A Model for Upgrading Fleets under Constrained Conditions

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Abstract

This paper begins with a general discussion of the dynamics of maintaining a fleet of vehicles in a high state of preparedness against high level and ongoing demands on the fleet. The paper presents a model that was used to simulate and evaluate three strategies for a major upgrade to the fleet. The paper concludes with some observations about the general conditions under which the model can be used.

Introduction

Maintenance scheduling is central to the readiness of land, sea and air vehicle fleets, particularly those that have heavy emergency demands in a military or paramilitary setting. The increasing complexity and sophistication of modern fleets means that there can be significant downtime involved in maintaining a fleet to an acceptable operating level.

The Rapid Response Training School (RRTS) is a large training facility responsible for training Rapid Response Vehicle (RRVs) personnel, located at a disused air base located on a large lake. RRTS maintains a large fleet of 30 RRVs both land-based and amphibious. The Instructor School maintains a fleet of 15. The main clients for RRTS are State and Federal paramilitary emergency services and the military. Training focuses on the use of emergency vehicles in both urban and non-urban settings. Most of the personnel who graduate from RRTS are already employed by organizations using RRVs. There are also an increasingly large number of international organizations sending trainees. In addition to the main training facility, there is also an Instructor School, which trains instructors for RRTS as well as maintaining a small group of highly skilled personnel, known as the Daredevils, who take part in public demonstrations of RRV driving skills. The reputation of this group generates significant demand for places at Instructor School.

The nature of the training is such that all vehicles work close to the limits of their performance and damage to the vehicles is commonplace. Occupational Health and Safety requirements mean the vehicles are subject to frequent and rigorous maintenance schedules involving significant downtime.

In addition to the maintenance schedules resulting from normal operations, changes in technology, particularly information technology, mean that the fleet often requires major time-consuming upgrades, which can severely choose the availability of vehicles for training. RRTS was originally a government owned and operated facility but was privatized in the early 1990s. Significant periods of downtime, especially those resulting from major upgrades, severely restrict cash flow and affect profitability. RRTS was particularly keen to mitigate the impact of a major technological upgrade on its vehicles. The model presented in this paper, the details of which are Commercial-in-Confidence, examines three strategies for the technological upgrade. The paper concludes by generalizing the strategies to a general class of problem and fleet management.

The Model

The model captures four dynamics, Serviceable Vehicles, Rate of Effort (ROE) Maintenance Processes and the Scheduling of Upgrades for the fleet of 45 vehicles. There are two scheduled maintenance processes: Level 1 and Level 2 maintenance which is performed on vehicle hours rather than kilometres travelled because of he nature of he work. Unscheduled maintenance is in response to faults detected during operations and damage.

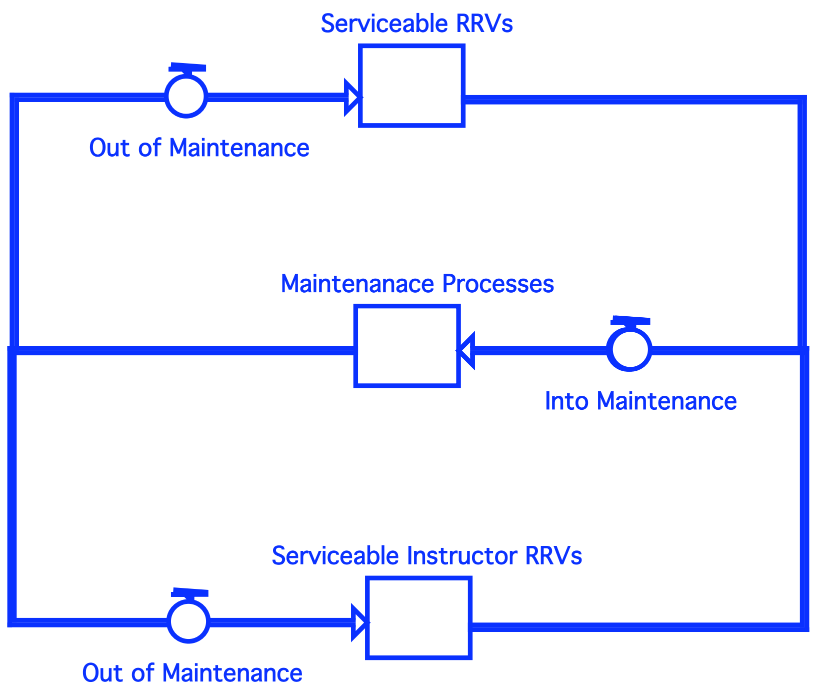

Figure 1: Generalized Maintenance Model

The number of vehicles in all forms of maintenance determines the number of Serviceable Vehicles. ROE per vehicle is driven by the annual schedule of intakes of trainees and the number of serviceable vehicles available for training. Trainees must complete 100hrs on their specialisation and 20hrs on all other vehicles. The intensity of the training means that unscheduled maintenance is a significant factor in maintaining profitable graduation rates.

As the number of serviceable vehicles declines, the ROE per vehicle increases, to meet the training schedule. This extra workload has the effect of not only increasing unscheduled maintenance speeding up the scheduled Level 1 and Level 2 Maintenance. The overall result is that while ROE per vehicle is increasing over time, the overall ROE for the base is declining because of declining Serviceability.

Serviceability is a measure of how many vehicles are of available to be driven on a given day. When a vehicle is considered unserviceable, often as a result of visual inspection, it is put in Unscheduled Maintenance for repairs. While this is often for a very short period of time, sometimes less than a day, there are always a significant number of vehicles in this process. The vehicles were achieving 65% serviceability early in its service history. This means that 65% of the fleet is available at that time. During 10 years of service of the current fleet, serviceability declined to 30%.

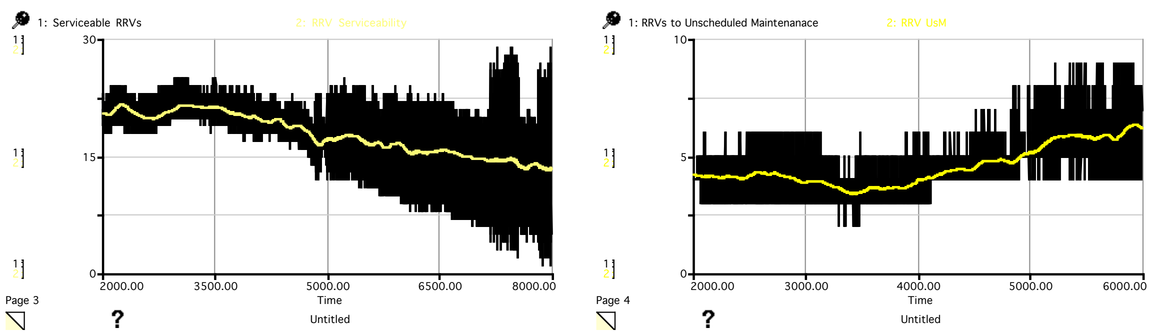

Figure 2: Declining Serviceability and Increasing Maintenance downtime.

Figure 2 indicates the vehicles serviceability history generated by the model, which was an accurate replication of data kept by RRTS. The rolling average data was based on a three-month rolling average. As the vehicles aged, rates of serviceability became increasingly unstable and unpredictable as a result of increasing unscheduled maintenance.

The number of serviceable vehicles is driven by Rate of Effort (ROE). ROE is a measure of the number of driving hours per day the vehicles. The Cumulative ROE is an indication of the amount of work the vehicles has done during its service history and an indication of the likelihood of the vehicles requiring Unscheduled Maintenance.

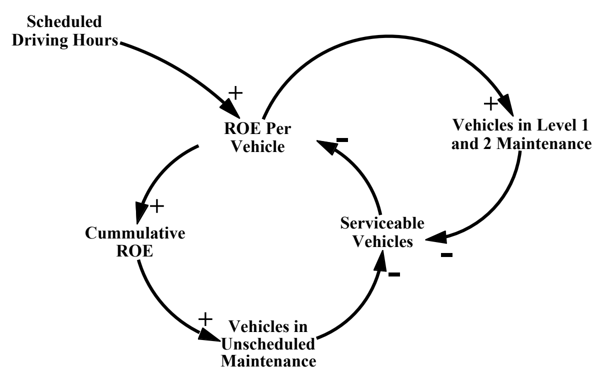

Figure 3: CLD showing the vicious cycle of increasing Cumulative ROE.

This means that, over time, there are fewer vehicles available to meet the scheduled demands of school's training program. With fewer vehicles available, the available vehicles are pushed harder to meet the schedule. This accelerates the decline in serviceability making fewer vehicles available for training.

The impact that this has on the training schedule is twofold. The first impact can be to slow the rate at which trainees complete their training. The second impact can be a conscious decision to restrict the intakes into the school to a level commensurate with the declining number of serviceable vehicles. In both cases, this results in a lower profitability for the school. The scheduled intakes into the school were two cohorts of 15 staggered approximately every 6-7 weeks. On average four trainees drop out, or are cut from, the training program. The total training period for one flight is 30 weeks. There are two to three graduations a year. The table below indicates the longer periods required for training the cadet pilots as the vehicles ages

Timing of a Major Upgrade

Advances in Ground Positioning Technology (GPT) and its increasing adoption in the client groups have meant that RRTS must upgrade all of its vehicles to remain competitive. The problem facing RRTS is when and how to schedule a major upgrade for the vehicles because this will represent a significant disruption to training schedules increasingly delayed through vehicles unavailability.

The floor loading of the upgrade process is 4 vehicles and the time for the upgrade was 25 days per vehicle if there are no complications. The total upgrade was expected to take a minimum of eight months and, given the time required to ramp up, it was expected that the gap between graduations could be as great as a year.

The major complication for the upgrade process was that trainees would need complete their training on the same type vehicle as they began it, meaning there would be no swaps to upgraded vehicles in midcourse. Graduates who had trained on the pre-upgrade vehicles would be offered a refresher program on the new GPT.

It was obvious that once the upgrade process had begun it would not be possible to make another intake into the training school as the number of serviceable vehicles would decline and only be capable of running out the current program. It would also not be possible to recommence training on the upgraded vehicles until there was a cohort probably of around 30 upgraded vehicles for a new intake. This would allow a normal intake of 30 cadets. The difficulty with taking smaller and earlier intakes is that attrition rates normally run at around 40% the graduation number would be much lower and there would be a substantial number of surplus upgraded vehicles waiting for the next intake that cannot begin until the previous intake is halfway through their course.

There were a number of strategies for competing the upgrade. One was to run all the training vehicles through the upgrade program and recommence training when a critical mass of upgraded vehicles is available. Figure 4 provides the generalised model on the left and on the right the decline in numbers of pre-upgrade vehicles, the increase of upgraded vehicles. The graduations for this strategy are shown as the black spikes.

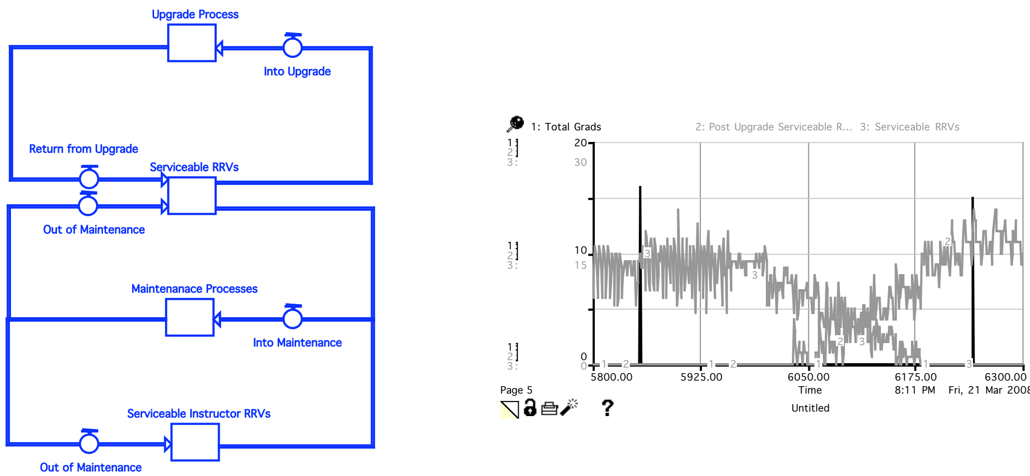

Figure 4: Generalised Model and Performance for the Training School Strategy

Using the Training School strategy gave an elapsed time between graduations of slightly under 12 months.

The second strategy was to send batches of four vehicles to ITS and begin running ITS vehicles through the upgrade, returning upgraded vehicles to the Training School and recommencing training when a critical mass of vehicles is available. The figures below show the differences in the times for graduations on the upgraded vehicles. The model and performance for the Instructor School model is shown in Figure 5.

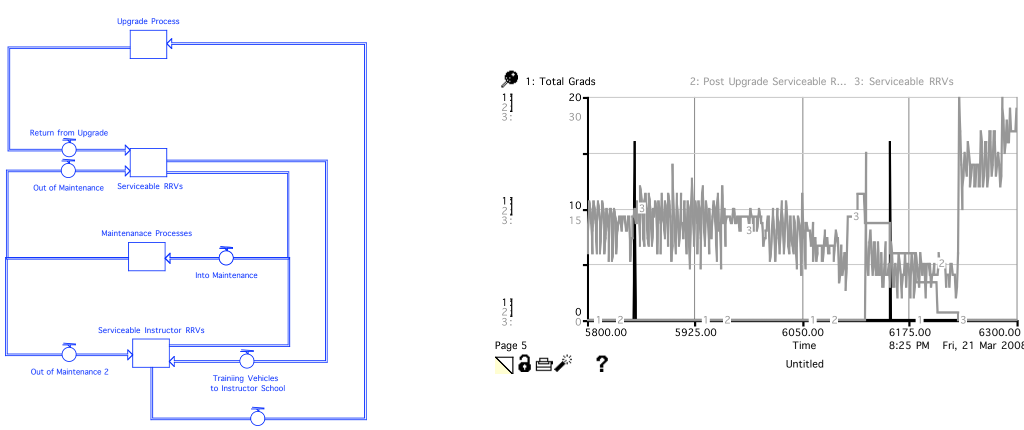

Figure 5: Generalised Model and Performance for the Instructor School Strategy

Using the Training School strategy gave an elapsed time between graduationsof9 and 10 months.

The final Integrated strategy was to send Training School vehicles to the Instructor School in batches of four and replace the training school fleet with instructor School vehicles immediately and then send Instructor School vehicles for upgrade. This effectively runs down the instructor fleet but maintains the Training School fleet. The impact of this strategy on Training School graduations is shown in Figure 6.

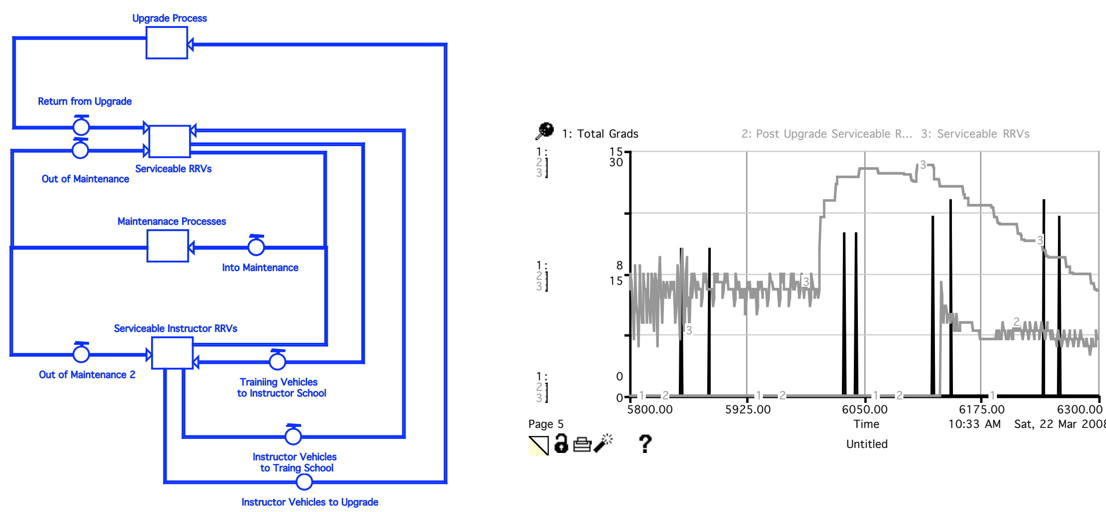

Figure 6: Generalised Model and Performance for the Integrated Strategy

Using the Integrated strategy gave an elapsed time between graduations slightly over three months. Adoption of this strategy would restore approximately 9 months cash flow to RRTS.

Discussion

The integrated strategy was clearly the superior one from the point of view of maintaining the cash flow generated by the Training School. Maintaining the Training Schools operations was done at the expense of the vehicles at the Instructor School. Because the Instructor School did not generate revenue, the Integrated Strategy was clearly the most viable financial option. The potential long-term downside for the strategy was that the capability of the instructors was expected to decline during the transition period. This would be particularly marked in the high profile elite Daredevils group, which played an important public relations and marketing role for RRTS.

This model has general application situations where major upgrades are required to vehicle fleets need to be maintained in a constant state of readiness against a defined but unpredictable threat and where there is a buffer system that can be used mitigate the downside risk to preparedness.