DETECTING ERP DATA FRAUD USING THE FIRST DIGITS FORMULA OF BENFORD'S LAW

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ABSTRACT: *Frauds in managing ERP system have been widely reported in Malaysia. The management should initiate a series of anti-fraud measures, as a leverage of cost control, while offsetting an existing resource. Fraud involves a significant financial risk that may threaten profit, as well as the image of the business entity. In this situation, where the development of the IT system plays a key role in the creation of competitive companies, the amount of processed data has grown rapidly. The integrated ERP system is growing rapidly in the country, so the increase in financial data becomes faster and risky. Internal control teams need to take a look at every transaction that has been done, but unfortunately, this issue can no longer be done manually, instead of requiring the use of data analytics tools. Since companies typically operate with large amounts of data, it is necessary to implement a continuous monitoring process, to identify anomalies in data flow or behavioral patterns, which are potentially fraudulent. Such new and important information will then be used in directing the inquiry, as well as making recommendations to enhance control activities. This research paper describes a method to identify and detect any potential fraud in ERP data using the application of Excel program based on Benford's law.*

Keywords: Anomaly, Data, ERP System, First Digit, Fraud

1. INTRODUCTION

ERP System

ERP System defined as Enterprise Resource Planning. ERP is a terminology that is commonly used in the industry and it refers to a business software solution that integrates all business functions and activities across departments. It means that the ERP systems automate sale, purchase, warehouse, and manufacturing, and other business processes to have only one single database to store all the information. ERP also addressed as one of the most important technologies for the integration of best practices in business management utilizing the power of information and communication technologies [1,17]. According to previous research [15-16], ERP is one of the popular technologies that many organizations are nowadays undertaking around the world. The ERP system is an entire enterprise package that integrates all the required business functions into a single platform with a single database. This software package can be customized to a certain extent (limit) according to the specific needs of each organization. ERP was characterized as the most important development in the use of corporate technology in the 1990s [20].

Benford's Law Rule of Thumb

Benford's Law is a very counterintuitive law that never stops surprising. Benford's Law was first used by accountants in late 1980. Benford's Law also called "First-Digit Law". This is a method of predicting, with surprising accuracy, the initial digits of any non-random series of numbers. Simon Newcomb (1835-1909) who first discovered Benford's Law is thought to have been the first to discover the phenomenon that would later be called Benford's law, or at least the first who published something about it [13]. He was a highly honored American astronomer, his most famous work regarding planetary theories and astronomical constant derivation. In this research, we will do a test on dummy ERP data set only to the first digit of Benford's Law formula as further explained in Figure (1) and Table (1).

Benford's law formula was derived by the probability of any number "d" from 1 through 9 being the first digit is;

$$P(d_1) = \log_{10}(1 + 1/d_1)$$

Source: [10]

Where: $\boldsymbol{d}$ is a number 1, 2 …9, and

$\boldsymbol{P}$ is the probability

$\boldsymbol{d_1}$ represents the first digit of a number

The logarithmic distribution of the first digit d_1 of various naturally occurring quantities is described by "Benford's law" or the "first digit phenomenon" [9]. Benford's law gives the probability of obtaining a digit 1 through 9 in each position of a number. For example, Number 3879;

3 - First Digit

8 - Second Digit

7 - Third Digit

9 - Fourth Digit

Most people assume the probability is 1/9 that the first digit will be 1 – 9. This would mean digits are equally likely to occur, but this is not the case. According to Benford's Law, the probability of obtaining a 1 in the first digit position is 30.10%. As per logic behind Benford's Law, if a data entry begins with the digit 1 it has to double in size (100%) before it begins with the digit 2 [18]. If a data entry begins with the digit 9 it only has to be increased by 11% for the first digit to be a 1 as shown in Table (1).

What is Anomaly in Benford's Law?

Anomaly (anomalies) defined as a deviation from a rule or from what is regarded as normal; an outlier. Synonymously, the word anomaly can be explained as an abnormality, deviance, deviation, exception, inconsistency, irregularity, phenomenon, or something or someone strange or unusual [7]. In data mining, anomaly detection (also outlier detection) is the identification of rare items, events, or observations that raise suspicions by differing significantly from the majority of the data [12]. Typically the anomalous items will be translated into some kind of problems such as bank fraud, a structural defect, medical problems, or errors in a text. Anomalies are also referred to as outliers, novelties, noise, deviations, and exceptions [7,21].

2. LITERATURE REVIEW

The Current Situation on ERP Data Fraud

In the real world or day-to-day examples of where Benford's Law should apply to the following data; Electricity bills, Street addresses, stock prices, population numbers, death rates, lengths of rivers, accounts payable invoice and payment values, general ledger balances, customer loan, and deposit account balances and land valuations. Malaysia becomes one of the countries which is not exempted from the fraud occurrence. The fraud reports published by PricewaterhouseCoopers (PwC) (2009, 2011) revealed a considerable decrease in financial performance among Malaysian companies of more than 60 percent (66%) due to fraud activities. While KPMG (2013) reported that 89% of the respondents believed that fraud cases have been increasing over the past three years. It is also indicated that 42% of the reported fraud incidents were within the range of RM10,001 to RM100,000. The reviewed evidence showed that fraud remains a problematic issue in Malaysia [4]. Therefore, a useful and appropriate tool like Excel technique to apply Benford's Law is needed to investigate the ERP Data Fraud problem in Malaysia. Nowadays, the Microsoft Excel program has been fully utilized as a forensic accounting tool with a lower cost and user-friendly [5].

In ERP implementation, customization of the standard ERP solution would also give impacts to the business process where the data inconsistency issues can happen and lead to the occurrence of anomalies. Businesses always looking for process improvement in ERP, therefore the change request has to be considered as part of the challenges during ERP implementation [15-16]. The ERP system integrates the majority of the business processes and allows access to the data in real-time [14]. This allows the user to get access to sensitive data very fast and easy. The following scenarios are the types of data that confirm or likely used and do not confirm or not likely used using Benford's Law adapted from [10]; Most of the data types stated below are the valid scenarios in the ERP system (some types of ERP system) implementation in Malaysia.

Types of data that confirm or likely used using Benford's Law;

i. Sets of numbers that result from a mathematical combination of numbers where the results come from two distribution. For example, accounts receivable (number sold * price) and accounts payable (number bought * price).

ii. Transaction-level data like disbursements, payments, sales, purchase, and expenses.

iii. On large data sets were, the more observations, the better the result. In this analysis, a full year's transaction like ERP data can be measured or analyzed (Profit and Loss Account for the year and Balance Sheet Account for the year).

iv. Accounts that appear to confirm. When the mean of a set of numbers is greater than the median and the skewness is positive. For example, most sets of accounting numbers.

v. Numbers that describe the 'count' or 'value' of the elements of a dataset

Types of data that do not confirm or not likely used using Benford's Law;

i. The data set is comprised of assigned numbers. Example, check numbers, invoice numbers, zip codes. Invoice numbers were normally generated in an ERP system based on the number ranges assigned to that particular transaction. This is part of the master data management that was maintained by the human (ERP System users).

ii. Numbers that are influenced by human thought. As an example, prices set at psychological thresholds ($1.99, ATM withdrawals)

iii. Accounts with a large number of form-specific numbers. For example, account specifically set up to record $100 refunds.

iv. Items/numbers/accounts with a built-in minimum or maximum. For example, a set of assets that must meet a threshold to be recorded. Another example like the first digit of heights (in meters) of a group of humans is most likely to be a 1 or a 2.

v. Where no transaction is recorded like thefts, kickbacks, and contract rigging.

vi. non-naturally occurring numbers (e.g. Telephone numbers).

Linking of Benford's Law and ERP Data Quality helps to identify duplicate payments (accounts payable), fraudulent payments, fraudulent expense claims, tax return fraud, biased estimation in General Ledger balances, arbitrarily invented numbers in forecasting (forecasts should conform to the expected distributions of their related 'actuals'), biased estimates in bad debt provisions, systemic error (e.g. Through incorrect ETL logic, resulting in accidentally duplicated or repeated values) and processing inefficiencies (e.g. high quantity/low $ transactions).

Fraud Identification of ERP Data

Benford's Law has been used to detect fraud in accounting for some time, thanks in large part to the work of Professor Mark Nigrini. The distribution is most often used on an individual account basis, such as accounts payable, to detect the over or under use of certain digits [8].

Despite the reports of the American Institute of Certified Public Accountants and ACFE (2008), most frauds are not detected in time because they are normally hidden from the eyes of the public or even the auditors. The high losses due to fraud reported by different organizations also confirmed failure in detection. Therefore, an effective tool is required to identify the signals of fraud [4].

Fraud Identification Using Benford's Law

It is the failure of assigned numbers to follow Benford's Law that makes the Law so powerful in detecting fraudulent "made up" numbers among calculated numbers. The general expectation is that Benford's Law will apply to any series of calculating numbers, and explanation is required when any series does not conform. The explanation may be in the exceptions (data set) in the previous paragraph, or the explanation may be in anomalous behavior [7]. Results are indicative, as we need to evaluate the results to conclude which applies a valid exception to Benford's Law, or an anomaly.

If the anomalous, further investigation should be conducted relating to the anomalies to confirm why they occur (e.g. fraud, estimation biases, unintended, or manual or programmed generation of duplicates). Benford's law can be used as an analytical tool to detect anomalies in ERP data which when investigated further anomalies will detect fraud [6-7].

3. RESEARCH METHODOLOGY

A suggested procedure and Excel technique were applied in the analysis of outgoing invoice payment data. The data set in Figure (2) was copied into a Column A in Excel program. The data can be generated from any ERP system from any ERP clients that have already implemented ERP systems for more than 5 years. In this research, the data used was a dummy, where the assumption of using outgoing invoice payment data as a test case. The data count cannot be tested using Benford's Law formula. The huge number of data, the more accuracy of the test result. In this research paper, the experiment for the dummy data counts was created in the total count of rows is 100,000 lines which comprise of the outgoing invoice payment amount paid to the vendors supposedly in the year 2014. The version of an Excel program used in this experiment is Microsoft Office Professional Plus 2016. Anomalies in the distribution of the actual occurrence of first digits compared with Benford's expected distribution – the telltale signs* is shown in Figure (2) and Table (2).

Benford's Law defines the frequency distribution of digits in a data set from the first position to the fourth position (starting from the left). According to Newcomb (1881) and Benford (1938), the frequency distribution of the digits zero to nine, also known as the distribution of digits, follows a logarithmic frequency distribution which depends on the position of the digit [18]. Table (1) below shows the Benford's distribution for the first four digits. From the fourth position onwards, the Benford's distribution approaches a uniform distribution Newcomb (1881). A data set that corresponds to Benford's law is generally referred to as Benford's set.

There were indications that checks for digit-preference anomalies should focus less on the first and more on the second and higher-digits [7]. In this research, the ERP data set was tested using the first digit formula as illustrated in Figure (1). According to [9], the probability that a number's first digit is "1" is 0.301, while a "9" is expected with a much lower probability of 0.046 as shown in Table (1). We have concluded that the test using the first digit and higher digit formulas are complimentary.

Table 1. Expected Frequencies Based on Benford's Law. Source [19]

Digit	1st	2nd	3rd	4th	5th or higher
0		11.97%	10.18%	10.02%	10.00%
1	30.10%	11.39%	10.14%	10.01%	10.00%
2	17.61%	10.88%	10.10%	10.01%	10.00%
3	12.49%	10.43%	10.06%	10.01%	10.00%
4	9.69%	10.03%	10.02%	10.00%	10.00%
5	7.92%	9.67%	9.98%	10.00%	10.00%
6	6.69%	9.34%	9.94%	9.99%	10.00%
7	5.80%	9.04%	9.90%	9.99%	10.00%
8	5.12%	8.76%	9.86%	9.99%	10.00%
9	4.58%	8.50%	9.83%	9.98%	10.00%

The formula is shown in Figure (1) resulted in the first digit percentage as in Table 1 above, while the second digit formula onwards (not in this paper) resulted in the second digit up to the fourth digit percentage in Table 1. Anyway, the test using the 5th digit and above will not give any impact to the data because the result will be the same as 10%. At this point, no fraudulent data can be detected.

$$P(d) = \log_{10}(d+1) - \log_{10}(d)$$

$$P(d) = \underbrace{\log_{10}(d+1) - \log_{10}(d)}_{\text{Original Formula}} = \underbrace{\log_{10}\left(\frac{d+1}{d}\right)}_{1^{st}\text{ simplified}} = \underbrace{\log_{10}\left(1+\frac{1}{d}\right)}_{\text{Final simplified}}$$

*d= first digit

Figure (1) First Digit Formula. Source [10]

The original formula stated above, where *d* is a number at the first digit. To simplify the formula, it can be derived as below steps;

Steps 1 $P(d) = \log_{10}\left(\frac{d+1}{d}\right)$

Steps 2 $P(d) = \log_{10}\left(\frac{d}{d}+\frac{1}{d}\right)$ Where $\frac{d}{d}=1$

Simplify Formula $P(d) = \log_{10}\left(1+\frac{1}{d}\right)$

d is all binary numbers from (1 to 9) starting with digit 1 except 0 because there is no number start with 0. An example of 4579; K = digit position, 4 → is the 1st digit, 5 → is a 2nd digit, 7 → 3rd digit, and 9 → 4th digit.

4. FINDINGS

For the distribution shown in Figure (2) below (Benford's Law), the size of the areas of the red bar and the black line is approximately proportional to the widths of each red bar and black line. Therefore, the numbers drawn from this distribution will approximately follow Benford's law.

Benford's law tends to apply most accurately to data that are distributed uniformly across several orders of magnitude. As a rule of thumb, the more orders of magnitude that the data evenly covers, the more accurately Benford's law applies [11].

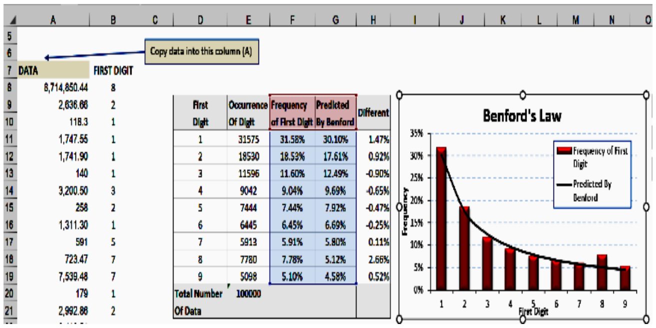

Figure (2) Fraudulent Test Calculation using First Digit Formula in Figure (1)

Figure (2) above shows the test result for possible fraudulent of the dummy ERP data set using an Excel program based on Benford's Law. The 100000 lines of data set inserted into column A (starting with cell A8) followed by the subsequent rows. The first digit column (Column B) indicates the first digit of each number that was calculated as =LEFT(A8,1). For example, the first digit in the amount of 8,714,850.44 is equal to 8. The formula applied to the subsequent rows regardless of how many lines in column A, starting with Cell A8 in Figure (2). The result in column B will be accumulated into Cell E11 (Occurrence of Digit). The total count for the first digit with number 1 (as well as number 2 to 9) is equal to 31575 by applying the following formula in Excel program;

=COUNTIF($B$8:INDIRECT("B" & MAX(INDEX(($B$8:$B$100007<>"")*ROW($B$8:$B$100007),0))),"1")

The Total Number of Data in Cell E20 is calculated using Excel formula =COUNTA(A8:A100007) as the result given as 100000 in total. To get the percentage of the Frequency of First Digit 1 to 9 in column F11 to F19, = (Occurrence of Digit / Total Number of Data) x 100% or as formulated by Excel =E11/$E$20

Column G represents the percentage of the first digit that was predicted by Benford in Table I. The differences in column H (Cell H11 to H19) can be obtained by subtracting the percentage Predicted by Benford (Column G11 to G19) by the Frequency of First Digit (Column F11 to F19), or as formulated by Excel =F11-G11.

Referring to Table (2) and Figure (3), the result clearly has shown that numbers 1 and 8 as the first digit are not complying with Benford's Law with the difference of 1.47% for number 1 as the first digit and 2.66% for number 8 as the first digit respectively. When the details of the outgoing invoice payment were carefully inspected for a digit started with 1 and 8, it is expected that one or more than one transaction is potentially having suspicious activities with a high possibility of fraud [2-3]. However, to avoid unfounded allegations, further investigation should be considered because, Benford's Law not only used to detect fraudulent activities, it is also detecting anomalies. Anomalies, in this case, can be anything related to an abnormality of invoice payment or work and data inconsistency for that particular account officer or could be an unintended human error is potentially occurred. In some cases, responsible officers need to justify and provide relevant evidence to support the cause of his/her action in that particular dubious transaction.

First Digit	Occurrence of Digit	A Frequency of First Digit	Predicted by Benford	Different
1	31575	31.58%	30.10%	1.47%
2	18530	18.53%	17.61%	0.92%
3	11596	11.60%	12.49%	-0.90%
4	9042	9.04%	9.69%	-0.65%
5	7444	7.44%	7.92%	-0.47%
6	6445	6.45%	6.69%	-0.25%
7	5913	5.91%	5.80%	0.11%
8	7780	7.78%	5.12%	2.66%
9	5098	5.10%	4.58%	0.52%
Total Number of Data	**100000**			

Table (2) Test Result from 100,000 of Dummy ERP Data Set

Table (2) shows the result from the tested ERP dataset with numbers of data count is equal to 100000 to the outgoing invoice payment amounts. The table divided into 5 columns where each column representing a different value. The first column represents the first digit number in each row of data. The second column indicates the total number of data count for the occurrence as the first digit in the data set and the third column count the first digit occurrence in the percentage of the frequency of first digit (from the second column), while the fourth column represents expected frequencies predicted by Benford's Law in percentage as shown in the 1st digit column in Table (1). The last column shows differences between column 3 (Frequency of First Digit) and column 4 (Predicted by Benford). For example; 31.58% - 30.10% = 1.47% different.

The whole data set comparison between columns 3 and 4 has been translated into the following graph in Figure (3):

Limitation and Future Research

The idea of this paper is to introduce the method of doing digital analysis on ERP data set using the Excel program. There were indications that checks for digit-preference anomalies should focus less on the first and more on the second and higher-digits. In this research paper, the dummy ERP data was tested using the first digit formula (Fig. 1) only, but to get more accuracy on the fraudulent data, a future test must be executed at least up to the second digit formula.

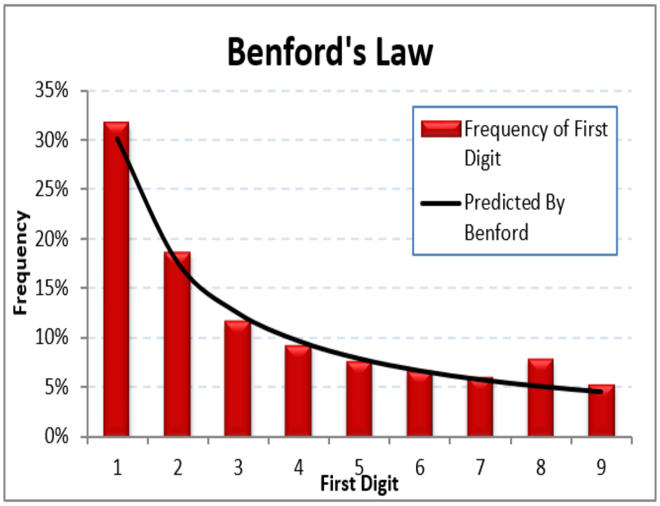

Figure (3) Possible Fraudulent of Outgoing Invoice Payment using Excel program based on Benford's Law.

The most accurate fraudulent data can be detected in the second digit until the fourth digit, not only in the first digit [9]. Future studies would be the data test up to the second digit of Benford's Law formula to get a more accurate result of the fraudulent ERP data. The same data set in this research can also be used and the result using the complementary formula starting from the first digit and followed by the higher digit formula will be compared to the test result in this paper (Where using only first digit formula).
The data source used in this system is dummy data. In the next research paper, the secondary data from an authorized agency in Malaysia will be used for testing purposes. The same method will be applied to an audited data set to see the result if fraudulent data probably exists in ERP System users in Malaysia.

5. CONCLUSIONS

Benford's Law does indeed apply to aggregated data sets which are very relevant to Data Quality Assessment (DQA) especially in detecting fraud in the ERP system. Where anomalies are found, further review may indicate the initial hypothesis regarding a data set's expected 'distribution' was incorrect. Alternatively, a review of outcomes may indicate that although the distribution should conform to Benford's Law, in reality, it doesn't – thus, further investigation required.
Further investigation should then reveal the true reasons for deviations. As an example, fraud, inefficient processes, genuine repeated patterns, or systemic data processing / ETL logic errors. Benford's Law provides a simple yet potentially powerful technique to add to our ERP Data Quality Assessment (DQA), and it can be achieved by applying nothing more than a very simple formula in an Excel Spreadsheet against your data set. We'll never look at General Ledger and data warehouse balances (or at least their leading digits) the same way again.
The research has concluded Benford's Law is one of the most powerful techniques to identify suspected fraudulent account activity and with further detailed investigations it may help to identify potential fraud. Since it has been introduced and authorized by many audits and financial bodies as the most accurate technique to detect fraud, many of auditing tools such as ACL, IDEA, Arbutus and SAS are now includes Benford's Law as one of the embedded functions. But some of it is limited to analysis only at the first digit and due to this limitation, some users start exploring the "second digit and higher" formula and translated it into an Excel spreadsheet.
Benford Law is a useful technique since it doesn't use aggregated data, rather it is conducted on specific accounts using available data and it can identify specific accounts for further analysis and investigation.

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