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Prediction for national catastrophe fund

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Abstract United States of America (US) Congress is considering a bill 'H.R. 2555: Homeowners' Defense Act of 2010' to form National Catastrophe Risk Consortium, one of whose functions is to fund a National Catastrophe Fund to help public and insurance companies meet the liability claims from hurricane, fire, and blizzard. However, before the act is enacted into law by US Congress, the bill has to pass through House Financial Services Committee which takes into account the projected costs, disbursements, and the amount required to be appropriated for the task and its source. Using data for three catastrophes for the last 100 years, the 2011 claims for hurricane, fire, and blizzard in United States of America are estimated. For predicting acres burned and economic damage due to blizzards, a trend analysis and linear regression were carried out using Excel and GraphPad Prism. Poisson distribution was used to model hurricanes. The estimates for the different catastrophes are based on a 95% confidence interval. The cost to the National Catastrophe Fund for the liabilities of fire, blizzard, and hurricane comes to over 2 billion. Of this, the bulk cost arises from fire damage, followed by hurricane damage and blizzard damage.

Keywords Hurricanes · Blizzards · Fire · Insurance · Catastrophe fund

1 Introduction

Natural disasters like hurricanes in Florida and Gulf of Mexico bordering states, tornadoes in the Midwest, wild fires in California, nuclear disasters as Chernobyl and Fukushima, and Tsunamis in Indonesia and Japan show the might of nature over humans. Most of these disasters cannot be predicted accurately in advance (varying timelines) but cause a havoc with lives and property, if and when they strike. One cannot bring back to life the persons who lose their life in these disasters but can help in rehabilitating those who suffer other loss, especially monetary. Insurance companies play a role in compensating for the property damage after these episodes. However, many a times, their funds are not sufficient to cover

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the damages especially if the disaster is of enormous proportions. A National Catastrophe Fund' can act as a security cushion to provide relief to the suffering people by compensating them directly or through the insurance companies. It would stabilize skyrocketing insurance rates and provide a common-sense federal backstop in the event of a major natural disaster. United States considered such a proposal. However, before such a policy is enacted into law by US Congress, the bill "Approaches to Mitigating and Managing Natural Catastrophe Risk: H.R. 2555, The Homeowners' Defense Act" has to pass through House Financial Services Committee which takes into account the projected costs, disbursements, and the amount required to be appropriated for the task and its source. The project herein quantifies the amount of dollars needed to create such a fund limiting it to 10% of the total monetary damage based upon estimated damage from hurricanes, tornadoes, and wild fires in the United States. The estimates are based upon mathematical models and application of statistics to data on these disasters for last hundred years.

2 Methodology

The data used for the analysis were obtained from Society of Actuaries, USA. The data for fires are from year 1900 to 2008 and included count of fires and acres burned. The data included number of blizzards and economic damages per year from year 1900 to 2006. The hurricane data include storm category, number of hurricanes and economic damages per year from year 1900 to 2005 For predicting acres burned and economic damage due to blizzards, a trend analysis and linear regression were carried out using Excel and GraphPad Prism (GraphPad Software Inc). Since storm category, year, and economic damages are provided for hurricanes, Poisson distribution (Ramsey 2011) analysis was used to model hurricanes. All the predictions were done for year 2011. Literature survey was conducted to find the reported average cost of one acre of fire loss (US Forest Service 2011). US fire departments responded to an estimated 1,348,500 fires in 2009. These fires resulted in 3,010 civilian fire fatalities, 17,050 civilian fire injuries, and an estimated $12,531,000,000 in direct property loss (Karter 2010).

Using these data, it is estimated that the cost of loss of one acre fire is about $1,200 in 2009. However, it has to keep in mind that the monetary loss of property in metropolitan or urban areas fires will be much more than in the rural area fires or forest and wild fires. Another datum used is the California wildfires of 2007. It was estimated that 2,000 houses burned in 500,000 acres of wildfire (Fitch 2007). Using an estimate of $300,000 per house, the total cost would be $600,000,000. Dividing the same by 500,000 acres, cost per acre comes to be $1,200 which is about the same as derived from other estimate. It is worth noting that these wild fire losses are for California where the costs may be much more than whole of USA. The average cost for USA might be in the range of $300–$500 per acre, but in the absence of availability of actual data, the data for California were used as a representative of the whole nation.

3 Analysis, results, and discussion

3.1 Acres burned analysis

The base data are presented as the number of acres that are burned each year since the year 1900. The data were plotted in a graph using Microsoft Excel to visualize the data and to observe trends if any (Fig. 1). The overall trend from year 1900 to 2008 shows a negative slope signifying a decreasing trend. However, it will be better to subdivide this range of 108 years into three regions of uniform slopes. It is observed from the figure that the acres burned were showing a uniform trend from 1900 to year 1950. However, after that till around year 1995, the trend showed a decreasing trend, though the inter year variation increased. On the other hand from early 1990s to 2008, there was an unprecedented increase in the number of acres burned. If the trend analysis and regression had been done from 1900 to 2008, the predicted value would be too low. The years 1993–2008 were chosen as the trend had started to show upward trend from year 1993, was the latest trend period, and the variation had started to increase in year 1993. Limiting the years for the analysis made a more accurate prediction.

To visualize these data properly, the data from year 1993 to 2008 were plotted in Fig. 2. A linear regression trend line was superimposed on the data. The data can be represented by the regression line having the equation: Acres burnt = 416,769x + 2,000,000 ($R^2 = 0.5$), where x is the year ($x = 1$ when year = 1993). The $R^2 = 0.5$ was much better than the $R^2 = 00{,}125$ which was obtained from the linear regression of acres burnt over all the years. Using the equation 416,769x + 2,000,000, it is estimated that 9,918,611 acres of land will be burned in year 2011. This is the predicted average. However, we need to predict the upper limit as per 95% confidence limit. To find the upper limit of the predicted acres of land at a 95% confidence, the data were analyzed using GraphPad Prism software.

Figure 3 shows the graph with 95% confidence band of the regression line and 95% prediction band of the linear regression line. The slope significantly differs from the zero slope ($p = 0.002$). The run test non-significant p value (0.9161) shows that the data assumption of linearity is met. The residuals are plotted in Fig. 4. No specific pattern in the residuals point that the assumptions of homogeneity are correct.

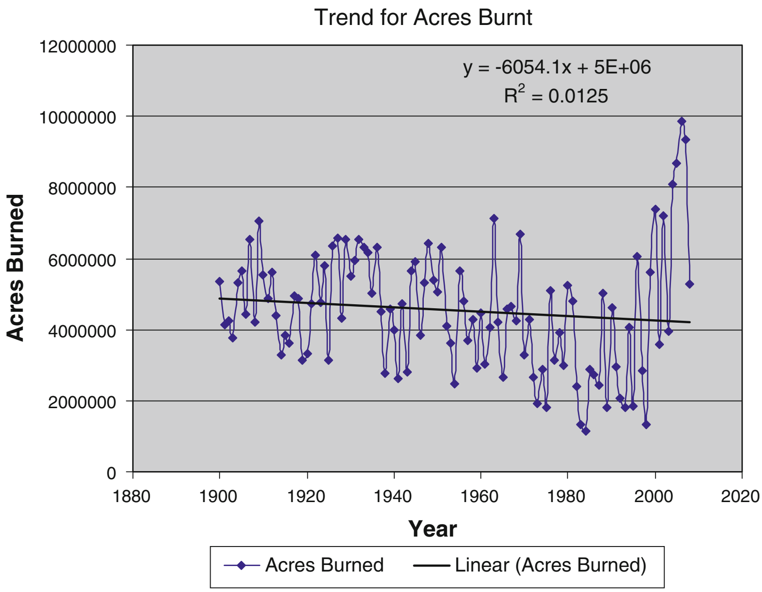


Fig. 1 Trend and linear regression of Acres burned over years for year 1900 to year 2008

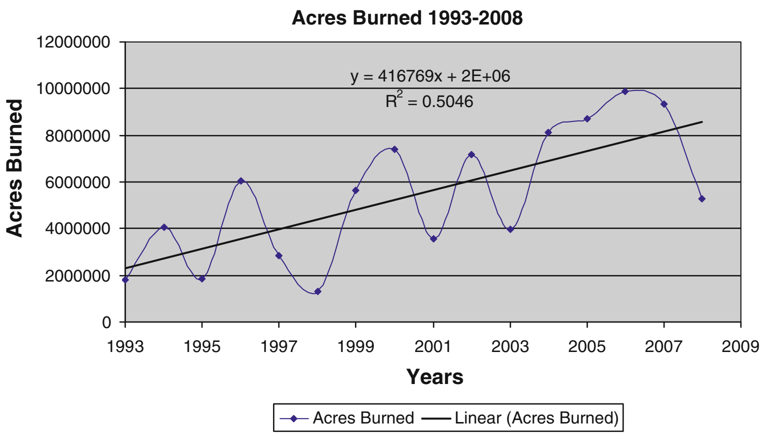
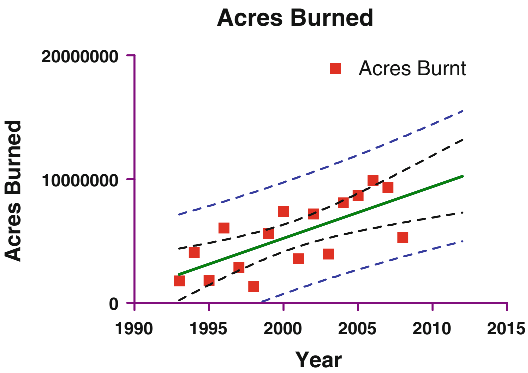


Fig. 2 Trend and linear regression of acres burned over years for year 1993 to year 2008

Fig. 3 The figure shows linear regression line shown by *bold line* surrounded by an inner 95% confidence band of regression and outer 95% prediction band of regression. The linear regression equation is acres burned = 416,769x + 20,00,000 (R^2 = 0.5) where x is the year (x = 1 when year = 1993)



The predicted value (acres burned) for year 2011 is 9,833,276 ± 5,146,565 at 95% confidence. For monetizing the loss due to fire, cost of loss per acre of fire is needed. However, this is not provided in the base data.

The data for population and housing units show the trend of increasing population and the housing units over the last century. This implies that even if the quantity and extent of acreage of wildfire damage remain same, the economic costs will increase as the number of housing units per acre are increasing. Linear regression of housing units from year 1981 to 2005 is shown in Fig. 5. The slope is = 1,000,000 meaning that every year 1,000,000 housing units are added. So, the ratio of housing units in 2011 to those in 2005 is (122,725,123 + 6 × slope)/122,725,123 = (122,725,123 + 6 × 1,000,000)/122,725,123 = 1.049. However, the wildfire data are till 2008. So, the ratio needs to be for housing units in year 2011 over housing units in 2008. This value is 122,725,123 + 6 × 1.000,000)/(122,725,123 + 3 × 1,000,000) = 1.024.

Methodology section describes the analysis for cost per acre. At the cost of $1,236 per acre (after adjusting for inflation of 1.5% per year from 2009 per acre cost of $1,200) (U.S. Bureau of Labor Statistics 2011), the predicted losses would be $12,153,929,136 ± 6,361,154,340 at 95% confidence level. This cost has to be increased by 1.024 to account for the increase in housing units (calculated earlier).

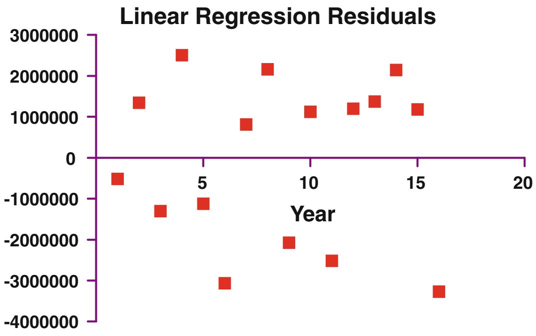


Fig. 4 Residual graph for linear regression. No specific pattern in the residuals point that the assumptions of homogeneity are correct

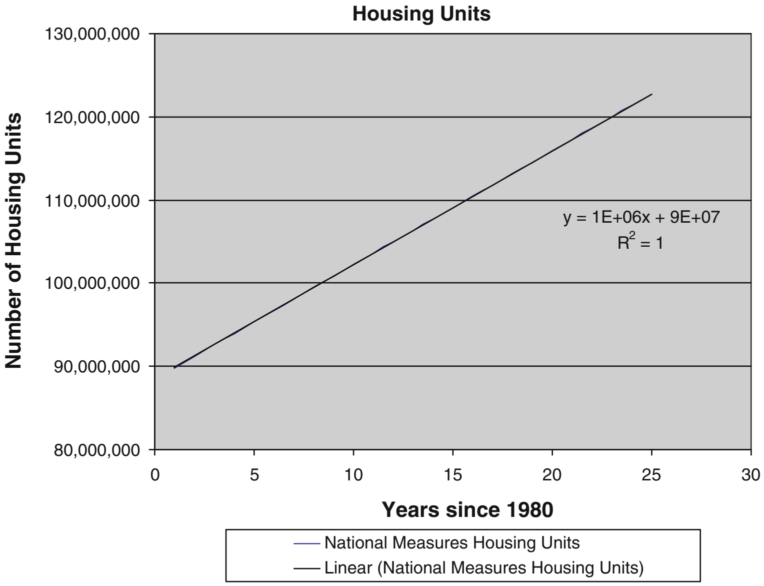


Fig. 5 Linear regression of housing units from year 1981 to 2005. The slope is = 1,000,000 meaning that every year 1,000,000 housing units are added

Since NCF is responsible for only 10% of the loss, sum of \$1,215,392,914 ± 636,115,434 at 95% confidence level will be required. To be on the safer side, the upper limit of 95% confidence level will be needed for the fund which is \$1,215,392,914 + \$636,115,434 = \$1,851,508,348 = \$1,851.5 × 10^6 = 1,851 million dollars. Multiplying this by the housing, increase factor of 1.024 gives the estimate to be 1,895 million dollars.

3.2 Blizzards analysis

A trend analysis for blizzards from the years 1900–2006 was performed (Fig. 6). As opposed to the fire acres burnt, this graph shows a consistent slope over the past 100 years. After late 1990s, the inter year variation has increased. Figure 7 shows the 95% confidence band of the data and 95% confidence level prediction band.

A trend analysis for blizzards from 1950 to 2006 was also carried out (Fig. 8), and the prediction band is shown in Fig. 9. However, the R^2 decreased to 0.29 from 0.39 and the slope doubled (Fig. 6). The regression of all the years (Figs. 6, 7) was selected for further calculations because of higher R^2 and that it is visually seen that in last 5 years the slope has relatively decreased. The residual plot and run test confirmed that the assumptions were valid (data or graph not shown). The predicted value of economic damages in year 2011 was computed to be $\$4.29 \times 10^8 \pm 2.61 \times 10^8$ at 95% predicted confidence levels. As NCF is responsible for only 10% of losses, a fund of $\$4.29 \times 10^7 + 2.61 \times 10^7 = \$6.90 \times 10^7$ (69 million dollars) which is the upper limit at 95% predicted confidence will be sufficient to cover the blizzard losses.

3.3 Hurricane analysis

Since the data have storm category, year, and economic damages, hurricanes can be modeled by Poisson distribution (Ramsey 2011). The data provided were summarized in Table 1. There were 44 category 1 hurricanes, 34 category 2, 53 category 3, 14 category 4, 3 category 5, and 59 tropical storms that caused damage to United States in the last 100 years (Table 1). In Poisson distribution, x is the average number of hurricanes. Therefore, $P(X = k) = e^{(-x)}(x)^k/k!$, where k is the integral number of hurricane. For example, $x = 0.5$ for category 3, so $P(X = 0)$ or zero numbers of category three hurricanes is $e^{(-0.5)}(0.5)^0/0! = 0.607$. Therefore, the probability of having zero numbers of category 3 hurricanes is 60.7%. Logically, the probability of having 1 or more hurricanes should be $1 - P(\text{Zero hurricanes}) = 39.3\%$. Likewise, the probability of having at least 1 hurricane in each of the categories was determined. The total damage in monetary terms was calculated for each categorical hurricane, and the average was taken per categorical hurricane. The data seemed to agree with logic in that as the hurricane strength increased, economic damages increased. However, category 3 caused more economic damage than category 4, which may be due to the lack of enough category 4 hurricanes in the data set or the striking of category 4 storms in less populous or less economically developed areas than the category 3 storms. Once the average damage was determined, the probability for each

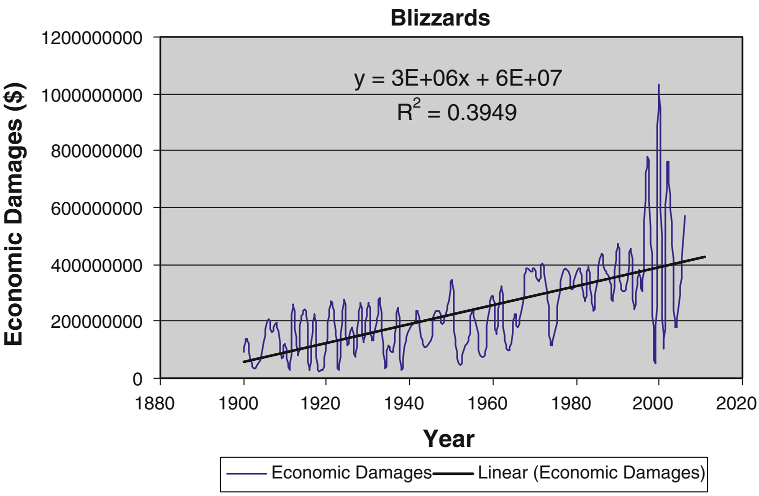
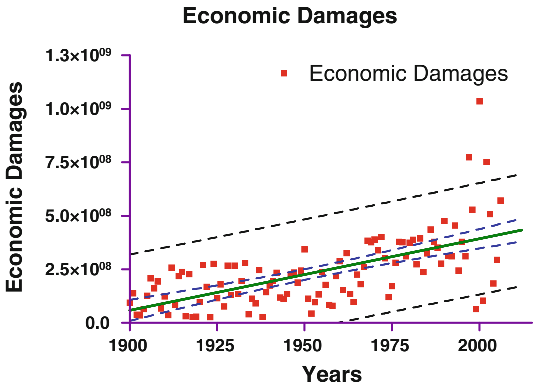


Fig. 6 Trend and linear regression of blizzards economic damage over years for year 1900 to year 2006

Fig. 7 The figure shows linear regression line for blizzards economic damage shown by *bold line* surrounded by an inner 95% confidence band of regression and outer 95% prediction band of regression for year 1900 to year 2006



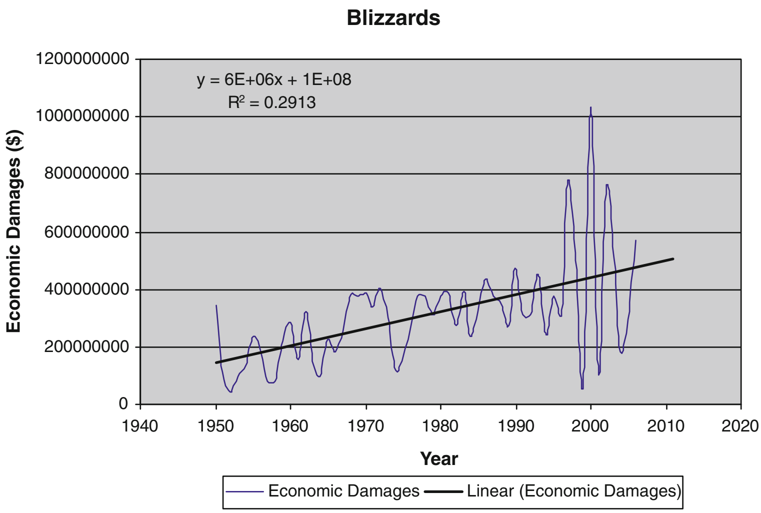
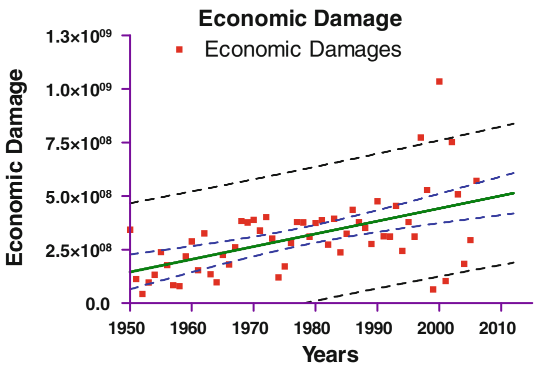


Fig. 8 Trend and linear regression of blizzard economic damage over years for year 1950 to year 2008

Fig. 9 Linear regression line for blizzards economic damage shown by *bold line* surrounded by an inner 95% confidence band of regression and outer 95% prediction band of regression for year 1950 to year 2008



categorical hurricane was multiplied by average economic damage to determine expected value for each categorical hurricane (Table 1). The total expected damage from hurricanes came out to be 1 billion and 920 million dollars.

Table 1 Probability and expected claims from hurricanes

Hurricane category	Number of hurricanes	Total damage	Average hurricane	Average damage	Probability of at least one hurricane	Expected claims
1	44	$6,855,700,000	0.415	$155,811,363.64	0.339722013	$52,932,550.04
2	34	23,462,400,000	0.321	$690,070,588.24	0.274398793	$189,354,536.62
3	53	$153,612,000,000	0.5	$2,898,339,622.64	0.39346934	$1,140,407,779.25
4	14	23,580,500,000	0.132	$1,684,321,428.57	0.123725141	$208,392,906.86
5	3	27,927,000,000	0.0283	$9,309,000,000.00	0.02790514	$259,768,949.18
Tropical storms	59	$9,569,200,000	0.557	$162,189,830.51	0.426847683	$69,230,353.33
Total hurricane claim						$1,920,087,075.28
Total NSF liability (10%)						$192 million

3.4 Total estimate

The three estimates for wildfires', blizzards', and hurricanes' economic damage were added to give total estimate (upper limit of 95% confidence for predicted values) per year for the claims. Ten percent of that cost was taken to be the dollar amount that National Catastrophe Fund would reimburse. The total value was 2.156 billion dollars (192 million for hurricane + 69 million for blizzards + 1,895 million for fire).

4 Discussion and limitations of data and analysis

For fires, 18,950 million dollars worth of damage was estimated. Inspecting the data, it seems that in the twenty-first century the number of fires relatively decreased, while acres burned increased. The cost per acre of fire burned area will be the key factor in economic loss calculation as the cost in urban, rural, and forest areas per acre would vary considerably. It is a shortcoming of the data that acres burnt is not subdivided into such regions, and thus, an accurate prediction is less likely. This may be an overestimate in barren areas of southwest, but an underestimate of the ones that directly affects houses. The worth of land could be equated to the worth of property once it is built. The mean was used instead of median to provide little more emphasis to heavy tail in the twenty-first century (even though one could have considered them as outliers). Likewise, for the blizzard, mean was used. Since total damages were provided, simple regression was used to predict future values. Linear regression method was seen as the best of the predictive regressions, because R^2 value was better.

For the hurricanes, the average number of significant hurricanes has increased from 2 all time to 4.33 in the last 5 years (Table 2). Total damage for each hurricane was determined by summing up all the hurricanes from that category. Using that information, average damage from each category was calculated. Expected value of the number of hurricanes in each category was multiplied by the average damage to give expected value of damage for each category. The assumption here is that hurricanes follow a Poisson distribution. This is most likely an overestimate as well, because there were not enough data for stronger hurricanes to have effective impact on the estimate. Hurricane such as Katrina was a Category 3 but caused much more damage than category 3 estimated damage.

Table 2 Average hurricanes per year

Years	Average hurricanes per year
All	1.952830189
Last 60	2.557377049
Last 30	2.870967742
Last 20	3.476190476
Last 10	4.181818182
Last 5	4.333333333

Pinelli and Pita (2011) have characterized damage from public hurricane loss model for Florida and have carried out various simulations. Recovery and mitigation efforts (Leatherman 2011) take a lot of time and economic resources. Still, predictions give us a direction for preparedness—economic or otherwise, but it is the actual natural calamity aftermath that is the true representation of the damage.

5 Conclusion

The National Catastrophe Fund should expect to provide close to 2.156 billion dollars in catastrophic damages in year 2011. There is limitation to the regression used because it assumes normal conditions that have existed in the past century. More stratified data for fire and blizzard will provide a better estimate.

6 Further research needs

Stratified data could be useful to produce more precise estimation for the catastrophes. The natural trends, El Nino effect and weather models can be investigated as added tools to modify the estimates.

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