2009

Development of an Electronic Job Control System

Nissan South Africa

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Executive Summary

Engineering Principles and Tools will be used by the author of this report to develop a Scheduling Algorithm for Nissan South Africa situated in Rosslyn to use as an Electronic Job Control System for Nissan dealers across South Africa.

The need for such a system was established due to the increase in servicing jobs for Nissan vehicles and the availablitity of the appropriately skilled technicians for the jobs. These are the key fundamentals that has to be addressed in the algorithm.

Research on different Operational Research techniques as well as already existing scheduling algorithms were done to gather the necessary information. Other methods such as Simulation Moddeling and Spreadsheet application designs were also investigated. Data about the vehicles and their service requirements where obtained from Nissan to identify the preeminent procedure in developing the JCS.

The best suited literature on the subject was kept and analyzed to find the solution for the development of the algorithm. Once all the information is studied and understood as to where it is applicable, the model can be developed.

The end result of the project would result in Nissan dealers being able to schedule their jobs for the day more efficiently between the available technicians, increasing Nissan's dealers productivity thus increasing overall income.

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Abbreviations

DP – Dynamic Programming

FCFS – First Come First Serviced

FRT – Flat Rate Time

FT – Finish Time

IE – Industrial Engineering

JCS – Job Control System

MP – Mathematical Programming

NSA – Nissan South Africa

OR – Operation Research

PERT/CPM – Program Evaluation and Review Technique/Critical Path Method

ST – Start Time

VB – Visual Basic (short for Visual Basic for Applications)

1. Introduction & Background

Nissan South Africa (NSA) was established in the Southern Region of Africa a few decades ago and their success lies in the quality product they deliver on the market for the targeted categories. NSA established the need to develop an electronic job control system to aid dealers in scheduling and controlling the servicing jobs in their workshops.

The scheduling and control of the dealers' workshops have been identified as key elements in ensuring that the required workshop efficiency is met (by scheduling the appropriate amount of work evenly for a day), as well as improving customer satisfaction through improved communication and ensuring that jobs are completed before the promised delivery time. If these elements are not met it can lead to customer dissatisfaction and an overall loss in productivity for the dealers.

Thus the key problem can be addressed by implementing a user friendly electronic job control system. The daily jobs can then be efficiently scheduled to technicians (with the appropriate skill and experience level), thus increasing productivity. An interface can be built by I.T specialists to make the algorithm user friendly and then distribute this interface/software between the Nissan dealers in South Africa. The scheduling tool will have easy to change variables, like choosing the car model, flat rate times, etc. Other variables that change over time can also be updated with ease.

The shareholders, customers, dealers and all Nissan personnel will benefit from this move to an electronic scheduling tool. Nissan as a brand name will increase its image if service efficiency can be established throughout all the Nissan dealers across South Africa.

2. Problem Statement

Nissan Dealers in South Africa want to distribute the servicing workload between their technicians evenly. Currently the specialized jobs are assigned to the more experienced/skilled level technician but these jobs tend to take longer that the flat rate time (FRT) specifies. The cause for this can be that the appropriate part is not available immediately or unforseen technical difficulties can occur causing the delay. If a new problem/technical difficulty that was never experienced before occurs, the FRT to fix the car might also be exceeded. This results in the lower skilled technician gaining more jobs for the day and increasing his profits while the more experienced technician is sometimes losing out due to lack of jobs possible for the day (extreme case scenario).

The maintenance workload can also be seperated into scheduled maintenance and unscheduled maintenance or emergency breakdowns (walk-in customers). The latter of the two can cause disruptions to the daily schedule and ultimately lead to delays.

3. Project Aim

The aim of the project is to develop an electronic Job Control System (JCS) to assist the dealer in scheduling the workshop jobs evenly to all the technicians and providing proper control over the jobs in progress. The jobs can include a major/minor service, repairs/maintenance, warranty repairs and diagnostics. To achieve this, the following has to happen:

- A user friendly JCS has to be developed that uses the relevant data for scheduling
- Updating should commence throughout the system should a variable change and give new output to the proposed schedule as necessary
- Training program for staff (a User manual for reference)

There are a few ways of achieving this, firstly, one can do optimisation using Operational Research techniques, or secondly, one can build an interactive database using Microsoft software like Excel or Access. This interactive database can display the schedule as a visual aid to ensure fairness in assigning jobs. Simulation modelling is another alternative to solve the scheduling problem.

The end result of a more productive workday, meaning more cars are serviced in a day, is an increase of overall income for the Nissan dealer.

The report will also focus on how to develop spreadsheet applications with hints plus task and planning guidelines to accomplish this.

4. Project Scope

Industrial Engineering (IE) principles will be used to develop a JCS for NSA that will increase productivity in the workshop of all the dealers in South Africa when a car is booked for a service, etc. NSA identified this as a problem due to the technicians complaining that they do not always get enough jobs assigned to them (a fairness issue), or jobs are assigned that take longer than specified resulting in a less profitable day than they would have liked. Thus the Flat Rate Time (FRT) for servicing a car is exceeded. This can also cause delays to jobs scheduled after the vehicle who has exceeded the FRT.

Note: Until a recent visit to Nissan in September the scope was to build a mathematical programming model in Lingo or Matlab with Operations Research techniques as primary IE principle, but due to complications and Nissan wanting a user friendly application (Lingo and Matlab is not readily available as well), Microsoft Excel was chosen as an alternative.

The principles required will include:

- Developing a database in the form of a spreadsheet containing the required data
- Integrating the data in an interface to schedule and control jobs
- Using productivity and ergonomical logic in the workplace
- Any relative statistical measures (Quality Assurance, etc.)

The output of the JCS will give a schedule for the week where day to day jobs can be scheduled in that week, allocating a service technician to a job in such a fashion that the technician will be idle only if there is a problem, if a tea/lunch break occurs or if there is not enough work available (hopefully this will never be the case). For this algorithm to work perfectly, the data required to schedule the next days' jobs should be available prior to the next day, meaning the customer made a booking and all the information is available.

Appropriate time should be allocated for walk-in customers as well in the model since this is a regular occurrence. These walk-in customers consist of emergency breakdowns or unscheduled arrivals. If this allocated time is full, the customer will be booked into the next days' schedule, unless other arrangements can be made. Manual scheduling should also be possible, thus you will be able to adjust the proposed schedule if needed. The adjusted schedule might incur the need to rearrange the jobs still available to accommodate the changes made and still deliver an improved schedule. The JCS will schedule the jobs to the available hours and technicians available in a day.

When investigating the causes that lead to delays in the FRT, the dealers can identify problem areas that need attention to increase performance. Something that has to be kept in mind as well is that as customers book their vehicle for an oppointment, the First Come First Serve (FCFS) principle will apply.

5. Literature Review

5.1 Introduction

A literature review on the relevant subject of the project needs to be done before officially starting with the project. By researching similar techniques in advance, insight can be gained to help achieve the goal that was set and analysing the data obtained made easier. One should also ensure that a thorough knowledge about different methods are obtained to achieve the project goal.

Other good reasons include:

- Comparison of available data sources
- Ties to previous projects
- Identifying researchable heuristics
- Developing something new

While gathering the appropriate information to conduct the project, a constant comparison and interrelation needs to be done to make sure that only the applicable information is kept. Other methods are discarded that have no relevance to the project.

This literature study focuses on gathering information about scheduling algorithms and how they can be implemented in scheduling the technicians to the available cars awaiting a service. These algorithms should aslo adhere to constraints identified within the project scope. Other methods that will also achieve the desired output as mentioned in 3. are discussed as well.

Steps that were followed to gather the information as adapted from Methods, Standard and Work Design (Niebel, Freivalds 2003:7) are as follows.:

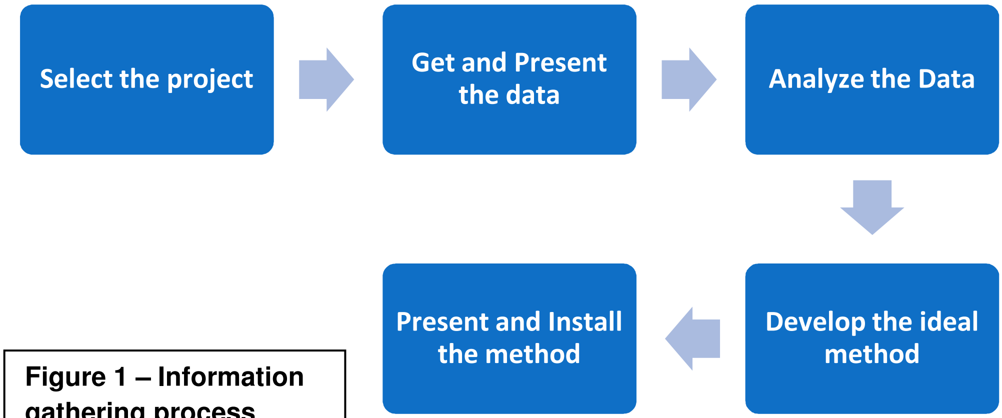


Figure 1 – Information gathering process

5.2 Methods of Information Gathering

The following was used to obtain the required literature and information:

i. The Library
ii. The Internet
iii. Electronic Journals
iv. Discussion with personnel at Nissan

5.3 What is Scheduling

What is a schedule? It is to obtain the best possible system performance when you assign resources to activities over time (Brown, Sherer, 1995).

A scheduling algorithm is the manner by which threads, processes or data flows gains access to the system resources. The aim is to balance a system load effectively or achieve a target quality of service (Wikipedia).

The problem NSA face is a scheduling problem since resources (technicians) needs to be assigned to tasks (jobs). This sounds a lot easier than what the schedule should actually portray once you start thinking about all the constraints, but with the methods researched and heuristics available, a sound algorithm should be developed.

The amount of vehicles capable of a service in a day depends on the service bays available as well as the amount of technicians employed. It is estimated that a technician can service a minimum of four vehicles in a day (Venter, 2006), but this can vary should a job occur with a higher FRT. It is also advisable not to book the maximum amount of jobs possible for a day since factors including walk-in customers as well as technical difficulties have to be kept in mind. For instance, say 28 jobs are possible to schedule in a day, then at least 15-20% (this is about the daily percentage of walk-in customers) less should rather be scheduled to accommodate walk-in customers and delays. Thus, 20-23 jobs overall should rather be scheduled to make provision for the above-mentioned.

One must also be careful not to book too little cars since this can result in the technicians being idle, and efficiency and productivity making a dive. A preventative measure to not book to little cars is gathering service data, analysing the data and using forecasting methods to determine the amount of vehicles that usually arrive for a service at the selected dealers.

In this kind of scheduling, it is essential to book according to the FRT specific to the job booked to increase the selling of productive hours for the service station, resulting in an increase of profits. The technician efficiency can also have an effect on the productive hours available in a day. Productive hours is a measure of the technician's performance to a standard time, 100% percent meaning conforming to the standard, 85% performance is a lack and NSA should focus on this. Then anything above 100% is more productive and the goal in meeting workshop competence.

5.4 Methods, Tools and Techniques Identified

For solving the JCS algorithm the following methods, tools and techniques were identified from the gathered information.

Note: Information about Visual Basic for Applications, a programmming language, was added later due to the change in the Project Scope.

5.4.1 Operational Research (OR) Techniques

OR algorithms and heuristics that focusses on the scheduling of resources to activities in a maintenance environment will be the first solution type to consider. The following OR tools were identified:

Dynamic Programming:

Dynamic programming (DP) can be used to solve optimization problems by working backward from the end of the problem to the beginning, thus breaking the large problem into smaller, tractable problems. Resource-allocation problems is one of the main dynamic programming traits (Winston, 2004).

Characteristics of DP (Winston, 2004) that are most used in its application are:

- The problem can be divided into stages with a required decision at each stage
- Each stage has associated with it a number of states, thus meaning the information needed by the stage to make the optimal decision
- The chosen decision at any stage describes how the state at the current stage is transformed into the state at the next stage
- Given the current state, the optimal decision for each of the left over stages must not depend on previously reached states or chosen decisions (Principle of Optimality)
- If the states for the problem have been classified into one of T stages, there must be a recursion that relates the cost/reward earned during stages t, t + 1,….,T to the cost or reward earned from stages t + 1, t + 2,….,T.

If the problem at hand correlates to the characteristics then DP can be used to develop the scheduling algorithm required.

DP can also be divided in two groups, first, Deterministic Dynamic Programming and second, Stochastic Dynamic Programming. The Deterministic part can be associated with *scheduled* maintenance and *unscheduled or emergency* maintenance can be associated with the latter. It is the unscheduled maintenance that creates backlogs in the system as well as solving the scheduling a challenging task. A realistic schedule must reflect both aspects (Duffuaa, Al-Sultan, 1998). In the course of the report a proposed solution by Duffuaa and Al-Sultan will be used as the basis of the algorithm.

A few assumptions have to be made to simplify the development of the algorithm due to the already complex mathematics that will be involved. The distribution of the arrival of emergency jobs is assumed to be known. This can be the percentage mentioned earlier. Spare parts are assumed to be available and do not cause any disruption to the schedule. Priorities of all jobs are specified in advance. Available skills are known at the beginning of each horizon.
The maintenance-scheduling problem has other stochastic elements in addition to the stochastic component of the load (Duffuaa, Al-Sultan, 1998).

1. Job completion times or job standard times.
2. Availability of equipment for performing maintenance jobs.
3. Spare parts delivery times at job sites. An inherent characteristic of the maintenance-scheduling problem is the occurrence of emergency jobs.

Queuing Theory:

The standard scheduling algorithm is First-Come-First-Served (FCFS), in which a task, process, etc. is accepted if the requested resource is less than the available resource, otherwise, it is rejected. (Xueli An, Ramin Hekmat) In simpler words, a queue forms and the first 'task' to arrive will be the first 'task' to be processed.
This results in another OR technique to consider, the queuing theory, although this seems a more abstract approach. Queues can correspond to a dynamic usage of capacity although realistic models can be too complex to analyze mathematically. The definition of queues and servers (Rech, 1987), corresponds to the problem of defining resource groups and timeslot types. Specific timeslots and appointments are not considered in queuing systems and therefore it will not capture the full scheduling problem (Vermeulen, Bohte. 2008).

5.4.2 Simulation Moddeling

Simulating the workshop processes with appropriate software like Rockwell's Arena, is also a useful tool to determine the capacity vehicles that can be serviced in a day. This can be insightfull as to where bottlenecks may arrise, meaning a "service queue" forms, making the targeting of problem areas easier. An Input will be a vehicle needing a service followed by the information gathering process, servicing processes, inspection process and lastly the serviced vehicle as an Output.

Due to the Nissan dealers having different amounts of service bays as well as technicians employed, a different model would have to be created for each dealer. Since this would be an avoidable tedious task, simulating service stations for the dealers will not be feasible.

5.4.3 Microsoft Excel or Access

Both of these software packages will also be sufficient to deliver a database with all the needed information about the vehicles. The application has to be interactive and easily updated should any information changes occur. The Nissan dealers can each enter their own workshop information (for example the names of the technicians working at that specific branch and their level of expertise as well as their productive ratios). The nice thing about using Mirosoft pakages is that it is almost used everywhere and easy to understand and use by anybody with the basic knowledge of the software.

5.5 Selection of Appropriate Methods, Tools and Techniques

From the above-mentioned methods identified to create an algorithm, Deterministic Dynamic Programming will be best suited to develop the scheduling solution for NSA. The reason for selecting a dynamic environment is that the schedule can be rescheduled should changes occur, whereas a static environment doesn't allow changes (Kruger, Scholl, 2009). Due to the predetermined constraints, the dynamic model will have to adhere to certain other techniques and heuristics to enhance the capability of the alorithm to effectively schedule the vehicles.

Things to keep in mind are for instance the fact that the resources can vary, meaning different Nissan dealers needs a different number of technician staff due to the workspace available. Unforseen changes to the day's schedules should also be incorporated. These changes can include walk-in customers seeking immediate attention due to emergency breakdowns, or, a technician might be sick and the schedule for the day has to be recalculated to determine the new workload between the available technicians. Thus the level of increases and decreases in the constraints needs to be considered.

A heuristic indentified to help with this problem states that any schedule developed at time t may have to be modified after some t + 1 time units. This outrules the fact that schedules can be planned ahead for a long period of time. The total reward gained from scheduling the activities at time t has to be maximized without violating any of the constraints (Belhe, Kusiak, 1997). This will ensure that the algorithm schedules the task best fitted to the resource with the appropriate skill. The weight of importance of an activity as well as slack on an activity to provide for walk-in customers can also be found in Belhe, Kusiak, 1997.

Genetic algorithms were developed for optimizing problems with more than 60 activities (Hartmann, 1998), which might often be the case for Nissan dealers. Further research on Genetic algorithms still needs to be done, but the focus of the algorithm entails that the computation when starting with an empty job sequence follows a 'step' selecting feasible precedence jobs. This step repeats itself until all the jobs are selected from the set. This specifies that the next job is selected randomly from the set of untaken jobs. Many random schedules are calculated and the optimal schedule selected.

With respect to Project Management and Timetable scheduling, the problems are such that they are NP-hard (French, 1982). Meaning, very tedious and time consuming to solve. Many OR techniques can be used to simplify (as a manner of saying) the problem to achieve a working solution. Some techniques delivers questionable results as found by reading (Ming, 2008), when handling large activity sizes. Stochastic dynamic procedures and heuristics was provided by (Brucker *et al,* 1999) to solve these problems. Stochastic dynamic programming is more advanced than what will be necessary to achieve the project scope, although the algorithm for this project can contain stochastic elements. Stochastic DP can be used in future to enhace the algorithm.

The Stony Brook Algorithm Repository was looked at since it focuses on precedence constrained scheduling problems. Another name for this is PERT/CPM (Program Evaluation and Review Technique/Critical Path Method). The whole day's jobs or tasks are then part of the big job (complete day). Each of the task times, how long it takes, is known. It is also known which task is of more importance than the others are and should be executed accordingly. A better schedule can be developed if there are fewer constraints to enforce. (www.algorist.com, 2008)

Model Formulation

The following was obtianed from the journal of (Duffuaa, Al-Sultan, 1998) as a possible solution to work from for the final algorithm. Only the applicable information will be used to formulate the model.

A few assumptions are made to formulate this model. The assumptions are: job duration times are known constants; spare parts are available and their delivery time is negligible; and equipment are available all the time. The limiting factor in this problem is manpower. Prior to stating the model, we introduce the following notation:

i	Subscript, for ith skill, $i = 1, 2, \ldots, S$
j	Subscript, for the jth job
k	Subscript, for the kth hour clock time
l	Subscript, for the lth starting time for a job
t	Subscript, for the tth hour from the start of a job, incremental time
h_{ijt}	Hours required for the ith skill on the jth job, at the tth hour from the start of the job
H	Horizon of scheduling in hours
n	Number of known jobs to be scheduled (deterministic part)
N	Total number of jobs (both deterministic and expected)
S	Total number of skill types available
S_{ik}	Skill hours available, for ith skill, kth hour clock time
Y_{jkl}	Binary variable for the jth job, kth hour clock time, lth starting time for the job, if $Y_{jkl} = 1$, the job is scheduled
	if $Y_{jkl} = 0$, the job is not scheduled
c_{jkl}	Values associated with Y_{jkl}
Z_{jl}	A binary variable for jth job, lth starting time for the job, $Z_{jl} = 1$, the job scheduled; $Z_{jl} = 0$, the job is not scheduled
θ_j	Job duration, number of clock hours for job j
$\{I_j\}$	Index set for skill types required for job j
$\{I_k\}$	Index set of skill types that are used in hour k
$\{J_{ik}\}$	Index set for jobs that use skill i in hour k, for all t and l subscripts
$\{K_i\}$	Index set of hours where skill i is used
n_j	Duration of job j in hours
R_{ijk}	Reserved manpower of skill i for anticipated job j in hour k (hour k is in the future)
P_j^k	Probability that a job of type j occurs in hour k for anticipated job j in hour k
d_{ijk}^-	Negative deviation from the required manpower of skill i for anticipated job j in hour k
μ_i^+	Penalty for having unused reserved manpower/person
μ_i^-	Penalty for having less manpower reserved/person
E	Expected value operator

The model formulated for the maintenance scheduling problem incorporating deterministic and stochastic components is given below.

$$\max \sum_j \sum_k \sum_l c_{jkl} Z_{jl} - \mu^+ E\left[\sum_{i=1}^{S}\sum_{k=1}^{H} R_{ijk}\right] - \mu^- E\left[\sum_{i=1}^{S}\sum_{k=1}^{H} d_{ijk}^-\right] \tag{4}$$

s.t.

Job-hour balances: The next set of inequalities formulates job-hour-balance and provides the job description in terms of the hours and skill, required for each job hour by hour. These constraints will determine the time the job must start in order to be completed before the end of the planning horizon. For example, if the planning horizon is 8 h and a job requires 4 h, then the job may begin in hours 1, or 2 or 3 or 4 or begin of hour 5, but not in hours 6, 7 or 8 because a 4-hour job would end beyond the planning horizon.

$$\sum_{i\in\{I_j\}} \sum_{t=1}^{\theta_j} h_{ijt} Y_{itl} \leqslant \sum_{i\in\{I_j\}} \sum_{t=1}^{\theta_j} h_{ijt}, \quad j = 1,\ldots,n \quad \text{and} \quad l = 1,\ldots,H-\theta_j+1. \tag{5}$$

Skill-hour balances: The next set of constraints formulates the skill hour balances and provides hour by hour (to each skill) requirements for the jobs, which must be less than the skill availability for each hour.

$$\sum_{j\in\{J_{ik}\}} h_{ijt} Y_{jlt} + \sum_{j\in\{J_{ik}\}} R_{ijk} \leqslant S_{ik}, \quad i = 1,2,\ldots,s, \;\; k = 1,2,\ldots,H. \tag{6}$$

Selection equations: These equations express that each job can be run once and only once.

$$\sum_{l=1}^{H-\theta_j+1} Z_{jl} = 1, \quad j = 1,2,\ldots,n, \tag{7}$$

$$Y_{itl} - Z_{jl} = 0, \quad j = 1,2,\ldots,n, \;\; l = 1,\ldots,H-\theta_j+1. \tag{8}$$

Reserved manpower constraints: These constraints ensure that the reserved manpower is as close as possible to the job requirements.

$$R_{ijk} - d_{ijk}^- = h_{ijk}, \quad j = 1,2,\ldots,n, \;\; l = 1,\ldots,H-\theta_j+1, \;\; i = 1,2,\ldots,S. \tag{9}$$

The above model incorporates the stochastic component through a recourse decision, maximizes the number of completed jobs and develops a schedule for the jobs on hand, and reserves adequate manpower for anticipated jobs. If an anticipated job does not arrive in a particular period and there is reserved manpower for it, then that manpower will be utilized in routine jobs or in the next horizon job.

The model expressed in Eqs. (4)–(9) can be simplified further if we consider the scheduling horizon in discrete time periods (h). This allows us to use discrete probability distribution and compute the expected value of the objective function easily. Now, let P_j^k be the probability of job j arriving in hour $k, j = n+1, \ldots, N, K = 1, \ldots, H$. Then the models (4)–(9) can be cast as follows:

$$\max \sum_j \sum_k \sum_l c_{jkl} Z_{jl} - \sum_{i=1}^{S} \mu_i^+ \left(\sum_{j=n+1}^{N} \sum_{k=1}^{H} P_j^k R_{ijk} \right) - \sum_{i=1}^{S} \mu_i^- \left(\sum_{j=n+1}^{N} \sum_{k=1}^{H} P_j^k d_{ijk}^- \right) \tag{10}$$

s.t.

Job-hour balances:

$$\sum_{i \in \{I_j\}} \sum_{t=1}^{\theta_j} h_{ijt} Y_{itl} \leqslant \sum_{i \in \{I_j\}} \sum_{t=1}^{\theta_j} h_{ijt}, \quad j = 1, \ldots, n \text{ and } l = 1, \ldots, H + \theta_j + 1. \tag{11}$$

Skill-hour balances:

$$\sum_{i \in \{J_{ik}\}} h_{ijt} Y_{jli} + \sum_{i \in \{J_{ik}\}} R_{ijk} \leqslant S_{ik}. \tag{12}$$

Selection equations:

$$\sum_{l=1}^{H-\theta_j+1} Z_{jl} = 1, \quad j = 1, 2, \ldots, n, \tag{13}$$

$$Y_{ill} - Z_{jl} = 0, \quad j = 1, 2, \ldots, n, \qquad l = 1, \ldots, H - \theta_j + 1. \tag{14}$$

Reserved manpower constraints:

$$R_{ijk} - d_{ijk}^- = h_{ijk}, \quad i = 1, 2, \ldots, S, \; j = 1, 2, \ldots, n, \; k = 1, 2, \ldots, H, \tag{15}$$

where Y_{ill}, Z_{jl} are zero-one variables $d_{ijt}^-, R_{ijk} \geqslant 0$.

Mathematical Programming (MP) is a method to develop the algorithm for NSA. MP can formulate methods to solve from linear programming, integer programming, dynamic programming, goal programming to networks (Topaloglu, 2009).

Matlab or Lingo/Lindo software will be used to formulate the algorithm and run the code with the desired inputs. The results can be analysed and debugging will commence should it deem necessary.

An objective function and constraints will be formulated as part of the dynamic MP. The objective gives the answer to the goals stipulated in the project and your constraints are everything limiting your goal or that has an effect on the outcome of the objective.

$f_t(r)$ can be defined as the maximum overall income generated from scheduling jobs for time t, t+1,..,T with 'r' resources available to schedule where 't' is your fifteen minute intervals from 7am to 7pm. This is your objective function.

Constraints will include:

- Jobs booked for a certain time slot cant be more that the available service bays in the workshop
- There cant be more jobs per timeslot than technicians available
- Certain jobs require skilled technicians of a higher degree
- The sum of FRT of the jobs allocated per service station cannot be more than available time in the day (thus a job that requires 2 hours FRT cannot be started if there is only half an hour still available in the day.
- Slack time for walk-in customers needs a percentage of overall time available
- Any other relevant constraints

As a solution, the schedule will show what technician has to take what job at what time interval to maximize the vehicle throughput for the day.
An example obtained from the journal of (Duffuaa, Al-Sultan, 1998) of how the formulation that was fed to the appropriate software (in this case Lindo) is shown below to display how the algorithm will give the results.

- *Objective function*:

max

$$
\begin{aligned}
& Y_{111} + Y_{122} + Y_{133} + Y_{144} + Y_{155} + Y_{166} + Y_{211} + Y_{222} + Y_{233} \\
& \quad + Y_{244} + Y_{311} + Y_{322} + Y_{333} + Y_{344} + Y_{355} + Y_{366} + Y_{377} + Y_{411} + Y_{422} \\
& \quad + Y_{433} + Y_{444} + Y_{455} + Y_{466} + Y_{511} + Y_{522} + Y_{533} + Y_{544} + Y_{555} + Y_{566} \\
& \quad + Y_{577} + Y_{611} + Y_{622} + Y_{633} + Y_{644} + Y_{655} + Y_{666} + Y_{711} + Y_{722} + Y_{733} \\
& \quad + Y_{744} + Y_{755} + Y_{766} + Y_{777} + Y_{811} + Y_{822} + Y_{833} + Y_{844} + Y_{855} + Y_{866} \\
& \quad - 0.5DN_{293} - 0.5DN_{392} - 0.1R_{293} - 0.25DN_{2A4} - 0.25DN_{3A3} \\
& \quad - 0.05R_{2A4} - 0.05R_{3A3} - 0.25DN_{2B6} - 0.25DN_{3B5} - 0.05R_{2B6} \\
& \quad - 0.05R_{3B5} - 0.3DN_{1C2} - 0.3N_{2C3} - 0.06R_{1C2} - 0.06R_{2C3} \\
& \quad - 0.7DN_{2D5} - 0.7DN_{1D4} - 0.14R_{2D5} - 0.14R_{1D4} - 0.1R_{392}
\end{aligned}
$$

s.t.

- *Job-hour balance constraints:*

$$Y_{111} + Y_{122} + Y_{133} + Y_{144} + Y_{155} + Y_{166} = 1,$$
$$Y_{211} + Y_{222} + Y_{233} + Y_{244} = 1,$$
$$Y_{311} + Y_{322} + Y_{333} + Y_{344} = Y_{355} + Y_{366} + Y_{377} = 1,$$
$$Y_{411} + Y_{422} + Y_{433} + Y_{444} + Y_{455} + Y_{466} = 1,$$
$$Y_{511} + Y_{522} + Y_{533} + Y_{544} = Y_{555} + Y_{566} + Y_{577} = 1,$$
$$Y_{611} + Y_{622} + Y_{633} + Y_{644} + Y_{655} + Y_{666} = 1.$$

- *Skill-hour balance constraints:*

$$Y_{711} + Y_{722} + Y_{733} + Y_{744} = Y_{755} + Y_{766} + Y_{777} = 1,$$
$$Y_{111} + Y_{811} + Y_{822} + Y_{833} = Y_{844} + Y_{855} + Y_{866} = 1,$$
$$Y_{211} + Y_{611} \leqslant 2,$$
$$Y_{122} + Y_{222} + Y_{311} + Y_{511} = Y_{611} + Y_{622} + R_{1C2} \leqslant 2,$$
$$Y_{133} + Y_{233} + Y_{322} + Y_{411} = Y_{522} + Y_{622} + Y_{633} + Y_{811} + R_{1D4} \leqslant 2,$$
$$Y_{144} + Y_{244} + Y_{333} + Y_{422} = Y_{533} + Y_{633} + Y_{644} + Y_{822} \leqslant 2,$$
$$Y_{155} + Y_{344} + Y_{433} + Y_{544} = Y_{644} + Y_{655} + Y_{833} \leqslant 2,$$
$$Y_{166} + Y_{355} + Y_{444} + Y_{555} = Y_{655} + Y_{666} + Y_{844} \leqslant 2,$$
$$Y_{366} + Y_{455} + Y_{566} + Y_{666} + Y_{855} \leqslant 2,$$
$$Y_{377} + Y_{466} + Y_{577} + Y_{866} \leqslant 2,$$
$$Y_{311} + Y_{511} + Y_{711} \leqslant 2,$$
$$Y_{111} + Y_{211} + Y_{322} + Y_{522} + Y_{722} + Y_{811} \leqslant 1,$$
$$Y_{111} + Y_{122} + Y_{222} + Y_{333} = Y_{533} + Y_{733} + Y_{822} + R_{2931} + R_{2C3} \leqslant 1,$$
$$Y_{122} + Y_{133} + Y_{233} + Y_{344} = Y_{544} + Y_{744} + Y_{833} + R_{2A4} \leqslant 1,$$
$$Y_{133} + Y_{144} + Y_{244} + Y_{355} = Y_{555} + Y_{755} + Y_{844} + R_{2D5} \leqslant 1,$$
$$Y_{144} + Y_{155} + Y_{366} + Y_{566} = Y_{766} + Y_{855} + R_{2B6} \leqslant 1,$$
$$Y_{155} + Y_{166} + Y_{377} + Y_{577} + Y_{777} + Y_{866} \leqslant 1,$$
$$Y_{166} \leqslant 1,$$
$$Y_{411} + Y_{811} \leqslant 1,$$
$$Y_{411} + Y_{422} + Y_{711} + Y_{822} + R_{392} \leqslant 1,$$
$$Y_{211} + Y_{422} + Y_{433} + Y_{611} + Y_{722} + Y_{833} + R_{3A3} \leqslant 1,$$
$$Y_{211} + Y_{222} + Y_{433} + Y_{444} + Y_{622} + Y_{733} + Y_{844} \leqslant 1,$$
$$Y_{211} + Y_{222} + Y_{233} + Y_{444} + Y_{455} + Y_{633} + Y_{744} + Y_{855} + R_{3B5} \leqslant 1,$$
$$Y_{222} + Y_{233} + Y_{244} + Y_{455} + Y_{466} + Y_{644} + Y_{755} + Y_{866} \leqslant 1,$$
$$Y_{233} + Y_{244} + Y_{466} + Y_{655} + Y_{766} \leqslant 1,$$
$$Y_{244} + Y_{666} + Y_{777} \leqslant 1.$$

- *Reserved manpower constraints:*

$$DN_{1C2} + R_{1C2} = 1,$$
$$DN_{1D4} + R_{1D4} = 1,$$
$$DN_{293} + R_{293} = 1,$$
$$DN_{2C3} + R_{2C3} = 1,$$
$$DN_{2A4} + R_{2A4} = 1,$$
$$DN_{2D5} + R_{2D5} = 1,$$
$$DN_{2B6} + R_{2B6} = 1,$$
$$DN_{392} + R_{392} = 1,$$
$$DN_{3A3} + R_{3A3} = 1,$$
$$DN_{3B5} + R_{3B5} = 1.$$

Y_{ijl} are zero-one variables, $R_{ijk}, DN_{ijk}, DP_{ijk}$ are nonnegative variables $\forall_{i,j,k,l}$.

The model above was fed to the package LINDO. The results are summarized below

$$Y_{166} = 1, \quad Y_{244} = 1, \quad Y_{344} = 1,$$
$$Y_{4444} = 1, \quad Y_{566} = 1, \quad Y_{611} = 1,$$
$$Y_{711} = 1, \quad Y_{811} = 1,$$
$$R_{293} = 1, \quad R_{1C2} = 1, \quad R_{1D4} = 1,$$

and the rest are zeros.

If the value of Y_{jkl} = 1, then it means that the specific job ‘j’ has to be scheduled at hour ‘k’ with start time ‘l’. Zero values is equal to unassigned timeslots due to it not being the most feasible solution.

5.6 Final selection of appropriate method

A database in the form of an interactive application Microsoft Excel spreadsheet will be the final choice in solving the scheduling of technicians. Visual Basic for Applications and Excel functions are mainly used to achieve this with NSA already supplying a partially completed Excel example of a Workshop Scheduling Tool to work off.

Visual Basic (VB) is a programming language used by Microsoft to add extra programming code into its already existing software to achieve rapid application development and graphical user interface applications (Wikipedia, 2009). In short, it means to customize your work to achieve the desired function you would like the software to perform. VB is said to be an easier programming language to learn as a beginner programmer to add controls and components on a sheet/form that enables the user to interact with the application.

In Excel a function is a preset formula, or in other words, a mathematical equation that is used to calculate a value. Functions begin with the equal sign (=) and the appropriate function's name followed by the function's arguments (contained in brackets). This function name excecutes the calculation that needs to be performed (About.com, 2009).

The SUM, AVERAGE, MIN and MAX as well as MEDIAN are some of Excel's most used functions. These functions are used with selected data on your worksheet.

The book, Excel 2007 Power Programming with VBA, was consulted to gain insight on how to use Visual Basic in Excel. The aim is to learn how to write programs in Excel to automate various tasks or functions that is not available in the software itself. A spreadsheet application is a spreadsheet file that consists of related files so that work can be done by the end user without the need for extensive training (Walkenbach, 2007).

It is possible to create spreadsheet applications with a wide variety of uses, the level of difficulty depending on the scope of what the end user requires.

5.7 Conclusion

With the amount of available literature on the subject of scheduling resources to activities, there will not be enough time in this course to go through all the relevent data and information available. Further research will be done should the problem require a function that was not found from the already researched information. Technology of today can help solve various scheduling problems a lot faster than a few years back, meaning a better optimal solution can be obtained for Nissan when scheduling their tasks for the day.

The reader can also use the whole content of this report to aid him/her in either further research or development of algorithms and spreadsheet applications in future.

6. Development of Supplementary Methods And Tools

After a discussion with the Nissan personnel on the progress of the Dynamic Programming algorithm, it was concluded the amount of programming required and physical difficulty of the programming would be to intense to continue with in this project. In addition, the Lingo and Matlab software that is required are not readily available and distributable between the Nissan dealers and will therefore not deem feasible. If a workable scaled down Dynamic Programming algorithm was to be developed, it will schedule in such a basic way that the Nissan dealers will not benefit from the output generated.

The JCS will be done in Microsoft Excel in the form of an interactive spreadsheet with all the scheduling functionalities incorporated. Microsoft Access could also be used to build the database for the JCS since it has the capability of doing what is required, but due to the technical difficulty of the software not being user friendly to make use of, it will not be used in this case.

The research done so far in the Literature Study on the Deterministic Dynamic Programming will not be discarded since it will deliver the best scheduling results as a solution if further research commences. The development of an interactive interface for the end user from the above as a final product will be better than the Excel format solution.

To develop the spreadsheet application the following tasks can be performed (Walkenbach, 2007):

- Determine the needs of the user
- Planning an application that meets these needs
- Determining the most appropriate user interface
- Creating the spreadsheet, formulas, macros, and user interface
- Testing the application under all reasonable sets of conditions

- Making the application relatively user-friendly (often based on results from the testing)
- Making the application aesthetically appealing and intuitive
- Documenting the development effort
- Updating the application if and when it's necessary

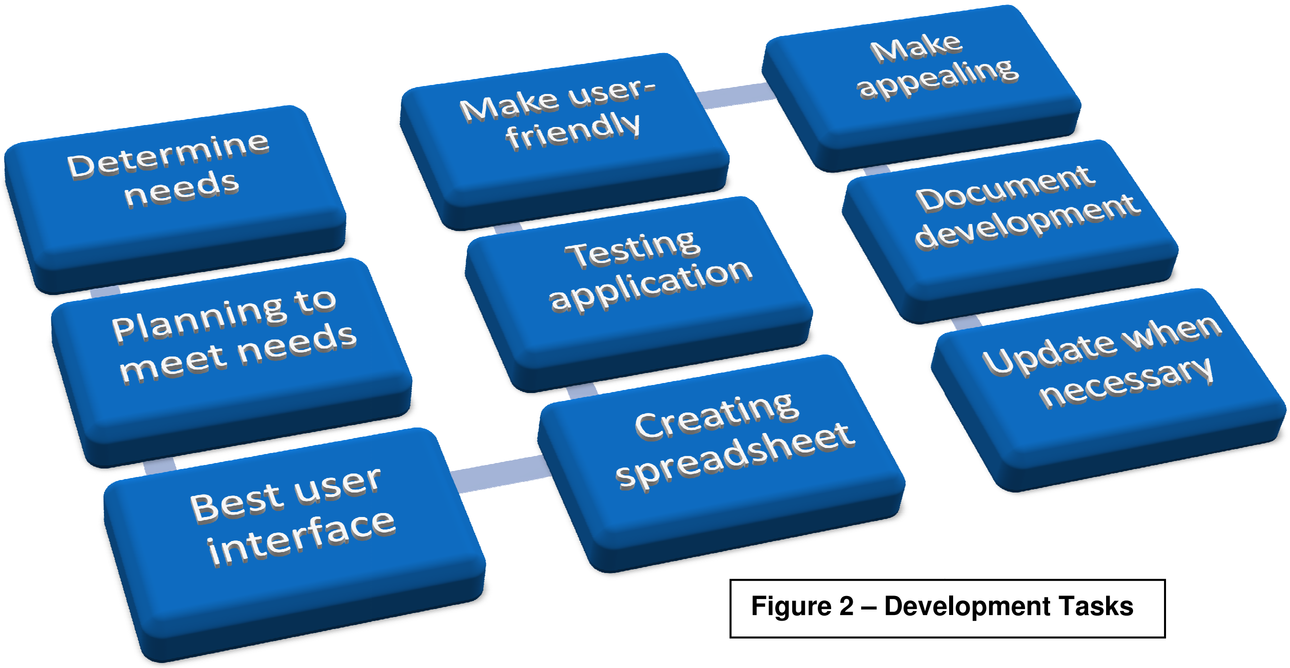


Figure 2 – Development Tasks

Once the tasks are outlined, a plan to start working on the application has to be set out. The scope of the project as well as the general style of working will decide the formality of your plan.

General options to consider in the planning period are as follows (Walkenbach, 2007):

- *File structure:* Think about whether you want to use one workbook with multiple sheets, several single-sheet workbooks, or a template file.

- *Data structure:* You should always consider how your data will be structured. This includes using external database files versus storing everything in worksheets.
- *Formulas versus VBA:* Should you use formulas or write Visual Basic for Applications (VBA) procedures to perform calculations? Both methods have advantages and disadvantages.
- *Add-in or workbook file:* In some cases, an add-in might be the best choice for your final product. Or, perhaps you might use an add-in in conjunction with a standard workbook.
- *Version of Excel:* Will your Excel application be used with Excel 2007 only? With Excel 2000 or Excel 2002? What about Excel 97, Excel 95, and Excel 5? Will it also be run on a Macintosh? These are very important considerations because each new version of Excel adds features that aren't available in previous versions. The new user interface in Excel 2007 makes it more challenging than ever to create an application that works with older versions.
- *Error handling:* Error handling is a major issue with applications. You need to determine how your application will detect and deal with errors. For example, if your application applies formatting to the active worksheet, you need to be able to handle a case in which a chart sheet is active.
- *Use of special features:* If your application needs to summarize a lot of data, you might want to consider using Excel's pivot table feature. Or, you might want to use Excel's data validation feature as a check for valid data entry.
- *Performance issues:* The time to start thinking about increasing the speed and efficiency of your application is at the development stage, not when the application is completed and users are complaining.
- *Level of security:* As you may know, Excel provides several protection options to restrict access to particular elements of a workbook. For example, you can lock cells so that formulas cannot be changed, and you can assign a password to prevent unauthorized users from viewing or accessing specific files. Determining up front exactly what you need to protect - and what level of protection is necessary - will make your job easier.

Testing your application upon completion is one of the most crucial steps to ensure a fully functional, user friendly, error free spreadsheet application. Generous time should be spent on testing and debugging during the development phase as well to check that it works the way it was supposed to. Who will use the application and how will it be used has to be kept in mind as well as what type of system will it run on, software compatibility and what other software will be running concurrently.

7. Analysis of Data and Project Environment

The data needed for development will include the time available in a day to service cars, FRT of the diferent vehicles booked for a service, technician skill level required for the job, etc. This can be stored in an MS Excel spreadsheet that will act as a database for the required information. Figure 2 shows a typical example of such a spreadsheet .

Task	Vehicle Model	Work Type Required	FRT	FRT (added)	Tech Skill Required
1	Micra	30000km	2.5	0	2
2	Navara	60000km	2.8	1.5	4

Etc.

Figure 3 – Information in Spreadsheet format

The start time (ST) will be spesified by the user and the finish time (FT) will be determined by the JCS for each task. The level technician required for the task can be selected from the list provided. Timeslots for the day can be broken into fifteen minute intervals allowing adequate time for teabreaks and lunch, etc. Cars are serviced from Monday to Saturday, excluding public holidays. The total hours worked by each technician can also be computed per day to determine the wages payable.

Currently in the workshop

Currently a Job Control Board is used at the service bays to schedule a job and update its status as the job progresses, but this seems a tedious task for the job controller if there are a lot of vehicles booked for the day. Some of the following information is displayed on the board:

- Job Nr
- Technician Name
- Registration Number of vehicle
- Customer name

- Make of vehicle
- Service requirements/Complaints received from customer
- Status (the status of the vehicle is marked with colour magnets

The Job Control Board does not display the starting time the job should commence in as well as the FRT associated with that specific job.

This board is not used as was intended since walk-in customers can not be accomodated and the new jobs scheduled as they would have wished.

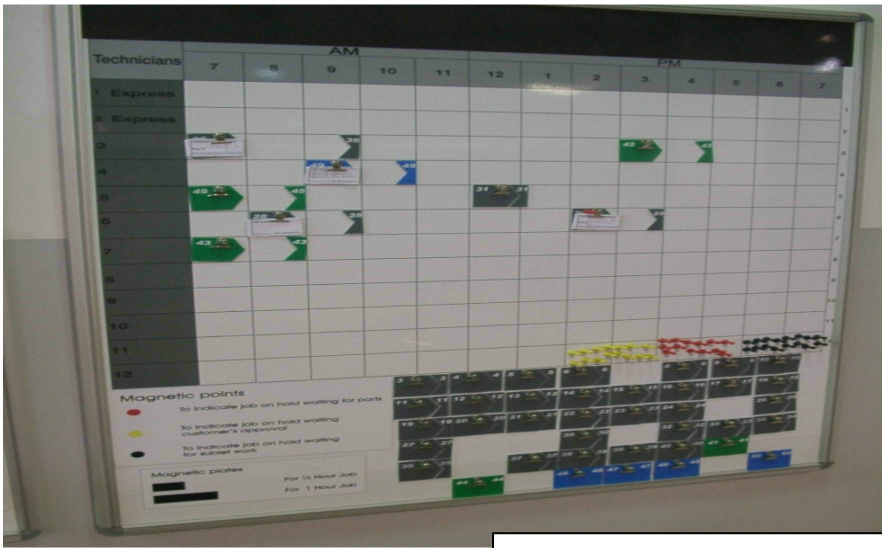


Figure 4 - Current Job Control Board

To increase productivity and efficiency in the workshop the following can be looked at:

- To reduce the time spent on the work order/job
- Increase the workload per technician
- Make the workshop service area as ergonomic as possible
- Determine if the workshop layout is correct

Standard operating procedures are also followed in the workshop to Service and Repair vehicles. These procedures are directly related to the efficiency in the workshop, in essence one can review these procedures and improve outdated procedures with the available new technology of today.

The workshop foreman should also be the only one in control of scheduling the tasks for the day. In the working algorithm he will read the data into the interface of the program to schedule the tasks between the technicians.

The workshop foreman is also in charge of obtaining the jobcard in advance with all the customers' details as well as the type of job the vehicle is booked for before scheduling the jobs between the technicians.

The workshop foreman will remove the job from the control board when a job is completed and the vehicle will go for a test. If a special request was indicated on the jobcard the foreman will focus on these requests during the test drive. The foreman is the last man to handle the vehicle and is thus in charge of parking the vehicle for collection by the customer.

Supply chain principles can be incorporated from other sources to address the parts shortages that occur from time to time. In effect this will lead to less delays in waiting for parts during a service and help in increasing the productivity of the workshop.

Suggestions for future use

If all the Nissan dealers across South Africa uses the same JCS, the statistical feedback of the application can be enhanced so that a log of the technician and workshop performance are captured. This in turn can be analysed using Quality Control methods to determine the 'out of control' instances. Investigating these occurances can lead to discovering problems with either the standard procedures currently employed or other technical difficulties that will lead to lack in performance. Obviously if the standard is higher, meaning a data point lies nearer to the Upper Control Limit of the data analysis, the techniques used at that workshop can be shared with other dealers to increase workshop efficiency.

Some technicians are just more efficient than others due to experience obtained, better training or just skilfulness. Establishing equal efficiency as a strategy for the dealers can lead to a more productive workday attributable to an increase in productive hours.

Due to the application being password protected from users editing and maybe accidentally deleting data, a person can be put in charge of updating the data should any changes occur. These changes can be new FRT, new vehicles released into the market, etc. Another way of doing this (since it is a rather small Excel file), is the application can be updated at NSA and redistributed to the Nissan dealers via e-mail. Upgrading to newer versions of the Software (like Excel 2003 to 2007) will not prevent the application from working since it is always backwards compatible. Technology of today also ensures newer and better ways of doing previously complex tasks, thus should a better spreadsheet application be developed or a substitute alternative found, a consensus should be reached about implenting these changes or not.

Each dealer usually services the same customer’s vehicle unless the customer moved or found the service unsatisfactory. The spreadsheet application should ‘remember’ the customer’s details and a lookup function developed to search for the details should the same customer book his/her vehicle for another service.

8. Development of conceptual solution

The following inserts will show the development of a conceptual solution for the Electronic JCS. The researched principles and techniques were used to develop the JCS in Excel. Suggestions regarding flaws in the spreadsheet will be highlighted where necessary. Visual Basic coding (if applicable) as well as the user manual for the JCS will follow in the Appendix.

The user manual is a necessity when delivering a product that is interactive with the end user. Thus, the user manual should be consulted when opening the JCS for the first time before using the spreadsheet application.

On opening the JCS in Excel the following worksheet will be displayed:

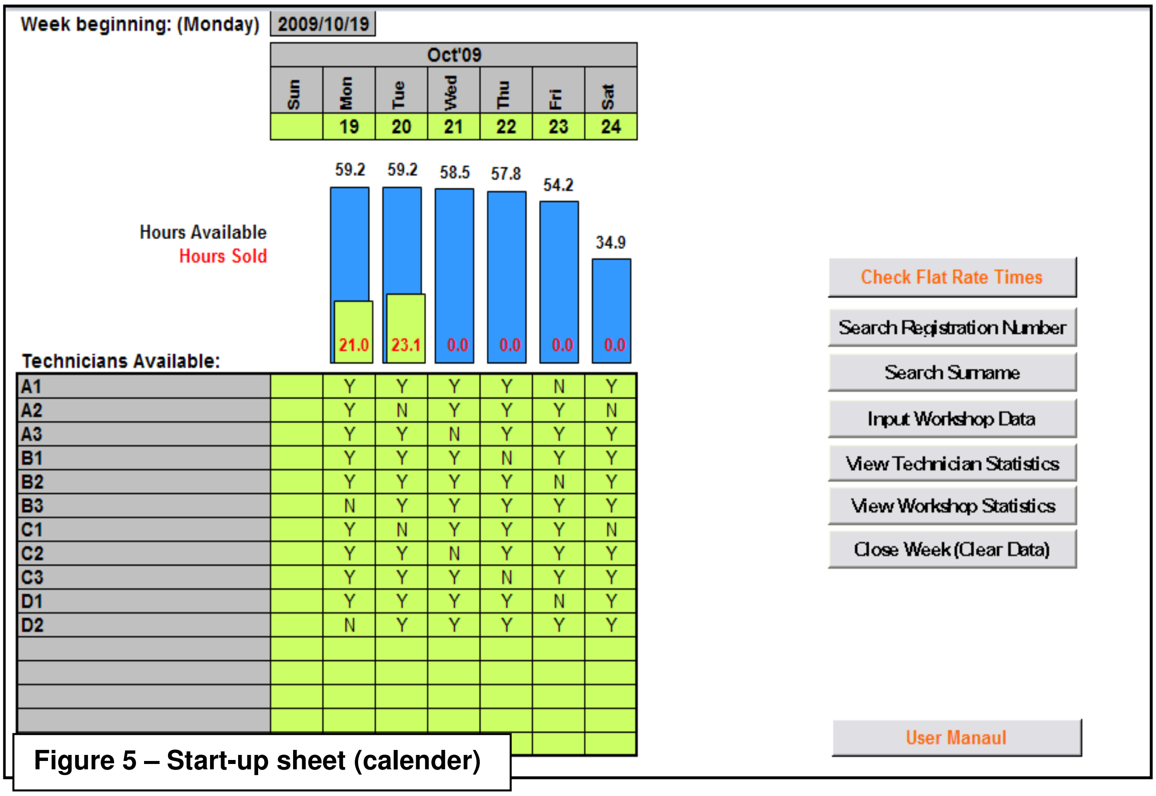


Figure 5 – Start-up sheet (calender)

Everything is done from this screen and this is also the sheet you always return back to. An important feature is that is has to be user friendly to opperate and should changes have be made to a booking, the booking must be easy to find. At the moment the JCS's schedule has to be deleted after a week before a new week's schedule can be booked. This causes all the customer's info to be lost. Saving the detail to a separate sheet and retrieving it by say using a lookup function can maybe solve this hassle.

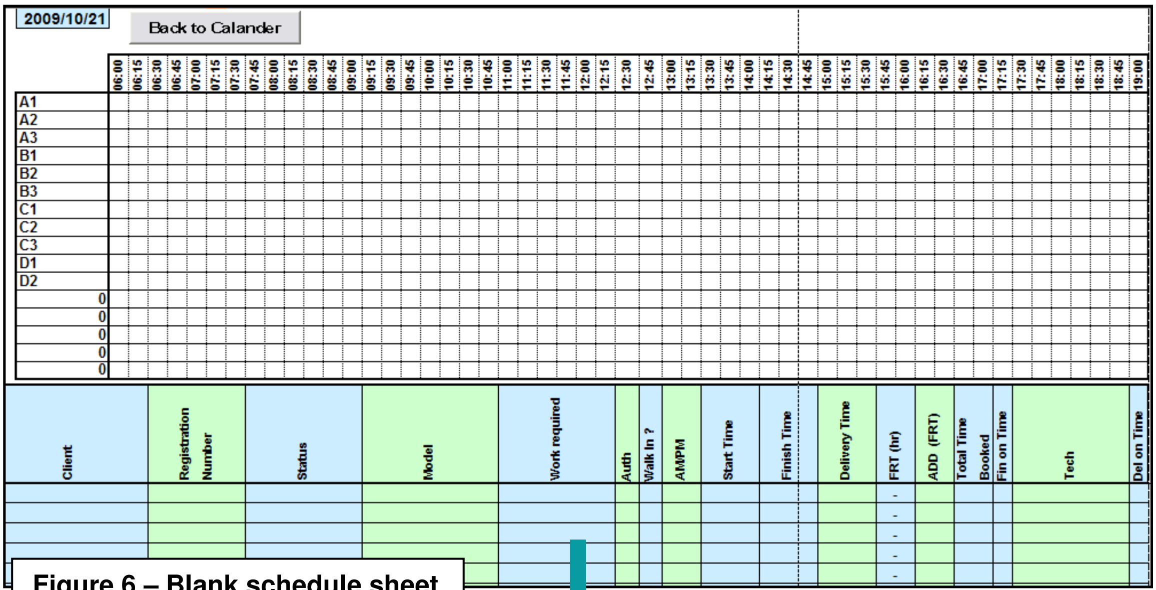
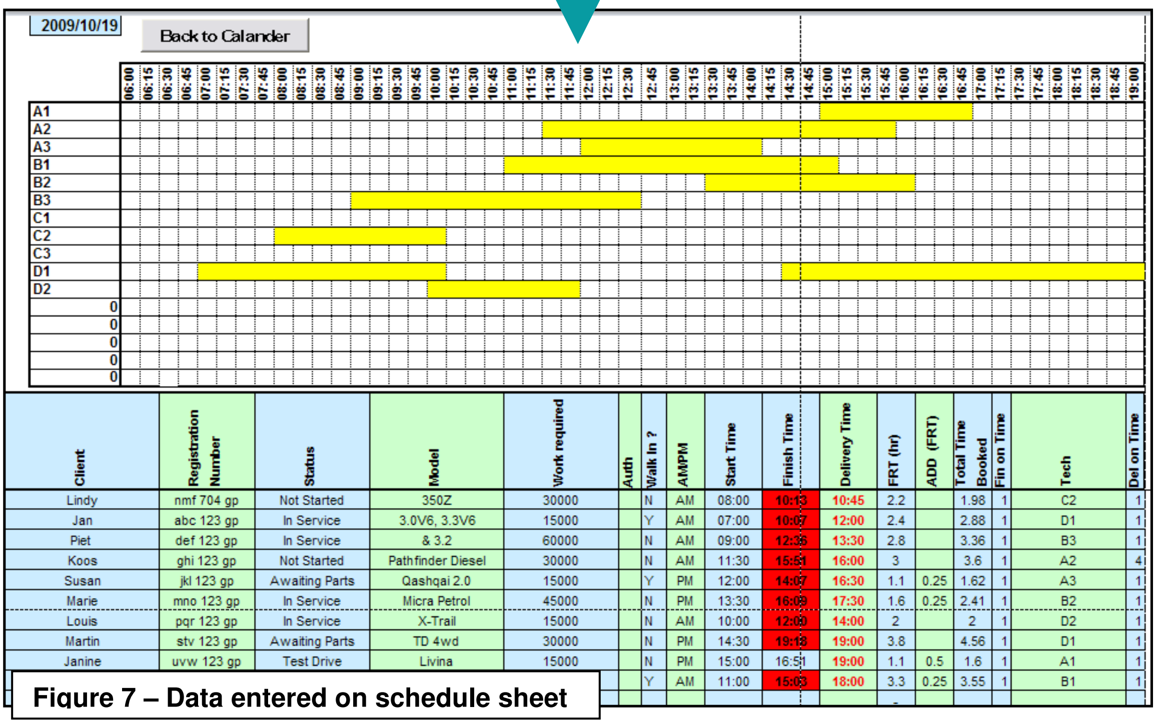


Figure 6 – Blank schedule sheet



Client	Registration Number	Status	Model	Work required	Auth	Walk In ?	AM/PM	Start Time	Finish Time	Delivery Time	FRT (hr)	ADD (FRT)	Total Time Booked	Fin on Time	Tech	Del on Time
Lindy	nmf 704 gp	Not Started	350Z	30000		N	AM	08:00	10:13	10:45	2.2		1.98	1	C2	1
Jan	abc 123 gp	In Service	3.0V6, 3.3V6	15000		Y	AM	07:00	10:07	12:00	2.4		2.88	1	D1	1
Piet	def 123 gp	In Service	& 3.2	60000		N	AM	09:00	12:36	13:30	2.8		3.36	1	B3	1
Koos	ghi 123 gp	Not Started	Pathfinder Diesel	30000		N	AM	11:30	15:51	16:00	3		3.6	1	A2	4
Susan	jkl 123 gp	Awaiting Parts	Qashqai 2.0	15000		Y	PM	12:00	14:07	16:30	1.1	0.25	1.62	1	A3	1
Marie	mno 123 gp	In Service	Micra Petrol	45000		N	PM	13:30	16:09	17:30	1.6	0.25	2.41	1	B2	1
Louis	pqr 123 gp	In Service	X-Trail	15000		N	AM	10:00	12:00	14:00	2		2	1	D2	1
Martin	stv 123 gp	Awaiting Parts	TD 4wd	30000		N	PM	14:30	19:18	19:00	3.8		4.56	1	D1	1
Janine	uvw 123 gp	Test Drive	Livina	15000		N	PM	15:00	16:51	19:00	1.1	0.5	1.6	1	A1	1
						Y	AM	11:00	15:03	18:00	3.3	0.25	3.55	1	B1	1

Figure 7 – Data entered on schedule sheet

Input to a specific days schedule will look like above. A problem identified that needs attention is that the technician list contains all the technician names instead of just the names of the technicians working on that particular day as specified on the start-up (Calender) sheet. This avoids choosing a technician that is not on duty and prevents realising the mistake too late.

Technician Information	Level	Ratio
A1		1
A2		0.8
A3		0.8
B1		1
B2		0.7
B3		0.8
C1		1
C2		1.1
C3		1
D1		0.8
D2		1

Back to Calander

Available Hours	
Monday-Friday	8.5
Saturday	5

Tea and Lunch Times	From:	To:
Morning Tea Time	09.00	09.15
Lunch	13.00	13.30
Afternoon Tea Time	15.00	15.15

Reserved for Walk-in Customers	15%

Figure 8 – Workshop info sheet

The above sheet obtains the information needed by the application to determine the productive hours available and the actual hours worked by each technician. The percentage of time reserved for walk-in customers are also entered on this interface.

Statistical information, the data as mentioned in the 'future use' section on a page 29, can also be generated from the Calender sheet. This data displays the technician and workshop information as to productive hours and reasons for delays, etc. If other reasons for a delay were specified, it will be displayed below the graphs of the relevant technician. An example of the statistical information is found on the next page.

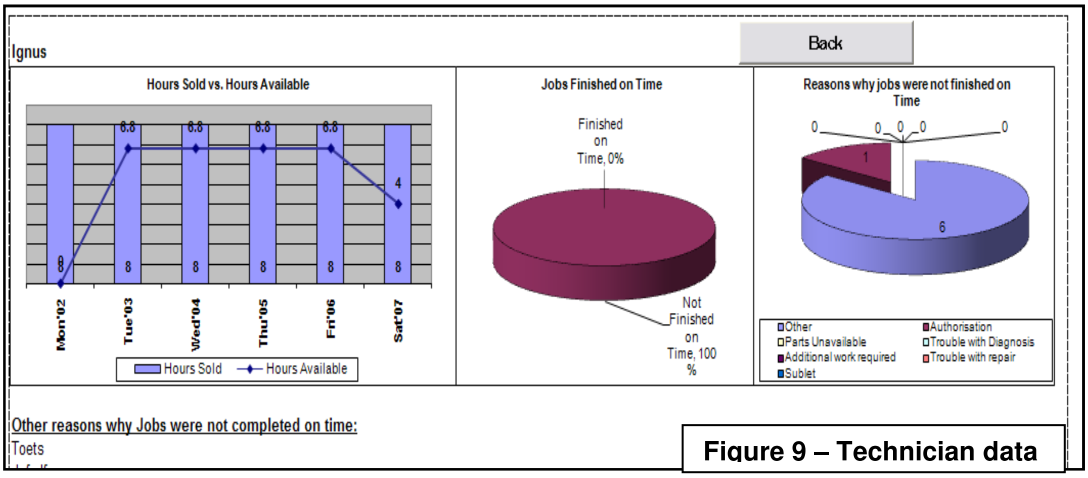
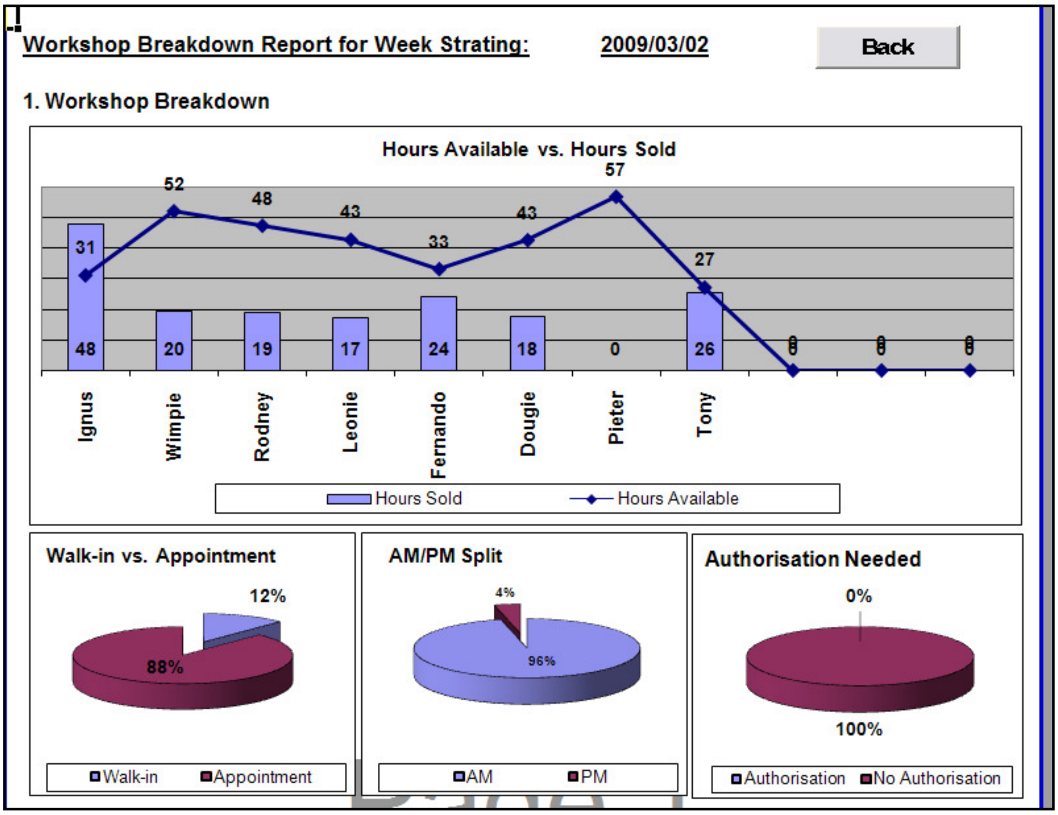
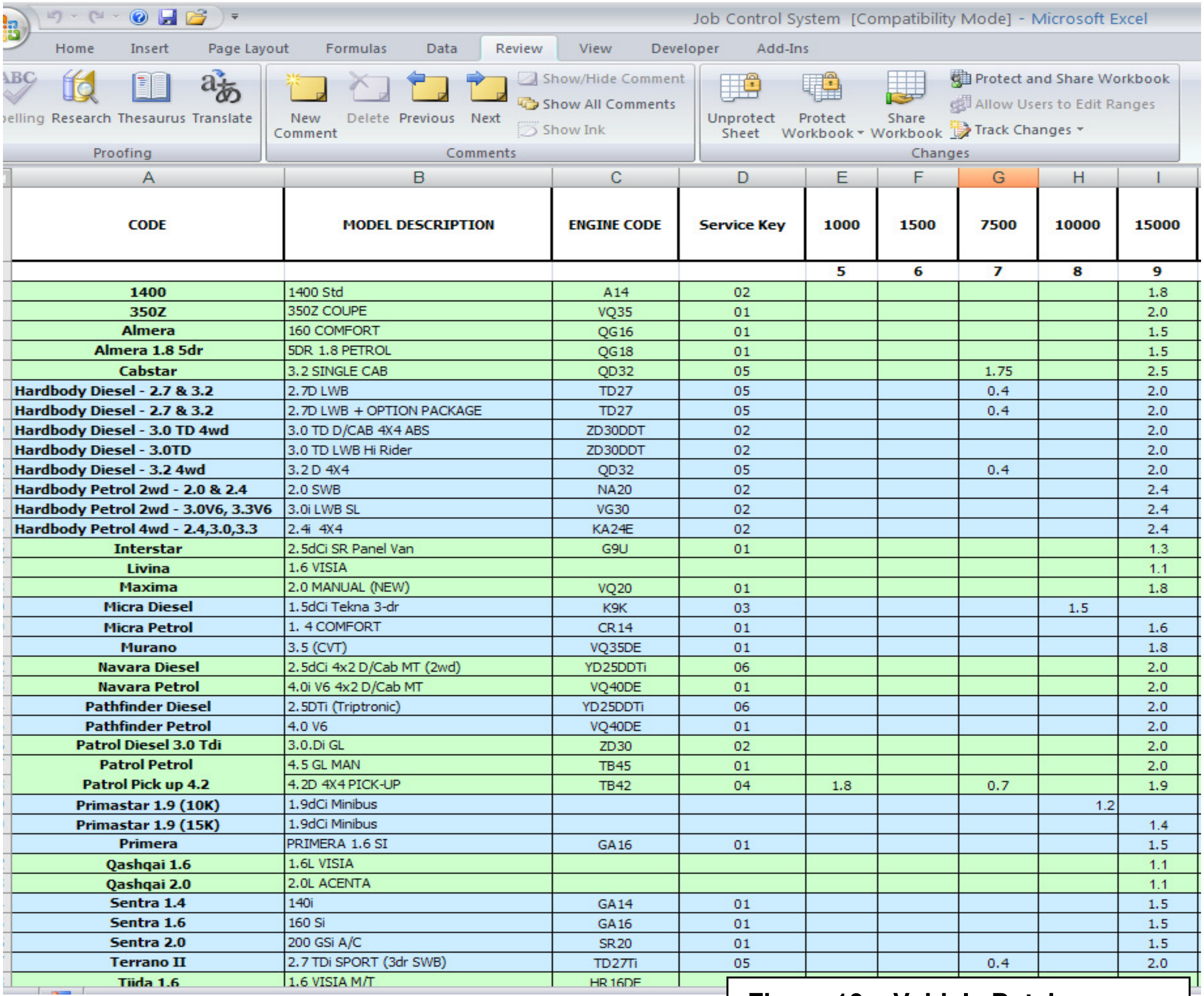


Figure 9 – Technician data



An example of the database with all the vehicle information, e.g. the FRT associated with the vehicle, engine code, etc. is displayed on the next page. This sheet is protected and only authorised people can change the data contained should it deem necessary.



CODE	MODEL DESCRIPTION	ENGINE CODE	Service Key	1000	1500	7500	10000	15000
				5	6	7	8	9
1400	1400 Std	A14	02					1.8
350Z	350Z COUPE	VQ35	01					2.0
Almera	160 COMFORT	QG16	01					1.5
Almera 1.8 5dr	5DR 1.8 PETROL	QG18	01					1.5
Cabstar	3.2 SINGLE CAB	QD32	05			1.75		2.5
Hardbody Diesel - 2.7 & 3.2	2.7D LWB	TD27	05			0.4		2.0
Hardbody Diesel - 2.7 & 3.2	2.7D LWB + OPTION PACKAGE	TD27	05			0.4		2.0
Hardbody Diesel - 3.0 TD 4wd	3.0 TD D/CAB 4X4 ABS	ZD30DDT	02					2.0
Hardbody Diesel - 3.0TD	3.0 TD LWB Hi Rider	ZD30DDT	02					2.0
Hardbody Diesel - 3.2 4wd	3.2 D 4X4	QD32	05			0.4		2.0
Hardbody Petrol 2wd - 2.0 & 2.4	2.0 SWB	NA20	02					2.4
Hardbody Petrol 2wd - 3.0V6, 3.3V6	3.0i LWB SL	VG30	02					2.4
Hardbody Petrol 4wd - 2.4,3.0,3.3	2.4i 4X4	KA24E	02					2.4
Interstar	2.5dCi SR Panel Van	G9U	01					1.3
Livina	1.6 VISIA							1.1
Maxima	2.0 MANUAL (NEW)	VQ20	01					1.8
Micra Diesel	1.5dCi Tekna 3-dr	K9K	03				1.5	
Micra Petrol	1. 4 COMFORT	CR14	01					1.6
Murano	3.5 (CVT)	VQ35DE	01					1.8
Navara Diesel	2.5dCi 4x2 D/Cab MT (2wd)	YD25DDTi	06					2.0
Navara Petrol	4.0i V6 4x2 D/Cab MT	VQ40DE	01					2.0
Pathfinder Diesel	2.5DTi (Triptronic)	YD25DDTi	06					2.0
Pathfinder Petrol	4.0 V6	VQ40DE	01					2.0
Patrol Diesel 3.0 Tdi	3.0.Di GL	ZD30	02					2.0
Patrol Petrol	4.5 GL MAN	TB45	01					2.0
Patrol Pick up 4.2	4.2D 4X4 PICK-UP	TB42	04	1.8		0.7		1.9
Primastar 1.9 (10K)	1.9dCi Minibus						1.2	
Primastar 1.9 (15K)	1.9dCi Minibus							1.4
Primera	PRIMERA 1.6 SI	GA16	01					1.5
Qashqai 1.6	1.6L VISIA							1.1
Qashqai 2.0	2.0L ACENTA							1.1
Sentra 1.4	140i	GA14	01					1.5
Sentra 1.6	160 Si	GA16	01					1.5
Sentra 2.0	200 GSi A/C	SR20	01					1.5
Terrano II	2.7 TDi SPORT (3dr SWB)	TD27Ti	05			0.4		2.0
Tiida 1.6	1.6 VISIA M/T	HR16DE						

Figure 10 – Vehicle Database

9. Conclusion

Even if the project scope changed and the Dynamic Programming could not be used, it is definitely the way forward in scheduling tasks to resources more optimally. It will deliver a quicker way of scheduling these tasks if a proper user interface can be built.

Nissan dealers will benefit from the spreadsheet application, especially when all the kinks are removed, because it will nullify the current Job Control Board that is not used as it was intended anyway (tedious if a lot of vehicles are booked). Excel with the help of functions and Visual Basic coding, can deliver really good interactive spreadsheet application to suit the end user's needs, if you make sure the customer requirements are fully specified beforehand.

Distributing the Electronic Job Control System between the dealers is the next step in ensuring an ever increase in the productivity of the workshops, delivering a better more efficient service, resulting in customer satisfaction and profit increase.

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Z
Altima
Altima Coupe
Quest
Rogue
Murano
Armada
Frontier
Titan
Xterra
Maxima
Versa
Pathfinder
Sentra
Sentra SE-R

11. Appendix

a. Visual Basic (code)

Following are a few abstracts of the code from the VB editor for the Calander sheet, but due to Nissan's confidentiality agreement not all the code will be displayed from the JCS.

```
Private Sub CommandButton1_Click()
Dim i As Integer, j As Integer, k As Variant, l As Integer, m As Integer
For m = 0 To 10

l = 0
If l < 22 Then
For j = 2 To 7
'Sheets(j).Select
'MsgBox j

For i = 1 To 80
            If Sheets(j).Cells(i + 24, 48) = 2 Then

            If Sheets(j).Cells(i + 24, 49) = Sheets("Technicians").Cells(m * 41 + 2, 1) Then
            k = Sheets(j).Cells(i + 24, 56)
            'MsgBox k
            Sheets("Technicians").Cells(m * 41 + l + 19, 1) = k
            l = l + 1
            Else

            End If
            Else
            l = l + 0
            End If

   Next i

Next j
Else
End If
Next m
Sheets("Technicians").Select
ActiveSheet.Cells(1, 1).Select
End Sub
```

```
Private Sub CommandButton2_Click()
Sheets("Sheet3").Select
End Sub

Private Sub CommandButton3_Click()

Dim i As Integer, j As Integer, k As Variant, l As Integer, m As Integer, q As Integer, r As
Integer, s As Variant, t As Integer, u As Integer
'For m = 0 To 10

l = 0
If l < 14 Then
For j = 2 To 7
'Sheets(j).Select
'MsgBox j

For i = 1 To 80
        If Sheets(j).Cells(i + 24, 55) = 2 Then

        'If Sheets(j).Cells(i + 19, 49) = Sheets("Technicians").Cells(m * 41 + 2, 1) Then
        k = Sheets(j).Cells(i + 24, 57)
        'MsgBox k
        Sheets("WS").Cells(44 + l, 1) = k
        l = l + 1
        Else

        End If

        l = l + 0


   Next i

Next j
Else
End If

t = 0
If t < 14 Then
For r = 2 To 7
'Sheets(j).Select
'MsgBox j

For q = 1 To 80
        If Sheets(r).Cells(q + 24, 48) = 2 Then
```

```
            'If Sheets(j).Cells(i + 19, 49) = Sheets("Technicians").Cells(m * 41 + 2, 1) Then
            s = Sheets(r).Cells(q + 24, 56)
            'MsgBox k
            Sheets("WS").Cells(74 + t, 1) = s
            t = t + 1
            Else

            End If

            t = t + 0


    Next q

Next r
Else
End If

'Next m
Sheets("WS").Select
ActiveSheet.Cells(1, 1).Select
'Sheets("WS").Select
End Sub

Private Sub CommandButton4_Click()
Dim j As Integer, Status As Variant
Status = MsgBox("Clear all Data?", vbYesNo)
If Status = 6 Then
For j = 2 To 7
Sheets(j).Select

ActiveSheet.Range("A25:AD89,AG25:AI89,AM25:AO89,AR25:AS89,AV25:AV89,AW25:
BE89").Select

    Selection.ClearContents
    Next j
Sheets("Calander").Select
ActiveSheet.Range("D10:I25").Select
Selection.ClearContents
Else
End If
End Sub

Private Sub CommandButton5_Click()
Dim Status As Variant, num2 As Variant, check2 As Variant, i As Integer, j As Integer, k As
Integer, check As Variant
```

```
Status = InputBox("Enter Registration number")
num2 = 1
check = Status
If check = "" Then
check2 = "True"
Else
check2 = "False"
End If
If check2 = "False" Then
For j = 2 To 7
'Sheets(j).Select
'MsgBox j

For i = 1 To 65
            If Sheets(j).Cells(i + 24, 5) = Status Then
            num2 = 2
              Sheets(j).Select
              ActiveSheet.Cells(i + 24, 5).Select
           ' MsgBox "Next"
          Else
         'num2 = 1
           End If
   Next i
Next j

'If num2 = 2 Then
'MsgBox ("Not Found")
'End If
Else
End If
If num2 = 1 Then
MsgBox "Registration number could not be found"
Else
End If

'MsgBox Status
End Sub

Private Sub CommandButton6_Click()
Dim Status As Variant, check As Variant, check2 As Variant, num2 As Variant, i As Integer,
j As Integer, k As Integer
'num2 = 2
Status = InputBox("Enter Surname")
num2 = 1
check = Status
If check = "" Then
```

```
check2 = "True"
Else
check2 = "False"
End If
If check2 = "False" Then
For j = 2 To 7
'Sheets(j).Select
'MsgBox j

For i = 1 To 65
              If Sheets(j).Cells(i + 24, 1) = Status Then
               num2 = 2
                Sheets(j).Select
                ActiveSheet.Cells(i + 24, 1).Select

            Else
           '  num2 = 2
             End If
    Next i

Next j
Else
End If

If num2 = 1 Then
MsgBox "Surname could not be found"
Else
End If
End Sub
```

b. User Manual

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