Bayesian Network-based Analysis of the Causes of Crowding in College Cafeterias

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Abstract. In order to address the crowding problem in college cafeterias, this paper classifies and summarizes the factors that may cause the crowding in college cafeterias by reviewing a large amount of related literature, establishes a fault tree model of the crowding in college cafeterias on this basis, and transforms it into a Bayesian network to construct a Bayesian network model of the crowding in college cafeterias. Then, we collect the case data of students' opinions about the cafeteria crowding event in Dalian Maritime University by conducting a questionnaire survey and normalizing them, and use the two-way inference function of Bayesian network to calculate the influence degree of each influencing factor on the cafeteria crowding event in colleges and the importance degree of each influencing factor when the cafeteria crowding event occurs. Finally, we find that the short meal service time, few cafeteria stores, insufficient cafeteria staff, low level of informatization and serious seat occupation problem are the five key factors that are most likely to lead to the occurrence of cafeteria crowding events.

Keywords: College cafeteria crowding events; Bayesian networks; Fault Tree Analysis; Influencing factors.

1. Introduction

For college students who come out of their homes to campus, eating becomes particularly important. With its affordable prices, safety and health, and a wide variety of advantages, college cafeterias have come to be the first choice of students and teachers' dining.

As a special kind of dining environment, college cafeterias actually have a large and single consumer population. According to the relevant data of the National Bureau of Statistics, the number of students receiving general higher education in China has increased significantly in recent years, and by 2021, the number of students in general higher education schools has reached 34.961 million. And the consumption crowd of college cafeterias is relatively single, mainly teachers and students with high consumption demand, which brings challenges to the service quality and resource allocation of college cafeterias. In addition, the consumption time and space in college cafeterias are concentrated, and a large number of people will rush into the cafeterias during the peak of meal time, so it is difficult to avoid the situation of crowding. Especially under the background of normalization of pandemic prevention and control, if the college cafeteria is crowded with a large number of people gathering and poor air circulating for a long time, it will further increase the risk of virus transmission and cause serious consequences. As a result, long queues and insufficient seating in the cafeteria have always been a problem for schools and cafeteria managers.

The smooth operation of college cafeterias is directly related to the vital interests of schools, students and cafeteria vendors. The long-term development of the school is inseparable from the support of the cafeteria logistics system. The physical and mental health of students is inseparable from the daily meals of the cafeteria, and the economic benefits of the cafeteria business are also closely related to the operation of the cafeteria. By analyzing and studying the causes of crowding in college cafeterias, constructive suggestions and references can be provided for solving the problem, which can help create a more comfortable and fast dining environment, help students save time in the dining queue, improve their happiness in campus life and put them into a better state to study, thus promoting the long-term sustainable development of colleges and universities. At the same time, it is of great significance to improve the operational efficiency of college cafeterias and increase the business income of cafeterias.

2. Review of the Literature

The purpose of this paper is to analyze the causes of college cafeteria crowding by using a combination of fault trees and Bayesian networks. The following research results are introduced from two aspects, college cafeteria crowding events, and the application of fault trees and Bayesian networks in academia.

At present, most scholars in China mainly regard the dining process in college cafeterias as a queuing problem and study how to use queuing theory and related technologies to improve the crowding problem in cafeterias. Liu, Gao, et al. (2020) used the queuing theory to establish the queuing model of the cafeteria during the peak period, and the modeling was carried out by using Flexsim system simulation. They also applied the theoretical knowledge of industrial engineering such as facility layout and process optimization, and proposed to set up a zigzag queuing lane to alleviate the congestion in the cafeteria during peak hours. Deng, Hou, et al. (2019) conducted field survey and used color Petri network to model and simulate the cafeteria queuing system, and showed that the simulation results can be used to provide dynamic prediction analysis of the queuing situation for the management of the cafeteria, so as to manage and control the cafeteria windows more conveniently and visually, maximize the utilization of the cafeteria queuing system, and solve the problem of cafeteria queuing congestion. Cao & Gu (2020) took Shanghai University of Electric Power as an example, analyzed and modeled the existing queuing system situation of the university using queuing theory. They also examined and pointed out that the queuing problem and aisle congestion could be improved by combining the relational table method and Flexsim simulation software to combine the optimization method to improve the service quality by merging the meaningless functional areas, utilizing the extra space, and adjusting the cafeteria window arrangement.

Some scholars study how to use intelligent and informative means to transform the traditional cafeteria operation mode, so as to improve the operation efficiency of cafeterias and avoid the occurrence of cafeteria crowding incidents. Chen (2019) thought that, with the advent of the era of big data, the traditional campus cafeteria services can no longer meet the needs of consumers. She then discussed the use of intelligent tools and means such as WeChat app and RFID technology to achieve intelligent cafeteria management to solve the problems of crowded queues and serious food waste in traditional college cafeterias from three aspects, namely, system requirement analysis, platform general architecture design and feasibility analysis. Zhou, Jin & Zheng (2017) proposed an intelligent checkout system based on RFID technology from the perspective of fast completion of checkout and accelerating the efficiency of queuing for meals. By implanting RFID radio frequency chips at the bottom of each matching tableware, implanting card readers in the checkout area, and using tags, readers and antennas to collect and analyze data, and using multi-tag anti-collision algorithms in the computer to process the data, the manual checkout process is eliminated, and the number of servings and the price of the food are displayed directly on the display, thus effectively avoiding the crowded events in the restaurant during special hours.

With the increasing research, the past model of single-factor and multi-factor analysis to study the influencing factors of events has been gradually replaced by systematic causal analysis. Bayesian Network, proposed by Pearl, is a graphical network model that describes uncertainty dependencies between variables through directed acyclic graphs, and is a common method for modeling and reasoning about uncertainty systems. In recent years, Bayesian networks have been widely applied to the analysis of influencing factors. Min Zhang (2021) established a Bayesian model for fire risk analysis in university dormitories and verified the accuracy of the model using data from the past ten years, and concluded that illegal use of electrical appliances and smoking are the key factors leading to dormitory fires through backward inference analysis of nodes. Kim et al. (2017) used a quantitative method of safety culture assessment based on Bayesian networks to verify the causal relationship between workers' safety culture awareness and the safety status of nuclear power plants.

Bayesian networks can describe the polymorphism of events and the uncertainty of logical relationships by adjusting the network topology and the conditional probability table between nodes, but the construction of the network structure is more complicated. The fault tree analysis method proposed by H.A. Watson of Bell Telephone Laboratory can simplify the construction process of Bayesian network structure. Also, the two-way inference of Bayesian network can make up for the defect that the fault tree can only carry out one-way inference, so the combination of the two applications can achieve better results. Liu et al. (2022) constructed a comprehensive model based on fault tree and Bayesian network, and the model was used for inverse inference and sensitivity analysis of Bayesian network to accurately identify the causal factors and severity factors of highway accidents under snow and ice. P. Dong et al. (2019) used a combination of fuzzy fault tree and Bayesian network to analyze the causal factors and some key factors of the risk of fire accidents in high-rise buildings using the statistics of fire accidents in high-rise buildings over the years and the fuzzy probabilities given by experts.

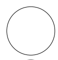
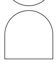
In summary, there is a lack of research on the systematic analysis of the causes of college cafeteria crowding in China, and the combination of fault tree and Bayesian network has a natural advantage in the study of uncertainty, especially in the analysis of the relationship between the causes of complex systems and their influencing factors. To this end, this paper summarizes and inducts the influencing factors of college cafeteria crowding events based on the study of a large amount of related literature and expert knowledge, analyzes the causal relationship between top events and basic events, constructs a top-down fault tree of college cafeteria crowding events, and further converts it into a Bayesian network model. By combining the data collected from the questionnaire survey, the structure learning and parameter learning of Bayesian network are carried out by Hugin software, and the probability of occurrence of the top event and the posterior probability of the basic event are calculated by Bayesian network and its forward risk prediction and backward inference diagnosis functions. Finally, according to the results of the model, the key factors causing the crowding events in college cafeterias are derived, and the corresponding measures and references are given for the management of college cafeterias.

3. Overview of the Basic Model

3.1 Fault Tree Model

A fault tree analysis method is a tree graph that represents the causal and logical relationships between the factors that lead to an event. A fault tree connects top events, intermediate events, and basic events using "with" and "or" logical relationships.

Table 1. Basic Symbols of a Fault Tree and Their Meanings

Symbol	Name	Meaning
	Top/ Intermediate Event	Top or intermediate event, or the consequence of the event
	Basic Event	A basic initiating failure fault, or cause of the event
	AND Gate	In an AND gate, the output event is positive if all input events occur.
	OR Gate	In an OR gate, the output event happens even if one of the input events occurs.

3.2 Bayesian Network Model

A Bayesian network is a directed acyclic graph consisting of nodes representing variables and directed edges connecting these nodes, which can be used to represent the dependencies between variables. The nodes represent random variables. In a Bayesian network, the node emitting the arrow is the parent node, the node pointed by the arrow is the child node, the root node has no parent node, the leaf node has no child node, and the remaining nodes are intermediate nodes. The directed edges connecting the nodes represent the interrelationship between the nodes. Each node has a corresponding conditional probability table to represent the probability of the quantitative dependency relationship existing between it and its parent node, and those without a parent node are expressed with their prior probabilities for information.

Suppose a Bayesian network with N nodes $BN = \{B_1, B_2, \ldots, B_N\}$, which consists of two parts, the network topology G and the local probability distribution of each node P, i.e.

$$BN =< G, P > \tag{1}$$

where the network topology G consists of the set of nodes B and the directed edges between nodes F , i.e.

$$G =< B, F > \tag{2}$$

If all parents of nodes B_i are $Par(B_i)$, and all non-offspring nodes are $Nos(B_i)$, then the local probability distribution of node P is equal to

$$P(B_i \,|\, Par(B_i), Nos(B_i)) = P(B_i \,|\, Par(B_i)) \tag{3}$$

According to the principle of independence, when a parent node is known and that node is conditionally independent of all its non-offspring nodes, the joint probability distribution of a Bayesian network is the probability of all possible combinations of states of multiple random variables $B_1, B_2, \ldots, B_N$, denotes as

$$\begin{aligned} P(B) &= P(B_1, B_2, \ldots, B_N) \\ &= \prod_{i=1}^{n} P(B_i \,|\, Par(B_i)) \end{aligned} \tag{4}$$

3.3 Transformation of Fault Trees to Bayesian Networks

When converting fault trees to Bayesian networks, the key is to complete the mapping between fault tree events and Bayesian network nodes, logic gates and Bayesian network probability distributions, as follows.

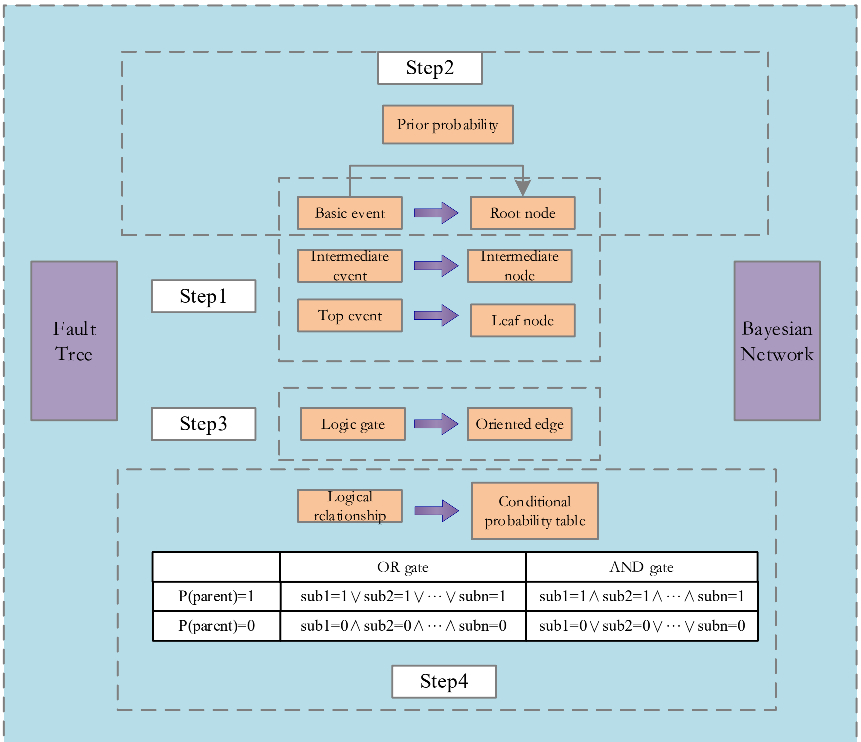


Figure 1. Flow Chart of the Conversion of Fault Tree to Bayesian Network

Convert the events in the fault tree one by one into the corresponding nodes in the Bayesian network, where the basic events in the fault tree model correspond to the root nodes in the Bayesian network, the intermediate events in the fault tree model correspond to the intermediate nodes in the Bayesian network, and the top events in the fault tree model correspond to the leaf nodes in the Bayesian network; if there are more than one identical events in the fault tree, only one node in the Bayesian network needs to be set a node.

The probability of occurrence of the basic events in the fault tree model is assigned to the corresponding root nodes in the Bayesian network as prior probability values.

Determine the directed edges between nodes using the logic gates in the fault tree.

The corresponding conditional probabilities are calculated based on the logical relationships of events in the fault tree model to obtain the conditional probability distribution table of the Bayesian network. Assuming that a state of 1 means that the event represented by the node occurs and a state of 0 means that the event does not occur, the rule with the gate transition is that the child node can be in state 1 only when all the parent nodes have a state of 1, otherwise the state of the child node is 0. The rule with the gate transition is that the state of the child node can be 0 only when all the parent nodes have a state of 0, otherwise the state of the child node is 1.

4. Building a Fault Tree-Bayesian Network Model for College Cafeteria Crowding Events

4.1 Identification of Factors Influencing Cafeteria Crowding Events in Colleges

Table 2. Factors Influencing Cafeteria Crowding Events

Category	Name	Source
Management Factors	Unreasonable setting of ordering windows	Huang et al. (2014)
	Unclear cuisines	Yang et al. (2015)
	Low utilization of cafeteria space	Zhou et al. (2019)
	Short meal service time	Huang et al. (2014)
	Insufficient logistical supervision of the cafeteria	Liu (2021)
Human Behavior	Low efficiency of cafeteria staff	Zhan (2011)
	Students' poor awareness of queuing	Li et al. (2015)
	On-site meal selection and long thinking time	Pan et al. (2021)
	Serious seat occupation problem	Zhang (2019)
Configuration Conditions	Few cafeteria stores	Huang et al. (2014)
	Insufficient dining tables and chairs	Zhou et al. (2019)
	Inflexibility of dining tables and chairs	Zhou et al. (2019)
	Relatively limited space at cafeteria	Zhou et al. (2019)
	Insufficient cafeteria staff	Zhan (2011)
	Low level of informatization	Chen (2019)
Realistic Conditions	Low price	Li et al. (2015)
	Health and wellness	Ma (2009)
	Tastiness and deliciousness	Ma (2009)
	Concentrated meal times	Huang et al. (2014)
	Large number of students and teachers	Wang et al. (2017)
	Encouragement of non-dine-in dining option	Yao (2020)
	Interval dining	Yao (2020)
	Temperature measurement in and out of the cafeteria	Yao (2020)

There are many factors that contribute to the crowding events in college cafeterias. For stance, Yang et al., after observing and investigating the problem of cafeteria crowding and using the queuing theory method to construct a model, they actually analyzed that the wrong queue of dining staff, wandering aimlessly and unclear cuisines are the key causes of cafeteria crowding. Huang et al. started from three stages of human nature, namely group nature, individual nature and class nature, to analyze the dining behavior in the cafeteria. It was concluded that the reasons for the disorderly dining and crowding in the cafeteria were the relatively concentrated dining time, the small range of choices available, and the unreasonable window settings and food availability. Zhan, in his study of students' expectations and perceptions of college cafeteria services, found that the most important thing students want to improve is the order of the cafeteria and reduce the waiting time, so he proposed the solutions of reasonable arrangement of staff, and reasonable layout of window locations to ensure the order of dining.

After analysis based on learning from a large number of available references and expert knowledge, the factors that cause crowding events in college cafeterias were grouped into four categories, management factors, human behavior, configuration conditions and realistic conditions, as shown in the following table.

4.2 Fault Tree of College Cafeteria Crowding Events

Combined with the basic principle of fault tree, the top events, intermediate events and basic events are effectively connected from top to bottom. Therefore, we obtained the fault trees, as shown in Figure 2 below.

Table 3. Fault Tree Base Node Labels and Names

Node Number	Node Name	Node Number	Node Name
$X1$	Few cafeteria stores	$X9$	Large number of students and teachers
$X2$	Students' poor awareness of queuing	$X10$	Concentrated meal times
$X3$	Low level of informatization	$X11$	Short meal service time
$X4$	Unclear cuisines	$X12$	Low efficiency of cafeteria staff
$X5$	Encouragement of non-dine-in dining option	$X13$	Relatively limited space at cafeteria
$X6$	Insufficient cafeteria staff	$X14$	Interval dining
$X7$	Unreasonable setting of ordering windows	$X15$	Inflexibility of dining tables and chairs
$X8$	Insufficient logistical supervision of the cafeteria	$X16$	Serious seat occupation problem

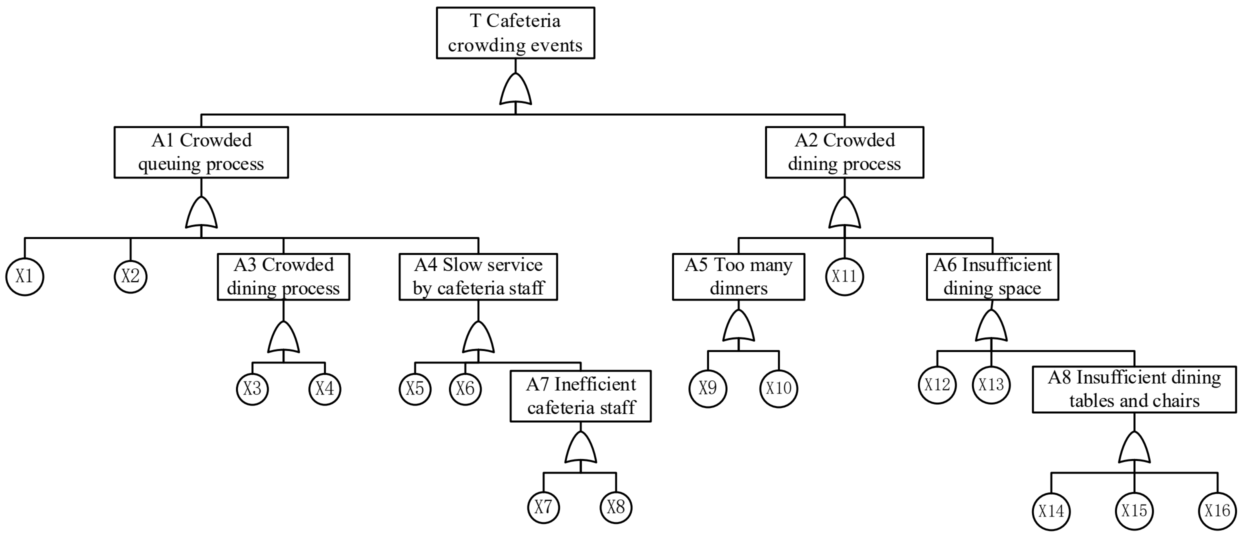


Figure 2. Fault Tree of Cafeteria Crowding Events in Colleges

4.3 Bayesian Network Model for Cafeteria Crowding Events in Colleges

After establishing the fault tree model of the college cafeteria crowding event, it can be transformed into the Bayesian network model, as shown in the figure below using the transformation principle.

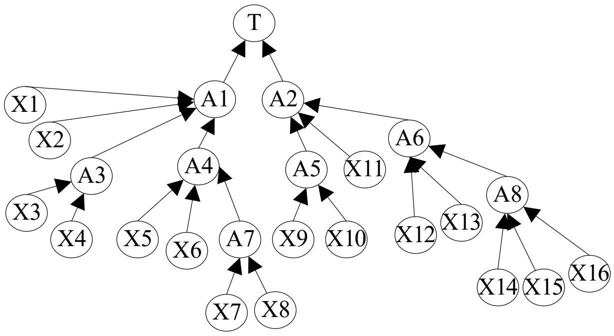


Figure 3. Bayesian Network Model of Cafeteria Congestion in Colleges

5. Data Sources and Data Processing

5.1 Data Sources

The data used in this paper is based on the opinions of the students of Dalian Maritime University about the crowding in the four cafeterias (Xinhai Cafeteria, the Fourth Cafeteria, the Fifth Cafeteria and the Central Cafeteria) of the Xishan Campus. The data was collected through questionnaires, which were distributed both online and offline, as well as in the most crowded places on campus. Finally, 298 valid questionnaires were collected.

5.2 Data Processing

4.2.1 Basic Information of Respondents

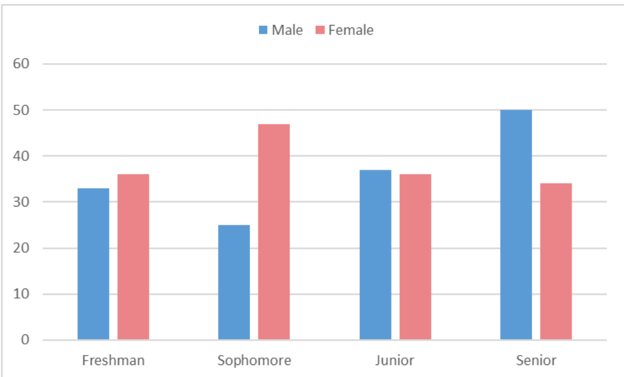


Figure 4. Bar Chart of Gender and Grade Distribution of Respondents

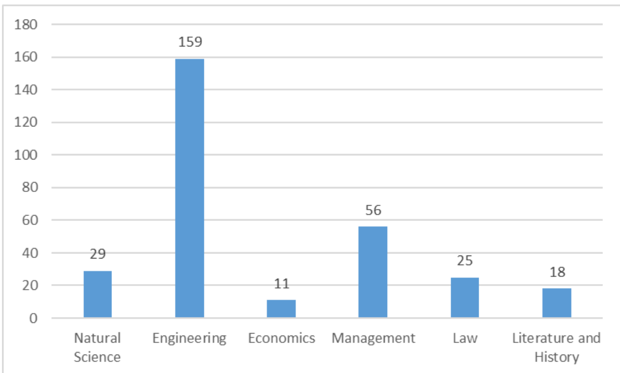


Figure 5. Bar Chart of Major Distribution of Respondents

The total number of people who received the questionnaire was 298. Among them, 145 were male, accounting for 48.66%, and 153 were female, accounting for 51.34%. Since the survey subjects are college students, the age group is mainly concentrated in 18-25 years old, accounting for 95.29%, of which 23.15%, 24.16%, 24.5% and 28.19% are freshmen, sophomores, juniors and to seniors respectively.

The survey results are more evenly distributed in terms of gender and grade, and each level is involved in the distribution of majors, ensuring a relatively good representation of the sample, providing a theoretical basis for the subsequent analysis and a higher degree of accuracy of the results when inferring the overall.

4.2.2 Surveys About Cafeteria Meals

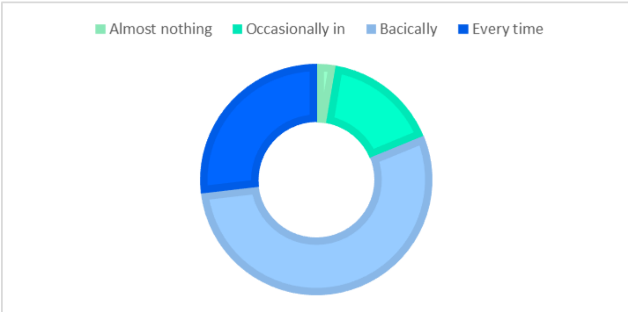


Figure 6. Doughnut Chart of the Frequency of Respondents Going to the Cafeteria for Meals

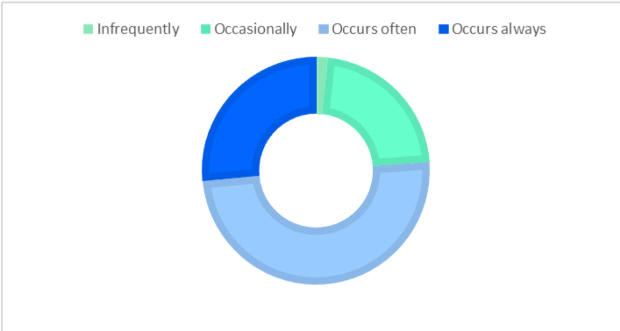


Figure 7. Doughnut Chart of the Frequency of Crowding Events in the Cafeteria as Perceived by the Respondents

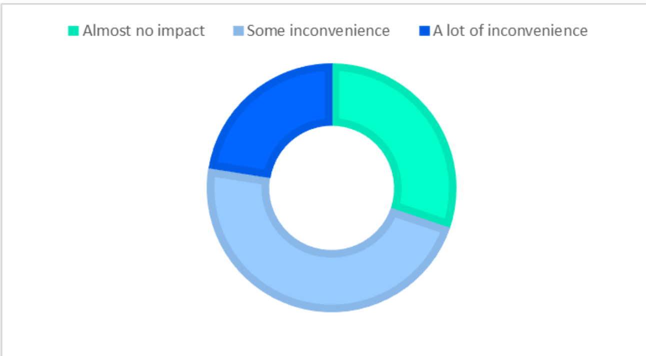


Figure 8. Doughnut Chart of Respondents' the Perceived Impact of Cafeteria Crowding Events on their Lives

Through the survey, it can be found that the percentage of those who dine in the cafeteria every time and those who basically dine in the cafeteria reached 81.21%, further indicating that the college cafeteria is an important place for students to dine. Meanwhile, 26.51% of the students said that crowding events in school cafeterias always happened, 49.66% said that crowding events in school cafeterias happened frequently, 22.15% thought that crowding events happened occasionally, and 1.68% thought that crowding events happened infrequently. In addition, 69.80% of the respondents said that the crowding events in the cafeteria brought inconvenience to their lives. Therefore, it is necessary to analyze the causes of crowding in the cafeteria with a systematic approach.

4.2.3 Investigation of the Causes of Cafeteria Crowding Events

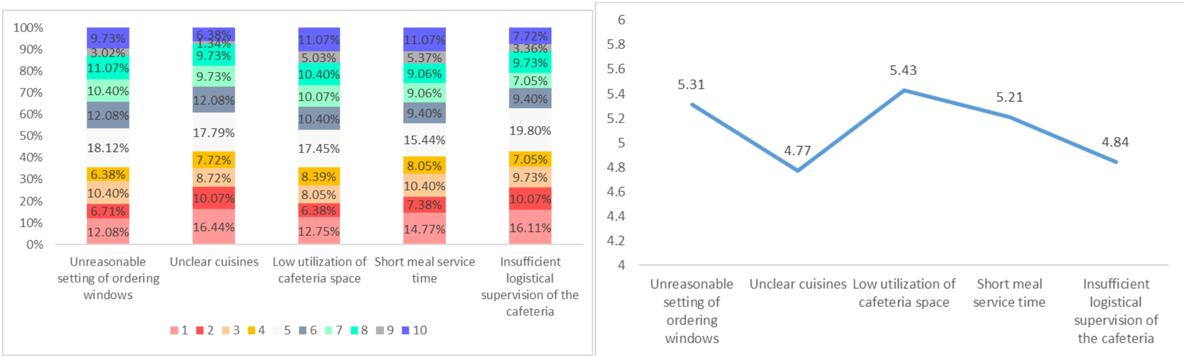


Figure 9. Stacked Graph of the Scores of Management Factors and the Line Graph of the Average Influence Degree

When analyzing the degree of influence of management factors on the crowding incidents in the cafeteria, the five factors given in descending order were: low utilization of cafeteria space, unreasonable setting of ordering windows, short meal service time, insufficient logistical supervision of the cafeteria, and unclear cuisines.

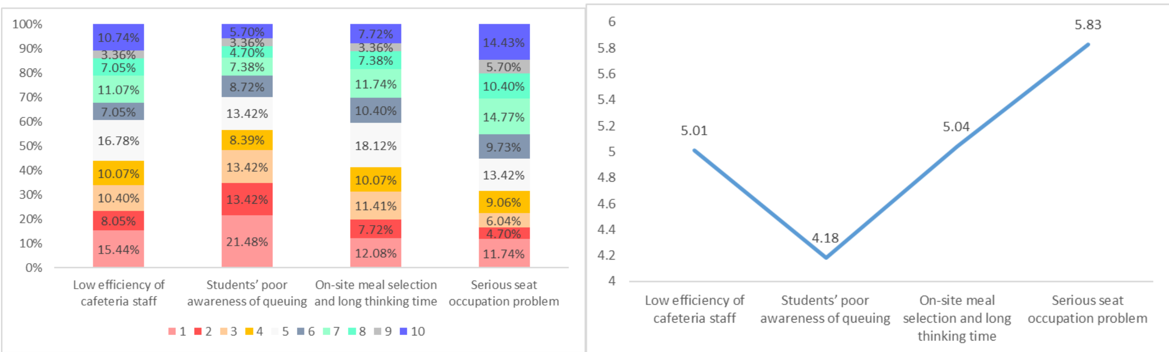


Figure 10. Stacked Graph of the Scores of Human Behavior Factors and the Line Graph of the Average Influence Degree

When analyzing the degree of influence of human behavioral factors on the crowding events in the cafeteria, the four factors given in descending order of influence were: serious seat occupancy problem, on-site meal selection and long thinking time, low efficiency of cafeteria staff and students' poor awareness of queuing up voluntarily.

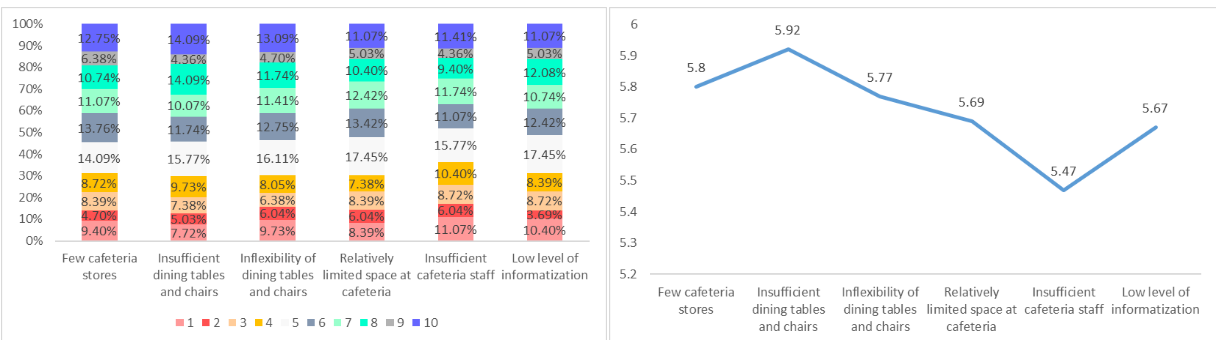


Figure 11. Stacked Graph of Scores of Configuration Conditions and the Line Graph of the Average Influence Degree

When analyzing the degree of influence of factors in terms of configuration conditions on crowding events in the cafeteria, the six factors given in descending order of influence were: insufficient dining tables and chairs, few cafeteria stores, inflexibility of dining tables and chairs, relatively limited space at cafeteria, low level of informatization, and insufficient cafeteria staff.

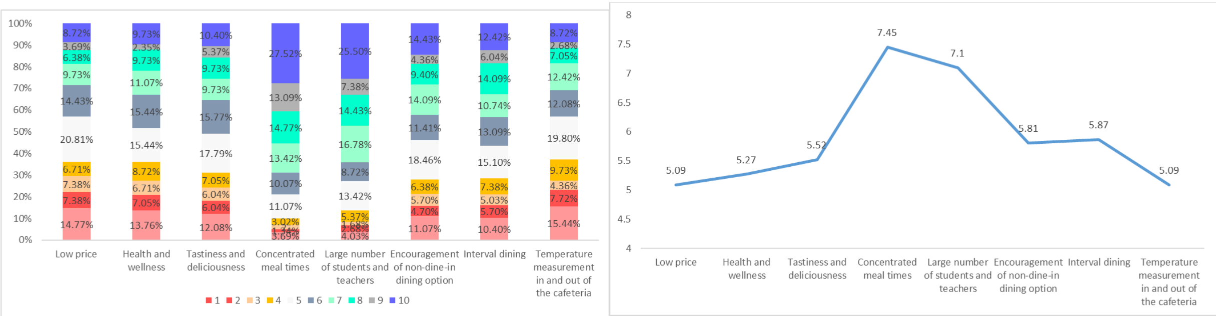


Figure 12. Stacked Graph of Scores of Realistic Conditions and the Line Graph of the Average Influence Degree

When analyzing the degree of influence of the realistic conditions on the crowding in the cafeteria, the eight factors given in descending order of influence are: concentrated meal times, large number of students and teachers, interval dining, encouragement of non-din-in dining option, tastiness and deliciousness, health and wellness, low price, and temperature measurement in and out of the cafeteria.

Based on the 298 case samples collected about the evaluation of the influence degree of a factor on the crowding events in college cafeterias, the average influence degree of the factor on the crowded events in cafeterias can be found = (influence degree rating × number of times that option was selected)/ number of valid responses. After obtaining the average influence degree of each factor on the crowding events in college cafeterias, it is scaled down equally to the range of 0-1 and converted into the prior probability values of the root nodes in the Bayesian network, as shown in Table 4 below.

Table 4. Prior Probability Values of the Root Nodes in Bayesian Networks

Node Number	**Node Name**	$P(X_i = 1)$	$P(X_i = 0)$
$X1$	Few cafeteria stores	0.58	0.42
$X2$	Students' poor awareness of queuing	0.418	0.582
$X3$	Low level of informatization	0.567	0.433
$X4$	Unclear cuisines	0.477	0.523
$X5$	Encouragement of non-dine-in dining option	0.581	0.419
$X6$	Insufficient cafeteria staff	0.547	0.453
$X7$	Unreasonable setting of ordering windows	0.531	0.469
$X8$	Insufficient logistical supervision of the cafeteria	0.484	0.516
$X9$	Large number of students and teachers	0.71	0.29
$X10$	Concentrated meal times	0.745	0.255
$X11$	Short meal service time	0.521	0.479
$X12$	Low utilization of cafeteria space	0.543	0.457
$X13$	Relatively limited space at cafeteria	0.569	0.431
$X14$	Interval dining	0.587	0.413
$X15$	Inflexibility of dining tables and chairs	0.577	0.423
$X16$	Serious seat occupation problem	0.583	0.417

6. Model Solving

A.The initial Bayesian network model is completed with the help of HUGIN software.

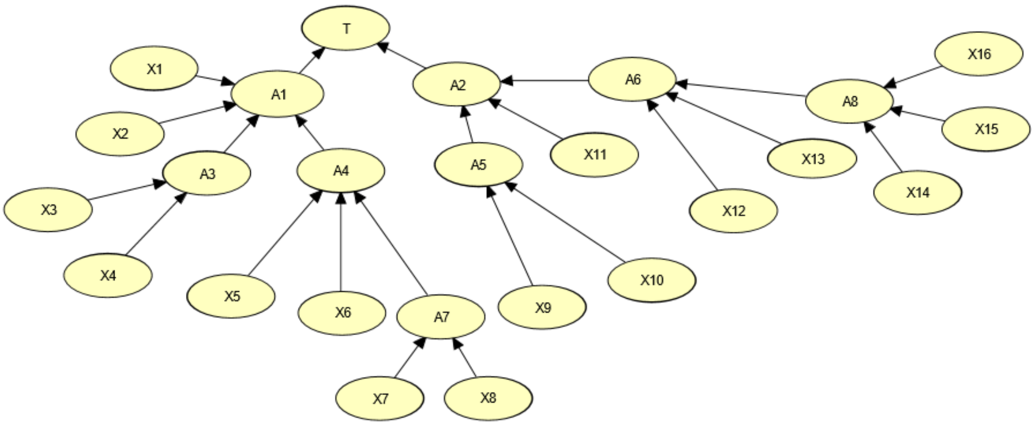


Figure 13. Initially-Built Bayesian network

B.Structure learning and parameter learning of Bayesian networks

After the initial Bayesian network is established, structure learning and parameter learning are required for the Bayesian network. Structure learning refers to finding the most appropriate Bayesian network topology by using known data and referring to a priori knowledge, where the NPC algorithm provided by Hugin software is used. After finding the optimal topology of the Bayesian network, parameter learning can be continued using the EM algorithm. For the root node in the Bayesian network, the data obtained in Section 4 (as shown in Table 4) is assigned to it as the conditional probability value, and for the intermediate layer nodes and top layer nodes, the software can be used to assign random values to them, and finally the probabilities of all nodes in the network can be obtained using parameter learning of the Bayesian network, as shown below.

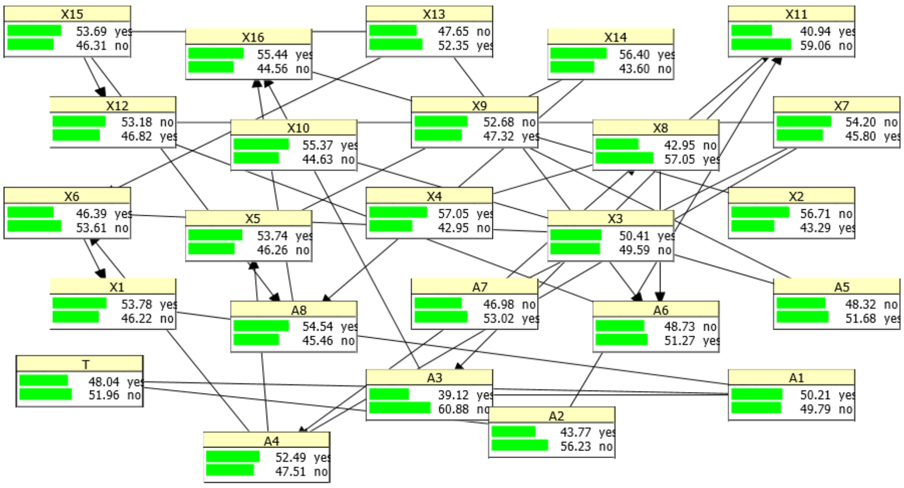


Figure 14. Results of Prior Probability Calculation in Bayesian Network Node

C.Inference in Bayesian networks

Forward risk prediction using Bayesian networks can predict the probability distribution of college cafeteria crowding events under the influence of each related factor, and analyze the degree of influence of each influencing factor on college cafeteria crowding events. By setting each node in the Bayesian network to 1, i.e., setting the occurrence of the factor represented by that node, the forward risk prediction of Bayesian network can calculate the probability of the college cafeteria crowding event occurring under the condition that the node occurs. For example, if the state of node X1 is set to 1, i.e., there are fewer cafeteria stores. It can be seen that the probability of occurrence of the node T, i.e., the college cafeteria crowding event, changes from 48.04% to 62.50% at this time. According to this analogy, the probability of occurrence of the college cafeteria crowding event is obtained when the state of each node in the network is set to 1. The final results are shown in Table 5.

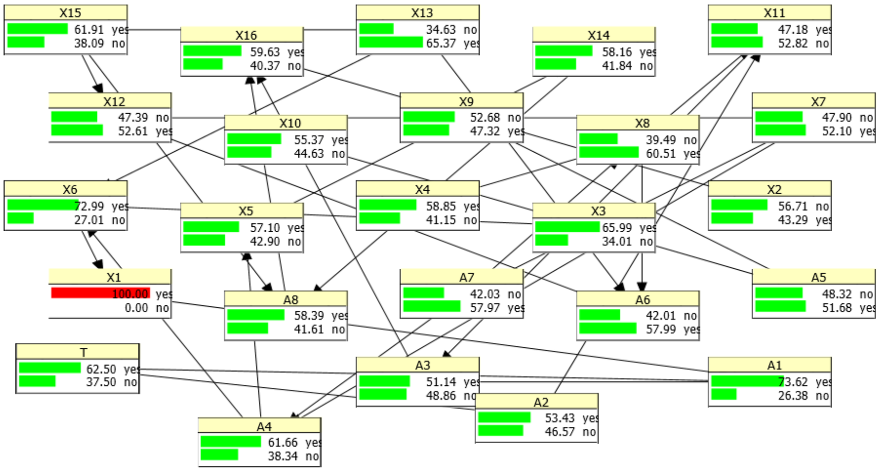


Figure 15. Set X1 Node to Represent the Node Probability Map of Bayesian Network When the Event Occurs

Table 5. Set the Probability of Occurrence of Crowding Events in College Cafeterias When Each Node Occurs

Node Name	T College Cafeteria Crowding Events	$A1$ Crowded Queuing	$A2$ Crowded Dining
$X1$ Few cafeteria stores	62.50%	73.62%	53.43%
$X2$ Students' poor awareness of queuing	48.04%	50.21%	43.77%
$X3$ Low level of informatization	53.24%	58.63%	47.24%
$X4$ Unclear cuisines	48.57%	51.07%	44.12%
$X5$ Encouragement of non-dine-in dining option	49.09%	51.91%	44.97%
$X6$ Insufficient cafeteria staff	67.69%	70.83%	50.21%
$X7$ Unreasonable setting of ordering windows	50.35%	53.95%	45.31%
$X8$ Insufficient logistical supervision of the cafeteria	49.06%	51.86%	44.45%
$X9$ Large number of students and teachers	48.04%	50.21%	43.77%
$X10$ Concentrated meal times	48.04%	50.21%	43.77%
$X11$ Short meal service time	71.16%	54.87%	77.64%
$X12$ Low utilization of cafeteria space	63.12%	45.16%	73.58%
$X13$ Relatively limited space at cafeteria	52.22%	56.98%	46.56%
$X14$ Interval dining	48.56%	51.56%	44.12%
$X15$ Inflexibility of dining tables and chairs	50.61%	54.38%	45.49%
$X16$ Serious seat occupation problem	62.88%	47.95%	71.91%

Through the forward risk prediction of the Bayesian network model constructed for the college cafeteria crowding event, it can be obtained that among all the influencing factors, the inferred probability of $X1$ few cafeteria stores, $X6$ insufficient cafeteria staff, $X11$ short meal service time, $X12$ low utilization of cafeteria space, and $X16$ serious seat occupancy problem are all greater than 60%. Among them, $X11$ and $X16$ led the occurrence of crowding in college cafeterias by causing crowding in the queuing process. $X11$, $X12$ and $X16$ led the occurrence of crowding events in college cafeterias by causing crowding in the dining process.

By applying the backward inference diagnosis of Bayesian network, it can be calculated that the probability distribution of each influencing factor when the cafeteria crowding event occurs, that is, the importance of each influencing factor when the college cafeteria crowding event occurs. By setting the state of the node college cafeteria crowding event in the Bayesian network to be 1, that is, setting the cafeteria crowding has occurred, the posterior probability of each node in the Bayesian network can be calculated through the inverse inference diagnosis of the Bayesian network, as shown in Figure 4 below.

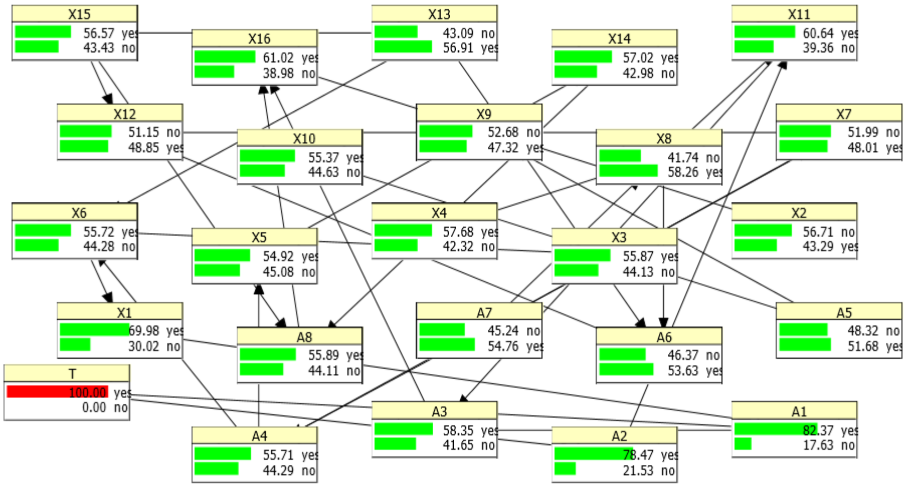


Figure 16. Posterior Probability Diagram of Each Underlying Cause When Setting Up a College Cafeteria Crowding Event

According to the results of the above figure, we have got the posterior probability of each influencing factor when the college cafeteria crowding event occurs. According to the ranking of the posterior probability values of the nodes, we can determine the importance of each influencing factor when the college cafeteria crowding event occurs. In daily management, special attention should be paid to the factors with higher posterior probability values, so that measures can be taken to prevent them in advance and ensure the safe and smooth operation of college cafeterias.

Finally, by comparing the a priori probability value of each basic factor with the a posteriori probability value of each basic factor when a college cafeteria overcrowding event occurs, the change rate of the probability value is obtained, and then the change rate is compared and ranked to be able to obtain the key factors that have an impact on the college cafeteria overcrowding event, that is, the factors that have a greater impact on the college cafeteria overcrowding event. The prior probability, the posterior probability, the rate of change of the posterior probability to the prior probability, and the ranking of the rate of change for each node are shown in Table 6.

Table 6. Table of Prior Probability, Posterior Probability, Change Rate and Ranking of Change Rate For Each Node

Node Number	Prior Probability of Nodes	Posterior Probability of Nodes	Change Rate	Ranking of Change Rate
x_1 Few cafeteria stores	53.78%	69.98%	30.12%	2
x_2 Students' poor awareness of queuing	40.83%	43.29%	6.02%	7
x_3 Low level of informatization	50.41%	55.87%	10.83%	4
x_4 Unclear cuisines	57.05%	57.68%	1.10%	16
x_5 式Encouragement of non-dine-in dining option	53.74%	54.92%	2.20%	12
x_6 Insufficient cafeteria staff	46.39%	55.72%	20.11%	3
x_7 Unreasonable setting of ordering windows	45.80%	48.01%	4.83%	10
x_8 Insufficient logistical supervision of the cafeteria	57.05%	58.26%;	2.12%	13
x_9 Large number of students and teachers	46.45%	47.32%	1.87%	14
x_{10} Concentrated meal times	52.67%	55.37%	5.13%	9
x_{11} Short meal service time	40.94%	60.64%	48.12%	1
x_{12} Low utilization of cafeteria space	46.82%	48.45%	3.48%	11
x_{13} Relatively limited space at cafeteria	52.35%	56.91%	8.71%	6
x_{14} Interval dining	56.40%	57.02%	1.11%	15
x_{15} Inflexibility of dining tables and chairs	53.69%	56.57%	5.36%	8
x_{16} Serious seat occupation problem	55.44%	61.02%	10.06%	5

According to the results of the above graph, it can be learned that the posterior probability values of few cafeteria stores, short meal service time, and serious seat occupancy problem are larger, all of which exceed 60%, and should be focused on prevention and control in the process of daily cafeteria management. At the same time, the variation rates of short meal service time, few cafeteria stores, insufficient cafeteria staff, low level of informatization and serious seat occupation problem are larger. Therefore, it can be considered that these factors are the key factors that have a large degree of influence on the crowding events in college cafeterias, for which it is suggested that schools can take measures to increase the number of cafeteria stores and cafeteria staff, extend the meal service time, actively develop cafeteria-related intelligent systems, as well as to dining order management to avoid the phenomenon of seat occupation problem.

7. Concluding Remarks

In this paper, based on the case data collected from the students of Dalian Maritime University about their views on the college cafeteria crowding events from the questionnaire survey, we have analyzed the influencing factors of the college cafeteria crowding events, constructed a fault tree and combined it with Bayesian network model to examine the causes. The probability situation of college cafeteria crowding events under the influence of different node states is obtained by forward risk prediction of Bayesian network, and the five influencing factors, namely, the short meal service time, few cafeteria stores, insufficient cafeteria staff, low level of informatization and serious seat occupation problem, are the key factors by reverse inference diagnosis of Bayesian network, and relevant suggestions are given. The method of this paper puts forward a new idea for solving the realistic college cafeteria crowding events, and it is of practical significance to provide a reference basis for college cafeteria management decision problems by using Bayesian networks for systematic analysis.

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