Bayesian Network Modelling in the Audit of Listed Companies: Optimising Evaluation Strategies and Mitigating Risks through Addressing Information Asymmetry

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Abstract: In the audit of listed companies, the reason why information asymmetry creates significant challenges for auditors, is because that it hinders their ability to fully grasp the true operational status of enterprises, which in turn may escalate audit risks. As a probabilistic tool for modelling uncertainty, Bayesian networks could offer the ability for the integration of multiple sources of information while dynamically updating risk assessments, presenting a novel approach to addressing the problem of information asymmetry in audits. This paper begins with an analysis of the interrelationships among audit variables, develops an audit evaluation model, which could be established on Bayesian networks, and explores the application mechanisms in optimising evaluation strategies, quantifying risk probabilities, and mitigating the impacts of information asymmetry. Furthermore, the paper highlights the advantages, which could be based on this model, in managing uncertainty, adapting dynamically, and integrating multidimensional risk factors, for the purpose of providing a theoretical foundation for enhancing the audit quality of listed companies.

***Keywords*:** Bayesian network; audit of listed companies; information asymmetry; risk assessment; probabilistic model

1. Introduction

As a critical component in ensuring the information integrity of the capital market, the effectiveness of audits conducted on listed companies directly influences investors' decision-making and the overall efficiency of market resource allocation. Bayesian Networks (BN), that include robust capability to model uncertain information and the strengths in probabilistic reasoning, may provide a novel pathway, which aims to solve the dilemma of information asymmetry in audits. Through the utilisation of a Directed Acyclic Graph (DAG), this model represents the causal relationships between variables, to quantify the strength of associations through a Conditional Probability Table (CPT). Which should be emphasised, is thatthe Bayesian network dynamically revises risk assessment outcomes as information is updated throughout the auditing process. This paper focuses on the modelling logic behind the use of Bayesian networks in the audit of listed companies, examining how they might optimise audit evaluation strategies and reduce risks induced by information asymmetry by integrating financial, nonfinancial, internal, and external data, thus offering theoretical support to auditing practices.

2. Construction of the Bayesian Network Model in the Audit of Listed Companies

2.1 Definition of the Audit Variable System

The primary challenge in applying Bayesian networks to the audit of listed companies lies in constructing a scientifically grounded audit variable system. Based on auditing standards and risk factors, the network node variables could be classified into four key elements. Basic risk variables focus on the inherent risks faced by enterprises, encompassing industry risks such as market competition intensity and policy sensitivity, corporate governance risks like equity concentration and the proportion of independent directors, as well as operational risks such as asset turnover rate and fluctuations in gross profit margin. Control variables assess the enterprise's ability to prevent risks, which include the pass rate of control tests, the rate of defect remediation, as well as the concurrent positions of the chairman and general manager, and the frequency of key position rotations, which are associated with the risk of management override. Misstatement risk variables are directly related to the core objectives of the audit, which could be subdivided into risks at the financial statement level, for instance, abnormal revenue recognition and related transaction proportions and assertion level risks, for example, inventory valuation accuracy and the recoverability of accounts receivable. Audit evidence variables could reflect the adequacy of information collection of the auditors, which include the coverage rate of substantive procedures, response rates to confirmation letters, and the depth of inspections of abnormal transactions. The selection of these variables strictly follows the principles of relevance and observability, for the purpose of ensuring that they could accurately reflect the audit risk status[1].

2.2 Topological Design of the Network Structure

The construction of the Bayesian network's topological structure requires an accurate mapping of the causal relationships between variables, employing a hybrid approach of "expert experience + data learning". The network may be designed with a three-layer structure. The first layer, that consists of root nodes, incorporates basic risk variables, which could be considered as the fundamental causes of audit risks. The second layer, that contain intermediate nodes, includes the control variables and misstatement risk variables. The basic risk variables are likely to be impacts of control variables, which might also have a reverse effect on misstatement risk variables. The third layer, consisting of leaf nodes, uses audit evidence variables as outputs, with their probability distributions jointly affected by misstatement risks and audit procedure design. During the structure construction, methods such as conditional independence tests and BIC scoring are utilised to verify the model's rationality, ensuring that each node's parent nodes are directly linked to relevant variables, thereby eliminating extraneous interference factors. This guarantees that the network structure aligns closely with audit logic and provides a reliable framework for risk assessment[2].

2.3 Parameter Estimation of Conditional Probability Tables

The conditional probability table is crucial for quantifying risk associations of Bayesian networks. The estimation of its parameters might be through a combination, that could be constructed on comprehensive methods of both historical audit data and expert judgement. For variables with ample historical data, such as the probability of abnormal inventory turnover rates and the rate of control test defects, maximum likelihood estimation or Bayesian estimation is employed to calculate conditional probabilities. For instance, by analysing audit data from listed companies in a specific industry over the past five years, the frequency of revenue misstatements under specific conditions could be computed. For variables with sparse data, such as the risk of management override, the Delphi method is applied, where senior auditors score the probability distribution of child nodes under various parent node states, and parameters are determined through consistency tests. Simultaneously, variable states are discretized to simplify computational complexity, and sensitivity analysis is performed to assess the impact of parameter changes on network outputs, which aims to define that the model remains robust and reliable.

3. Optimisation of Audit Evaluation Strategies Based on Bayesian Networks

3.1 Dynamic Risk Assessment Mechanism

Bayesian networks facilitate dynamic risk assessment by updating posterior probabilities, thereby optimising the allocation of audit resources. During the audit planning phase, prior probabilities could be determined using historical data and industry benchmarks to identify high-risk nodes, for example, for companies with a "related transaction ratio > 50%", the prior probability of "misstatement risk" is significantly higher than the industry average. During the implementation phase, when audit evidence, for instance, "abnormal responses to confirmation letters", is input, the model may automatically update the posterior probabilities of relevant nodes and adjust the risk ranking accordingly[3].

3.2 Quantitative Compensation for Information Asymmetry

Bayesian networks could decrease the impact of information asymmetry through the "probabilistic processing of missing information". For private information that cannot be directly obtained, such as undisclosed related party transactions, the model treats it as a latent variable and infers its probability distribution, which might depend on observable variables. For example, through the implementation of observable nodes, which includes "abnormal sales expense rate" and "mismatch between cash flow and income", the model might infer the existence probability of "undisclosed related transactions" in reverse, compensating for the lack of information available to auditors.

4. Advantages of Bayesian Networks in Audit Risk Mitigation

4.1 Accurate Quantification of Uncertainty

In contrast to traditional audit methods that could be established on qualitative risk classifications of "high/medium/low", Bayesian networks quantify risks by applying probability values, for instance, "the risk of material misstatement in financial statements is 12.3%", which supply a more precise basis for audit decisions. This ability, which aims to quantify risks, allows auditors to establish clear risk thresholds, for example, implementing additional procedures when misstatement risk exceeds 15%, which might decrease subjective judgement deviations, particularly in scenarios with incomplete information. Through the description of uncertainty by probability distributions, Bayesian networks prevent extreme decisions, which may be driven by information loss.

4.2 Systematic Capture of Variable Associations

Audit risks in listed companies arise from the interaction of multiple factors, for example, the combined risk of "industry downturn + internal control failures + aggressive management". It would be quite difficult to identify the synergistic effects among variables, through the traditional methods. Bayesian networks, however, systematically describe both direct and indirect associations between variables using topological structures and conditional probability tables, for instance, the risk transmission path of "equity concentration" → "internal control failure" → "asset misstatement". Thus, it is possible for auditors to identify risk transmission chains, for the purpose of the development of targeted preventive and control measures.

4.3 Balance between Dynamic Adaptability and Interpretability

Different from black-box machine learning models, for example, neural networks, the topological structure of Bayesian networks visually presents risk transmission paths, which could provide useful interpretability, which aligns with the "audit trail traceability" requirement in auditing standards. At the same time, the network's probability update mechanism supports the real-time incorporation of new information, with the adaptation of dynamic changes in enterprise operations and market environments. This is particularly advantageous in auditing emerging industries characterised by high levels of information asymmetry.

5. Conclusion

Bayesian networks make it feasible to create a systematic solution to the issue of information asymmetry, which could be through the construction of a probability-based association model for audit variables, in the audit of listed companies. The core value of this approach may lie in mapping out risk transmission paths, which are established on topological structures, quantifying the strength of variable associations with conditional probabilities, and dynamically updating risk assessments through probabilistic reasoning to achieve precise optimisation of audit strategies. Compared to traditional methods, the advantages of this model in uncertainty quantification, multifactor association capture, and dynamic adaptability could significantly reduce the risks, which might be associated with incorrect acceptance and efficiency losses, that may result from information asymmetry.

Future research may expand more in-depth the application scenarios of this model, including the integration with big data technologies, for the purpose of accuracy escalation of parameter estimation or introducing time series Bayesian networks, aiming to capture the dynamic evolution of risks. It is essential to enhance the understanding and application for auditors of probabilistic modelling, in audit practice, which could facilitate the transformation, that is based on Bayesian networks from theoretical models to practical tools, with the supply of technical support for the improvement of audit quality and the stability maintenance of the capital market, for listed companies.

References

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