Docket No. 041272
Witness: Javier Portuondo
Exhibit ___ (JP-3)
Evaluation of Currently Approved
Storm Damage Accrual

Before the
Florida Public Service Commission

In re: Petition for Authorization to Implement a Self-Insurance Program for Storm Damage to its T&D Lines and to Increase Annual Storm Damage Expense by Florida Power Corporation.	)	**Docket No. 930867-EI** **Filed: February 28, 1994**

EVALUATION OF CURRENTLY APPROVED STORM DAMAGE ACCRUAL

Florida Power
CORPORATION

FLORIDA POWER CORPORATION
EVALUATION OF CURRENTLY APPROVED STORM DAMAGE ACCRUAL
AS REQUIRED BY THE FLORIDA PUBLIC SERVICE COMMISSION
DOCKET 930867-EI, ORDER No. PSC-93-1522-FOF-EI

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SECTION I
EXECUTIVE SUMMARY

As ordered by the Florida Public Service Commission (herein after referred to as "Commission" or "FPSC") in Order number PSC-93-1522-FOF-EI, Docket Number 930867-EI, dated October 15, 1993, Florida Power Corporation (herein after referred to as "Company" or "FPC") was required to prepare a study to determine the appropriate annual amount to be accrued to the storm damage reserve. The Commission's Order has been attached as Exhibit Number 1. The Company decided the most reasonable approach to determine the appropriate annual storm damage accrual was to estimate the annual expected cost of property damage to its transmission and distribution (T&D) lines from hurricanes. Accordingly, the Company conducted a simulation study to estimate such damage.

In an effort to reasonably quantify the Company's major exposure to storm damage and prepare a study in a short time frame, it was determined that the study should be limited to damage to T&D lines from hurricanes. The Company acknowledges it has additional uninsured exposure to property damage on facilities other than T&D lines and from all "destructive acts of nature" not necessarily limited to hurricanes. However, the availability of information required to estimate other damage is limited and would be too subjective to produce reliable results.

The study was prepared using a Monte Carlo simulation model developed by FPC personnel to simulate the average cost of a hurricane strike. The model simulated 10,000 hurricane strikes selecting from defined statistical distributions of input variables to determine the average cost. The major input variables were 1) hurricane distribution by category, 2) cost distribution of T&D facilities (replacement cost), 3) area of storm damage, and 4) damage factor. The results of the simulation study produced an average cost of $20.3 million for an individual hurricane. The probability of a hurricane striking the FPC territory was determined to be 23.3% per year. **Thus, the average expected annual hurricane damage to T&D lines was determined to be $4.7 million.**

Category IV and V hurricanes were excluded from the simulation. This was based on the fact that no category IV or V hurricanes have made landfall in the FPC territory in the past 90 years. Meteorological information obtained supports an extremely low probability of these category storms striking the FPC territory.

Cost data for the T&D lines excluded underground lines and associated equipment. This was based on the assumption that hurricane damage would primarily be caused by wind and underground equipment would presumably not suffer wind damage. Storm surge damage was excluded because it was assumed to be minimal for T&D lines.

Cost data for T&D lines was based on an estimate of the replacement cost of equipment. The data did not include other costs directly associated with restoration of facilities that the Company proposes to charge against the reserve such as providing meals and lodging to work crews or the cost of preparing temporary staging facilities for materials and supplies, etc.

The FPC service territory was divided into three areas to develop the probability of hurricane strike by location. This was done to more accurately reflect strike probabilities and was based on projected hurricane landfall information Cost distribution data was also developed for each section.

The average estimated cost of a hurricane strike represents the total damage. No assumption was made in the simulation to identify of segregate the capital portion from the Operations and Maintenance (O&M) expense portion of the damage. Based on FPC's historical storm experience, we estimate that the O&M portion would average approximately 80% of the total damage for category I, II and III storms. Applying this historical experience factor to the total expected annual cost of $4.7 million, results in the annual expected O&M portion of hurricane damage of $3.8 million.

In addition to the expected average damage cost of a hurricane, the statistical study provides other relevant information associated with hurricane damage. In 53% of the individual storms simulated, the calculated damage was less than $5 million. The study included 1,018 storms (or 10%) with damage in excess of $50 million. The lowest cost of an individual storm was simulated to be $15 thousand. This was a category I storm damaging a very small section of FPC's service territory. The highest cost of an individual storm, although having an extremely low probability, was simulated to be $574 million. This storm was a category III storm taking out a significant portion of the highest cost density area of our territory.

The Company also prepared a sensitivity case to emulate the amount of insurance recovery the Company would have collected under its prior T&D policy. This case calculated the expected annual cost of reimbursable damage to T&D facilities under the previous insurance coverage. The previous T&D policy provided coverage of $90 million of property damage in excess of a $5 million deductible. The expected annual cost of reimbursable damage was calculated to be $2.9 million, with the O&M portion (based on 80% historical factor) amounting to $2.3 million. In the Company's last base rate proceeding the Commission approved a storm damage expense of $.1 million to cover all self insured exposure from any "destructive acts of nature" which included a $5 million deductible on the T&D policy. The Commission subsequently approved an annual storm damage expense of $3 million as a result of the Company's petition to implement a self insurance program for T&D lines.

The Company acknowledges that the storm damage reserve is an operating reserve and as such would only be charged with the O&M costs directly associated with storm damage and related restoration activities. The capital costs would be determined consistent with capitalization practices used under normal operating conditions. The Company further acknowledges that the storm damage reserve is primarily considered to be for non-catastrophic events. If the Company were to actually experience storm damage significantly in excess of the reserve balance, a petition requesting a mechanism to recover the excess costs in a timely manner would be filed for consideration before the Commission. Although the expected annual cost was determined to be $4.7 million ($3.8 million for O&M), significant and/or catastrophic damage could occur at any time.

The Company believes that in the next three to five years there will be changes in the availability of T&D insurance options. Although we do not expect the insurance market to return to coverage at previous rates, it is expected that some level of traditional insurance coverage will be available at economical rates with deductibles in the range of $15 to $20 million. We expect this to ultimately result in some combination of self insurance and traditional insurance with a much higher reliance on self insurance than was experienced in the past. If the Company does purchase traditional insurance, the annual accrual for storm damage should be reevaluated to properly consider the premium costs and remaining self insurance exposure. As in the past, any proceeds from insurance recoveries would be credited to the reserve balance for the appropriate O&M portion.

In conclusion, the Company believes that its current annual accrual for storm damage expense of $3 million is reasonable and should not be adjusted at this time. Although the study produces an average annual expected total cost of $4.7 million of damage to T&D lines from hurricanes, the O&M portion is estimated to be only $3.8 million. Furthermore, the study shows that 53% of the storms simulated a total cost of less than $5 million and the probability of a storm occurrence is only 23.3% per year. The Company's sensitivity case based on prior insurance coverage also supports this conclusion. Although it is possible that the Company may experience a catastrophic storm at any time, such an occurrence would require the Company to petition the Commission for timely cost recovery. In addition, the Company is required to file a report to evaluate the adequacy of the reserve on an annual basis.

SECTION II
BACKGROUND AND REQUIREMENTS OF COMMISSION ORDER

On August 31, 1993, Florida Power Corporation filed a petition with the FPSC seeking authorization to implement a self insurance program for damage to its T&D lines in the event of hurricanes, tornados or other destructive acts of nature. The self insurance program would become effective November 1, 1993. The FPC petition (attached as Exhibit Number 2) also sought to increase the annual storm damage expense from $100,000 to $3 million in replacement of commercial insurance and to continue the use of an unfunded reserve. The petition was supported by the direct testimony of Mr. John Scardino, Jr. which further explained the Company's decision to implement a self insurance program. The Company was faced with the expiration of its traditional T&D insurance coverage on November 1, 1993 and had been unable to obtain reasonably priced insurance considering premiums, limits and deductibles. This situation was considered by the Company to be a short term "crisis" in the insurance industry resulting from the loss experience of hurricanes Andrew and Hugo, as well as the March 1993 "storm of the century".

On October 12, 1993, the Commission voted to approve FPC's request to implement a self insurance program for storm damage to its T&D lines. This vote was confirmed by Order number PSC-93-1522-FOF-EI dated October 15, 1993. Concerned that the requested $3 million annual accrual to FPC's storm and property insurance reserve might not be adequate, the Commission ordered FPC to submit a study, within 3 months, to evaluate the amount that should be annually accrued to the storm damage reserve. The order required among other things, that FPC's study provide:

a) information concerning the treatment of T&D damages under its then existing policy;
b) a listing of the type of storm-related expenses FPC intends to draw from the reserve; and,
c) the type of accounting entries which will be made for each item.

On January 6, 1994, FPC filed a motion requesting a 45 day extension of time to file the study. On February 1, 1994, the Commission approved this request and revised the due date to February 28, 1994.

SECTION III
TREATMENT OF T&D DAMAGES UNDER PRIOR INSURANCE POLICY

Prior to the time that FPC implemented a self insurance program for T&D lines, traditional insurance coverage was provided by Arkwright Mutual Insurance Company and various excess carriers. The excess carriers provided their T&D coverage on a following-form basis, meaning that their coverage was subject to the same terms and conditions contained in Arkwright's policy. FPC had never filed a claim for T&D damage under its former policies due to actual damage experience not exceeding the $5 million deductible.

In the event of a loss, the insurers would have paid the lesser of the cost to repair or replace the damaged T&D property with materials of like kind and quality. In general, the policies provided coverage for the "actual costs incurred for necessary labor (including overtime and bonus wages), materials, supplies and other services for the temporary or permanent repair or replacement of the damaged property". The policies provided expediting expense coverage to the extent that such expenses were clearly associated with the prompt restoration of service to customers. In addition, the policies agreed to reimburse FPC for 100% of the payroll loading rate normally applied to FPC labor charges. The payroll loading rate is designed to cover the cost of payroll related taxes, administrative expenses and employee benefits costs.

"Necessary" labor was not defined in the policy, but based on past experience with non T&D claims under this policy, we believe it would have included labor charges for those employees involved in actual repair activities as well as those in supporting roles. Supporting roles would have included, but not necessarily been limited to, engineering, storeroom and transportation personnel. It is not clear whether the insurers would have reimbursed FPC for labor charges associated with the work performed by customer service employees and other division personnel during the restoration period. While the functions these employees perform are not actual repair activities, they do provide necessary interface with customers to discover and locate areas of damage and help prioritize restoration.

Examples of items that were not covered under the T&D policies are damages related to normal wear and tear, costs arising from business interruption, delay or loss of market, and any damage resulting from nuclear reaction, radiation, or radioactive contamination.

SECTION IV
ACCOUNTING ISSUES

PART A - TYPES OF STORM RELATED EXPENSES TO BE CHARGED TO THE RESERVE

The Company proposes to use a replacement cost approach for determining the appropriate amounts to be charged to the storm damage reserve. This approach is consistent with both the Company's prior coverage under traditional insurance for T&D lines as well as its current insurance coverage for other facilities. The damage to facilities currently covered through a self insurance program should be treated comparably. The replacement cost method represents by far the simplest approach and will transition well with any changes made in the Company's current insurance program for all facilities. The replacement cost approach assumes that the total cost of restoration and related activities will be charged against the storm damage reserve.

The Company anticipates changes in its insurance program in the near future as the insurance industry begins to recover from the "crisis" situation of recent storm damage experience. However, the Company believes its insurance program will continue to be a combination of traditional insurance coverage along with some level of self insurance. Any requirement to use an approach other than replacement cost would place undue administrative burden on the Company which would presumably occur at a time when Company efforts would need to be dedicated to restoration of service and related activities.

Actual repair activities and those activities directly associated with storm damage and restoration activities would be charged to the reserve. Indirect costs would not be charged to the reserve. Direct costs would typically be payroll, transportation, materials and supplies, and other services necessary to locate and repair or replace damaged property. Payroll includes labor charges for those employees involved in actual repair activities as well as those in supporting roles such as customer service, engineering, storeroom and transportation personnel. See Exhibit Number 3 for a detailed list of the types of costs the Company believes would be directly associated with storm damage and restoration activities.

The Company's storm damage reserve is an "operating reserve" as defined by Commission rule 25-6.0143 and as such would only be charged with the Operations and Maintenance (O&M) expense associated with storm damage. Capital costs, including cost of removal, would be charged to the appropriate Electric Plant in Service or Accumulated Provision for Depreciation accounts. Capital costs and cost of removal would be determined based on a "fair and reasonable" standard assuming normal operating conditions. The Company uses a standard cost approach for labor and material components of retirement units for the determination of normal operating conditions. Any costs in excess of the standard cost components is considered extraordinary or emergency in nature and would be considered O&M and therefore charged to the reserve. This assures that the Company's rate base investment is not artificially overstated for the purposes of future ratemaking activity.

PART B - ACCOUNTING ENTRIES

Initially, the Company records storm damage and related restoration costs in a deferred debit (FERC 186) account. This procedure facilitates the accounting process and allows the Company to properly analyze all charges to determine the appropriate capital portion and to eliminate any costs not directly associated with storm damage and restoration activities. Once the charges have been analyzed in detail, the proper amounts are then charged to the storm damage reserve and appropriate capital accounts. Retirements of damaged property are recorded in the normal manner as prescribed by the FPSC's Uniform System of Accounts. See Exhibit Number 4 for sample journal entries of accounting activity.

In the Company's last base rate proceeding, the Commission approved the use of the storm damage reserve for any "destructive acts of nature". The Company therefore intends to charge the storm damage reserve for any such property damage not covered by insurance. In addition to T&D lines, the Company currently has uninsured exposure for deductibles on its non-T&D property policies. These policies include a deductible for wind damage to non-T&D property located within 50 miles of the coast. The deductible is based on 2% of the damaged property's value with a maximum annual exposure of $15 million. Any insurance recoveries would be credited to the storm damage reserve and capital accounts in the same proportion as the damage costs recorded.

PART C - BALANCE OF THE STORM DAMAGE RESERVE

The Company utilizes FPSC rule 25-6.0143 titled Use of Accumulated Provision Accounts 228.1, 228.2 and 228.4 as guidance for the charges to the reserve:

> "If a utility elects to use any of the above listed accumulated provision accounts, each and every loss or cost which is covered by the account shall be charged to that account and shall not be charged directly to expenses. Charges shall be made to accumulated provision accounts regardless of the balance of those accounts."

The Company's storm damage reserve was completely depleted from the storm damage experience of the October 1992 tornados and the March 1993 storm of the century. As of January 31, 1994, the balance in the Company's storm damage reserve was $598,000. This balance includes the effect of recording the currently approved $3 million annual accrual effective November 1, 1993.

If the Company experiences storm damage costs significantly in excess of the balance of the reserve, it would be compelled to petition the Commission for a mechanism to recover those costs in a timely manner. The Company would propose that those excess costs be recovered over a five year period. The Commission has stated it would act expeditiously to review any petition for deferral, amortization or recovery of prudently incurred costs in excess of the reserve. In order to protect the Company, its customers and shareholders, the Company believes the balance of the reserve should be positive. The Company also believes it would be inappropriate to establish a maximum cap for the reserve at this time.

SECTION V
SIMULATIONS MODEL

Part A - SUMMARY

The simulation study using the Monte Carlo technique was developed to calculate an average cost of damage to T&D lines of an individual hurricane strike. The major inputs were as follows: 1) hurricane distribution by category, 2) cost distribution of T&D facilities, 3) area of storm damage (hurricane size), and 4) damage factors for T&D by hurricane category. The average cost of an individual hurricane was determined to be $20.3 million. The annual probability of a hurricane making landfall in the FPC territory was determined to be 23.3%. Thus, the expected annual cost of hurricane damage to the Company's T&D lines from hurricanes was determined to be $4.7 million. Please refer to Exhibit Number 5 which provides both summary and detail information of the input variables as well as the results of the study. Exhibit Number 5 also provides some diagrams which explain the decision process of the model and the development of both the average cost of a hurricane and the development of the expected annual cost of hurricane damage.

In addition to the expected average cost of a hurricane, the following information was derived by analyzing the model output. For 53% of the storms simulated, the calculated damage was less than $5 million. The simulation produced 1,018 storms (approximately 10%) with damage in excess of $50 million. The lowest cost storm was simulated to be approximately $15 thousand and the highest cost storm was simulated to be $574 million. By definition, each of these occurrences was experienced only once in the 10,000 storms simulated.

PART B - ANALYSIS METHODOLOGY

Florida Power Corporation developed a model to simulate hurricane strikes and potential damage to calculate the average cost of an individual hurricane striking its service territory. Admittedly, there are thousands of scenarios and degrees of damage that could occur from a hurricane strike. Due to the extensive variability in the size and intensity of a storm, the cost density of the facilities damaged, and the square miles of territory affected, a modelling technique had to be chosen which could randomly simulate a variety of each of the major input variables. The model was thus developed with the Monte Carlo technique. The Monte Carlo technique allows for a model to be developed with multiple input variables (either independent or dependent) with different probability distributions to be randomly sampled to simulate events that are representative of all possible variations of each input. Rare events that are on the tail end of probability distributions are properly represented as long as the sample size is adequate. FPC determined that a sample size of 10,000 was adequate for the simulation.

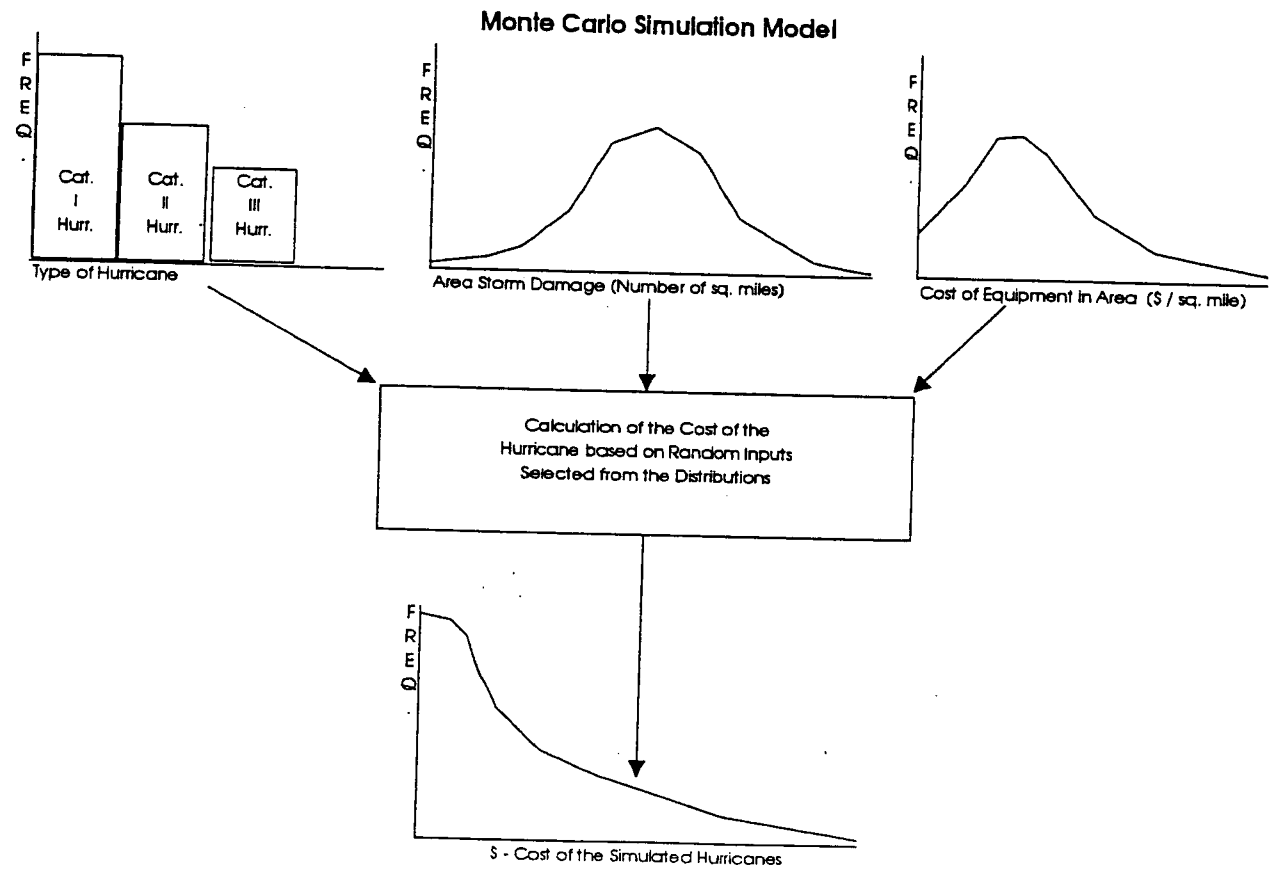
The Monte Carlo simulation technique is relatively simple. It requires that a range of input variables be defined in terms of probabilities. The probability distributions can be based on empirical data, known distribution functions, or can be hypothesized. Once these inputs are defined, a random selection is made from the probability distribution of each input. The simulation is repeated for each number in the sample size and the results are tabulated and presented in terms of minimum, maximum, mean (average) and standard deviation. The model can also provide a range and frequency of the different results. FPC's model was designed to produce the average cost of an individual hurricane strike. For more information on Monte Carlo technique please refer to the copy of the article in Exhibit Number 6, "Risk Analysis in Capital Investment".

Once the average cost of an individual hurricane was calculated, it was multiplied by the probability of a hurricane striking the FPC service territory in a given year to develop the estimated annual expected cost of damage to its T&D lines. The probability of a hurricane striking FPC's service territory was estimated to be 23.3% per year. This was based on historical data for hurricane landfalls and is discussed in detail below along with the input variables and their development.

For the input variables of cost distribution and area of storm damage, it was decided after testing the output, that a gamma distribution best represented the data. The distribution is defined by alpha(α), beta(β) and the maximum cost. Alpha (α) is the shape coefficient and is defined in terms of the mean (x) and standard deviation (s) or in terms of mean (x), standard deviation (s) and the maximum costs. Beta (β) is the scale coefficient and is defined in terms of mean (x), and standard deviation (s) or in terms of mean (x), standard deviation (s) and the maximum costs. For more detail on the gamma distribution please see Exhibit Number 7. For the category of hurricane input variable, a uniform distribution function was used and the appropriate probability was assigned.

PART C - INPUT AND ASSUMPTIONS

Very little data is readily available which specifically addresses the damage that would occur to a utility system as a result of hurricane landfall. This is due to the fact that much of the damage information is not specific to utility systems. In addition, cost density of the system and the strike zone can differ significantly, and there no correlation between the size and intensity of a hurricane. However, a thorough search and review of hurricane data and related damage information was made in order to assure that the result of this study would be as accurate as possible. FPC developed its model inputs and assumptions with what was considered to be the most reasonable and reliable information available. The following diagram shows the distribution curves of the input variables of the model.



The following is a detailed discussion of the development of the input variables and justification for assumptions made.

INPUT VARIABLES

Hurricane Frequency Distribution by Category

Historical data was determined to be the best source of estimating the frequency and category of hurricanes that might strike the FPC service territory. FPC obtained an electronic bank of data from the National Oceanic and Atmospheric Administration (NOAA). This data provided the actual longitude, latitude and wind speeds of hurricane tracks taken every 6 hours for each hurricane which made landfall in the continental United States for the period of 1903 to 1992. Analysis of this 90 years of storm track data indicated that 21 hurricanes have hit the FPC service territory. A summary table of the historical data for hurricanes making landfall in FPC's territory is shown below:

Hurricane Category	Wind Speeds (mph)	Number of Hurricanes Striking FPC Territory	Probability by Category
I	74-95	13	62%
II	96-110	5	24%
III	111-130	3	14%
IV	131-155	0	0%
V	over 155	0	0%
	TOTAL	21	100%

The above probabilities represent the distribution by category of storm in the event of a hurricane striking the FPC service territory. The probability of a hurricane making landfall in our service territory in a given year is discussed below.

Cost Distribution of T&D Facilities

The replacement cost distribution function of the Company's T&D facilities was developed in the following manner. The Company's service territory was first broken up into 30 sectors, 100 miles deep, in order to develop cost density by location. One hundred miles is an average representation of our service territory. Next, the replacement cost for transmission lines was developed by determining the miles of transmission line which currently exist by voltage level for each sector. The miles of line by voltage level were multiplied by the Company's current construction cost per mile which was developed by transmission engineering and construction personnel.

The replacement cost of distribution lines was developed by taking the book value of the Company's gross plant investment by type of retirement unit and adjusting it to a current replacement cost utilizing the appropriate Handy Whitman index. The cost was then developed by sector utilizing the Company's Distribution Facilities Information System (DFIS). Using DFIS, the replacement cost of poles, conductors and towers was developed by sector in proportion to the line miles by sector. The replacement cost of transformers, services, and street lights was developed by sector in proportion to the number of customers by sector. Both transmission and distribution replacement costs were expressed in terms of dollars per square mile. See Exhibit Number 8 for the definition of sectors and the replacement cost of T&D plant by sector.

<u>Area of Storm Damage (Hurricane Size)</u>

The probability distribution of the size of the Hurricane determines the area of damage. Our objective was to create a gamma distribution that would simulate all possibilities of storms, from one damaging a very small section of our territory to one damaging an extensive area. By developing a distribution in this manner, we properly considered damage from storms moving across the state and/or from any direction as the historical storm path data indicated was necessary.

In an attempt to determine a correlation between storm size and intensity, we relied on the expertise and knowledge of the National Hurricane Centers in Miami and Ruskin, the office of Dr. William Gray of Colorado State University and the Company's emergency management and hurricane planning team. According to Mr. Max Mayfield of the Miami Hurricane Center, "There is no correlation between size and intensity of hurricanes." For instance, Hurricane Andrew was an intense and narrow storm with hurricane force winds approximately 30 miles in diameter. Hurricane Gilbert was an intense and wide storm with hurricane force winds of 250 miles in diameter.

The Company's research indicated that information on wind profiles was the most reliable data for estimating the average size of a hurricane. The graph shown in Exhibit Number 9 (obtained from Dr. Gray's office) provides samples of wind profiles. Based on this information, it was decided that 10,000 square miles would be an appropriate average damage area per hurricane. This area might represent a hurricane with a 100 mile diameter of hurricane force winds crossing 100 miles of our service territory. A standard deviation of 2,000 square miles was assumed.

Damage Factor Index

A hurricane damage factor index was developed that could be applied to category of storm in order to simulate the average damage caused by each strike. This method was consistent with the development of the average storm size. Due to the fact that transmission and distribution equipment serve significantly different roles in the delivery of electricity, and thus are not located similarly, a different factor was developed for each. The transmission equipment is designed to withstand 120 mph winds (representing a category III storm) and is generally located on easements where trees are well trimmed and not a significant factor. Historical experience with all types of storms indicates that the distribution system tends to be very susceptible to damage resulting from trees growing in close proximity to the lines. Despite the design criteria, historical experience has proven that there would be some damage, albeit minimal, to transmission lines for a category I or II storm. It was determined that historical data would be the best source to develop a damage factor for transmission lines for category I and II storms. This data, presented in Exhibit Number 10, indicated that the transmission damage was approximately 5% of the distribution damage. Thus, the damage factor for transmission lines for category I and II storms was developed by applying 5% to the distribution damage factors.

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The basis of the damage index factor for all category storms for distribution lines and category III storms for transmission lines was the Hurricane Damage Potential Index (HDP) published by Dr. William Gray of Colorado State University. From this index, we developed an overall weighted average damage index for each category of storm based on the range of wind speed within the diameter of a hurricane. Since the winds of a hurricane are known to be the most intense at the center and decrease in speed from the center to the outer core of the storm, the diameter of the hurricane was divided in sections to estimate the average damage to the service territory resulting from a single hurricane. For example, a category V storm could best be described as five hurricanes that appear as concentric circles. Each circle would represent a storm for each category (I through V). The center would represent a category V storm and the outer most regions of the storm would represent a category I storm. This indicates that the damage caused by the storm will actually be an average of that caused by each category of winds, assuming an appropriate distribution of wind speeds within the storm. An illustrative example of this concept is provided in Exhibit Number 11.

One final refinement was made in the development of the damage factor indices. A hurricane is highest in intensity over the water and as soon as it makes landfall it begins to lose energy and wind speeds decrease. In an attempt to synchronize the average damage factor with the other input variables of the study (the most important being the average service territory of 100 miles in depth), it was determined that an appropriate assumption would be to adjust the factor down 80% of its value. This assumes that at the point of landfall, the damage would be at its maximum. Once the hurricane travels 100 miles inland, the damage would decrease to 60% of that at the point of landfall. This decrease was deemed to be appropriate based on the fact that Dr. Gray's damage factors vary exponentially by category of hurricane.

The following is a table which indicates the method of calculating the weighted average damage index factor applicable to distribution lines for a category V storm. Similar indices were developed for each category of storm for both Transmission and distribution. This table is further supported by the data in Exhibit Number 11.

FLORIDA POWER CORPORATION
DEVELOPMENT OF WEIGHTED DISTRIBUTION DAMAGE FACTOR
FOR A CATEGORY V HURRICANE

	Hurricane Category V	Hurricane Category IV	Hurricane Category III	Hurricane Category II	Hurricane Category I
Total Radial Miles from Hurricane Center	45	60	75	110	140
Incremental Miles for Weighted Average Calculation	45	15	15	35	30
Weighted Average of Area for Total Hurricane	.32	.11	.11	.25	.21
HDP Index published by Dr. Gray	25	16	9	4	1
Index adjusted to be a percent of maximum expected damage.	1.00	.64	.36	.16	.04
Adjustment factor for drop in intensity due to land fall.	.8	.8	.8	.8	.8
Weighted Damage Factor by Category	.257	.055	.031	.032	.007

SUM OF WEIGHTED DAMAGE FACTORS FOR AREA STRUCK BY CATEGORY V HURRICANE = **.382** or 38.2%

ASSUMPTIONS

Annual Probability of Hurricane Strike

Based on the historical storm track data obtained from the NOAA (discussed above), the number of hurricanes striking the FPC territory in the last 90 years was 21. This was determined by analyzing the longitudes and latitudes of the storm tracks and comparing those to the FPC territory. The historical data was considered to be the most reliable information available. Thus by dividing 21 strikes by 90 years, the annual probability of a hurricane was determined to be 23.3%.

Probability of Area of Hurricane Strike

Based on the historical storm path data and other data obtained from the NOAA, we determined that separate probabilities needed to be developed for hurricane strikes within sectors of FPC's service territory. After analyzing the storm path data and the graph included as Exhibit Number 12 which presents smoothed probabilities of landfalling tropical storms and hurricanes, it was determined that FPC's service territory should be segregated into 3 major areas for the appropriate application of strike probabilities. The probabilities were assigned based on the graph in Exhibit Number 12. The 3 areas were determined consistent with the 30 sectors of cost data to facilitate the development of the average expected cost. Area 1, which essentially represents St. Petersburg to Yankeetown, was assigned a probability of 27%. Area 2, which essentially represents Yankeetown to Adams Beach, was assigned a probability of 34%. Area 3, which essentially represents Adams Beach to Port St. Joe, was assigned a probability of 39%.

Other Assumptions

The simulation model excluded category IV and category V storms because both historical experience and meteorological information supported the assumption that the probability of a category IV or V storm striking the FPC service territory is extremely low. Although the probability is extremely low, Florida Power fully acknowledges that it is possible for a category IV or V storm to strike its service territory. However, we believe it is not appropriate to build a storm damage reserve to insure for such a remote possibility. The Company further acknowledges that if a category IV or V storm were to strike a significant portion of our service territory, the damage would be extensive and would require the Company to petition the Commission for timely recovery of the costs.

A study prepared by the NOAA titled "Hurricane Climatology for the Atlantic and Gulf Coasts of the United States" states that storms moving out of the east, toward the west, should they strike Florida, are most likely to strike the east coast of Florida. A storm heading in a westerly direction must have recurvature to turn and strike the west coast of Florida. When a storm experiences recurvature it tends to weaken. See Exhibit Number 13 for a more detailed explanation. Thus it was decided to exclude these storms from the base study.

In an attempt to develop a model that produced reasonably accurate results in a short time frame, some simplifying assumptions were made. For instance, the cost data used in the study included replacement cost of overhead T&D lines only. The study excluded the cost of underground T&D lines and associated equipment as well as production and general plant facilities. This equipment might suffer damage from hurricanes, but much of this equipment is currently covered by traditional insurance. In addition, the cost data for the T&D lines modeled in the study included only the replacement cost of the physical equipment damaged. This does not include all of the costs directly related to storm damage and restoration activities that the Company proposes to charge against the storm damage reserve (as explained in section IV A). The types of costs not included tend to be a minor percent of the total storm damage and restoration cost and would vary based on the extent of the damage. Thus it was decided to exclude these costs in the simulation study.

Wherever possible, the input assumptions were verified to FPC's actual storm damage experience. FPC analyzed the storm damage costs of its most recent storm damage activity - Hurricanes Elena and Kate, and Tropical Storm Keith. This data indicated that the O&M costs represented on average 80% of the total damage costs with distribution O&M representing 90% of the total O&M costs and transmission O&M representing 5%. See Exhibit Number 10 for a detailed breakdown by storm.

PART D - OUTPUT AND RESULTS

As previously indicated, the output and results of the study are presented in Exhibit Number 5. The model output presentation is the standard procedure default output. Page 1 of Exhibit Number 5 is a summary of both the input data and output data. This summary indicates that the simulated output data was representative of the distributions, probabilities and ranges of the input data within acceptable tolerance. This validates the design and accuracy of the model as well as the sample size. This can be evidenced by examining the mean and ranges of the output data as compared to the input data.

PART E - SENSITIVITY CASES

In addition to the base case, the Company also prepared two other cases to further evaluate the sensitivity of the model. These cases 1) calculated the amount of storm damage experience that would have been reimbursed to the Company under its previous T&D policy, and 2) included the occurrence of category IV & V hurricanes.

The Company's previous insurance policy covered damages in the range of $5 million to $95 million ($90 million coverage excess of $5 million). The following adjustments were made to the base case to simulate insurance proceeds under this coverage. To represent the $5 million deductible for each storm, the first $5 million of damage was excluded from the estimated damage summarized in the average. For storms with damage in excess of $95 million, only $90 million was included in the estimated damage summarized in the average. The $90 million represents the maximum amount of recovery the insurance would have provided. The result of this case was an average reimbursed cost per hurricane of $12.6 million. When multiplied by the 23.3% annual probability of a hurricane strike, the result is an annual expected insurance recovery of $2.9 million.

Another sensitivity case was prepared to include the occurrence of category IV and V storms. In this case, the only change made to the base case was to add the category IV and V storms to the hurricane frequency distribution. The probability of occurrence of category IV and V storms was extrapolated from return probabilities information prepared by the National Hurricane Center. The result of this model was an average cost per hurricane of $33.5 million. When multiplied by the annual probability of hurricane strike of 23.3% the result is an annual expected cost of hurricane damage cost of $7.8 million.

SECTION VI
SUMMARY AND RECOMMENDATIONS

As directed by the FPSC, Florida Power prepared a study to evaluate the amount to be annually accrued to its storm damage reserve. The Company decided the most reasonable approach would be to determine the average expected annual amount of damage to T&D lines from hurricanes. This was done by utilizing a Monte Carlo simulation model to estimate the average cost of damage from an individual hurricane and applying the expected annual probability of a hurricane strike in the FPC service territory. The resultant average expected annual damage was determined to be $4.7 million.

The major input assumptions of the simulation model were hurricane probability by category, cost distribution of T&D lines, damage factor, and area of storm damage. The model was limited to damage to T&D lines from category I through III hurricanes and simulated the total replacement cost of equipment. This cost includes both capital and O&M, but excludes some costs which would be directly related to storm damage and restoration activities.

Sensitivity cases of the model were run to include category IV and V storms as well as emulate our past insurance program. The case designed to emulate prior T&D coverage produced an annual expected insurance recovery of $2.9 million. The case which included category IV and V hurricanes produced an annual expected total cost of hurricane damage of $8.5 million.

In addition to the evaluation of the annual accrual, the Company was ordered to provide information on the treatment of T&D damages under its existing policy, a listing of the types of expenses to be charged to the reserve, and the associated accounting entries. The Company's previous T&D insurance policy was for $90 million of coverage in excess of a $5 million deductible. This policy provided for repair or replacement of facilities based on actual costs incurred for necessary labor, materials and supplies and other services associated with the repairs or replacement.

Consistent with the Company's previous traditional insurance, the Company proposes to charge the storm damage reserve for any damage not currently covered by insurance, caused by destructive acts of nature, using a replacement cost approach. This approach is the simplest and will continue to provide consistency should the Company be able to purchase traditional insurance coverage at economical prices. Any prudently incurred costs that are deemed to be directly associated with storm damage and restoration activity would be charged to the reserve. The storm damage reserve will be used for O&M costs only. Capital costs will be charged at standard rates to the appropriate capital accounts. The Company estimates the O&M costs to be approximately 80% of the total damage costs.

The Company intends to charge the reserve account as dictated by FPSC rule 25-6.0143 for all such storm related costs regardless of the balance of the reserve. If the Company experiences storm damage significantly in excess of its reserve balance, it would at that time petition the Commission for timely recovery.

To conclude, the Company recommends the following:

- The currently approved annual accrual of $3 million is reasonable and should not be adjusted at this time. This is based on the fact that the simulation model produced an expected annual O&M cost of hurricane damage of $3.8 million and the anticipation of future availability of economical insurance coverage.

- The annual storm damage accrual should be reevaluated at such time as the Company makes a significant change in its current insurance program. This evaluation would at a minimum occur at such time as the Company submits its annual report to this Commission which is required to include, (among other things), an evaluation of the adequacy of its reserve.

- The replacement cost method should be used to determine the costs to be charged against the reserve for the types of costs listed within this study and associated exhibits. The appropriateness of this approach and its potential impact on the Company's customer can be monitored by the Commission's current surveillance program.

- The Company does not recommend at this time that an absolute minimum or maximum level of the reserve be established.

SECTION VII
EXHIBITS

Number	Description
1	Commission Order Number PSC-93-1522-FOF-EI – see Order Tab
2	FPC Petition for Self Insurance Program – see petition Tab
3	List of Types of Costs to be Charged Against the Reserve
4	Accounting Journal Entries
5	Simulation Model - Summary and Detail
6	Reference Article on Monte Carlo Technique
7	The Gamma Distribution
8	Replacement Cost of T&D Plant by Sector
9	Tangential Wind Profiles
10	Historical Data on Actual FPC Storm Damage
11	Damage Index Factor
12	Smoothed Frequency of Landfalling Storms
13	Reference information on Recurvature

LIST OF TYPES OF STORM RELATED EXPENSES TO BE CHARGED TO THE STORM DAMAGE RESERVE

The following is a list of examples of the types of costs the Company proposes to charge to the storm damage reserve.

Actual Repair Activities:

Labor costs - including overtime or premium pay for employees dedicated to repair activities such as line crews, storeroom, engineering, and transportation personnel; payroll loading for associated taxes; administrative; and employee benefits.

Materials and Supplies - all materials and supplies (M&S) utilized for the temporary or permanent repair or replacement of facilities. This would include a standard loading factor to cover the administration of M&S inventories.

Cost of preparing, operating and staffing temporary staging facilities for materials and supplies distribution.

Outside Services - including reimbursement costs to other utilities and payments to subcontractors dedicated to restoration activities.

Transportation costs - including operating costs, fuel expense and repairs and maintenance of Company fleet and/or rented vehicles.

Costs Directly Associated with Storm Damage and Restoration Activities:

Damage assessment costs - including surveys, helicopter line patrol, and operation of assessment and control facilities.

Costs associated with the rental and/or operation and maintenance of any equipment used in direct support of restoration activities such as communication equipment, office equipment, computer equipment, etc.

Costs associated with injuries and damages to personnel and/or their property as a direct result of restoration activities.

Costs Directly Associated with Storm Damage and Restoration Activities (continued):

Costs of temporary housing for restoration crews and support personnel and their related subsistence costs.

Storm preparation - including information costs and training for Company employees.

Fuel and related costs for back-up generators.

Costs of customer service personnel, phone center personnel and other division personnel dedicated to customer service needs, and locating and prioritizing areas of damage.

Special advertising and media costs associated with customer information, public education and/or safety.

Special employee assistance - including cost of cash advances, housing and/or subsistence for employees and families to expedite their return to work.

Identifiable bad debt write-offs due to storm damage.

Any other appropriate costs directly related to storm damage and restoration activities.

FLORIDA POWER CORPORATION
STUDY ON STORM DAMAGE ACCRUAL

EXHIBIT No. 4

ACCOUNTING ENTRIES FOR STORM DAMAGE ACTIVITY
($ MILLION)

(BB) Beginning balance before storm.
(1) Record annual storm damage expense.
(2) Record storm damage costs (assume $20).
(3) Record insurance proceeds (assume $0).
(4) Retire cost of property removed (assume $3).
(5) Capitalize new additions at replacement cost estimate (assume 20% of damage).
(6) Transfer O & M damage costs to the Storm and Property Insurance Reserve.
(EB) Ending Balance.

Cash (Acct. 131)

DR	CR
(3) 0	(2) 20
	(EB) 20 (a)

Misc. Deferred Debit (Acct. 186)

DR	CR
(BB) 0	
(2) 20	(5) 4
	(6) 16
(EB) 0	

Electric Plant in Service (Acct. 101)

DR	CR
(BB) 100	
	(3) 0 (d)
(5) 4	(4) 3
(EB) 101 (b)	

Accumulated Provision for Depreciation (Acct. 108)

DR	CR
	(BB) 50
(4) 3	
	(EB) 47

Storm and Property Insurance Reserve (Acct. 228.1)

DR	CR
	(BB) 0
(6) 16	(1) 3
	(3) 0 (d)
(EB) 13 (c)	

Storm Damage Expense (Acct. 924.2)

DR	CR
(1) 3	
(1) 3	

Notes:
(a) To be temporarily funded through lines of credit.
(b) To be recovered through future depreciation expense.
(c) To remain in the reserve pending future disposition under FPSC Rule 25-6.0143.
(d) Insurance proceeds would be applied to Capital and Operation & Maintenance Expense in proportion to the actual damage cost.

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Feb-94

SUMMARY RESULTS OF MONTE CARLO SIMULATION

EXPECTED COST OF HURRICANE

Florida Power Corporation
Study on Storm Damage Accrual
Exhibit No. 5
Page 1 of 15

INPUTS

Hurricane (74 - 95 mph) - Class I

Probability of class I	0.62
Avg Damage Factor Dist.	0.032
Avg Damage Factor Trans.	0.001
Avg Storm Size I	10,000 Square Miles
Std Dev. Storm Size I	2,000 Square Miles

Hurricane (95 - 110 mph) - Class II

Probability of class II	0.24
Avg Damage Factor Dist.	0.08
Avg Damage Factor Trans.	0.002
Avg Storm Size II	10,000 Square Miles
Std Dev. Storm Size II	2,000 Square Miles

Hurricane (110 - 130 mph) - Class III

Probability of class III	0.14
Avg Damage Factor Dist.	0.162
Avg Damage Factor Trans.	0.13
Avg Storm Size III	10,000 Square Miles
Std Dev. Storm Size III	2,000 Square Miles

Area 1

Prob. Hit in Area 1	0.27
Avg Cost 1	$96,161
Std Dev Cost 1	$48,282

Area 2

Prob. Hit in Area 2	0.34
Avg Cost 2	$8,996
Std Dev Cost 2	$7,709

Area 3

Prob. Hit in Area 3	0.39
Avg Cost 3	$4,932
Std Dev Cost 3	$3,369

Hurricanes that hit FPC Service Territory in 90 years

	Number	Probability
Category I	13	62%
Category II	5	24%
Category III	3	14%
Category IV	0	0%
Category V	0	0%
	21	

Frequency 23.3%

OUTPUTS

Hurricane - Class I

Avg Size of Storm		9,957
Max. Size of Storm		18,928
Area 1	Freq	0.167
	Avg Cost	$23.8 Mil
	Max Cost	$88.6 Mil
Area 2	Freq	0.205
	Avg Cost	$2.9 Mil
	Max Cost	$11.8 Mil
Area 3	Freq	0.249
	Avg Cost	$1.7 Mil
	Max Cost	$5.8 Mil

Hurricane - Class II

Avg Size of Storm		9,968 sq. miles
Max. Size of Storm		16,975 sq. miles
Area 1	Freq	0.064
	Avg Cost	$58.2 Mil
	Max Cost	$166.8 Mil
Area 2	Freq	0.082
	Avg Cost	$7.1 Mil
	Max Cost	$32.1 Mil
Area 3	Freq	0.094
	Avg Cost	$4.2 Mil
	Max Cost	$13.0 Mil

Hurricane - Class III

Avg Size of Storm		10,048
Max. Size of Storm		18,388
Area 1	Freq	0.038
	Avg Cost	$197.8 Mil
	Max Cost	$574.3 Mil
Area 2	Freq	0.044
	Avg Cost	$42.4 Mil
	Max Cost	$146.5 Mil
Area 3	Freq	0.056
	Avg Cost	$21.8 Mil
	Max Cost	$55.4 Mil

SUMMARY RESULTS OF ALL HURRICANES
In 10,000 Simulations

Avg Size of Storm	9,973 square miles
Max. Size of Storm	18,929 square miles
Average Costs	$20.3 Million
Max Cost Simulated	$574.3 Million
Frequency =	0.233 Hurr. per year
Annual Expected Cost =	$4.74 Million

Business Planning
Date: 2/23/94

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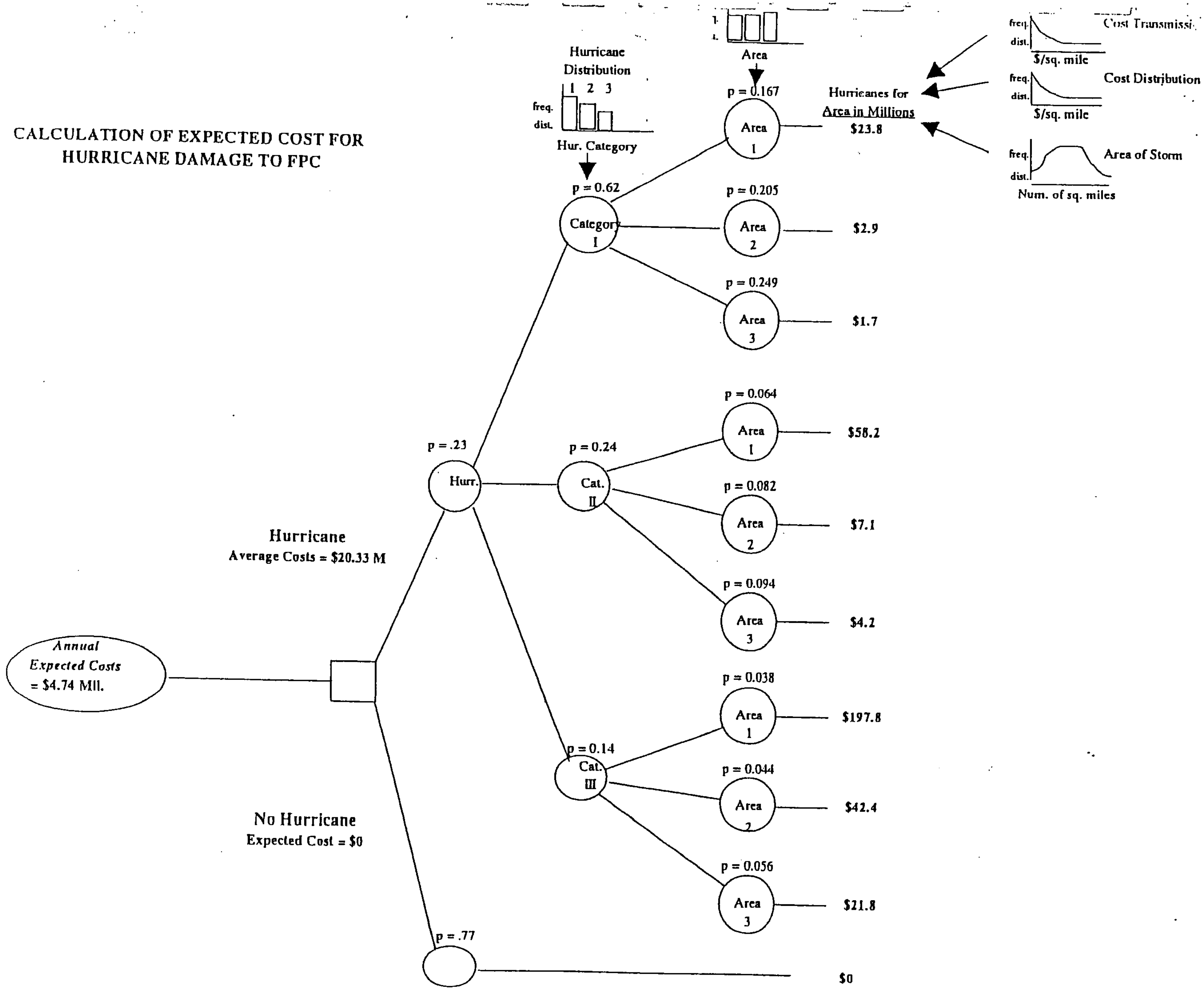
CALCULATION OF EXPECTED COST FOR HURRICANE DAMAGE TO FPC



Business Planning
Date: 2/23/94

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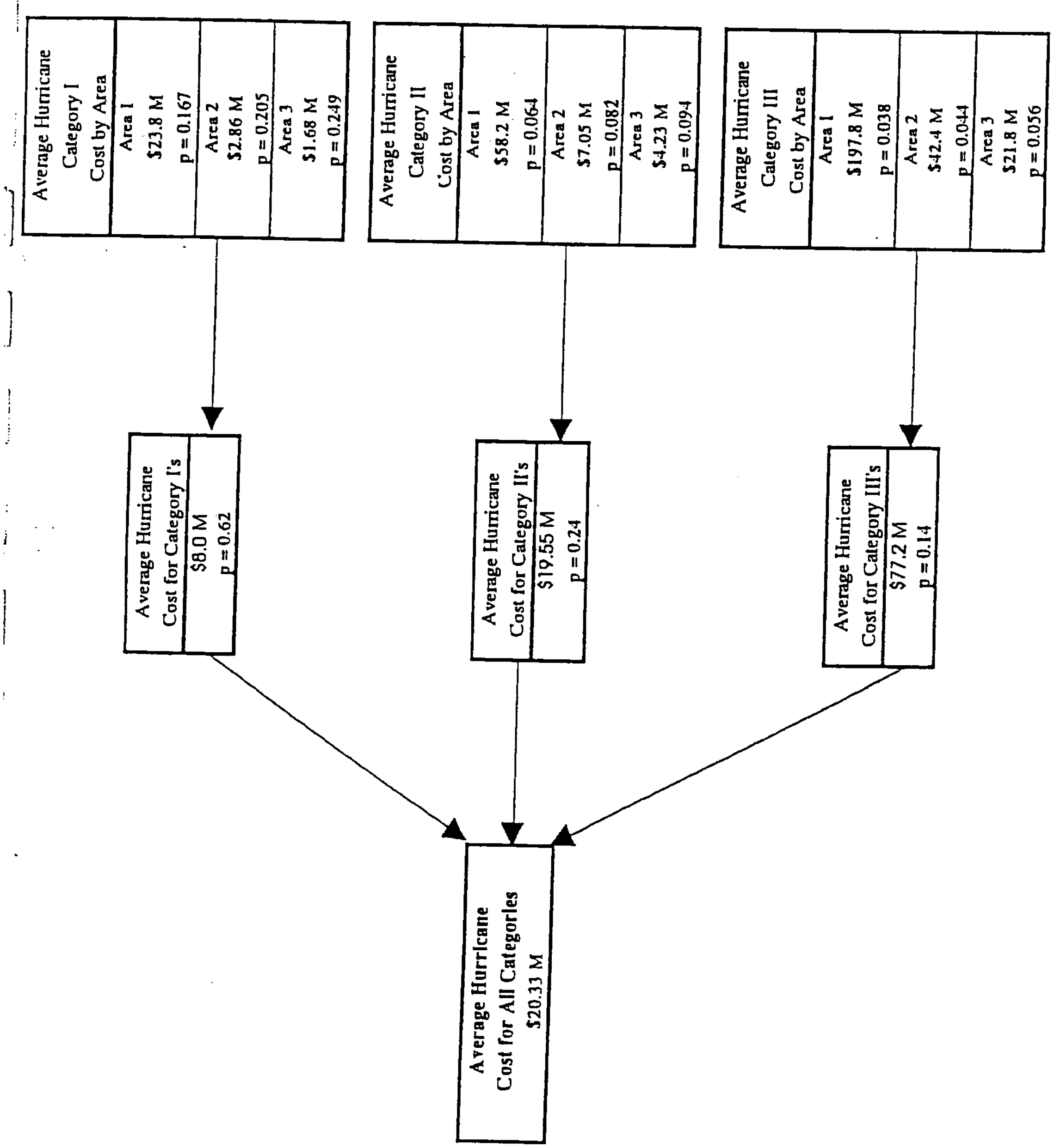
File: DEC_TREE.XLS

Calculation of Average Cost of Hurricane Damage



LIST OF INPUT DATA

OBS	CASE_NME	COM1	COM2	AREA1_P	TCST1_X	TCST1_S	TCST1_M	DCST1_X	DCST1_S	DCST1_M	AREA2_P
1	HURRICANE - EXPECTE D STORM DAMAGE FROM HURRICANES		AREA1_P T	0.27	66011	30642	123731	77469	45243	159028	0.34

OBS	TCST2_X	TCST2_S	TCST2_M	DCST2_X	DCST2_S	DCST2_M	AREA3_P	TCST3_X	TCST3_S	TCST3_M	DCST3_X	DCST3_S	DCST3_M	AREA4_P	TCST4_X	TCST4_S
1	22791	13436	59098	8995	7709	27148	0.39	10343	5091	22556	4932	3368	10346	0	5000	1000

OBS	TCST4_M	DCST4_X	DCST4_S	DCST4_M	AREA5_P	TCST5_X	TCST5_S	TCST5_M	DCST5_X	DCST5_S	DCST5_M	COM3	HUR1_P	MILE1_X	MILE1_S	T1_DMG
1	10000	1000	1000	10000	0	5000	1000	10000	1000	1000	10000	HUR1_P S	0.62	10000	2000	.001

OBS	D1_DMG	HUR2_P	MILE2_X	MILE2_S	T2_DMG	D2_DMG	HUR3_P	MILE3_X	MILE3_S	T3_DMG	D3_DMG	HUR4_P	MILE4_X	MILE4_S	T4_DMG	D4_DMG	HUR5_P
1	0.032	0.24	10000	2000	.002	0.08	0.14	10000	2000	0.13	0.162	0	10000	2000	0.249	0.276	0

OBS	MILE5_X	MILE5_S	T5_DMG	D5_DMG	COM4	PROB_HUR	LIM_A1	LIM_A2	LIM_A3	LIM_A4	LIM_A5	LIM_H1	LIM_H2	LIM_H3	LIM_H4	LIM_H5	SIM
1	10000	2000	0.343	0.382	FREQ	0.233	0.27	0.61	1	1	1	0.62	0.86	1	1	1	10000

Univariate Procedure

Variable=TCST_MI (Transmission Cost Per mile)

Moments

N	10000	Sum Wgts	10000
Mean	29378.5	Sum	2.9378E8
Std Dev	29139.95	Variance	8.4914E8
Skewness	1.477121	Kurtosis	1.246279
USS	1.712E13	CSS	8.491E12
CV	99.18804	Std Mean	291.3995
T:Mean=0	100.8186	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	123472.6	99%	115847.8
75% Q3	39627.66	95%	98266.47
50% Med	16994.8	90%	79263.19
25% Q1	9291.996	10%	4957.124
0% Min	26.12148	5%	3311.536
		1%	1237.856
Range	123446.5		
Q3-Q1	30335.67		
Mode	26.12148		

Extremes

Lowest	Obs	Highest	Obs
26.12148(	4034)	123062.4(	225)
27.47337(	7434)	123316.9(	3013)
49.3093(	5052)	123368.7(	3353)
113.2075(	429)	123453.8(	9500)
160.4828(	3404)	123472.6(	2983)

```
                    Histogram                                   #   Boxplot
122500+**                                                       45     0
      .**                                                       72     0
      .***                                                     104     0
      .***                                                     111     0
      .****                                                    123     0
      .****                                                    131     0
      .****                                                    129     0
      .****                                                    135     0
      .****                                                    130     |
      .****                                                    142     |
      .****                                                    138     |
 62500+****                                                    130     |
      .****                                                    134     |
      .*****                                                   154     |
      .******                                                  190     |
      .********                                                291     |
      .*********                                               319     |
      .**********                                              336  +-----+
      .*************                                           445  |     |
      .*************                                           458  |  +  |
      .******************                                      637  |     |
      .**********************************                     1227  *-----*
      .**********************************************         1675  |     |
      .***********************************************        1730  +-----+
  2500+****************************                           1014     |
       ----+----+----+----+----+----+----+----+----+---
       * may represent up to 37 counts
```

```
                         Normal Probability Plot
122500+                                                        *
      |                                                     ***
      |                                                 ****
      |                                               ***
      |                                              **      +
      |                                             **     ++
      |                                            **    ++
      |                                           **    +
      |                                          **   ++
      |                                         **  ++
      |                                        ** ++
 62500+                                        * +
      |                                       **+
      |                                      +*
      |                                     +**
      |                                   ++**
      |                                 ++ **
      |                               ++ **
      |                              + **
      |                            ++***
      |                          ++ **
      |                        + ****
      |                  ++******
      |            ********
  2500+************* ++
       +----+----+----+----+----+----+----+----+----+----+
           -2        -1         0        +1        +2
```

Florida Power Corporation
Study on Storm Damage Accrual
Exhibit No. 5
Page 5 of 15

Univariate Procedure

Variable=DCST_MI (Distribution Cost per mile)

Moments

N	10000	Sum Wgts	10000
Mean	23952.24	Sum	2.3952E8
Std Dev	37692.71	Variance	1.4207E9
Skewness	2.042655	Kurtosis	3.085174
USS	1.994E13	CSS	1.421E13
CV	157.3661	Std Mean	376.9271
T:Mean=0	63.54609	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	158950.3	99%	150620.1
75% Q3	21241.57	95%	121838.9
50% Med	7847.643	90%	88552.53
25% Q1	2765.347	10%	584.8166
0% Min	0.000742	5%	165.5552
		1%	10.63813
Range	158950.3		
Q3-Q1	18476.22		
Mode	0.000742		

Extremes

Lowest	Obs	Highest	Obs
0.000742(	1258)	158751.1(	717)
0.001935(	4495)	158762.5(	9306)
0.00822(	1118)	158792.9(	1632)
0.008475(	8137)	158826.8(	9525)
0.030226(	7545)	158950.3(	9179)

```
                  Histogram                                #  Boxplot
155000+*
      .**                                                109     *
      .**                                                138     *
125000+**                                                129     *
      .**                                                152     *
      .**                                                148     *
 95000+**                                                151     *
      .**                                                156     *
      .**                                                141     *
 65000+**                                                176     0
      .**                                                197     0
      .**                                                160     0
 35000+**                                                194     0
      .*****                                             198     |
      .**********                                        552  +--+--+
  5000+*********************************************    1273  |     |
       ----+----+----+----+----+----+----+----+----+--- 6126  *-----*
       * may represent up to 128 counts
```

```
                   Normal Probability Plot
155000+
      |                                                 ***
      |                                              ****
125000+                                            ***
      |                                          ***
      |                                         **      +++
 95000+                                        **     ++
      |                                       **    +++
      |                                      **  +++
 65000+                                      **++
      |                                     **+
      |                                  +++*
 35000+                               ++  **
      |                            +++  **
      |                        +++   ***
  5000+**************************++****
       +----+----+----+----+----+----+----+----+----+----+
           -2        -1         0        +1        +2
```

Florida Power Corporation
Study on Storm Damage Accrual
Exhibit No. 5
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Univariate Procedure

Variable=NUM_MI (size of storm)

Moments

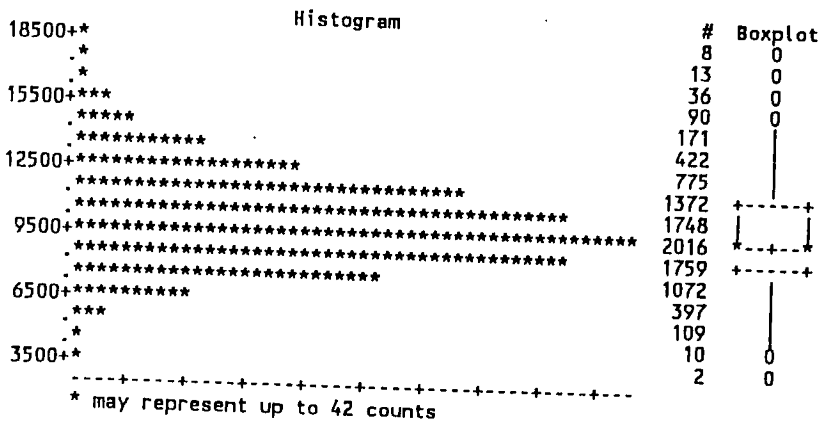
N	10000	Sum Wgts	10000
Mean	9972.598	Sum	99725981
Std Dev	2007.035	Variance	4028189
Skewness	0.454234	Kurtosis	0.391325
USS	1.035E12	CSS	4.028E10
CV	20.1255	Std Mean	20.07035
T:Mean=0	496.8821	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

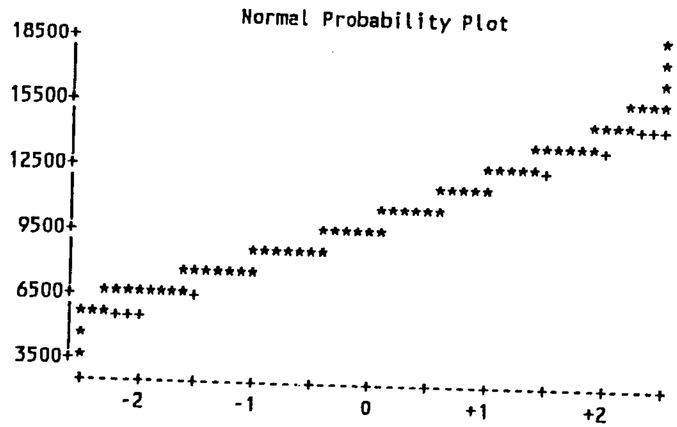
Quantiles(Def=5)

100% Max	18928.93	99%	15470.74
75% Q3	11236.31	95%	13483.33
50% Med	9825.432	90%	12558.64
25% Q1	8546.717	10%	7533.351
0% Min	3847.14	5%	6967.801
		1%	5871.083
Range	15081.79		
Q3-Q1	2689.593		
Mode	3847.14		

Extremes

Lowest	Obs	Highest	Obs
3847.14(	8473)	18293.34(	6543)
3917.931(	544)	18388.21(	1472)
4182.085(	4780)	18418.4(	197)
4621.8(	6745)	18486.6(	6100)
4641.082(	6044)	18928.93(	9441)





Florida Power Corporation
Study on Storm Damage Accrual
Exhibit No. 5
Page 7 of 15

Univariate Procedure

Variable=HUR_CST (Hurricane Cost)

Moments

N	10000	Sum Wgts	10000
Mean	20333238	Sum	2.033E11
Std Dev	45671099	Variance	2.086E15
Skewness	4.969303	Kurtosis	31.71265
USS	2.499E19	CSS	2.086E19
CV	224.613	Std Mean	456711
T:Mean=0	44.52102	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	5.7432E8	99%	2.5829E8
75% Q3	19714145	95%	89099892
50% Med	4147172	90%	49399264
25% Q1	1489489	10%	516326.5
0% Min	14663.1	5%	270661.6
		1%	97949.19
Range	5.7431E8		
Q3-Q1	18224656		
Mode	14663.1		

Extremes

Lowest	Obs	Highest	Obs
14663.1(	5833)	4.846E8(	1006)
17822.8(	8636)	5.0136E8(	5844)
24890.87(	317)	5.2308E8(	1675)
27031.73(	544)	5.2773E8(	6959)
27616.28(	8099)	5.7432E8(	8669)

```
                 Histogram                          #  Boxplot                 Normal Probability Plot
5.75E8+*                                            1     *       5.75E8+                                                  *
      .*                                            3     *             |                                                  *
      .*                                            5     *             |                                                  *
      .*                                            6     *             |                                                  *
      .*                                           13     *             |                                                  *
      .*                                           37     *             |                                                  *
      .*                                           46     *             |                                                ***
      .*                                           56     *             |                                              ***
      .*                                           87     *             |                                             **
      .***                                        179     *             |                                          ****+++++
2.5E7+*********************************************  557     0             |                              ++++++*****
       ----+----+----+----+----+----+----+----+---  9010  +--0--+  25000000+*****************************************
       * may represent up to 188 counts                                    +----+----+----+----+----+----+----+----+----+
                                                                               -2        -1         0        +1        +2
```

Florida Power Corporation
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Univariate Procedure

Variable=THUR_CST (Transmission Cost)

Moments

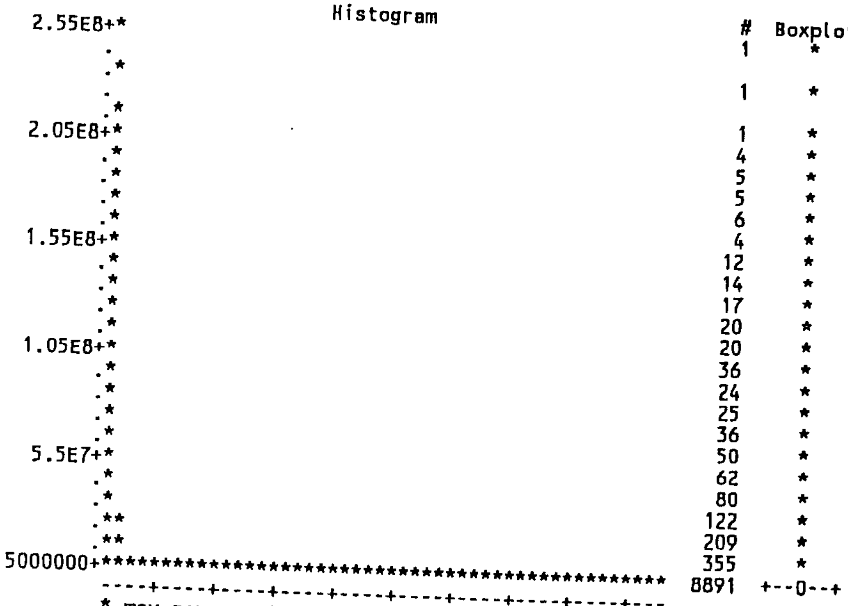
N	10000	Sum Wgts	10000
Mean	5657047	Sum	5.657E10
Std Dev	20068542	Variance	4.027E14
Skewness	5.534896	Kurtosis	36.14022
USS	4.347E18	CSS	4.027E18
CV	354.753	Std Mean	200685.4
T:Mean=0	28.18863	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

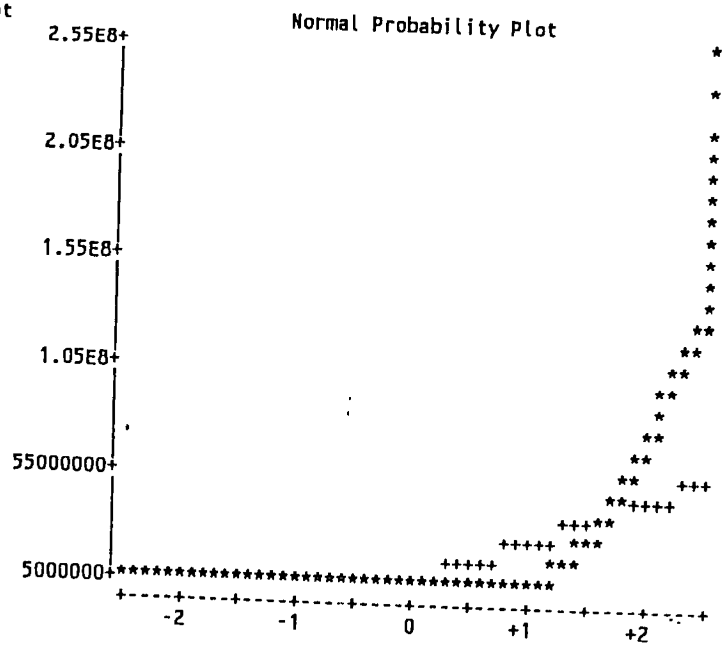
100% Max	2.5088E8	99%	1.1623E8
75% Q3	806146.5	95%	32883869
50% Med	267013.5	90%	13195551
25% Q1	116156.2	10%	59810.3
0% Min	235.334	5%	39223.64
		1%	14142.97
Range	2.5088E8		
Q3-Q1	689990.4		
Mode	235.334		

Extremes

Lowest	Obs	Highest	Obs
235.334(	7434)	2.0445E8(	8669)
600.4325(	5052)	2.0462E8(	505)
1852.873(	1664)	2.1499E8(	1675)
1881.511(	3471)	2.3006E8(	8556)
2647.872(	3755)	2.5088E8(	8693)



* may represent up to 186 counts



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Output ~~INPUT~~

LIST OF ~~INPUT~~ 10:23 Friday, February 4, 1994 7

Univariate Procedure

Variable=DHUR_CST (Distribution Cost)

Moments

N	10000	Sum Wgts	10000
Mean	14676191	Sum	1.468E11
Std Dev	31255678	Variance	9.769E14
Skewness	4.568018	Kurtosis	27.92683
USS	1.192E19	CSS	9.768E18
CV	212.9686	Std Mean	312556.8
T:Mean=0	46.95528	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

(A)

Quantiles(Def=5)

100% Max	4.2495E8	99%	1.6107E8
75% Q3	12860609	95%	66600605
50% Med	3392984	90%	39708830
25% Q1	1189187	10%	254659.4
0% Min	0.530405	5%	71684.62
		1%	4169.123
Range	4.2495E8		
Q3-Q1	11671422		
Mode	0.530405		

Extremes

Lowest	Obs	Highest	Obs
0.530405(	1258)	3.2214E8(	5765)
1.722811(	4495)	3.2546E8(	9661)
3.143719(	1118)	3.2921E8(	5844)
17.67156(	8137)	3.6987E8(	8669)
18.88578(	2041)	4.2495E8(	6959)

```
              Histogram                                        #  Boxplot
4.3E8+*                                                        1     *
     .
     .*                                                        1     *
     .
     .*                                                        3     *
     .*                                                        3     *
2.9E8+*                                                        4     *
     .*                                                        3     *
     .*                                                       10     *
     .*                                                       16     *
     .*                                                       19     *
     .*                                                       19     *
     .*                                                       22     *
1.5E8+*                                                       46     *
     .*                                                       54     *
     .*                                                       98     *
     .*                                                      106     *
     .*                                                      155     *
     .***                                                    423     0
     .******                                                 875     0
  1E7+*************************************************     8142  +--+--+
      ----+----+----+----+----+----+----+----+----+---
     * may represent up to 170 counts
```

```
                    Normal Probability Plot
    4.3E8+                                                   *
         |
         |                                                   *
         |
         |                                                   *
         |                                                   *
    2.9E8+                                                   *
         |                                                   *
         |                                                   *
         |                                                   *
         |                                                   *
         |                                                  **
    1.5E8+                                                 **
         |                                                **
         |                                               **
         |                                             ***
         |                                           *** +++++
         |                                         +**+++
         |                                   ++++****
         |                             ++++++*****
 10000000+************************************
          +----+----+----+----+----+----+----+----+----+----+
               -2        -1         0        +1        +2
```

Transmission $ 5,657,047 p.9

Distribution 14,676,191 (A)

$ 20,333,238

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SUMMARY OUTPUT RESULTS FOR ALL AR[illegible] - HURRICANES 10:23 Friday, February 4, 1994 8

OBS	CASE_NME	COM1	COM2	AREA1_P	TCST1_X	TCST1_S	TCST1_M	DCST1_X	DCST1_S	DCST1_M	AREA2_P
1	HURRICANE	- EXPECTE D STORM DAMAGE FROM HURRICANES	AREA1_P T	0.27	66011	30642	123731	77469	45243	159028	0.34

OBS	TCST2_X	TCST2_S	TCST2_M	DCST2_X	DCST2_S	DCST2_M	AREA3_P	TCST3_X	TCST3_S	TCST3_M	DCST3_X	DCST3_S	DCST3_M	AREA4_P	TCST4_X	TCST4_S
1	22791	13436	59098	8995	7709	27148	0.39	10343	5091	22556	4932	3368	10346	0	5000	1000

OBS	TCST4_M	DCST4_X	DCST4_S	DCST4_M	AREA5_P	TCST5_X	TCST5_S	TCST5_M	DCST5_X	DCST5_S	DCST5_M	COM3	HUR1_P	MILE1_X	MILE1_S	T1_DMG
1	10000	1000	1000	10000	0	5000	1000	10000	1000	1000	10000	HUR1_P S	0.62	10000	2000	.001

OBS	D1_DMG	HUR2_P	MILE2_X	MILE2_S	T2_DMG	D2_DMG	HUR3_P	MILE3_X	MILE3_S	T3_DMG	D3_DMG	HUR4_P	MILE4_X	MILE4_S	T4_DMG	D4_DMG	HUR5_P
1	0.032	0.24	10000	2000	.002	0.08	0.14	10000	2000	0.13	0.162	0	10000	2000	0.249	0.276	0

OBS	MILE5_X	MILE5_S	T5_DMG	D5_DMG	COM4	PROB_HUR	LIM_A1	LIM_A2	LIM_A3	LIM_A4	LIM_A5	LIM_H1	LIM_H2	LIM_H3	LIM_H4	LIM_H5	SIM	TCST_AVG
1	10000	2000	0.343	0.382	FREQ	0.233	0.27	0.61	1	1	1	0.62	0.86	1	1	1	10000	29378.50

OBS	DCST_AVG	MILE_AVG	HCST_AVG	THUR_CST	DHUR_CST	TCST_MAX	DCST_MAX	MILE_MAX	HCST_MAX	EXP_CST
1	23952.24	9972.60	20333238.02	5657047.33	14676190.70	123472.62	158950.28	18,928.9	574,321,109.	4,737,644. =========

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SUMMARY OUTPUT RESULTS BY CAT URRICANE 10:23 Friday, February 4, 1994 9

OBS	HUR_TYPE	HUR_N	HUR_AVG	THUR_AVG	DHUR_AVG	MILE_AVG
1	1	6217	8,005,274.	289,505.5	7,715,769.	9,957.1
2	2	2402	19,546,007.	597,705.2	18,948,301.	9,968.9
3	3	1381	77,200,635.	38,620,514.9	38,580,120.	10,048.5

SUMMARY OUTPUT RESULTS BY CATEGO… …IE AND BY AREA 10:23 Friday, February 4, 1994 10

OBS	HUR_TYPE	HUR_AREA	HUR_N	HUR_AVG	THUR_AVG	DHUR_AVG	HUR_MAX	MILE_AVG	MILE_MAX
1	1	1	1670	23,788,674.	648,611.5	23,139,762.	88,604,055.	9,930.6	17,340.5
2	1	2	2053	2,856,192.	224,995.7	2,631,196.	11,823,176.	9,986.9	18,928.9
3	1	3	2494	1,675,399.	102,147.7	1,573,251.	5,804,601.	9,950.3	18,250.8
4	2	1	639	58,176,499.	1,349,001.6	56,827,498.	166,807,297.	10,039.4	16,606.8
5	2	2	822	7,053,372.	458,481.5	6,594,891.	32,067,810.	9,924.5	16,975.4
6	2	3	941	4,226,199.	209,143.6	4,017,055.	13,006,624.	9,959.8	16,575.8
7	3	1	383	197,872,950.	85,466,139.	112,406,811.	574,321,109.	10,145.5	17,658.5
8	3	2	439	42,432,491.	29,337,602.	13,094,889.	146,499,217.	10,009.3	18,388.2
9	3	3	559	21,826,249.	13,814,297.	8,011,952.	55,367,954.	10,012.8	16,933.7

OBS	CNT5	CNT10	CNT15	CNT20	CNT95	CNT200	CNT201	MAX DAMAGE HUR_CST
9	5350	1221	491	462	2021	288	166	527,732,305.
10	5350	1221	491	462	2021	288	167	574,321,109.

SUMMARY RESULTS - $90 M INSURANCE-80% $5 M DEDUCT 10:23 Friday, February 4, 1994 12

OBS	HUR_N	INSURANCE HUR_AVG
1	10000	$ 12,593,779

X .233 = $2,934,351

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OBS	CNT5	CNT10	CNT15	CNT20	CNT95	CNT200	CNT201	MAX DAMAGE HUR_CST
9	5350	1221	491	462	2021	288	166	527,732,305.
10	5350	1221	491	462	2021	288	167	574,321,109.

OBS	HUR_N	INSURANCE HUR_AVG	
1	10000	$ 12,593,779	X .233 = $2,934,351

Florida Power Corporation
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Exhibit No. 5
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LIST OF INPUT DA.

SENSITIVITY CASE - CATEGORY 1 - 5 HURRICANES

OBS	CASE_NME	COM1	COM2	AREA1_P	TCST1_X	TCST1_S	TCST1_M	DCST1_X	DCST1_S	DCST1_M	AREA2_P
1	HURRICANE	- EXPECTE D STORM DAMAGE FROM HUR. CAT 1 - 5	AREA1_P T	0.27	66011	30642	123731	77469	45243	159028	0.34

OBS	TCST2_X	TCST2_S	TCST2_M	DCST2_X	DCST2_S	DCST2_M	AREA3_P	TCST3_X	TCST3_S	TCST3_M	DCST3_X	DCST3_S	DCST3_M	AREA4_P	TCST4_X	TCST4_S
1	18758	6154	31527	6979	5035	17429	0.39	10343	5092	22557	4932	3369	10346	0	5000	1000

OBS	TCST4_M	DCST4_X	DCST4_S	DCST4_M	AREA5_P	TCST5_X	TCST5_S	TCST5_M	DCST5_X	DCST5_S	DCST5_M	COM3	HUR1_P	MILE1_X	MILE1_S	T1_DMG
1	10000	1000	1000	10000	0	5000	1000	10000	1000	1000	10000	HUR1_P S	0.56	10000	2000	.001

OBS	D1_DMG	HUR2_P	MILE2_X	MILE2_S	T2_DMG	D2_DMG	HUR3_P	MILE3_X	MILE3_S	T3_DMG	D3_DMG	HUR4_P	MILE4_X	MILE4_S	T4_DMG	D4_DMG	HUR5_P
1	0.032	0.22	10000	2000	.002	0.08	0.13	10000	2000	0.138	0.162	0.06	10000	2000	0.256	0.276	0.03

OBS	MILE5_X	MILE5_S	T5_DMG	D5_DMG	COM4	PROB_HUR	LIM_A1	LIM_A2	LIM_A3	LIM_A4	LIM_A5	LIM_H1	LIM_H2	LIM_H3	LIM_H4	LIM_H5	SIM
1	10000	2000	0.353	0.382	FREQ	0.233	0.27	0.61	1	1	1	0.56	0.78	0.91	0.97	1	10000

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Univariate Procedure

VARIABLE=TCST_MI (TRANSMISSION COST $/ SQ MILE)

Moments

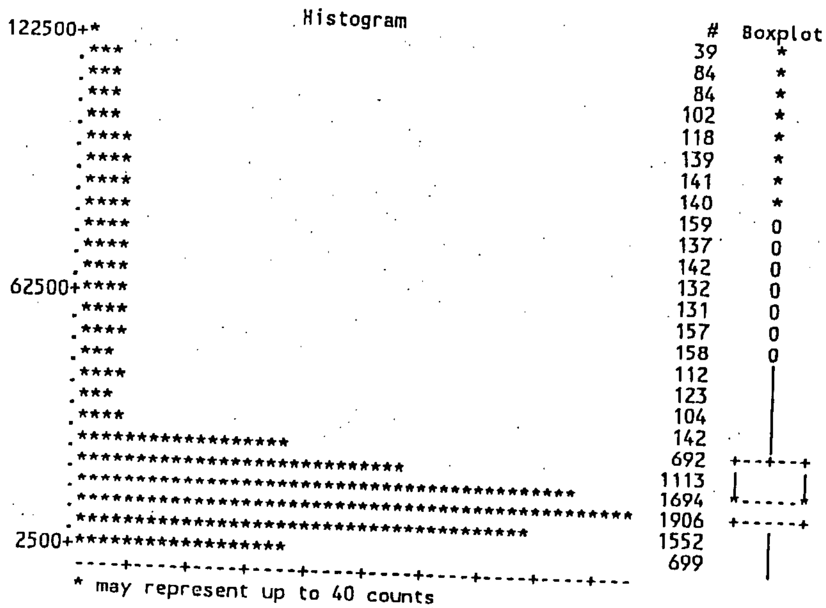
N	10000	Sum Wgts	10000
Mean	28436.72	Sum	2.8437E8
Std Dev	28619.88	Variance	8.191E8
Skewness	1.65606	Kurtosis	1.662944
USS	1.628E13	CSS	8.19E12
CV	100.6441	Std Mean	286.1988
T:Mean=0	99.36003	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

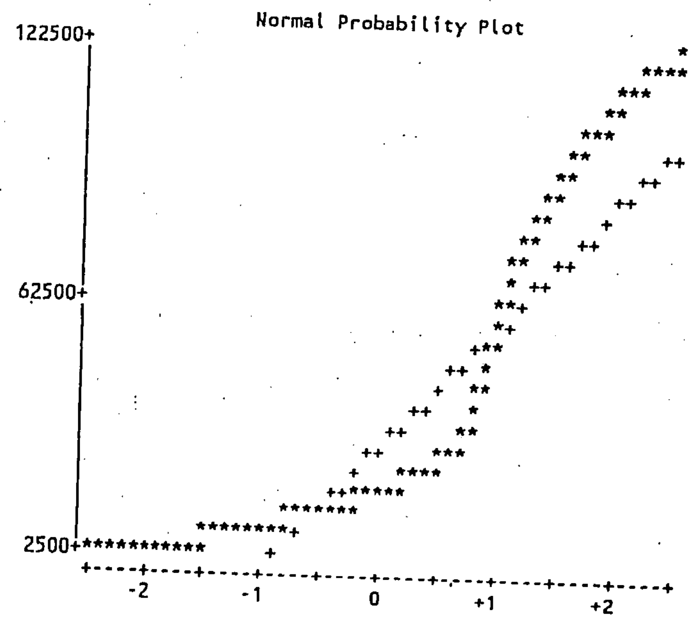
Quantiles(Def=5)

100% Max	123559.7	99%	116259.1
75% Q3	28220.56	95%	96898.09
50% Med	17347.08	90%	80203.37
25% Q1	10706.44	10%	6094.339
0% Min	66.16004	5%	4089.269
		1%	1762.159
Range	123493.5		
Q3-Q1	17514.12		
Mode	66.16004		

Extremes

Lowest	Obs	Highest	Obs
66.16004(	6963)	123073.8(	1215)
105.0359(	5686)	123125.8(	3194)
160.2473(	3432)	123241.9(	4038)
238.4415(	5564)	123242.1(	727)
304.7211(	9529)	123559.7(	9233)





STATISTICAL SUMMARY OF DISTRIBUTION C... .MULATION   13:28 WEDNESDAY, MARCH 9, 1994   3

Univariate Procedure

VARIABLE=DCST_MI (DISTRIBUTION COST- $/ SQ MILE)

Moments

N	10000	Sum Wgts	10000
Mean	22661.74	Sum	2.2662E8
Std Dev	38157.84	Variance	1.456E9
Skewness	2.065744	Kurtosis	3.113488
USS	1.969E13	CSS	1.456E13
CV	168.38	Std Mean	381.5784
T:Mean=0	59.38947	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	158972	99%	150873.2
75% Q3	14519.04	95%	121432.6
50% Med	6406.996	90%	88809.66
25% Q1	1750.806	10%	259.7641
0% Min	2.456E-8	5%	49.85131
		1%	0.879579
Range	158972		
Q3-Q1	12768.23		
Mode	2.456E-8		

Extremes

Lowest	Obs	Highest	Obs
2.456E-8(	5916)	158701.2(	3968)
0.000016(	3286)	158861.5(	6406)
0.000192(	6172)	158908.5(	5784)
0.000219(	725)	158954(	1126)
0.000346(	8520)	158972(	7431)

```
                     Histogram                                    #  Boxplot
155000+*                                                        113     *
       .*                                                       133     *
       .*                                                       133     *
125000+**                                                       148     *
       .**                                                      145     *
       .**                                                      152     *
 95000+**                                                       163     *
       .**                                                      171     *
       .*                                                       138     *
 65000+**                                                       167     *
       .**                                                      194     0
       .**                                                      179     0
 35000+**                                                       206     0
       .**                                                      211     +
       .*******                                                 984  +-----+
  5000+*********************************************************  6763  *-----*
       ----+----+----+----+----+----+----+----+----+----+----
       * may represent up to 141 counts
```

```
                      Normal Probability Plot
155000+                                                  ***
      |                                               ****
125000+                                             ***
      |                                           ***
      |                                          **     +++
 95000+                                         **    ++
      |                                        **  +++
      |                                       ** ++
 65000+                                      **+++
      |                                     +*+
      |                                    ++**
 35000+                                 +++ **
      |                               +++  **
      |                             ++     *
  5000+*******************************+++ ****
       +----+----+----+----+----+----+----+----+----+----+
           -2        -1         0        +1        +2
```

Univariate Procedure

VARIABLE=NUM_MI (NUMBER OF SQ MILES DAMAGED BY HUR.)

Moments

N	10000	Sum Wgts	10000
Mean	9996.266	Sum	99962660
Std Dev	2007.959	Variance	4031901
Skewness	0.423317	Kurtosis	0.26901
USS	1.04E12	CSS	4.031E10
CV	20.08709	Std Mean	20.07959
T:Mean=0	497.8321	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	18334.27	99%	15341.06
75% Q3	11252.63	95%	13528.76
50% Med	9842.476	90%	12647.02
25% Q1	8583.534	10%	7546.541
0% Min	3841.664	5%	6954.094
		1%	5917.012
Range	14492.61		
Q3-Q1	2669.098		
Mode	3841.664		

Extremes

Lowest	Obs	Highest	Obs
3841.664(	2208)	17645.68(	2425)
3964.185(	3804)	17881.72(	256)
4053.662(	6183)	17972.15(	8359)
4152.511(	8537)	18227.67(	610)
4182.085(	4833)	18334.27(	9944)

```
             Histogram                                      #  Boxplot
18500+*                                                     2     0
     .*                                                    12     0
     .*                                                    34     0
15500+***                                                  87     0
     .*****                                               208     |
     .***********                                         436     |
12500+*******************                                 782     |
     .*******************************                    1306  +-----+
     .******************************************         1799  |     |
 9500+************************************************   2054  *--+--*
     .*****************************************          1751  +-----+
     .************************                            998     |
 6500+**********                                          411     |
     .***                                                 102     |
     .*                                                    16     0
 3500+*                                                     2     0
      ----+----+----+----+----+----+----+----+----+---
     * may represent up to 43 counts
```

```
                  Normal Probability Plot
18500+
     |                                                   *
     |                                                   *
15500+                                                   *
     |                                                ****
     |                                            *****++
12500+                                        *****+
     |                                    *****
     |                               +*****
 9500+                           ******
     |                      ******
     |                *******
     |          *******
 6500+   *********+
     |***+++
     |*
 3500+*
      +----+----+----+----+----+----+----+----+----+----+
          -2        -1         0        +1        +2
```

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STATISTICAL SUMMARY OF HURRICANE COST ...ATION

Univariate Procedure

VARIABLE=HUR_CST (HUR. TOTAL COST - $ / HUR.)

Moments

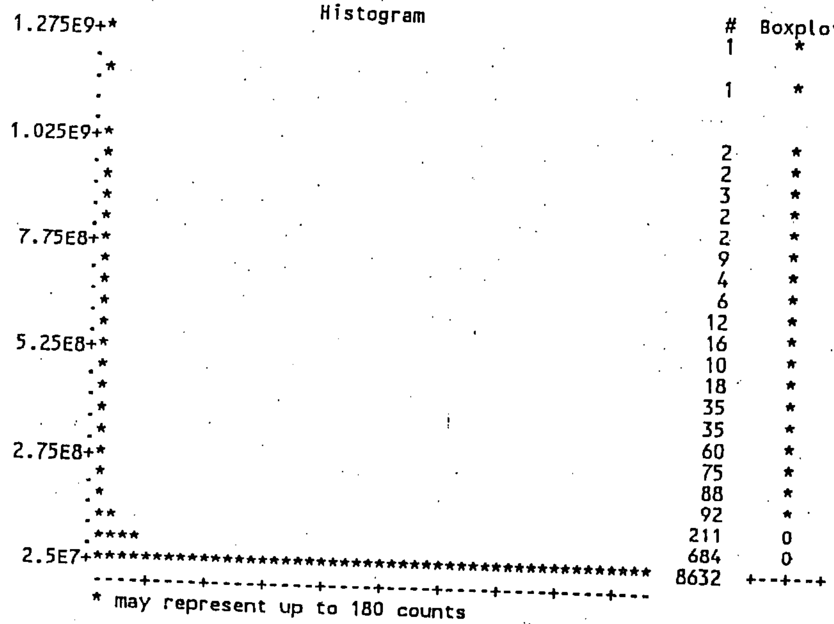
N	10000	Sum Wgts	10000
MEAN	31,592,348	SUM	3.159E11
Std Dev	82906032	Variance	6.873E15
Skewness	5.8074	Kurtosis	44.78083
USS	7.871E19	CSS	6.873E19
CV	262.4244	Std Mean	829060.3
T:Mean=0	38.10621	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

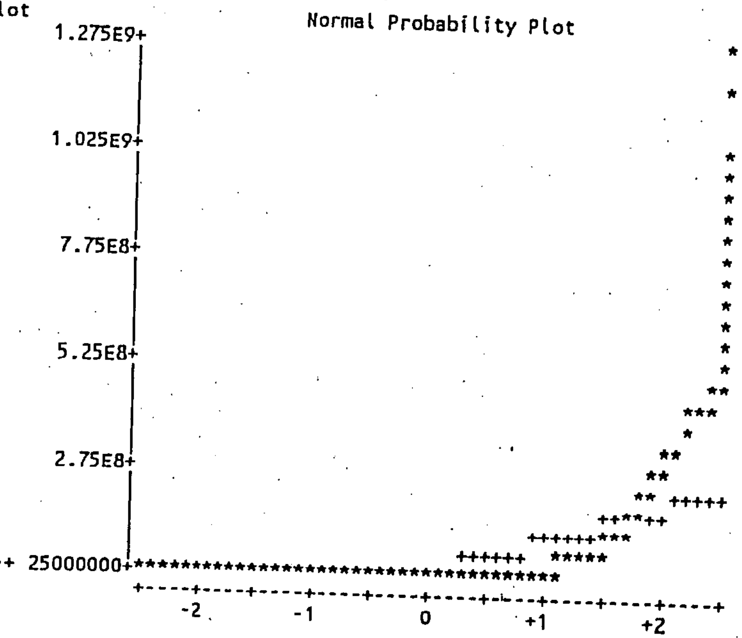
Quantiles(Def=5)

100% Max	1.266E9	99%	4.2243E8
75% Q3	28595822	95%	1.3705E8
50% Med	4003205	90%	67984229
25% Q1	1259736	10%	370106.7
0% Min	20374.12	5%	220005.5
		1%	107906.8
Range	1.266E9		
Q3-Q1	27336086		
Mode	20374.12		

Extremes

Lowest	Obs	Highest	Obs
20374.12(	8412)	9.9628E8(	4998)
23484.97(	9035)	1.0271E9(	4913)
25524.28(	2867)	1.0397E9(	4287)
41535.22(	3882)	1.1523E9(	4709)
42598.56(	1355)	1.266E9(	6857)





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Univariate Procedure

VARIABLE=THUR_CST ($ TRANS. COST/HUR)

Moments

N	10000	Sum Wgts	10000
Mean	12355974	Sum	1.236E11
Std Dev	38962567	Variance	1.518E15
Skewness	5.712538	Kurtosis	43.69665
USS	1.671E19	CSS	1.518E19
CV	315.3338	Std Mean	389625.7
T:Mean=0	31.71242	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	6.1441E8	99%	2.0306E8
75% Q3	1261647	95%	73894800
50% Med	280015.1	90%	33298057
25% Q1	138316.5	10%	75097.08
0% Min	727.7071	5%	50263.92
		1%	20725.01
Range	6.144E8		
Q3-Q1	1123330		
Mode	727.7071		

Extremes

Lowest	Obs	Highest	Obs
727.7071(	5686)	4.7931E8(	6081)
1207.337(	6963)	4.8188E8(	4300)
1260.467(	3432)	5.2023E8(	4709)
3548.208(	1390)	5.2064E8(	6857)
4295.538(	5057)	6.1441E8(	358)

```
             Histogram                                  #  Boxplot                  Normal Probability Plot
6.25E8+*                                                1     *      6.25E8+                                                    *
      .*                                                             |
      .*                                                2     *      |                                                          *
      .*                                                2     *      |                                                          *
      .*                                                4     *      |                                                          *
3.25E8+*                                               10     *      |                                                          *
      .*                                               15     *      3.25E8+                                                    *
      .*                                               27     *      |                                                          *
      .*                                               43     *      |                                                          *
      .*                                               75     *      |                                                        ***
      .**                                             160     *      |                                                      ***
2.5E7+************************************************ 364    *      |                                                   ****  +++
      ----+----+----+----+----+----+----+----+----+---  9297 +--0--+ 25000000+*************************************+++++****++++
      * may represent up to 194 counts                                        +----+----+----+----+----+----+----+----+----+----+
                                                                                   -2        -1        0        +1        +2
```

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Univariate Procedure

VARIABLE=DHUR_CST ($ DIST COST / HUR)

Moments

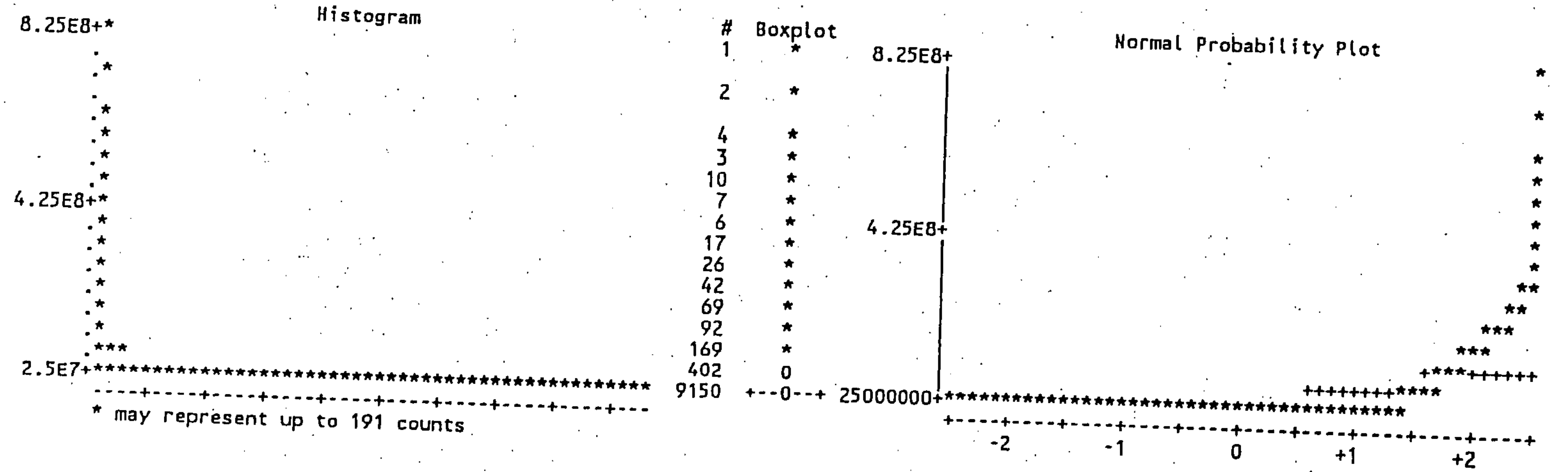
N	10000	Sum Wgts	10000
Mean	19236374	Sum	1.924E11
Std Dev	51721577	Variance	2.675E15
Skewness	6.042654	Kurtosis	49.29626
USS	3.045E19	CSS	2.675E19
CV	268.8738	Std Mean	517215.8
T:Mean=0	37.19216	Pr>|T|	0.0001
Num ^= 0	10000	Num > 0	10000
M(Sign)	5000	Pr>=|M|	0.0001
Sgn Rank	25002500	Pr>=|S|	0.0001

Quantiles(Def=5)

100% Max	8.0114E8	99%	2.7232E8
75% Q3	14281263	95%	89893577
50% Med	2977769	90%	43559523
25% Q1	869688.9	10%	122215.9
0% Min	0.000021	5%	26883.02
		1%	405.3598
Range	8.0114E8		
Q3-Q1	13411574		
Mode	0.000021		

Extremes

Lowest	Obs	Highest	Obs
0.000021(	5916)	6.321E8(	4709)
0.004361(	3286)	6.4148E8(	2496)
0.071318(	725)	7.4314E8(	4913)
0.161066(	6172)	7.4537E8(	6857)
0.561076(	8520)	8.0114E8(	2780)



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OBS	CASE_NME	COM1	COM2	AREA1_P	TCST1_X	TCST1_S	TCST1_M	DCST1_X	DCST1_S	DCST1_M	AREA2_P
1	HURRICANE - EXPECTE D STORM DAMAGE FROM HUR. CAT 1 - 5		AREA1_P T	0.27	66011	30642	123731	77469	45243	159028	0.34

OBS	TCST2_X	TCST2_S	TCST2_M	DCST2_X	DCST2_S	DCST2_M	AREA3_P	TCST3_X	TCST3_S	TCST3_M	DCST3_X	DCST3_S	DCST3_M	AREA4_P	TCST4_X	TCST4_S
1	18758	6154	31527	6979	5035	17429	0.39	10343	5092	22557	4932	3369	10346	0	5000	1000

OBS	TCST4_M	DCST4_X	DCST4_S	DCST4_M	AREA5_P	TCST5_X	TCST5_S	TCST5_M	DCST5_X	DCST5_S	DCST5_M	COM3	HUR1_P	MILE1_X	MILE1_S	T1_DMG
1	10000	1000	1000	10000	0	5000	1000	10000	1000	1000	10000	HUR1_P S	0.56	10000	2000	.001

OBS	D1_DMG	HUR2_P	MILE2_X	MILE2_S	T2_DMG	D2_DMG	HUR3_P	MILE3_X	MILE3_S	T3_DMG	D3_DMG	HUR4_P	MILE4_X	MILE4_S	T4_DMG	D4_DMG	HUR5_P
1	0.032	0.22	10000	2000	.002	0.08	0.13	10000	2000	0.138	0.162	0.06	10000	2000	0.256	0.276	0.03

OBS	MILE5_X	MILE5_S	T5_DMG	D5_DMG	COM4	PROB_HUR	LIM_A1	LIM_A2	LIM_A3	LIM_A4	LIM_A5	LIM_H1	LIM_H2	LIM_H3	LIM_H4	LIM_H5	SIM	TCST_AVG
1	10000	2000	0.353	0.382	FREQ	0.233	0.27	0.61	1	1	1	0.56	0.78	0.91	0.97	1	10000	28436.72

OBS	DCST_AVG	MILE_AVG	AVERAGE HUR COST	THUR_CST	DHUR_CST	TCST_MAX	DCST_MAX	MILE_MAX	MAXIMUM HUR COST	ANNUAL EXPECTED HUR COST
1	22661.74	9996.27	31,592,347.	12355973.81	19236374.03	123559.69	158972.03	18334.27	1,266,015,960	$7,361,017

OBS	HUR_TYPE	HUR_N	AVERAGE HUR COST	THUR_AVG	DHUR_AVG	MILE_AVG
1	1	5662	73,72,871.	282873.22	7089998.58	10002.26
2	2	2207	18,795,506.	579295.63	18216210.62	9977.05
3	3	1269	79,457,527.	39647299.47	39810227.98	9982.73
4	4	575	133,340,120.	70569249.64	62770871.24	10024.96
5	5	287	192,315,066.	103797431.63	88517634.99	10028.22

OBS	HUR_TYPE	HUR_AREA	HUR_N	AVERAGE HUR COST	THUR_AVG	DHUR_AVG	MAXIMUM HUR COST	MILE_AVG	MILE_MAX
1	1	1	1517	23,085,331.	665039.05	22420292.37	75,834,203.	9980.08	16524.12
2	1	2	1920	1,539,046.	188217.32	1350829.11	8,388,729.	10064.14	17608.05
3	1	3	2225	1,694,284.	103994.01	1590290.59	5,397,344.	9963.97	18334.27
4	2	1	612	57,282,850.	1331677.20	55951173.72	189,672,222.	10022.10	16491.53
5	2	2	757	3,784,991.	382796.30	3402195.19	18,622,761.	10084.00	17881.72
6	2	3	838	4,247,421.	207329.60	4040091.61	12,053,721.	9847.54	17645.68
7	3	1	355	212,814,826.	90947834.96	121866991.53	576,665,108.	9954.88	16564.48
8	3	2	414	33,624,221.	26130882.94	7493338.90	75,212,699.	9982.15	16401.79
9	3	3	500	22,723,822.	14415512.17	8308310.01	59,160,408.	10002.98	16431.45
10	4	1	143	379,971,450.	170948977.39	209022472.70	785,840,205.	10207.73	16861.41
11	4	2	217	62,442,931.	48785198.98	13657733.00	153,274,741.	9969.28	18227.67
12	4	3	215	40,858,306.	25791751.62	15066554.90	88,604,927.	9959.60	16653.85
13	5	1	73	544,902,877.	250458747.04	294444130.23	1,266,015,960.	10186.86	14393.87
14	5	2	114	84,001,750.	66474403.67	17527347.31	193,797,140.	9990.53	14627.21
15	5	3	100	58,403,144.	39282923.26	19120221.40	122,712,894.	9955.38	15347.14

OBS	$0-5M CNT5	$5-10M CNT10	$10-15M CNT15	$15-20M CNT20	$20-35M CNT25	$25-50M CNT50	$50-95M CNT95	$95-200M CNT200	$>200M CNT201	MAXIMUM HUR COST
1	5335	828	381	373	352	1363	653	334	381	1,266,015,960

OBS	HUR_N	PA[illegible]ENT AVG. HUR.
1	10000	$16,240,289.

EXPECTED PAYMENT = $16,240,289 X .233 = $3,783,987

Assessment of Potential Hurricane Damage

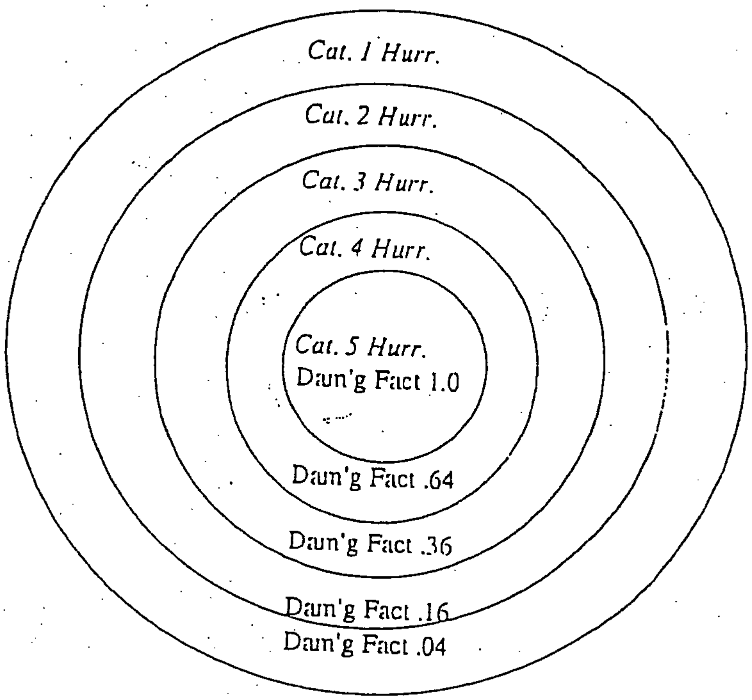
1,000 Square Miles

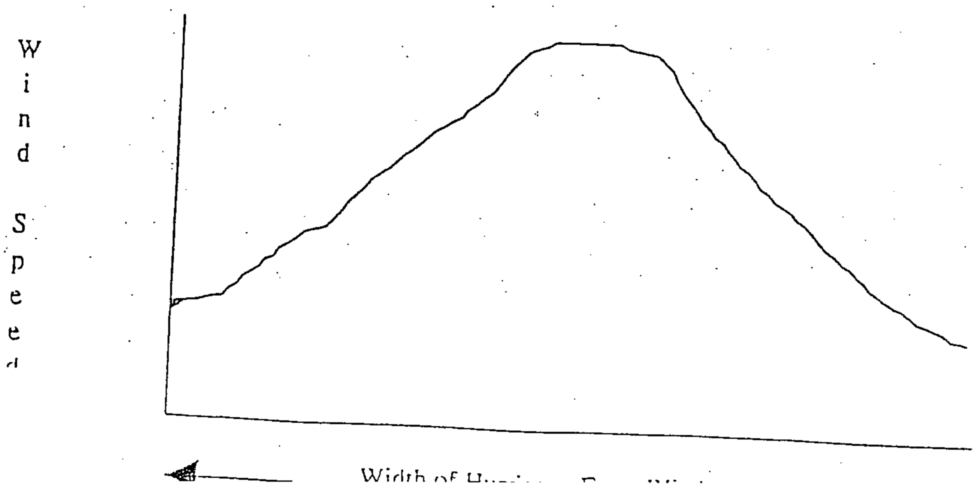
		1	2	3	4	5	6
		Distribution Costs 10x100 sq mi.	Avg Costs Dist $/Sq Mile 1000	Transmission Costs 10x100 sq mi.	Avg Costs Trans. $/Sq Mile 1000	Total Cost Costs 10x100 sq mi.	Avg Costs by $/Sq Mile 1000
Area 1	1	23,952,816	$23,953	26,669,650	$26,670	50,622,466	$50,622
	2	38,817,312	38,817	29,222,750	$29,223	68,040,062	68,040
	3	151,646,944	151,647	37,026,475	$37,026	188,673,419	188,673
	4	110,595,392	110,595	43,007,350	$43,007	153,602,742	153,603
	5	70,553,184	70,553	82,759,650	$82,760	153,312,834	153,313
	6	159,028,880	159,029	100,242,875	$100,243	259,271,755	259,272
	7	97,232,640	97,233	95,778,200	$95,778	193,010,840	193,011
	8	78,450,672	78,451	77,226,750	$77,227	155,677,422	155,677
	9	39,538,096	39,538	123,730,700	$123,731	163,268,796	163,269
	10	55,194,064	55,194	51,364,600	$51,365	106,558,664	106,559
Area 1	11	27,148,736	27,149	59,098,050	$59,098	86,246,786	86,247
Average for area 1			77,469		66,012		143,481
Std Dev.			45,243		30,642		58,462
Max Value			159,029		123,731		259,272
Area 2	12	14,426,361	14,426	11,734,200	11,734	26,160,561	26,161
	13	4,215,100	4,215	20,937,800	20,938	25,152,900	25,153
	14	3,880,817	3,881	15,578,200	15,578	19,459,017	19,459
	15	8,142,007	8,142	31,526,950	31,527	39,668,957	39,669
	16	4,045,479	4,045	16,472,650	16,473	20,518,129	20,518
	17	2,682,947	2,683	17,939,175	17,939	20,622,122	20,622
	18	3,936,861	3,937	25,138,500	25,139	29,075,361	29,075
	19	4,050,544	4,051	18,916,150	18,916	22,966,694	22,967
Area 2	20	17,428,704	17,429	10,577,550	10,578	28,006,254	28,006
Average for area 2			6,979		18,758		25,737
Std Dev.			5,035		6,154		5,882
Max Value			17,429		31,527		39,669
Area 3	21	15,547	16	9,141,450	9,141	9,156,997	9,157
	22	10,148,531	10,149	8,608,975	8,609	18,757,506	18,758
	23	7,628,715	7,629	6,513,725	6,514	14,142,440	14,142
	24	10,346,343	10,346	10,826,000	10,826	21,172,343	21,172
	25	4,446,543	4,447	22,556,575	22,557	27,003,118	27,003
	26	3,798,346	3,798	16,647,450	16,647	20,445,796	20,446
	27	3,278,035	3,278	7,456,925	7,457	10,734,960	10,735
	28	476,281	476	6,439,150	6,439	6,915,431	6,915
	29	5,352,639	5,353	5,111,750	5,112	10,464,389	10,464
Area 3	30	3,831,105	3,831	10,131,850	10,132	13,962,955	13,963
Average for area 3			4,932		10,343		15,276
Std Dev.			3,369		5,092	1,962,671,716	6,044
Max Value			10,346		22,557	65,422,391	27,003
Total 30 Seg.		964,289,641		998,382,075		1,962,671,716	
Avg. 30 Seg.		32,142,988		33,279,403		65,422,391	

HURRICANE DAMAGE STUDY – DISTRIBUTION

WEIGHTED DAMAGE FACTOR OF CATEGORY 5 HURRICANE.

1 CATEGORY	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 Dr Gray's Damage Factor x 4	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
5	45	45	0.32	1.00	0.8	0.257
4	60	15	0.11	0.64	0.8	0.055
3	75	15	0.11	0.36	0.8	0.031
2	110	35	0.25	0.16	0.8	0.032
1	140	30	0.21	0.04	0.8	0.007
TOTAL RADIUS OF STORM		140			SUM	0.382





…IGHTED DAMAGE FACTOR OF CATEGORY 4 HURRICANE. – Distribution

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 DAMAGE FACTOR	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
4	45	45	0.41	0.64	0.8	0.209
3	60	15	0.14	0.36	0.8	0.039
2	75	15	0.14	0.16	0.8	0.017
1	110	35	0.32	0.04	0.8	0.010

TOTAL RADIUS OF STORM 110

SUM 0.276

WEIGHTED DAMAGE FACTOR OF CATEGORY 3 HURRICANE. – Distribution

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 DAMAGE FACTOR	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
3	45	45	0.45	0.36	0.8	0.130
2	60	15	0.15	0.16	0.8	0.019
1	100	40	0.40	0.04	0.8	0.013

TOTAL RADIUS OF STORM 100

SUM 0.162

WEIGHTED DAMAGE FACTOR OF CATEGORY 2 HURRICANE. – Distribution

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 DAMAGE FACTOR	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
2	45	45	0.50	0.16	0.8	0.064
1	90	45	0.50	0.04	0.8	0.016

TOTAL RADIUS OF STORM 90

SUM 0.080

Damage factor – Cat 1 – Distribution

1.0 x .04 x .8 = .032

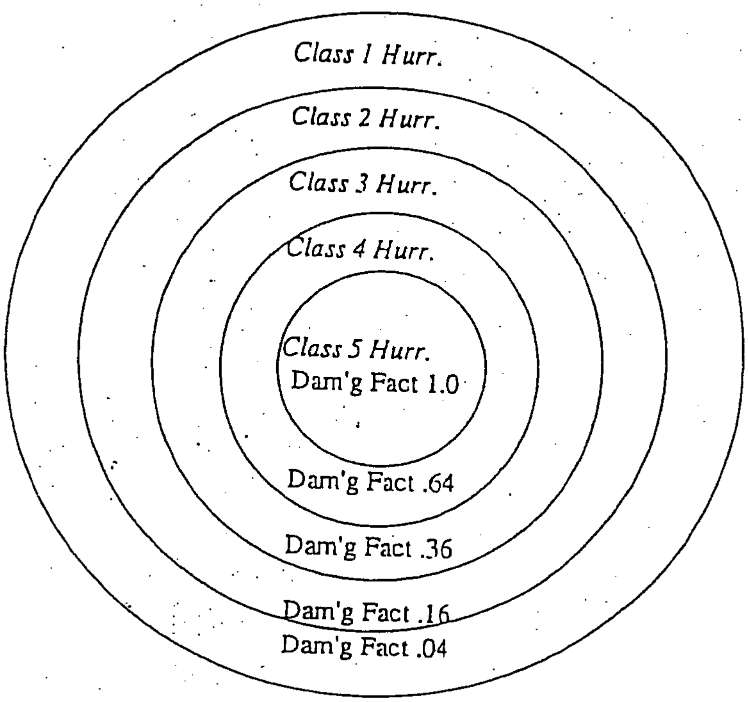
HURRICANE DAMAGE STUDY - TRANSMISSION

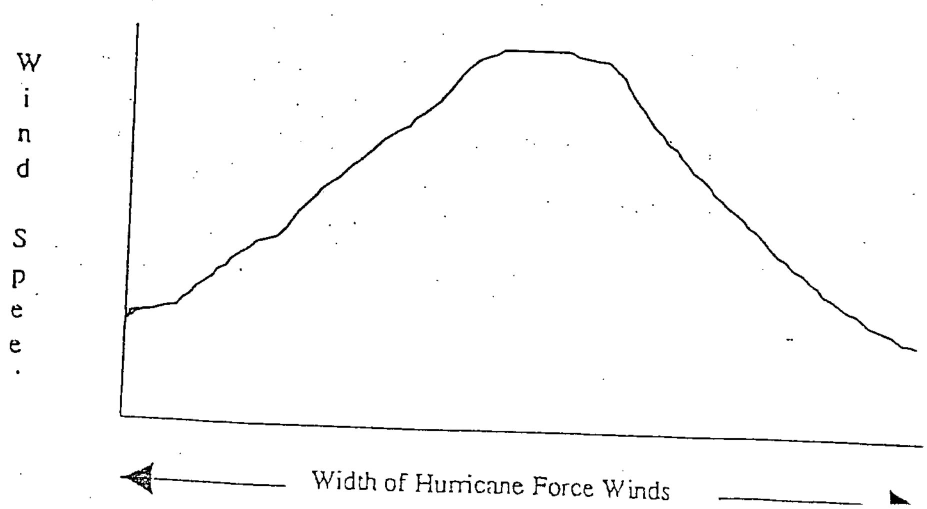
WEIGHTED DAMAGE FACTOR OF CLASS 5 HURRICANE.

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 Dr Gray's Damage Factor x 4	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
5	45	45	0.32	1.00	0.8	0.257
4	60	15	0.11	0.64	0.8	0.055
3	75	15	0.11	0.36	0.8	0.031
2	110	35	0.25	0.002	0.8	0.000
1	140	30	0.21	0.001	0.8	0.000

TOTAL RADIUS OF STORM 140

SUM 0.343





:GHTED DAMAGE FACTOR OF CLASS 4 HURRICANE. – Transmission

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 DAMAGE FACTOR	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
4	45	45	0.41	0.64	0.8	0.209
3	60	15	0.14	0.36	0.8	0.039
2	75	15	0.14	0.002	0.8	0.000
1	110	35	0.32	0.001	0.8	0.000

TOTAL RADIUS OF STORM 110

SUM 0.249

WEIGHTED DAMAGE FACTOR OF CLASS 3 HURRICANE. – Transmission

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 DAMAGE FACTOR	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
3	45	45	0.45	0.36	0.8	0.130
2	60	15	0.15	0.002	0.8	0.000
1	100	40	0.40	0.002	0.8	0.001

TOTAL RADIUS OF STORM 100

SUM 0.130

WEIGHTED DAMAGE FACTOR OF CLASS 2 HURRICANE. – Transmission

1 CLASS	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 DAMAGE FACTOR	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
2	45	45	0.50	0.002	0.8	0.001
1	90	45	0.50	0.002	0.8	0.001

TOTAL RADIUS OF STORM 90

SUM 0.002

Application of probabilities will often yield entirely different and better decisions.

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Risk Analysis in Capital Investment

By David B. Hertz

Of all the decisions that business executives ust make, none is more challenging — and e has received more attention — than choos- among alternative capital investment oppor- ities. What makes this kind of decision so anding, of course, is not the problem of pro- ting return on investment under any given of assumptions. The difficulty is in the as- mptions and in their impact. Each assump- involves its own degree — often a high ree — of uncertainty; and, taken together, se combined uncertainties can multiply into tal uncertainty of critical proportions. This where the element of risk enters, and it is in evaluation of risk that the executive has able to get little help from currently avail- e tools and techniques.

There is a way to help the executive sharpen key capital investment decisions by providing with a realistic measurement of the risks olved. Armed with this measurement, which luates for him the risk at each possible level return, he is then in a position to measure e knowledgeably alternative courses of action inst corporate objectives.

Need for New Concept

The evaluation of a capital investment proj- starts with the principle that the produc- ity of capital is measured by the rate of re- n we expect to receive over some future pe- d. A dollar received next year is worth less us than a dollar in hand today. Expendi- es three years hence are less costly than ex- nditures of equal magnitude two years from now. For this reason we cannot calculate the rate of return realistically unless we take into account (a) when the sums involved in an investment are spent and (b) when the returns are received.

Comparing alternative investments is thus complicated by the fact that they usually differ not only in size but also in the length of time over which expenditures will have to be made and benefits returned.

It is these facts of investment life that long ago made apparent the shortcomings of approaches that simply averaged expenditures and benefits, or lumped them, as in the number-of-years-to-pay-out method. These shortcomings stimulated students of decision making to explore more precise methods for determining whether one investment would leave a company better off in the long run than would another course of action.

It is not surprising, then, that much effort has been applied to the development of ways to improve our ability to discriminate among investment alternatives. The focus of all of these investigations has been to sharpen the definition of the value of capital investments to the company. The controversy and furor that once came out in the business press over the most appropriate way of calculating these values has largely been resolved in favor of the discounted cash flow method as a reasonable means of measuring the rate of return that can be expected in the future from an investment made today.

Thus we have methods which, in general, are more or less elaborate mathematical formulas for comparing the outcomes of various investments and the combinations of the variables that

Source: Harvard Business Review

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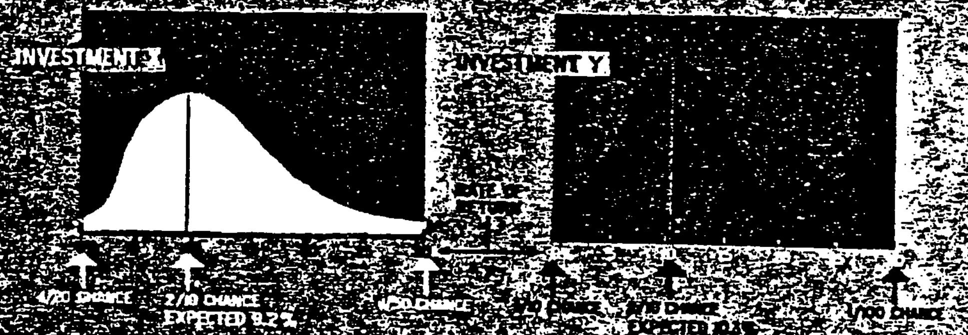
SUMMARY OF NEW APPROACH

After examining present methods of comparing alternative investments, Mr. Hertz reports on his firm's experience in applying a new approach to the problem. Using this approach, management takes the various levels of possible cash flows, return on investment, and other results of a proposed outlay and gets an estimate of the odds for each potential outcome.

Currently, many facilities decisions are based on discounted cash flow calculations. Management is told, for example, that Investment X has an expected internal rate of return of 9.2%, while for Investment Y a 10.3% return can be expected.

By contrast, the new approach would put in front of the executive a schedule which gives him the most likely return from X, but also tells him that X has 1 chance in 20 of being a total loss, 1 in 10 of earning from 4% to 5%, 2 in 10 of paying from 8% to 10%, and 1 chance in 50 of attaining a 30% rate of return. From another schedule he learns what the most likely rate of return is from Y, but also that Y has 1 chance in 10 of resulting in a total loss, 1 in 10 of earning from 3% to 5% return, 2 in 10 of paying between 9% and 11%, and 1 chance in 100 of 30%. Or portrayed graphically:



In this instance, the estimates of the rates of return provided by the two approaches would not be substantially different. However, to the decision-maker with the added information, Investment Y no longer looks like the clearly better choice, since with X the chances of substantial gain are higher and the risks of loss lower.

Two things have made this approach appealing to managers who have used it:

1. Certainly in every case it is a more descriptive statement of the two opportunities. And in some cases it might well reverse the decision, in line with particular corporate objectives.

2. This is not a difficult technique to use, since much of the information needed is already available — or readily accessible — and the validity of the principles involved has, for the most part, already been proved in other applications.

The enthusiasm with which managements exposed to this approach have received it suggests that it may have wide application. It has particular relevance, for example, in such knotty problems as investments relating to acquisitions or new products, and in decisions that might involve excess capacity.

will affect the investments.[1] As these techniques have progressed, the mathematics involved has become more and more precise, so that we can now calculate discounted returns to a fraction of a per cent.

But the sophisticated businessman knows that behind these precise calculations are data which are not that precise. At best, the rate-of-return information he is provided with is based on an average of different opinions with varying reliabilities and different ranges of probability. When the expected returns on two investments are close, he is likely to be influenced by "intangibles" — a precarious pursuit at best. Even when the figures for two investments are quite far apart, and the choice seems clear, there lurks in the back of the businessman's mind memories of the Edsel and other ill-fated ventures.

In short, the decision-maker realizes that there is something more he ought to know,

[1] See for example, Joel Dean, *Capital Budgeting* (New York, Columbia University Press, 1951); "Return on Capital as a Guide to Managerial Decisions," *National Association of Accounts Research Report No. 35*, December 1, 1959; and Bruce F. Young, "Overcoming Obstacles to Use of Discounted Cash Flow for Investment Shares," *NAA Bulletin*, March 1963, p. 15.

something in addition to the expected rate of return. He suspects that what is missing has to do with the nature of the data on which the expected rate of return is calculated, and with the way those data are processed. It has something to do with uncertainty, with possibilities and probabilities extending across a wide range of rewards and risks.

The Achilles Heel

The fatal weakness of past approaches thus has nothing to do with the mathematics of rate-of-return calculation. We have pushed along this path so far that the precision of our calculation is, if anything, somewhat illusory. The fact is that, no matter what mathematics is used, each of the variables entering into the calculation of rate of return is subject to a high level of uncertainty. For example:

The useful life of a new piece of capital equipment is rarely known in advance with any degree of certainty. It may be affected by variations in obsolescence or deterioration, and relatively small changes in use life can lead to large changes in return. Yet an expected value for the life of the equipment — based on a great deal of data from which a single best possible forecast has been developed — is entered into the rate-of-return calculation. The same is done for the other factors that have a significant bearing on the decision at hand.

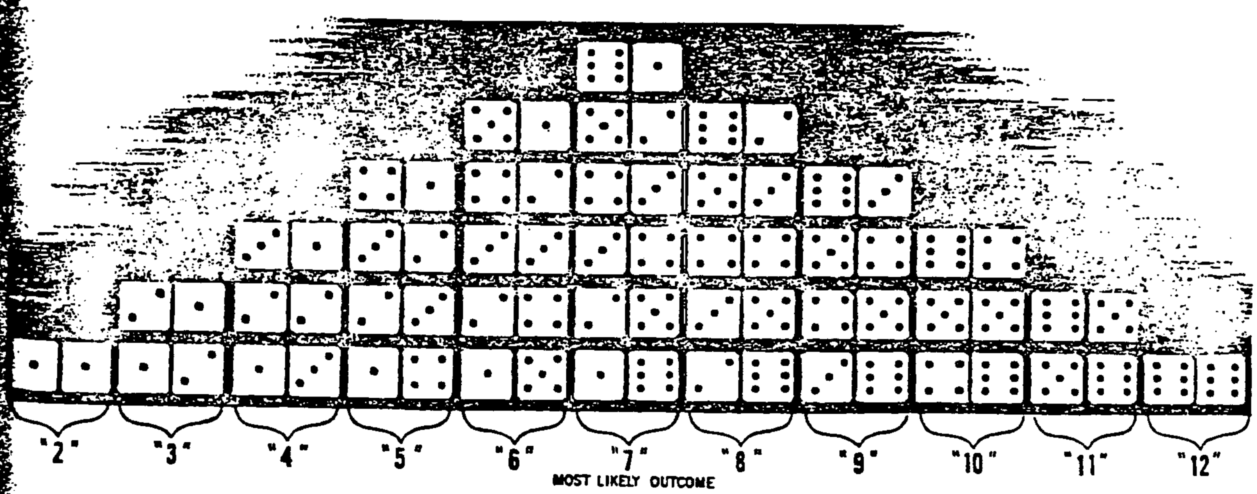
Let us look at how this works out in a simple case — one in which the odds appear to be all in favor of a particular decision:

The executives of a food company must decide whether to launch a new packaged cereal. They have come to the conclusion that five factors are the determining variables: *advertising and promotion expense, total cereal market, share of market for this product, operating costs,* and *new capital investment.* On the basis of the "most likely" estimate for each of these variables the picture looks very bright — a healthy 30% return. This future, however, depends on each of the "most likely" estimates coming true in the actual case. If each of these "educated guesses" has, for example, a 60% chance of being correct, there is only an 8% chance that *all five* will be correct ($.60 \times .60 \times .60 \times .60 \times .60$). So the "expected" return is actually dependent on a rather unlikely coincidence. The decision-maker needs to know a great deal more about the *other* values used to make each of the five estimates and about what he stands to gain or lose from various combinations of these values.

This simple example illustrates that the rate of return actually depends on a specific combination of values of a great many different variables. But only the expected levels of ranges (e.g., worst, average, best; or pessimistic, most likely, optimistic) of these variables are used in formal mathematical ways to provide the figures given to management. Thus, predicting a single most likely rate of return gives precise numbers that do not tell the whole story.

The "expected" rate of return represents only a few points on a continuous curve of possible combinations of future happenings. It is a bit like trying to predict the outcome in a dice game by saying that the most likely outcome is a "7." The description is incomplete because it does not tell us about all the other things that could happen. In EXHIBIT I, for instance, we see the odds on throws of only two dice having six

EXHIBIT I. DESCRIBING UNCERTAINTY — A THROW OF THE DICE



sides. Now suppose that each die has 100 sides and there are eight of them! This is a situation more comparable to business investment, where the company's market share might become any one of 100 different sizes and where there are eight different factors (pricing, promotion, and so on) that can affect the outcome.

Nor is this the only trouble. Our willingness to bet on a roll of the dice depends not only on the odds but also on the stakes. Since the probability of rolling a "7" is 1 in 6, we might be quite willing to risk a few dollars on that outcome at suitable odds. But would we be equally willing to wager $10,000 or $100,000 at those same odds, or even at better odds? In short, risk is influenced both by the odds on various events occurring and by the magnitude of the rewards or penalties which are involved when they do occur. To illustrate again:

> Suppose that a company is considering an investment of $1 million. The "best estimate" of the probable return is $200,000 a year. It could well be that this estimate is the average of three possible returns — a 1-in-3 chance of getting no return at all, a 1-in-3 chance of getting $200,000 per year, a 1-in-3 chance of getting $400,000 per year. Suppose that getting no return at all would put the company out of business. Then, by accepting this proposal, management is taking a 1-in-3 chance of going bankrupt.
>
> If only the "best estimate" analysis is used, management might go ahead, however, unaware that it is taking a big chance. If all of the available information were examined, management might prefer an alternative proposal with a smaller, but more certain (i.e., less variable), expectation.

Such considerations have led almost all advocates of the use of modern capital-investment-index calculations to plead for a recognition of the elements of uncertainty. Perhaps Ross G. Walker sums up current thinking when he speaks of "the almost impenetrable mists of any forecast." [2]

How can the executive penetrate the mists of uncertainty that surround the choices among alternatives?

Limited Improvements

A number of efforts to cope with uncertainty have been successful up to a point, but all seem to fall short of the mark in one way or another:

1. *More accurate forecasts* — Reducing the error in estimates is a worthy objective. But no matter how many estimates of the future go into a capital investment decision, when all is said and done, the future is still the future. Therefore, however well we forecast, we are still left with the certain knowledge that we cannot eliminate all uncertainty.

2. *Empirical adjustments* — Adjusting the factors influencing the outcome of a decision is subject to serious difficulties. We would like to adjust them so as to cut down the likelihood that we will make a "bad" investment, but how can we do that without at the same time spoiling our chances to make a "good" one? And in any case, what is the basis for adjustment? We adjust, not for uncertainty, but for bias.

For example, construction estimates are often exceeded. If a company's history of construction costs is that 90% of its estimates have been exceeded by 15%, then in a capital estimate there is every justification for increasing the value of this factor by 15%. This is a matter of improving the accuracy of the estimate.

But suppose that new-product sales estimates have been exceeded by more than 75% in one-fourth of all historical cases, and have not reached 50% of the estimate in one-sixth of all such cases? Penalties for overestimating are very tangible, and so management is apt to reduce the sales estimate to "cover" the one case in six — thereby reducing the calculated rate of return. In doing so, it is possibly missing some of its best opportunities.

3. *Revising cutoff rates* — Selecting higher cutoff rates for protecting against uncertainty is attempting much the same thing. Management would like to have a possibility of return in proportion to the risk it takes. Where there is much uncertainty involved in the various estimates of sales, costs, prices, and so on, a high calculated return from the investment provides some incentive for taking the risk. This is, in fact, a perfectly sound position. The trouble is that the decision-maker still needs to know explicitly what risks he is taking — and what the odds are on achieving the expected return.

4. *Three-level estimates* — A start at spelling out risks is sometimes made by taking the high, medium, and low values of the estimated factors and calculating rates of return based on various combinations of the pessimistic, average, and optimistic estimates. These calculations give a picture of the range of possible results, but do not tell the executive whether the pessimistic result is more likely than the optimistic one — or, in fact, whether the average result is much more likely to occur than either of the extremes. So, although this is a step in the right direction, it still does

[2] "The Judgment Factor in Investment Decisions," HBR March–April 1961, p. 99.

not give a clear enough picture for comparing alternatives.

5. *Selected probabilities* — Various methods have been used to include the probabilities of specific factors in the return calculation. L. C. Grant discusses a program for forecasting discounted cash flow rates of return where the service life is subject to obsolescence and deterioration. He calculates the odds that the investment will terminate at any time after it is made depending on the probability distribution of the service-life factor. After calculating these factors for each year through maximum service life, he then determines an overall expected rate of return.[3]

Edward G. Bennion suggests the use of game theory to take into account alternative market growth rates as they would determine rate of return for various alternatives. He uses the estimated probabilities that specific growth rates will occur to develop optimum strategies. Bennion points out:

> "Forecasting can result in a negative contribution to capital budget decisions unless it goes further than merely providing a single most probable prediction. . . . [With] an estimated probability coefficient for the forecast, plus knowledge of the payoffs for the company's alternative investments and calculation of indifference probabilities . . . the margin of error may be substantially reduced, and the businessman can tell just how far off his forecast may be before it leads him to a wrong decision."[4]

Note that both of these methods yield an expected return, each based on only one uncertain input factor — service life in the first case, market growth in the second. Both are helpful, and both tend to improve the clarity with which the executive can view investment alternatives. But neither sharpens up the range of "risk taken" or "return hoped for" sufficiently to help very much in the complex decisions of capital planning.

Sharpening the Picture

Since every one of the many factors that enter into the evaluation of a specific decision is subject to some uncertainty, the executive needs a helpful portrayal of the effects that the uncertainty surrounding each of the significant factors has on the returns he is likely to achieve. Therefore, the method we have developed at McKinsey & Company, Inc., combines the variabilities inherent in all the relevant factors. Our objective is to give a clear picture of the relative risk and the probable odds of coming out ahead or behind in the light of uncertain foreknowledge.

A simulation of the way these factors may combine as the future unfolds is the key to extracting the maximum information from the available forecasts. In fact, the approach is very simple, using a computer to do the necessary arithmetic. (Recently, a computer program to do this was suggested by S. W. Hess and H. A. Quigley for chemical process investments.[5])

To carry out the analysis, a company must follow three steps:

(1) Estimate the range of values for each of the factors (e.g., range of selling price, sales growth rate, and so on) and within that range the likelihood of occurrence of each value.

(2) Select at random from the distribution of values for each factor one particular value. Then combine the values for all of the factors and compute the rate of return (or present value) from that combination. For instance, the lowest in the range of prices might be combined with the highest in the range of growth rate and other factors. (The fact that the factors are dependent should be taken into account, as we shall see later.)

(3) Do this over and over again to define and evaluate the odds of the occurrence of each possible rate of return. Since there are literally millions of possible combinations of values, we need to test the likelihood that various specific returns on the investment will occur. This is like finding out by recording the results of a great many throws what per cent of "7"s or other combinations we may expect in tossing dice. The result will be a listing of the rates of return we might achieve, ranging from a loss (if the factors go against us) to whatever maximum gain is possible with the estimates that have been made.

For each of these rates the chances that it may occur are determined. (Note that a specific return can usually be achieved through more than one combination of events. The more combinations for a given rate, the higher the chances of achieving it — as with "7"s in tossing dice.) The average expectation is the average of the values of all outcomes weighted by the chances of each occurring.

The variability of outcome values from the average is also determined. This is important since,

[3] "Monitoring Capital Investments," *Financial Executive*, April 1963, p. 19.
[4] "Capital Budgeting and Game Theory," HBR November-December 1956, p. 123.
[5] "Analysis of Risk in Investments Using Monte Carlo Techniques," *Chemical Engineering Symposium Series 42: Statistics and Numerical Methods in Chemical Engineering* (New York, American Institute of Chemical Engineering, 1963), p. 55.

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all other factors being equal, management would presumably prefer lower variability for the same return if given the choice. This concept has already been applied to investment portfolios.[6]

When the expected return and variability of each of a series of investments have been determined, the same techniques may be used to examine the effectiveness of various combinations of them in meeting management objectives.

Practical Test

To see how this new approach works in practice, let us take the experience of a management that has already analyzed a specific investment proposal by conventional techniques. Taking the same investment schedule and the same expected values actually used, we can find what results the new method would produce and compare them with the results obtained when conventional methods were applied. As we shall see, the new picture of risks and returns is different from the old one. Yet the differences are attributable in no way to changes in the basic data — *only to the increased sensitivity of the method to management's uncertainties about the key factors.*

Investment Proposal

In this case a medium-size industrial chemical producer is considering a $10-million extension to its processing plant. The estimated service life of the facility is 10 years; the engineers expect to be able to utilize 250,000 tons of processed material worth $510 per ton at an average processing cost of $435 per ton. Is this investment a good bet? In fact, what is the return that the company may expect? What are the risks? We need to make the best and fullest use we can of all the market research and financial analyses that have been developed, so as to give management a clear picture of this project in an uncertain world.

The key input factors management has decided to use are:

1. Market size.
2. Selling prices.
3. Market growth rate.
4. Share of market (which results in physical sales volume).
5. Investment required.
6. Residual value of investment.
7. Operating costs.
8. Fixed costs.
9. Useful life of facilities.

These factors are typical of those in many company projects that must be analyzed and combined to obtain a measure of the attractiveness of a proposed capital facilities investment.

Obtaining Estimates

How do we make the recommended type of analysis of this proposal?

Our aim is to develop for each of the nine factors listed a frequency distribution or probability curve. The information we need includes the possible range of values for each factor, the average, and some ideas as to the likelihood that the various possible values will be reached. It has been our experience that for major capital proposals managements usually make a significant investment in time and funds to pinpoint information about each of the relevant factors. An objective analysis of the values to be assigned to each can, with little additional effort, yield a subjective probability distribution.

Specifically, it is necessary to probe and question each of the experts involved — to find out, for example, whether the estimated cost of production really can be said to be exactly a certain value or whether, as is more likely, it should be estimated to lie within a certain range of values. It is that range which is ignored in the analysis management usually makes. The range is relatively easy to determine; if a guess has to be made — as it often does — it is easier to guess with some accuracy a range rather than a specific single value. We have found from past experience at McKinsey & Company, Inc., that a series of meetings with management personnel to discuss such distributions is most helpful in getting at realistic answers to the a priori questions. (The term "realistic answers" implies all the information management does *not* have as well as all that it does have.)

The ranges are directly related to the degree of confidence that the estimator has in his estimate. Thus, certain estimates may be known to be quite accurate. They would be represented by probability distributions stating, for instance,

[6] See Harry Markowitz, *Portfolio Selection, Efficient Diversification of Investments* (New York, John Wiley and Sons, 1959); Donald E. Fararr, *The Investment Decision Under Uncertainty* (Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1962); William F. Sharpe, "A Simplified Model for Portfolio Analysis," *Management Science*, January 1963, p. 277.

that there is only 1 chance in 10 that the actual value will be different from the best estimate by more than 10%. Others may have as much as 100% ranges above and below the best estimate.

Thus, we treat the factor of selling price for the finished product by asking executives who are responsible for the original estimates these questions:

1. Given that $510 is the expected sales price, what is the probability that the price will exceed $550?

2. Is there any chance that the price will exceed $650?

3. How likely is it that the price will drop below $475?

Managements must ask similar questions for each of the other factors, until they can construct a curve for each. Experience shows that this is not as difficult as it might sound. Often information on the degree of variation in factors is readily available. For instance, historical information on variations in the price of a commodity is readily available. Similarly, management can estimate the variability of sales from industry sales records. Even for factors that have no history, such as operating costs for a new product, the person who makes the "average" estimate must have some idea of the degree of confidence he has in his prediction, and therefore he is usually only too glad to express his feelings. Likewise, the less confidence he has in his estimate, the greater will be the range of possible values that the variable will assume.

This last point is likely to trouble businessmen. Does it really make sense to seek estimates of variations? It cannot be emphasized too strongly that the less certainty there is in an "average" estimate, *the more important it is to consider the possible variation in that estimate*.

Further, an estimate of the variation possible in a factor, no matter how judgmental it may be, is always better than a simple "average" estimate, since it includes more information about what is known and what is not known. It is, in fact, this very *lack* of knowledge which may distinguish one investment possibility from another, so that for rational decision making it *must* be taken into account.

This lack of knowledge is in itself important information about the proposed investment. To throw any information away simply because it is highly uncertain is a serious error in analysis which the new approach is designed to correct.

Computer Runs

The next step in the proposed approach is to determine the returns that will result from random combinations of the factors involved. This requires realistic restrictions, such as not allowing the total market to vary more than some reasonable amount from year to year. Of course, any method of rating the return which is suitable to the company may be used at this point; in the actual case management preferred discounted cash flow for the reasons cited earlier, so that method is followed here.

A computer can be used to carry out the trials for the simulation method in very little time and at very little expense. Thus, for one trial actually made in this case, 3,600 discounted cash flow calculations, each based on a selection of the nine input factors, were run in two minutes at a cost of $15 for computer time. The resulting rate-of-return probabilities were read out immediately and graphed. The process is shown schematically in EXHIBIT II.

Data Comparisons

The nine input factors described earlier fall into three categories:

1. *Market analyses.* Included are market size, market growth rate, the firm's share of the market, and selling prices. For a given combination of these factors sales revenue may be determined.

2. *Investment cost analyses.* Being tied to the kinds of service-life and operating-cost characteristics expected, these are subject to various kinds of error and uncertainty; for instance, automation progress makes service life uncertain.

3. *Operating and fixed costs.* These also are subject to uncertainty, but are perhaps the easiest to estimate.

These categories are not independent, and for realistic results our approach allows the various factors to be tied together. Thus, if price determines the total market, we first select from a probability distribution the price for the specific computer run and then use for the total market a probability distribution that is logically related to the price selected.

We are now ready to compare the values obtained under the new approach with the values

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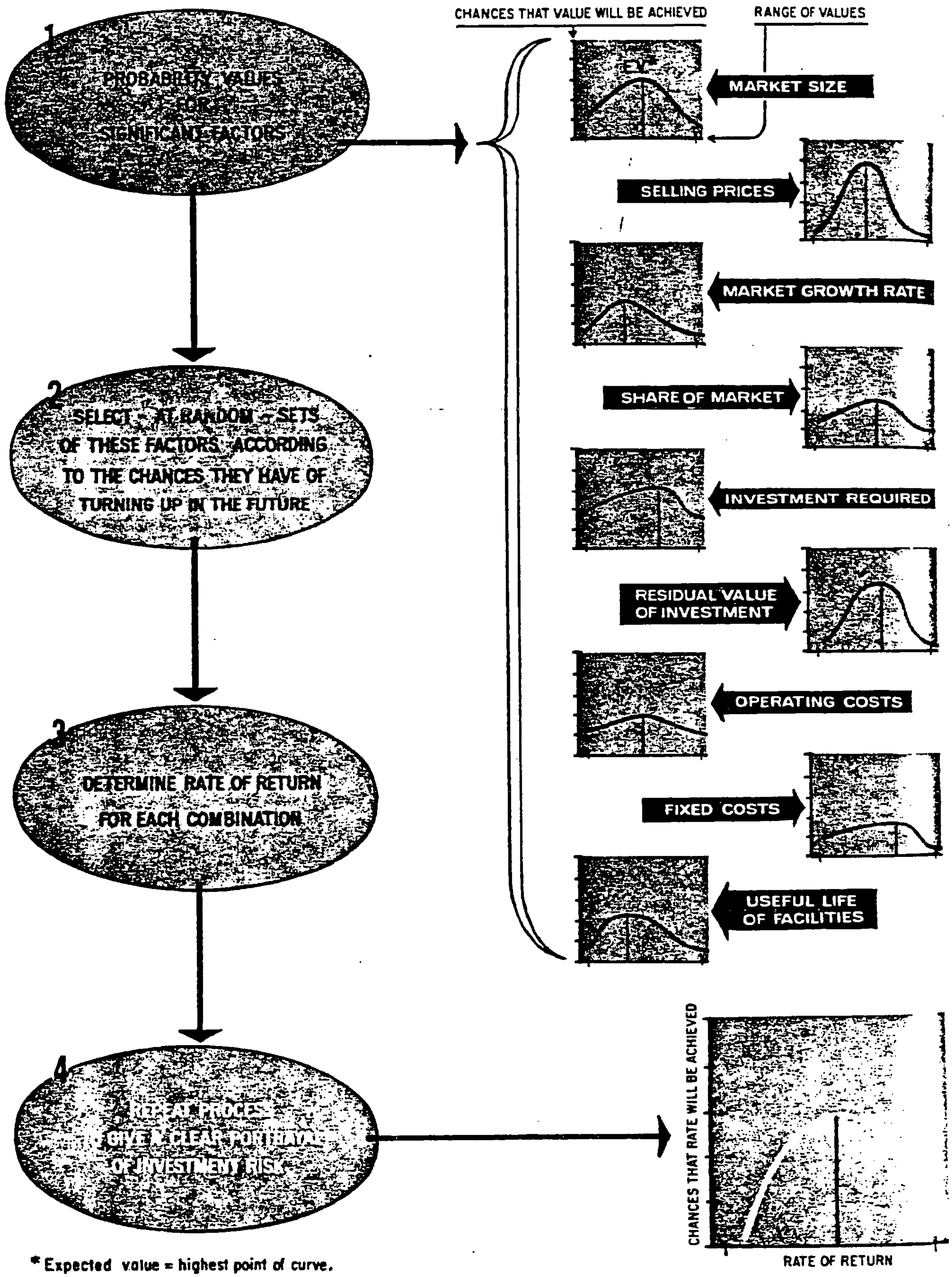
EXHIBIT II. SIMULATION FOR INVESTMENT PLANNING



* Expected value = highest point of curve.

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obtained under the old. This comparison is shown in EXHIBIT III.

Valuable Results

How do the results under the new and old approaches compare?

In this case, management had been informed, on the basis of the "one best estimate" approach, that the expected return was 25.2% before taxes. When we ran the new set of data through the computer program, however, we got an expected return of only 14.6% before taxes. This surprising difference not only is due to the fact that under the new approach we use a range of values; it also reflects the fact that we have weighted each value in the range by the chances of its occurrence.

EXHIBIT III. COMPARISON OF EXPECTED VALUES UNDER OLD AND NEW APPROACHES

	Conventional "best estimate" approach	New approach
MARKET ANALYSES		
1. *Market size*		
Expected value (in tons)	250,000	250,000
Range	–	100,000–340,000
2. *Selling prices*		
Expected value (in dollars/ton)	$510	$510
Range	–	$385–$575
3. *Market growth rate*		
Expected value	3%	3%
Range	–	0–6%
4. *Eventual share of market*		
Expected value	12%	12%
Range	–	3%–17%
INVESTMENT COST ANALYSES		
5. *Total investment required*		
Expected value (in millions)	$9.5	$9.5
Range	–	$7.0–$10.5
6. *Useful life of facilities*		
Expected value (in years)	10	10
Range	–	5–15
7. *Residual value (at 10 years)*		
Expected value (in millions)	$4.5	$4.5
Range	–	$3.5–$5.0
OTHER COSTS		
8. *Operating costs*		
Expected value (in dollars/ton)	$435	$435
Range	–	$370–$545
9. *Fixed costs*		
Expected value (in thousands)	$300	$300
Range	–	$250–$375

NOTE: Range figures in right-hand column represent approximately 1% to 99% probabilities. That is, there is only a 1 in a 100 chance that the value actually achieved will be respectively greater or less than the range.

Our new analysis thus may help management to avoid an unwise investment. In fact, the general result of carefully weighing the information and lack of information in the manner I have suggested is to indicate the true nature of otherwise seemingly satisfactory investment proposals. If this practice were followed by managements, much regretted overcapacity might be avoided.

The computer program developed to carry out the simulation allows for easy insertion of new variables. In fact, some programs have previously been suggested that take variability into account.[7] But most programs do not allow for dependence relationships between the various input factors. Further, the program used here permits the choice of a value for price from one distribution, which value determines a particular probability distribution (from among several) that will be used to determine the value for sales volume. To show how this important technique works:

Suppose we have a wheel, as in roulette, with the numbers from 0 to 15 representing one price for the product or material, the numbers 16 to 30 representing a second price, the numbers 31 to 45 a third price, and so on. For each of these segments we would have a different range of expected market volumes; e.g., $150,000–$200,000 for the first, $100,000–$150,000 for the second, $75,000–$100,000 for the third, and so forth. Now suppose that we spin the wheel and the ball falls in 37. This would mean that we pick a sales volume in the $75,000–$100,000 range. If the ball goes in 11, we have a different price and we turn to the $150,000–$200,000 range for a price.

Most significant, perhaps, is the fact that the program allows management to ascertain the sensitivity of the results to each or all of the input factors. Simply by running the program with changes in the distribution of an input factor, it is possible to determine the effect of added or changed information (or of the lack of information). It may turn out that fairly large changes in some factors do not significantly af-

[7] See Frederick S. Hillier, "The Derivation of Probabilistic Information for the Evaluation of Risky Investments," *Management Science*, April 1963, p. 443.

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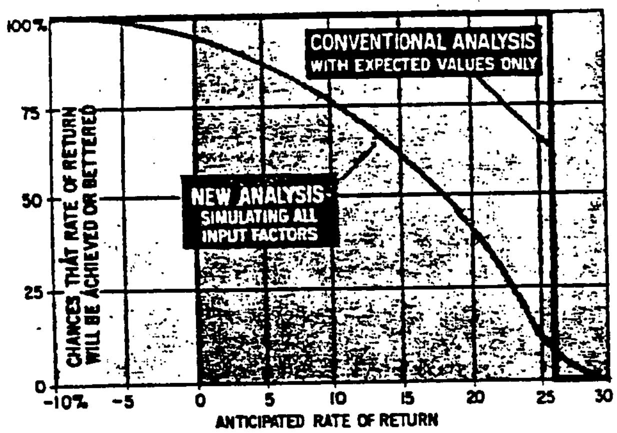
EXHIBIT IV. ANTICIPATED RATES OF RETURN UNDER OLD AND NEW APPROACHES



fect the outcomes. In this case, as a matter of fact, management was particularly concerned about the difficulty in estimating market growth. Running the program with variations in this factor quickly demonstrated to us that for average annual growths from 3% and 5% there was no significant difference in the expected outcome.

In addition, let us see what the implications are of the detailed knowledge the simulation method gives us. Under the method using single expected values, management arrives only at a hoped-for expectation of 25.2% after taxes (which, as we have seen, is wrong unless there is no variability in the various input factors — a highly unlikely event). On the other hand, with the method we propose, the uncertainties are clearly portrayed:

Per cent return	*Probability of achieving at least the return shown*
0%	96.5%
5	80.6
10	75.2
15	53.8
20	43.0
25	12.6
30	0

This profile is shown in EXHIBIT IV. Note the contrast with the profile obtained under the conventional approach. This concept has been used also for evaluation of new product introductions, acquisitions of new businesses, and plant modernization.

Comparing Opportunities

From a decision-making point of view one of the most significant advantages of the new

EXHIBIT V. COMPARISON OF TWO INVESTMENT OPPORTUNITIES

SELECTED STATISTICS	INVESTMENT A	INVESTMENT B
AMOUNT OF INVESTMENT	$10,000,000	$10,000,000
LIFE OF INVESTMENT (IN YEARS)	10	10
EXPECTED ANNUAL NET CASH INFLOW	$ 1,300,000	$ 1,400,000
VARIABILITY OF CASH INFLOW		
1 CHANCE IN 50 OF BEING *GREATER* THAN	$ 1,700,000	$ 3,400,000
1 CHANCE IN 50 OF BEING *LESS** THAN	$ 00,000	($600,000)
EXPECTED RETURN ON INVESTMENT	5.0%	6.8%
VARIABILITY OF RETURN ON INVESTMENT		
1 CHANCE IN 50 OF BEING *GREATER* THAN	7.0%	15.5%
1 CHANCE IN 50 OF BEING *LESS** THAN	3.0%	(4.0%)
RISK OF INVESTMENT		
CHANCES OF A LOSS	NEGLIGIBLE	1 IN 10
EXPECTED SIZE OF LOSS		$ 200,000

* In the case of negative figures (indicated by parentheses) "less than" means "worse than."

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method of determining rate of return is that it allows management to discriminate between measures of (1) expected return based on weighted probabilities of all possible returns, (2) variability of return, and (3) risks.

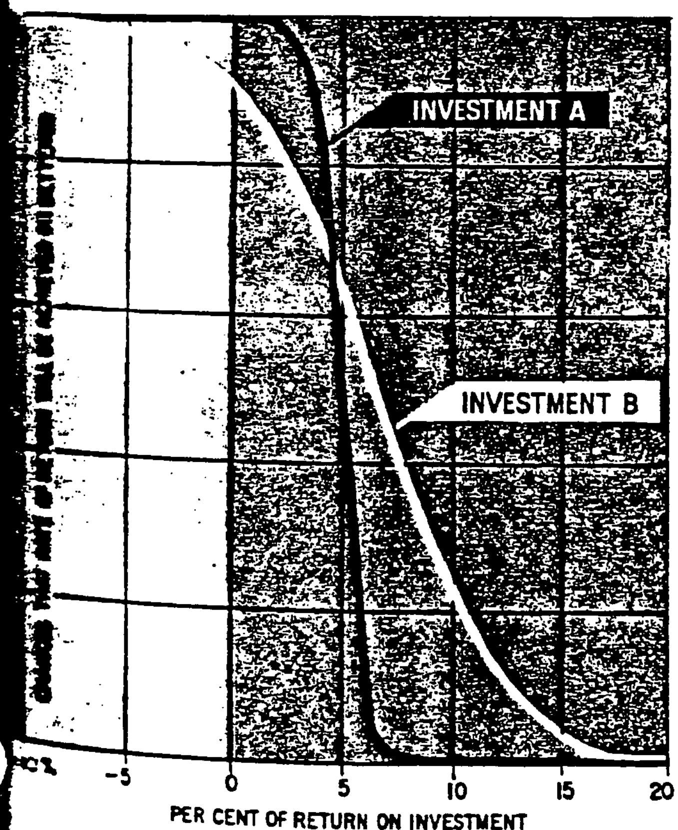
To visualize this advantage, let us take an example which is based on another actual case but simplified for purposes of explanation. The example involves two investments under consideration, A and B.

When the investments are analyzed, the data tabulated and plotted in EXHIBIT V are obtained. We see that:

- Investment B has a higher expected return than Investment A.

- Investment B also has substantially more variability than Investment A. There is a good chance that Investment B will earn a return which is quite different from the expected return of 6.8%, possibly as high as 15% or as low as a loss of 5%. Investment A is not likely to vary greatly from the expected 5% return.

- Investment B involves far more risk than does Investment A. There is virtually no chance of incurring a loss on Investment A. However, there is 1 chance in 10 of losing money on Investment B.



If such a loss occurs, its expected size is approximately $200,000.

Clearly, the new method of evaluating investments provides management with far more information on which to base a decision. Investment decisions made only on the basis of maximum expected return are not unequivocally the best decisions.

Conclusion

The question management faces in selecting capital investments is first and foremost: What information is needed to clarify the key differences among various alternatives? There is agreement as to the basic factors that should be considered — markets, prices, costs, and so on. And the way the future return on the investment should be calculated, if not agreed on, is at least limited to a few methods, any of which can be consistently used in a given company. If the input variables turn out as estimated, any of the methods customarily used to rate investments should provide satisfactory (if not necessarily maximum) returns.

In actual practice, however, the conventional methods do *not* work out satisfactorily. Why? The reason, as we have seen earlier in this article, and as every executive and economist knows, is that the estimates used in making the advance calculations are just that — estimates. More accurate estimates would be helpful, but at best the residual uncertainty can easily make a mockery of corporate hopes. Nevertheless, there is a solution. To collect realistic estimates for the key factors means to find out a great deal about them. Hence the kind of uncertainty that is involved in each estimate can be evaluated ahead of time. Using this knowledge of uncertainty, executives can maximize the value of the information for decision making.

The value of computer programs in developing clear portrayals of the uncertainty and risk surrounding alternative investments has been proved. Such programs can produce valuable information about the sensitivity of the possible outcomes to the variability of input factors and to the likelihood of achieving various possible rates of return. This information can be extremely important as a backup to management judgment. To have calculations of the odds on all possible outcomes lends some assurance to the decision-makers that the available information has been used with maximum efficiency.

This simulation approach has the inherent advantage of simplicity. It requires only an extension of the input estimates (to the best of our ability) in terms of probabilities. No projection should be pinpointed unless we are *certain* of it.

The discipline of thinking through the uncertainties of the problem will in itself help to ensure improvement in making investment choices. For to understand uncertainty and risk is to understand the key business problem — and the key business opportunity. Since the new approach can be applied on a continuing basis to each capital alternative as it comes up for consideration and progresses toward fruition, gradual progress may be expected in improving the estimation of the probabilities of variation.

Lastly, the courage to act boldly in the face of apparent uncertainty can be greatly bolstered by the clarity of portrayal of the risks and possible rewards. To achieve these lasting results requires only a slight effort beyond what most companies already exert in studying capital investments.

3.5 Gamma Distribution

A probability distribution that arises naturally in the study of the length of life of industrial equipment, and which occurs frequently in various other statistical problems as well, is a distribution called the gamma distribution. The name came from the relationship of the distribution to the gamma function of advanced calculus. It involves two parameters, $\alpha > 0$ and $\beta > 0$, and is defined as follows:

(34) GAMMA DISTRIBUTION: $$f(x) = \frac{x^{\alpha-1}e^{-\frac{x}{\beta}}}{\beta^{\alpha}\Gamma(\alpha)}, \quad x > 0$$
$$= 0, \quad x \leq 0.$$

The quantity $\Gamma(\alpha)$ is a symbol representing the value of the gamma function at the point α. This function is defined by the integral

(35) $$\Gamma(\alpha) = \int_0^{\infty} x^{\alpha-1}e^{-x}\,dx.$$

It is easily shown by integrating by parts that $\Gamma(\alpha + 1) = \alpha\Gamma(\alpha)$. If α is a positive integer, this recurrence relation gives the factorial result that $\Gamma(\alpha + 1) = \alpha!$. As a consequence of this property the gamma function is sometimes called the factorial function.

3.5.1 Moments. The moments of the gamma distribution are easily computed by means of (35). From (34)

$$E[X^k] = \frac{1}{\beta^{\alpha}\Gamma(\alpha)}\int_0^{\infty} x^{k+\alpha-1}e^{-\frac{x}{\beta}}\,dx.$$

Letting $t = x/\beta$ gives

$$E[X^k] = \frac{\beta^{k+\alpha}}{\beta^{\alpha}\Gamma(\alpha)}\int_0^{\infty} t^{k+\alpha-1}e^{-t}\,dt.$$

The use of (35) then gives

$$E[X^k] = \beta^k\frac{\Gamma(k+\alpha)}{\Gamma(\alpha)}.$$

Since k is a positive integer, it follows from repeated application of the recurrence relation $\Gamma(\alpha + 1) = \alpha\Gamma(\alpha)$ that

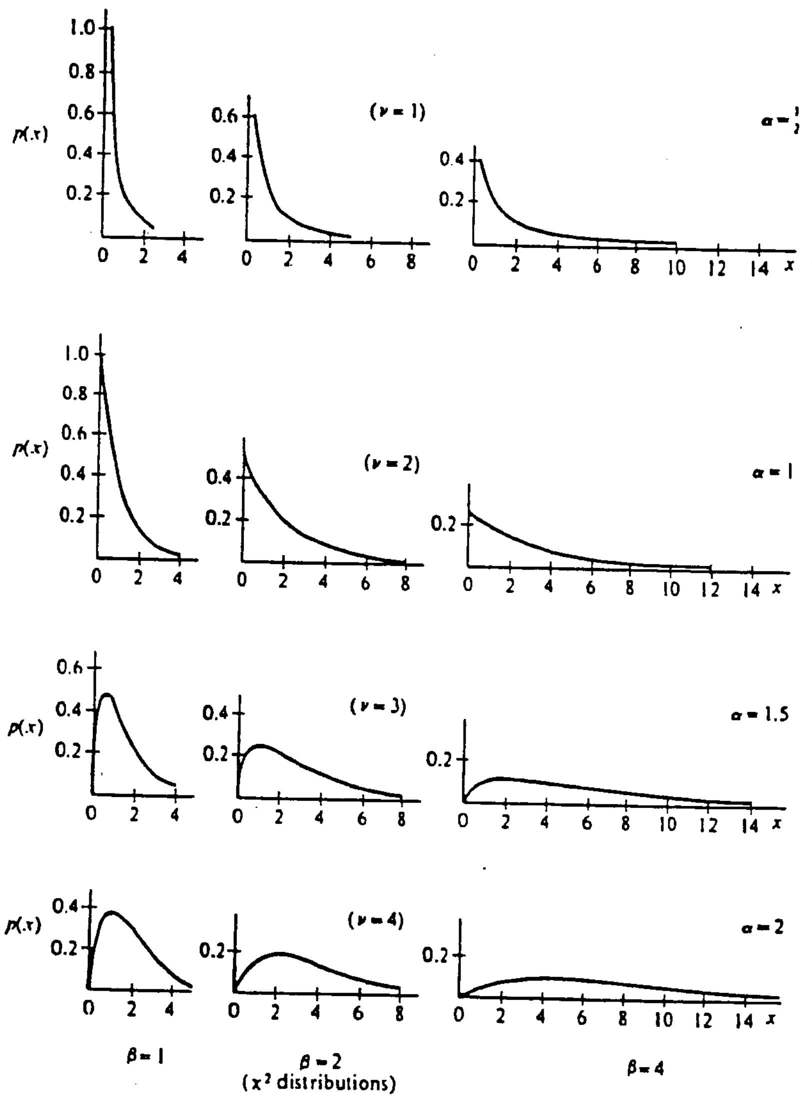
$$\Gamma(k + \alpha) = (k + \alpha - 1)\cdots(\alpha)\Gamma(\alpha),$$

and hence that

(36) $$E[X^k] = \beta^k(k + \alpha - 1)(k + \alpha - 2)\cdots(\alpha).$$

From this formula it follows that the mean and variance of a gamma distribution are given by

(37) $$\mu = \beta\alpha \quad \text{and} \quad \sigma^2 = \beta^2\alpha.$$


p(x)
1.0
0.8
0.6
0.4
0.2
(ν = 1)
α = 1/2
(ν = 2)
α = 1
(ν = 3)
α = 1.5
(ν = 4)
α = 2
0 2 4 6 8 10 12 14 x
β = 1
β = 2
(χ^2 distributions)
β = 4

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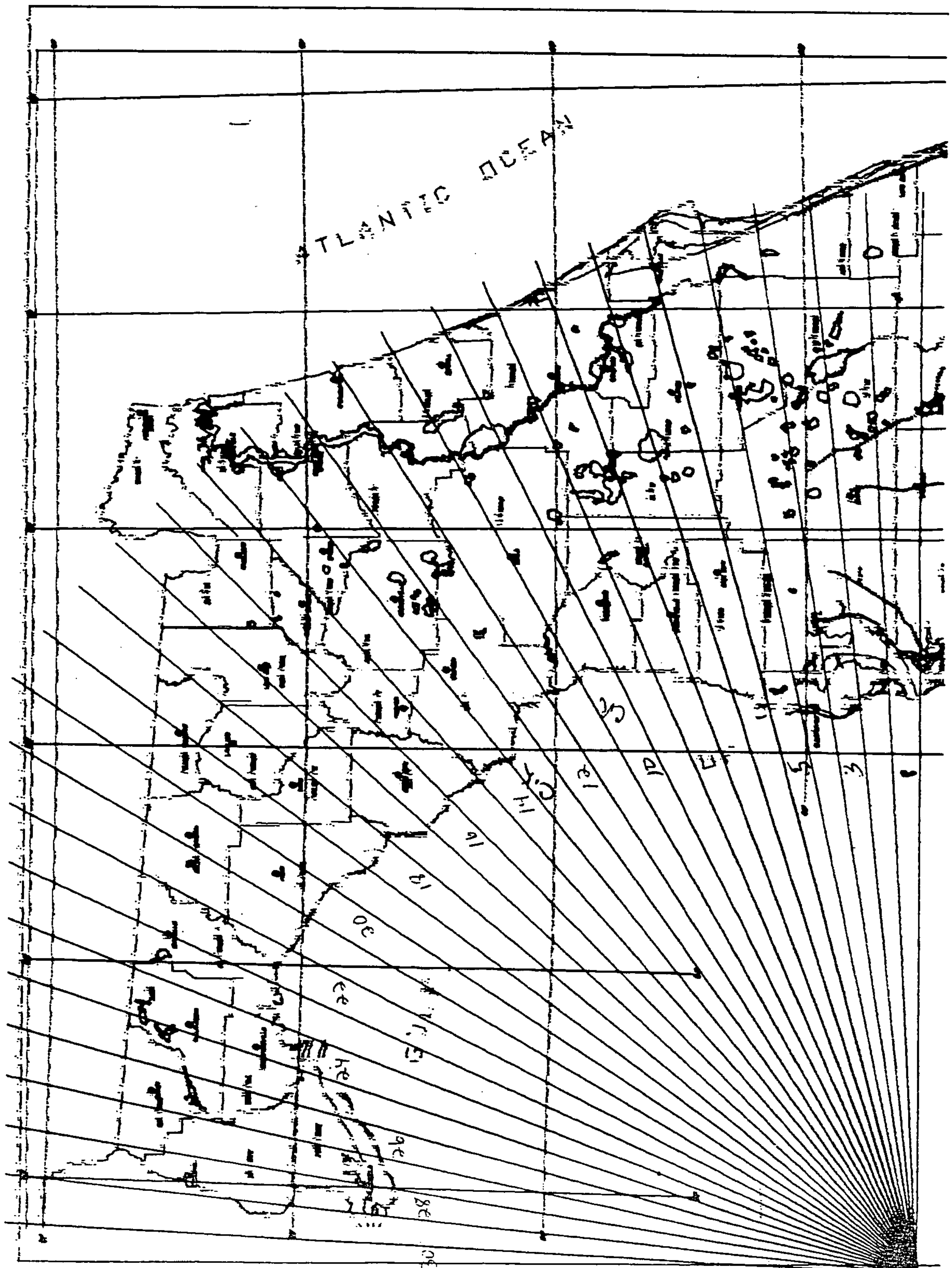
Service Territory divided into 30 sectors



Replacement Cost by Sector

Assessment of Potential Hurricane Damage

1,000 Square Miles

		1	2	3	4	5	6
		Distribution Costs 10x100 sq mi.	Avg Costs Dist $/Sq Mile 1000	Transmission Costs 10x100 sq mi.	Avg Costs Trans. $/Sq Mile 1000	Total Cost Costs 10x100 sq mi.	Avg Costs by $/Sq Mile 1000
Area 1	1	23,952,816	$23,953	26,669,650	$26,670	50,622,466	$50,622
	2	38,817,312	38,817	29,222,750	$29,223	68,040,062	68,040
	3	151,646,944	151,647	37,026,475	$37,026	188,673,419	188,673
	4	110,595,392	110,595	43,007,350	$43,007	153,602,742	153,603
	5	70,553,184	70,553	82,759,650	$82,760	153,312,834	153,313
	6	159,028,880	159,029	100,242,875	$100,243	259,271,755	259,272
	7	97,232,640	97,233	95,778,200	$95,778	193,010,840	193,011
	8	78,450,672	78,451	77,226,750	$77,227	155,677,422	155,677
	9	39,538,096	39,538	123,730,700	$123,731	163,268,796	163,269
	10	55,194,064	55,194	51,364,600	$51,365	106,558,664	106,559
Area 1	11	27,148,736	27,149	59,098,050	$59,098	86,246,786	86,247
Average for area 1			**77,469**		**66,012**		**143,481**
Std Dev.			**45,243**		**30,642**		**58,462**
Max Value			**159,029**		**123,731**		**259,272**
Area 2	12	14,426,361	14,426	11,734,200	11,734	26,160,561	26,161
	13	4,215,100	4,215	20,937,800	20,938	25,152,900	25,153
	14	3,880,817	3,881	15,578,200	15,578	19,459,017	19,459
	15	8,142,007	8,142	31,526,950	31,527	39,668,957	39,669
	16	4,045,479	4,045	16,472,650	16,473	20,518,129	20,518
	17	2,682,947	2,683	17,939,175	17,939	20,622,122	20,622
	18	3,936,861	3,937	25,138,500	25,139	29,075,361	29,075
	19	4,050,544	4,051	18,916,150	18,916	22,966,694	22,967
Area 2	20	17,428,704	17,429	10,577,550	10,578	28,006,254	28,006
Average for area 2			**28,592**		**34,485**		**59,930**
Std Dev.			**43,069**		**30,567**		**66,937**
Max Value			**159,029**		**123,731**		**259,272**
Area 3	21	15,547	16	9,141,450	9,141	9,156,997	9,157
	22	10,148,531	10,149	8,608,975	8,609	18,757,506	18,758
	23	7,628,715	7,629	6,513,725	6,514	14,142,440	14,142
	24	10,346,343	10,346	10,826,000	10,826	21,172,343	21,172
	25	4,446,543	4,447	22,556,575	22,557	27,003,118	27,003
	26	3,798,346	3,798	16,647,450	16,647	20,445,796	20,446
	27	3,278,035	3,278	7,456,925	7,457	10,734,960	10,735
	28	476,281	476	6,439,150	6,439	6,915,431	6,915
	29	5,352,639	5,353	5,111,750	5,112	10,464,389	10,464
Area 3	30	3,831,105	3,831	10,131,850	10,132	13,962,955	13,963
Average for area 3			**4,932**		**10,343**		**15,276**
Std Dev.			**3,369**		**5,092**	1,962,671,716	**6,044**
Max Value			**10,346**		**22,557**	65,422,391	**27,003**

Total 30 Seg.	**964,289,641**		**998,382,075**		**1,962,671,716**
Avg. 30 Seg.	**32,142,988**		**33,279,403**		**65,422,391**

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Date: 2/23/94

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Wind Profiles

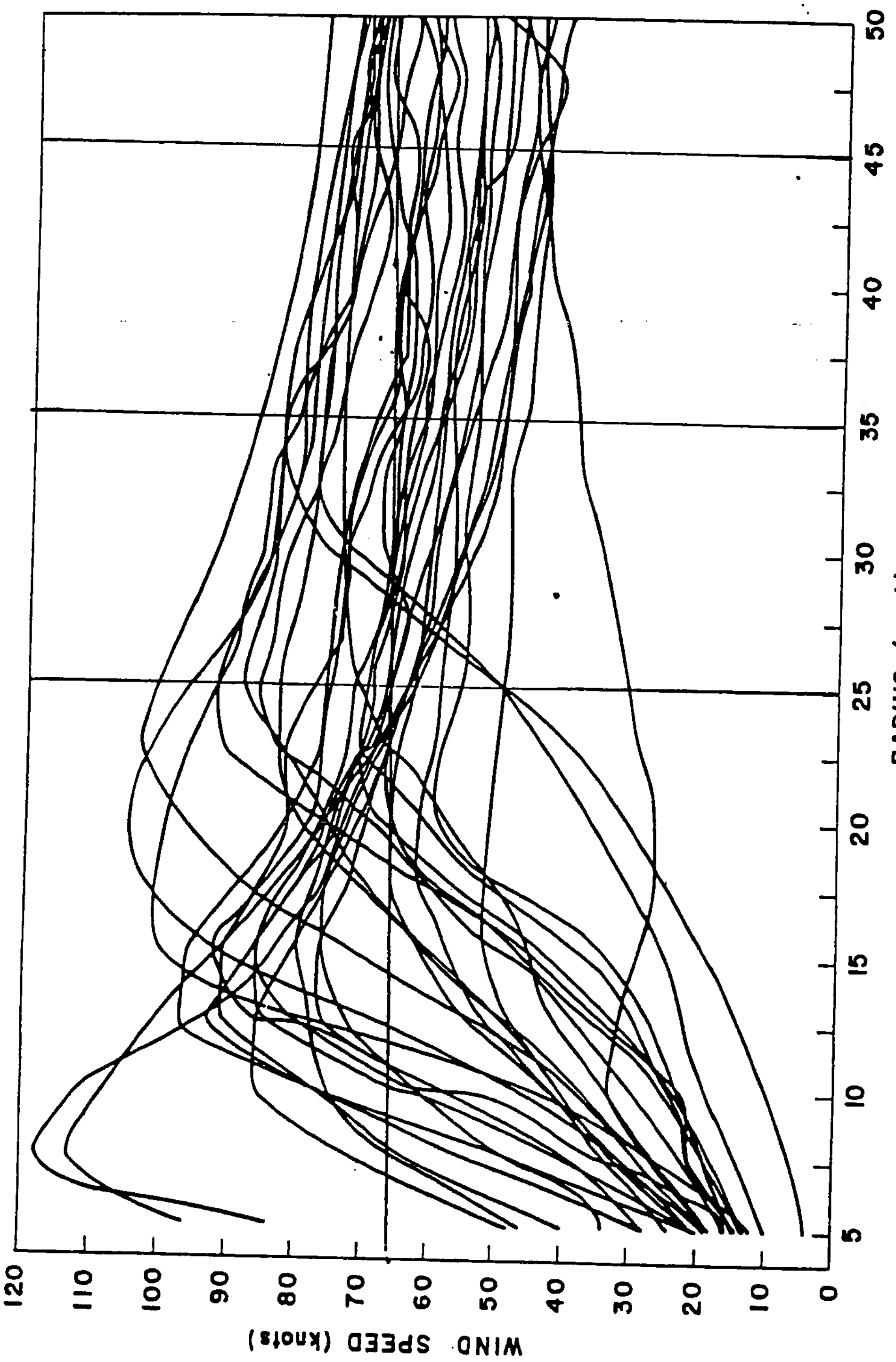

Fig. 12. Sample of observed tangential wind profiles.

Source: Journal of Atmospheric Sciences, Dennis Shea and William Gray.

HISTORICAL DATA OF ACTUAL STORM DAMAGE

		Total	Hurricane Elena	Hurricane Kate	Tropical Storm Keith
Date		–	9/85	11/85	11/88
Category		–	III	II	NA
Total Damage Costs		$6,176,883	$3,673,091	$1,531,886	$971,906
Summary of Costs:					
Operation & Maintenance (O&M)					
Distribution	90%	$4,465,464	$2,612,457	$1,132,539	$720,468
Transmission	5%	265,158	232,573	6,796	25,789
Other	5%	233,891	165,227	65,035	3,629
Total O & M	100%	4,964,513	3,010,257	1,204,370	749,886
Capital		1,212,370	662,834	327,516	222,020
Total Damage Costs		$6,176,883	$3,673,091	$1,531,886	$971,906
Percentages of Total Costs:					
Operation & Maintenance					
Distribution		72%	71%	74%	74%
Transmission		4%	6%	0%	3%
Other		4%	5%	4%	0%
Total O & M		80%	82%	78%	77%
Capital		20%	18%	22%	23%
Total Damage Costs		100%	100%	100%	100%

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24–Feb–94

HURRICANE DAMAGE STUDY

WEIGHTED DAMAGE FACTOR OF CATEGORY 5 HURRICANE.

1 CATEGORY	2 TOTAL RADIUS MILES	3 INC. MILES	4 WEIGHT FACTOR	5 Dr Gray's Damage Factor x 4	6 Adjustment Factor for 100 mile penetration	7 WEIGHT DAMAGE FACTOR
5	45	45	0.32	1.00	0.8	0.257
4	60	15	0.11	0.64	0.8	0.055
3	75	15	0.11	0.36	0.8	0.031
2	110	35	0.25	0.16	0.8	0.032
1	140	30	0.21	0.04	0.8	0.007

TOTAL RADIUS OF STORM 140 SUM **0.382**

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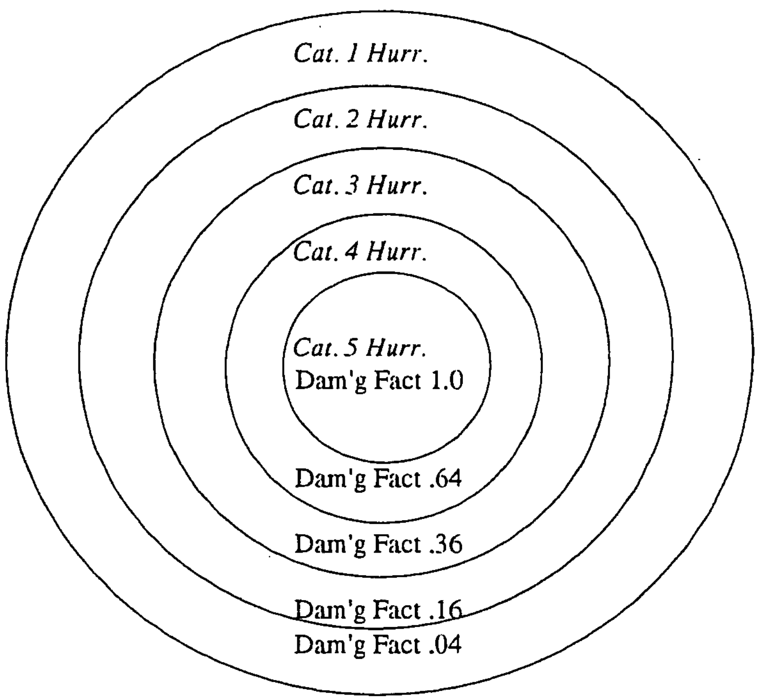

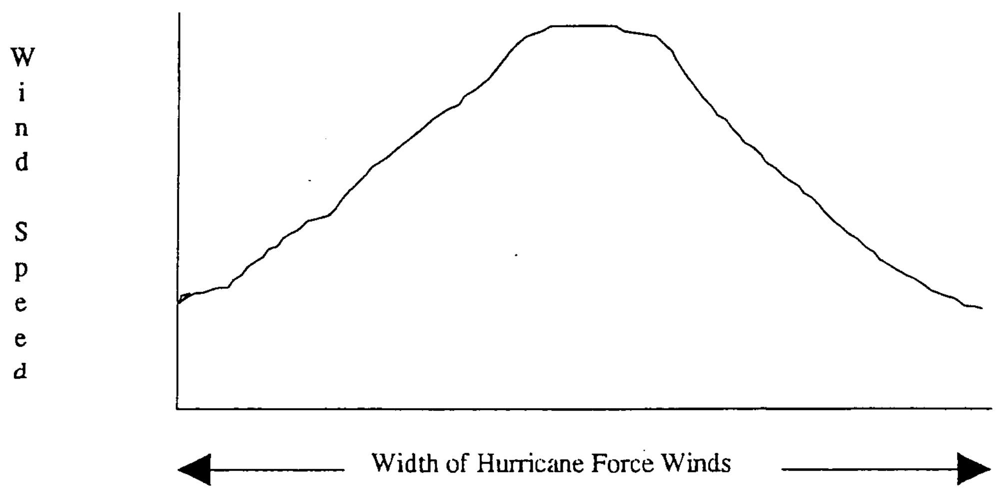

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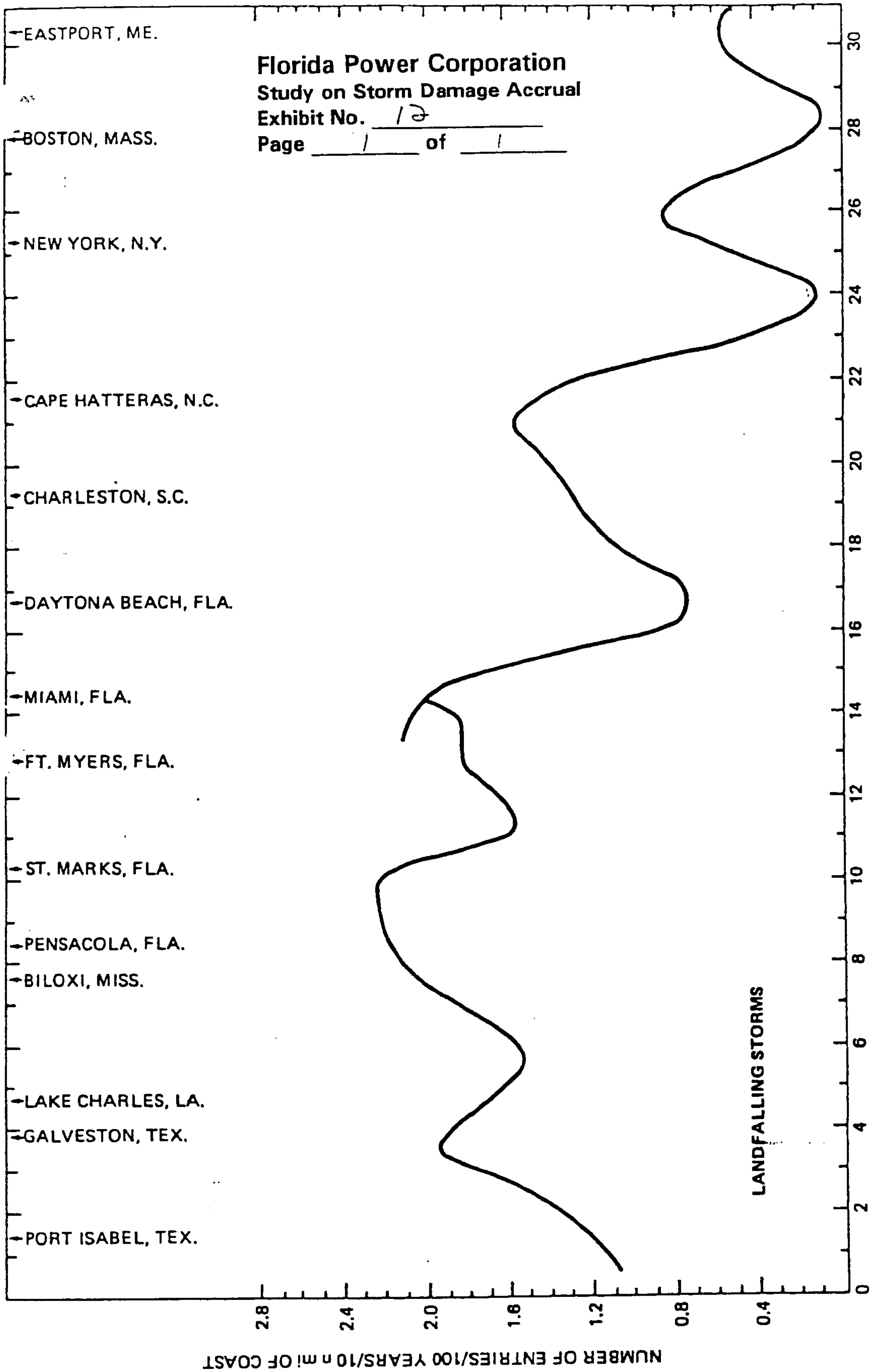

Figure 10.—Smoothed frequency of landfalling tropical storms and hurricanes (1871 through 1973) for the Gulf and East Coasts of the United States. Discontinuity between Miami and Ft. Myers represents Florida Keys. (From Ho, et al. (47), page 21)

Source: Study of Tropical Cyclones of the North Atlantic Ocean by the National Climatic Data Center (Ashville, North Carolina) in cooperation with the National Hurricane Center (Coral Gables, Florida).

Smoothed Frequency of Land Falling Storms

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Reference info on Recurvature

NOAA Technical Report NWS 38

Hurricane Climatology for the Atlantic and Gulf Coasts of the United States

Silver Spring, MD

April 1987

Study completed under agreement EMW-84-E-1589 for
FEDERAL EMERGENCY MANAGEMENT AGENCY

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service

3.3.3.1 **Gulf Coast.** Both our meteorological judgment and statistical analyse suggested that the region along the coast of Texas could be considered meteoro logically homogeneous. Our initial boundary was at milepost 400 and the analyses in Sections 3.3.2.2 through 3.3.2.4 suggested a break near milepost 500. Since the Gulf coast turned most sharply around milepost 450, we decided to select this point to delineate our first homogeneous region. We had initially divided the south-facing portion of the Gulf coast (mileposts 400-1100) into two portions, with the break near the Mississippi delta (milepost 700). We did this to consider the possibility that storms affecting the eastern and western portions might be different. The results of the statistical analysis did not support this division. The statistical analysis suggested extending this region to the middle portion of the west coast of Florida. However, the storms affecting the west coast of Florida tend to be weaker (see fig. 8). Since the frequency of landfalling storms on the west coast of Florida is low, we felt that the statistical techniques were not able to discriminate this difference. We selected milepost 1050 as the dividing point between the two regions. Again, the coastal orientation changes most rapidly near this point.

3.3.3.2 **Florida Coast.** The Gulf and Atlantic coasts of the United States were considered separately because of their differences in geographical and meteorological conditions. Division of the Florida peninsula involves consideration of a number of factors, some of which suggest contradictory groupings. The statistical analyses as well as meteorological considerations (e.g., Kuo 1959) demonstrate that hurricane characteristics vary noticeably with latitude. This is due to both latitudinal variations in atmospheric circulation patterns and generally decreasing sea-surface temperature with increasing latitude. Warm water has been identified as an important factor in supporting the energy transformations necessary to maintain a hurricane circulation. These facts suggest that the data for all of Florida be considered homogeneous. In fact, the results of the cluster analysis support such a grouping for the southern portion of the peninsula. However, coastal orientation suggests dividing the data sample near the southern tip of Florida. Tropical circulation typically is associated with easterly flow. Therefore, storms moving from the east would strike the east coast of Florida. The synoptic scale meteorological patterns under such flows are most conducive to development and maintenance of hurricanes. On this basis, we suggest that there is the potential for strong hurricanes to affect the east coast of Florida.

For a hurricane to strike the west coast of Florida, it must have a westerly component in the direction from which it approaches the coast. Usually such motion is associated with storms that have undergone recurvature. Recurvature, as opposed to more random variations in storm direction, is almost always associated with the tropical cyclone becoming embedded in the westerlies. This is usually a critical transition in the hurricane's lifecycle. When this happens, the upper-level outflow necessary to maintain the warm-core circulation is impeded. Such storms tend to weaken and some take on extratropical characteristics. Occasionally, hurricanes that formed in the Gulf of Mexico moved across the Florida peninsula in a west to east direction before recurving northeastward. Though intense hurricanes were reported to have struck near Cedar Key and Tampa Bay in the mid-1800's (Ludlum 1963), it is reasonable to expect that, on the average, hurricanes striking the west coast of Florida will probably be weaker. The data (since 1900) in Figure 8 lends support to this observation.

3.3.3.3 **Atlantic coast.** When five clusters were used, the cluster analysis suggested that the Atlantic coast include 3 regions: (1) the southern half of Florida peninsula, including the west coast, (2) a segment from about Vero Beach (milepost 1600) to the vicinity of Cape Hatteras (milepost 2250), and (3) a region including all the coast north of Cape Hatteras. Our a priori judgment suggested four segments, with only the boundary in the vicinity of Cape Hatteras being common with the cluster analysis. The reasons for selecting milepost 1415 at the tip of Florida have been discussed in the previous section. As mentioned in Section 3.3.2.2, the boundaries of a cluster represents a region, rather than a clearly defined point. Examination of Figure 27 shows that from mileposts 1600–1800 there is a broad minimum in frequency of landfalling storms. In fact, it is probably reasonable to place the boundary between clusters any place within this region. For this reason, we chose to maintain milepost 1800 as the divider between the homogeneous cluster of storms striking the east coast of Florida and those affecting the coast to the north. This point is near the Florida-Georgia state line where the coastal orientation changes from NNW-SSE to NE-SW.

Both our judgment and the statistical analysis support considering the region from Florida-Georgia state line to the vicinity of Cape Hatteras as homogeneous. Conditions to the north of Cape Hatteras may not be homogeneous, either meteorologically or statistically. However, the region north of milepost 2300 is specified as "homogeneous" because of the very limited number of observations of landfalling storms in this area. In general, we did not base our analysis for this portion of the coast on the results of formal statistical techniques. We believed that the only way to treat this area was by exercising meteorological judgment. Our analysis ensured consistency and a smooth transition from the more data-rich areas to the south of this area.

3.4 Interrelations Between Hurricane Parameters

3.4.1 Brief Review of Previous Studies

Previous studies have suggested that some interrelations between hurricane parameters may exist. TR 15 suggested specifically that:

1. hurricanes with P_o below 920 mb have small R;
2. for P_o from 920 to 970 mb, there is "no detectable interrelation" between P_o and R when the entire Atlantic coast was considered;
3. "if the latitudinal trend [along the Atlantic coast] is removed from P_o and R, little local interrelation between P_o and R remains"; and
4. hurricanes that have recurved and move toward the north-northeast tend to be faster (larger T) than those that are at the same latitude and have a more westward component in the forward velocity.

National Academy of Sciences (1983) evaluated the FEMA storm-surge model and indicated that:

1. The Tetra Tech report claimed no strong linear relations among any hurricane parameters were found for the Gulf region as a whole;

Hatteras area. It is in these latitudes that hurricanes most often pass from a tropical to a temperate environment, and it is in this region where one would expect R to show its greatest increase for the reasons discussed in Section 8.3. The slope of the lower probabilities curves change less between Georgia and Cape Hatteras because there are a few storms with small R in the data sample.

8.3 Radius of Maximum Winds for Intense Hurricanes

Observations indicate that hurricanes with very large R's are of moderate or weak intensity. In hurricanes moving northward in the Atlantic and becoming extratropical, R tends to become larger and more diffuse and P_o generally rises. Data from intense hurricanes of record (see table 16 and fig. 14) indicate that the most extreme hurricanes (P_o less than 920 mb) tend to have small R's. The question of interdependence of P_o and R was discussed in Chapter 4. We recommend that an R value of 13 nmi be used for hurricanes with P_o in the range of 908-920 mb, and R = 9 nmi be used with P_o less than 908 mb.

9. SPEED AND DIRECTION OF STORM MOTION

9.1 Speed of Storm Motion

Data for the speed of storm motion is discussed in Section 2.5. Included in these data are a few subtropical storms. We chose to include them since they also have the ability to produce storm surges.

9.1.1 Forward Speed of Landfalling Tropical Cyclones

9.1.1.1 Analysis. Cumulative frequencies of forward speed for landfalling tropical cyclones were determined for the same overlapping zones used for both P_o (sec. 7.2) and R (sec. 8.1). As indicated in Section 2.5, both T and θ could be reliably determined for tropical storms as well as hurricanes, thus increasing the sample size. Cumulative probability curves of forward speeds were determined using Weibul's plotting position formula (see sec. 7.2). Figure 39 shows examples of the cumulative frequency analysis of raw data at two points along the coast (near Corpus Christi, Texas and Vero Beach, Florida). Percentage values at each 50-nmi location were determined from analyses such as Figure 39 for 5-, 20-, 40-, 60-, 80- and 95-percent levels. The values were then analyzed to ensure consistency along the coast. The resulting curves are shown in Figures 40 and 41.

9.1.1.2 Results and Discussion. Figures 40 and 41 show that tropical cyclone speed generally increases with northward progression of each storm, especially after recurvature to a northerly or northeasterly direction. The upper 50 percent of forward speeds increases from 11-17 kn near Daytona Beach, Florida, to 35-53 kn at the northern extent of the United States' Atlantic coastline.

Overall, there was a marked increase in values of T along the west coast of Florida as compared with the variation shown in values of TR 15. In this study, we omitted hurricanes prior to 1900 that had been used in TR 15. This was done to ensure a consistent sampling period for all parameters (P_o, R, T and θ). Before finalizing this decision, however, we examined the effect of omitting storms prior to the turn of the century. We found that there were no significant

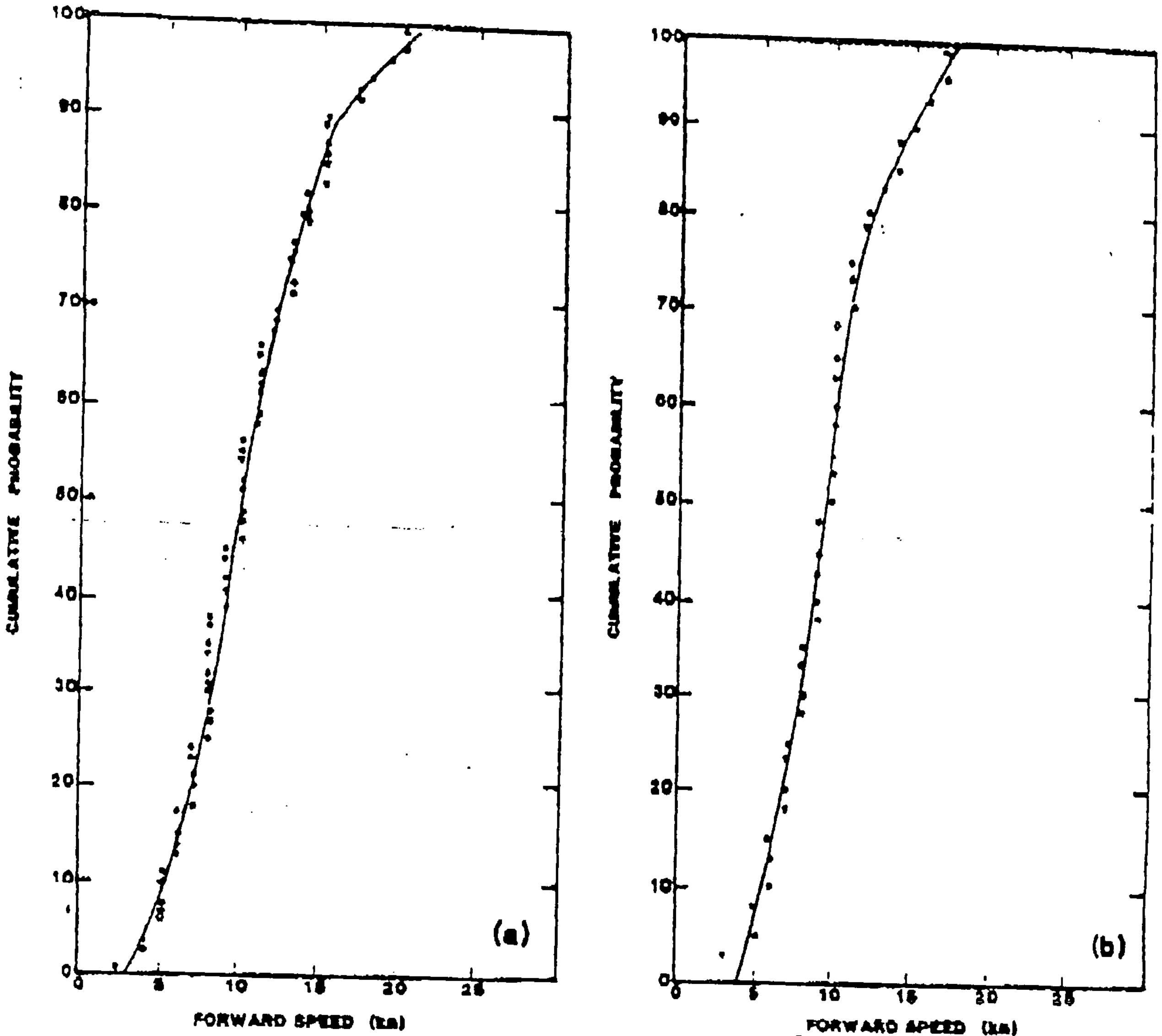

Figure 39.—Cumulative probability curve of forward speed of tropical cyclones landfalling within (a) 250 nmi of milepost 250, near Corpus Christi, Texas, and (b) 200 nmi of milepost 1600, near Vero Beach, Florida.

differences in the probability distribution of speed for hurricanes by this truncation of the period of record. TR 15 had based its speed distribution on hurricanes only. To provide a sample that was consistent with the storms used for the direction distributions, and to increase the sample size, the speeds of tropical storms were used in determining the speed distribution.

The substantial increase in the speeds in the higher percentile levels along the west coast of Florida (see fig. 40) was due, not to the change in period of record, but to the addition of tropical storms. Between coastal reference points 900 to 1300, 12 storms with speeds greater than 20 kn were added to the data sample. All were less than hurricane intensity. Storms that exceed 20 kn at these latitudes generally have become embedded in a broader-scale circulation that usually leads to these higher translation speeds. These same meteorological conditions involve recurvature, usually into an environment associated with horizontal temperature gradients that create conditions that are not favorable to the thermal circulation associated with strong hurricanes (see discussion in sec. 7.3.2.1). Therefore, the faster translation speeds appear to be associated with weaker storms. However, the small number of storms and high degree of