares the garbage level as data with the robot, which tracks the bin using the line follower technique and recognizes the filled bin using RFID scanning, then disposes rubbish from that bin. When an Ultrasonic sensor provides data to the Arduino board, the garbage monitoring and clearance robots begin their work. The exposed ultrasonic sensor is a form of audio sensor that can be categorized as the transmitter, transceiver, or receiver. Ultrasonic sensors have transmitters those turn signals into ultrasound, and receivers that translate ultrasound into signals. The period between delivering an ultrasonic pulse and receiving an echo will be taken as the distance. The sensor sends out a wave, which is reflected by the obstructions. It detects the amount of rubbish and sends the data to the Arduino Uno.

This paper describes [6] the concept of a GSM-based garbage monitoring system. People are disposing of their junk in the trash container. At the top of the garbage can, they are installing ultrasonic sensors. Currently, the ultrasonic sensor can detect the level of garbage. If the amount of rubbish produced continues to rise, it will soon hit the limit. As soon as the threshold value is met, an automatic alarm will be sent to the registered range via the GSM module, informing them that the trash value has reached a distance of around 5cm from the ultrasonic sensor. The garbage cans are emptied, and the data is forwarded to the appropriate authority for processing. For real-time information, they used GSM. It is the most important component of the communication system because of its low cost, high performance, and ease of implementation. Even if the threshold value crosses the range, the LED will illuminate if somebody tries to dump their trash in the garbage can. This strategy reduces the amount of time, fuel, and money used. In the future, this technology will be beneficial to a large number of rural areas.

According to the research paper, "Smart Garbage System with Garbage Separation Using Object Detection" [10] garbage collection is one of the most pressing concerns that the globe faces, regardless of whether a country is developed or developing. The traditional method of manually monitoring and clearing rubbish in bins is inefficient. As a solution to these issues, the smart bin is developed utilizing IoT. The bins have a Raspberry Pi fitted with an ultrasonic sensor for garbage level

detection and a pi camera that uses the YOLO algorithm to segregate rubbish by object detection and opens the appropriate bin lid using a servo motor. The intelligent bin is linked to mobile applications through the cloud for garbage monitoring and disposal, which is accomplished through optimum routing.

In 2020, "Deep Learning-Based Smart Garbage Monitoring System" [9] an IoT-based, automated smart bin monitoring system is proposed in this research. Furthermore, based on the data acquired, a deep learning model was utilized to anticipate future garbage levels. With an accuracy of 80.33%, the suggested neural network model was able to forecast garbage levels. The findings support the accuracy of the rubbish level forecast. Bar charts were also used to assess the data. The combination of IoT and deep learning can result in a technological revolution that can be used for trash management. As a result, forecasting and examining garbage levels may assist municipal authorities in implementing an efficient garbage management system and reducing garbage bin overflow.

B. Related works in Sri Lanka

Over the past 20 years or so, or thereabouts, government entities have been working to identify the ideal waste management strategy in the country. Although certain tactics and initiatives promoted clean landfills, other actions were focused on energy programs against waste. With the goal of "Squander Free Sri Lanka by 2018," CEA launched the "Pilisaru Project," a 10-year waste management framework, in 2008. Unfortunately, the lack of a sensible, long-lasting approach has increased the amount of opaque and pointless processes [1].

The distance between waste producers and recyclers should be closed by igniting more variety of communities and making the cycle more readily available. Plastic, polyethylene, metal, and glass recycling activities should be stimulated and funded at diverse scales. Waste is a resource; hence efficient waste management practices should be implemented. The industry should be set up as a business that generates revenue rather than one that offers no incentives to the corporation [5].

III. Methodology

A. Data collection

Sri Lanka, being a developing country, is currently experiencing fast population growth, infrastructure development, and urbanization. The first step in data collection to create this system was to identify the objectives through a literature review. To identify the existing problems, interviews were held with the municipal employees and citizens who are the primary users, and information was obtained. A comprehensive experimental case study was carried out with Moratuwa municipal council to obtain information. 40 truck drivers and garbage collectors belonging to the municipality were selected as the sample. And 50 citizens belonging to different age groups were randomly interviewed in some selected cities. According to the data obtained, the percentage of citizens who are not satisfied with the existing waste collection system is 68.2%. About 9% of the respondents are satisfied with the current system.

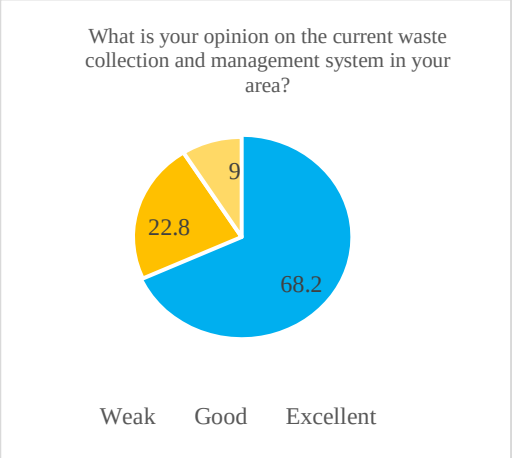
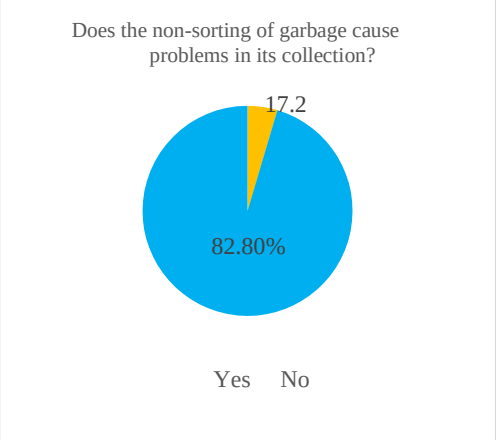


Figure 2. Pie chart I of Questionnaire Survey Results

Percentage of 61.8% of the truck drivers said that problems arise due to the non-sorting of garbage.

Figure 3. Pie chart II of Questionnaire Survey Results



According to the information obtained from the Moratuwa Municipal Council, the garbage of about 700 houses should be collected by one truck per day, which is seemingly impossible due to extra effort and time. The primary purpose of this data collection was to obtain the data needed to create these proposed systems through problem identification and analysis. Key issues identified through this data collection are outlined below. Problems faced by citizens,

- The resident is unable to dispose of garbage on the scheduled day; he will have to wait until the next day.
- In some areas, the interval between dates maybe four or three days. If it is decaying debris like disposable foods, it will decompose while, breeding

worms and rodents around it, causing odors and polluting the environment.

- The public can have a lot of problems in disposing of non-biodegradable waste and they are many problems with waste sorting as well as recycling.

A problem faced by Truck drivers,

- The main problem here is that even though they have been given the proper roads, they have to park the truck near every road and every house to see if there is any garbage. This consumes their time as well as labor.
- Householders do not properly sort garbage and face problems in garbage collection.
- Similarly, worms and rodents can breed in decaying materials such as disposable foods, which have been deteriorating for days, and they may be exposed to various diseases while collecting garbage.

B. Technology Adopted

Using acceptable tools is essential to developing a defect-minimized productive system. Failure to do so may result in the development of a system with unnecessary bugs and errors using inappropriate tools. Therefore, it is essential to choose the right tools while creating a system so that a superior product can be developed. However, these technologies could lead to the creation of a system that requires a lot of time and resources to complete a task that the system had expected. The usage of application programming languages and the other required tools is crucial for the development of a successful system. As a result, these technologies and tools can contribute to the system's development in the least amount of time. Instead of using a manual approach, this type of application seeks to provide users with a more effective work system. This research purpose is to develop an automated solid waste management collection "Bin-Eazy" mobile application and web application. This mobile application has two types of users: citizens and municipal council Truck drivers. This mobile application supports the following technologies:

1) Google Map API:

Google provides technology and an application called Google Maps for its online mapping platform. The Google Maps API enables you to produce customized maps that can be used in cutting-edge Google Maps-based apps. In all Maps API applications, the maps are loaded using an API key. The API key is free, but Google will monitor your application's use of the Maps API and, if it reaches the use cap, require you to purchase more capacity. (Smita S, *et al*, 2019) Here, Google Maps is mainly used to help truck drivers find the optimal route to collect waste. Truck drivers are shown only the request to collect garbage bins and garbage dump through Google Maps, so they can reach them using the best shortest path in a very short time. Fuel, money, and time can be saved by these methods. The second major step here is that citizens can also use Google Maps to find the garbage truck.

2) Flutter:

Although highly unique, Flutter is also maybe a viable platform that has already gained the interest of major firms that have already published their apps. However, since Flutter implements components, there is no layer of interfacing between the view and the code. Because of this, the graphics engine of Flutter is used to draw buttons, text, media elements, and context. Flutter is used to create The Mobile application front development.

This web application has one user: The municipal council administrator. This web application supports the following technologies:

1) Image Processing:

The technical analysis of images using sophisticated algorithms is known as image processing. Image enhancement, pattern detection, and effective picture coding are three major areas where image processing techniques are used. The mathematical operations that one is likely to run into and how to execute them using optics and digital computers, as well as image description and image quality assessment, are some of the areas of image processing that are covered. The system checks whether the photos uploaded to the system by the citizens through the mobile application have been correctly classified using an algorithm trained by image processing

IV. Experimental design

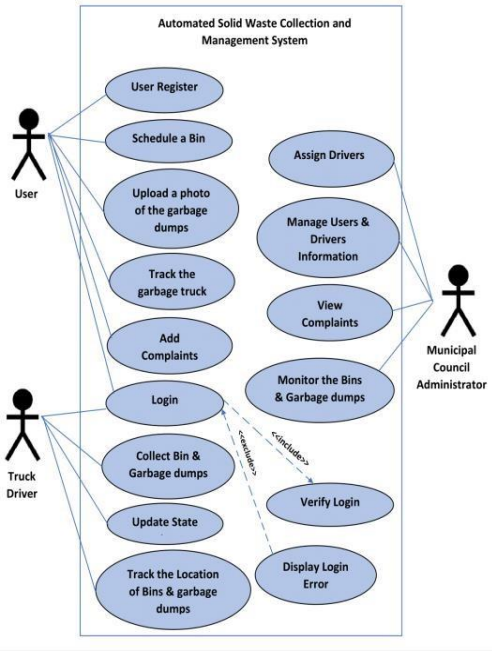


Figure 4. A use case diagram for experimental system design

A. Mobile application

Mobile application users the truck drivers and citizens. In the waste collection system process first, the citizens and truck drivers (users) should create a profile. Next, they should log in to the mobile application by providing the username and phone

number to the system. Citizens and truck drivers have a separate interface after the authentication process. This mobile application is provided in both Sinhala and English languages.

Figure 5. User register interface

Figure 6. User login interface

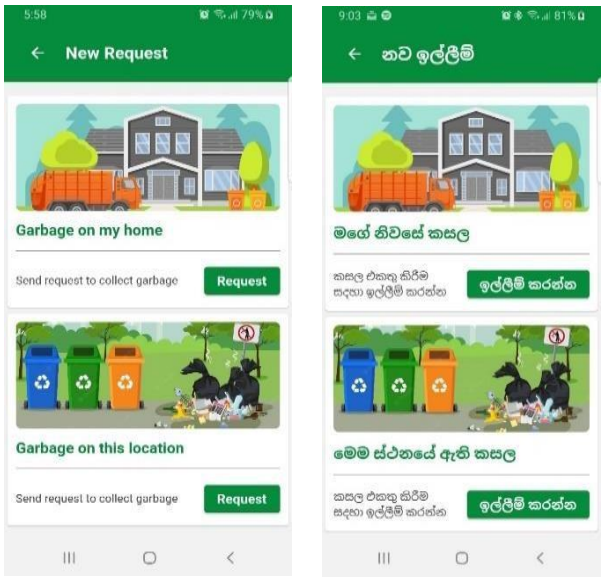


Figure 7. Request interface for citizens (English & Sinhala)

As in figure 7 above users can then use the mobile application to request that their trash be picked up. And also, as in figure 9 citizens should take photos of the requested garbage dumps and upload them to the system to see if they have correctly sorted the bins. After they get the approval of the request then they can track the garbage truck location.

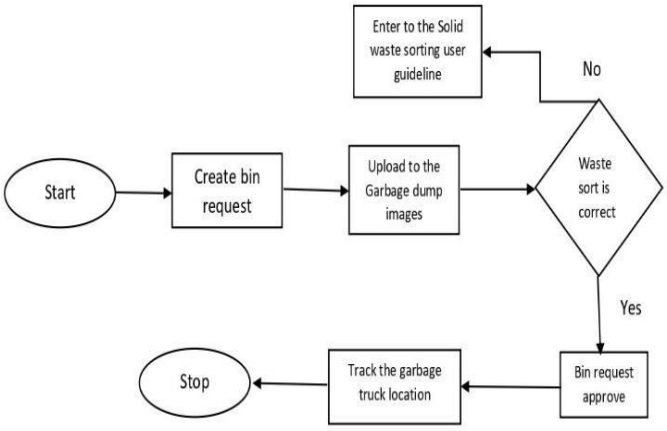


Figure 8. Process flow diagram for citizens bin request process

Figure 9. Request the Garbage bin Interface and show the identified garbage type using Image Processing

Truck drivers are shown only the request to collect garbage bins and garbage dump and their locations through Google Maps through the mobile application. After tracking the bins' locations, they will be shown the shortest route through google Maps. Garbage collectors should report bins' status to the system after collecting them.

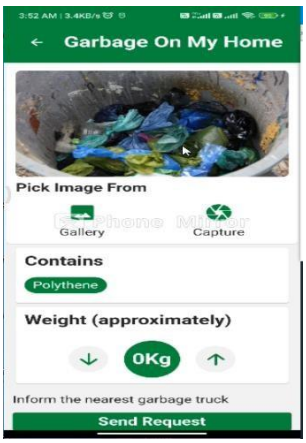


Figure 10. Garbage truck location interface for citizens

B. Web application

Only the municipal council administrator can be accessed using the web application. The details from the mobile application will be presented on the municipal council's web server after they have been extracted. The mobile application will then track the coordinates (longitude and latitude) of the user's location (where the garbage dump is located). The information, including the user's identity, mobile phone number, date and time, and coordinates of the tracked waste dump, is then sent to the municipal council's web server. Using image processing, the image uploaded by the users is checked to whether it is correctly sorted under the given instructions and then their request is approved. According to the coordinates received by the mobile application, the location of the waste will be displayed on a map. The appointed employees will then be dispatched to that specific location to collect the waste. Then through the system municipal council administrators can track their location and assign a driver collect to the waste the web application will send a notification to the user whether the information sends successfully or not. Each information that users send will store in the SQLite server database successfully and for work with the application.

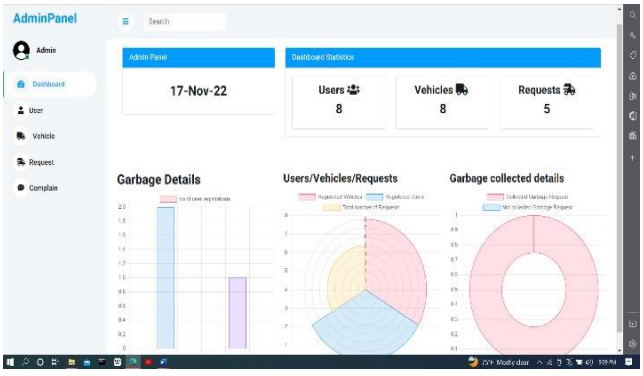


Figure 11. Municipal Council Admin Dashboard

V. Discussion and conclusion

Based on logical presumptions, the results and consequences produced concerning the problem domain's specificity are expanded into broader notions. This chapter attempts to highlight the project's outcomes and findings and to identify how they might be matched in other situations that share issues with those that the developed solid waste collecting and tracking system addresses. To obtain a comprehensive waste collection system to meet efficiency and optimization, this test work requires that the proposed system only knows the exact location of the waste and collects them. When citizens request through the mobile app to pick up their garbage, the system administrator in the municipality directs the relevant truck drivers to those locations and collects the garbage. Similarly, by using modern tools i.e., using image processing, the classification of them into biodegradable and non-biodegradable materials is done through this system. Then it becomes easier for the garbage collectors. Our project's primary goal is to make it possible for city infrastructure put there to communicate with its operators and administrators in both directions. Our objective is to realize a centralized system for real-time monitoring. With this approach, the municipal government and the general public both gain from an efficient system that reduces urban pollution and results in significant cost savings. The research outcome can be stated as follows. Saving time for the Municipal council's laborers and administrators who work on solid waste disposal.

- Reduce the time consumption of the collection of household solid waste.
- Reduce human errors.
- Make the workload of the municipal council more efficient.
- Reduce the workload of municipal truck drivers.
- Increase the efficiency of service in Municipal councils.
- Improve the solid waste management program in Sri Lanka

VI. Future work

There isn't a system in place with a mobile application to address the current problems that have been affecting the waste collection process on the overall traditional waste collection strategy, especially in Sri Lanka, eventhough there are numerous different waste management and waste collection systematic approaches. As well as waste management and related research have already been done in many projects. Therefore, this proposed tracking-based solid waste collection system is presented. With more effective usage of the app and improvement of additional crucial hardware components for future development, the Google map API advanced feature activation can be included as a further improvement. The information on the efficiency of a systematic solution may have been gathered to conclude this research study area by reviewing related works and existing systems, and its evaluation summary provided the points to be taken into account in creating such a real-world application in the future with the digital era and to survive with challenges like pandemic situations and the current new normal.

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