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Calculating the Cost of Poor Quality

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Abstract
Quality improvement is essential, not optional, for an organization competing in the current global marketplace. An organization must constantly improve its performance in order to stay competitive. The cost associated with poor quality considerably affects an organization's ability to compete. The cost of poor quality (COPQ) can account for 15 to 30 percent of a company's overall costs. Architectural finishes in a construction project amount to a considerable portion of the total value of work. This paper focuses its attention on the cost of rework from the subcontractors in charge of architectural finishes in a public-sector construction project in South Florida. The objective of this paper is to measure the cost of poor quality; identify and prioritize rework processes most in need of improvement and define appropriate actions that can be implemented to reduce COPQ in an ongoing construction project. The data analyzed is a sample list of unapproved work items extracted from the project punch list. The cost of this specific portion of rework is then analyzed through the use of quality management tools such as Pareto chart, Cause and Effect Diagram, Histograms and Flow-Charts. This leads to identifying those work items most in need of quality improvement. This paper concludes that the cost of poor quality in this job is caused by two main factors (i) Bad quality of Execution- Installation; 55% of the cost of the repairs (ii) Material damaged after installation; 42% of the total COPQ. Measurement of COPQ can be utilized to reduce the company's overall costs.

Keywords
Quality, Cost, Rework, COPQ

1. Introduction

Nowadays, construction organizations are under growing pressure, especially from clients, to improve performance. An organization can sharpen its competitive edge by reducing the losses due to cost of poor quality (COPQ). According to quality expert H. James Harrington (1991, pp.190), poor quality costs a company money, whereas good quality saves a company money. Some experts say that a typical company can save more money by cutting poor quality costs in half than by doubling sales. Furthermore, a 50 to 90 percent of quality-related costs are spent to resolve problems, defects, or other failures (Suresh, Gameson, & Chinyio, 2008, pp. 7). Rework represents the unnecessary effort of redoing a process or activity that is incorrectly implemented the first time. A substantial amount of the cost of poor quality in construction is rework. The cost of rework has been put as high as 12 percent of the total cost of a project (Suresh, Gameson, & Chinyio, 2008, pp. 1). Also, Chapalkar (2011) states that the nature of poor works/ errors are quit diverse estimating that 20-40% of all construction project poor quality have their roots in errors arising during the construction phase, and a whopping 54% of all construction poor quality defects can be attributed to human factors like unskilled workers or insufficient supervision of construction work.

Architectural finishes in a construction project amount to a considerable portion of the total value of work. Therefore, any effort to minimize the cost of rework in this phase of construction is bound to produce significant cost savings. With the use of COPQ tools, one can identify and measure the company-incurred costs that result from errors or, as Harrington (1991, pp. 193) put it another way, “all the money the company spends because all activities were not done right every time”.

This study examines the cost of rework from the subcontractors responsible for architectural finishes in the selected project. In general, the common factors that contribute to rework from the subcontractors are: inadequate supervision, damage to other trade’s work due to carelessness, low skill-level of designers or construction labor; and poor choice of materials (Suresh, Gameson, & Chinyio, pp.1). A reduction in cost of poor quality (COPQ) can help in getting management’s attention; in changing the way employees think about errors; in providing a better return on the problem-solving efforts and a means to measure the true impact of corrective action and changes made to improve the process; in creating a simple, understandable, method of measuring what effect poor quality has on the company; in producing an effective way to measure the impact of the improvement process and a single measurement that brings together efficiency and effectiveness measurements (Harrington, 1991, pp.191). COPQ should be seen in an organization not just as a problem, but as a perfect opportunity to improve performance.

2. Literature Review

Quality is a dynamic state associated with products, services, people, processes, and environments that meet or exceed expectations. In early years, one of the major obstacles to the establishment of quality programs was the mistaken notion that the achievement of better quality required much higher costs. The truth is that unsatisfactory quality means unsatisfactory resource utilization. This involves waste of material, waste of labor and waste of equipment time. In contrast, satisfactory quality means satisfactory resource utilization and consequently, lower costs. During those years there was also the widespread belief that quality could not be measured in cost terms. Today, the measurability of quality costs is not only recognized but these costs are central to the management and engineering of modern quality control as well as to the business strategy Compare cost of quality versus cost of non-quality in construction. The methodology is based on quantifying the four types of quality-related costs in residential construction, and relates them to each other by expressing them all as percentages of the relevant total construction revenues. (Rosenfeld, 2009)

Armand Feigenbaum estimated that 15% to 40% of the manufacturer costs of almost any American product that you buy today are for waste embedded in it (waste of human effort, waste of machine-time and nonproductive use of accompanying burden). Feigenbaum (Total Quality Control, 1991) breaks down the quality costs in two areas: “the cost of control -those costs associated with the definition, creation and control of quality as well as evaluation and feedback of conformance with quality, reliability and safety requirements- and the cost of failure of control -those costs associated with the consequences of failure to meet the requirements both within the factory and in the hands of customers.”

According to Feigenbaum, the problem is that Internal and External Failure costs have usually represented about 65 to 70 cents of every quality cost dollar. Appraisal costs probably range in the neighborhood of 20 to 25 cents, and prevention costs probably do not exceed 5 to 10 cents out of the total quality cost dollar for many businesses. This means that the companies have traditionally been spending the dollars the wrong way. Very little money has been spent for the true defect-prevention technology that can do something about reversing the cycle of higher quality costs and less reliable product quality. The unprofitable cycle works like this: the more defects or nonconformities produced, the higher the failure costs.

The classical answer to higher failure costs has been more inspections (higher appraisal costs). Now, the tighter inspection does not have much effect in eliminating the defects and, since defective products are still being produced, some of them will end up in the hands of complaining customers. This keeps up the cost of failure and appraisal. The way of turning down this cycle is by is by focusing on prevention systems as suggested by the Total Quality approach. The additional dollars spent in prevention systems will be financed by a portion of the savings in failure and appraisal costs with the balance of quality cost dollars going to profit. The end result would be a reduction in the cost of quality and an increase in the level of quality. Edwards Deming (Out of the Crisis, 1982) agrees with the abovementioned concept in his
"14 points for Management" where he urges to "cease dependence on inspection to achieve quality" and to "eliminate the need for inspection on a mass basis by building quality into the product".

Although the abovementioned prevention-appraisal-failure cost model (PAF) is universally accepted for quality costing, Porter and Rayner (1992) describe some of the drawbacks of this process:

- Difficulty to decide which activities stand for "prevention" since almost everything a well-managed company does have to do with preventing quality problems.
- It is difficult to classify the costs into the different categories.
- The PAF model doesn't include intangible costs.
- The PAF model does not consider process costs while TQM focus on process improvement.

Davis (1987): The Construction Industry Institute developed the QPMS to track quality costs. This tool defines the cost of quality as the cost of correcting deviations (rework) plus the cost of quality management activity. The QPMS classifies the quality costs for tracking in 11 rework causes and 15 QM activities. The drawback for this system is that it doesn't consider the effect of failure on time-related cost and knock-on cost.

Abdul-Rahman (1993): developed a quality cost matrix to capture the cost of non-conformance during construction. No attempts were made to capture other quality costs such as prevention and appraisal. He did not consider the origin of deviations like Davis did.

Low and Yeo (1998): proposed a quantifying system called CQCQS. The cost system is basically a documentation matrix that accounts for quality costs expressed as prevention, appraisal and failure costs. The main feature of this model is the use of coding to classify the project items under "work concerned". The matrix was designed to capture the cost of failure primarily.

Finally, due to the difficulties in identifying and collecting construction quality costs with the PAF model, Tang, Ahmed, Aoieong & Poon (2005) had proposed the use a different approach called the "Process Cost Model". This model is based on the measurement of COC (cost of conformance) and CONC (cost of non-conformance) for individual processes. Each process contains a number of key activities with COC and CONC costs associated to them. Also, the findings from the current work concurs with the study of Mahmood, Shahrukh and Sajid (2012) when they found that team work; providing effective leadership; fulfilling health and safety requirements; measuring performance of activities on critical path; improving the productivity of resources and initiating accountability process are key for the reduction of the COPQ in construction projects in the Pakistani construction industry

2. Scope and Objectives

The main objective of this study is to collect COPQ data associated to rework activities from the selected construction project, analyze (identify and prioritize) rework processes most in need of improvement, through the use of COPQ tools and define appropriate actions that can be implemented to reduce COPQ in the current construction project as well as in future projects. For the purpose of this paper, the measurement of COPQ has been limited to a representative sample of rework from subcontractors engaged in finish operations in an actual public-sector construction project in South Florida.

3. Research Methodology

The project studied is a real construction project located in Miami-Dade County, FL. The punch list only includes Architectural items from the project. The total of the items recorded in this punch list were about 220, and at the time of the inspection the contractor stated that the building was substantially completed and ready for punch list inspection by A/E. In order to organize the data, clarify the problems, and help to identify the critical few, some TQM tools are employed. The tools used are the Pareto chart, Cause and Effect Diagram and Histograms. For further clarification, the information is also presented in tables and Pie Charts.

4. Data Collection and Catergorization

Data was collected in the form of punch list provided by the project staff. Items were included as recorded during the inspection and classified into 14 different categories. The cost of fixing these items was indicated by the General Contractor's and based on the cost of past repairs for other projects. Following table 1 summarizes the data collected for the study. A code was assigned to each category to ease the analysis process, frequency of the each category is also identified. Quantities are displayed according to the product; some of them are calculated by Unit, Square feet or Linear feet. Value indicates the cost per measuring unit, quantity (Qty.) is defected quantity and total (TOT ($)) total rework cost per category. Total Rework cost is estimated as 6,496 US Dollars.

Table 1: Data Collected

CODE	DESCRIPTION	FREQ.	C'TIVE	Unit	Value($)	Qty.	TOT($)
1-CD	Clean door	13	13	By unit	4.5	13	58.5
2-CL	Clean Light Fixtures	15	28	By unit	2.5	125	312.5
3-DC	Caulking required at door frame	21	49	By unit	6.25	21	131.25
4-DP	Door Paint	13	62	By unit	12.5	13	162.5
5-FS	Fix and secure door Hardwood	13	75	By unit	3	13	39
6-FRG	Fix return grill	17	92	By unit	3.25	28	91
7-GC	Glue carpet at edges	8	100	S/F	2	378	756
8-RCT	Replace damaged ceiling tiles	24	124	S/F	13	98	1274
9-RPB	Remove paint from wall base	14	138	L/F	1	102	102
10-RVCT	Replace VCT Tile	23	161	S/F	4.5	385	1733
11-TC	Touch up hard soffits	14	175	S/F	2.5	325	812.5
12-TW	Touch up walls	22	197	S/F	1.8	484	871.2
13-CP	Door not closing properly	7	204	By unit	3	7	21
14-RCF	Replace damaged ceiling fixt	10	214	By unit	13	10	130

4. Data Analysis

Data Analysis is performed in three steps first the data is represented in bar charts and pie charts to have a better understanding of the data. In the second step the causes of the defects leading to rework are identified and finally critical causes are identified which needs to be emphasized in the strategies for reducing the cost of poor quality.

4.1 Representation of Data

Figure 1 below shows a Histogram for the 14 categories indentified earlier for the recording of rework items. The five most frequent items are (i) Replace damaged ceiling tiles (8-RCT), (ii) VCT Tiles replacement (10- RVCT), (iii) Touch up walls (12- TW), (iv) Caulking at door frames (3-DC) and (v) Fix return grill (6-FRG). The five categories add upto 50% of the total 214 punch list items.

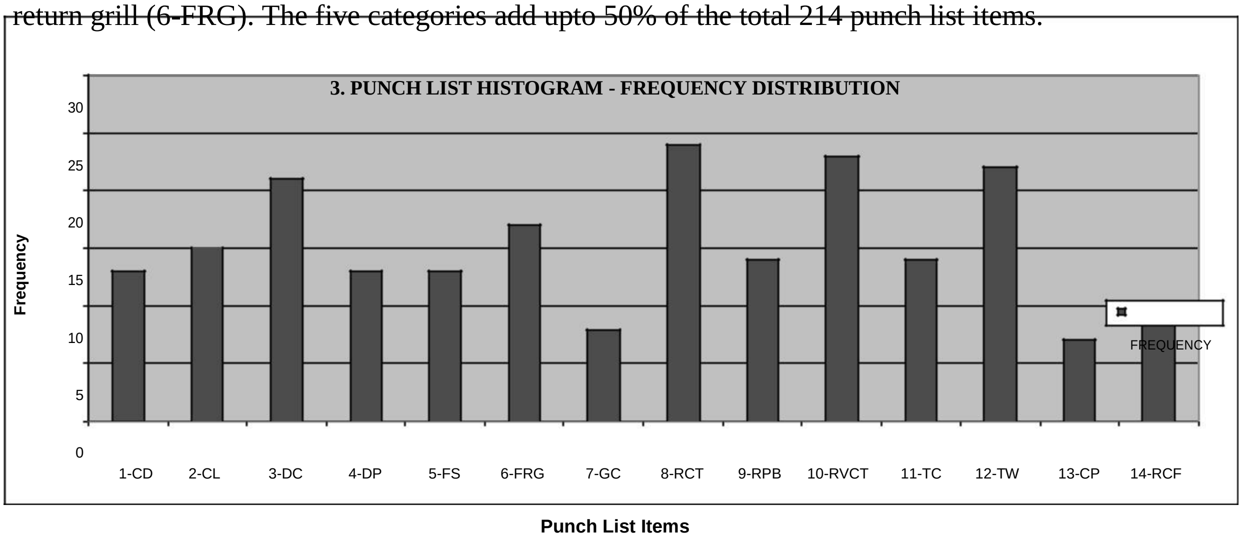

Figure 1: Histogram of Punch List Items

Figure 2 below shows the cost of the items. The five most expensive items include (i) VCT tiles replacement (10-RVCT), (ii) Replace damaged ceiling tiles (8-RCT), (iii) Touch up walls (12-TW), (iv) Touch up paint on soffits (11-TC) and (v) Glue Carpet (7-GC). The total cost of these five items is 5,447 US Dollars which constitutes of 78.4 % of the total rework cost.

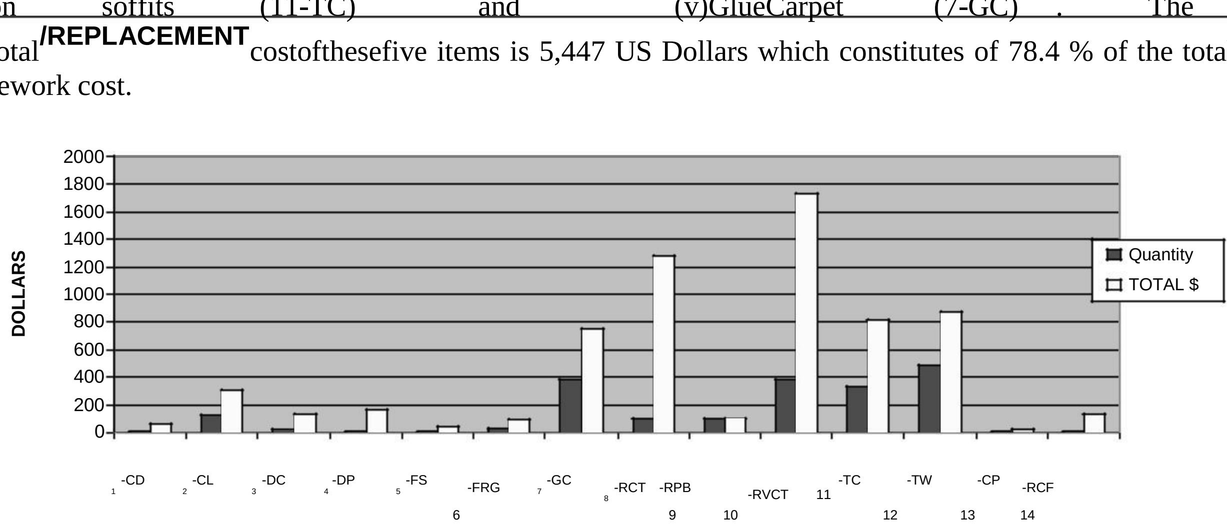

Figure 2: Cost of Rework category

Figure 3 below show the pie chart of the above mentioned five most expensive rework categories.

Category 5- Replacement of VCT tiles constitute most 32% and 1,733 US Dollars.

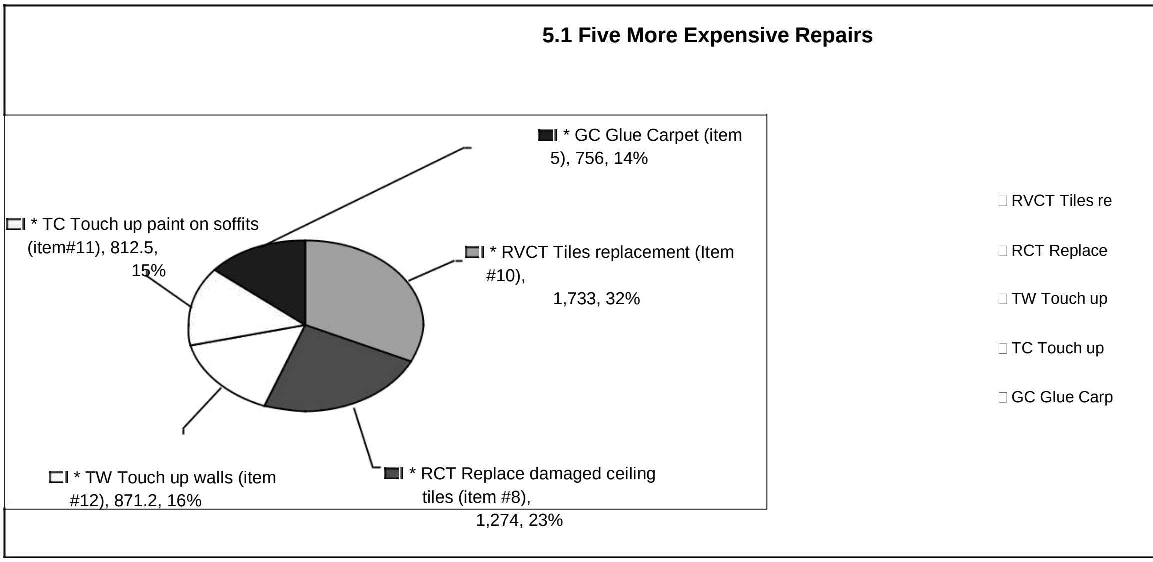

Figure 3: Pie-chat for 5 most expensive reworks.

4.2 Causes of Rework

The GC's final goal is to bring the punch list items to a "conformance condition" in order to get the architect's final sign-off. The submittal process starts when the trade contractor submits to the general contractor the shop drawings, cut sheet or sample based on the requirements of the specification section. Once this is reviewed and approved by the GC it is forwarded to the A/E team for final approval. Finally, upon approval by the A/E, the fabrication and delivery phase starts. When asked about potential impacts as a result of delays in fabrication or errors in the submittals, General Contractor reported that the submittals were approved in a timely manner and that there were no errors to be accounted for; this rules out the possibility of problems generated by the submittal process. By using the Cause and Effect diagram from the TQM tools the common causes involved in the material delivery process are identified, which includes from the time the material arrives to the site, when it's delivered, stored and finally installed.

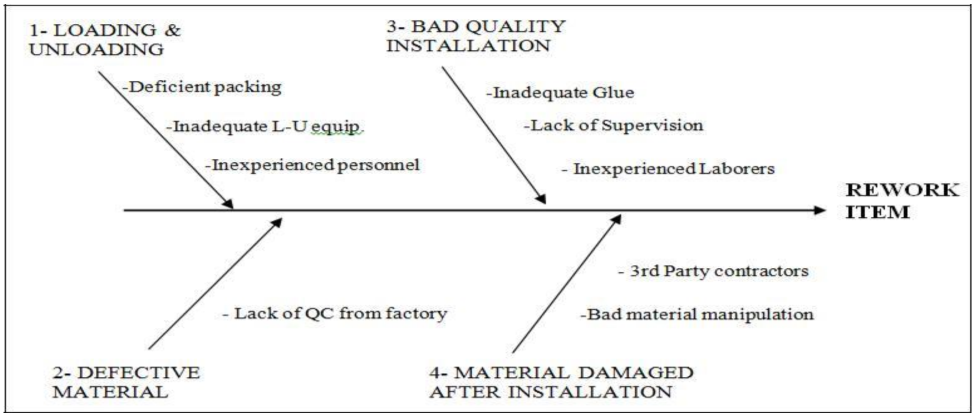

Figure 4: Cause and Effect Diagram

Figure 4 above shows the cause and effect diagram created after a brief feedback according to the General Contractor of the process summarized below:

4.2.1 Loading and unloading

This process starts when the trade contractor gets the approval for the material and coordinates with the G.C the delivery schedule. As soon the material is required it is prepared by the T.C for delivery at the job site, this activity includes the following activities: receipt of approved submittal, selection of material on warehouse, preparation of the invoice, packing and loading to delivery trucks. According to the G.C in this project the Vinyl Composite Tiles were delivered in an acceptable condition by the manufacturer. However, there were some concerns about the packing process of the product since at the time of unloading and storage some of the items were damaged as a consequence of falling off from the pallet.

This only accounts for a low percentage of the material and was estimated by the General Contractor as only 2 or 3% of the total cost.

4.2.2 Defective material
The G.C. reported that the product arrived in good condition; there were no incidents due to defects reported at this time.

4.2.3 Bad quality- Installation
About 55% percent of the defects found by the A/E in the punch list process were as a consequence of the VCT tiles lifting up on the corners, especially in the areas when cut outs have been done (around door frames and corners). The Contractor stated that the glue used for the VCT installation was not the one recommended by the manufacturer but that the one used has the same performance specification when compared to the recommended product. In any case, the final assessment points out that the glue used during the installation is creating the installation problems and for this reason the defective VCT needs to be reinstalled, adding extra cost for repairs in materials and labor. In relation to the remaining four items same percentages may be applied because of the similarity of its common causes.

4.2.4 Material damaged after installation
The study building has retail areas that were leased to different tenants. The corridors and common areas were built by the G.C but third party Contractors were responsible for the tenant improvements. The scope of work performed by TI contractors was the following:

Ceilings: Installation of ceilings and ductwork
Wall: Construction of new interior partitions at tenant spaces
Floor: New Flooring installed
Doors: Some doors need to be reworked due to 3rd party damage

Due to the traffic of materials and ongoing construction at the tenant spaces, the floors, ceilings, doors and walls at the common areas have been affected. The third-party contractors have been responsible for additional damages that account to 42% of the total cost of the punch list repairs. Unfortunately, the G.C. contract states that he is fully responsible for all the construction management including the coordination with other trades so the GC is accountable for fixing all the defects which according to our analysis add up to a total of $6,495.00.

4.3 Special and Common Causes Chart

Table 2: Percentage value of Rework Caused

DESCRIPTION	PERCENTAGE	DOLLARS
1- Loading and unloading material	3%	$163.41
3- Bad Quality-Installation	55%	$2,995.85
4- Material damaged after installation	42%	$2,287.74
	TOTAL	**$5,447**

Table 2 shows the estimated percentage values for each of the causes which are contributing to the cost of rework of the punch list items. Installation procedures for tiles such as glue indicated earlier caused the most rework cost.

5. Conclusions & Recommendations

"Often, we hear that companies cannot afford to measure their business processes. We contend that you cannot afford not to measure them." (Harrington, 1991, pp. 201). The cost of poor quality in this job is

caused by three main factors (i) Loading and unloading material: Although this procedure is the less costly to the project, improving storage techniques and proper handling of the material will prevent future damages at the time of delivery or when material is being manipulated within the site; (ii) Material damaged after installation: Bad coordination between the trades is responsible for the rework of the Architectural Items generated on the Punch list which accounts for the 42% of the total cost, the lack of planning and coordination of this process is very well reflected on the final cost of repairs; (iii) Bad quality of Execution-Installation: This procedure is accountable for 55% of the cost of the repairs and there are several factors associated with it, in the specific case of the VCT tiles it was found that the usage of alternative glue was the cause of the nonconformance tile installation. This paper concludes that the findings from the measurement of COPQ in the selected construction project can be applied to present operations and to subsequent projects to reduce the company's overall costs.

As a future recommendation to the builder they should look more in detail to improving coordination and planning. Responsibility for the activity of third party contractors should be properly addressed in the main contract in order to prevent the extra costs associated with this condition. A closer look at the submittal and installation process is also recommended. In addition to the above there is potential for further analysis to some of these processes through the use a tool like the "Process Cost Model" (Tang, Ahmed, Aoieong & Poon, 2005). Through the collection of data on a periodic basis and the preparation of a Process Cost Report, the model could be used for regular reporting on performance.

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