# Case Study of Obsolescence and Equipment Productivity

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**Abstract:** The change in productivity is studied for six different pieces of earthmoving equipment over a period of 15 years. It is shown that the production rate of this group of equipment has increased 1.58% on average per year. During the same period, without adjusting for inflation and making specific assumptions, the unit price of production has increased at an average rate of 1.77% per year. The results of this analysis may be used in modeling obsolescence costs in equipment replacement analysis. The equipment considered includes two models of wheel-type loaders, one track-type loader, one scraper, and two track-type dozer models.

**DOI:** 10.1061/(ASCE)0733-9364(2002)128:4(357)

**CE Database keywords:** Construction equipment; Productivity; Costs; Case reports.



## Background

Obsolescence in construction equipment is the economic decline in equipment occurring over time due to technological advances. It is generally understood that newer models are more productive and hence more competitive in the construction business environment. Because of this, a traditional equipment replacement analysis usually considers the effect of obsolescence in deciding whether to replace an existing piece of equipment (defender) with a new one (challenger) (Douglas 1968; Jaafari and Mateffy 1990; Nunnally 2000).

Schexnayder and Hancher (1982) note that in the mid 1950s and early 1960s introduction of several new technologies and materials helped increase equipment productivity at a rapid pace. During the 1970s, much of the manufacturers' efforts were directed toward safety regulation compliance. Arditi et al. (1997) contend that the rate of innovation in the construction industry has increased during 1962–1992.

### *Estimates of Obsolescence*

Estimates of obsolescence cost are relatively rare. The following studies appeared in the construction technical literature in the past 30 years. Schrader (1971) considered obsolescence in his mathematical formulas as the rate of decline in maintenance and operating costs of replacement machines; he estimated this decline rate to be 2% of maintenance and operating costs per year. Also, he estimated the cost growth in future machines due to technological improvements as 1.74% per year. Nunnally (2000) assumed an average 5% annual increase in productivity in new models. Schexnayder and Hancher (1981) estimated the obsolescence to range from 1 to 15%, with a mean of 5.6% per year. This was based on a survey that the writers conducted on heavy contractors and in response to the following definition of obsolescence: ‘‘newer model machines have increased production capacity, and, therefore, can accomplish an equivalent amount of work at a lower cost’’ (Schexnayder and Hancher 1981). This paper established that many of the responding contractors based their equipment replacement decisions on experience rather than a formal analysis. This paper concluded that while contractors recognized the importance of obsolescence in replacement decisions, they were not sure of its ‘‘appropriate weight.’’

Schexnayder and Hancher (1982) suggest that obsolescence costs consist of two components, one due to inflation and the other to technological improvements. Cost of inflation is affected by many economic factors and varies from period to period. For example, Associated General Contractors (AGC), one of the largest contractors' association in the United States, used 7% replacement cost escalation (expressed as a percentage of the new acquisition cost) in their *Contractor's Equipment Manual* (AGC 1974). It is not clear what portion of this escalation factor is due to purely inflationary trends and what portion is due to technological improvements.

## Objective

The objective of this paper is to estimate the productivity increases of new construction equipment in the past 15 years due to technological advancements. This information is important in equipment replacement analysis, where equipment obsolescence affects the replacement decision.

## Research Approach

In order to quantify the equipment productivity increase in newer models, we have used various issues of the *Caterpillar Performance Handbook* (1983, 1992, 1998); using the same source ensures that consistent assumptions are used in production esti-

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Note. Discussion open until January 1, 2003. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this technical note was submitted for review and possible publication on December 3, 1999; approved on August 21, 2001. This technical note is part of the ***Journal of Construction Engineering and Management***, Vol. 128, No. 4, August 1, 2002. ©ASCE, ISSN 0733-9364/2002/4-357–361/$8.00+$.50 per page.



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**Table 1.** Operating Conditions Assumed in Production and Unit Cost Estimating

| Equipment | Conditions | Travel distance |
|---|---|---|
| Dozers | Soil density = 2,300 lb/lcy: cut in first 50 ft; Coefficient of traction $\geqslant 0.5$[a] | 75 ft, and 100–300 ft in increments of 50 ft |
| Scraper | Total resistance = 0%; soil density = 2,750 lb/lcy | 500–3,000 ft in increments of 500 ft |
| Track loaders | Grade = 0; bucket fill factor = 100%; general purpose bucket | 20–120 ft in increments of 20 ft |
| Wheel loaders | Total resistance = 6%; bucket fill factor = 100%; general purpose bucket | 25 ft–300 ft in increments of 25 ft |

Note: 1 ft = 0.305 m.

[a]All other conditions ''standard'' as described in *Caterpillar Performance Handbook*.



mates. Several equipment types are selected, and each machine's production rate and hourly cost are estimated for a range of operating conditions in various years. A comparison is made between productivity and unit cost results obtained for different years, and average rates of change are calculated.

### Equipment Selection

The choice of equipment in this study is limited to Caterpillar models. Caterpillar is believed to control more than 45% of the U.S. construction equipment market and 35% of the world market (Arditi et al. 1997). Also, using the same manufacturer allows us to follow a consistent method for estimating productivity and unit costs using the manufacturer's suggested approach. So in a strict sense, the results of this study are applicable only to Caterpillar models; however, the writers believe that because of the dominant position of Caterpillar in the equipment market, the results of the study can be used as a reasonable measure for the whole heavy equipment industry. The machines selected consisted of a variety of earthmoving equipment such as to represent a heavy contractor's fleet. The following equipment was selected for this study:

- Wheel-type loaders: 950B (1983), 950F (1992), and 950G (1998), 966D (1983), 966F (1992), and 966F (1998);
- Track-type loaders: 963 (1983 and 1992) and 963B (1998);
- Scrapers: 623B (1983), 623E (1992), and 623F (1998); and
- Crawler dozer with U blade and SU blade: D7H (1992) and D7R (1998), D9N (1992) and D9R (1998).

In choosing these machines, we noted that while changes were made from year to year in some models, the basic machine remained the same in terms of engine model and general machine dimensions. In other words, changes in model names, to a certain extent, imply technological changes and updates. This was confirmed after checking with Caterpillar sales representatives in the Northeast region. Several machine types in the Caterpillar handbook kept the same model number over the years with virtually no change in performance data. These machines were not considered in this study because they represented no obsolescence, except the inflation/escalation factor. We assume that the effect of these models is offset by models that have been discontinued and presumably replaced with superior new models with different model numbers.

### Operating and Production Assumptions

The following procedure and assumptions were followed in production estimation. For each machine, the hourly production was estimated using the procedure suggested in the relevant *Caterpillar Performance Handbook* (editions 14, 23, and 29). An efficiency factor of 100% was assumed; maximum capacities of equipment were used; and average operating conditions were assumed in all calculations (Table 1). Caterpillar's methods and assumptions in calculating equipment production rates (such as haul distances, soil type, adjustment factors, and computation approach) have remained consistent during the period 1983–1998.

## Production Estimates

Table 2 gives production estimates for all machines with assumed haul distances. The production rates presented here are calculated using standard Caterpillar fixed cycles and other conditions described in the previous section and listed in Table 1. In some cases (tractor dozers), the change in productivity is only calculated for the period between 1992 and 1998. This is because we could not find corresponding models between 1983 and 1992 for these models.

Table 3 gives the rate of change per year in hourly production for various equipment models. For each machine and specified period, an average rate of change per year in hourly production levels is calculated. As an example, the Model 623 Scraper's hourly production rate has increased an average of 0.59% per year during the period 1992–1998. This is the rate that has been averaged over various haul distances (ranging between 500 and 3,000 ft) and can be calculated by averaging the values given in the corresponding row of Table 3. The average rate of productivity improvement for the group of equipment consisting of the model 623 scraper, model 950 and 966 wheel loaders, and the model 963 track loader for the period spanning 1983–1998 is calculated as 1.22% per year. The same improvement rate for these four machines for the period 1983–1992 is 1.38% per year. The average rate of productivity improvement for all six pieces of equipment considered for the period 1992–1998 is calculated as 1.78% per year. These rates are calculated as arithmetic means of average rate changes for the group of equipment studied. A weighted average for all six machines was calculated as 1.58% by considering the rates in Table 3 and weighing these with their corresponding time spans.

$$1.02\% \times 15 + 0.93\% \times 15 + 1.43\% \times 15 + 1.49\% \times 15 + 5.75\% \times 6 + 1.00\% \times 6 = 113.55\%$$

$$113.55\% \div (15 + 15 + 15 + 15 + 6 + 6) = 1.58\%$$

These changes seem to be related to the technological improvements in the design of the same basic model over the course of the years.

## Unit Cost Estimates

As another indicator of obsolescence, the cost per cubic yard (cy) of excavation was calculated for each case. It is assumed that an



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**Table 2.** Hourly Production Estimates for Equipment

| Machine | Fixed time (min) | Capacity (BCY) | Productivity (cy/h)/haul distance (ft) | | | | | |
|---|---|---|---|---|---|---|---|---|
| (a) Scraper | | | | | | | | |
| 623B(1983) | 1.60 | 18.20 | 467/(500) | 403/(1000) | 351/(1500) | 320/(2000) | 289/(2500) | 270/(3000) |
| 623E(1992) | 1.60 | 20.00 | 533/(500) | 462(1000) | 401/(1500) | 358/(2000) | 320/(2500) | 293/(3000) |
| 623F(1998) | 1.60 | 20.00 | 541/(500) | 469/(1000) | 415/(1500) | 374/(2000) | 338/(2500) | 308/(3000) |
| (b) Wheel Loader | | | | | | | | |
| 950B(1983) | 0.48 | 3.50 | 388/(25) | 339/(50) | 284/(100) | 256/(150) | 214/(200) | 169/(300) |
| 950F(1992) | 0.48 | 3.75 | 388/(25) | 357/(50) | 308/(100) | 281/(150) | 253/(200) | 214/(300) |
| 950G(1998) | 0.48 | 4.00 | 414/(25) | 375/(50) | 320/(100) | 286/(150) | 255/(200) | 220/(300) |
| 966D(1983) | 0.53 | 4.00 | 390/(25) | 353/(50) | 300/(100) | 270/(150) | 247/(200) | 214/(300) |
| 966F(1992) | 0.53 | 4.75 | 452/(25) | 419/(50) | 370/(100) | 339/(150) | 303/(200) | 259/(300) |
| 966FII(1998) | 0.53 | 5.00 | 469/(25) | 435/(50) | 380/(100) | 343/(150) | 306/(200) | 261/(300) |
| (c) Track Loader | | | | | | | | |
| 963(1983) | 0.31 | 2.50 | 395/(20) | 333/(40) | 288/(60) | 254/(80) | 227/(100) | 205/(120) |
| 963(1992) | 0.29 | 2.60 | 433/(20) | 363/(40) | 312/(60) | 274/(80) | 244/(100) | 220/(120) |
| 963B(1998) | 0.29 | 3.00 | 500/(20) | 419/(40) | 360/(60) | 316/(80) | 281/(100) | 254/(120) |
| (d) Dozer—SU Blade | | | | | | | | |
| D7HII(1992) | — | 8.98 | 620/(75) | 500/(100) | 375/(150) | 300/(200) | 240/(250) | 200/(300) |
| D7R(1998) | — | 8.98 | 850/(75) | 700/(100) | 500/(150) | 400/(200) | 350/(250) | 300/(300) |
| D9N(1992) | — | 15.60 | 1300/(75) | 1100/(100) | 835/(150) | 660/(200) | 540/(250) | 460/(300) |
| D9R(1998) | — | 17.70 | 1550/(75) | 1240/(100) | 900/(150) | 690/(200) | 550/(250) | 425/(300) |

Note: 1 cy = 0.766 $m^3$.

**Table 3.** Average Annual Change in Hourly Production Rates

| Duration | Change in hourly production rate (%)/haul distance (ft) | | | | | | Average (%) |
|---|---|---|---|---|---|---|---|
| (a) Scraper—623 | | | | | | | |
| 1983–1998 | 0.99/(500) | 1.02/(1,000) | 1.12/(1,500) | 1.04/(2,000) | 1.05/(2,500) | 0.88/(3,000) | 1.02 |
| 1983–1992 | 1.48/(500) | 1.53/(1,000) | 1.49/(1,500) | 1.25/(2,000) | 1.14/(2,500) | 0.91/(3,000) | 1.30 |
| 1992–1998 | 0.25/(500) | 0.25/(1,000) | 0.57/(1,500) | 0.73/(2,000) | 0.92/(2,500) | 0.84/(3,000) | 0.59 |
| (b) Wheel Loader—950 | | | | | | | |
| 1983–1998 | 0.43/(25) | 0.68/(50) | 0.80/(100) | 0.74/(150) | 1.18/(200) | 1.77/(300) | 0.93 |
| 1983–1992 | 0.00/(25) | 0.58/(50) | 0.91/(100) | 1.04/(150) | 1.88/(200) | 2.66/(300) | 1.18 |
| 1992–1998 | 1.09/(25) | 0.82/(50) | 0.64/(100) | 0.29/(150) | 0.13/(200) | 0.46/(300) | 0.57 |
| (c) Wheel Loader—966 | | | | | | | |
| 1983–1998 | 1.24/(25) | 1.40/(50) | 1.59/(100) | 1.61/(150) | 1.44/(200) | 1.33/(300) | 1.43 |
| 1983–1992 | 1.65/(25) | 1.92/(50) | 2.36/(100) | 2.56/(150) | 2.30/(200) | 2.14/(300) | 2.16 |
| 1992–1998 | 0.62/(25) | 0.63/(50) | 0.45/(100) | 0.20/(150) | 0.16/(200) | 0.13/(300) | 0.36 |
| (d) Track Loader—963 | | | | | | | |
| 1983–1998 | 1.58/(20) | 1.54/(40) | 1.50/(60) | 1.47/(80) | 1.43/(100) | 1.44/(120) | 1.49 |
| 1983–1992 | 1.03/(20) | 0.96/(40) | 0.89/(60) | 0.85/(80) | 0.81/(100) | 0.79/(120) | 0.89 |
| 1992–1998 | 2.43/(20) | 2.42/(40) | 2.41/(60) | 2.41/(80) | 2.38/(100) | 2.42/(120) | 2.41 |
| (e) Dozer—D7 with SU Blade | | | | | | | |
| 1992–1998 | 5.40/(75) | 5.77/(100) | 4.91/(150) | 4.91/(200) | 6.49/(250) | 6.99/(300) | 5.75 |
| (f) Dozer—D9 with SU Blade | | | | | | | |
| 1992–1998 | 2.97/(75) | 2.02/(100) | 1.26/(150) | 0.74/(200) | 0.31/(250) | −1.31/(300) | 1.00 |

Note: 1 ft = 0.305 m.



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**Table 4.** Equipment Unit Cost Data for Various Haul Distances

| Machine | O&O cost ($/h) | Unit cost ($/cy)/haul distance (ft) | | | | | |
|---|---|---|---|---|---|---|---|
| (a) Scraper | | | | | | | |
| 623B(1983) | $46.00 | $0.10/(500) | $0.11/(1,000) | $0.13/(1,500) | $0.14/(2,000) | $0.16/(2,500) | $0.17/(3,000) |
| 623E(1992) | $58.00 | $0.11/(500) | $0.13/(1,000) | $0.15/(1,500) | $0.16/(2,000) | $0.18/(2,500) | $0.20/(3,000) |
| 623F(1998) | $72.00 | $0.13/(500) | $0.15/(1,000) | $0.17/(1,500) | $0.19/(2,000) | $0.21/(2,500) | $0.23/(3,000) |
| (b) Wheel Loader | | | | | | | |
| 950B(1983) | $18.00 | $0.05/(25) | $0.05/(50) | $0.06/(100) | $0.07/(150) | $0.08/(200) | $0.11/(300) |
| 950F(1992) | $25.00 | $0.06/(25) | $0.07/(50) | $0.08/(100) | $0.09/(150) | $0.10/(200) | $0.12/(300) |
| 950G(1998) | $31.00 | $0.08/(25) | $0.08/(50) | $0.10/(100) | $0.11/(150) | $0.12/(200) | $0.14/(300) |
| 966D(1983) | $24.00 | $0.06/(25) | $0.07/(50) | $0.08/(100) | $0.09/(150) | $0.10/(200) | $0.11/(300) |
| 966F(1992) | $33.00 | $0.07/(25) | $0.08/(50) | $0.09/(100) | $0.10/(150) | $0.11/(200) | $0.13/(300) |
| 966FII(1998) | $41.00 | $0.09/(25) | $0.09/(50) | $0.11/(100) | $0.12/(150) | $0.13/(200) | $0.16/(300) |
| (c) Track Loader | | | | | | | |
| 963(1983) | $28.00 | $0.07/(20) | $0.08/(40) | $0.10/(60) | $0.11/(80) | $0.12/(100) | $0.14/(120) |
| 963(1992) | $30.00 | $0.07/(20) | $0.08/(40) | $0.10/(60) | $0.11/(80) | $0.12/(100) | $0.14/(120) |
| 963B(1998) | $38.00 | $0.08/(20) | $0.09/(40) | $0.11/(60) | $0.12/(80) | $0.14/(100) | $0.15/(120) |
| (d) Dozer—SU Blade | | | | | | | |
| D7HII(1992) | $37.00 | $0.06/(75) | $0.07/(100) | $0.10/(150) | $0.12/(200) | $0.15/(250) | $0.19/(300) |
| D7R(1998) | $46.00 | $0.05/(75) | $0.07/(100) | $0.09/(150) | $0.12/(200) | $0.13/(250) | $0.15/(300) |
| D9N(1992) | $62.00 | $0.05/(75) | $0.06/(100) | $0.07/(150) | $0.09/(200) | $0.12/(250) | $0.14/(300) |
| D9R(1998) | $86.00 | $0.06/(75) | $0.07/(100) | $0.10/(150) | $0.13/(200) | $0.16/(250) | $0.20/(300) |

Note: 1 cy = 0.766 $m^3$.

**Table 5.** Average Annual Percent Change in Unit Costs

| Duration | Change in unit cost (%)/haul distance (ft) | | | | | | Average (%) |
|---|---|---|---|---|---|---|---|
| (a) Scraper—623 | | | | | | | |
| 1983–1998 | 1.99/(500) | 2.03/(1,000) | 1.87/(1,500) | 1.97/(2,000) | 1.97/(2,500) | 2.15/(3,000) | 200 |
| 1983–1992 | 1.07/(500) | 1.12/(1,000) | 1.13/(1,500) | 1.32/(2,000) | 1.45/(2,500) | 1.71/(3,000) | 1.30 |
| 1992–1998 | 3.37/(500) | 3.40/(1,000) | 2.99/(1,500) | 2.96/(2,000) | 2.75/(2,500) | 2.82/(3,000) | 3.05 |
| (b) Wheel Loader—950 | | | | | | | |
| 1983–1998 | 3.25/(25) | 3.02/(50) | 2.88/(100) | 2.90/(150) | 2.51/(200) | 1.89/(300) | 2.74 |
| 1983–1992 | 3.64/(25) | 3.12/(50) | 2.76/(100) | 2.65/(150) | 1.83/(200) | 1.05/(300) | 2.51 |
| 1992–1998 | 2.68/(25) | 2.88/(50) | 3.05/(100) | 3.28/(150) | 3.54/(200) | 3.16/(300) | 3.10 |
| (c) Wheel Loader—966 | | | | | | | |
| 1983–1998 | 2.28/(25) | 2.18/(50) | 2.02/(100) | 2.01/(150) | 2.18/(200) | 2.28/(300) | 2.16 |
| 1983–1992 | 1.83/(25) | 1.68/(50) | 1.19/(100) | 0.96/(150) | 1.30/(200) | 1.41/(300) | 1.40 |
| 1992–1998 | 2.97/(25) | 2.94/(50) | 3.28/(100) | 3.61/(150) | 3.50/(200) | 3.60/(300) | 3.32 |
| (d) Track Loader—963 | | | | | | | |
| 1983–1998 | 0.45/(20) | 0.54/(40) | 0.59/(60) | 0.58/(80) | 0.62/(100) | 0.61/(120) | 0.57 |
| 1983–1992 | −0.32/(20) | −0.13/(40) | −0.12/(60) | −0.10/(80) | 0.00/(100) | −0.08/(120) | −0.12 |
| 1992–1998 | 1.62/(20) | 1.55/(40) | 1.67/(60) | 1.62/(80) | 1.56/(100) | 1.65/(120) | 1.61 |
| (e) Dozer—D7 with SU Blade | | | | | | | |
| 1992–1998 | −1.74/(75) | −1.89/(100) | −1.21/(150) | −1.11/(200) | −2.66/(250) | −3.12/(300) | −1.96 |
| (f) Dozer—D9 with SU Blade | | | | | | | |
| 1992–1998 | 2.29/(75) | 3.54/(100) | 4.43/(150) | 4.86/(200) | 5.21/(250) | 6.95/(300) | 4.55 |

Note: 1 ft = 0.305 m.



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increase in the price of equipment is mainly due to two parameters: (1) inflation, and (2) cost of technological improvements in the machine. In order to exclude the effect of inflation, the equipment prices may be adjusted using cost indexes. The source of equipment owning and operating costs for various years is the quick estimator guide from the relevant Caterpillar handbook. This is done to ensure consistency in assumptions for models in various years. It should be noted that these costs do not include finance charge, insurance, tax, storage, and operator's wage.

For cost escalation, one may use various indexes such as *Engineering News Record (ENR)* or the consumer price index. Each of these indexes is effective in modeling price variations of some components of equipment cost.

Table 4 shows the results of the unit cost analysis for the equipment studied in this work. No cost adjustment is implemented in this table. This means that, for example, the cost per cy of material moved for the model 950F wheel loader was \$0.12 (assuming a 300 ft haul distance and 100% efficiency) in 1992 dollars; the same unit cost for a model 950G wheel loader was \$0.14 in 1998 dollars. Table 5 gives percent change in unit costs on an annual basis. For example, during the period 1983–1992, the unit cost (dollars per cy) for material moved by scraper model 623 increased at a rate of 1.30% per year. Please note that because of rounding off unit costs to the nearest cent, the percentages reported in Table 5 may not be exactly reproduced using unit prices in Table 4. We have used unit costs that were not rounded off to calculate percent rates reported in Table 5. A weighted average for all six machines was calculated as 1.77% by considering the rates in Table 5 and weighing these with their corresponding time spans.

$$2.00\%\times15+2.74\%\times15+2.16\%\times15+0.57\%\times15-1.96\%\times6$$
$$+4.55\%\times6=127.59\%$$
$$127.59\%\div(15+15+15+15+6+6)=1.77\%$$

## Limitations of Analysis

In this study the production rates for various earthmoving equipment were calculated under ideal steady–state conditions. Several other factors such as job and management conditions affecting operation efficiency, job size, available duration, and availability of support equipment should be considered in any specific project. While calculated production rates may not be applicable for actual planning and estimating of a specific job, they are adequate for the purpose of comparisons used in this paper. The main objective here is to observe and quantify the trend in change in productivity and unit costs of equipment operation during the period 1983–1998. We believe that the study provides a reasonable assessment of these trends.

## Conclusion

Obsolescence is one of the factors that need to be considered in an equipment replacement analysis. This paper provides an estimate of obsolescence based on the change in production rates of several models over the course of the last 15 years. It is shown that given certain limitations and assumptions, the productivity of earthmoving equipment has increased an average of 1.58% per year. The unit cost of earthmoving for the same family of equipment, without adjusting for cost escalation over the period 1983–1998, has increased by 1.77% per year. This is a modest price increase, noting that the rate of escalation was well above the rate calculated. As an example, we use the *Engineering News Record (ENR)* cost index values to evaluate this price increase. It is understood that these index values represent the price of construction labor and material. Despite this, the construction industry perceives them as reasonable indicators of overall construction cost movements. The *ENR*'s Building Cost Index has increased on average 2.37% per year during the period 1983–1998, and the *ENR*'s Construction Cost Index has increased on average 2.54% per year during the same period. So in real terms, the unit cost of earthmoving for the equipment group studied has actually decreased during the past 15 years. The amount of this decrease is of course quite modest, more or less in the same order that the production rates have improved. We believe that the results of this paper can help the contractor or the equipment owner in equipment replacement analysis.

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