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New Metrics and Visualizations to Help the Army Reduce Customer Wait Time

The Army maintenance process uses customer wait time (CWT, in days) as a metric of the responsiveness of its order fulfillment process—i.e., the number of days for a mechanic or supply clerk to order a repair part and receive it. CWT requires close management because the order fulfillment process is subject to delays and disruption. For many reasons, the logistics system might not fulfill a specific requisition for a repair part in a timely manner, and CWT might begin to lengthen. The Army continually seeks to manage and reduce CWT, particularly for those repair parts that are needed to complete a repair and make a piece of Army equipment operational, mission capable, and available for use.

RECOMMENDATIONS

- The Logistics Support Activity should implement new Tableau dashboards into the Materiel Common Operating Picture to help managers analyze CWT.
- To reduce CWT, managers should focus on reducing the longest segment times.
- The Army should set standards for duration and goals for decreasing the standard. These standard times should be short and should decline gradually over time.
- Unit commanders should be accountable for reducing the maxima of these segments over time, as well as the variability.
- To manage outbound delivery, the Army should use statistical process control, specifically on counts of requisitions with long outbound delivery times. An approach with statistical process control will provide an alert mechanism for unusually long outbound delivery times.

CWT is composed of time segments corresponding to the steps in the logistics chain, from the time the part is ordered, to financial approval and allocation of inventory from local and national sources, through to receipt at the unit. Managers' responsibilities vary with level and the segment of CWT. The Army currently measures how CWT is distributed among five segments of the order fulfillment process:

1. ZPARK: a financial approval activity that checks on the availability of funds
2. release strategy (RS): a logistics approval step early in the process of ordering parts
3. outbound delivery (OBD): the time between an order to the national level from the supply support activity (SSA) and delivery of the order to the SSA
4. post goods issue (PGI): the time between delivery to the SSA and posting of the part to the customer's bin at the SSA
5. post goods receipt (PGR): the time between posting to the customer's bin at the SSA and the customer's retrieval of the parts from the SSA.

Managers at different levels focus on different segments of the order fulfillment process, according to their ability to influence each segment. Local commanders and managers can influence ZPARK, RS, and PGR. They have the least control over OBD, especially back orders, which may involve multiple suppliers, distributors, and transporters in the supply chain. In contrast, item managers at Army Materiel Command (AMC) are each responsible for a number of specific Army-managed repair parts, ensuring that

the Army has reliable sources of supply and an adequate on-hand inventory distributed among storage sites worldwide. Item managers have influence over OBD and PGI.

Research Approach

To help Army managers monitor and reduce CWT, we developed several new tools that utilize data available in Global Combat Support System–Army (GCSS-A), the Army's new enterprise resource planning system for logistics. These tools include new metrics and visualizations:

- Three different sand charts show the number of requisitions in each segment of the order fulfillment process. The first dashboard shows stacked bar charts by National Item Identification Number (NIIN). The second shows stacked bar charts by unit identification code (UIC). The third shows stacked bar charts by UIC-NIIN combinations.
- Three different stacked bar charts show the contribution of each segment to total CWT. The first dashboard shows stacked bar charts by NIIN. The second shows stacked bar charts by UIC. The third shows stacked bar charts by UIC-NIIN combinations.
- The rifle chart—a new type of visualization—shows the start, end, and duration of every requisition from user-selected NIINs, UICs, and time periods.

We also devised a new metric: the count of orders in process that are older than a particular threshold. This new metric enables process control similar to the widely used statistical process control (SPC) in factory settings.¹ While the U.S. Army could use SPC for every segment, it is most important for outbound delivery, simply because the other segments are amenable to management by use of standards (e.g., ZPARK should be no more than one day).

We designed Tableau dashboards to facilitate AMC's implementation of the new metrics and

Abbreviations

AMC	Army Materiel Command
ASL	authorized stockage list
CWT	customer wait time
GCSS-A	Global Combat Support System–Army
LOGSA	Logistics Support Activity
M-COP	Materiel Common Operating Picture
NIIN	National Item Identification Number
OBD	outbound delivery
PGI	post goods issue
PGR	post goods receipt
RS	release strategy
SPC	statistical process control
SSA	supply support activity
UIC	unit identification code

¹ One of the classic articles on this topic is W. E. Deming, "On Probability as a Basis for Action," *The American Statistician*, Vol. 29, No. 4, 1975, pp. 146–152.

visualizations in its Materiel Common Operating Picture (M-COP) application.² If the Army implements these tools in M-COP, they would help managers monitor CWT, identify delayed orders and take action to expedite them, and identify negative trends in performance that signal a need for further diagnosis and intervention to help with process improvement.

This short report describes and illustrates the proposed metrics and visualizations. The final section provides recommendations for implementing and using the new tools.³

Visualizations in Tableau

This section introduces the sand charts, the stacked bar charts, and the rifle chart for visualizing CWT, as well as how to use rifle charts for statistical process control and studying reorders.

The data for these charts include back orders, but those back orders cannot be identified here. We note that some managers, especially commanders at brigade and below, may wish to filter out back orders, because they have no ability to control them. We note that GCSS-A is a retail system, so bringing in back-order data to these reports would require joining with the wholesale logistics data. In some cases, the programmer may be able to subtract national-level back-order time from OBD, by linking document numbers using additional data sources for national-level status. After that, the user should be able to toggle inclusion of back orders.

Sand Charts

Sand charts show the number of requisitions in each segment of the order fulfillment process. We developed sand chart dashboards in Tableau to help managers quickly locate where in the process the majority

of CWT occurs. This information helps managers understand where to focus their efforts to reduce CWT. These dashboards can track the total number of requisitioned repair parts for high-priority maintenance jobs, by segment and by day, as in Figure 1. Note that our data include only requisitions that were closed at the time of writing.

The sand chart reveals substantial time in OBD and also substantial time in ZPARK, RS, and PGR segments. The tooltip box in the figure shows that 36.7 percent of the time was in these segments at the peak period in the data. These three segments are under the control of the unit requisitioning the parts.

A manager can specify groups of requisitions (e.g., by specific SSA and UIC) and create sand charts accordingly. A dashboard allows further drilldown for a specific NIIN by UIC, reparability, end-item family, and whether the part is on the authorized stockage list (ASL).

Stacked Bar Charts

We created three Tableau dashboards that sum CWT over time—e.g., a year, as stacked bar charts, showing days in each segment. The first dashboard groups by NIIN. The second groups by UIC. The third shows UIC-NIIN combinations. Each dashboard shows the 20 items with highest CWT, in decreasing order. The user can select more items for comparison. These visualizations show managers which components of CWT consume the most time. Figure 2 shows an example for the 20 NIINs with the longest CWT, again with data including only requisitions closed at the time of writing.

Rifle Charts

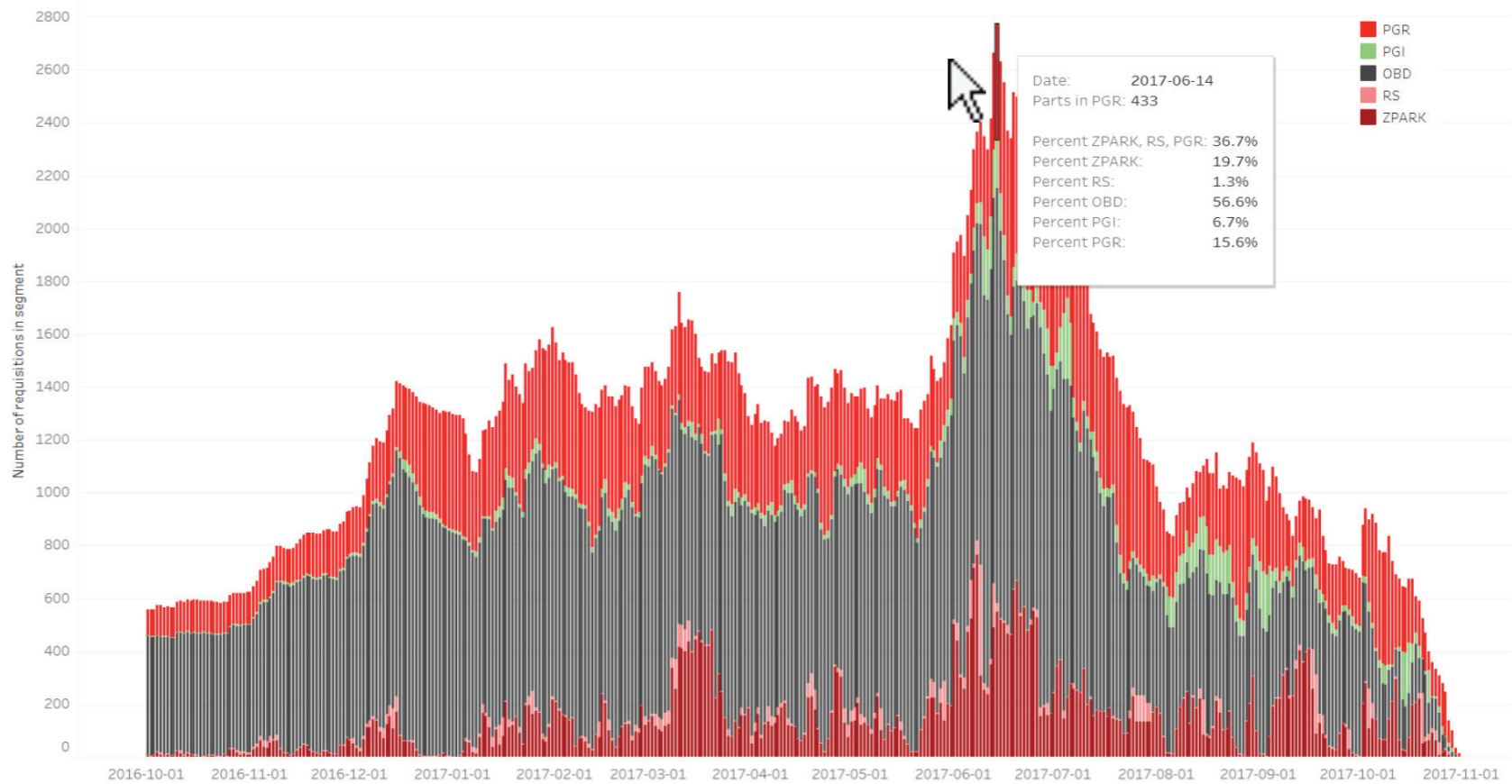
In addition to sand charts and stacked bar charts, we developed a new visualization, the rifle chart. A rifle chart shows the start, length, and end of every requisition in a segment of the order fulfillment process, for a specified population and period (e.g., every requisition placed by one UIC in one year). The rifle chart draws managers' attention to requisitions with long segments of the order fulfillment process. This visualization can be used to visualize any operations with start and end times and is especially appropriate

² Tableau is a commercial software package tool for analyzing and visualizing business data.

³ We used data from about October 2016 to October 2017, with some 2016 examples where noted (e.g., Table 2). All figures in this report are for requisitions associated with closed priority 1 and 2 work orders. These priorities indicate maintenance issues that down the equipment or are likely to down the equipment.

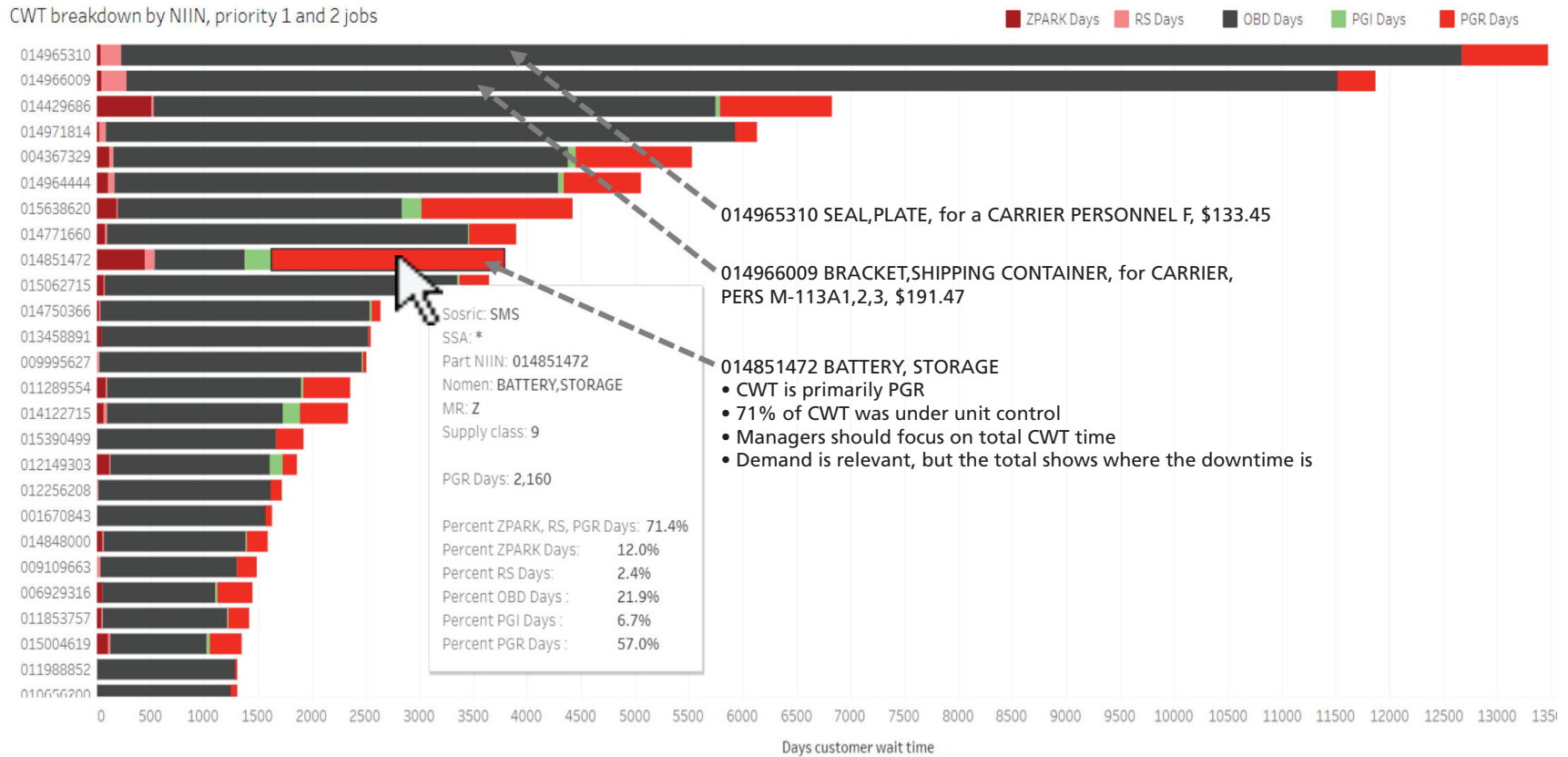
FIGURE 1
Sand Chart Showing the Number of Open Requisitions from Priority 1 and 2 Work Orders, by Segment and Day, for W50 (Fort Bliss) and WDM (Fort Irwin)

Number of parts in priority 1 and 2 jobs by segment by day



NOTE: The tooltip changes to show detail as the user moves the mouse over points within the sand chart.

FIGURE 2
Stacked Bar Chart for the NIINs with Longest Total CWT



NOTE: Sosric = source of supply routing identifier code; SMS indicates that the part is supplied by the General Services Administration; UPRICE = unit price.

A rifle chart is best when the user is careful to select sets of requisitions that are similar with respect to reparability, level of demand, and cost.

for queuing data. While we use it to study retail CWT, managers could use rifle charts and our SPC approach to study wholesale time segments as well.

The Army currently uses the metrics of average time in segment and the 85th percentile of time in segment. We found that these metrics do a poor job of signaling problems, because they depends on the *number* of requisitions. A decline in the number of requisitions often increases the average (and the 85th percentile), because long requisitions still remain. Similarly, an increase in the number of requisitions usually decreases the average (and the 85th percentile), simply because new requisitions have low current segment time. Thus, when demand jumps, the metric conveys reassurance when managers need to get warnings. We therefore developed the rifle chart to avoid misleading the user with averages and percentiles.

Like other metrics for OBD, a rifle chart is best when the user is careful to select sets of requisitions that are similar with respect to reparability, level of demand, and cost.

Figure 3 presents a typical rifle chart for selected requisitions in the segment ZPARK. (The user can select any CWT segment.) A requisition starts the segment at the horizontal axis and moves up and to the right until the requisition clears the segment. For instance, on October 5, a requisition for a parking light, work order 1002523867, entered ZPARK. That

ZPARK segment ended on October 12, seven days later. The rifle chart represents the time that a requisition resides in the segment as a sequence of rising dots. In the case of the requisition that began on October 5 and ended on October 12, the line rises to a level of seven days.

Rifle charts include other information to help managers understand the segment times and identify poor performance. The rifle chart in Figure 3 includes the 99th percentile as a horizontal yellow line and the average of 1.5 days as a black horizontal line. Although the average number of days in ZPARK looks acceptable for a financial approval activity, the rifle chart reveals that the Army has lost considerable equipment downtime to a few requisitions, with relatively long times in ZPARK.

If the Army established a standard for the execution of ZPARK, such as 24 hours, this standard could also be added to the rifle chart so that requisitions that fail to meet the standard would stand out clearly as long rifles.

We also developed rifle charts for three other segments of the order fulfillment process: RS, PGI, and PGR. In addition to the UIC selection table, the Tableau dashboard has dropdowns for creating more-specific rifle charts, including for part reparability, whether the NIIN is on the ASL, SSA, end-item family, NIIN, and month.

Using Rifle Charts to Support Statistical Process Control

OBD is often the longest segment of order fulfillment. OBD encompasses different activities that may affect CWT. For these reasons, analyzing and managing OBD are more complicated than for other segments. OBD is a good candidate to manage with SPC, and the rifle charts we have developed in Tableau can support this management approach.⁴ Managers may wish to omit back orders in this analysis.

⁴In unpublished RAND research, Marc L. Robbins and Daniel Somerhauser proposed that the Army implement SPC to enable exception reporting for requisition wait time. Our work here develops their approach further, with an improved statistical approach, using data from the Army's new GCSS-A system and implemented with web-based dashboards.

FIGURE 3
Rifle Chart for Selected Requisitions in ZPARK



NOTES: The 99th percentile is calculated based on every point: A segment length of n days contains n points. For example, the segment time starting October 3 has three points. The 99th percentile is calculated over all these points for this graph. This is due to a limitation in Tableau. Our data include only requisitions that were closed at the time of writing. The different colors refer to different orders.

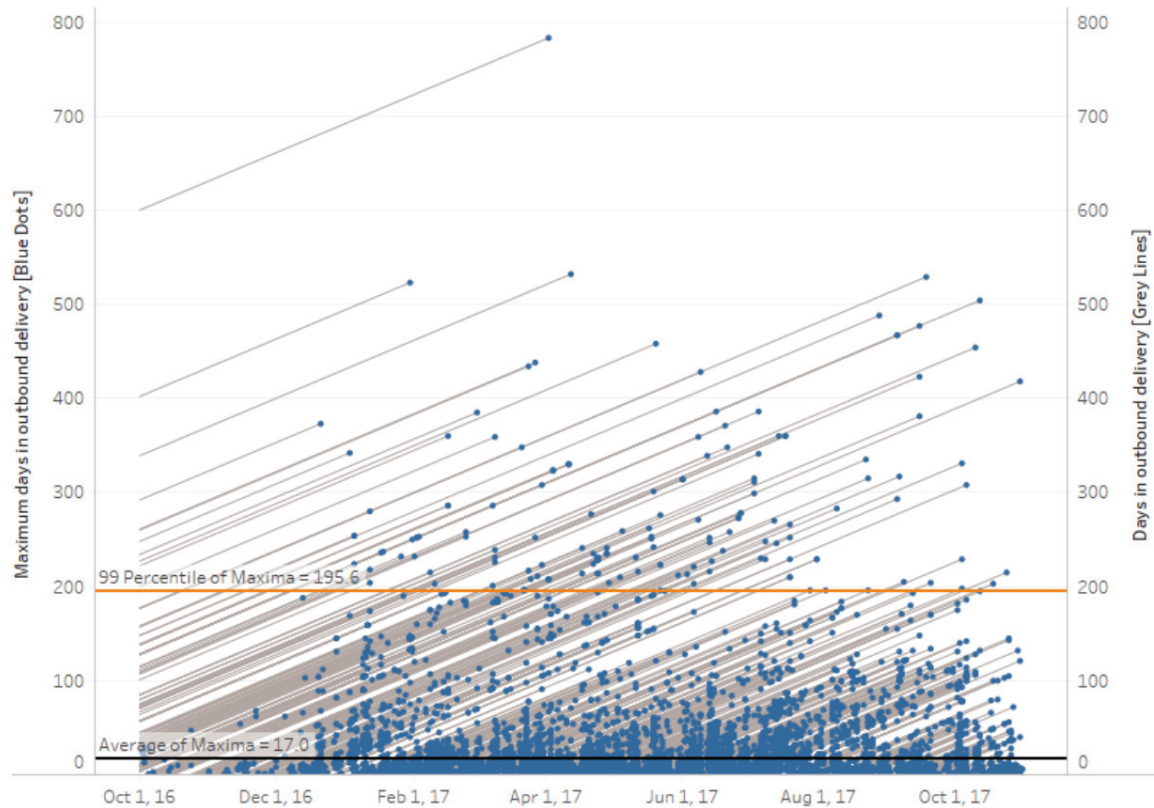
The basic idea of SPC is to use statistical analysis of process metrics to identify negative trends in performance that exceed expected variability and that require management intervention to diagnose and address. For instance, if a process output has three points outside statistical control limits, or is trending with four points moving in the same direction, then management should consider that the process is out of control and should identify and address causal problems.

To enable the manager to identify exceptions to OBD performance, we developed a new metric: the number of requisitions older than a certain threshold number of days—e.g., the number of requisitions in OBD 100 days or older. The manager can specify the

threshold; in the example in Figure 4, we use the 99th percentile. This metric would reveal a trend (worsening performance) only with an increasing count of requisitions above the threshold (“old requisitions” that are still unfilled).

Rifle charts are useful for visualizing old requisitions. Figure 4 shows a sample OBD rifle chart from Tableau. It has dual axes, superimposing the gray rifle lines and the maxima (blue dots), from which Tableau calculates the average and the 99th percentile. The Army may need additional analytic tools to determine whether these instances have trends that indicate that a process is out of control and in need of management intervention. The OBD dashboard has three tools:

FIGURE 4
 OBD Rifle Chart for W50 Priority 1 and 2 Requisitions



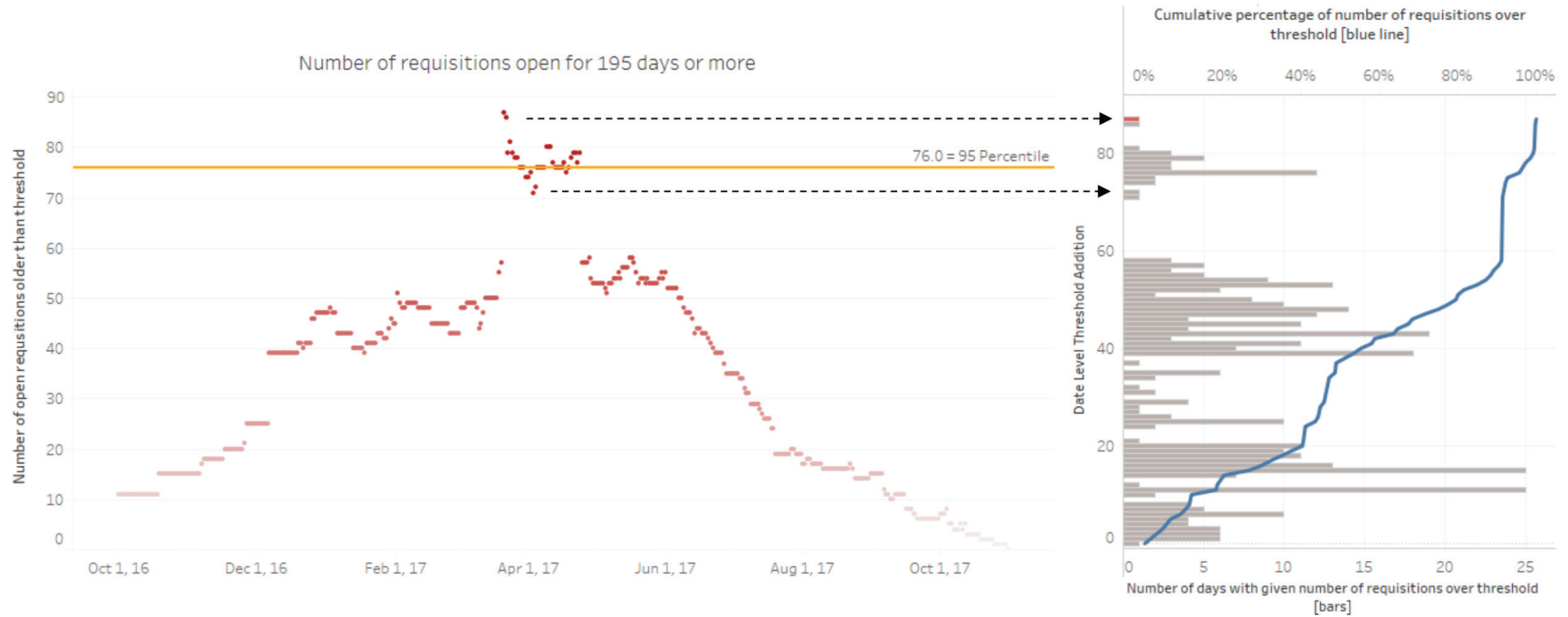
NOTES: The 99th percentile is calculated based on the end of each segment. The decrease in the number of old requisitions since April is an artifact of our data set's lack of CWT information for open requisitions. Because we are interested in the maxima, the 99th percentile here is calculated based on only the end of each segment, not each point in each segment.

1. The dashboard has a table of NIINs, sorted in decreasing order by days in OBD, allowing the manager to select a specific NIIN for highlighting.
2. The dashboard has a plot over time for the number of old requisitions over time—i.e., the number of open requisitions older than T days. The left chart in Figure 5 shows an example where $T = 195$.
3. The dashboard has a histogram of the same data as in the plot. The right-hand chart in Figure 5 shows an example. The histogram counts the number of days with a given number of open requisitions and plots that as the length of the bars; the vertical axis is the number of open orders. The bar associated with the largest number of open orders is red. We then created a dual-axis graph; the top

horizontal axis is the running cumulative percentage.

Figure 5 should be used with care. Because OBD processes may differ from part to part, managers should study sets of parts that are similar in some way. Whether a part is repairable could have a large bearing on OBD, so the manager should analyze OBD for repairable parts separately from OBD for nonrepairable parts. Moreover, different groups of parts will have different underlying processes in OBD, so they should have different statistical limits for exception reporting. We note that managers may want to see these reports with and without back orders, such as unit managers (who have no control over back orders); if the programmer can distinguish these, adding a toggle should be simple.

FIGURE 5
The Histogram Sums the Counts by Time Period



NOTE: The vertical axis on the right-hand chart could instead be labeled "Number of Open Requisitions Exceeding the Threshold."

The dashboard enables the manager to analyze OBD for repair parts, grouped in several ways:

- by NIIN, if demand is high enough to support statistical analysis of the population
- by demand level, for NIINs with low demand—for example, a manager may wish to see a rifle chart of requisitions for all NIINs having demand of four or fewer over the past year⁵
- by SSA
- on the ASL or not
- by reparability (maintenance repair code)
- by source of supply.

Using Rifle Charts to Manage and Reduce Reorders

GCSS-A data about requisitions for repair parts can provide insights into the order fulfillment process and the maintenance activities that lead to requisitions being placed. For example, we developed a Tableau dashboard to help Army managers monitor reorders, a form of rework in the maintenance process. A reorder occurs when a mechanic requisitions a part on a given day, and then on a later day requisitions another part for the same job. A mechanic may do this for many reasons, perhaps because the mechanic is using the end item for strategic parts sharing, the mechanic found that the end item needed additional parts, or the delivered part had some problem.

Table 1 shows how a reorder appears in the data. On January 14, 2015, work center WAPSC0 created order number 1000140240 for equipment number 1000076683, which is NIIN 012308862, BLADE,MINE CLEARING M1, costing \$77,672. The fault was recorded as “SPRING ON LOCKING MECHANISM DAMAGED.” The staff immediately (January 15, 2015) ordered eight parts. But three months later, on March 25, 2015, the

⁵ Parts with low demand—such as demand of one, two, or three over a year—together constitute a large fraction of the Army’s total OBD. For example, for WDM (Fort Irwin), about half of the time in OBD comes from NIINs with four or fewer demands per year. About 25 percent of the time in OBD comes from NIINs with one or fewer demands per year. About 14 percent of the time in OBD comes from NIINs with less than one demand per year.

staff ordered a ninth part—NIIN 12767050, PLATE,ADJUSTING,RIGHT HAND, for \$801.

An Army manager may be concerned that reordering is a symptom of problems in the maintenance process, such as shortfalls in diagnostics or in unit supplies of repair parts. The Army can leverage GCSS-A data to manage reorders. Reorders are straightforward to detect in the data—simply look for an item purchase order date later than the first order date.

To help Army managers monitor reorders, we developed a Tableau dashboard with two reports and supporting drilldowns and visualizations:

- **All reorders:** This report lists all reorders of repair parts to repair the same piece of equipment—i.e., when a mechanic ordered a given NIIN and later ordered another NIIN, as illustrated in Table 2. The table is sorted decreasing by the count of reorders.
- **Duplicate reorders:** This report lists reorders of a previously ordered NIIN—i.e., cases in which a mechanic requisitioned a given NIIN and later requisitioned the same NIIN for the same repair. This report can be useful for spotting problems with NIIN quality, installation instructions, or some other aspect specifically with the NIIN.

These reports are useful because they enable managers to focus and prioritize their improvement activities. For instance, using the first report, a manager can scan all reordered repair parts to find those that are reordered most often.

Table 2 illustrates this report for one UIC, W50. This information is actionable. Cheap parts on the list, such as the O-ring, could be stocked locally to reduce CWT, and maintainers could be trained to focus on other commonly reordered repair parts during technical inspection when diagnosing faults on equipment. Table 2 shows reorders by UIC, derived from the Tableau dashboard by NIIN for all UICs. The dashboard also includes reorder rifle charts for same-NIIN reorders. Managers can use these to identify to see the impact of time, such as the 84 days OBD for item 8 versus the eight days OBD for item 9 in Table 1.

TABLE 1
Example of Data for a Reordered Repair Part

	Order Item 1	...	Order Item 8	Order Item 9
NIIN	012781215	...	012767051	012767050
Purchase order date	2015-01-15	...	2015-01-15	2015-03-25
ZPARK days	0	...	0	5
OBD days	8	...	84	8
PGR days	3	...	0	6
Tech complete	2015-04-10	...		

NOTES: The ellipses replace order items 2–7 which would appear in the full data set. Tech complete = Technical completion, when the mechanic has fully installed the new part.

TABLE 2
Repair Parts Most Often Reordered for UIC W50 (Fort Bliss), 2015–2016 Data

NIIN	Nomen	Price	Count
014851472	BATTERY,STORAG	\$333	20
014345423	COUPLING HALF,SHAFT	\$217	15
015987684	CONTROL MODULE,POWE	\$14,701	12
015755045	CIRCUIT CARD ASSEMBLY	\$178	12
011687891	STARTER,ENGINE,ELECTRICAL	\$376	9
015288653	COVER,ACCESS	\$0 ^a	9
015764093	BEARING,SLEEVE	\$118	9
013458891	WIRING HARNESS,BRANCHED	\$266	8
015987677	CONTROL MODULE,POWE	\$16,707	6
006929316	TRACK SHOE,VEHICULAR	\$545	6
000200203	O-RING	\$0.09	6
015520369	FUSE LINK,ELECTRICAL	\$15	6
000730165	PUMP,FUEL,ELECTRICAL	\$195	5
016042783	INSTALLATION AND EQUIPMENT KIT,D	\$445	5
015918751	INSTALLATION AND EQUIPMENT KIT,D	\$2,047	5

^a The price for 015288653 was not in the Defense Logistic Agency's Federal Logistics (FED LOG) data application as of September 2017.

Recommendations

We developed visualizations and metrics using CWT data in GCSS-A, and we implemented them in Tableau dashboards. We recommend that the Logistics Support Activity (LOGSA) implement these Tableau dashboards into M-COP, or whichever system may supersede it, to help managers analyze CWT. Although we developed the dashboards using data only for closed requisitions—i.e., requisitions that completed the order fulfillment process—LOGSA should enable managers to use the dashboards with near-real-time data, including open requisitions. If managers can analyze CWT for open requisitions, particularly those in OBD, they can detect exceptions in sufficient time to address them.

To reduce CWT, managers should focus on reducing the longest segment times. To manage ZPARK, RS, PGI, and PGR, the Army should set standards for duration and goals for decreasing the standard. These standard times should be short (e.g., 24 hours) and should decline gradually over time (e.g., an hour per year). Unit commanders should be accountable for reducing the maxima of these segments over time, as well as the variability.

To manage OBD, the Army should use SPC, specifically on counts of requisitions with long OBD times (old requisitions). An SPC approach will provide an alert mechanism for unusually long OBD times.

About This Report

This report documents research and analysis conducted as part of a project entitled *Developing an Equipment Down Time Analyzer for the M-COP*, sponsored by Army Materiel Command. The purpose of the project was to leverage Global Combat Support System–Army Wave 2 data to develop an equipment downtime analyzer–like diagnostic capability, as part of the Materiel Common Operating Picture.

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