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Predicting Retail Failure using Bayesian Networks: A Case Study of Tesco

Abstract: This study develops and evaluates a Bayesian Network model to predict the probability of failure of Tesco. The model considers various financial ratios and environmental factors that influence the retailer's performance and risk. The results show that the model can help managers and decision-makers assess and prevent retail failure.
Keywords: Retail failure, Bayesian Network, Tesco

Introduction

Retail corporations operate in a fiercely competitive and dynamic milieu where triumph hinges on a myriad of factors including geographical location, supply chain management, and economic conditions. Nevertheless, the collapse of a retailer is primarily the result of a conglomerate of internal and external factors, making it arduous to forecast. Hence, it is vital to devise a predictive model to assess the probability of failure of a retail entity.

Bayesian Networks (BNs) are a probabilistic graphical model that provides a comprehensive method of modeling intricate systems, while accounting for various variables and dependencies. The utilization of BNs has gained widespread application in a plethora of fields to facilitate prediction, diagnosis, and decision-making.

In this research, we endeavor to construct a simple BN model to prognosticate the likelihood of failure of a retailer, particularly Tesco. The formulated model will be executed using GeNIe software and scrutinized using pertinent evidence.

Literature Review

Bayesian Networks (BN) have been extensively employed in a sundry of fields such as operational research, production planning, and transportation research. For instance, in operational research, BNs have been utilized to make decisions in supply chain management, quality control, and risk assessment (Druzdzel & Flynn, 2003). BNs have also acted as a tool for optimizing production processes, managing inventory, and predicting machine failure in production planning (Duarte et al., 2020).

Over the past few years, numerous studies have proposed diverse BN models to prognosticate facility failure. For example, Wu et al. (2017) developed a BN model to predict the likelihood of failure in a logistics hub. Similarly, Wang et al. (2016) employed a BN model to evaluate the reliability of a distribution system in a hub and spoke network.

Furthermore, other studies have proposed hybrid models that combine BNs with other techniques like fuzzy logic and decision trees. For example, Alquthami et al. (2020) proposed a hybrid model that merges BNs with fuzzy logic to predict the likelihood of failure in a hub and spoke network.

Model Description

(1) Geographical Location/Region: The BN was created for Tesco, a retail organization with its headquarters in the UK and over 6,500 stores worldwide, operating in various geographic locations.
(2) Hypothesis of Interest: The hypothesis being tested is that the failure of Tesco is dependent on various factors, including both external (economic conditions and market competition) and internal factors (company's financial ratios).
(3) Problem Domain: The variables comprising the problem domain (Table 1) were identified based on pertinent literature and expert opinions (see Beaver, 1966; (Pahwa, 2004; Maricica and Georgeta, 2012; Lakshan and Wijekoon, 2013; Potential Causes of Failures of EIA (Environmental Impact Assessments) in Ensuring Sustainability, 2020).

Table 1: Variables chosen and prior probability set for each state

Variable Name	States	Prior Probability
Current Asset	Poor	0.3
	Wealthy	0.7
Current Liability	Low	0.65
	High	0.35
Liquid Assets	Low	0.33
	High	0.67
Cash Flow	Low	0.21
	High	0.79
Interest Expense	Low	0.32
	High	0.68
EBIT	Low	0.54
	High	0.46
Economic Conditions	Bad	0.77
	Good	0.23
Competition	Not_fierce	0.39
	Fierce	0.61
Revenue	Low	0.3
	High	0.7
Profit	Low	0.4
	High	0.6
Total Liability	Low	0.65
	High	0.35
Total Assets	Poor	0.33
	Wealthy	0.67
Equity	Poor	0.49
	Wealthy	0.51
Inventory	Poor	0.19
	Wealthy	0.81
Cost of Sales	Low	0.11
	High	0.89
Payable	Low	0.22
	High	0.78
Net Credit Purchases	Low	0.35
	High	0.65

(4) Relationship between Variables: The BN was established based on the causal and influential relationship between variables. For instance, profit margin is calculated by profit and revenue, which can subsequently impact the profitability ratios, thus affecting the likelihood of the retailer's failure.

(5) Prior and Conditional Probabilities: The prior probabilities were estimated using historical data and expert opinions. The conditional probabilities were evaluated using the qualitative explanation approach proposed by Daniel et al. (2003). We set the threshold values for strong, medium, and weak relationships as 0.98, 0.8, and 0.6, respectively. The base value and weight value were calculated based on these threshold values, and the conditional probability table (CPT) was generated accordingly.

(6) Implementation: GeNIe, a software tool for modeling and inference of BNs, was used to

implement the BN model. Sensitivity analysis was then conducted to evaluate the robustness of the model.

Computational results and analysis

Our BN model for predicting the failure of Tesco considers various financial ratios and environmental factors. Based on expert opinions and surveys, we estimate the prior probability of failure for the retailer to be around 40%.

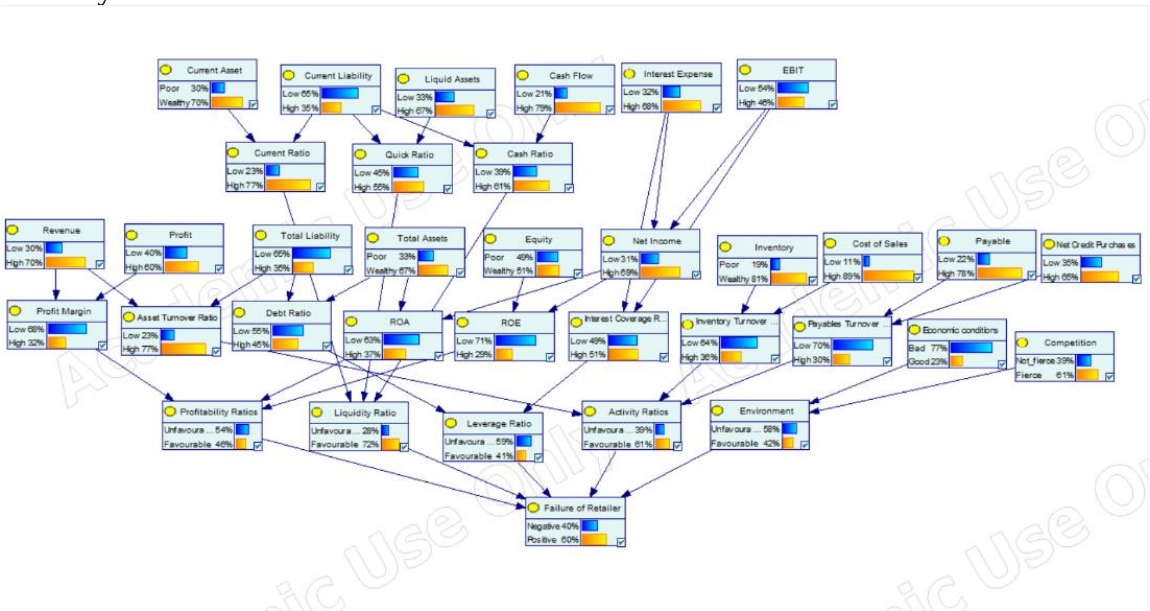

Figure 1: Bayesian Network for predicting the failure of Tesco

Each variable specified in the BN model is assumed to have a strong relationship with the final failure status of the retailer. For instance, a ratio with two variables having strong influential relationships would have a conditional probability table (CPT) like Table 2.1.

Table 2.1: CPT of 2 parent nodes case (Qualitative Explanation Approach by Daniel et al., 2003)

Numerator	Low		High	
Denominator	Low	High	Low	High
Low	0.26	0.98	0.02	0.26
High	0.74	0.02	0.98	0.74

For nodes that have three parent nodes, such as the profitability ratio, its parent nodes include ROA, ROE, and Profit Margin, and its CPT is shown in Table 2.2.

Table 2.2: CPT of 3 parent nodes case (Example: profitability ratio)

ROA	Low				High			
ROE	Low		High		Low		High	
Profit Margin	Low	High	Low	High	Low	High	Low	High
Unfavourable	0.98	0.451	0.451	0.235	0.451	0.235	0.235	0.019
Favourable	0.02	0.549	0.549	0.765	0.549	0.765	0.765	0.981

Our computational results demonstrate that profitability ratios, liquidity ratios, leverage ratios, activity ratios, and environmental factors collectively impact Tesco's final failure status (see Table 2.3 and 2.4). Furthermore, we find that only the debt ratio has a negative impact on the leverage ratio, which, in turn, adversely affects the facility's failure.

Table 2.3: CPT illustrating the overall effect of Tier 3 variables

Profitability Ratios	Unfavourable								Favourable							
Liquidity Ratio	Unfavourable				Favourable				Unfavourable				Favourable			
Leverage Ratio	Unfavourable				Favourable				Unfavourable				Favourable			
Environment	Unfavourable		Favourable		Unfavourable		Favourable		Unfavourable		Favourable		Unfavourable		Favourable	
Activity Ratios	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable
Negative	0.98	0.644	0.644	0.488	0.644	0.488	0.488	0.332	0.644	0.488	0.488	0.332	0.488	0.332	0.332	0.176
Positive	0.02	0.356	0.356	0.512	0.356	0.512	0.512	0.668	0.356	0.512	0.512	0.668	0.512	0.668	0.668	0.824

Table 2.4: CPT (continued)

Profitability Ratios	Favourable															
Liquidity Ratio	Unfavourable								Favourable							
Leverage Ratio	Unfavourable				Favourable				Unfavourable				Favourable			
Environment	Unfavourable		Favourable		Unfavourable		Favourable		Unfavourable		Favourable		Unfavourable		Favourable	
Activity Ratios	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable	Unfavour...	Favourable
Negative	0.644	0.488	0.488	0.332	0.488	0.332	0.332	0.2025	0.488	0.332	0.332	0.176	0.332	0.176	0.176	0.02
Positive	0.356	0.512	0.512	0.668	0.512	0.668	0.668	0.7975	0.512	0.668	0.668	0.824	0.668	0.824	0.824	0.98

Sensitivity Analysis

For the BN model of Tesco's failure, we categorized the variables and ratios into three tiers based on the number of levels for parent nodes and their proximity to the failure node, specifically Tier 1, Tier 2, and Tier 3 (refer to Table 3.1, 3.2, and 3.3).

Table 3.1: Change of Probability of Failure after Evidence-setting (Tier 1)

Variables	Status	Probability of Failure	Delta
Current Asset	Poor	41	-1
	Wealthy	39	1
Current Liability	Low	37	3
	High	44	-4
Liquid Assets	Low	41	-1
	High	39	1
Cash Flow	Low	41	-1
	High	39	1
Interest Expense	Low	37	3
	High	41	-1
EBIT	Low	42	-2
	High	37	3
Revenue	Low	39	1
	High	40	0
Profit	Low	41	-1
	High	39	1
Total Liability	Low	37	3
	High	44	-4
Total Assets	Poor	40	0
	Wealthy	39	1
Equity	Poor	41	-1
	Wealthy	38	2
Inventory	Poor	37	3
	Wealthy	40	0
Cost of Sales	Low	41	-1
	High	39	1
Payable	Low	38	2
	High	40	0
Net Credit Purchases	Low	41	-1
	High	39	1

Table 3.2: Change of Probability of Failure after Evidence-setting (Tier 2)

Variables	Status	Probaility of Failure	Delta
Current Ratio	Low	46	-6
	High	38	2
Quick Ratio	Low	43	-3
	High	36	4
Cash Ratio	Low	44	-4
	High	37	3
Net Income	Low	39	1
	High	40	0
Profit Margin	Low	41	-1
	High	37	3
Asset Turnover Ratio	Low	45	-5
	High	38	2
Debt Ratio	Low	36	4
	High	43	-3
ROA	Low	41	-1
	High	38	2
ROE	Low	41	-1
	High	36	4
Interest Coverage Ratio	Low	44	-4
	High	36	4
Inventory Turnover Ratio	Low	41	-1
	High	37	3
Payables Turnover Ratio	Low	41	-1
	High	37	3
Economic Conditions	Bad	42	-2
	Good	33	7
Competition	Not_fierce	34	6
	Fierce	43	-3

Table 3.3: Change of Probability of Failure after Evidence-setting (Tier 3)

Variables	State	Probability of Failure	Delta
Profitability Ratios	Low	46	-6
	High	31	9
Liquidity Ratios	Low	52	-12
	High	35	5
Leverage Ratios	Low	46	-6
	High	30	10
Activity Ratios	Low	50	-10
	High	33	7
Environment	Low	46	-6
	High	30	10

As per Table 3.3, among all the ratios, we found that liquidity ratios (Tier 3) have the most significant impact on the probability of failure. This outcome aligns with real-world practices where cash flow and liabilities play vital roles in determining a company's financial health. Specifically, if the liquidity ratio is low, the likelihood of failure will increase by 12%, from

40% to 52%.

Moreover, our analysis identified the current ratio (Tier 2) as the most critical liquidity ratio to consider, as it measures a company's ability to cover its current liabilities by using its current assets. Table 3.2 indicates that a low current ratio would increase the failure probability by 6%, from 40% to 46%.

In the Tier 1 scenario (Table 3.1), we highlight liabilities (including current and total liability) as the most critical factor in determining the probability of Tesco's failure. Both current and total liability could increase the probability of failure by 4%, which is concerning, particularly in situations with poor cash flow.

Moreover, our results demonstrate that economic conditions and competition (Tier 2) have a non-negligible impact on the BN model, as they are components of the environment variable (Tier 3). Their degrees of influence are 7% and 6%, respectively, when the economic condition is good and the competition level is not fierce, which has a positive effect on the business overall.

Conclusion

In this study, we have developed a simple Bayesian Network model to predict the probability of failure of a retailer, specifically Tesco. The model considers various financial ratios and environmental factors that influence the retailer's performance and risk. We have implemented the model using GeNIe software and evaluated its robustness using sensitivity analysis. Our results show that profitability ratios, liquidity ratios, leverage ratios, activity ratios, and environmental factors have a collective impact on Tesco's final failure status. The model can be used by managers and decision-makers to assess the likelihood of failure of a retailer and take preventive measures accordingly. However, the prior and conditional probabilities used in this study are based on historical data and expert opinions, which may not reflect the current or future situation of Tesco or other retailers. Therefore, further research is needed to refine and validate the model using more recent and reliable data sources as well as incorporating other relevant factors into the analysis.

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