A Conceptual Model for Effective Early Warning Information Systems (EEWIS)

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Abstract: This paper addresses the need for effective early warning information systems (EEWIS) that are capable of predicting future crises and that can help prevent them or reduce their negative effects. The main problem facing any EWIS is the lack of effectiveness. The most effective early warning information systems are characterized by accuracy, flexibility and the ability to detect risks. Effective early warning information systems can empower communities to prepare for and confront risks and disasters. An effective EWIS should be based on a reliable and consistent model, yet the models currently available are mostly deterministic, simplified or inconsistent in application and assumption; thus making them unreliable and impractical. The goals of this paper are to provide guidelines for professionals involved in implementing effective early warning information systems, and to present a novel model for EEWIS that can be adapted to the dynamic needs of the field of crisis management and preparedness.

1 INTRODUCTION

Although early warning information systems are used to collect and share information at a time of crisis, such systems are not always effective. While Assilzadeha and Mansor (2008) believe that the development and implementation of application software for early warning- especially for disaster data and information management- is crucial, Glantz (2004) claims that there is no perfect Early Warning System (EWS), except on paper, in governmental plans, or in a PowerPoint presentation, and that most of the current systems are not as effective as they should be. Along the same lines, Sanada et al., (2006) also agree that the information systems used to collect and share information in the time of a disaster are not always effective. Furthermore, Harff (1998) argues that at present, early warnings are rarely "early," seldom accurate, and moreover lack the capacity to distinguish among different kinds of crises. In this context, after analyzing the current problems in existing early warning information systems used in crisis or disaster preparedness, we have found that in many cases these systems tend to be fairly narrow in scope and do not have an adequate or clear model for collecting, classifying, processing and producing accurate forecasting information. The accuracy of forecasting models is essential for building EEWIS. The limitations of existing early warning information systems suggest the need for a more comprehensive conceptual model. This is the goal we aim to achieve from this paper. Furthermore, other motivations for this paper are: The scarcity of specialized EWIS researches used in crisis preparedness, most of the previous studies did not address the key steps used in building EEWIS and there is no agreement on the ideal structure or functions of EEWIS.

The proposed model provides a guideline for any organization or sector in the country that needs to have an EEWIS for crisis preparedness. Moreover, this model will support any information system in producing more effective and accurate predictions of the future. In addition, it will provide decision makers with a reliable and manageable amount of warning information for taking preventive actions.

2 EARLY WARNING INFORMATION SYSTEMS

The idea of early warning emerged in the fifties of the past century, and was used for the first time in

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military domains to predict risks and potential attacks before they occur. Until the early eighties; the concept of early warning had not evolved noticeably due to a number of reasons; such as the difficulty of creating its applications and its high cost. However, the concept has been rediscovered again after a series of crises and disasters had taken place in the world and after witnessing their major impact on lives and property (Eldin, 2011). The expression 'Early Warning' is used in many fields to mean the provision of information on an emerging dangerous circumstance where that information can enable action in advance to reduce the risks involved (Basher, 2006). A universally accepted definition of an EWS does not yet exist and most probably never will (Sivakuma, 2009). There are many definitions of an EWS that are used to guide the actions of individuals, groups, and governments. The formal UN definition is as follows: "The provision of timely and effective information, through identifying institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response" (ISDR, 2003). An EWS can also be defined as "a social process for generating maximally accurate information about possible future harm and for ensuring that this information reaches the people threatened by this harm, as well as others disposed to protect them from the harm" (Glantz, 2004); (Davies and Gurr, 1998). An *'Early Warning Information System (EWIS)'* (see Figure 1.) can be understood as a set of institutional and technical solutions designed and implemented in a coherent way to make available, to a wide range of users and more particularly to decision makers, information useful to carry out vulnerability analyses, to evaluate and manage the risk of a hazard that can become a disaster, and to manage disasters from prevention to recovery and rehabilitation (Scott, 2003); (ISCRAM, 2008); (IAD, 2002). The objective of EWIS is to generate accurate information to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life and damage to property or the environment. We can use the term EWIS for any information system that collects, shares, analyzes data, produces future predictions about potential crises and gives recommendations or warnings for those involved. Early Warning Information Systems are still not widely practiced around the world. .The applications of EWIS are costly, limited and not widely available especially in some international organizations. The best known EWIS is the HEWS- Humanitarian Early Warning System- used by the Department of Humanitarian Affairs in the United Nations, and the GIEWS -The Global Information and Early Warning System- used by the Food and Agriculture Organization of the United Nations (Verstegen, 1999).

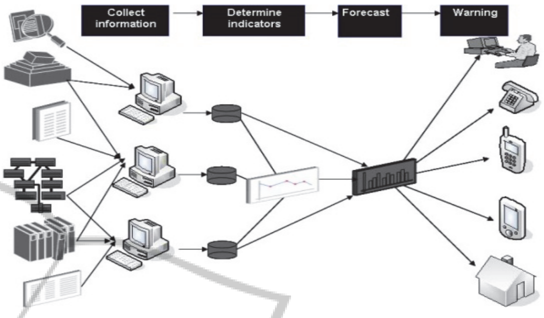


Figure 1: EWIS architecture.

3 EFFECTIVE EARLY WARNING INFORMATION SYSTEMS

Many developing countries, in particular the least developed among them, have limited capacities for effective early warning systems, and in some cases they are virtually non-existent (Villagran 2006). The challenges facing any early warning system are ineffectiveness and failure to achieve its goals. Any information system can be called effective if it supports the organization in reaching its objectives (Malik, 2001**)**. Effective early warning systems not only save lives but also help protect livelihoods and national development gains (United Nations, 2006). Early warning systems are widely recognized as worthwhile and necessary investments. However in many cases, early warning systems do not exist, are ineffective, or break down at critical points – risking devastation, death, and destitution (ISDR, 2003). Two international conferences on early warning, in 1998 and 2003 produced a set of internationally agreed upon guiding principles for effective early warning systems. The 1998 Potsdam Conference on Early Warning Systems and the 2003 Second International Conference on Early Warning in Germany addressed technical considerations, strategic issues and institutional requirements in the early warning field, Moreover, the conferences made specific recommendations for strengthening early warning systems; including increasing the ability of these systems to be more accurate and flexible (United Nations, 2006); (EWC, 1998); (EWC-ll, 2003); (EWC-lll, 2006). Furthermore, the core message of the session "People-Centred Early

Warning Systems" at the World Conference on Disaster Reduction that was held in January 2005, in Kobe Japan, was that effective early warning systems must be embedded in an understandable manner and relevant to the communities which they serve. Therefore, these systems must be developed in such a way that ensures that they are functioning when needed and that the warnings are timely, comprehensible and ultimately acted upon by the diverse array of individuals at risk in any emergency. The Global Survey of Early Warning Systems (2006) and the UN-ISDR/Platform for the Promotion of Early Warning (2006) concluded that a complete and effective early warning system model should comprise four inter-related elements: risk knowledge, monitoring and warning service, dissemination and communication, and response capability. A weakness or failure in any one part could result in failure of the whole system (United Nations, 2006). Along the same lines, the World Meteorological Organization (2011) suggested that effective early warning systems are comprised of four operational components

1. Hazards are detected, monitored, forecasted, and hazard warnings are developed;
2. Risks are analyzed and this information is incorporated in warning messages;
3. Warnings are issued (by a designated authoritative source) and disseminated in a timely fashion to authorities and the public at risk;
4. Community-based emergency plans are activated in response to warnings to reduce impact on lives and livelihoods.

Failure in one component or lack of coordination across them leads to failure of the whole system (WMO, 2011). Martin (2008) also points out in his paper that the effectiveness of any EWIS largely depends on the transformation of the event recognition into the report of warning to the population or people at risk (Martin et al., 2008); (Wikipedia, 2012).

From our review of previous studies about effective early warning information systems; we have concluded that the effectiveness of EWIS will depend on the following characteristics:

1. Integrated: All early warning information system phases should be integrated into one generic model
2. Detectability: Effective early warning information systems should have the ability to confirm the prediction that impacts are going to occur.
3. Predictability: Effective early warning information systems should be highly predictive and capable of forecasting the crisis/hazard before they occur.
4. Accuracy: An Effective EWIS should produce accurate results.
5. Certainty: An effective EWIS should have a very high level of confidence in that the predictions and detections will be accurate and not result in false alarms.
6. Flexible: An effective early warning information system should be flexible and expand its activities to include different varieties of risks and hazards.

4 EWIS MODEL

Various writers have identified what they consider to be the components of a successful EWIS model; for example, a paper by Verstegen (1999) suggests that the EWIS model should have five components: selection of indicators; communication of warnings; reception of warnings; early warning education; generation and maintenance of awareness. However, this model does not specify the methods or steps of data collection. Moreover, it does not explain how to measure the precursors, evaluate the event or specify the forecasting models. Along the same lines, Lundin (2008) suggests that an EWIS is responsible for issuing forecasts, warnings, and responses. Yet, the model he proposes does not clarify how the data is collected and analyzed; explain how to prepare future forecasts or how to select the most suitable model for forecasting. Obviously, there is no agreement on the ideal structure or function of an early warning system (Shrestha, 2009). This means that the structure and functions of EWIS may vary from one organization to another and from one field to another. Therefore, after reviewing most of the previous studies about the major components of an EEWIS model we suggest that any EEWIS (see Figure 2.) should take into considerations four essential sub-models. The first model (Societal Detection of Events sub-model) includes functions that capture and analyze the event/crisis information; the second model (Determining Early Warning Indicators sub-model) determines the set of mathematical indicators that should be measured frequently; the third model (Future Forecasting sub-model) provides future forecasts depending on the data calculated from the previous model, and finally the fourth model (Issuance of Warnings sub-model)

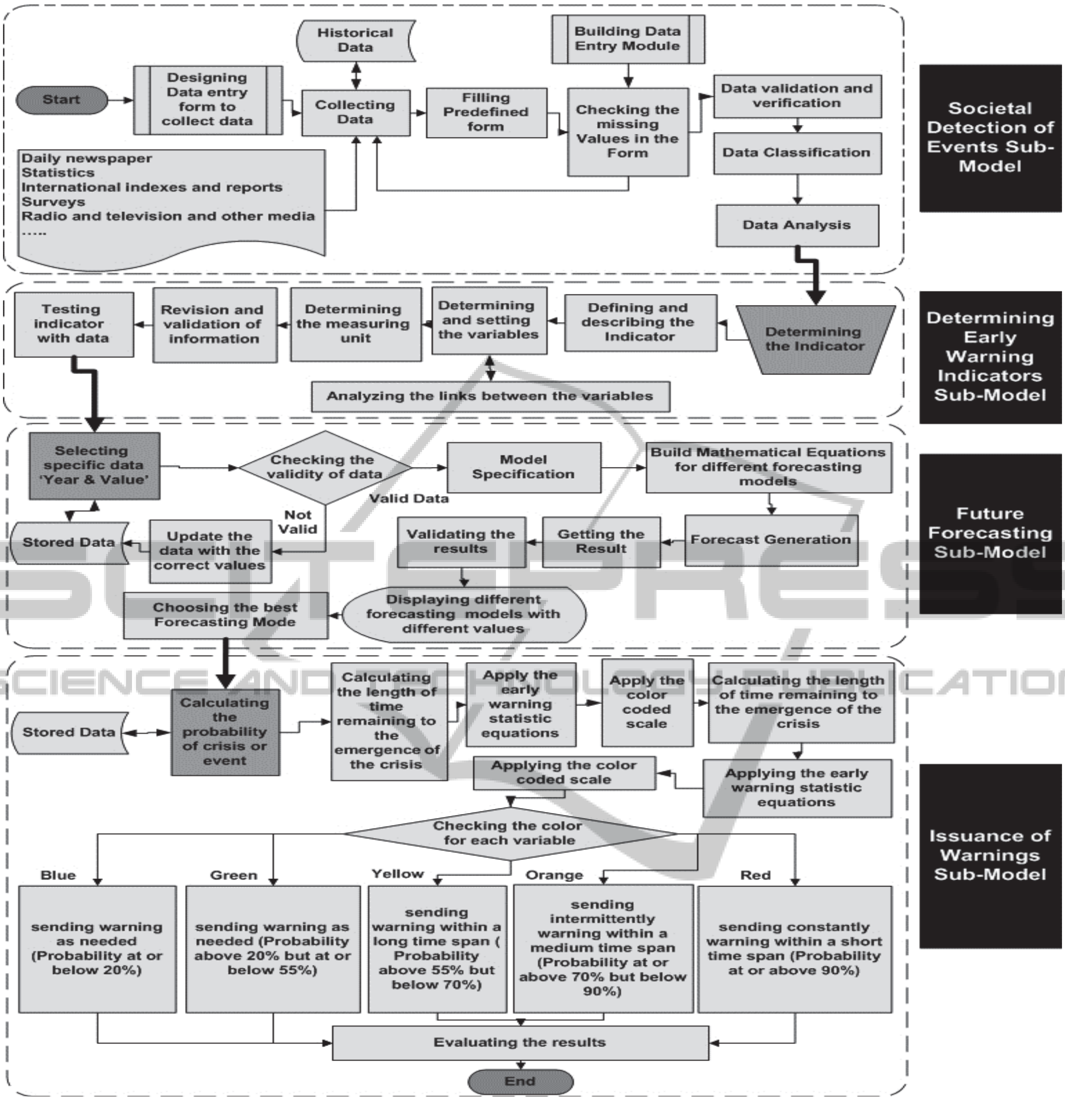


Figure 2: EEWIS model.

is concerned with ending warnings (alerts) to users. Each of the four models is explained below in detail. EEWIS (Proposed System) is based on the conceptual model which consists of set of four sub-models, the major inputs of the proposed EEWIS depend on the heterogeneous information which is gathered from different sources include (News, Statistics, Reports, Databases, Radio & T.V, Data, etc). The major outputs from the proposed system are set of warnings (alerts).

5 CASE STUDY

In order to demonstrate some of the key concepts introduced in the model described above, we have implemented a proof-of-concept prototype purely in software. The key objectives for the proof of concept are to demonstrate the early warning theoretical concept, and to show how the theoretical concept can be implemented practically against data from the law enforcement sector. The next few pages will explain the case study in more detail.

5.1 Societal Detection of Event

a) The event data is collected from different sources and is regularly inputted into the EWIS.
b) The number of occurrences is calculated for each event in a specific time frame.
c) The EWIS selected the most frequent event; which is "widespread drug abuse among the

youth" (see Table 1.), because this event has the highest number of occurrences. This event was detected from multiple sources through the period of time from January 2006 to December 2010 (see Table 2.).

d) Data is collected from different data sources and entered into the EWIS.

e) After analyzing the data, the system found that this event is increasing on an annual basis (see Table 2).

Table 1: Event occurrences (2010).

Event /Phenomena	No. of Occurrences
Drug abuse (youth)	64
Spinsterhood	24
The collapse of buildings	22
Hooliganism	21
Child molestation	20
Luxury consumer	19
Unknown Parentage	18
Train accidents	18
Drug trafficking	14
Trafficking in Persons	12

Table 2: Event (drug abuse) occurrences (2006-2010).

Year	2006	2007	2008	2009	2010
No of occurrences	36	40	43	52	64

5.2 Determine the Event Indicators

a) Determining the indicators that best describe the event: The EWIS uses from 3 (minimum) to 10 (maximum) indicators for each event/phenomena to work efficiently, the number of indicators varies from one event/phenomena to another. The process of determining the indicators is implemented by a group of experts specialized in designing law enforcement indicators and these indicators are:

- Indicator A: Total number of drug users in the country.
- Indicator B: Total number of drug cases.
- Indicator C: The percentage of people arrested in drug cases to the total population.
- Indicator D: The percentage of local people arrested to the total of arrests.

b) Defining the indicators and determining the variables involved in calculating them:

- Total number of addicted youth.
- Total number of drug cases.
- Percentage of youth arrested in drug cases to the total youth population = (total number of youth arrested/ total youth population) * 100.
- Percentage of local people arrested to the total of arrests of other nationalities= (total number of local youth population arrested in drug abuse cases/ total youth arrested from all nationalities in drug abuse cases) * 100.

Table 3: Indicators time series data (2003-2010).

Year	Indicator A	Indicator B	Indicator C	Indicator D
2003	700	650	4%	40%
2004	800	800	5%	45%
2005	850	825	5.5%	48%
2006	1050	1000	7%	49%
2007	1110	1050	7.2%	55%
2008	1206	1200	7.7%	60%
2009	1708	1400	9%	62%
2010	2000	1650	10.6%	69%

Table 4: Mathematical measures for indicator (A).

Model	Fitted Equation	MAPE	Correlation
Linear	$y = 386.9 + 175.8\,x$	11	$R^2 = 0.891$
Quadratic	$y = 783.3 - 62\,x + 26.4\,x^2$	5.2	$R^2 = 0.971$
Cubic	$y = 547.3 + 183.5\,x - 37.9\,x^2 + 4.8\,x^3$	3.5	$R^2 = 0.981$

5.3 Designing a Forecasting Model for each Indicator

a) Creating a Time Series Data for Each Indicator: Table (3) shows the time series data for all indicators and Figure (3) shows the same table is implemented in the EWIS.

b) Specifying the Mathematical Model: The EWIS uses three forecasting models to be applied (Linear, Building mathematical equations for different forecasting models:

- Linear equation $(y) = mx + b$ (where m and b designate constants, m is a slope of the line)
- Quadratic equation $(y) = ax^2 + bx + c$ (where a, b, c are constants with $a \neq 0$)
- Cubic equation $(y) = ax^3 + bx^2 + cx + d$ (where a, b, c, d are constants with $a \neq 0$).
- MAPE (Mean Absolute Percentage Error) =

$$\frac{\sum \left|\frac{\text{Actual Value} - \text{Fitted Value}}{\text{Actual Value}}\right|}{\text{n}} \times 100$$

(Where n = total number of actual values)

- R^2: The coefficient of determination.

Table 5: Forecasting Models for Indicator (A) for the years (2011-2014).

Year	X	Actual Data	Linear	Quadratic	Cubic
2003	1	700	563	748	698
2004	2	800	739	765	801
2005	3	850	914	835	885
2006	4	1050	1090	958	979
2007	5	1110	1266	1134	1112
2008	6	1206	1442	1362	1312
2009	7	1708	1618	1644	1608
2010	8	2000	1793	1978	2029
2011	9		1969	2366	2602
2012	10		2145	2806	3357
2013	11		2321	3299	4322
2014	12		2497	3844	5526

c) Creating Forecasts for Each Indicator (Forecast Generation):

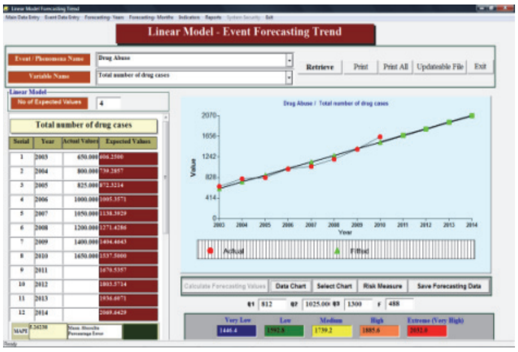
Indicator (A), (B), (C) and (D)

Table (4) shows the correlation of variables for each model, the EWIS will automatically choose the cubic model because its correlation value is the largest from among other models (=0.981), and the value of (MAPE) is the smallest (=3.5), so the forecasting data for the cubic model will be more accurate. Table (5) shows the comparison between the forecasting data for indicator (A). The system will carry out the same processes as indicators (B, C and D); the EWIS will automatically choose the cubic model because its correlation value is the largest among other models. In addition, the value of (MAPE) is the smallest, so the forecasting data for the cubic model will be more accurate.

d) Charting the forecasting data for each indicator (see Figure 3.)

e) Choosing the best model: After analyzing and validating the data, the EWIS will choose the best forecasting model (see Figure 4.) depending on the following criteria:

1. Lowest MAPE.
2. Highest correlation between variables.



Linear Model - Event Forecasting Trend

Event / Phenomena Name: Drug Abuse

Variable Name: Total number of drug cases

No of Expected Values: 4

Total number of drug cases

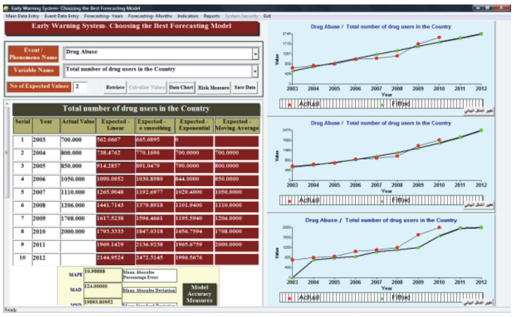
Serial	Year	Actual Values	Expected Values
1	2003	650.000	606.2500
2	2004	800.000	739.2857
3	2005	825.000	872.3214
4	2006	1000.000	1005.3571
5	2007	1050.000	1138.3929
6	2008	1200.000	1271.4286
7	2009	1400.000	1404.4643
8	2010	1650.000	1537.5000
9	2011		1670.5357
10	2012		1803.5714
11	2013		1936.6071
12	2014		2069.6429

MAPE: [illegible] Mean Absolute Percentage Error

Q1: 812 Q2: 1025.00 Q3: 1300 r: 488

Very Low	Low	Medium	High	Extreme (Very High)
1446.4	1592.8	1739.2	1885.6	2032.0

Figure 3: EWIS: linear forecasting trend.



Early Warning System- Choosing the Best Forecasting Model

Event / Phenomena Name: Drug Abuse

Variable Name: Total number of drug users in the Country

No of Expected Values: 2

Total number of drug users in the Country

Serial	Year	Actual Value	Expected - Linear	Expected - e smoothing	Expected - Exponential	Expected - Moving Average
1	2003	700.000	562.6667	665.6895	0	
2	2004	800.000	738.4762	770.1696	700.0000	700.0000
3	2005	850.000	914.2857	891.0479	790.0000	800.0000
4	2006	1050.000	1090.0952	1030.8980	844.0000	850.0000
5	2007	1110.000	1265.9048	1192.6977	1029.4000	1050.0000
6	2008	1206.000	1441.7143	1379.8918	1101.9400	1110.0000
7	2009	1708.000	1617.5238	1596.4661	1195.5940	1206.0000
8	2010	2000.000	1793.3333	1847.0318	1656.7594	1708.0000
9	2011		1969.1429	2136.9238	1965.6759	2000.0000
10	2012		2144.9524	2472.3145	1996.5676	

MAPE: 10.98888 Mean Absolute Percentage Error

MAD: 124.00000 Mean Absolute Deviation

MSD: 19893.80952 Mean Standard Deviation

Figure 4: Choosing the best model.

5.4 Sending Warning Messages

a. Calculating the Probability of a Crisis:

1. Calculating the probability of each indicator by setting a range for each one, the probabilities will have values between 0.1 and 1 as shown in (Table 6.).
2. Determining the level of danger (see Table 7.) the level of danger equation will be : [(Probability of indicator A + Probability of indicator B + Probability of indicator C + Probability of indicator D) / total Number of indicators] * 100.
3. Converting the result into the color coded scale as shown in (Table 8.).

b. Calculating the Length of Time Remaining to the Emergence of the Crisis: The system found that in the year 2014 the detected event will reach a dangerous level.

c. Charting Data to Determine the Level of Danger: the EWIS charted the data for each indicator to determine the level of danger (there are 5 levels of danger: dangerous, high, medium, low, and nil), the probability of a crisis and the time frame remaining to its emergence.

d. Matching the Level of Danger to the Color Coded Scale: The EWIS matched the level of danger (see Table 7. and Table 8.) to the color coded scale. (Red, orange, yellow, green and blue).

e. Generating Alerts: the system will automatically generate alerts based on the forecasting data calculated through the system. Once generated, alerts can be distributed through different channels to many parties.

Table 6: Probability table.

Indicator A		Indicator B		Indicator C		Indicator D	
Range	Probability	Range	Probability	Range	Probability	Range	Probability
<500	0.1	<400	0.1	< 1	0.1	<10%	0.1
50-1000	0.2	40-800	0.2	1- 3	0.2	10-19	0.2
1001-1500	0.3	80-1200	0.3	>3-6	0.3	20-29	0.3
1501-2000	0.4	1201-1600	0.4	>6-9	0.4	30-39	0.4
2001-2500	0.5	1601-2000	0.5	>9-12	0.5	40-49	0.5
2501-3000	0.6	2001-2400	0.6	>12-15	0.6	50-59	0.6
3001-3500	0.7	2401-2800	0.7	>15-18	0.7	60-69	0.7
3501-4000	0.8	2801-3200	0.8	>18-21	0.8	70-79	0.8
4001-4500	0.9	3201-3600	0.9	>21-24	0.9	80-89	0.9
> 4500	1	> 3600	1	>24	1	90-100	1

Table 7: Final results.

Year	Indicator A	Probability	Indicator B	Probability	Indicator C	Probability	Indicator D	Probability	Level of Danger (%)	Description
2003	700	0.2	650	0.2	4%	0.3	40%	0.5	30	Low
2004	800	0.2	800	0.2	5%	0.3	45%	0.5	30	Low
2005	850	0.2	825	0.3	5.5%	0.3	48%	0.5	32.5	Low
2006	1050	0.3	1000	0.3	7%	0.4	49%	0.5	37.5	Low
2007	1110	0.3	1050	0.3	7.2%	0.4	55%	0.6	40	Low
2008	1206	0.3	1200	0.3	7.7%	0.4	60%	0.7	42.5	Low
2009	1708	0.4	1400	0.4	9%	0.4	62%	0.7	47.5	Low
2010	2000	0.4	1650	0.5	10.6%	0.5	69%	0.7	52.5	Low
2011	2602	0.6	1999.7	0.5	12.9%	0.6	75.2%	0.8	62.5	Medium
2012	3357	0.7	2454.4	0.7	15.9%	0.7	83%	0.8	72.5	High
2013	4322	0.9	3034.6	0.8	19.8%	0.8	92.9%	1	87.5	High
2014	5526	1	3658.9	1	24.8%	1	104.4%	1	100	Dangerous

Table 8: Description of the color coded scale.

Color Coded Scale	Description
Dangerous (Red Color)	Threat already occurring or its eventual occurrence is “almost certain”, Probability >= 90%
High (Orange Color)	The occurrence of the threat is “probable” to “highly likely", Probability >= 70% but < 90%
Medium (Yellow Color)	There is “likely” chance that the threat will occur, Probability >=55% but < 70%
Low (Green Color)	Occurrence is possible but “improbable”; “little chance” to “about even” chance of occurrence, Probability >= 20% but < 55%
Nil (Blue Color)	Probability of event occurrence is negligible or “highly unlikely”, Probability < 20%

6 TESTING THE EFFICIENCY OF THE EWIS

According to the effectiveness criteria in section 3 of this paper we have obtained the following results:

1. Integration: The proposed EWIS sub-models are integrated into unified model with specific inputs and outputs.
2. Detectability: The proposed EWIS detected number of events occurrences as described in table (1,2).
3. Predictability: The proposed EWIS uses three prediction models (Linear, Quadratic and Cubic) to forecast future data trends, in addition the system selects the best forecasting model according to the accuracy and correlation between variables.
4. Accuracy: The proposed EWIS produces accurate results (see Table 9.), accuracy can be measured using the following equation:

Table 9: EWIS results.

Year	Indicator A	Predicted Value	Accuracy (%)	Indicator B	Predicted Value	Accuracy (%)	Indicator C	Predicted Value	Accuracy (%)	Indicator D	Predicted Value	Accuracy (%)
2003	700	698	99.7	650	656.1	99.1	4	3.9	97.4	40	40.4	99
2004	800	801	99.9	800	774.2	96.8	5	5.1	98.0	45	44.1	98
2005	850	885	95.9	825	869.5	94.6	5.5	5.9	93.2	48	47.6	99.2
2006	1050	979	93.2	1000	960.5	96.1	7	6.5	92.3	49	50.9	96.1
2007	1110	1112	99.8	1050	1065.6	98.5	7.2	7.2	100	55	54.5	99.1
2008	1206	1312	91.2	1200	1203.6	99.7	7.7	8	96.3	60	58.4	97.3
2009	1708	1608	94.2	1400	1392.9	99.5	9	9	100	62	63	98.4
2010	2000	2029	98.6	1650	1652.1	99.9	10.6	10.7	99.1	69	68.5	99.3
2011	2600	2602	99.9	1987	1999.7	99.4	11.2	12.9	86.8	73	75.2	97
2012	3350	3357	99.8	2502	2454.4	98.1	14.5	15.9	91.2	77	83	92.2
f. 2013		4322			3034.6			19.8	97.4		92.9	
2014		5526			3658.9			24.8	98.0		104.4	
Average			97.2%			98.4%			95.4%			97.56%

$$\textbf{Accuracy} = 100 - \left|\frac{\text{Predicted Value(EWIS)} - \text{Actual Value}}{\text{Actual Value}}\right| \text{X } 100$$

5. Certainty: The proposed EWIS has a very high level of confidence in its predictions which in average =97.14% and correlation of data is above 98%.
6. Flexible: The proposed EWIS can be used in different organization with different events or hazards. The system featured in the case study used an event from the law enforcement sector, which had the highest number of occurrences during the period of the study. However, it can use events from other sectors and apply the same processes that were mentioned above.

7 CONCLUSIONS

In this paper, we have proposed a conceptual model to build an effective EWIS. We have also presented the detailed structure of this model and how it will be implemented. The model was tested through a case study to prove the concept. A list of issues related to the EWIS was also presented. Based on our literature review, we have concluded that hitherto there had only been a few models worldwide for building an efficient EWIS. Hence, an information system that is built using our new model will be effective and beneficial due to a number of reasons. Firstly, it will provide information on the past, present and future and on relevant events inside and outside any organization. Secondly, it will be an integrated system for gathering relevant data, converting it to warning information and supplying the same to concerned executives and decision makers. Thirdly, it will reduce the time needed to build a sophisticated EWIS from scratch. Fourthly, it will select the best model for forecasting; which leads up to accurate results. And finally, it will strengthen the ability of the organization to prevent disasters and crises before they occur.

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