Case Study: The Dupit Corp. Problem

{source: Introduction to Management Science by Hillier, Hillier & Lieberman.}

Some Background

The Dupit Corporation is a long-time leader in the office photocopier marketplace. One reason for this leadership position is the service the company provides to customers. Dupit has enjoyed a reputation of excellent service and intends to maintain that reputation.

Dupit has a service division that is responsible for providing high-quality support to the company's customers by promptly repairing the Dupit machines when needed. This work is done on the customer's site by the company's *service technical representatives*, more commonly known as **tech reps**.

Each tech rep is given responsibility for a specified territory. This enables providing personalized service, since a customer sees the same tech rep on each service call. The tech rep generally feels like a one-person territory manager and takes pride in this role.

John Phixitt is the Dupit senior vice president in charge of the service division. He has spent his entire career with the company, and actually began as tech rep. While in this initial position. John took classes in the evening for several years to earn his business degree. Since then, he has moved steadily up the corporate ladder. He is well respected for his sound judgment and his thorough understanding of the company's business from the ground up.

John's years as a tech rep impressed upon him the importance of the tech rep's role as an ambassador of the company to its customers. He continues to preach this message regularly. He has established high personnel standards for becoming and remaining a tech rep and has built up the salaries accordingly. The morale in the division is quite high, largely through his efforts.

John also emphasizes obtaining regular feedback from a random sample of the company's customers on the quality of the service being provided. He likes to refer to this as keeping his ear to the ground. The customer feedback is channeled to both the tech reps and management of their information.

Another of John's themes is the importance of not overloading the tech reps. When he was a tech rep himself, the company policy had been to assign each tech rep enough machines in his or her territory that the tech rep would be active repairing machines 90 percent of the time (during an eight-hour working day). The intent was to maintain a high utilization of expensive personnel while providing some slack so that customers would not have to wait very long for repairs. John's own experience was that this did not work very well. He did have his idle periods about 10 percent of the time, which was helpful for catching up on his paperwork and maintaining his equipment. However, he also had frequent busy periods with many repair requests, including some long ones, and a large backlog of unhappy customers waiting for repairs would build up.

Therefore, when he was appointed to his current position, one of his first moves was to make the case to Dupit top management that tech reps needed to have more slack time to ensure providing prompt service to customers. A major part of his

argument was that customer feedback indicated that the company was failing to deliver on the second and third part of the company slogan given below.

1. High-quality products.
2. High-quality service.
3. All delivered efficiently.

The company president had been promoting this slogan for years and so found this argument persuasive. Despite continuing pressure to hold costs down, John won approval for changing company policy regarding tech reps as summarized below.

> **Current Policy:** Each tech rep's territory should be assigned enough machines so that the tech rep will be active repairing machines (or traveling to the repair site) approximately 75 percent of the time. When working continuously, each tech rep should be able to repair an average of four machines per day (an average of two hours per machine, including travel time). Therefore, to minimize customer waiting times, the goal is to have an average of three repair calls per working day. Since the company's machines now are averaging 50 work days between needing repairs, the target is to assign approximately 150 machines to each tech rep's territory.

Under this policy, the company now has nearly 10,000 tech reps, with a total payroll (including benefits) of approximately $600 million per year.

The Issue Facing Top Management

Dupit has had a long succession of very successful products that has maintained its position as a market leader for many years. Furthermore, its latest product has been a particularly big winner. It is a color printer-copier that collates, staples, and so on, as well as having faxing capabilities. Thus, it is a state-of-the-art, all-in-one copier for the modern office. Sales have even exceeded the optimistic predictions made by the vice president for marketing.

However, this success also has brought its problems. The fact that the machine performs so many key functions makes it a vital part of the purchaser's office. The owner has great difficulty in getting along without it for even a few hours when it is down requiring repair. Consequently, even though the tech reps are giving the same level of the service as they have in the past, complaints about intolerable waits for repairs have skyrocketed.

This crisis has led to an emergency meeting of top management, with John Phixitt the man on the spot. He assures his colleagues that service has not deteriorated in the least. There is agreement that the company is a victim of its own success. The new machine is so valuable that a much higher level of service is required.

Alternative Approaches to the Problem

After considerable discussion about how to achieve the needed service, Dupit's president suggests the following four-step approach to dealing with the problem.

1. Agree on a tentative new standard for the level of service that needs to be provided.
2. Develop some proposals for alternative approaches that might achieve this standard.
3. Have management science teamwork with John Phixitt to analyze these alternative approaches in detail to evaluate the effectiveness and cost of each one.
4. Reconvene this group of top management to make a final decision on what to do.

The group agrees.

Discussion then turns to what the new standard should be for the level of service. John proposes that this standard should specify that a customer's average waiting time before the tech rep can respond to the request for a repair should not exceed some maximum quantity. The customer relations manager agrees and argues that this average waiting time should not exceed two hours (versus about six hours now). The group agrees to adopt two hours as the tentative standard, pending further analysis by the management science team.

> **Proposed New Service Standard**: The average waiting time of customers before the tech rep begins to the customer site to repair the machine should not exceed two hours.

After further discussion of various ideas about how to meet this service standard, the meeting concludes. The president asks the participants who had proposed some approach to think further about their idea. If they conclude that their idea should be a particularly sound approach to the problem, they are to send him a memorandum supporting that approach.

The president subsequently receives three memoranda supporting the approaches summarized below.

> **Approach suggested by John Phixitt**: Modify the current policy by decreasing the percentage of time that tech reps are expected to be active repairing machines. This involves simply decreasing the number of machines assigned to each tech rep and adding more tech reps. This approach would enable continuing the mode of operation for the service division that has served the company so well in the past while increasing the level of service to meet the new demands of the marketplace.
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> **Approach Suggested by the Vice President for Engineering**: Provide new state-of-the-art equipment to the tech rep that would substantially reduce the time required for the longer repairs. Although expensive, this would significantly reduce the average repair time. Perhaps more importantly, it would greatly reduce

the variability of repair times, which might decrease average waiting times for repairs.

Approach Suggested by the Chief Financial Officer: Replace the current one-person tech rep territories by larger territories that would be served by multiple tech reps. Having teams of tech reps to back each other up during busy periods might decrease average waiting times for repairs enough that the company would not need to hire additional tech reps.

Current Situation

The Dupit management science team begins their study by gathering some data on the experiences of some representative tech reps. They determine that the company's current policy regarding tech rep workloads (they are supposed to be busy repairing machines 75 percent of the time) is operating basically as intended. Although there is some variation from one tech rep to the next, they typically are averaging about three calls requesting repairs per day. They also are averaging about two hours per repair (including a little travel time), and so can average four repairs for each eight-hour working day that they are continuously repairing machines. This verifies that the best estimates of the daily rates for a typical tech rep's queuing system (where the tech rep is the server and the machines needing repairs are the customers) are a mean arrival rate of $\lambda=3$ customers per day and a mean service rate of $\mu=4$ customers per day (so $\rho=\lambda/\mu=0.75$), just as assumed under the current policy. (Other time units, such as *hourly* rates rather than *daily* rates, could be used for λ and μ, but it is essential that the same time units be used for both.)

The team also concludes that the customer arrivals (calls requesting repairs) are occurring *randomly*, so the first assumption of the *M/M*/1 model (an exponential distribution for interarrival times) is a good one for this situation. The team is less comfortable with the second assumption (an exponential distribution for service times), since the *total service time* (travel time plus repair time) never is extremely short as allowed by the exponential distribution. However, many service times are at least fairly short (well under the mean) and occasional service times are very long, which does fit the exponential distribution reasonably well. Furthermore, calculations with the data gathered on service times indicate that the standard deviation of the service0time distribution is just about as large as the mean (they are equal for the exponential distribution). Therefore, the team decides that it is reasonable to use the M/M/1 model to represent a typical tech rep's queueing system under the current policy.

The Excel template shows the results from applying the various formulas for this model to this queueing system.

The management science team now is ready to begin analyzing each of the suggested approaches for lowering to two hours (1/4 workday) the average waiting time before service begins. Thus, the new constraint is that

$$W_q \leq \tfrac{1}{4} \text{ day}$$

	A	B	C	D
1	**M/M/1 Model**			
2	Arrival rate, per time period (lambda)			3
3	Service rate, per time period (mu)			4
4	Lq, Mean number in line			2.25
5	L, Mean number in system			3.00
6	Wq, Mean wait in line (time periods)			0.75
7	W, Mean time in system (time pds)			1.00
8	Probability of no one in system			25%
9	Rho, Utilization of facility			75%
10				
11	Prob W (Wait) More than t days			0.368
12			when t =	1
13	Prob Wq More than t days			0.276
14			when t =	1

Approach suggested by John Phixitt:

The first approach, suggested by John Phixitt, is to modify the current policy by lowering a tech rep's utilization factor sufficiently to meet this new service requirement. This involves decreasing the number of machines assigned to each tech rep from about 150 to some smaller number. Since each machine needs repair about once every 50 work days on the average, decreasing the number of machines in a tech rep's territory results in decreasing the mean arrival rate λ from 3 to

$$\lambda = \frac{\text{number of machines assigned to tech rep}}{50}$$

With μ fixed at four, this decrease in λ will decrease the utilization factor, $\rho = \lambda/\mu$.

Since decreasing λ decreases W_q, the largest value of λ that has $W_q \leq$ ¼ day is the one that makes W_q equal to ¼ day. The easiest way to find this λ is by trail and error with the Excel template, trying various values of λ until one is found where $W_q = 0.25$. (By using the formula for W_q, it is also possible to solve algebraically to find $\lambda = 2$.)

	A	B	C	D
1	**M/M/1 Model**			
2	Arrival rate, per time period (lambda)			2
3	Service rate, per time period (mu)			4
4	Lq, Mean number in line			0.50
5	L, Mean number in system			1.00
6	Wq, Mean wait in line (time periods)			0.25
7	W, Mean time in system (time pds)			0.50
8	Probability of no one in system			50%
9	Rho, Utilization of facility			50%
10				
11	Prob W (Wait) More than t days			0.135
12			when t =	1
13	Prob Wq More than t days			0.068
14			when t =	1

Decreasing λ from three to two would require decreasing the target for the number of machines assigned to each tech rep from 150 to 100. This 100 is the maximum number that would satisfy the requirement that $W_q \leq$ ¼ day. With $\lambda = 2$ and $\mu = 4$, the utilization factor for each tech rep would be only

$$\rho = \lambda/\mu = 2/4 = 0.5$$

Recall that the company's payroll (including benefits) for its nearly 10,000 tech reps currently is about $600 million annually. Decreasing the number of machines assigned to each tech rep from 150 to 100 would require hiring nearly 5,000 more tech reps to cover all the machines. The additional payroll cost would be about $270 million annually. (It is a little less than half the current payroll cost because the new tech reps would have less seniority than the current ones.) However, the management science team estimates that the additional costs of hiring and training the new tech reps, covering their work expenses, providing them with equipment, and adding more field service managers to administer them would be equivalent to about $30 million annually.

Total Additional Cost of the Approach Suggested by John Phixitt: Approximately $300 million annually.

Approach Suggested by the Vice President for Engineering:

Dupit's vice president for engineering has suggested providing the tech reps with new state-of-the-art equipment that would substantially reduce the time required for the longer repairs. This would decrease the average repair time a little, and also would substantially decrease the variability of the repair times.

After gathering more information from this vice president and analyzing it further, the management science team makes the following estimates about eh effect this approach would have on the service-time distribution.

The mean would decrease from 1/4 day to 1/5 day.
The standard deviation would decrease from 1/4 day to 1/10 day.

Thus, the standard deviation would decrease from equaling the previous mean (as for the exponential distribution) to being just half the new mean (as for the Erlang distribution with shape parameter K=4). Since μ = 1/mean, we now have $\mu = 5$ instead of $\mu = 4$.

With $\sigma = 0.1$, the Excel template for the M/G/1 model yields the results shown that $W_q = 0.188$ day. This big reduction from $W_q = 0.75$ day under the current policy is largely due to the big decrease in σ. If the service time distribution continued to be an exponential distribution, then increasing μ from 4 to 5 would decrease W_q from 0.75 day to 0.3 day. The additional reduction from

0.3 day to 0.188 day is because of the large reduction in the variability of service times.

	A	B	C	D
1	**M/G/1 Model**			
2	Arrival rate, per time period			3
3	Expected service time (1/mu)			0.2
4	Standard Deviation			0.1
5	Lq, Mean number in line			0.56
6	L, Mean number in system			1.16
7	Wq, Mean wait in line (time periods)			0.19
8	W, Mean time in system (time pds)			0.39
9	Probability of no one in system			40%
10	Rho, Utilization of facility			60%

Recall that the proposed new service standard is $W_q \geq 0.25$ day. Therefore, the approach suggested by the vice president for engineering would satisfy this standard.

Unfortunately, the management science team also determines that this approach would be expensive, as summarized below.

Approach Suggested by the Chief Financial Officer

Dupit's chief financial officer has suggested combining the current one-person tech rep territories into larger territories that would be served jointly by multiple tech reps. The hope is that, without changing the total number of tech reps, this reorganization might decrease W_q sufficiently for its current value ($W_q = 0.75$ day) to satisfy the proposed new service standard ($W_q \geq 0.25$ day).

Comparison of Wq Values with Territories of Different Sizes for the Dupit Problem

Number of Tech Reps	***Number of Machines***	***l***	***m***	***S***	***P***	***W_q***
1	150	3	4	1	0.75	0.75 workday (6 hours)
2	300	6	4	2	0.75	0.321 workday (2.57 hou
3	450	9	4	3	0.75	0.189 workday (1.51 hou

	A	B	C	D	E	F
1	**M/M/S Model (no more than 5 servers)**					
2	Arrival rate			9	per	minute
3	Service rate			4	per	minute
4	Number of servers			3		
5	Lq, Mean number in line			1.70		
6	L, Mean number in system			3.95		
7	Wq, Mean wait in line (time periods)			0.19	minute	
8	W, Mean time in system (time pds)			0.44	minute	
9	Probability the system is empty			7%		
10	Rho, Utilization of facility			75%		
11	Probability of waiting (n=> s)			0.57		

Conclusion: The approach suggested by the chief financial officer would indeed satisfy the proposed new service standard ($Wq \geq 0.25$ day) if each three contiguous one-person tech rep territories are combined into a larger territory served jointly by the same three tech reps. Since the total number of tech reps does not change, there would be no significant additional cost from implementing this approach other than the disadvantages of larger territories cited above. To minimize these disadvantages, the territories should not be enlarged any further than having three tech reps per territory.