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DEVELOPMENT OF QUEUE MANAGEMENT MODEL FOR EFFECTIVE SERVICE DELIVERY IN AUTOMOBILE REPAIR SHOPS

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Abstract

In this study, a queue management model/software was developed for automobile repair shops. This software minimizes both waiting time of customers, and idle time of workers. The software groups all jobs done in an automobile repair shop into three sections: mechanical, electrical and air conditioning (A/C) sections. The developed software prioritizes all jobs performed in a typical automobile repair shop in terms of urgency, using the 'shortest processing time' scheduling approach. The jobs are then ranked and assigned to workers based on number of available workstations. Also, expected time of delivery of the job is estimated by the software. The software was tested using data obtained over a two weeks period and percentage reduction in waiting time was found to range between: 0.889-0.122, 0.895-0.25 and 1-0.167 for the mechanical, electrical and A/C sections respectively. In the mechanical section, servicing/replacement of piston and rings and changing/servicing of gear box were discovered to be the jobs with maximum delivery time (15 hrs) while changing of engine belt was seen as the job with the least delivery time (0.3 hrs). For the electrical section, changing of alternator, with delivery time of 3 hrs 30 mins and changing of headlamp and fuse breakage with delivery time of 0.15 hrs are the jobs with maximum and minimum delivery times respectively. For the A/C section, changing of freezer with delivery time of 10 hrs and refilling of gas with delivery time of 0.10 hrs are the maximum and minimum respectively. Implementation of this research will reduce time wastage experienced by customers, idle time at service facilities, frustration caused by unnecessary queue, and encourage allocation of resources accordingly.

1.0 INTRODUCTION

Waiting on queue is an inevitable part of everyday life. Queues are found everywhere; in the market places, on the road, at bus/train stations, in the hospitals, in schools, in the bank etc. Statistics have it that the average person will spend six (6) months of their life waiting in queue [1-5]. Waiting in queue can be exasperating, and to achieve excellent customer satisfaction, queue management has become a priority [6,7]. Optimising the service while reducing the time of the service is an integral part for production [8-13]. The queueing theory helps in understanding the waiting lengths and times, and correlates them with the performance and customer satisfaction [14-20].

Queue management organizes jobs and reduces waiting times, keeping customers engaged and moving through the process, as well as increases the efficiency of the organisation [21,22]. Auto car service is one of the emerging industries in the

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business world, the key factor pertaining to every service-based industry is to provide the best and quality service within the shortest possible time [23-27]. Making a stronger relationship with customers, delivering a high level of service and support, eventually improving the organizational sales and its goodwill are the ultimate aim of such a system [28-30].

The number of cars on our roads are constantly increasing. Consequently, more cars visit mechanic shops frequently. This situation leads to queue at mechanic shops, especially as the number of workshops are not increasing at the same rate. If not managed properly, customers may become impatient and go to competitor's shop. An important factor that needs to be considered when an automobile workshop is already attracting customers is the queuing time [31-33]. The average time in the system, the expected queue length, the expected number of customers served at one time, the expected waiting time in the queue, the probability of balking customers as well as the probability of the system to be in certain states such as full or empty are some of the analyses that can be derived using queuing theory. Waiting lines are common sights in workshops. Hence, queuing theory can be applied in a workshop setting since customers that cannot be served immediately have to queue for service [34].

This work used queuing theory to study the waiting lines at Udo Motors Ltd in Umuahia Abia state, Nigeria and developed a model for queue management.

1.1 Objectives of Study

The main objective of this work is to develop a queue management model for effective customer care service delivery in automobile repair shops.
Specific objectives include:

i. To increase the efficiency of service providers, and improve customer satisfaction through reducing customer waiting time as well as workers idle time
ii. To prioritize all jobs/services performed in a typical automobile repair shop in terms of urgency, using the "shortest processing time" scheduling approach.
iii. To develop a software capable of ranking jobs, assigning jobs to workers, and also estimating the expected time of the delivery of the job.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used in the development, validation and testing of the software are as follows:

i. Questionnaire
ii. Excel spreadsheet
iii. JavaScript programming language
iv. Json server
v. Data generated from Udo Motors Ltd.

2.2 Procedure for Model Development

2.2.1 Model development concept and assumptions

The development of the model/software for assigning jobs to the different sections (mechanical, electrical and air conditioning) in an automobile servicing and repair workshop were based on the following concepts and assumptions:

i. Each section has specified work stations.
ii. One work station specifically handles heavy/long jobs (to avoid lag of long jobs in the system), but can also handle short jobs in the absence of long ones.
iii. No work station should be idle at any given time, provided there is a job to be carried out; therefore, a long job can be assigned to short job station in the absence of short jobs.
iv. A work station should always finish a job before taking on another job.
v. The jobs in the queue should always be shuffled, and arranged in order of priorities (the shortest job should be ranked first, and the longest ranked last).
vi. The software should analyze the job, assign the jobs, and give a range of time, within which the job should be ready (e.g.: your car will be ready in 30mins to 1hour time).
vii. The software should be able to tell the scheduler the work station that are busy and are free for easy assigning of jobs.
viii. Once a work station is through with a job, it should indicate for another job to be assigned to them.
ix. During breaks, the work stations should show busy, so that works will not be assigned to them during the break period.
x. Work must end at exactly closing hours, and unfinished work paused to be continued and completed the next working day.
xi. Work should also be able to be paused on the software. This is also applicable to break time.

2.2.2 Data collection method

Two sets of data were collected. Firstly, for the estimated time for jobs in each section; different types of jobs, time in of the vehicle, time when service begun, and finish time were recorded for a period of time between 8am to 6pm every day for two weeks. The estimated time for each job was found by subtracting the finish time of a job from the time when service begun. The average time a vehicle spends in the mechanical, electrical and air conditioning sections respectively based on data collected for two weeks are shown in Tables 1-3.

Table 1: Data for average time a vehicle spends in the mechanical section

Day	Sum Total service time	Average Total Service time	Sum Total waiting time	Average Total waiting time	Sum Total time in system	Average total time in system
1	41h 24m	3h 45m	2h 17m	12m	43h 41m	3h 58m
2	34h 19m	3h 07m	1h 54m	10m	36h 13m	3h 17m
3	51h 37	4h 41m	1h 18m	7m	52h 55m	4h 48m
4	44h 56m	4h 29m	1h 12m	7m	46h 08m	4h 36m
5	41h 35m	4h 09m	2h 06m	12m	43h 41m	4h 22m
6	42h 18m	3h 31m	2h 31m	12m	44h 49m	3h 44m
7	43h 46m	4h 22m	1h 47m	10m	45h33m	4h 33m
8	28h 13m	2h 49m	1h 35m	9m	29h 48m	2h 58m
9	28h 11m	2h 49m	1h 43m	10m	29h 54m	2h 59m
10	27h 38m	2h 30m	1h 46m	9m	29h 24m	2h 40m
11	35h 55m	3h 35m	1h 49m	10m	37h 44m	3h 46m
12	28h 20m	2h 34m	1h 41m	9m	30h 01m	2h 43m

Table 2: Data for average time a vehicle spends in the electrical section

Day	Sum Total service time	Average Total Service time	Sum Total waiting time	Average Total waiting time	Sum Total time in system	Average total time in system
1	10h 28m	1h 18m	1h 28m	11m	11h 56m	1h 29m
2	7h 04m	53m	1h 32m	11m	8h 36m	1h 04m
3	8h 29m	56m	1h 20m	8m	9h 49m	1h 05m
4	5h 47m	38m	38m	4m	6h 25m	42m
5	7h 36m	50m	32m	3m	8h 08m	54m
6	7h 34m	50m	35m	3m	8h 09m	54m
7	7h 40m	51m	44m	4m	8h 24h	56m
8	6h 26m	48m	33m	4m	6h 59m	52m
9	8h 29m	50m	39m	3m	9h 08m	54m
10	6h 43m	44m	42m	4m	7h 25m	49m
11	8h 07m	54m	59m	6m	9h 06m	1h 00m
12	7h 36m	57m	1h 06m	8m	8h 42m	1h 05m

Table 3: Data for average time a vehicle spends in the air conditioning section

Day	Sum Total service time	Average Total Service time	Sum Total waiting time	Average Total waiting time	Sum Total time in system	Average total time in system
1	5h 23m	1h 04m	20m	4m	5h 43m	1h 08m
2	17h 06m	2h 51m	23m	3m	17h 29m	2h 54m
3	9h 00m	1h 17m	17m	2m	9h 17m	1h 19m
4	13h 51m	2h 18m	15m	2m	14h 06m	2h 21m
5	3h 47m	37m	0	0	3h 47m	37m
6	6h 55m	59m	46m	6m	7h 41m	1h 05m
7	7h 54m	1h 19m	0	0	7h 54m	1h 19m
8	14h 59m	2h 59m	1h 30m	18m	16h 29m	3h 17m
9	6h 34m	1h 05m	20m	3m	6h 54m	1h 09m
10	5h 49m	58m	1h 31m	15m	7h 20m	1h 13m
11	7h 48m	1h 33m	0	0	7h 48m	1h 33m
12	8h 16m	1h 22m	21m	3m	8h 37m	1h 26m

In Tables 1-3, sum total service time refers to the total time required to complete all the jobs that come into the workshop in day. Average total service time is the average time required to service one vehicle in a day. Sum total waiting time is the total idle time vehicles spend before their servicing commences. Average total waiting time is the average time between when the vehicle enters the workshop and when servicing commences on the vehicle. Sum total time in the system is the time interval between when the first car enters the workshop in a day and when the last car leaves. Finally, average total time in system is the time interval between when a vehicle comes into the workshop and when it leaves the workshop.

The second data set was collected through a questionnaire to obtain the automobile maintenance service details, the number of active work stations in each section and a couple of other information.

2.2.3 Model development

Shortest job first (SJF), is a scheduling policy that selects the waiting job with the smallest completion time to carry out next. It is a non-pre-emptive algorithm.

i. It has the advantage of having a minimum average waiting time among all scheduling algorithms.
ii. It sorts all the jobs according to the arrival time.

iii. It then selects that job which has the least finishing time.
iv. Since it's a non-pre-emptive algorithm, when a new job arrives, the model creates a pool of jobs, then allows the current running job to finish its CPU burst, after which it selects among the pool a job having a minimum burst time.

A. Mathematical approach

Let $J_{1,} J_{2,} J_n$ be n-process, which are arranged according to how they arrived at the workshop. The queue is a temporal queue, (Q^T).

Also ST_i; $i = 1,2,3,..,n$, which are the estimated service time for job completion. Depending on the service time, genuine to each job, (J), the submitted jobs are arranged in a ready queue (pool), Q^R, which is maintained for all processes.

The n-jobs are arranged in ascending order, with respect to their service time (ST)

$$Q_n^R = (J_1), (J_2) \ldots .(J_n) \qquad (1)$$

i. Total turn around time:

Total turn-around time for job J_i can be calculated by summing up its total time genuine to the Q^R.

Turnaround time of $J_1 = ST_1$ (2)
Turnaround time of $J_2 = ST_1 + ST_2$ (3)
Turnaround time of $J_i = ST_1 + ST_2 + \ldots + ST_i$ (4)

$$J_i(TAT) = \sum_{w=1}^{i} ST_w - AT_i \qquad (5)$$

TAT= Turn Around Time

Average Turn Around Time of a job J_i can be calculated thus:

$$\text{Av. TAT} = \frac{\sum_{w=1}^{b} J_w(TAT)}{n} \qquad (6)$$

ii. Total waiting time:

Total waiting time for job J_i $\{J_i(TWT)\}$, can be calculated by summing up total time devoted to job $J_i \ in \ Q^R$.

Waiting time of $J_1 = 0$ (7)
Waiting time of $J_2 = ST_1$ (8)
Waiting time of $J_3 = ST_1 + ST_2$ (9)
Waiting time of $J_i = ST_{i-1} + ST_{i-2} + \ldots + ST_i$ (10)

$$J_i(TWT) = \sum_{w=1}^{i-1} ST_w - AT_i \qquad (11)$$

$$\text{Av. TWT} = \frac{\sum_{w=1}^{b} J_w(TWT)}{n} \qquad (12)$$

2.3 Software Development Procedure

Project lifecycle refers to the basic steps taken in software development, to ensure that a software is completed from start to finish without bugs. These stages that the software undergoes from start to finish is called project lifecycle. In this work, a modified software development cycle was used because of its numerous advantages which includes: increased flexibility, faster time to market, improved customer satisfaction, enhanced quality and a focus on continuous improvement. The modified software development cycle refers to an adapted or customized version of the traditional software development life cycle (SDLC) that incorporates changes or modifications to better suit specific project requirements or development methodologies. The specific modifications may vary depending on the organization, project or approach being followed. The steps in a modified software development cycle are sequential, systematically proceeding from: analysis to design, coding and unit test, integration and system test. The flow chart for the developed Algorithm is shown in Figure 1.

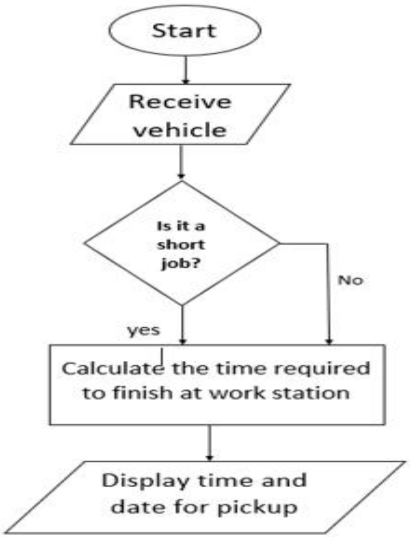

Figure 1: Flow chart for the development of the queue management software

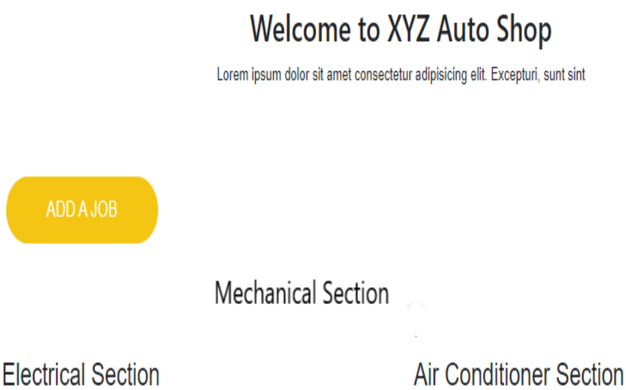

Figure 2: The Queue Management Software user interface

3.0 RESULTS AND DISCUSION

3.1 The Queue Management Software Interface

The software was designed to carry out the queue management process; it calculates the waiting time and turn around using the model generated, and displays the finished time (time of completion of job). The software also displays the car name, car model and job carried out, for easy identification. The name, phone number and e-mail of the customer is also supplied to the software, so as to communicate the customer when the job is successfully carried out and is ready to be picked up by the customer (owner of the vehicle). The software interface is shown in Figures 2 - 4.

Figure 3: Software interface showing details of job added

Figure 4: Software interface showing a completed job

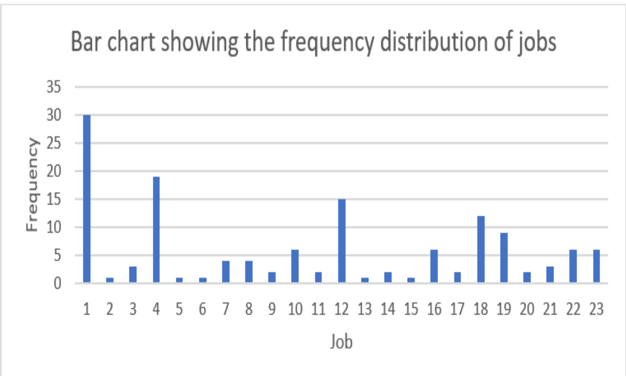

Figure 5: Frequency distribution of jobs within two weeks (mechanical section)

3.2 Classification of Jobs according to their Urgency Level

Results of the frequency of jobs and estimated processing time of the jobs carried out in the mechanical section are shown in Figure 5 and 6 respectively.

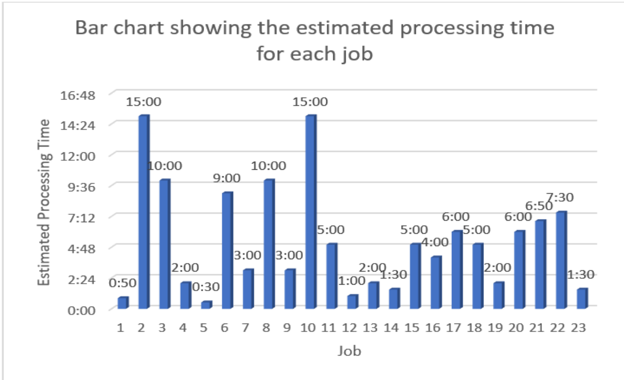

Figure 6: Estimated processing time for each job (mechanical section)

The list of jobs recorded, that were carried out within the two weeks of inspection were:
1. Changing of engine oil, 2. Servicing and replacement of piston and rings, 3. Changing of engine top/gasket, 4. Changing of spark plugs and servicing of nozzles, plug coils, 5. Changing of Engine Belt 6. Changing of oil seals, 7. Servicing of valve cover, 8. Changing of Engine, 9. Changing of radiator 10. Changing/servicing of gear box, 11. Servicing of bottom, 12. Change of brake pad, 13. Bleeding and refilling of brake fluid, 14. Servicing of brake shoe/ hand brake, 15. Servicing ABS 16. Changing of brake disc, 17. Changing of brake master and servo 18. Shock replacement, 19. Linkages and bushings replacement, 20. Transmission shaft maintenance /replacement, 21. Changing of suspension, 22. Changing of camber, ball joints, u-rubber, tyroid, 23. Changing of power steering/pump.

These jobs correspond to the jobs 1-23 on the bar charts. From Figure 6, we see that: jobs 2, 3, 6, 8, 10, have the highest estimated processing time (15 hours, 10 hours, 9 hours, 10 hours, 15 hours, respectively) and we can also see that, they have minimal occurrence, from Figure 5. These jobs are the “long jobs”, and have a dedicated work station for processing. These jobs are ranked as “less urgent” jobs.

Also, jobs, 11, 15, 16, 17, 18, 20, 21, 22, have a mid-estimated processing time (a range of 4 hours to 7 hours 30 mins), these jobs are ranked as “urgent jobs”

For the "very urgent" jobs, they have the least estimated processing time, these jobs are jobs, 1, 4, 5, 7, 9, 12, 13, 14, 19, 23.

Results of the frequency of jobs and estimated processing time of the jobs carried out in the electrical section are shown in Figures 7 and 8 respectively.

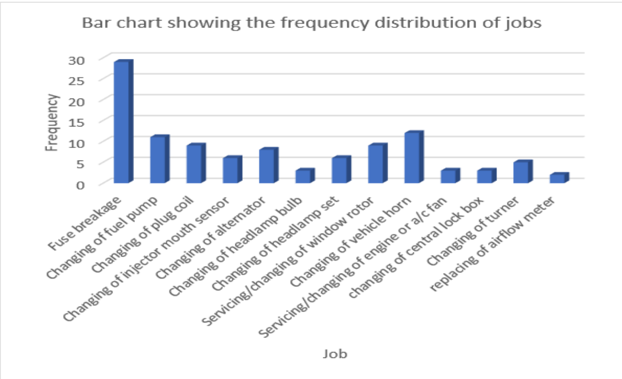

Figure 7: Frequency distribution of jobs within two weeks (electrical section)

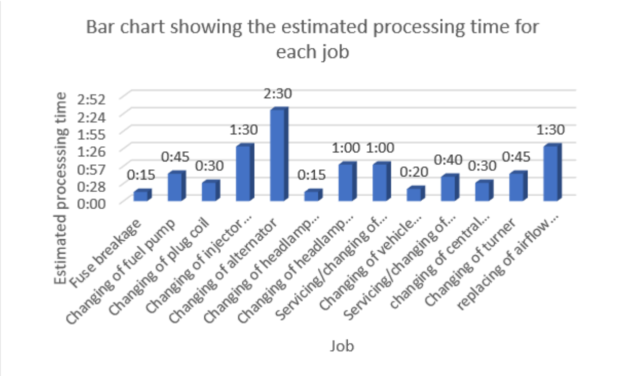

Figure 8: Estimated processing time for each job (electrical section)

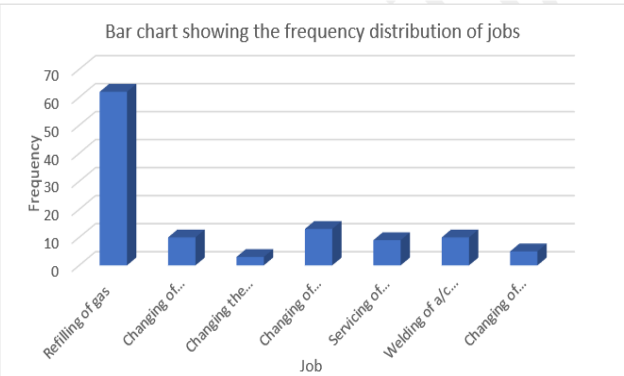

Figure 9: Frequency distribution of jobs within two weeks (A/C section)

From Figure 7, we see some jobs with high occurrence in the space of two weeks, and from Figure 8, we see jobs with estimated processing time of (2 hours 30 mins, 1 hour 30 mins, and 1 hour), these jobs are defined as long jobs and are dedicated to one work station. these jobs are ranked as "less urgent" jobs. Also, jobs with estimated processing time of 45 mins, 40 mins, 30 mins, are ranked as "urgent jobs". For the "very urgent" jobs, they have the least estimated processing time, these jobs have estimated times of 15 mins and 20 mins.

Results of the frequency of jobs and estimated processing time of the jobs carried out in the air conditioning (A/C) section are shown in Figures 9 and 10 respectively.

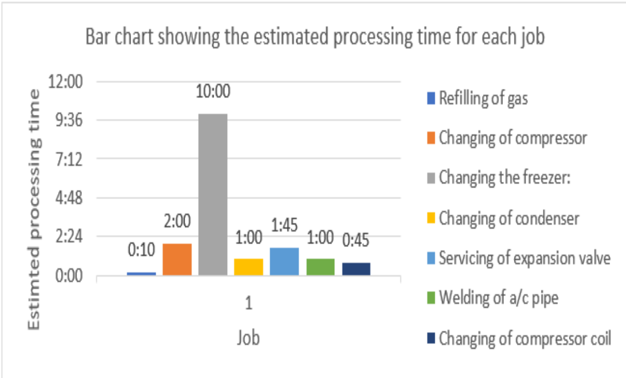

Figure 10: Estimated processing time for each job (A/C section)

From Figure 9, we see some jobs with high occurrence in the space of two weeks, and from Figure 10, we see jobs with estimated processing time of (10 hours), these jobs are defined as long jobs and are dedicated to one work station. these jobs are ranked as "less urgent" jobs. Also, jobs with estimated processing time of less than 2 hours are ranked as "urgent jobs". For the "very urgent" jobs, they have the least estimated processing time, these jobs have estimated times of 10 mins and 45 mins.

3.3 Determination of Percentage Reduction in Waiting Time

The data gotten from the automobile maintenance workshop was inputted into the software to determine percentage reduction in waiting time. The results are shown in Tables 4-6.

Table 4: Percentage reduction in waiting time for mechanical section

S/N	Waiting time (unmodelled)	Waiting time (modelled)	% Reduction in waiting time
1	2h 17m	35 m	0.744526
2	1h 54m	1hr 35 m	0.264516
3	1h 18m	29 m	0.628205
4	1h 12m	1hr 02 m	0.121951
5	2h 06m	14 m	0.888889
6	2h 31m	40 m	0.735099
7	1h 47m	49 m	0.542056
8	1h 35m	41 m	0.568421
9	1h 43m	38 m	0.631068

10	1h 46m	37 m	0.650943
11	1h 49m	44 m	0.59633
12	1h 41m	30 m	0.70297

Table 5: Percentage reduction in waiting time for Electrical section

S/N	Waiting time (unmodelled)	Waiting time (modelled)	% Reduction in waiting time
1	1h 28m	38 m	0.568182
2	1h 32m	49 m	0.467391
3	1h 20m	42 m	0.475
4	38m	04 m	0.894737
5	32m	13 m	0.59375
6	35m	22 m	0.371429
7	44m	33 m	0.25
8	33m	12 m	0.636364
9	39m	25 m	0.358974
10	42m	14 m	0.666667
11	59m	39 m	0.338983
12	1h 06m	26 m	0.606061

Table 6: Table showing the percentage reduction in waiting time for A/C section

S/N	Waiting time (unmodelled)	Waiting time (modelled)	% Reduction in waiting time
1	20m	0	1
2	23m	14m	0.391304
3	17m	12m	0.294118
4	15m	11m	0.266667
5	0	0	0
6	46m	36m	0.217391
7	0	0	0
8	1h 30m	1h 15m	0.166667
9	20m	14m	0.3
10	1h 31m	40m	0.56044
11	0	0	0
12	21m	18m	0.142857

Tables 4-6 show that with the use of the developed software, an appreciable percentage reduction in waiting time of customers was achieved.

4.0 CONCLUSION

A queue management software for effective service delivery in automobile repair shops was developed and tested. This software was designed to reduce both waiting time of customers, and idle time of workers in automobile repair shops. Once a vehicle enters the workshop, details of the work to be done is determined through scan or other physical fault detection techniques. This data is immediately entered into the software and the software automatically calculates how long the repair will take, based on several factors like: type of maintenance to be done, number of vehicles in queue, number of workstations available, etc. The software automatically notifies the customers once their vehicles are ready for pick up, through their mobile phones and emails. Evaluation of the software showed very notable reductions in waiting time in the mechanical, electrical and A/C sections of the workshop. The software has a user-friendly interface, which will be easily understood by anyone who wants to adopt this system in his automobile workshop.

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