The Framework of Risk-based Decision Support System (DSS+R) for Forensic Investigation in Detecting Human Cadaver of Clandestine Graves

To cite this article: Noor Maizura Mohamad Noor et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 453 012017

View the article online for updates and enhancements.
The Framework of Risk-based Decision Support System (DSS+R) for Forensic Investigation in Detecting Human Cadaver of Clandestine Graves

Noor Maizura Mohamad Noor¹, Amirul Harfirie Ahmad Nubli, Rosmayati Mohemad and Zuriana Abu Bakar

¹School of Informatics and Applied Mathematics, Universiti Malaysia Terengganu, 21030, Kuala Nerus, Terengganu, Malaysia

E-mail: {maizura, rosmayati, zuriana}@umt.edu.my, harfirie.umt@gmail.com

Abstract. Decision-making process in detecting buried bodies in clandestine grave is crucial to solve criminal cases. Generally, cadaveric derived lipid is used as 'biomarkers' for biomolecular analysis to detect a clandestine grave. However, there are a few environmental factors around the grave that could help in increasing the chance of detecting the clandestine grave. The existing framework has many factors which are inefficient in locating human cadaver. For example, risk is not implemented in the framework which may affect the percentage of locating the graves. Moreover, most of the framework is not computerized which mean it requires a lot of time to locate graves. Therefore, the proposed modified framework will contain guidelines for risk management in decision-making processes. The framework is expected to illustrate guidelines that involve computerized risk and decision-making process. The chosen method is a multi-criteria decision-making (MCDM) method which is known as the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) where the risks that have been identified can be analysed according to their weight of priorities. Hence, it makes the forensic investigation work more efficient and helps to reduce human errors. This research demonstrates that the inclusion of risk as a fundamental component of DSS is able to improve accuracy and efficiency in the decision-making process.

1. Introduction

The rising crime rates in developing countries are of great concern to government authorities and the public. Report from the European Institute in 2010 for crime prevention and control shows significant increase in crime rates including murder, kidnapping, and drugs smuggling [1]. A lot of money and human-power have been invested for sophisticated and computerized decision-making tools to solve crimes especially in forensic science and crime detection. When confronted with a murder case, a criminal will on occasion attempt to conceal his/her crime by burying the evidence, for example disposing the human cadaver in a soil environment. In previous researches, manual decision-making approaches, such as the Cadaver dog [2] and the Ground Penetrating Radar (GPR) [3], developed to locate such clandestine graves and soils, have typically been used by forensic science to link objects and persons to crime scenes. The potential implications of different physical and chemical soil properties have been recognized to be used in locating a clandestine grave. It is known that these properties, for instance rock fragment content, soil reaction, soil moisture, organic compounds, and acidity, play a significant role in the fate of a body buried in soil.
However, the possibility of wrongly distinguishing between the decomposition fluids of a human or another mammal such as animal faeces and non-human decomposition could contribute to false results, thus becoming one of the possible risks of making the right decision. In addition, the variety of methods either invasive (method that disturbs the ground) or non-invasive is another risk that could affect the decision maker’s decision when detecting human cadaver in a clandestine grave [4]. Furthermore, environmental factor such as type of soil also contributes to a wrong decision as the decomposition rates differ from one type to another. Therefore, an improved framework of risk-based decision support system (DSS+R) for forensic investigation in detecting buried bodies in clandestine graves is proposed. Risk management in decision-making processes helps decision-makers to critically analyze the scenario before making any decisions.

The DSS+R framework does not neglect the fundamentally existing DSS components such as the model base, database, and user interface. As far as the authors are concerned, there are only a few literatures found discussing this issue and none of the DSS framework developed thus far is combined with risk. Therefore, in this research, through the combination of knowledge in forensic science and computer science, we are realizing the significance of risk in decision-making processes and propose the DSS and risk framework to solve the problem of determination of a clandestine grave.

The remainder of this paper is organized as follows. Section 2 discusses the research background related to the human cadaver of clandestine graves and risk-based decision support system. Meanwhile, Section 3 explains the method that has been used to detecting human cadaver. Subsequently, Section 4, an architectural design and prototype of the system is presented and finally, section 5 summarizes with a discussion and the conclusion.

2. Research Background

The following sub-section provide a details background of this study such as forensic investigation in detecting human cadaver, human cadaver of clandestine graves and risk-based decision support system (DSS+R).

2.1. Forensic Investigation in detecting human cadaver

Forensic investigation is in essence, the process of answering questions as to if, how, where, when, why, and by whom a crime is committed. To this end, investigators must assemble clues from various sources and arrive at a coherent account of the critical event. Although it is important to understand as completely as possible the circumstances surrounding a crime, this is not an end in itself. Interactive Decision-Support tool for risk-based radiation therapy plan comparison for Hodgkin Lymphoma [5] is a recent example of a DSS that considers risks in its analysis. Critical fields during emergency involve risks in decision making [6][7][8]. Environmental decisions involve risk [9], and even the simplest situation such as crossing the street involves a risk analysis in making decisions [8].

2.2. Human Cadaver of a Clandestine Grave

Finding buried bodies can be crucial to solving cases as well as providing closure for victims’ families. Criminals will on occasion attempt to conceal their crimes by burying the evidence, i.e., dispose the human cadaver in a soil environment. This can cause problems during a forensic investigation for a number of reasons. In most of the crime cases, the search of a body may firstly be relatively clueless as investigators have little or no idea where the body has been buried. In some instances, the criminal may later remove the body from the burial site, leaving behind no obvious trace that a body was ever buried there. A number of methods has been developed to locate such clandestine graves, and soils have typically been used by forensic science to link objects and persons to crime scenes.

The potential implications of different physical and chemical soil properties have been recognized to be used in locating a clandestine grave. It is known that these properties, for instance rock fragment content, soil reaction, soil moisture, organic compounds, and acidity, play a significant role in the fate of a body buried in soil. Even though the presence of this substance in soil can indicate the decomposition
of a body, but how does one distinguish between the decomposition fluids of a human and those of another mammal?

The existing framework has many factors which are inefficient in locating human cadaver. For example, risk is not implemented in the framework which may affect the percentage of locating the graves. Moreover, most of the framework is not computerized which mean it requires a lot of time to locate graves. Therefore, the proposed modified framework will contain guidelines for risk management in decision-making processes. The framework is expected to illustrate guidelines that involve computerized risk and decision-making. This research demonstrates that the inclusion of risk as a fundamental component of DSS is able to improve accuracy and efficiency in the decision-making process. Table 1 shows the comparison of efficiency in detecting human cadaver of clandestine graves from existing frameworks.

| Framework                                                                 | Accuracy | System | Risk |
|---------------------------------------------------------------------------|----------|--------|------|
| The Living Dead: Bacterial Community Structure of a Cadaver at the Onset and End of the Bloat Stage of Decomposition (Embriette et al., 2013) | ✓        | X      | X    |
| Lipid Analysis on Potential Grave Soil Products (Ismail S. S. & Daud, N. A) | ✓        | X      | X    |
| New Framework of Risk-based Decision Support System (DSS+R) for Forensic Investigation in Detecting Human Cadaver of Clandestine Graves | ✓        | ✓      | ✓    |

2.3. Risk-Based Decision Support System (DSS+R)

DSS is not a replacement of humans but it can give clues and recommendations in the chosen problem domain such as crime investigation. The recommendations for the decision-making processes in a DSS are important to help decision-makers such as in the risk analysis for a crime investigation. DSS can also be explained as a computerized system which is meant to help decision-makers in a variety of fields and it is already being applied especially in problematic domains of social science and management. Data for risk analysis is also gained from domain experts through interviews and informal discussions. This is important for qualitative and quantitative analyses. The numerical values for weight of attributes for quantitative analysis will be obtained through questionnaires with controlled questions. This information is crucial for the analysis needs of the DSS and the results of its risk analysis.

Research work that involves risks decision analysis [6][7] has recently emerged. The only situation that seems to underestimate the capability of risk in decision making is the risk concept that has not been integrated as one of the main DSS components. Justification to show the significance of risk to be functioning as one of the main components in DSS is required. Current related research works that can be mentioned include decision country risk [10], decision risk AHP [11], risk ethical decision [12], risk financial decision [13], decision risk healthcare [14], and risk-based group decision-making [5]. If the risk concept is one of the main components, DSS would be more efficient since the DSS researchers do not need to do an analysis of the decision separately with its associated risks. Realizing this scenario, we propose the risk-based component as one of the DSS components besides the existing DSS components - knowledge base, model base, database, and user interface.

DSS aims to support decision-makers in a variety of fields using a computerized analysis. For example, the scenario in this case study. Perpetrators of fatal crimes will on occasion attempt to conceal their wrongdoings by burying the evidence that is, attempting to bury human cadavers. This
can be problematic during a forensic investigation for a number of reasons. Firstly, the search for a victim’s body may well be relatively blind, with investigators having little or no idea as to where a body has been buried. In some instances, a body may be so damaged or decomposed that very few recognizable human remains are present. The perpetrator may later remove the body from the burial site, perhaps fearing discovery, leaving behind no obvious trace that a body was ever buried there. Thus, what can investigators do to determine if an area of soil was the site of a clandestine grave (illicit burial site)? A number of methods have been developed to solve this question. All data needed will be supplied by forensic teams such as the police authority and selected hospitals. Therefore, the case study on detecting clandestine graves is chosen to demonstrate the applicability of the DSS+R framework which is to consider risk in the decision making and before any further actions are taken.

3. Methodology

Figure 1 shows the proposed framework for detecting human cadaver. The extraction of the sample soils as shown in the circle is the pH value of the soils, the soils redox reaction, and lipid extraction (C_{12}, C_{16}, C_{18}). For the next stage of the framework, the sample soil extraction is combined with multi risk that is collected from the suspected grave and the ambient temperature in that area.

This extraction collection is used to identify human biolipid that is present after a few stages of human decomposition. With the combination of the multi risk such as the weather condition, humidity and wind speed. Finally, all the criteria needed is transform into decision matrix by using TOPSIS algorithm. The decision matrix later is normalized to find the best results by calculated using equation in (1).

\[ v_{ij} = w_j r_{ij}, \quad i = 1, \ldots, m; j = 1, \ldots, n. \]  

Figure 1. Framework of DSS+R.
From normalized decision matrix, the algorithm will rank the possible result according to weighted and two separation values which is positive ($A^*$) and negative ($A^-$) as shown in equation (2) and (3).

\[ A^* = \{v_1^*, v_2^*, ..., v_i^*, ..., v_n^*\} = (\max_{j \in F_1} v_{ij} | j \in F_2) \mid i = 1, ..., m \]  \hspace{1cm} (2)

\[ A^- = \{v_1^-, v_2^-, ..., v_i^-, ..., v_n^-\} = (\min_{j \in F_1} v_{ij} | j \in F_2) \mid i = 1, ..., m \]  \hspace{1cm} (3)

Finally, the algorithm calculates the similarities between the results to find ideal result by using equation in (4).

\[ C_i^* = \frac{s_i}{s_i^* + s_i} \hspace{1cm} i = 1, ..., m \]  \hspace{1cm} (4)

Note that $0 \leq C_i^{\wedge \ast} \leq 1$, where $C_i^{\wedge \ast} = 0$ when $A_i = A^-$, and $C_i^{\wedge \ast} = 1$ when $A_i = A^*$.

3.1. Research Phases

The overall research methodology in this study is divided into 3 main phases:

3.1.1. Phase 1 (analysing research problems)

The first phase is to identify and analyze the potential risks and to combine the concept of risk and decision-making processes. There are various ways to integrate risk and decision-making processes. Researchers differ in their methodology or even definitions of approach as they have proposed and explained. The outcome or output of this phase is the state-of-art frameworks such as related works that have been documented by several researchers in this field [15] [16]. The analysis can be done using several techniques.

Statistical methods are discovered to be the most suitable representative techniques to demonstrate the applicability of the proposed new framework called DSS+R. Other methods that can also be employed if required are including but not limited to decision tree as in several related works [6][17], and Fault Tree Analysis [18][19]. Both of these works involve risk and decision elements in their analysis. This technique will be adopted in this study.

3.1.2. Phase 2 (designing and implementing the proposed framework)

The next phase of this research involves designing and implementing the proposed framework. Method chosen to be adopted for ranking is using a multi-criteria decision-making (MCDM) method known as the Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) where the risks that have been identified can be analyzed according to their weight of priorities. Further research is currently conducted in order to determine the most suitable methods by considering the statistical analysis.

The work by Ozturkoglu and Turker (2013) shows that the weight can be assumed if the criteria are categorical (yes or no, hence use 0 or 1) or similar weights can be used if it is assumed that all criteria are equally important in the analysis [20]. The output in this phase is a decision support system (DSS) that includes the risk-based component as proposed. This will reflect the applicability of the DSS+R framework proposed. Obtaining the correct likelihood ratio for the hypotheses based on available evidences may help in constructing Bayesian networks (BN) to represent the described problems.

3.1.3. Phase 3 (evaluate and validate the proposed DSS+R framework)

The final phase is to evaluate and validate the proposed DSS+R framework to demonstrate the concept depicted in the proposed DSS+R framework. One or more case studies are being considered for this
last phase, but as a start, detecting clandestine grave cases will be applied based on this new generic framework called the DSS+R. The improve DSS+R framework will contain further guidelines once applied and implemented for risk management in decision-making processes.

The framework is expected to illustrate the guidelines involving computerized decision-making and computerized risk analysis for DSS in the chosen problem domain, which is the crime investigation and detection of clandestine graves. In addition to the DSS+R framework, risk categorization is one of the expected outcomes to be included in the decision-making processes of DSS. Among the actions that can be taken is risk mitigation or risk removal. These are applicable in order to determine the rate, probability, or likelihood of risk impact for risk safety and risk of victimization in crime investigation.

4. System Prototype

System architecture and prototype was designed to implement the framework proposed in Figure 1. Figure 2 illustrates the architecture of the system that helps in determining a human clandestine grave.

![Figure 2. System Architecture](image)

The user will first select a soil site that forensic will need to set its criteria and risk by giving it a weightage in the range of 1 to 5 as shown in Figure 3. Criteria such as soil type, soil pH, soil temperature, extracted lipid concentration, and redox condition is already made available by the system. Risk is listed in the same manner as creating new criteria. Since the system is made to be dynamic, the criteria’s weightage can be changed to cater for different regions’ suitability.

![Figure 3. Setting Soil Sub-Criterion](image)
Then, the selection is made based on the criteria using the sub-criteria as shown in Fig. 4. The assigned weightage of the sub-criteria will affect the analysis made later.

![Figure 4. Setting Soil Criterion](image)

In case the practitioner wants to create new criteria, user will then need to list the sub-criteria for the criteria. Practitioners can create the sub-criteria for each of the criteria available by giving it a name and assigning its weightage as shown in Figure 4.

5. Conclusion
In conclusion, Risk-based Decision Support System (DSS+R) for Forensic Investigation in Detecting Human Cadaver of Clandestine Graves (CHAVET) helps the forensic technique practitioner in determining a human clandestine grave as well as making prioritization of the more probable crime site thus helping to save time in a search. The calculation of probability for a site is done with the TOPSIS decision support algorithm based on the weightage for criteria and risk for lipid biomolecular analysis of soil.

In terms of limitations of the system, this system does not have enough data to identify the most suitable and exact weightage for any particular region of the world where the site is located. Moreover, the risk analysis is made together with criteria analysis and however this works, it affects the probability for a site being a crime site exponentially compared to if it was calculated separately after the calculation of soil’s criteria. Furthermore, the system is only for searching and determining a human clandestine grave.

In future, this system should be improved by doing the risk analysis calculation separately after performing the criteria risk analysis calculation. The system should be tested in different parts of the world as some of the criteria’s weightage are not suitable when used in a different region of the world.

6. Acknowledgement
The authors would like to thank the Royal Police Malaysia (RPM) for its continuous support. This work is supported by a grant from the Fundamental Research Grant Scheme (FRGS) and the Ministry of Education (MOE) with the Vot number 59432.

References
[1] Harrendorf, S., Heiskanen, M., Malby, S.: International Statistics on Crime and Justice. Helsinki (2010).
[2] AE, L., KP, J., R, F., L, H.: Cadaver dog and handler team capabilities in the recovery of buried human remains in the southeastern United States. J. Forensic Sci. 48, 617–21 (2003).
[3] Schultz, J.J.: Sequential monitoring of burials containing small pig cadavers using ground penetrating radar. J. Forensic Sci. 53, 279–87 (2008).
[4] Schultz, J.J., Grasmueck, M., Weger, R., Muztaza, N.M., Saidin, M.M., Azwin, I.N., Saad, R., Kofun, H., Leucci, G., Giacomo, G. Di, Conyers, L.B., Leckebusch, J., Roman, A., Lukyanov, S.P., Stepanov, R.A., Stukach, O. V, Úrxqg, V.D.Q.G.F., Fxkn, P., Kn, H.G.X., Lukyanov, S.P., Stukach, O. V, Barone, P.M., Altunel, E.: Detecting Buried Remains Using Ground-Penetrating Radar. J. Archaeol. Sci. 36, 235 (2012).
[5] Chou, J.S., Ongkowijoyo, C.S.: Risk-based group decision making regarding renewable energy schemes using a stochastic graphical matrix model. Autom. Constr. 37, 98–109 (2014).
[6] Liu, Y., Fan, Z.-P., Zhang, Y.: Risk decision analysis in emergency response: A method based on cumulative prospect theory. Comput. Oper. Res. 42, 75–82 (2014).
[7] Liu, Y., Fan, Z.P., Yuan, Y., Li, H.: A FTA-based method for risk decision-making in emergency response. Comput. Oper. Res. 42, 49–57 (2014).
[8] Liu, Y.C., Tung, Y.C.: Risk analysis of pedestrians’ road-crossing decisions: Effects of age, time gap, time of day, and vehicle speed. Saf. Sci. 63, 77–82 (2014).
[9] Davies, G.J., Kendall, G., Soane, E., Li, J., Rocks, S.A., Jude, S.R., Pollard, S.J.T.: Regulators as agents: Modelling personality and power as evidence is brokered to support decisions on environmental risk. Sci. Total Environ. 466–467, 74–83 (2014).
[10] Li, J., Tang, L., Sun, X., Wu, D.: Oil-importing optimal decision considering country risk with extreme events: A multi-objective programming approach. Comput. Oper. Res. 42, 108–115 (2014).
[11] Ergu, D., Kou, G., Shi, Y., Shi, Y.: Analytic network process in risk assessment and decision analysis. Comput. Oper. Res. 42, 58–74 (2014).
[12] Fergusson, J.L.: Excessive risk exposure: A question of ethical decision-making. J. Bus. Res. 67, 2684–2685 (2014).
[13] Holper, L., Wolf, M., Tobler, P.N.: Comparison of functional near-infrared spectroscopy and electrodermal activity in assessing objective versus subjective risk during risky financial decisions. Neuroimage. 84, 833–842 (2014).
[14] Bai, X., Gopal, R., Nunez, M., Zhdanov, D.: A decision methodology for managing operational efficiency and information disclosure risk in healthcare processes. Decis. Support Syst. 57, 406–416 (2014).
[15] Noor, N.M.M., Ghazali, A.F., Saman, M.Y.M., Zainuddin, Z., Harun, M.I.H., Abdulllah, M.C.: Evolutionary Framework of a Decision Support System for Forensic DNA Analysis. Lect. Notes Softw. Eng. 2, 150 (2014).
[16] Noor, N.M.M., Harun, M.I.H., Ghazali, A.F.: Improved Algorithms for Data Visualization in Forensic DNA Analysis. Lect. Notes Softw. Eng. 2, 167–171 (2014).
[17] Marmier, F., Filipas Deniaud, I., Gourc, D.: Strategic decision-making in NPD projects according to risk: Application to satellites design projects. Comput. Ind. 65, 1107–1114 (2014).
[18] Demichela, M., Camuncoli, G.: Risk based decision making. Discussion on two methodological milestones. J. Loss Prev. Process Ind. 28, 101–108 (2014).
[19] Miniati, R., Capone, P., Hosser, D.: Decision support system for rapid seismic risk mitigation of hospital systems. Comparison between models and countries. Int. J. Disaster Risk Reduct. 9, 12–25 (2014).
[20] Janic, M., Reggiani, A.: An application of the multiple criteria decision making (MCDM) analysis to the selection of a new hub airport. Eur. J. Transp. Infrastruct. Res. 2, 113–141 (2002).