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PLANNING AND CONTROL FOR A WARRANTY SERVICE FACILITY

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ABSTRACT

A warranty service facility for industrial products that also provides internal support by reworking production defects is considered. An important concern is the evaluation of policies for how technicians with flexible skills should be moved between the service facility and adjacent production facility. Relevant measures include warranty cycle times and the overall technician utilization levels. An approach is developed that allows incoming warranty work loads to be monitored using control charts. Workload information is then used in simulating behavior using different "flexing" policies. As well, warranty cycle times are monitored using control charts. Results indicate the approach is of practical interest and can be effectively implemented.

1 INTRODUCTION

Planning and control within a warranty service facility is distinctly different from manufacturing planning and control. On the one hand, warranty service for many industrial products is simpler and can often be described as a single processing stage. As well, there are not likely to be various lot size and coordination issues. On the other hand, the service facility usually has no control over the arrival patterns of warranty jobs. Therefore work loads are more difficult to manage. Using flexible resources may be a good option if workers can readily be moved between production and service functions. This is referred to as "flexing".

The scenario examined in this study is one where industrial electro-mechanical products are manufactured and serviced. Products that have failed in the field are shipped back to the manufacturer by the customer. There is flexibility to move trained workers between the production and service functional areas. As well, the warranty service area provides support for manufacturing problems. In other words, quality problems identified on the manufacturing floor are sent to the warranty service area for rectification. These internal jobs tend to have priority.

The challenge in managing the service facility is one of maintaining high customer service levels while keeping costs low. This amounts to controlling warranty cycle times, defined to be the time from when the defective unit is received to the time the repaired unit is shipped back, while still maintaining high utilization rates for service technicians. In this research, the tradeoffs between customer service levels and technician utilization levels are investigated using discrete-event simulation. The objective is to come up with an operating policy that can take advantage of technician "flexing" to meet desired metrics on service and utilization.

The approach developed has three components. First, a system is developed to monitor the arrival rates of incoming warranty claims, for on each product line. This monitoring is done using statistical control charts. If significant changes in arrival rates are signaled, the effects of changes in workloads may need to be considered. Second, simulation is used to evaluate policies for changing technical staffing levels in the warranty lab. In other words, simulation is used to determine policies for "flexing" technicians in and out of the warranty service area. Third, a system is developed to monitor the warranty cycle times. This is again done using a statistical control chart. Since cycle times are dependent on transient workloads, the fact that observations are highly auto-correlated must be taken into account.

2 MONITORING INCOMING WORK LOADS

The product arrivals requiring warranty service come from many different customers or distributors at diverse geographical locations. There are a number of different product lines, each of which has different sales and failure rates. The product applications are industrial and demand or failure is not seasonal. From a customer's perspective, it is important that parts sent for warranty service are repaired or replaced quickly.

Since failures are independent for each of the product lines, the arrival of warranty claims can be viewed as a

Poisson process. This means claim interarrival times for each product line will fall into a negative exponential distribution. The claims for any given period are therefore approximately normal when the expected number of failures is sufficiently high. In this research it was assumed that an appropriate review period was one month. Therefore, the number of claims per month was monitored for each product line. These claims were graphed using normal probability plots to verify they were normally distributed.

Since there is only one value for the number of claims per month, a sample size of one must be used if plotting the results on a control chart. An Individual-Moving Range (I-MR) chart is appropriate for this purpose if the assumption of normally distributed claims per period is acceptable. Figure 1 shows an I-MR chart, generated using Minitab® (Minitab, 2000), of claims per month for one of the product lines. The results indicate the frequency of claims remained statistically unchanged over the year-long time horizon being plotted. In other words, there were no significant shifts in the pattern of warranty claim arrivals.

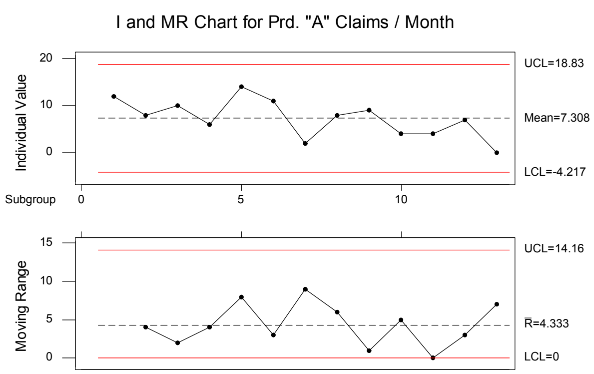

Figure 1: I-MR Chart for Claims

For some products the number of warranty claims per period was not high enough to be normally distributed. In such cases the use of Cumulative Sum (CUSUM) and Exponentially Weighted Moving Average (EWMA) charts was investigated. Figure 2 shows a sample of an EWMA chart for claims per period for one such product. A smoothing constant of 0.10 and control limits at 2.7 standard deviations were chosen (see Montgomery, 2005, p. 412). This chart shows the pattern of warranty claims arriving is again under statistical control.

EWMA charts are suitable for this application since they are quite insensitive to the data distribution. They are also more sensitive to shifts in the mean than I-MR charts and therefore can detect changes in the arrival rate of warranty claims more quickly. In some cases these shifts may be expected. Examples would be due to growth / decline in sales or phase in / phase out issues. However, shifts could also be due to design, production or material problems. In such cases, more rapid detection of changes in the warranty claim rates could lead to earlier investigation of the root cause.

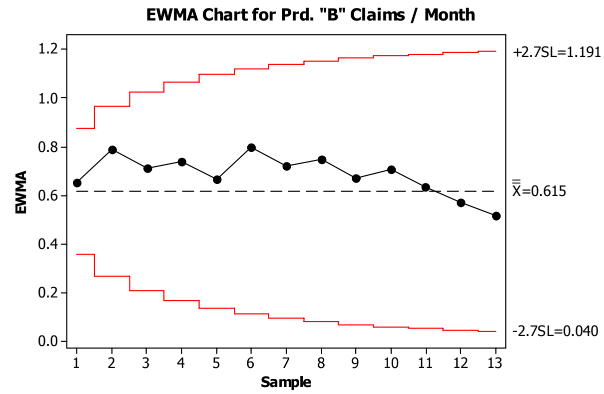

Figure 2: EWMA Chart for Claims

3 MODELING THE SERVICE FACILITY

The warranty service facility was modeled using ARENA® 5.0 simulation software (Kelton, et al., 2002). An EXCEL® workbook was used as an interface for inputs and outputs. Visual Basic for Applications® (VBA) was used to facilitate communication between the workbook and simulation model. VBA was also used to specify the structured experimental designs used in evaluating the performance under various parameter settings.

The incoming stream of warranty jobs was modeled using a negative exponential interarrival time distribution. The mean interarrival times for each product line were determined from historical data. As well, the mean and variance of warranty service times for each product line were determined from past data. The technician service time delays for warranty jobs were modeled using a normal distribution.

The facility had three full time technicians assigned to the service facility. A fourth technician could be brought over from the manufacturing facility on demand. This was referred to as a “flex” worker. All incoming warranty jobs joined a common queue and were processed on a first-come-first-served (FCFS) basis.

The warranty service facility also provided support to manufacturing by reworking defects identified in production. These jobs had priority. Analysis showed that over the long term, production support required the equivalent of 1.69 full time technicians. However, the technicians normally all worked on production rework jobs and then, when completed, all switched over to warranty service jobs. Therefore, a portion of each day was assumed to be unavailable for warranty work. The actual time unavailable each day was modeled using a Gamma distribution with a coefficient of variation (CV) of 0.30. It was assumed all technicians were involved in internal rework during this block of time. If the fourth technician was in the service facility during the time internal production rework jobs were being done, this person was also assigned to work on internal jobs along with the other three technicians. The duration of the time spent doing internal jobs was adjusted on the basis of the number of technicians currently in the service facility. The fourth technician was never allowed to "flex" out of the service facility during the time internal jobs were being processed.

An important objective of this research was to determine when to "flex" the fourth technician in and out of the warranty service facility. It was recognized that this technician should be brought in if the warranty work in queue exceeded some level. Otherwise, warranty cycle times would become excessive. However, once a technician is moved from production to service, it is desirable to keep this person busy in the service facility for some length of time. Therefore a decision rule, or trigger, is required to bring the technician into the service facility and another one is required to release the technician back to production.

Two types of triggers were used in this research. The first was based on the number of warranty jobs in queue (JIQ). If the jobs in queue reached an upper trigger, the fourth technician was brought in. If the jobs in queue fell to a lower trigger, the technician was released. The second type was based on the estimated warranty load (EWL), where load was defined to be the estimated total warranty service time required for jobs in queue. This estimated load was based on the types of products in queue and the expected service times for jobs of this type. Therefore, the amount of work rather than just the number of jobs in queue was considered. An upper and lower work load trigger again needed to be defined.

Customer service performance was evaluated in terms of the mean warranty queue time. In other words, the time between the arrival of a warranty job and the time service started was monitored. However, it was also of interest to make sure the utilization level of technicians assigned to the service facility remained quite high. If the fourth technician is assigned to the service facility too high a proportion of the time, the utilization level of the other three technicians will be too low. If the fourth technician is not assigned to the service facility enough of the time, warranty cycle times will be too high. Therefore, a tradeoff between these performance measures exists. Acceptable performance on both dimensions depends on the appropriate selection of the trigger levels.

4 EVALUATING STAFF "FLEXING" POLICIES

Scenarios were simulated using different combinations of trigger settings. Each run involved a warm up period of 5000 minutes and a data collection period of 1,000,000 minutes of simulated time. Twenty replications were run at each combination of settings tested.

Figure 3 shows one set of results obtained using different jobs-in-queue (JIQ) trigger levels. The upper trigger is shown on the horizontal axis. The policy used in generating these results was to set the lower trigger equal to half the upper trigger. For example, if the upper trigger is 10, the fourth technician would be called into the service facility once the warranty jobs in queue reached 10. This technician would remain in the service facility until the warranty jobs in queue fell to 5. In other words, if there were 5 or less jobs in queue at the time the "flex" technician completed a warranty job, this technician would return to work in the manufacturing facility.

The behavior in Figure 3 is consistent with expectations. As the upper trigger moves from 0 to 30, the average queue time (QTime) for warranty service jobs increases from about 80 to 920 minutes. The utilization level for the "flex" technician (FL_War), shown on the right hand axis, drops from about 32% to about 10%. The average utilization for the three full-time technicians (FT_War) increases from about 37% to 44%. Note that these utilization levels are only for the time spent working on warranty jobs. If only three technicians were used to do all internal production rework, this would represent 56.45% of their time. Therefore, overall utilization rates for the full-time technicians (FT_Tot) are actually quite high at the larger JIQ trigger levels.

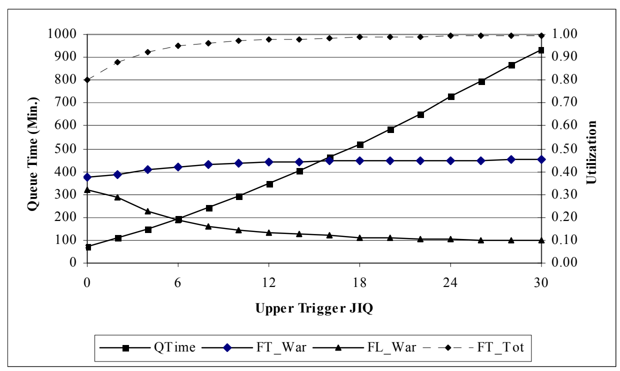

Figure 3: JIQ Results

Additional analysis related to the frequency of moves and duration of "flex" worker time in the service facility was of interest. Figure 4 shows a plot of the average time the fourth worker spends in the service facility each visit (FL_Work). As well, the average time interval between visits to the service facility (FL_Interval) are plotted. These times are indicated on the right-hand axis.

Similar results were obtained using EWL triggers. It might be expected that using the estimated work load in queue, based on the types of products needing service, would provide better information for "flex" control than just counting the jobs in queue. However, the practical benefits proved to be insignificant. The reason was that service times for any product type were quite variable. As well, the distribution of service times for different product types was not greatly different. Therefore, little benefit was obtained by using the expected service times to calculate work loads. Since "flexing" based on JIQ triggers was simpler than using EWL triggers, JIQ triggers were chosen for implementation.

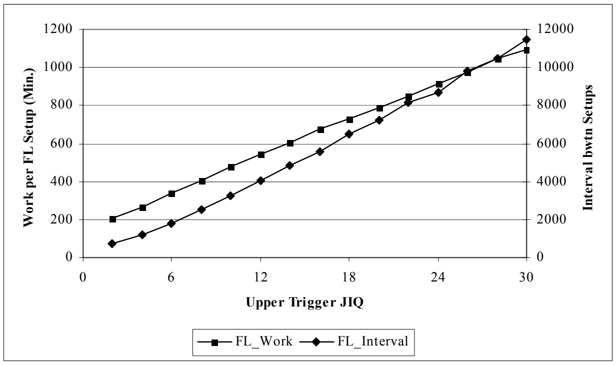

Figure 4: "Flex" Technician Time Intervals

5 MONITORING WARRANTY CYCLE TIMES

The waiting times for warranty jobs were highly correlated since they are dependent on the number of jobs already in queue. Figure 5 shows the queue time pattern, generated using the simulation model, for 1000 consecutive jobs. The auto-correlation function of these queue times is shown in Figure 6.

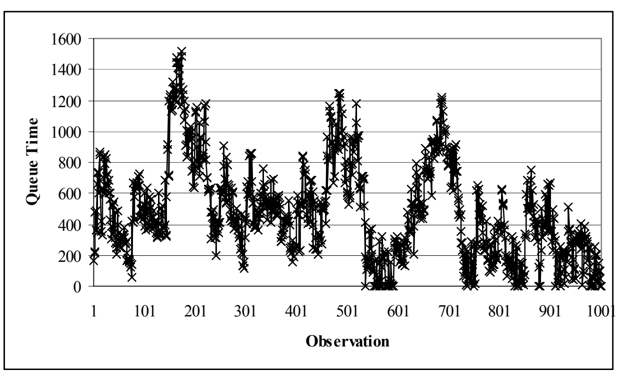

Figure 5: Transient Queue Times

ARIMA modeling was used to evaluate the queue time auto-correlation relationships. It was found that a first-order auto-regressive model using a lag of two fit well. This model is shown as follows,

$$Wq_{t_t} = 28.5 + 0.66Wq_{t-1} + 0.28Wq_{t-2}.$$

The partial auto-correlation function for the residuals obtained after fitting this model are shown as Figure 7. From this graph it can be seen that removing the auto-correlation effects from within a two-period lag results in residuals that are no longer auto-correlated.

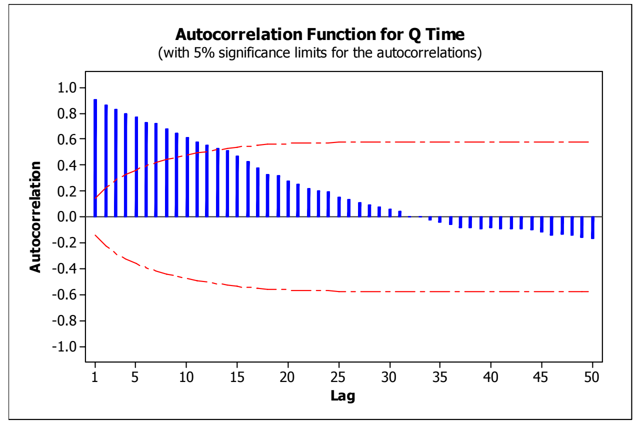

Figure 6: Auto-correlation Function

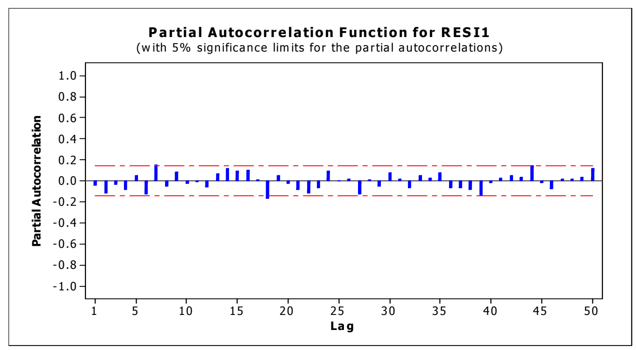

Figure 7: Partial Auto-correlation

An individual-moving range (I-MR) control chart for the residuals is shown in Figure 8. This graph shows that the residuals resulting from the model are within statistical control for the most part. Several points are shown to exceed the control limits but typically these do not involve sequential observations. Therefore, the model was judged to be acceptable and residuals based on future queue times can be plotted on this type of control chart. If the points plotted remain within the control limits, it can be concluded that the underlying warranty queue time pattern has not changed. An out of control signal would indicate the pattern has likely changed and warranty service performance may have to be further examined. Although the queue time analysis is shown using simulation results, implementation would be based on using actual observed queue times.

6 CONCLUSIONS

The objective of this research was to develop a structured way of examining the warranty service process and to introduce ways of evaluating and controlling the process. The approach of using control charts to monitor incoming warranty claim rates by product line appeared to be effective. The charts can be used for work load planning as well as for detecting shifts in arrival patterns which may be due to design or production problems.

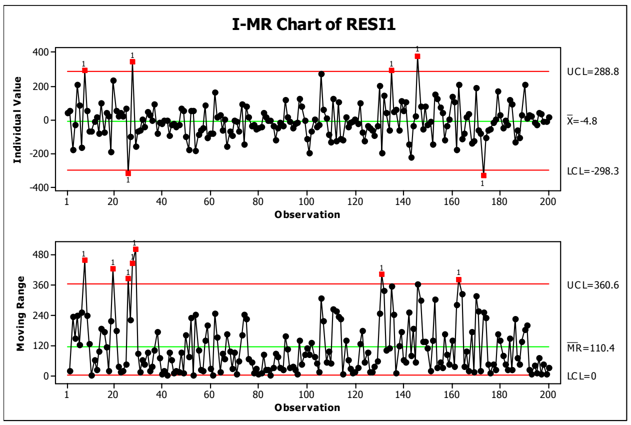

Figure 8: Control Chart for Residuals

Simulation of the system is useful in evaluating the tradeoffs between warranty cycle times and the utilization level of service personnel. Different rules for "flexing" workers in and out of the service facility can be very quickly evaluated. Results showed that having workers which can be moved between production and service functions is beneficial. However, no attempt was made to optimize performance since defining an objective function is somewhat arbitrary, given the problem environment. Instead, it was determined that professional judgment could be used to evaluate the tradeoffs observed from the simulation results and to select a decision-rule to "flex" workers in and out of the warranty service facility.

Finally, the warranty cycle times can be statistically monitored even though they are highly auto-correlated through time. The use of control charts for the residuals from first-order auto-regressive models can be used to determine if there are significant changes in the underlying waiting time pattern.

The combination of using statistical control charts and simulation to analyze and monitor the warranty service facility is summarized in Figure 9. This methodology appears to offer significant benefits. The opportunity to apply such modeling and analysis techniques to other service industry applications needs to be explored further.

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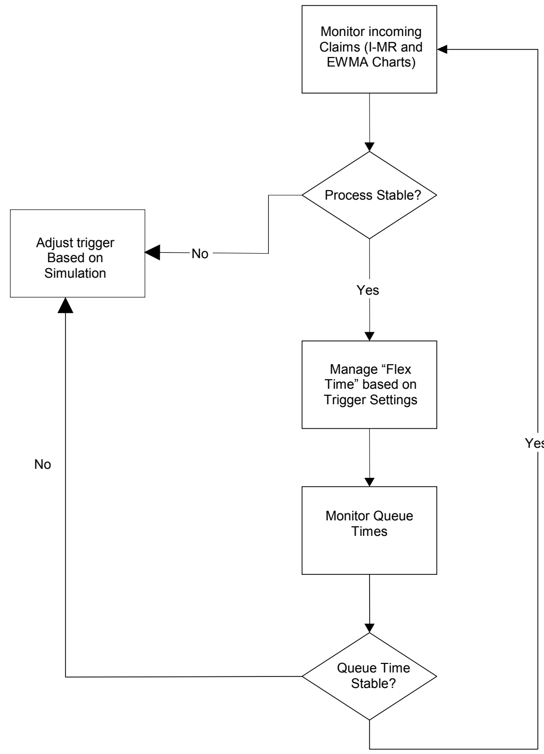

Figure 9: Planning and Control Flow Chart

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