

# Warehousing Cost Optimization in the Restaurant Brands International (Canada) Inc.

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**Abstract.** Restaurant Brands International (RBI), a global catering company, faces significant warehousing cost challenges, primarily driven by labor expenses. This study aims to minimize these costs while maintaining service quality through an integer linear programming model for optimal employee scheduling. The model incorporates various constraints, such as the minimum number of shifts per week and employee preferences, and considers real data from RBI's financial reports. Sensitivity analyses were conducted to assess the impact of salary adjustments, changes in the minimum number of shifts, and the reduction of part-time work opportunities. The results indicate that the optimized scheduling model can significantly reduce labor costs and improve operational efficiency. The findings provide a reference for RBI and other companies with similar warehousing needs, emphasizing the importance of flexible scheduling, employee satisfaction, and adapting to peak demand periods.

**Keywords:** Restaurant Brands International, warehousing cost optimization, employee scheduling, integer linear programming, labor cost minimization, operational efficiency, sensitivity analysis.

## 1. Introduction

### 1.1 Background

Restaurant Brands International (RBI) is a global catering company based in Canada, established in 2014. The company owns and operates several popular chain restaurants worldwide, including Burger King, Popeyes Louisiana Kitchen, and Tim Hortons. As of early 2024, RBI's brands have over 30,000 stores in more than 100 countries. In 2023, RBI's global sales increased by 12% compared to the previous year, with an adjusted operating income of \$2.2 billion, representing an organic increase of 7.5% over the previous year [11]. Despite this performance, RBI faces significant operational challenges, such as fluctuations in raw material prices and increasing warehousing costs [21]. According to Johnson & Smith [22], RBI's warehousing costs have been rising annually, making it one of the company's largest expenses. Due to the highly competitive catering market, RBI must continuously enhance its brand influence and maintain growth momentum. Addressing warehousing-related issues is crucial. Among the various warehousing expenses, labor costs are the highest and most amenable to optimization. Therefore, the optimization problem for RBI is defined as: arranging the scheduling of warehouse staff to reduce employment costs while ensuring that service quality aligns with corporate culture and ultimately minimizing warehouse employment costs.

### 1.2 Staff scheduling optimization problem

As the global economy gradually recovers from the epidemic and consumer spending increases in some regions, the labor market continues to face uncertainty. There is a labor shortage in many industries, especially for low-paid positions, and the changing economic environment complicates long-term manpower planning. Additionally, the application rate of artificial intelligence in food warehouses is growing rapidly. The adoption of these technologies reduces dependence on front-line low-skilled labor and lowers labor costs. However, these changes necessitate more scientific



personnel scheduling for offline warehouses and stores. RBI must adapt to the rapidly changing external environment, optimize labor allocation, improve operational efficiency through flexible human resource management and technological innovation[32], and minimize operating costs while also considering employee satisfaction and retention rates.

This report presents a set of integer linear programming models to calculate the optimal scheduling scheme for employees in the RBI food storage warehouse. This scheme aims to minimize warehouse labor costs while satisfying all constraints. The model has high applicability and can be used by most companies with shift scheduling needs.

### 1.3 Research Objectives

Standardization and rationality of warehouse management are of great significance to modern enterprises and may directly impact operations, profits, and losses[17]. For catering companies, warehouse operation strategies and storage management methods directly affect the freshness and quality of ingredients, impacting consumer satisfaction and brand loyalty[18]. For most catering companies, the storage and preservation of food ingredients represent a significant expense [19]. Even with advanced preservation technology, a certain proportion of spoilage often occurs, increasing operating costs. Therefore, a reasonable and feasible warehousing optimization plan is imperative.

RBI, founded in 2014, is a global catering company headquartered in Canada. Its brands operate tens of thousands of chain stores worldwide, primarily including Burger King, Popeyes Louisiana Kitchen, and Tim Hortons. By early 2024, the total number of RBI stores exceeds 30,000 across more than 100 countries and regions[4]. In 2023, RBI's global system-wide sales increased by more than 12% compared to the previous year, and adjusted operating income was \$2.2 billion, an organic increase of 7.5% over the previous year [12]. Despite this success, RBI faces operational challenges, such as significant fluctuations in raw material prices, rising warehousing costs, and spoilage of reserve ingredients[21]. RBI's warehousing expenditure has increased yearly, becoming one of its largest costs[22]. To continuously enhance brand influence and maintain growth momentum in the highly competitive catering market, RBI must optimize existing warehousing-related issues. The optimization problem for RBI is defined as: ensuring that food inventory meets market demand in a timely manner, avoiding food expiration and waste to the greatest extent, reducing inventory backlog and capital expenditures in the warehousing process (including warehouse rent and employee wages), and ultimately minimizing warehousing costs[28].

## 2. Evaluation Criteria

To find a more optimal model for solving the staff scheduling problem of RBI, ten academic journal articles on staff scheduling and mobilization from different industries were re-collected. These articles used various models due to the limitation of information resources. For instance, Smet et al. used an integer linear programming model to optimize the scheduling of integrated tasks and personnel scheduling problems[15]. Similarly, Kilinclı Taskiran et al. employed a mixed-integer programming model to address cross-training staff scheduling at call centers. Analyzing the strengths and weaknesses of these articles helps in creating a comprehensive optimization model for RBI.

The primary objective function is to minimize the warehousing cost. The decision variables considered include the transportation cost, which is the cost of transporting products from warehouses to destinations, the storage capacity, referring to the warehouses' ability to store products, and the warehousing fee, which covers the cost of warehouse maintenance, equipment usage, and labor costs. Additionally, the spoilage rate, representing the proportion of products damaged or lost during storage, and the marketing demand, which involves planning inventory and production according to market demand, are also essential variables.

Various constraints are also considered in this evaluation. These include the number of warehouses required in different spots, known as the spots of warehouse location, and the adoption of technological and operational flexibility, which involves the adoption of technology innovations and

operational adaptability to match evolving product lines, market demands, and storage needs, ensuring the warehouse's capacity to react quickly to changes in customer demand. The scale of the warehouse, which defines the dimensions required for warehouses, is also considered. Additionally, policy factors such as safety and health standards, environmental regulations, import and export restrictions, labor regulations, and storage limits are crucial. Finally, space utilization optimization, which maximizes the use of ground and vertical space in warehouses to increase operational efficiency without sacrificing the ability to store all product types, is an important consideration.

## 2.1 Strengths

The strengths derived from these articles can inform more comprehensive improvements to the mathematical model created. The employee scheduling problem identified can be effectively optimized by considering several assumptions and constraints. For example, Kilincli Taskiran and Zhang suggested that companies should consider each employee's personal preferences (such as shift selection) while ensuring compliance with labor regulations[30]. This approach can enhance employee job satisfaction and retention rates.

Guerrero and Guido's research emphasized the importance of flexible scheduling models in unpredictable situations, such as epidemics<sup>5</sup>. Their study is applicable to RBI, where there is a need to develop scheduling systems that can adjust easily to changes in demand.

Amir and Seyed's article demonstrated the use of mixed-integer linear programming models to optimize staff scheduling in Iranian hospitals, focusing on reducing the cost of flexibility associated with employee salaries[7].

Applying this approach to RBI can solve complex scheduling problems by rationalizing the use of differently paid employees, helping RBI find cost-effective solutions more efficiently. Incorporating these findings into RBI's employee scheduling and rostering models can improve the ability to adapt to changing market conditions while optimizing employee resources and reducing overwork or resource wastage.

## 2.2 Weaknesses

Burgy proposed an integer linear programming model with scalable shifts to improve workplace flexibility<sup>1</sup>, but the model primarily focused on the distribution of the number of employees without fully considering differences in work efficiency and individual needs.

Some studies, such as Nobil & Sharifnia emphasized employee satisfaction and the legitimacy of the company's system but lacked consideration of employees' personal preferences and loyalty[9]. Such models may lead to negative work attitudes and high churn rates.

Addressing these downsides involves incorporating qualitative analysis and employee feedback when implementing scheduling models. Conducting simulations and milestone evaluations can ensure the new system enhances efficiency and responsiveness without compromising employee well-being.

## 3. Methodology

### 3.1 RBI Information

In this study, data on working hour restrictions [3] and minimum hourly wages [4] were obtained from the official Canadian government website. Additional information on current employee work schedules, rest schedules, and basic salaries was sourced from the RBI corporate website.

#### 3.1.1 Information from Official Public Data

**Working Hours and Shift Schedule:** RBI, primarily focused on warehousing, does not have precise business hours. Working hours are based on recent information from RBI's website[20]. According

to business policies, employees have two shifts with 10 hours of working time per day in total. The two shifts are from 10:00 AM to 3:00 PM and from 3:00 PM to 8:00 PM, with adjustments on weekends. Different types of employees have different minimum shift requirements: supervisors need 8 shifts per week, full-time employees need 6 shifts per week, and part-time employees need 7 shifts per week[10].

### **3.1.2 Information from RBI's Staff**

**Employee Types:** To maintain normal warehouse operations, a total of 14 employees are required. This includes 3 supervisors, 9 full-time employees, and 2 part-time employees, with no casual employees employed[14].

**Wages of Different Types of Employees:** RBI's Enterprise Agreement does not specify differences in remuneration for full-time or part-time employees. Therefore, standard wages are assumed: supervisors receive 28 CAD per hour on weekdays and 32 CAD per hour on weekends, while full-time and part-time employees receive 24 CAD per hour on weekdays and 28 CAD per hour on weekends. All employees receive an additional 4 CAD per hour on weekends[13].

## **3.2 Assumptions**

To conduct a detailed study on the allocation of key personnel in RBI's warehousing, the following assumptions were made:

### **3.2.1 Duration of Shifts**

The shift period is assumed to be seven days a week with consistent working hours each day. Considering the preparation and organization required in the warehouse, working hours are extended by half an hour in the morning and half an hour after closing on weekends. Two shifts per day are assumed. Detailed duration of shifts is as follows: On Monday, Tuesday, Wednesday, Thursday, and Friday, there are shifts 1, 2, 3, 4, and 5 respectively, each with 5 hours of working time. On Saturday, there are shifts 6 and 7, and on Sunday, there are shifts 8 and 9, each with 4.5 hours of working time.

### **3.2.2 Number of Employees Needed in Each Shift**

Based on customer demand at most RBI fast-food restaurants, demand peaks on weekends. Therefore, the number of employees needed per shift is fixed, with the highest demand on weekends. The number of employees in each shift is as follows: On Monday, shift 1 requires 5 employees, and shift 2 requires 7 employees. On Tuesday, shift 3 requires 3 employees, and shift 4 requires 5 employees. On Wednesday, shift 5 requires 4 employees, and shift 6 requires 6 employees. On Thursday, shift 7 requires 3 employees, and shift 8 requires 4 employees. On Friday, shift 9 requires 8 employees, and shift 10 requires 10 employees. On Saturday, shift 11 requires 12 employees, and shift 12 requires 13 employees. On Sunday, shift 13 requires 9 employees, and shift 14 requires 11 employees.

### **3.2.3 Issues of Fines**

Fines are considered for non-compliance with employee shift requirements and the proportion of full-time to part-time employees. However, adding a penalty mechanism increased the model's complexity, making it unsuitable for linear programming in Excel.

## **3.3 Constraints**

### **3.3.1 Shift Restrictions**

According to the RBI, a minimum of 3 employees is required for each shift to meet warehouse workload demands.

### **3.3.2 Supervisors (Leader Limitation)**

To improve management efficiency, the number of supervisors is limited based on customer flow changes. One supervisor is required on Tuesday, Wednesday, and Thursday, while two or more are needed on Friday, Saturday, Sunday, and Monday.

### **3.3.3 Minimum Number of Shifts per Person**

There are 14 shifts in total every week, assigned as follows:

- 1) Each supervisor is required to work at least 8 shifts a week.
- 2) Each full-time employee is required to work at least 6 shifts a week.
- 3) Each part-time employee is required to work at least 7 shifts a week.

Part-time employees have more work opportunities because the warehouse has a manageable amount of complex work requirements.

### **3.3.4 Personal Preference**

Personalized scheduling restrictions are implemented to accommodate employees' personal needs. The collected data is organized and appropriately adjusted to fit the mathematical model. Details are as follows:

- 1) Supervisor NO.2: Needs to take care of the children every Tuesday, Thursday, and Friday.
- 2) Full-time Employee NO.4: Only have time to work in the morning on weekdays.
- 3) Full-time Employee NO.5: Has no working time in the morning on every Monday and Thursday.
- 4) Full-time Employee NO.6: Required to work up to 40 hours per week.
- 5) Full-time Employee NO.11: Must attend exactly 4 shifts among shift 2, 5, 8, 9, and 14.
- 6) Part-time Employee NO.13: Could attend up to 2 shifts among shift 1, 6, 8, 11.

To further understand the warehousing planning and cost minimization problem in the RBI supply chain, a review of extensive journal articles was conducted. Through numerous company cases and their solutions documented in these articles, optimization solutions for warehousing cost problems were collected. Data was obtained from Google search and the University of Melbourne online library, using keywords such as "warehouse cost optimization," "inventory management," "logistics optimization," and "linear programming." Research literature from the last decade was screened to ensure the timeliness and relevance of the information.

Ten academic journals were selected, which utilize specific methods of data modeling for data analysis, such as "Integer Linear Programming Model," "Multi-objective Optimization Model," "Mixed-source Optimization Model," and "Numerical Optimization Model." These journals provide specific improvements that can be proposed through this research and how they can be implemented to achieve cost optimization. Expected results may include cost savings, quantification of efficiency gains, and potential challenges and solutions. Additionally, RBI's official website and the company's fiscal year 2023 financial statements were investigated to obtain relevant data to support subsequent mathematical modeling and improve accuracy.

## 4. Implementation and Results

### 4.1 Implementation

#### Step 1. Fully understand the optimization problem

RBI's warehouse is facing the increasing labor costs because of the increasing employees. Therefore, linear program was used to optimize the labor allocation problem, which aims to find the best schedule of employees to minimize the labor costs and to minimize the funds produced by the unreasonable employee configuration and proportion between the different types of employees.

#### Step 2. Define the decision variables

$$\textcircled{1} x_{ij} = \begin{cases} 1, & \text{if warehouse keeper is assigned to shift } j \\ 0, & \text{otherwise} \end{cases}$$

$x_{ij}$  = one shift that need to be assigned

where,

$i$  = staff

$i = 1,2,3 \rightarrow$  warehouse supervisor for full-time works

$i = 4,5,6,7,8,9,10,11 \rightarrow$  full-time warehouse keeper

$i = 12,13,14 \rightarrow$  part-time warehouse keeper

$j$  = shift

$j = 1 \rightarrow$  day shift

$j = 2 \rightarrow$  afternoon shift

i.e.)

$x_{24}$  = if supervisor 2 is assigned to shift 4 on Tuesday afternoon shift

$x_{79}$  = if full-time warehouse keeper 7 is assigned to shift 0 on Friday day shift

$x_{13,12}$  = if part-time warehouse keeper 13 is assigned to shift 12 on Saturday afternoon shift

**Table 1.** Decision variables.

Staff i	Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun	
	Shift k	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Supervisor	1	x11	x12	x13	x14	x15	x16	x17	x18	x19	x110	x111	x112	x113	x114
	2	x21	x22	x23	x24	x25	x26	x27	x28	x29	x210	x211	x212	x213	x214
	3	x31	x32	x33	x34	x35	x36	x37	x38	x39	x310	x311	x312	x313	x314
Full-time	4	x41	x42	x43	x44	x45	x46	x47	x48	x49	x410	x411	x412	x413	x414
	5	x51	x52	x53	x54	x55	x56	x57	x58	x59	x510	x511	x512	x513	x514
	6	x61	x62	x63	x64	x65	x66	x67	x68	x69	x610	x611	x612	x613	x614
	7	x71	x72	x73	x74	x75	x76	x77	x78	x79	x710	x711	x712	x713	x714
	8	x81	x82	x83	x84	x85	x86	x87	x88	x89	x810	x811	x812	x813	x814
	9	x91	x92	x93	x94	x95	x96	x97	x98	x99	x910	x911	x912	x913	x914
	10	x101	x102	x103	x104	x105	x106	x107	x108	x109	x1010	x1011	x1012	x1013	x1014
	11	x111	x112	x113	x114	x115	x116	x117	x118	x119	x1110	x1111	x1112	x1113	x1114
	12	x121	x122	x123	x124	x125	x126	x127	x128	x129	x1210	x1211	x1212	x1213	x1214
	Part-time	13	x131	x132	x133	x134	x135	x136	x137	x138	x139	x1310	x1311	x1312	x1313
14		x141	x142	x143	x144	x145	x146	x147	x148	x149	x1410	x1411	x1412	x1413	x1414
Total of staff/shift		5	7	3	5	4	6	3	4	8	10	12	13	9	11

$$\textcircled{2} C_{ij} = \text{the salary if employee } i \text{ is assigned to shift } j \text{ (unit: CAD)}$$

**Table 2. Objective Function**

Staff i	Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun	
	Shift k	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Supervisor	1	140	140	140	140	140	140	140	140	140	140	144	144	144	144
	2	140	140	140	140	140	140	140	140	140	140	144	144	144	144
	3	140	140	140	140	140	140	140	140	140	140	144	144	144	144
Full-time	4	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	5	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	6	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	7	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	8	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	9	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	10	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	11	120	120	120	120	120	120	120	120	120	120	126	126	126	126
12	120	120	120	120	120	120	120	120	120	120	126	126	126	126	
Part-time	13	120	120	120	120	120	120	120	120	120	120	126	126	126	126
	14	120	120	120	120	120	120	120	120	120	120	126	126	126	126
Total of staff/shift		120	120	120	120	120	120	120	120	120	120	126	126	126	126

**Step 3. Identify the objective function**

$$\text{Minimize total cost} = \sum_{i=1}^{14} \sum_{j=1}^{14} x_{ij} \times C_{ij}$$

**Step 4. Identify the constraints**

**A. Shift Restrictions**

Constraint 1: Number of full-time employees must not be fewer than 3.

$$\sum_{i=1}^{12} x_{ij} \geq 3, \text{ for each same } j1$$

Specifically, the least number of full-time employees for each shift is as follows: For shifts 1 through 14, the number of full-time employees must be at least 3. This constraint ensures that for each shift, the number of full-time employees is equal to or greater than 3, which is essential to meet the operational requirements of the warehouse.

**B. Supervisors (Leader Limitation)**

To improve the management efficiency of employees, the number of supervisors is limited according to changes in customer flow at fast-food restaurants. There is only one supervisor on Tuesday, Wednesday, and Thursday.

$$x_{ij1} + x_{ij2} + x_{ij3} = 1,$$

For employee  $i \in 1,2,3$ ; shift  $j \in 3,4,5,6,7,8$ ;

Constraints 2: Friday, Saturday, Sunday, and Monday, 2 or more supervisors are required.

$$x_{ij1} + x_{ij2} + x_{ij3} \geq 2;$$

For employee  $i \in 1,2,3$ ; shift  $j \in 1,2,9,10,11,12,13,14$ ;

The number of supervisors is limited according to changes in customer flow at fast-food restaurants. On Monday, at least 2 supervisors are required. On Tuesday, only 1 supervisor is needed. Similarly, for Wednesday and Thursday, only 1 supervisor is needed for each day. On Friday, a minimum of 2 supervisors is required. On Saturday and Sunday, at least 2 supervisors are required for both days. This constraint ensures adequate supervision to manage the varying customer flow throughout the week.

### **C. Number of Shifts Per Person Per Week**

Constraint 3: Different types of employees have different requirements for the number of shifts per week, as follows:

- 1) Each supervisor is required to work at least 8 shifts a week.
- 2) Each full-time employee is required to work at least 6 shifts a week.
- 3) Each part-time employee is required to work at least 7 shifts a week.

### **D. Employee Number**

Constraint 4: The number of employees in each shift is fixed, as shown below.

For shift 1, the number of employees required is 5. For shift 2, the number of employees required is 7. For shift 3, the number of employees required is 3. For shift 4, the number of employees required is 5. For shift 5, the number of employees required is 4. For shift 6, the number of employees required is 6. For shift 7, the number of employees required is 3. For shift 8, the number of employees required is 4. For shift 9, the number of employees required is 8. For shift 10, the number of employees required is 10. For shift 11, the number of employees required is 12. For shift 12, the number of employees required is 13. For shift 13, the number of employees required is 9. For shift 14, the number of employees required is 11. This ensures that each shift is staffed according to the specific needs and operational requirements of the warehouse.

### **E. Personal Preference**

Constraint 5: Different employees have different shift requirements, as detailed in the table below.

- 1) Supervisor NO.2: Needs to take care of the children every Tuesday, Thursday, and Friday.
- 2) Full-time Employee NO.4: Only have time to work in the morning on weekdays.
- 3) Full-time Employee NO.5: Has no working time in the morning on every Monday and Thursday.
- 4) Full-time Employee NO.6: Required to work up to 40 hours per week.
- 5) Full-time Employee NO.11: Must attend exactly 4 shifts among shift 2, 5, 8, 9, and 14.
- 6) Part-time Employee NO.13: Could attend up to 2 shifts among shift 1, 6, 8, 11.

## **4.2 Results**

After the implementation of the model using Excel, a minimum cost of 12,726 CAD per week was identified when all assumptions and constraints were satisfied, with a total of 14 shifts per week. The optimal schedule is shown below. The minimized labor cost is 12,726 CAD.

**Table 3.** Decision variables.

Staff i	Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun		Weekly Salary
		Shift k	1	2	3	4	5	6	7	8	9	10	11	12	13	
Supervisor	1	0	1	0	1	0	0	0	1	0	1	1	1	1	1	1136
	2	1	1	0	0	0	1	0	0	1	0	1	1	1	1	1136
	3	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1136
Full-time	4	1	0	1	0	1	0	1	0	0	0	1	1	1	1	984
	5	0	0	1	1	1	1	0	1	0	1	0	1	0	0	846
	6	1	0	0	1	0	1	1	1	0	1	1	1	0	0	972
	7	0	0	0	1	0	1	0	0	1	1	0	1	0	1	732
	8	1	1	0	0	0	0	0	0	1	1	1	0	0	1	732
	9	0	0	0	0	0	0	0	0	1	1	1	1	1	1	744
	10	0	0	0	1	0	0	1	0	0	0	1	1	1	1	744
	11	0	1	0	0	1	0	0	1	0	1	1	1	0	1	858
	12	0	1	1	0	0	0	0	0	1	0	1	1	1	0	738
Part-time	13	0	1	0	0	1	1	0	0	1	1	1	1	1	1	1104
	14	0	0	0	0	0	1	0	0	1	1	1	1	1	1	864

Constraint 1:

**Table 4.** The least full-time employee number for each shift.

		LHS		RHS
Full-time staff of each shift	1	5	$\geq$	3
	2	6	$\geq$	3
	3	3	$\geq$	3
	4	5	$\geq$	3
	5	3	$\geq$	3
	6	4	$\geq$	3
	7	3	$\geq$	3
	8	4	$\geq$	3
	9	6	$\geq$	3
	10	8	$\geq$	3
	11	10	$\geq$	3
	12	11	$\geq$	3
	13	7	$\geq$	3
	14	9	$\geq$	3

Constraint 2:

**Table 5.** Limit of supervisors for everyday.

	LHS		RHS
Mon	5	$\geq$	2
Tue	1	=	1
Wed	1	=	1
Thu	1	=	1
Fri	4	$\geq$	2
Sat	6	$\geq$	2
Sun	6	$\geq$	2

Constraint 3:

**Table 6.** Shift of each employee per week.

Staff Number	LHS		RHS
1	8	$\geq$	8
2	8	$\geq$	8
3	8	$\geq$	8
4	8	$\geq$	6
5	7	$\geq$	6
6	8	$\geq$	6
7	6	$\geq$	6
8	6	$\geq$	6
9	6	$\geq$	6
10	6	$\geq$	6
11	7	$\geq$	6
12	6	$\geq$	6
13	9	$\geq$	7
14	7	$\geq$	7

Constraint 4:

**Table 7.** Fixed staff requirement for each shift

Staff Number	LHS		RHS
1	5	=	5
2	7	=	7
3	3	=	3
4	5	=	5
5	4	=	4
6	6	=	6
7	3	=	3
8	4	=	4
9	8	=	8
10	10	=	10
11	12	=	12
12	13	=	13
13	9	=	9
14	11	=	11

Constraint 5:

**Table 8.** Special Preference of Some Staff.

Staff Number	LHS		RHS
2	0	=	0
4	0	=	0
5	0	=	0
6	39	$\leq$	40
11	4	=	4
13	2	$\leq$	2

### 4.3 Sensitivity Analysis

#### 4.3.1 Increase the Salary for Full-time Employees and Part-time Employees

Based on the actual situation, the salary of part-time employees occupied a higher proportion of total costs than initially predicted. Therefore, salaries for both full-time and part-time employees were increased by 10% to reduce the proportion of temporary employment expenses. After these adjustments, the new optimal solution indicates that the minimized labor cost is now 13,657.8 CAD.

The new schedule is shown below.

**Table 9.** New Schedule

Staff i	Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun		Weekly Salary
	Shift k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Supervisor	1	0	1	0	1	0	0	0	1	0	1	1	1	1	1	1136
	2	1	1	0	0	0	1	0	0	1	0	1	1	1	1	1136
	3	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1136
Full-time	4	1	0	1	0	1	0	1	0	0	0	1	1	1	1	1082.4
	5	0	0	1	1	1	1	0	1	0	1	0	1	0	0	930.6
	6	1	0	0	1	0	1	1	1	0	1	1	1	0	0	1069.2
	7	0	0	0	1	0	1	0	0	1	1	0	1	0	1	805.2
	8	1	1	0	0	0	0	0	0	1	1	1	0	0	1	805.2
	9	0	0	0	0	0	0	0	0	1	1	1	1	1	1	818.4
	10	0	0	0	1	0	0	1	0	0	0	1	1	1	1	818.4
	11	0	1	0	0	1	0	0	1	0	1	1	1	0	1	943.8
	12	0	1	1	0	0	0	0	0	1	0	1	1	1	0	811.8
Part-time	13	0	1	0	0	1	1	0	0	1	1	1	1	1	1	1214.4
	14	0	0	0	0	0	1	0	0	1	1	1	1	1	1	950.4

A new minimum cost of 13,657 CAD was identified using the new linear programming solver based on improved data, which represents an increase of approximately 7.316% compared to the original minimum cost. The total minimum cost increased after making the adjustments, indicating that the minimum cost of RBI's warehouse could not be decreased by increasing the salaries of full-time and part-time employees by a small proportion. However, increasing employees' salaries is expected to improve their motivation and work efficiency, potentially leading to more benefits in the long term.

#### 4.3.2 Changes in the Minimum Number of Shifts Per Week

In the mathematical model, some employees may not be satisfied with the required minimum number of weekly shifts. To address this, the minimum number of shifts was adjusted without affecting the minimum cost. The requirement for supervisors was initially at least 8 shifts per week, which was changed to at least 6 shifts per week. For full-time employees, the requirement was reduced from at least 6 shifts per week to at least 4 shifts per week. For part-time employees, the requirement was adjusted from at least 7 shifts per week to at least 5 shifts per week. After these adjustments, the new optimal solution indicates that the minimized labor cost is now 12,608 CAD.

The new schedule is shown below.

**Table 1. New Optimal Solution**

Staff i	Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun		Weekly Salary
	Shift k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Supervisor	1	0	1	0	1	0	0	0	1	0	0	1	1	0	1	852
	2	1	0	0	0	0	1	0	0	0	0	1	1	1	1	856
	3	0	0	0	0	0	0	0	0	1	1	1	1	1	1	856
Full-time	4	1	0	1	0	1	0	1	0	1	0	1	1	0	1	978
	5	0	1	1	1	1	1	0	1	1	1	1	1	0	1	1338
	6	1	0	0	1	0	1	1	1	0	0	0	0	0	0	720
	7	0	0	0	0	0	1	1	0	0	1	1	1	0	0	612
	8	0	0	0	0	0	0	0	0	0	1	0	1	1	1	498
	9	1	1	0	0	0	0	0	0	1	1	1	1	1	1	984
	10	1	1	0	1	1	0	0	0	0	1	1	1	1	1	1104
	11	0	1	0	1	1	0	0	1	1	1	1	1	1	0	1098
12	0	1	0	0	0	1	0	0	1	1	1	1	1	1	984	
Part-time	13	0	1	0	0	0	1	0	0	1	1	1	1	1	1	984
	14	0	0	0	0	0	0	0	0	1	1	1	1	1	1	744

Using the new linear programming solver based on improved data, a new minimum cost of 12,608 CAD was identified, representing a decrease of approximately 0.0927% compared to the original minimum cost. By changing the minimum number of shifts per week, more flexible working time was provided to employees, which also offered more flexible work opportunities to employees with special needs.

**4.3.3 Reduce One Part-time Work Opportunity**

It was predicted that the original number of employees may exceed RBI’s requirements due to a smaller workload during the off-season or other external factors, such as social reasons (flu, etc.). Therefore, an analysis was conducted to determine if the minimum cost could be decreased by reducing one part-time work opportunity. After this adjustment, the new optimal solution indicates that the minimized labor cost is now 11,470 CAD.

The new schedule and objective equation are shown below.

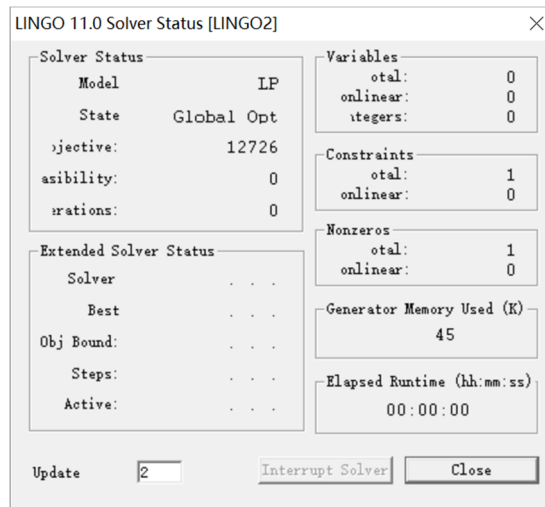
**Table 11. New Optimal Solution**

Staff i	Day	Mon		Tue		Wed		Thu		Fri		Sat		Sun		Weekly Salary
	Shift k	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Supervisor	1	1	1	0	1	0	0	0	0	1	1	1	1	1	0	1132
	2	1	1	0	0	0	1	1	0	1	0	1	1	1	0	1132
	3	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1136
Full-time	4	1	0	1	0	0	0	1	0	1	0	1	1	0	0	732
	5	0	0	1	1	1	1	0	1	0	1	0	1	0	0	846
	6	1	0	0	1	0	1	1	1	0	1	1	1	0	0	972
	7	0	1	0	1	0	1	0	0	1	1	1	1	0	0	852
	8	0	1	0	0	0	1	0	0	0	1	1	1	1	0	738
	9	0	1	0	0	0	1	0	0	0	1	1	1	1	0	738
	10	0	0	0	0	1	0	0	0	1	1	1	1	1	0	738
	11	0	1	0	0	1	0	0	1	1	0	0	1	1	0	858
12	0	0	1	0	1	0	0	0	0	1	1	1	1	0	738	
Part-time	13	0	0	0	1	0	0	0	0	1	1	1	1	1	0	858
	14															0

The new minimum cost identified was 11,470 CAD using the new linear programming solver based on improved data, representing a decrease of approximately 9.870% compared to the original minimum cost. This minimum cost reduction ratio is larger than that of the first two sensitivity analyses. However, reducing one work opportunity will increase the work pressure on other employees. In the long term, this may diminish employees' satisfaction and enthusiasm for work, which is not conducive to the development of RBI.

## 5. Outcome Applies in Lingo

Some outcome applies in lingo.



**Figure 1.** Salary result output with staff limitation of each shift.

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```

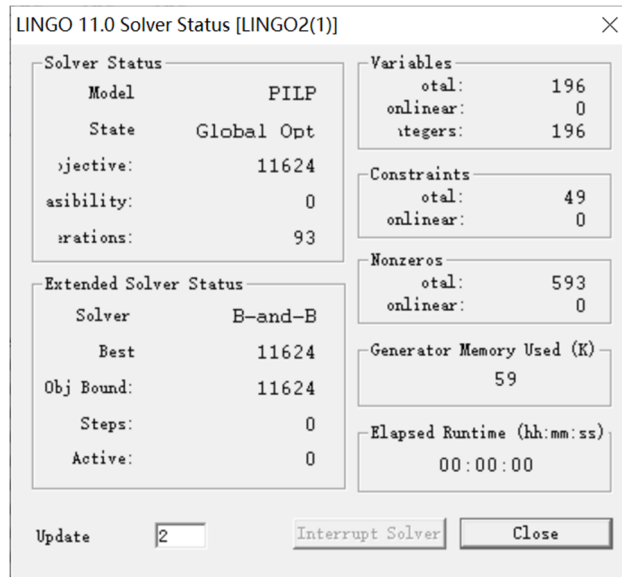
Global optimal solution found.
Objective value:                12726.00
Infeasibilities:                0.000000
Total solver iterations:        0

```

Variable	Value	Reduced Cost
B( 1)	5.000000	0.000000
B( 2)	7.000000	0.000000
B( 3)	3.000000	0.000000
B( 4)	5.000000	0.000000
B( 5)	4.000000	0.000000
B( 6)	6.000000	0.000000
B( 7)	3.000000	0.000000
B( 8)	4.000000	0.000000
B( 9)	8.000000	0.000000
B( 10)	10.00000	0.000000
B( 11)	12.00000	0.000000
B( 12)	13.00000	0.000000
B( 13)	9.000000	0.000000
B( 14)	11.00000	0.000000
H( 1)	5.000000	0.000000
H( 2)	5.000000	0.000000
H( 3)	5.000000	0.000000
H( 4)	5.000000	0.000000
H( 5)	5.000000	0.000000
H( 6)	5.000000	0.000000
H( 7)	5.000000	0.000000
H( 8)	5.000000	0.000000
H( 9)	5.000000	0.000000
H( 10)	5.000000	0.000000
H( 11)	4.500000	0.000000
H( 12)	4.500000	0.000000
H( 13)	4.500000	0.000000
H( 14)	4.500000	0.000000
X( 1, 1)	0.000000	0.000000
X( 1, 2)	1.000000	0.000000
X( 1, 3)	0.000000	0.000000
X( 1, 4)	1.000000	0.000000

---

**Figure 2.** Staff number result output with staff limitation of each shift



**Figure 3.** Salary result output without staff limitation of each shift

```

Global optimal solution found.
Objective value:                11624.00
Objective bound:                11624.00
Infeasibilities:                0.000000
Extended solver steps:          0
Total solver iterations:        93

```

Variable	Value	Reduced Cost
B( 1)	5.000000	0.000000
B( 2)	7.000000	0.000000
B( 3)	3.000000	0.000000
B( 4)	5.000000	0.000000
B( 5)	4.000000	0.000000
B( 6)	6.000000	0.000000
B( 7)	3.000000	0.000000
B( 8)	4.000000	0.000000
B( 9)	8.000000	0.000000
B( 10)	10.000000	0.000000
B( 11)	12.000000	0.000000
B( 12)	13.000000	0.000000
B( 13)	9.000000	0.000000
B( 14)	11.000000	0.000000
H( 1)	5.000000	0.000000
H( 2)	5.000000	0.000000
H( 3)	5.000000	0.000000
H( 4)	5.000000	0.000000
H( 5)	5.000000	0.000000
H( 6)	5.000000	0.000000
H( 7)	5.000000	0.000000
H( 8)	5.000000	0.000000
H( 9)	5.000000	0.000000
H( 10)	5.000000	0.000000
H( 11)	4.500000	0.000000
H( 12)	4.500000	0.000000
H( 13)	4.500000	0.000000
H( 14)	4.500000	0.000000

**Figure 4.** Staff number result output with staff limitation of each shift

## **6. Strategic Analysis**

### **6.1. Strength Analysis**

#### **6.1.1 Measured that related to warehousing problems faced by RBI**

The reviewed articles can be applied to the warehousing problems currently faced by RBI. Most articles focus on optimizing the scale of the warehouse and improving its utilization rate. For example, Derpich et al. utilize restricted and unrestricted models to offer easy-to-implement, close-form solutions for calculating warehouse dimensions[28]. This includes considering multi-level warehouse designs to accommodate various heights and storage configurations, emphasizing energy efficiency, and minimizing horizontal and vertical movement within the warehouse. Qiu et al. analyzed the impact of key parameters on inventory policies and cost performance through numerical research, providing warehouse structure suggestions for enterprises[31].

Furthermore, Fan et al. developed a highly flexible model that can proactively modify the size of the warehouse to account for variations in supply, demand, and batch sizes over several cycles[23]. This adaptability helps businesses swiftly respond to shifts in consumer demand, enhancing the responsiveness and flexibility of supply chains. Additionally, Zhang et al. researched decision-making supporting logistics network distribution nodes or front warehouses for fresh food e-commerce[30], which has significant implications for warehousing logistics nodes under other needs and can be applied to distribution system location decisions for RBI's sustainable operations.

#### **6.1.2 Considered various factors**

Most papers examined a range of real elements impacting RBI's circumstances. Paam et al. analyzed several variables influencing inventory control, such as product spoilage rates, energy costs, demand fluctuations, and warehouse operation patterns, to enhance the model's efficacy and accuracy[24]. This integrated strategy provides comprehensive solutions to the complex problems faced by businesses requiring food storage and can serve as a model to address corporate challenges at RBI.

#### **6.1.3 Used multiple math models to solve problems**

These articles employed various mathematical models. For different space allocations, Duque-Jaramillo et al. used an integer linear programming model and a two-phase algorithm[29]. They also utilized diverse integration methodologies to synchronize overall operation timings, increasing the model's actual accuracy beyond standard models. This model can serve as a basis for more intricate models suitable for various industrial sectors, incorporating additional warehouse operational elements or limit amounts.

A unique model called FWLAP, developed by Zhang et al., combines a mathematical model with a programming paradigm[30]. This algorithm model, which outperforms the conventional genetic algorithm and improves upon traditional methods, can address the transportation network issue at RBI.

#### **6.1.4 Related to the actual situations**

The models and solutions proposed in these articles are appropriate for resolving RBI's real-world issues and are pertinent to actual circumstances. According to Perera et al., goal programming and linear programming models offer a systematic and quantitative method for resolving warehouse space optimization issues[27]. These models can be applied with moderate processing power, making them suitable for practical real-world applications. Furthermore, Galindo et al. provide guidelines for cost-cutting strategies that enable businesses[26] to make data-driven decisions based on mathematical models rather than solely on evaluations. This systematic and efficient approach to operations optimization helps RBI find the most economical ways to reduce operational expenses.

## **6.2. Weakness Analysis**

### **6.2.1 Limiting Assumptions and Scope Restriction**

The applicability of the model is influenced by limiting assumptions, which may not always hold true in real-life situations. For example, Fan and Wang studied only the case where a single product is used as a warehousing object, which cannot be applied to the optimization of warehouses with multiple product categories[23]. Paam et al. based their model on a constant product spoilage rate<sup>24</sup>. Duque-Jaramillo et al. assumed that the slot sizes are all the same, making the models only flexible for operational decisions in dual-channel warehouses[29]. Qiu et al. also created a model that is flexible only for dual-channel warehouses[31]. Additionally, the failure to consider uncertainty factors could lead to limitations in the model, necessitating adjustments and modifications for improved applicability in different scenarios.

### **6.2.2 High Complexity of Some Models and High Accuracy Requirement for Data**

The complexity of the model leads to a high demand for input data, including accuracy and quantity, which may pose challenges in data collection and processing. Additionally, complex mathematical models are highly susceptible to computational errors due to minor deviations in the data. For example, Fan and Wang[23] considered multiple decision-making aspects; Paam et al. developed a mixed-integer quadratic programming model with complex principles and applications[24]. Xu et al. relied on historical data to predict customer demand and determine optimal warehouse locations[25].

### **6.2.3 Relatively Fewer Models on Linear Programs**

Although all ten journals examined employed feasible mathematical models to address real-world problems, only three specifically focused on linear programming and integer programming. The remaining models, such as the multi-objective optimization model by Xu et al.[25], the mixed-integer quadratic programming model by Paam et al. [24], and the convex programming models by Qiu et al.[31] were outside the scope of the study. This implies that if the goal is to optimize mathematical models in subsequent work, the models mentioned in these journals would require further integration and refinement to provide substantial assistance and insight into the problems being addressed.

## **7. Discussion and Recommendation**

### **7.1 Advantages**

#### **7.1.1 The Model Uses Real Data**

RBI's financial reports and related labor policies were reviewed and summarized to obtain real salary data, ensuring the authenticity and validity of the data sources, including the number of full-time and part-time employees, salary levels, and working hours. Sufficient and effective decision variables and constraints were constructed by combining relevant journal articles, thereby improving the accuracy and applicability of these variables and conditions.

#### **7.1.2 Ensuring Service Quality and Standardization of Each Shift**

The model ensures that at least one leader is present in each shift to supervise the working status of employees and manage and divide labor on-site in a timely manner, while also ensuring the standardization of warehouse work processes<sup>16</sup>. Additionally, considering that full-time employees have more experience and professional qualities than part-time employees, the model ensures that there are no fewer than three full-time employees in each shift to maintain high-quality services in the warehouse.

#### **7.1.3 Consideration of Individual Needs of Employees**

The individual needs of employees were fully considered based on the actual situation during the operation of the food warehouse. For example, specific scheduling adjustments were made for

employees with childcare responsibilities or limited availability on certain days. The model accommodates these individual needs and allows for quick and effective adjustments according to changes in employee requirements. Additionally, the model accounts for workload consistency among employees of the same type, ensuring a fair distribution of workload and similar salaries, thereby improving employee satisfaction and service quality.

#### **7.1.4 Consideration of Fluctuations in Employee Demand During Peak Periods**

The model ensures that warehouse staffing matches the demand for same-day shipments. According to public information from RBI, food consumption demand is higher on Mondays, Fridays, Saturdays, and Sundays compared to other days. The model accounts for these fluctuations and allocates more employees to peak shifts, ensuring that the average work intensity of employees in each shift is similar, which promotes employee happiness and loyalty. Therefore, the model has high applicability across various time periods.

### **7.2 Limitations**

#### **7.2.1 Lack of Consideration of Employee Welfare and Rest**

The model does not consider employee welfare policies and emergencies. For instance, RBI's full-time employees enjoy benefits such as paid annual leave, sick leave, personal leave, and other holidays. These unplanned holidays and employee absences due to emergencies are not accounted for in the model. Additionally, the model divides each day into only two shifts (morning and afternoon), with each shift lasting a long time, which lacks consideration of employees' rest time during continuous work. This could reduce the accuracy and practicality of the model results and negatively impact employees' work efficiency and happiness due to insufficient incentives and freedom, thus affecting overall company performance.

#### **7.2.2 Lack of Consideration for Employees' Professional Differences**

The model simplifies employee types into three categories: leadership, full-time, and part-time, without fully considering differences in work efficiency due to professional differences among employees. This necessitates comprehensive multi-position training for employees to ensure they are qualified for all positions, increasing the company's training costs and potentially reducing workers' enthusiasm and work performance due to not leveraging individual advantages.

#### **7.2.3 Lack of Consideration of Differences between Off-Peak and Peak Seasons**

The model ensures personnel scheduling matches the difference in warehouse employee demand between weekdays and weekends but does not account for larger time span demand changes. For example, January and July are peak tourist seasons, leading to increased food consumption. The model does not account for these seasonal fluctuations, potentially increasing work intensity during peak seasons and reducing employee happiness and loyalty. The model addresses small-scale demand fluctuations but not long-term demand differences such as off-peak and peak seasons.

### **7.3 Recommendations**

Based on the above limitations, the following improvements are suggested for RBI:

#### **7.3.1 Increase Flexibility of Employee Scheduling**

RBI's warehouse shifts are currently divided into two shifts (day and afternoon), limiting employee selectivity and causing fatigue due to long shift durations. It is recommended to refine employee shifts to three shifts (morning, afternoon, and evening) to shorten continuous working hours while maintaining total working hours, thereby improving work efficiency.

### **7.3.2 Differentiate Employees' Work Content**

Employee types can be further refined during recruitment, categorizing full-time employees into roles such as reception staff, financial staff, statisticians, and porters based on their abilities. Ensure part-time employees are adaptable enough to flexibly handle all positions, reducing labor constraints. This allows full-time employees to perform their respective duties efficiently with the cooperation of adaptable part-time employees, maximizing professional advantages and ensuring overall efficiency and professionalism in each position.

### **7.3.3 Establish Contingency Measures for Unexpected Employee Absences and High Demand During Peak Seasons**

Increase the minimum number of employees in each warehouse during peak periods and hire additional temporary workers during peak months. Implement benefits such as paid leave to allow employees to respond flexibly to emergencies. Consider employees' co-worker preferences to assign employees with good relationships to the same shift whenever possible, improving employee happiness.

## **8. Conclusion**

To minimize the employment cost of the RBI warehouse, this report analyzes the staffing problem, provides three assumptions and six constraints to build the model, and identifies a set of employee schedules most suitable for the RBI warehouse. As a result, employment costs can be minimized while ensuring that warehouse service quality meets standards. Microsoft Excel was used for modeling, with the results executed through Microsoft Excel Solver and Lingo. Additionally, sensitivity analysis was conducted to find the optimal employee scheduling plan when variables such as salary, the minimum number of shifts, and the number of employees change. The report also outlines the model's advantages, limitations, and recommendations for RBI.

Through analysis, certain limitations were identified, such as the lack of an effective reward mechanism and measures to handle sudden increases in employee demand during peak periods. To address these, continuous improvement of the model is suggested, including considering options like bonuses, vacations, and detailed employee responsibilities to further optimize the model, ensuring a more flexible, feasible, and applicable schedule. This model not only provides reference value for RBI's warehouse scheduling but can also be used by various companies requiring large-scale warehousing[8].

In summary, effective cost control in warehouse management is pivotal for ensuring optimal operational efficiency at Restaurant Brands International Inc. The maximization of warehouse space utilization, mitigation of stagnant goods accumulation, and reduction of warehousing expenses constitute significant challenges for RBI. Consequently, a mixed-integer linear programming model is employed to minimize warehousing costs while fulfilling essential operational requisites within the organizational framework.

This article first explores and analyzes diverse models, including linear programming, aimed at minimizing warehousing costs by studying and analyzing ten journal articles on various optimal warehousing problems. Constraints and binary decision variables are formulated based on foundational knowledge from prior research. The compendium of these ten literatures provides innovative perspectives and mathematical frameworks recommended for tackling the challenge of warehousing cost optimization. These methodologies range from convex programming models to goal programming models, each tailored to address the exigencies of diverse and intricate real-world scenarios.

However, certain areas for improvement were identified in the analyzed articles. Some literature lacks real data on the operations of the study, casting doubt on the feasibility of their respective models. Additionally, some modeling assumptions do not match the actual situation faced by RBI, limiting their applicability. Considering these observations, the development of a more realistic mathematical

model is advocated. Data on RBI's warehousing cost will be collected, followed by case studies and empirical research to ensure the model is accurate and intuitive. Finally, perspectives such as the use of modernized warehousing equipment and technological tools, or reducing material wastage through accurate demand forecasting, will be considered to further reduce warehousing costs.

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