A WORKFORCE PLANNING MODEL FOR FAIR SCHEDULES CONSIDERING EMPLOYEE SATISFACTION, SERVICE LEVEL, AND OPERATING COST

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A WORKFORCE PLANNING MODEL FOR FAIR SCHEDULES CONSIDERING EMPLOYEE SATISFACTION, SERVICE LEVEL, AND OPERATING COST

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ABSTRACT

We study workforce planning issues for call centers and propose a solution approach with a scheduling model. In this study, we emphasize the effects of employee satisfaction, fair distribution of shifts, and agent-related restrictions on working hours. We consider a cost minimization model with agent satisfaction targets through a Mixed Integer Programming model. In this model, we aim to minimize labor costs, personnel service costs, and customer loss costs as whole operating cost. In addition to minimizing operating costs, we define a happiness function which takes into account the shift preferences of contact center agents. The goal of increasing total happiness and individual distribution are included in the model. Finally, the agent-related restrictions of working hours are included in the model. Results are obtained using the contact center data of a consumer electronics company. In the results, besides the cost dimension, two separate dimensions are discussed as fair shift distribution and customer representative restriction scenarios. We examine the effects of these two different dimensions on operation costs and long-term planning. In different scenarios, we point out that these fair happiness and restrictiveness cause dramatic changes in cost when they exceed critical values.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The number of interactions between customers and companies have been dramatically increasing for the last couple of decades. Many new technologies became interaction channels such as emails, chats, and even the social media. As a result, traditional call centers evolved to massive multi-channel contact centers. The workforce requirement in contact centers increased and still significantly rises in contrary to other industries (Manyika et al., 2017).

Managing workforce in a multi-channel or omni-channel environment gets more important and complex. Contact centers generally manage their operations by tracking service level targets. In some industries, service level targets regulated by laws. For other industries, it is a matter of satisfying customer expectations. Customer experiences have a critical impact on profitability and abandonment rates have a notable influence on customer satisfaction (Lywood et al., 2009). This situation force companies to improve their service qualities.

Workforce planners design their planning process according to service level targets regarding the service quality. In a typical contact center, average labor expenses are above 75% of total organization cost (Smart, 2010). Dealing with biggest pie in cost, Workforce Management (WFM) became one of the core concepts in contact centers. WFM mainly covers forecasting workload, scheduling staff and tracking staff adherence topics. All of these phases significantly effects contact centers' efficiency.

Nowadays, several well-known technology companies provide solutions of WFM. Almost 89% of contact centers use a WFM solution and 61% of all use a complete WFM software (ICMI, 2017). However, the solutions are not yet ripe. According to a research of Creelman (2014), 58% of users are not satisfied with WFM solutions. As an initiative step of this study, we look through the reasons of dissatisfaction in the WFM topics. We examine industry reports and researches such as WorkForceSoftware (2017), Fluss (2013), Creelman (2014), ICMI (2017). These studies highlight several topics as an improvement subject including integration, employee engagements, fair schedules, long term agent requirements, adherence tracking, what-if analysis capabilities, requirement of manual labor overseeing. In the light of these research studies and our experience in WFM implementation projects, we focus on the following issues for this study:

- unfair schedule distribution,
- incompetence in what-if analysis of agent based scenarios,
- inadequate long-term agent requirements.

To understand the importance of these focused issues, we state details and effects of issues in following chapter.

CHAPTER II

PROBLEM DEFINITION

Contact center managements seek for better balanced staff assignments and more efficiency both. In this aspect, we define the issues mentioned in previous chapter as the sources of problems to be handled. Any improvement in handling these issues will assist contact center management and employees. We propose a shift assignment model to improve solution for three separate viewpoints described in following sections. Before mentioning handling of these issues, we describe our general assumptions about classical assignment problem.

Fixed Shifts Along a Week: Changing shifts of agents during a week may be more productive than working at same shifts during the week. However, changing shifts during the weeks make problem more complex to solve. On the other hands, the implementation of a model in which agents' shifts can be changed within a week is another problem. Difficulty in daily organizations and traceability of operations, and the need to follow the transportation problem on a daily basis are among the causes of this implementation problem. It also creates a challenge for the employee to work in different shifts within a week. Similarly, where employees have to follow their shifts on a daily basis, they could confuse their shifts on working days. In the call center environment where even break times are critically monitored and adherence is an important metric, daily shift changes pose an operational problem. Above all, it is very difficult to maintain by the agent because it causes irregularity and irregularity negatively affects work-life balance (Golden, 2015). Therefore, in this problem, we accept the shifts of the employees as steady during the week.

Two phase of the assignment problem: In shift assignment problem, all shifts of agents on all working days are assigned. When shifts are fixed during the weeks, shift assignment problems can also be solved in two steps. The first step is to assign shifts to agents with all financial and operational considerations, and the second step is to assign day-offs to agents. The solution of a theoretical day in which all agents are working allows the model to solve in these two steps. Firstly, we assign employees to the weekly shifts for this theoretical day and then assign the day-offs. Typically, call volumes of all intervals in a peak day are higher than in other days' intervals. Mondays are the peak days for most call centers. In this model, we aim to produce solutions for shifts assignment step for the whole week based on the peak days only.

Theoretical Call Volumes According To Shift Descriptions and Working Hours: In the call centers, the weekly working hours are generally fixed for agents with full time contracts. For example, In Turkey, weekly working hours' limit is 45 hours. An 8-hour shifts include 7.5 legal working hours, while 10-hour shifts include 9 legal working hours. Therefore, 8-hour shifts work for 6 days and use a day-off, while 10-hour shifts work for 5 days and take 2 day-offs. In a call center where agents work five days in a week, 20% of the whole week call volume is a critical call volume level. If peak day has 20% call volume of the whole week, where 20% is the rate of the working days to all week's call volume (5/100%), we can consider this day as the bottleneck of the whole week and a solution where all agents are working on this peak day subsumes other days with two day-off assignments. The day-off assignment for the remaining days after the shift assignment is made for peak day does not impair the optimization for the employees coming in a fixed shift during the week. Similarly, where agents work six days in a week, 16.7% of the whole week call volume is a critical call volume level for peak-day solution approach. For cases where the peak day does not achieve this critical call volume levels, a theoretical dummy day can be created which has the critical call volume and this dummy peak-day can be solved for the shift assignment problem.

Approaches Where Shift Lengths Can Vary: Our approach cannot guarantee optimal solution if the number of working days is not certain and if the original peak day call volume cannot cover the critical call volumes. In these cases, a dummy peak day solution also may not be enough. For such cases, we consider shift groups with short working hours and short day-offs as base shift definition. For example, in the case where there are 8-hour shifts and one day-off and 10-hour shifts and two day-off shifts, we consider the 8-hour shift and one-off shifts as the base shift definition. This makes it acceptable for the peak-day volume to be covered to be less than 20%. In addition, we define 10-hour shifts as usable too. These longer shifts are defined with an extra cost called as undesirability cost per worker like an overtime payment. However, we do not know if these shifts will be used as overtime shifts with one day-off or will be regular shifts with two day-offs. This is a downside of this approach. If a 10-hour shift assigned agent takes double-off in the day-off assignment step, then the additional cost will remain as an unrealistic redundant cost in the shift assignment step. However, this undesirability cost definition can be improved by know-how of the operational dynamics. When the practitioner of the implementation observe the number employees with double day-off and single day-off assignments, this undesirability cost can be set in a more sensitive way. The more precision here is successful, the more the approach closes to the optimal solution.

2.1 Unfair Schedules

This issue is relatively important in developing countries. Transportation structure, work culture, inadequate technical skills and necessity for training process make this issue worthwhile.

Perception of scheduling fairness plays an important role in employee engagement.

Here are the causal links of unfair schedules: unfair schedules reduce employee engagement, low engagement causes employee turnover and turnover brings extra operational cost on companies (WorkForceSoftware, 2017). On the other side, creating fair schedules in a constricted environment is a challenging process. Results must meet legal restrictions. Furthermore, it should consider agent satisfaction and daily variances as well. Current approaches give agents opportunity to specify working hours limitations and working time options. That causes a trade-off between efficiency and agent satisfaction. Keeping this trade-off under control can be difficult and may require intense labor attention. This is the main reason behind the standpoint of WorkForceSoftware (2017) survey.

In practice, providing a less irregular work scheduling improves agent satisfaction. According to Economic Policy Institute research (Golden, 2015), both irregular and rotating shift employees report experiencing work-family conflict considerably more than regular employees. However, this report also indicates that irregular shift employees report 37% more conflict in comparison to rotating shift employees. If company cannot compromise on flexible working hours, then rotating and less irregular shifts seem as one of the keys for agent satisfaction. Current solutions do not treat this issue in this perspective. They suggest slightly balancing distribution of shifts among the agents. Moreover, solutions generally handle this issue in a rather long term and do not provide regularity.

We propose a multi-criteria model that considers happiness of agents along with business requirements and operational cost. Model decides which shifts to be used with number of staffs in each one with minimum cost. At the same time, model considers assignments for each employee with minimum individual happiness levels.

We also include average transportation cost per person as an input on deciding agent assignments. Call centers may provide a contractual taxi or a passenger van or a large bus to pick up employees on a route. Each type of vehicle has different cost.

However, these differences between vehicles cause very minor changes in total cost comparing to other input elements such as employee number and service level cost. Besides, vehicle and route assignments are generally solved in an operational level on daily routines where agents have steady locations along months or years. Therefore, we only consider average per person cost and leave fine tuning up to daily hands on operations.

2.2 Incompetence of What-If Analysis

Especially in 24 hours working contact centers, flexibility becomes more substantial. Meeting customer demands with minimum workforce requires flexibility. Providing endurance for employees to keep these flexible working hours is a critical issue. Contact centers generally manage working time limits of agents by contracts. However, employee's personal issues can cause more restrictions on working time beyond contract terms for operation (Schalk and Van Rijckevorsel, 2007). What-if analysis capability is important to estimate effects of this issue. In terms of scheduling, when flexibility scales up and restrictions bottom out, effectiveness goes up.

For time windows, in a typical contact center environment, starting time intervals of shifts, rules of break-time distributions, range of shifts lengths are main variables that affects flexibility. For assignment restrictions, variables may be more diversified. Labor legislation, health restrictions, workplace rules, agent preferences, allowances for specific agents due to personal conditions and business rules affect flexibility.

For most contact centers, these mentioned variables are modifiable. Besides, decisions needed to be changed according to performance scenarios. Workforce managers need to look at how they are performing first, then respectively modify rules. In other words, decision makers require to see how inputs affects the outcomes. This requirement generates a business need for a sensitivity analysis.

Many solutions provide forecast based what-if scenarios. Some of them also provides a limited analysis for time windows parameters. However, in a holistic view, there is not any complete and sufficient solution (Fluss, 2013). For this study, we suggest an analysis approach considering agent requirements.

2.3 Required Number of Agents for Long Term Planning

Long term planning is another unfavorable topic. Long term plans cannot be discriminated from workforce planning process. Flexibility and captured efficiency of scheduling may vary due to external factors. Fluctuations of contact volumes directly affect occupancy ratios of agents. On the other hand, seasonal factors, vacation habits and even student ratio of employees dramatically affect turnover ratio and assignment restrictions.

2.3.1 A Real-World Scenario

This scenario is a real case observed by the author in a consumer electronic company. In contact center forecasts, call volumes increase in mid-summer season. To fill the gap between actual staff and needed staff, company plans recruiting employees just before the high season. The listed events occur in one high season:

Events

- Company seeks for mass recruitment
- Student ratio in applicants increases before summer
- Company hires many students
- Inexperienced employee ratio increases
- Average service time increases
- Vacation demands of agents increases in summer
- Working students demands limited working time windows

Unanticipated Chain Effects

- Scheduling efficiency drops because of more restrictive working hours demands
- Employee satisfaction decreases
- Unscheduled vacation requests accumulate
- After summer, while high season decreasingly continues, students start to leave their job
- Due to unsatisfactory, resigning of none-student employees also increases

As a result of listed occurrence, contact center reviews all plans for the forthcoming seasons. Administration demands crisis management plans against unexpected results. Contact center starts to overrate employee happiness because of increasing turnover rates.

We observe that recruiting policy and assignment restrictions have impacts on long term planning. An approach that considers these unanticipated effects is necessary for successful long-term plans. In this study, we provide an approach to analyze solutions for long term effects.

CHAPTER III

FORMULATION

In this section, we formulate a shift scheduling model to minimize the operational cost and consider happiness of agents. Table 1 indicates inputs and outputs of this model. In contact centers, call forecasting and staffing phases are preceding phases of WFM. Call forecasting is the phase that demand volumes are estimated for intraday, days and weeks. Staffing refers to demand which is the calculation of the number of agents that is required to provide a certain service level based on call forecasting. Contact centers commonly use Erlang-C functions to calculate staff requirements. We consider these requirements as demand which is accepted as an input to our model.

Table 1: Model Inputs and Outputs.

Inputs	**Outputs**
Demand	Number of Agents in Each Shift
Starting Time Intervals	Total Employee Cost
Average Cost of Shuttles	Total Shuttle Cost
Break Time Distribution Rules	Understaffed Hours
Possible Shifts	Agent-Shift Assignments
Agent Wages	Total Happiness Score
Undesirability Levels of Shifts	Happiness Score Distribution
Scheduling Period	
Shift Preference Scores of Agents	

3.1 Operating Cost and Weekly Agent Assignment

Figure 1 presents structure of a day in the model. Shifts, working time intervals, assigned agents, required agents, break time usages, undesirability of shifts and shuttle costs are main inputs of the structure in operational cost aspect. In this model, we accept length of a time interval as 1 hour. Which means shifts can start hourly. Each shift lasts either 8 hours or 10 hours. However, a night shift (starting after 14:00) can last only 8 hours due to business rules. We define undesirability cost for each shift. This cost indicates the value of inefficiency of shifts or cost of longer working hours. We also suggest using this cost as a symbolic penalty in case the management does not prefer any shift for any reason. For every starting and ending time of active shifts, there will be a shuttle cost. Departure and arrival shuttle cost depends station time of related shift. In some hours, transportation costs less than other times. In this model, we consider shuttles as average expenses only.

Shifts		Working Time Intervals (1 Hour Interval)																								
Start Time	End Time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Undesirable Shift Cost
		Number of Agents																								
08:00	16:00									46	38	38	31	31	38	38	38									$0,00
08:00	18:00									7	6	6	6	5	5	6	6	6	7							$10,00
09:00	17:00										0	0	0	0	0	0	0	0								$0,00
09:00	19:00										13	10	10	10	8	8	10	10	10	13						$10,00
10:00	18:00											0	0	0	0	0	0	0	0							$0,00
10:00	20:00											14	11	11	11	9	9	11	11	11	14					$10,00
11:00	19:00												0	0	0	0	0	0	0	0						$0,00
11:00	21:00												11	9	9	9	7	7	9	9	9	11				$10,00
12:00	20:00													0	0	0	0	0	0	0	0					$0,00
12:00	22:00													0	0	0	0	0	0	0	0	0	0			$10,00
13:00	21:00														8	7	7	5	5	7	7	8				$0,00
13:00	23:00														0	0	0	0	0	0	0	0	0	0		$10,00
14:00	22:00															0	0	0	0	0	0	0	0			$0,00
14:00	00:00															0	0	0	0	0	0	0	0	0	0	$0,00
15:00	23:00																0	0	0	0	0	0	0	0		$0,00
16:00	00:00																	33	27	27	22	22	27	27	33	$0,00
00:00	08:00	2	2	2	1	1	2	2	2																	$0,00
Total Assigned Agents		2	2	2	1	1	2	2	2	53	57	68	70	67	80	78	78	74	71	67	52	41	27	27	33	
Required Agents		4	3	2	2	1	1	2	4	37	76	84	86	83	83	80	86	83	77	68	53	47	29	20	13	
Avg Arrival Cost		$0	$15	$15	$15	$15	$15	$15	$15	$0	$15	$15	$15	$15	$15	$15	$15	$0	$15	$15	$15	$15	$15	$15	$15	
Avg Departure Cost		$15	$15	$15	$15	$15	$15	$15	$0	$15	$15	$15	$15	$15	$15	$15	$0	$15	$0	$5	$0	$15	$15	$15	$0	

Figure 1: Visualization of Shift Templates

Contact center mostly works 7/24. We described 17 possible shifts to cover all hours of a day. Distribution of these 17 shifts in these groups reflect industry averages. Each shift has a start time, end time, agents, undesirability cost and break time distribution. The number of each cell in Figure 1 indicates average number of actively working agents along the interval. In the figure, first number of each shift also equals to total number of agents working in that shift. Upcoming numbers of same shift is equal or less than first cell. That means, in the following hours, active agent numbers drop because of break time usage. We describe break times according to length of shifts. We observe that, on average, most contact centers describe break time ratio between 15% and 20% of total time. In this description, break time includes lunch time. We accepted a 17% break time on average. Distribution of break times is indicated in Figure 2. Cell fullness in each interval indicates rate of concurrent working agents. In middle hours, lunch breaks decrease working agent percentage down to 67%. In principle, agents do not use breaks in intervals following starting time or preceding ending time.

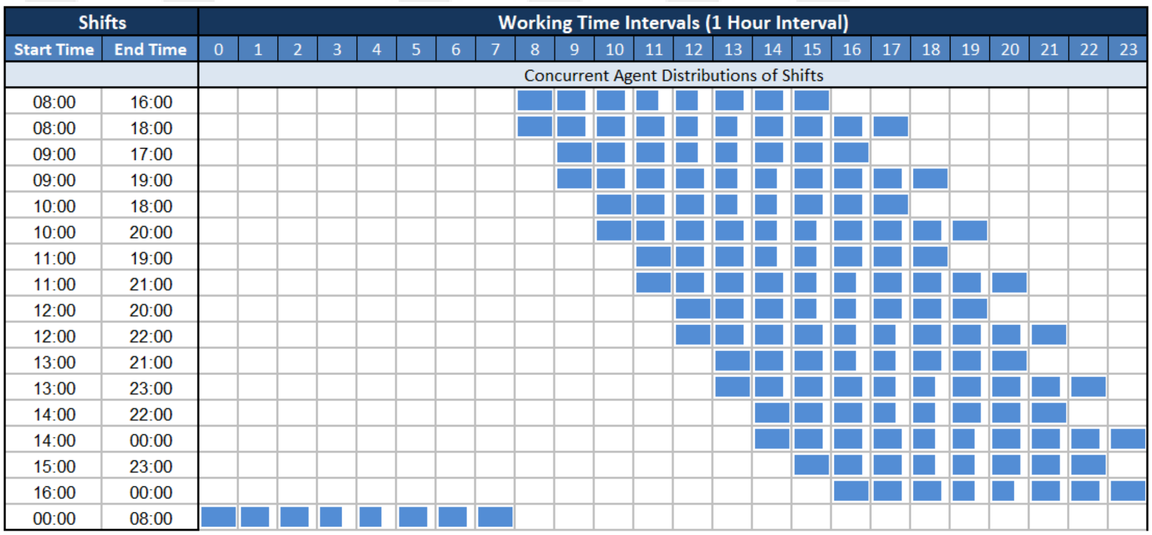

Figure 2: Break Time Factor

Our goal is to minimize operational costs and providing a satisfying service level for the customers. Typically, contact centers do not use monetary figures for unsatisfied services. We consider understaffing as cost of poor customer experiences occurring during the waiting time in line. Fink and Gillett (2006) suggest a cost function related to waiting times in queue with a utilization of Taguchi loss function. We do not consider waiting times in the queue as an input to our model. Most contact centers strategically set a service level and only tracks their shortage from their target service level. We accept required number of staffs for the service level as demand. Our input is average shortage of headcounts which we call understaffed to these demand levels in an interval. We evaluate a demand loss function from Taguchi loss function approach.

Figure 3 shows the required number of agents (red-line) and the number of agents in each shift (blue stacked areas) for a sample day. Input restriction of contact centers precludes alignment of required and working number of agents. As a result of this, over-staffing and understaffing occur. In Figure 3, an over-staffing period is demonstrated along $8th$ and $9th$ intervals. In these intervals, scheduled number of agents (stacked area with blue tones) exceed required number of agents. In contrary, scheduled number of agents fall behind required number (understaffing) between $10th$ and $13th$ intervals.

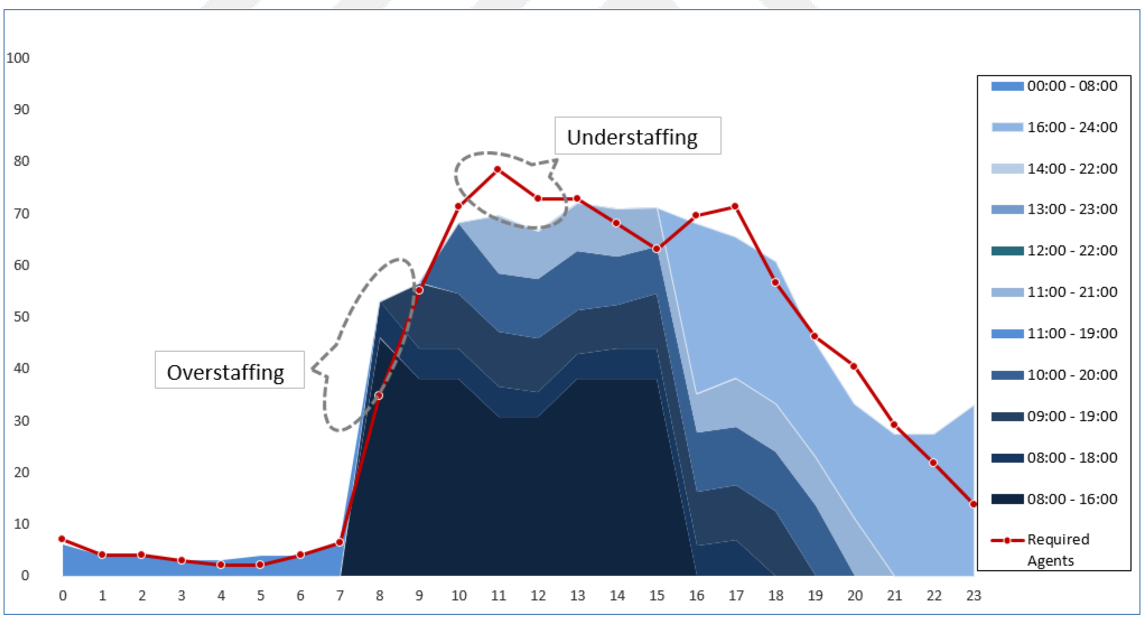

Figure 3: Required and Working Number of Agents

When understaffing levels increase in an interval, waiting times increase exponentially in queues. For our model, we propose a simple formulation that exponentially penalize ratio of understaffing to demand. We explain details of the function in Section 3.3.

3.2 Agent Happiness in Consecutive Weeks

Agents work multiple days in a week. A full time agent is expected to work some hours which is between business' upper and lower weekly working time bounds. In this model, we assume an agent works in the same shift across a week. However, in the week following, agents can work in different shifts. We call this as shift rotations. In this model, our aim is to balance shift rotations for all agents in employee satisfaction perspective. This way, we create shift rotations in which agents are expected to be more satisfied.

From an employee's perspective, each shift has a different level of desirability. We split these desirable levels into five priority degrees. In our solution, we accept that importance of these preferences is exponential. Table 2 indicates the happiness scores of agents and priority degrees.

Table 2: Preference Scoring Sample

Preference Priority	**Preference Score**
First	8
Second	4
Third	2
Fourth	1
Others	0

We collect preferences of all agents with a survey to create scores in model. We observe that, while most agents prefer morning shifts which are typical working shifts in any industry, some agents prefer other shifts as well. Table 3 is a demonstration of a sample preference matrix for nine agents and eight shifts. In this table, preference order of agent 1 is shift 1, shift 2, shift 8 and shift 5, respectively. Besides, agent 1 has no interest in other shifts.

In the solution, for the first week, model assigns all agents to some of available shifts.

Table 3: Preference Matrix Sample

Agents	shift 1	shift 2	shift 3	shift 4	shift 5	shift 6	shift 7	shift 8
agent 1	8	4	0	0	1	0	0	2
agent 2	8	4	0	0	0	0	2	1
agent 3	4	8	0	2	0	0	0	1
agent 4	4	2	0	1	0	0	1	0
agent 5	4	2	0	1	0	8	0	0
agent 6	2	1	8	4	0	0	0	0
agent 7	1	2	0	4	8	0	0	0
agent 8	0	0	1	2	4	0	0	8
agent 9	0	8	0	4	2	0	0	1

For a cost-effective result, some agents get favourite shifts while others may get non-desired shifts. For second week, assignments of agents need to be improved in terms of preference score. So that unsatisfied agents of first week will be more likely to be assigned their relatively favourite shifts. On the contrary, satisfied agents of first week will be more likely to be assigned non-desired shifts. Thus, we aim to provide a balance in satisfaction level of agents. To do so, we consider overall and individual satisfaction levels of agents beyond operational cost.

3.3 Mathematical Model

According to the rules and objectives described above, we propose a mathematical model to solve the addressed issues. The list of parameters and variables in this model are shown in Table 4 and Table 5. Given the set of available shifts, break time distribution, agents, demand, shift preferences, average shuttle and employee costs, the agent assignment problem entails deciding which shifts to be used and which agents to be assigned to these shifts in order to minimize the total expected cost and maximize happiness while covering demands along consecutive weeks. We consider demands in intervals. Demand forecasts differ from one week to another. We accept that shift assignments do not change within the weeks. Furthermore, we

Table 4: Model Parameters

Description	Parameter
Week Index in Planning Horizon	w
Shift Index in a Week	s
Interval Index in a Day	t
Agent Index	i
Individual Happiness Lower Limit	h
Total Happiness Lower Limit	H
Weekly Cost Per Agent	c^{agent}
Cost Estimation for 1% of Understaffing	$c^{\text{understaff}}$
Undesirable Cost of Shifts	$c_s^{\text{undesirable}}$
Average Per Person Arrival Shuttle Cost for Intervals	c_t^{v}
Average Per Person Departure Shuttle Cost for Intervals	$c_t^{\prime\text{v}}$
Break Time Factor of Intervals in Shift Horizon	a_t^s
Demand in Intervals of Weeks	d_t^w
Agents' Preference Value of Shifts	p_{is}
Starting Interval Binary of Shifts	s_t^s
Ending Interval Binary of Shifts	e_t^s

Table 5: Model Variables

Description	DV
Binary Variable of Agents' Shift in Weeks	Y_{isw}
Individual Average Happiness Score Auxiliary Variable of Working Weeks	A_{iw}
Individual Average Weekly Happiness Score Variable	Z_i
Number of Agents Variable in Shifts of Weeks	X_s^w
Understaff Level Variable in Intervals	U_t^w

observe that peak day of each week has at least 18% of total demand. So that peak day solution subsumes other days where agents work six days in a week or most of the scenarios where agents work five days in a week. In the light of these, for optimizing problem set, demand volumes and shift assignments of everyday does not concern us. We only consider peak days of each week. In this case, we do not provide assignment of day-offs as a part of the solution. Since the solution covers peak days, and peak days are the bottlenecks of working weeks, day-offs can be assigned with using output of this model. For most cases, excluding day horizon from the problem do not effect efficiency of solution. For only occasional call distribution scenarios, where demand in days are distributed evenly, peak day solution may not be sufficient to solve day-off assignment problem. For such occasions, an optimal dummy volume can be added to original peak day's demand to make peak day solution sufficient for day-off assignment problem.

3.3.1 Objective Definitions

We approach this problem with a goal programming model. Let $W = \{0, 1, ...W\}$ be the weeks, $S = \{0, 1, ...S\}$ be the set of S different shift types and $T = \{0, 1, ...T\}$ be the set of T time intervals in a day. Each shift type $s \in S$ has a number of X_s^w working agents for each week $w \in W$. Each agent costs c^{agent} weekly to company. Beyond this, all s shifts have $c_s^{\text{undesirable}}$ cost parameters. Each $c_s^{\text{undesirable}}$ description reflects extra hours cost or inefficiency in perspective of management for that specific s shift. We describe these costs as employee cost function to be minimized;

$$C_{\text{employee}} = \sum_{w=1}^{W} \sum_{s=1}^{S} (c^{\text{agent}} + c_s^{\text{undesirable}}) \times X_s^w \tag{1}$$

A shift starts where s_t^s binary is equal to 1 and ends where e_t^s binary is equal to 1. For t intervals of w weeks where s_t^s or e_t^s binaries are equal to 1, there is a shuttle requirement for agent transportation. We define c_t^{v} cost for arrival shuttles as average per person cost and $c_t'^{\text{v}}$ cost for departure shuttles as average per person cost. Cost of shuttles may differ for any t interval or for arrival and departure types. We accept shuttle costs as average per person prices for any number of agents. Thus, we consider X_s^w number of agents factor in calculation of shuttle costs. We describe arrival and departure shuttle costs function as;

$$
\begin{aligned}
C_{\text{arrivalshuttle}} &= \sum_{w=1}^{W}\sum_{t=1}^{T}\sum_{s=1}^{S}(X_s^w \times s_t^s \times c_t^{\text{v}}) \\
C_{\text{departureshuttle}} &= \sum_{w=1}^{W}\sum_{t=1}^{T}\sum_{s=1}^{S}(X_s^w \times e_t^s \times c_t^{\text{v}}) \\
C_{\text{shuttle}} &= C_{\text{arrivalshuttle}} + C_{\text{departureshuttle}}
\end{aligned} \tag{2}
$$

Agents cost and shuttle cost are the all operational costs of the contact center which we deal with. Beyond these costs, there are understaffing and over-staffing situations to be minimized. Over-staffing creates unnecessary workforce in terms of demand covering. C_{employee} is enough to prevent over-staffing. However, understaffing situations create cost to company because of dropping customer satisfaction. Model aims to cover all d_t^w demand with a U_t^w understaffing deficiency. This deficiency prevents infeasibility and redundant expenses in t interval of w week. We define $c^{\text{understaff}}$ as cost parameter for unsatisfied service levels. Understaffing effects queue lengths gradually. Also the waiting times of customer depends on service capacity, which we accept that demand represents service capacity without breaking linearity of function. When demand is low, even a small understaffing affects the waiting time of customers in queue significantly. Thus, we use the rate of understaffing to demand in formulation. To reflect these gradually growing effects of understaffing to demand ratio, we simply define understaffing penalty as a square function of the understaff rate. The cost function is one of the objective criteria to be minimized as;

$$
C_{\text{understaff}} = \sum_{w=1}^{W}\sum_{t=1}^{T} c^{\text{understaff}} \times (100 \times U_t^w / d_t^w)^2 \tag{3}
$$

Employee cost, shuttle cost, understaffing penalty are all to be minimized as the whole operating cost in the objective. Considering all, conclusive objective function is:

$$
\min\ C_{\text{employee}} + C_{\text{shuttle}} + C_{\text{understaff}} \tag{4}
$$

3.3.2 Competing Goals: P1 and P2 against total cost

We additionally have happiness goals which are competing against minimum cost goal described in objective function. We define the following two different problem models for happiness goals:

- P1: has minimum individual happiness levels for each agent,
- P2: has minimum overall happiness levels for all agents.

3.3.2.1 Happiness Calculation

Let $I = \{0, 1, ...I\}$ be the set of all I agents in the company. Each individual $i \in I$ agent work in one shift of S set. Y_{isw} is decision variable for shift assignment. When agent i works in shift s within week w, Y_{isw} equals to 1 and otherwise equals to 0. Each i agent has a preference value for all s shifts. p_{is} matrix indicates these preference values of all agent for all shifts. When an i agent is assigned to a s shifts, agent also gets an average Z_i happiness score from multiplication of Y_{isw} assignment matrix and p_{is} preference matrix for all weeks that agent assigned to any shift.

3.3.2.2 P1: Individual Happiness Level

We want fair schedules for all agents. Therefore, we do not want to Z_i individual happiness fall under h level for every agent in the end of the working weeks. We set a lower one-sided goal for Z_i happiness values for each agent as Equation (5).

$$Z_i \geq h \quad \forall i \in I \tag{5}$$

3.3.2.3 P2: Overall Happiness Level

Second goal is to make cumulative happiness greater. We do not want total happiness level fall under H score. Equation (6) satisfies this as a cumulative one-sided goal.

$$\sum_{i \in I} Z_i \geq H \tag{6}$$

3.3.3 Constraints

$$\sum_{s=1}^{S} a_t^s \times X_s^w + U_t^w \geq d_t^w \quad \forall t \in T, w \in W \tag{7}$$

$$\sum_{w=1}^{W}\sum_{s=1}^{S} p_{is} \times Y_{isw} = \sum_{w=1}^{W} A_{iw} \quad \forall i \in I \tag{8}$$

$$Z_i - M \times (1 - \sum_{s=1}^{S} Y_{isw}) \leq A_{iw} \leq M \times \sum_{s=1}^{S} Y_{isw} \quad \forall i \in I, w \in W \tag{9}$$

$$A_{iw} \leq Z_i \quad \forall i \in I, w \in W \tag{10}$$

$$\sum_{s=1}^{S} Y_{isw} \leq 1 \quad \forall i \in I, w \in W \tag{11}$$

$$\sum_{i \in I} Y_{isw} = X_s^w \quad \forall s \in S, w \in W \tag{12}$$

$$\begin{aligned}
Y_{isw} + Y_{ik(w+1)} &<= 1 \quad \forall i \in I, k \in \{1,2,3,4,5,6\}, s = 16, w <= 3 \\
Y_{isw} + Y_{ik(w+1)} &<= 1 \quad \forall i \in I, k \in \{1,2,3,4\}, s = 15, w <= 3 \\
Y_{isw} + Y_{ik(w+1)} &<= 1 \quad \forall i \in I, k \in \{1,2,3,4,5,6\}, s = 14, w <= 3 \\
Y_{isw} + Y_{ik(w+1)} &<= 1 \quad \forall i \in I, k \in \{1,2\}, s = 13, w <= 3 \\
Y_{isw} + Y_{ik(w+1)} &<= 1 \quad \forall i \in I, k \in \{1,2,3,4\}, s = 12, w <= 3 \\
Y_{isw} + Y_{ik(w+1)} &<= 1 \quad \forall i \in I, k \in \{1,2\}, s = 10, w <= 3
\end{aligned} \tag{13}$$

$$\begin{aligned}
V_t^w, V_t'^w &\in \{0,1\} && \forall t \in T, w \in W \\
Y_{isw} &\in \{0,1\} && \forall i \in I, s \in S, w \in W \\
X_s^w &\geq 0 && \forall s \in S, w \in W \\
A_{iw} &\geq 0 && \forall i \in I, w \in W \\
H_i &\geq 0 && \forall i \in I \\
U_t^w &\geq 0 && \forall t \in T, w \in W
\end{aligned} \tag{14}$$

An s shift consists of successive 8 or 10 working hours. Each agent works as much as s shift lasts. However, each agent has break times which are planned as unproductive times. For every $t \in T$, a_t^s is the productive time coefficient which is defined for all s shifts. It reflects workforce loss break time applications for agents. The required number of agents for each interval is satisfied in Equation (7). Equation (8) is calculation of weekly individual happiness scores of all agents from their preference scores of working shifts. Equation (9) and (10) calculates Z_i average happiness scores of agents in their working weeks and shifts. P1 and P2 goals are based on this average happiness scores. Equation (11) ensures that any agent can only work in one shift at most. Equation (12) ensures each assigned agent contributes as worker to X_s^w. In Equation (13), we define workable shifts in consecutive weeks. In shift transitions across the weeks, agents must rest at least 11 hours according to labor legislation. Thus, after working in some of the shifts, agents are not allowed to work in particular shifts. For example, when an agent works for shift 16, which ends midnight, that agent can not work for shifts that starts earlier than 11:00 o'clock (shift 1,2,3,4,5, and 6) for the following week. Equation (14) includes bounds for decision variables.

CHAPTER IV

RESULTS

In this chapter, we indicate the instances which we use in our model. For different problem sets, we examine outcomes of all problems and analyze the results. Lastly, we discuss the findings about results.

4.1 Instances

Demand: We solve this model for a real call volume sample of a consumer electronics manufacturer. We use only peak day volumes for each week. Demands are processed in weekly and interval based as shown in Figure 4. Demand volume increases from week 1 to week 4 because of seasonality effect in the beginning of summer.

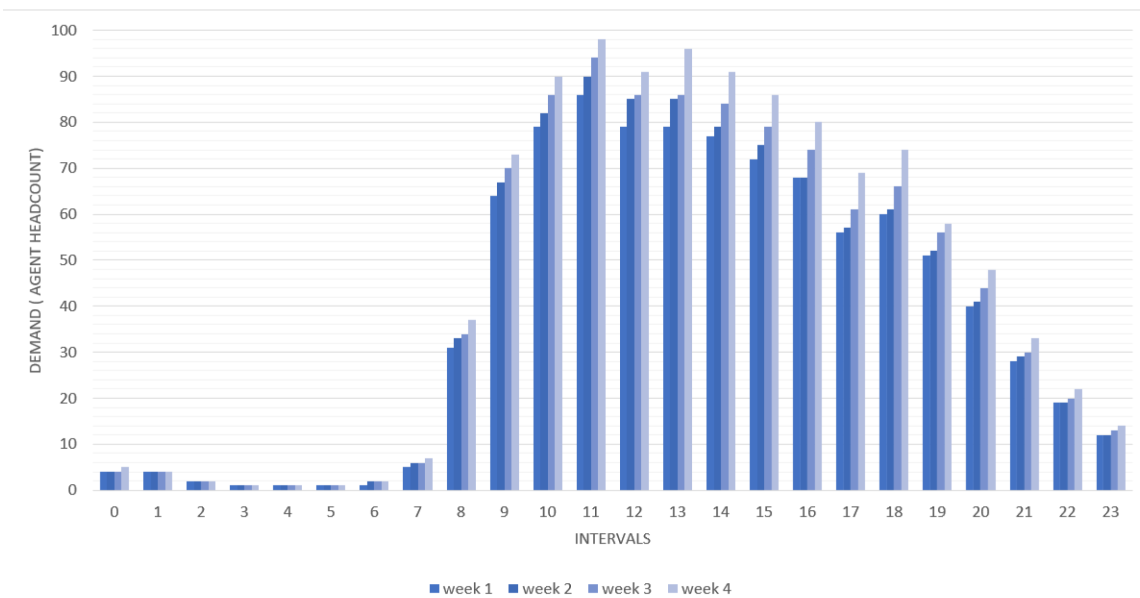

Figure 4: Demand Volumes

Shifts: We describe 24 intervals and 17 possible shifts for a day. Figure 5 indicates all shifts with break time factors for each hour and undesirability cost. a_t^s break time factors are the multiplier of concurrent workforce in intervals. When an agent's shift is off, a_t^s is equal to zero for these off intervals. We define undesirability cost as a multiplier of working agent in the same shift. We only set undesirability cost for longer shifts where agents get overtime pay.

intervals	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	undesireablity
shifts	Break Time Factor of Intervals in Shifts																								cost
1	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	$0,00
2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	0,00	$50,00
3	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	0,00	0,00	$0,00
4	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	$50,00
5	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	0,00	$0,00
6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	$50,00
7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	$0,00
8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	$50,00
9	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	$0,00
10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	0,00	0,00	$50,00
11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	$0,00
12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	0,00	$50,00
13	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	$0,00
14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**0,83**	**1,00**	$50,00
15	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	$0,00
16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	$0,00
17	**1,00**	**0,83**	**0,83**	**0,67**	**0,67**	**0,83**	**0,83**	**1,00**	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	$0,00

Figure 5: Shift Descriptions

Shuttles: In our model, employer provides shuttles for all agents. If any number of agents starts work in a shift, there must be a shuttle for starting and ending interval of these shifts. Average shuttle costs vary for intervals within a day. Figure 6 indicates average arrival and departure shuttle costs per person for each interval. We assume the cost are lower for intervals that can be useful for other group employees.

Intervals	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Avg Arrival Cost Per Agent	$2	$8	$8	$8	$8	$8	$8	$8	$2	$6	$6	$6	$6	$6	$6	$6	$2	$6	$6	$6	$6	$8	$8	$8
Avg Departure Cost Per Agent	$2	$8	$8	$8	$8	$8	$8	$8	$2	$6	$6	$6	$6	$6	$6	$6	$2	$6	$2	$4	$2	$8	$8	$8

Figure 6: Shuttle Costs

Agents: We accepted that company can employ at most 150 agents to handle all call demands. All agents do not necessarily work all weeks. Contact centers hire employees gradually when requirements increase from week to week. On the other hand, we observed that employer can use excess workforce on other tasks or for annual leaves. Thus, we only have an upper limit for number of agents.

Preference Scores: Each agent specifies 4 shifts out of 17 as preferred shifts. We projected real preference orders of an agent group of the consumer electronics manufacturer. We give 8, 4, 2, 1 scores respectively for $1st, 2nd, 3rd$ and $4th$ shift preference orders. Average preference scores for each shift is shown at Figure 7. Most agents prefer early shifts (Shift 1 and Shift 2) which starts at 08:00 am. Some evening and night shifts (Shift 16 and Shift 17) are also relatively popular shifts among agents.

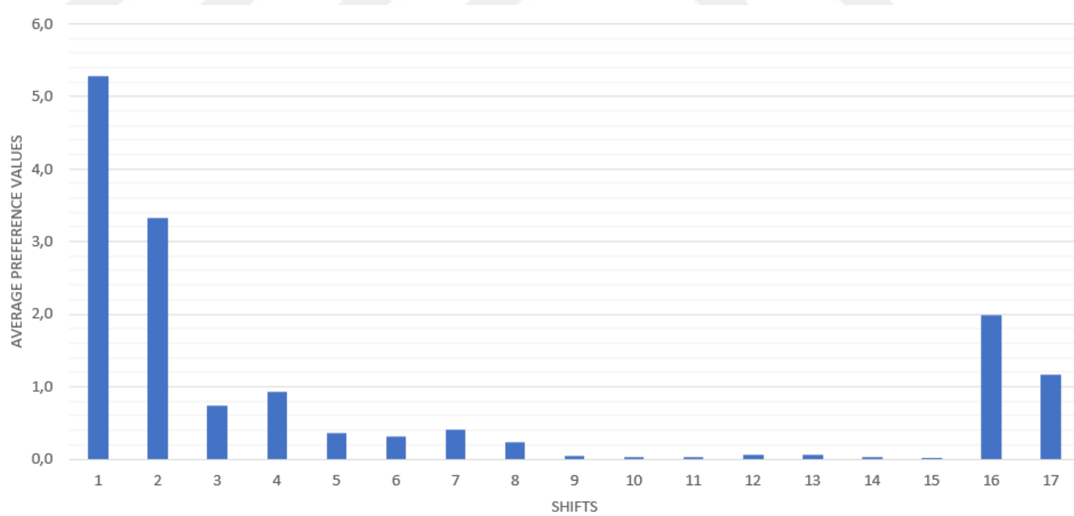

Figure 7: Preference Scores

Other parameter values are indicated in Table 6. We run all our instances in GUROBI 8.0 with a gap tolerance of 1% on a 3.6 GHz Intel i7 Quad-core Computer with 16 GB RAM running a Linux operating system. For optimization problem, instance was solved within 5 minutes.

Table 6: Parameter Values

Description	Parameter	Value
Week Set	W	4
Shift Set	S	17
Interval Set	T	24
Agent Set	I	150
Agent Cost	c^{agent}	\$ 200
Understaff Cost	$c^{\text{understaff}}$	\$ 10

4.2 Results and Sensitivity Analysis: P1

As we mentioned in the previous chapter, P1 is the problem in which individual happiness levels are constrained by a lower bound. For different runs, while keeping all parameters and data constant, we solve the model with different lower bounds on happiness (h values). We run the model for $h \in \{0, 1, 2, 3, 4, 6, 7, 8\}$ and get 8 solutions. We observe the objective value, total happiness level, and happiness distribution for every h value. Agents get average Z_i happiness scores from their assignments' preference scores. Z_i can be fractional because it is divided by the number of working weeks.

Minimum Individual Happiness Levels: Table 7 indicates the number of agents within happiness ranges for all runs. Column headers denote the h value input to the optimization model. Optimal objective values are given as cost in \$ 1000's at the bottom row of this table. In each column, we present the average happiness distribution, breaking into intervals of length 1. For instance, for $h = 0$, Z_i scores of 83 agents are in range of $[0 - 1)$ and 19 agents' scores are in range of $[1 - 2)$. While lower h bound increases, individual happiness levels of agents converge significantly. The more happiness scores converge, the more schedules become fair for all agents (Blöchliger, 2004).

Table 7: Happiness Distribution

Z_i Range/h	0	1	2	3	4	5	6	7	8
[0-1)	83	0	0	0	0	0	0	0	0
[1-2)	19	62	0	0	0	0	0	0	0
[2-3)	35	68	120	0	0	0	0	0	0
[3-4)	8	9	14	89	0	0	0	0	0
[4-5)	3	8	12	61	130	0	0	0	0
[5-6)	0	1	3	0	14	81	0	0	0
[6-7)	0	2	1	0	6	68	149	0	0
[7-8)	0	0	0	0	0	0	1	77	0
[8]	2	0	0	0	0	1	0	73	150
Cost (in $ 1000)	139	139	139	139	140	143	157	522	618

Distribution of Shifts: Figure 8 shows the distribution of agents in all available shifts. We see that when h increases, diversification in distribution decreases. Especially in the mid-day shifts (shift-numbers 3 to 15), we see the number of assignments diminishes for greater h values. On the contrary, shift 1, shift 2, and shift 16 wage increases. We see that the assignment distribution reflects the preference distribution in the right-hand side of the table. Figure 10 and Figure 8 present the trade-off between shift efficiency and happiness levels.

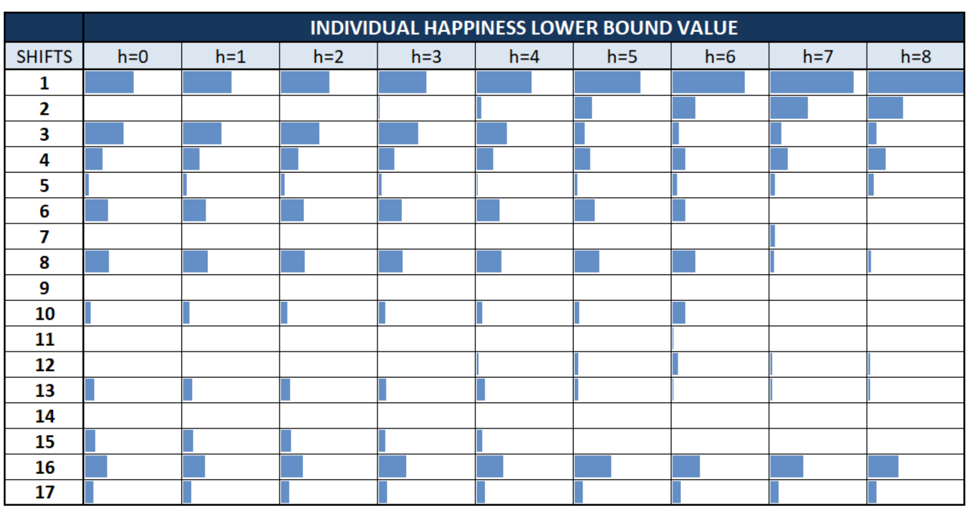

Figure 8: Distribution of Agents in Shifts

Cost of Happiness: Figure 9 indicates the objective value and total happiness value relationship. Objective value is the cost estimation and total happiness value is summation of all agents' happiness scores. When we increase individual happiness lower bound, total happiness is also increased in the same proportion. When h is between 0 and 5, we see the objective value stays still around $ 140 K. However, when we keep increasing h from 6 to 8, objective value significantly raises. Especially, when the bound goes from 6 to 7, the cost triples. Note that the number of agents is limited to 150. Workforce, shuttles, and undesirability costs are limited to around $ 132 K. We know the excess cost occurs due to of understaffing which leads to loss of unsatisfied customers. When h is greater than 6, demand cannot be covered within an acceptable service level.

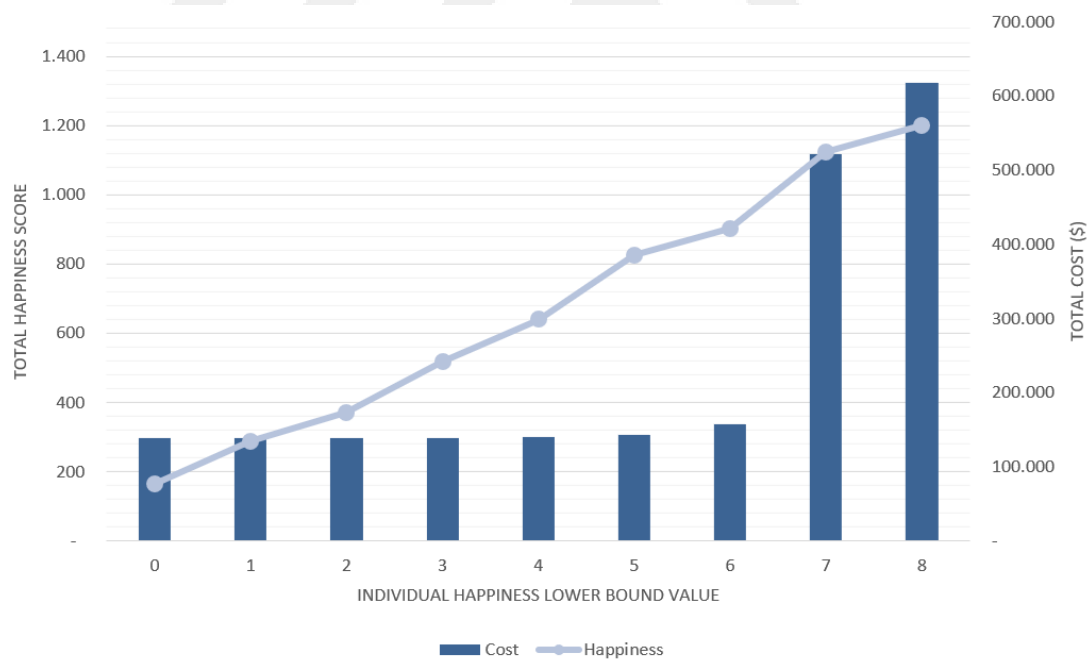

Figure 9: Cost and Happiness Values of P1

Working Hours and Understaffed Hours We track two additional measures on covering demand which are given in Figure 10. We measure the total understaff hours as in equation (15) and total working hours in equation (16).

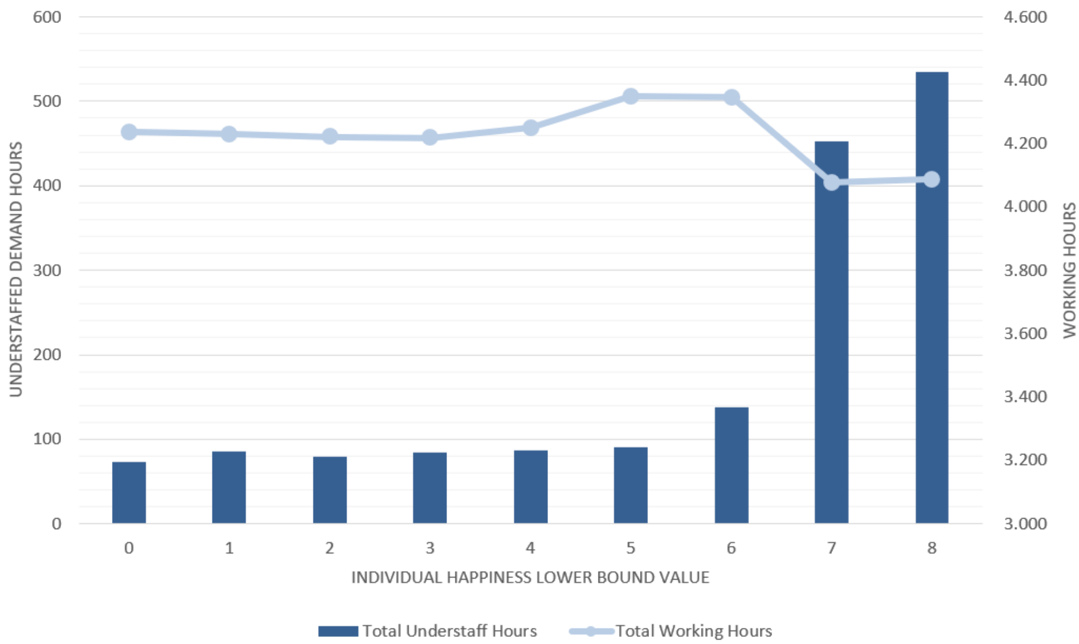

Figure 10: Total Understaff and Working Hours

$$\text{Total Understaff Hours} = \sum_{t=0}^{23} \sum_{w=1}^{4} U_t^w \tag{15}$$

$$\text{Total Working Hours} = \sum_{s=1}^{17} \sum_{t=0}^{23} \sum_{w=1}^{4} a_t^s \times X_s^w \tag{16}$$

In Figure 10, total working hours slightly increase when h increases up to 4. For the same part, there is no significant change for total understaff hours. We can infer that increasing the individual happiness lower bound from 0 to 4 have no significant effect on either required workforce level or service level. When h moves from 4 to 5, we see a hike in both total working hours and total understaff hours. For $h = 6$, we observe that total working hours is still near peak. However, we see that total understaff hours increases significantly. We observe that individual happiness lower bound starts to force model to assign some agents to less efficient but happier shifts for $h = 6$. When h is greater than 6, we see total working hours drops heavily. Solution becomes unfeasible for some of the agents in particular weeks because of high average individual happiness lower bound. Model creates enforced off-weeks for certain agents. Total understaff hours also increase in great amount because more agents are assigned to inefficient shifts and some of agents have unassigned weeks.

4.3 Results and Sensitivity Analysis: P2

In this problem, we consider the bound for overall happiness of all agents as well, donated by H. In P2, we do not consider the distribution of individual shifts and happiness levels. This means we do not consider fairness of schedules but only overall happiness score. For P1, we observe that lower happiness bounds have no significant effect on the objective function values. In Figure 9, we see that the objective value changes when individual happiness lower bound is greater than 4. Therefore, we pick the overall happiness levels in P1 where h is greater than 4. We observe that the overall happiness scores are respectively 640, 824, 904, 1123, and 1200 where $h \in \{4, 5, 6, 7, 8\}$ in P1. Therefore, we use these overall happiness scores as a bound in P2. We also know the result for $h = 8$ represents the solution where all agent gets the maximum average happiness level and overall happiness level together. Therefore, we run instances for $H \in \{640, 824, 904, 1123\}$ in P2 to compare the results with P1. Table 8 indicates that costs of overall happiness levels are different for P1 and P2. Bottom row highlights percentage of cost difference between P2 and P1.

Table 8: Overall Happiness Cost

Overall Happiness Scores	**640**	**824**	**904**	**1123**
P1 Cost ($ 1000)	140	143	157	522
P2 Cost ($ 1000)	139	139	141	304
(P1 Cost - P2 Cost) / P2 Cost	0.7%	2.3%	10.9%	71.5%

In this table, we see the cost difference is worthwhile where overall happiness score is greater than 824. P2 is more cost effective than P1 in this aspect. The gap between objective costs (bottom row of the table) significantly increases for higher overall happiness scores. We know that the difference between P2 and P1 problems is the consideration of fairness with regard to individual happiness distributions. Therefore, we consider the cost difference between P2 and P1 as the cost of fairness. So we can summarize these costs as follows: an overall gain of around 1100 happiness score costs around $220 K. However, a fair happiness distribution that leads to a total of around 1100 happiness score costs almost twice as much. Table 8 shows that cost of fairness can be very expensive for higher happiness levels. However, fairness has a modest price under 824 happiness score, in which h bound is equal to 5 or less.

4.4 Results and Sensitivity Analysis: Restrictive Scenarios

In this problem, we involve the availability of agents to our problem set. Availability of agents can be limited by legal restrictions or personal issues. We divide agents into 5 groups according to their availability: unrestricted agents, pregnant agents, student agents, disabled agents and outlying agents. Unrestricted agents have no limitations. Working hours of pregnant agents are restricted by labor laws. Pregnant agents are not allowed to work more than 8 hours in a day and in their work time, company has to keep a medical doctor. Within all available shifts, only shift 1 and shift 3 are workable shift for pregnant agents because of this labor law. Company follows a similar policy for disabled agents too. Students have to be off in daytime. Outlying agents are the ones that resides remotely. The company cannot provide shuttles to those agents for some specific time windows due to vehicle route restrictions. We indicate all workable shifts as "1" and non-workable shifts as "0" in Table 9 for all agent groups.

We consider four agent scenarios named as high restriction, medium restriction, low

Table 9: Available Shifts of Agent Groups

Shifts	Unrestricted	Pregnant	Disabled	Student	Outlying
1	1	1	1	0	1
2	1	0	1	0	1
3	1	1	1	0	0
4	1	0	0	0	0
5	1	0	1	0	0
6	1	0	0	0	0
7	1	0	0	0	0
8	1	0	0	0	0
9	1	0	0	0	0
10	1	0	0	0	0
11	1	0	0	0	0
12	1	0	0	0	0
13	1	0	0	0	0
14	1	0	0	0	0
15	1	0	0	1	0
16	1	0	0	1	1
17	1	0	0	1	1

restriction and no restriction. Each one uses 150 agents. In high restriction scenario, group populations are distributed as highly restrictive. In medium restriction scenario, the group populations are close to the actual distribution of agents. Low restriction scenario has fewer and no restriction scenario has no restrictive agents. Number of agents in each group are given in Table 10.

Table 10: Number of Agents in Groups

Scenario	Unrestricted	Pregnant	Disabled	Student	Outlying
high restriction	30	20	20	20	60
med. restriction	90	10	10	10	30
low restriction	120	5	5	5	15
no restriction	150	0	0	0	0

We observe the objective values for all scenarios. We accept no restriction scenario as base scenario to compare cost with others. Table 11 indicates costs of all scenarios and cost differences to no restriction scenario. We see the medium restriction and low restriction scenarios have no effect on total cost. However, high restriction scenario is 14 % more expensive than no restriction, medium restriction, and low restriction. Like happiness limit results in P1, we see that restrictiveness of agents can be unimportant up to a point. On the other hand, exceeding that critical point dramatically increase total cost.

Table 11: Cost of Restriction

	no rest.	**low rest.**	**medium rest.**	**high rest.**
total cost ($ 1000)	139	139	139	159
cost gap	-	0%	0%	14%

4.5 Results and Sensitivity Analysis: P1 with Restrictive Scenarios

We combine P1 and Restrictive Scenarios problem to see results for a more realistic scenario. In P1, we accept best frontier solutions are for $h \in \{4, 5, 6\}$. We combine these h bounds with agent restriction scenarios.

Total costs of all scenarios are given in Table 12. We see when h bound increases, operating costs get past endurance for more restrictive scenarios. Mutually, we can say when restriction levels increase, tolerance to individual happiness levels decreases for the operation.

Table 12: Cost of Happiness Levels with Restriction

	no rest.	**low rest.**	**med. rest.**	**high rest.**
cost for h=4 ($ 1000)	140	140	140	193
cost for h=5 ($ 1000)	143	144	155	224
cost for h=6 ($ 1000)	157	160	176	243

Efficient Scenarios for Long Term Planning: For long term planning, Table 12 can assist decision making process on available scenarios. When only goal is the cost minimization, we see contact center has to spend at least \$138 K operating cost. Generally, operations have tolerance for extra costs to conform their other goals. We approach other goals with efficient extreme points in the outcome set likewise to Benson (1998). We create Table 13 to show outputs of efficient set in two perspectives along operating cost. First perspective is minimum happiness level: We accept that any higher h bound which does not add extra cost is always a better option rather than lower h bound scenarios. Second perspective is tolerance to agent restrictiveness. Higher tolerance levels to agent restrictiveness relieve contact centers in their human resource management policies. Decreases in tolerance reduces recruiting options of contact centers and responsiveness in seasonal changes when demand suddenly increases. Thus, we accept that higher level of tolerance to restrictive scenarios is always a better option for the same amount of acceptable cost.

Table 13: Efficient Solutions for Happiness Levels with Restriction

Cost Tolerance	**Acceptable Cost (\$ 1000)**	**Solution 1**	**Solution 2**
0%	139	h=0—medium rest. scenario	N/A
1%	140	h=4—medium rest. scenario	N/A
2%	141	h=4—medium rest. scenario	N/A
3%	143	h=4—medium rest. scenario	h=5—no rest. scenario
4%	144	h=4—medium rest. scenario	h=5—low rest. scenario
5%	146	h=4—medium rest. scenario	h=5—low rest. scenario
10%	153	h=4—medium rest. scenario	h=5—low rest. scenario
15%	160	h=5—medium rest. scenario	h=6—low rest. scenario

In Table 13, different efficient solutions are listed according to acceptable operating costs. We figure eight level of cost tolerance. These tolerance levels can be replicated by many. In solutions, h bounds and restrictive scenario combinations are evaluated according to two perspective described above. Best solutions are listed with cost budget. We only observe two efficient solutions at most for the given cost tolerances. For other tolerance levels, number of efficient solutions can increase.

With using a table like Table 13, contact centers can figure out their budget, individual happiness level targets or recruitment policies. As an example, let us assume contact center currently operating with low restricted agent groups and cannot change it. The management can evaluate their options as following:

- Accept 0% cost increase, does not set any individual happiness minimum lower bound
- Accept 1% cost increase, set individual happiness minimum lower bound as 4
- Accept 4% cost increase, set individual happiness minimum lower bound as 5
- Accept 10% cost increase, set individual happiness minimum lower bound as 6

When the solution model sets this table related to parameters of problem, contact center management can decide current and long term planning strategies accordingly.

CHAPTER V

CONCLUSION

We study a call center workforce planning model. This model aims to increase the employee satisfaction in contact centers as well as providing a cost-effective shift plan. We include elements such as increasing employee happiness, distributing shifts fairly, incorporating work flexibility of agents and shuttle service costs of agent transportation in the plan. In addition, we define the shortage for meeting demand as a loss function.

We produce results using actual call center data in our model. We examine the effects of these elements on each other and to operating cost. Besides these effects, we study efficient solutions of all considerations. As a result of these reviews, we provide an approach on how employees' satisfaction and working flexibility should be evaluated in a long-term manner. This approach affects the recruitment policies of contact centers. Our approach is effective for including availability and preferences of agents into workforce plan.

Although we do not give place to skill structure in the model, it can be adapted to the model easily. With these additions and a day-off assignment process, the model and approach can be useful as a complete workforce planning method.

5.1 Future Work and Suggestions

As a related future study, performance metrics of agents can be included in planning model. Experience levels and capabilities of agents effect their performance. Besides, agent performance can vary in different time windows of a day. For a multi-skill environment, including performance of agents into assignment phase, like preference scores of our model, could create difference in results.

Another topic which we consider in a narrower perspective in this study is the loss function of a customer. We use a simple formulation to estimate the cost of understaffing in an interval. Sensitivity and accuracy of this loss function could depend on customer type and impatience characteristics of customer groups. Although we place a burden on management to set formulation parameters with knowing their own customer voice, a more extensive formulation could be useful on accuracy of cost estimation.

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VITA

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