Journal of Modelling in Management

Modeling customer support performance in Indian IT hardware industry

R. Shankar P. Vijayaraghavan T. Narendran

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R. Shankar
Institute of Management Technology, Ghaziabad, India, and
P. Vijayaraghavan and T. Narendran
Department of Management Studies, Indian Institute of Technology, Chennai, India

Abstract

Purpose – Customer support assumes strategic importance in India for branded IT-hardware products. An authorized service center and a stream of specialized service centers undertake field services and represent a sale-territory's support network. "Time constrained" service men have to deliver customized service meeting a promised time-standard. The stochastic demand for support services severely mars the customer response resulting in poor service quality. A manufacturer has to address the following decisions under these conditions: what is the ideal staffing level in a territory considering restricted server availability? What will be the impact of changing the staffing levels on customer service level? This study develops an analytical model to address these decisions.

Design/methodology/approach – The study identifies the variables underlying stochastic service demand through a field survey and determines the demand distribution. Applying *stochastic* principles the study derives relation between field staffing level and customer response considering server time constraint. Study performs statistical analysis to validate this model with real time data on variables collected from the field survey.

Findings – The outcomes of analysis reveal the following findings: this model can be applied in service systems where a time constrained server has to deliver expected level of performance (research implication); and increasing field staffing levels obscures the significant difference between the customer waiting times under very high levels of uncertain demand (practical implication).

Originality/value – The study derives relation between the staffing levels and customer waiting time considering uncertain demand with restricted working hour conditions.

Keywords Stochastic modelling, Demand forecasting, Customers, India, Electrical goods

Paper type Research paper

Introduction

Customers evaluate products based on the purchase and consumption experiences over time (Fornell, 1992; Fournier and Mick, 1999). Customer satisfaction results when the product's performance matches with customer expectations after the purchase. Repeat purchase behavior stems from customer satisfaction (Sharma and Lambert, 1990). This in turn improves market share and profitability (Anderson *et al.*, 1994; Crosby *et al.*, 1990; Leuthesser and Kohli, 1995; Reichheld and Sasser, 1990). To enhance positive assessment of product, manufacturers offer post-purchase assistance to customers called customer support (Goffin, 1999). Customer support is a critical element of product's market success (Lele and Karmarkar, 1983).

Generally, firms possess distinctive competencies or processes that create competitive differentiation called capabilities (Conant *et al.*, 1990). Logistic capabilities of a firm

Journal of Modelling in Management
Vol. 1 No. 3, 2006
pp. 232-254

1746-5664
DOI 10.1108/17465660610715221

create market differentiation in customer service (Anderson *et al.*, 1994). Manufacturers of high-tech products establish logistic capabilities for customer support (Armistead and Clark, 1992; Goffin, 1999). Maltz and Maltz (1998) identify the need for analytical tools in any logistics system to measure customer service in some specific settings. Hence, this study was aimed to model and evaluate the performance of a specific type of logistic system, viz. customer support system. Literature regards customer support as a neglected area that requires research priority (Hull and Cox, 1994; Loomba, 1996).

Motivation

Study draws inspiration from explicit appeal in the literature for research contributions in customer support. Existence of a strong relationship between supply chain management (SCM) and customer services (Christopher, 1998) constitutes the study's basic framework.

About this study

This study models customer support performance in Indian IT hardware industry applying stochastic principles. The model captures uncertainty involved in customer arrival rate through its underlying variables. A field survey identifies and elicits these variables underlying uncertain demand to determine the arrival distribution.

These real-time data on variables are applied in the developed model to compute the theoretical values of customer waiting times. The study validates the model performing statistical analysis with theoretical values with industry prescribed (contractual) waiting time. Following sections organize the study towards this purpose.

Environmental context of the problem

To model customer support performance, an exploratory study (in-depth interview and secondary record survey) that investigates the issue was conducted. The out comes of exploratory study addresses management decision, questions and "environmental context" of this research problem. Problem's environmental context brought to light the customer support practices followed in Indian IT-hardware industry.

Customer support in Indian IT-hardware industry

Customer support in India is basically a "contractual agreement" signed by the buyer and seller of PC. As per the agreement, manufacturer promises a list of services that includes installation, upgradations, user training, repairs and maintenance after the purchase of the product. These services are delivered through manufacturer's "customer support" network in a territory that comprise of authorized and specialized service centers. Following points present the manner in which customer support services are executed in a sale-territory:

- A PC customer receives the company contact details for "product support" (authorized service center) while buying the product. The "contact modes" include telephone, e-mail, contact-in person, etc. to approach for after-sale problem.
- On receipt of a customer request, an authorized service center diagnoses the details and registers the nature and specificity of customer request.

- The authorized service center then raises a "request order" with a number (called ticket number) and conveys the customer.
- Based on the specificity and complexity of the customer request, the authorized service center schedules and sends its service personal to the customer's point to fulfill the customer requests.
- Authorized service center diverts certain number of requests to "specialized" service centers based on the relevancy. "Authorized" service centers face the "part" or "replacement" inventory shortage pertinent to certain customer calls. Such customer calls get diverted to "specialized" service centers.

More importantly the above privileges are extended to customers in warranty period or customers who have signed AMC agreement (annual maintenance contract). Service centers must comply with following conditions while fulfilling a customer's request.

General conditions.

- A field personal should reach the customer location and must have engaged in "request-fulfilling" process within a stipulated "time window" (say 5 hours) from the time of "request registration". Strictly speaking, a customer's request should be met within five hours.
- A service center guarantees the fulfilled service request, e.g. of 90 days. This implies that the same customer problem will not surface again in next 90 days.
- If the service center complies with all the above conditions, then the manufacturer will pay the service center as per the terms of partnership agreement at the end of the month.

Critical conditions in fulfilling customer requests.

- For any delay in fulfilling the customer requests manufacturer deducts a stipulated percentage of service charge amount. For example, manufacturer deducts 20 per cent of due service charge if the service center fulfills the customer request the next working day.
- The requests are attended on first-come first serve basis.
- Service centers have to maintain inventory of all the relevant spares that comes under its "service specialization".

A survey on customer opinion revealed that promised time of five hours is not met in practice. Field staffing is one of the options that favor positive customer response. Given this environment context, a review of existing research works in literature was undertaken to study and model the performance of a customer support system in Indian context.

Literature review

Customer support constitutes a major element of customer service. Hence, mandatory understanding of customer services was considered more appropriate.

Customer service - as understood from literature

Customer services are termed "battleground of 90s, and has substantially gained the top management focus" (Woods, 1991). Historically, customer service has been nearly synonymous with inventory availability and order cycle time. These quantitative measures do not completely explain the service levels (LaLonde *et al.*, 1988). Market growth has forced firms to comply with varied customer preferences (Davis and Manrodt, 1994; Stank *et al.*, 2003). Relevantly, literature captures all the customer preferences under two "dimensions of customer service" (Emerson and Grimm, 1998):

- *Marketing dimension.* This dimension incorporates elements of customer service like terms of sale, customer service representative's competence, overall product quality and action on complaints that enhance possession utility.
- *Logistics dimension.* Logistic dimension includes all elements of time, place and form utility. Services are quantified as percentage of orders filled, order-service time consistency, order accuracy, order status information, etc.

Developments in various areas of customer service – referenced from literature

Tucker (1983) postulated the importance of viewing customer service from customer's perspective. As evidence to this phenomenon, empirical studies point out that firms configure their logistic systems considering customer preferences (Donaldson, 1995). "Customer preferences and perspectives must be incorporated into strategic decision-making and system design such that they are reflected in daily operational decisions" (Daugherty *et al.*, 1998). Such measures nurture customer loyalty and repurchase intent resulting in high market share and profitability (Innis and LaLonde, 1994).

In summary, customer satisfaction results when firms focus on key processes and activities defined by the customer as a part of SCM process (Lockamy *et al.*, 2000).

Measures of customer service

An exclusive part of customer service literature measures customer service performance. LaLonde and Zinszer (1976) and Mentzer *et al.* (1989) suggest timeliness and consistency of order cycle time, inventory availability, etc. as measures of customer service. Davis and Manrodt (1994), Stank *et al.* (2003) and LaLonde, *et al.* (1988) include value-added services to this measure.

Parasuraman *et al.* (1985, 1991) recommended "reliability" (i.e. perform promised services consistently) as prominent measure of customer service. Maltz and Maltz (1998) suggest following improvements in measures of customer service:

- elements of customer service should be objectively measured;
- customer responsiveness requires detailed models for "real-world"; and
- the above elements should be replicated in varied industry settings.

In essence, "customer responsiveness" signifies a prolific measure of customer service. Literature emphasizes objective measures for post-sale support also (LaLonde *et al.*, 1988). Such aspects are not sufficiently addressed in the literature.

Need for analytical modeling of service logistics systems

The logistics success depends on data and information flow (Brock *et al.*, 2005). Sophisticated mathematical models have aided successful logistic system management (Coyle *et al.*, 1992; Simchi-Levi *et al.*, 2002). With logistics riding the management forefront for many firms, desperate need for analytical models are felt. Latest studies testify the indispensable nature of analytical models in track and trace, improved service parts availability, business decision-making and logistics system control (Koh *et al.*, 2003; Schuster and Koh, 2004; Kar *et al.*, 2003; Brock, 2000; Engels *et al.*, 2004). This implies that analytical modeling can be applied in customer support.

Customer support models in literature – status and background of the research problem
To model customer support system, existing service system models in literature were reviewed. Heyman (1968), Bell (1975), Lippman (1973), Eisenberg (1971) and Crabill *et al.* (1977) have modeled customer service systems with queueing theory. Bertsimas and Ryzin (1991), Bent and Hentenryck (2004) and Gendreau *et al.* (1996) developed analytical models incorporating queuing theory for complex service systems. Stochastic and dynamic variants of traveling sales man problem (TSP), vehicle routing problem (VRP) and traveling repairman problem (TRP) constitute important analytical models. Literature recommends probabilistic (stochastic) approaches for field service systems to capture the reality (Stecke and Aronson, 1985). Agnihothri and Karmarkar (1992) modeled customer support system with finite calling source and evaluated the highly uncertain server travel times. Bertsimas and Ryzin (1991) address a similar problem with dynamic vehicle routing problem (DVRP) model.

Importance of the research work
The pursuit of modeling a customer support system in Indian context was conceptualized from Daugherty *et al.* (1998), Maltz and Maltz (1998) and Koh *et al.* (2003). Existing models (Agnihothri and Karmarkar, 1992; Bertsimas and Ryzin, 1991) provide study's model-base. Following points stress the study's importance:

- the study offers real-time tool for practitioners in customer support to improve the customer response for delivering promised services in time; and
- in the literature front, study's model adds some real-time constraints like server's working hour restriction and servers outsourcing option with non-poisson demand arrivals (function of several independent variables).

Objectives

Outcomes of the exploratory study offered details on management decision, research questions, scope, actual problem and objectives addressed in this study.

Management decision (major question addressed by the research)

> How to improve the customer responsiveness in a product support system considering industry specific variables in the context of assured inventory availability?

The study identified "optimal field staffing level" as a remedy among various available alternatives for the above decision.

Research questions
The "management decision" requires various elements to be addressed in the study. The elements form the "modeling issues". Phrasing these issues give rise to research questions for the management problem:

RQ1. Which independent variables influence the customer support demand?

RQ2. With the knowledge of these variables how to address the stochastic demand?

RQ3. Which decision variables (resources) should be considered for countering the stochastic demand?

RQ4. How to mathematically relate the decision elements with the customer response under stochastic demand? If so, how to validate the mathematical relation?

Boundaries of the study (scope)

Conceptual boundary. This study was carried out with following broad-level conceptual considerations:

- customer support is one of the few vital elements of customer service (Emerson and Grimm, 1998);
- firms establish logistical capabilities (processes) for efficient customer support (Daugherty *et al.*, 1998); and
- reliability (Parasuraman *et al.* 1985, 1991) is an important measure of customer support (Goffin, 1998).

Analytical boundary. Analytical model building was based on assumptions resulted from the survey of customer support practices in India. These assumptions matched with problem addressed by Agnihothri and Karmarkar (1992) and offered following extension:

- Territory has "N" machines (large number ensuring steady state demand arrivals). This extends Agnihothri and Karmarkar (1992) assumption.
- "m" servers are responsible for the customer calls. Servers make sequential trips to calling customers strictly on "first-come first-serve" (FCFS) basis.
- Customer call arrivals are based on several extraneous factors.
- Servers work for a restricted "h" hours (implying restricted availability paradoxical to Agnihothri and Karmarkar (1992)). Servers are bound to offer 100 percent service fill rate within the working hours (*h*).
- Onsite service, travel times are random variables with known distribution functions.
- The term "customers" refer strictly to the customers who have signed annual maintenance contract (AMC) and those who are in the warranty period.
- The system is featured with assured spare-part/tool and component inventory.

Research problem

Refining the management decision resulted in the statement of research problem. The broad statement of research problem addresses the following issue:

> How to improve the customer response efficiently in a product support system considering industry specific variables in the context of assured inventory availability?

Specific elements of the research problem include the following questions:

- Which independent variables impact customer response in different market segments?

- Which decision elements can be controlled by the manufacturer to improve the customer response considering the practices followed in different market segments?
- How to establish the relation between independent variables, decision elements and customer response in different segments?
- 4 How to validate the above relationships between the variables and outcome for various market segments?

Objectives

- "To develop analytical model for customer support system in Indian IT-hardware industry considering influence of independent variables and related the decision elements with the outcome, viz. customer responsiveness."
- "To validate the analytical model using real-time field data."

Methodology

A broad outlook of research methodology is shown in the Figure 1. Exploratory study elicited the variables that impact customer support services in two market segments, viz. Assemblers and branded PC segments. The variables provided the input for analytical modeling of customer support systems. The analytical models thus built were validated with the field data and analysis.

Data collection tool for the field data. A structured questionnaire was designed to elicit the independent variables and decision elements from the service centers in a territory.

Modeling approach

The exploratory survey provided the variables that underlie customer support practices. Based on the variables, the study has built an analytical model that relates these variables with the service standard, viz. customer waiting time using stochastic principles. Further, by collecting field data on service standard and variables used in the study, the study validates the model with statistical analysis.

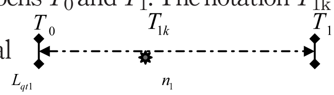
Procedure

Empirical distribution from field data implied existence demand fluctuation. Therefore, decision elements (field staffing levels and working hour) are factored into the mathematical derivation for customer wait along with fluctuation (Figure 2).

Model considers working hour duration of a service center. Model is evolved based on the events as presented in the following figure.

Demand distribution. Fluctuation levels of the incoming demand are uniformly spread from 10 to 60 percent of the base demand.

The study assumes a random time interval between epochs T_0 and T_1. The notation T_{1k} represents the arrival epoch of kth customer in the interval



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T_0	time epoch denoting beginning of working hours.
T_1	time epoch marking the end of working hours.
n_1	number of customers that request for customer service between T_0 and T_1.

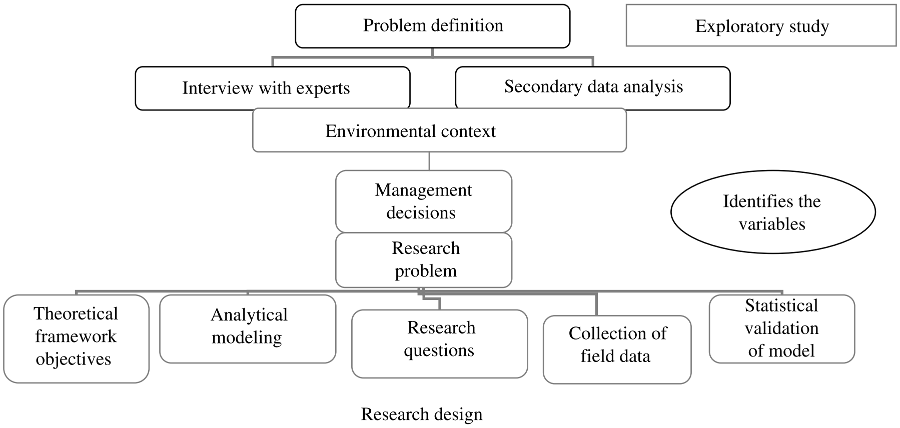

Figure 1. Research methodology followed in the study

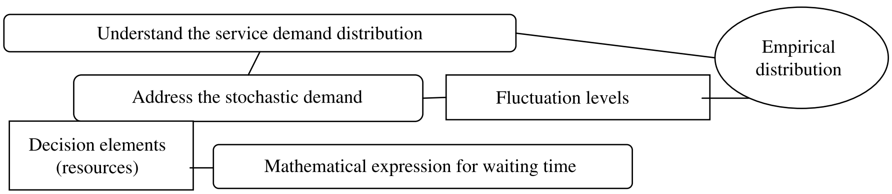

Figure 2. Modeling the customer support system in branded segment

T_{1k} time epoch marking arrival of "k"th customer.

L_{qt1} number of customers that have requested for customer support services before T_0, i.e. the queue length at T_0.

n_1/k_1 L_{qt1} expressed as fraction of n_1.

$1/k_1$ fraction that represents fluctuation.

S_{t1} number of field service men employed.

T^k_{Reach} time epoch when server reaches customer "k" who arrived at T_{1k}.

$T^k_{Complete}$ time epoch required to complete the service for customer "k".

$T^k_{complete}$ $T^k_{Reach} + S^k$, where S^k = service time of "k".

A residual time, i.e. expected and fluctuating traveling and service time components per customer.

$$A = (n \times \bar{s}) + (n \times \bar{t}) + R^{ser}_{time} + R^{tra}_{time} \qquad (1)$$

$\bar{s}$ average service time per customer.

$\bar{t}_r$ average traveling time per customer.

σ_{tra} standard deviation of traveling time per customer.

σ_{ser} standard deviation of service time per customer.

w_{1k}	Waiting time of "k"$_{\text{th}}$ customer.
$w^{i}_{(\text{ave})}$	Average waiting time of 'i'th customer where i = 1, 2, ..., n_1.

Determining the value of "A"

For ∀ new customer arrival k_i, "n" customers are in the system and customer k_i has to wait for time "A":

$$A = (n \times \bar{s}) + (n \times \bar{t}) + R^{\text{ser}}_{\text{time}} + R^{\text{tra}}_{\text{time}} \tag{2}$$

where $R^{\text{ser}}_{\text{time}}$ = residual service time and:

$$R^{\text{ser}}_{\text{time}} = \frac{\lambda \times \overline{s^2}}{2 \times t} \tag{3}$$

$\overline{s^2}$ = second moment of service time:

$$\overline{s^2} = (\bar{s})^2 + \sigma^2 \tag{4}$$

(or):

$$E[x^2] = [E(x)]^2 + \text{Var}[x] \tag{5}$$

$s_i =$ service time of customer "I" ∀ $i = 1, 2, 3, \ldots n$ (Kleinrock, 1976).

Each s_i occupies some fraction of "W". s_i/W = fraction of "W" consumed by "I" ∀ $i = 1, 2, 3, \ldots n$, where:

$$W = \sum_{i=1}^{n} s_i$$

When k_i, entered the system, a fraction "z" of this fraction of service time before s_1 would have been in the process. In addition, a fraction of "n-1" customers may detain the server for some time above $\bar{s}$:

$$\begin{aligned} R^{\text{ser}}_{\text{time}} = &[\text{Fraction of service time taken by the first customer}] \\ &+ [\text{Fraction of } n-1 \text{ customers who detain the server for more than } \bar{s}] \end{aligned} \tag{6}$$

For ∀ each one of the customers who arrive in the system at various point of times, the value of $R^{\text{ser}}_{\text{time}}$ assumes following equation:

$$R^{\text{ser}}_{\text{time}} = \left[\frac{\left(\int_0^1 z\,\text{d}z \right) \times \sum_{i=1}^{n} s_i \times \bar{s}}{t} \right] + \left[\frac{\left(\int_0^1 z\,\text{d}z \right) \times (n-1) \times \sigma_s^2}{t} \right] \tag{7}$$

Applying Wald's equation and solving for $\left(\int_0^1 z\,\text{d}z \right)$, we get the following equation:

$$R_{\text{time}}^{\text{ser}} = \left[\frac{n\times(\bar{s})^2}{2\times t}\right] + \left[\frac{(n-1)\times\left[\frac{\sum_{i=1}^{n}(s_i-\bar{s})^2}{(n-1)}\right]}{2\times t}\right] \tag{8}$$

$$R_{\text{time}}^{\text{ser}} = \left[\frac{n\times(\bar{s})^2}{2\times t}\right] + \left[\frac{\sum_{i=1}^{n}\left\{s_i^2+(\bar{s})^2-\left[2\times s_i\times\bar{s}\right]\right\}}{2\times t}\right] \tag{9}$$

Again applying Wald's equation, we get the following formula:

$$R_{\text{time}}^{\text{ser}} = \left[\frac{n\times(\bar{s})^2}{2\times t}\right] + \left[\frac{n\times E(x^2)}{2\times t}\right] + \left[\frac{n\times(\bar{s})^2}{2\times t}\right] - \left[\frac{2\times n\times(\bar{s})^2}{2\times t}\right] \tag{10}$$

By rearranging the components we get the following equation:

$$R_{\text{time}}^{\text{ser}} = \left[\frac{n\times E(x^2)}{2\times t}\right] + \left[\frac{2\times n\times(\bar{s})^2}{2\times t}\right] - \left[\frac{2\times n\times(\bar{s})^2}{2\times t}\right] \tag{11}$$

Finally, the equation gets reduced to the following form:

$$R_{\text{time}}^{\text{ser}} = \left[\frac{n\times E(x^2)}{2\times t}\right]$$

where $n/t = \lambda$, we get the following reduced form of equation (Bertsimas and Ryzin, 1991):

$$R_{\text{time}}^{\text{ser}} = \left[\frac{\lambda\times E(x^2)}{2}\right] \quad \text{(or)} \quad R_{\text{time}}^{\text{ser}} = \left[\frac{\lambda\times\overline{s^2}}{2}\right] \tag{12}$$

On similar lines, one can derive following expression of residual travel times:

$$R_{\text{time}}^{\text{tra}} = \left[\frac{\lambda\times\overline{t^2}}{2}\right] \tag{13}$$

where, $\overline{t^2}$ = second moment of travel time. These values were substituted in the equation $A = (n\times\bar{s}) + (n\times\bar{t}) + R_{\text{time}}^{\text{ser}} + R_{\text{time}}^{\text{tra}}$

Study then derives the waiting time of this customer in the following way:

$$\frac{(T_{1k} - T_0)}{t_1} \times n_1 = \text{number of customers incident in the system at } T_{1k} (\text{after } T_0) \quad (14)$$

$$L_{qt1} = \frac{n_1}{k_1} = \text{number of customers incident in the system before } T_0 \quad (15)$$

Equation (1) + equation (2) = total number of customers either waiting or availed service at T_{1k}.

Following equation expresses the time required to reach customer "k" $\left(T^k_{\text{Reach}}\right)$ when the system has one service engineer:

$$T^k_{\text{Reach}} = \left[\frac{(T_{1k} - T_0)}{t_1} \times n_1 \times A\right] + \left[\frac{n_1}{k_1} \times A\right] \quad (16)$$

The equation below describes time required to reach customer "k" $\left(T^k_{\text{Reach}}\right)$ when the system has more than one (i.e. S_{t1}) service engineers:

$$T^k_{\text{Reach}} = \frac{\left[\frac{(T_{1k} - T_0)}{t_1} \times n_1 \times A\right] + \left[\frac{n_1}{k_1} \times A\right]}{S_{t1}} \quad (17)$$

With S_{t1}service engineers in the system, customer "k" stays in the system (completes his service), i.e. T^k_{Complete}, until the time mentioned in the following equation:

$$T^k_{\text{Complete}} = \frac{\left[\frac{(T_{1k} - T_0)}{t_1} \times n_1 \times A\right] + \left[\frac{n_1}{k_1} \times A\right]}{S_{t1}} + A \quad (18)$$

The equation below gives the exact waiting time of customer "k" i.e. w_{1k} in the system:

$$w_{1k} = \left\{\frac{\left[\frac{(T_{1k} - T_0)}{t_1} \times n_1 \times A\right] + \left[\frac{n_1}{k_1} \times A\right]}{S_{t1}} + A\right\} - (T_{1k} - T_0) \quad (19)$$

The system has to find mean waiting times of all the $n_1$customers that call for service during t_1. This requires the expression for $\sum_{k=1}^{n_1} w_{1k}$:

$$\sum_{k=1}^{n_1} w_{1k} = \left\{\frac{\left[\frac{\sum_{k=1}^{n_1} (T_{1k} - T_0)}{t_1} \times n_1 \times A\right] + \left[\frac{n_1}{k_1} \times A\right]}{S_{t1}} + A\right\} - \sum_{k=1}^{n_1} (T_{1k} - T_0) \quad (20)$$

To determine $\sum_{k=1}^{n_1} w_{1k}$ one has to find the value of $\sum_{k=1}^{n_1} (T_{1k} - T_0)$:

$$\text{The value of } \left[\sum_{k=1}^{n_1} (T_{1k} - T_0)\right] = \frac{t_1 \times n_1}{2} \tag{21}$$

Applying this value (21) in equation (20) results in following expression (Ravi Shankar *et al.*, 2006):

$$\sum_{k=1}^{n_1} w_{1k} = \left[\frac{n_1 \times t_1 \times A \times n_1}{2 \times S_{t1} \times t_1}\right] + \left[\frac{n_1^2 \times A}{k_1 \times S_{t1}}\right] + [A \times n_1] - \left[\frac{n_1 \times t_1}{2}\right] \tag{22}$$

On further analysis, the value of $\sum_{k=1}^{n_1} w_{1k}$ reduces to the following equation:

$$\sum_{k=1}^{n_1} w_{1k} = \left[\frac{n_1^2 \times A}{S_{t1}}\right]\left[\frac{1}{2} + \frac{1}{k_1}\right] + n_1\left[A - \frac{t_1}{2}\right] \tag{23}$$

From the above expression one can derive the average waiting time of a customer "k" in the system during the time t_1, i.e. $w^1_{(\text{ave})}$.

Mathematical expression for average customer waiting time $[w^1_{(\text{ave})}]$.

$n_1 + L_{qt1}$ Number of customers wait for service during t_1. The expression:

$$\sum_{k=1}^{n_1} w_{1k}$$

gives the total waiting time of $n_1 + L_{qt1}$ customers. The ratio between these two values gives the average waiting time, i.e. $w^1_{(\text{ave})}$:

$$w^1_{(\text{ave})} = \frac{\sum_{k=1}^{n_1} w_{1k}}{n_1 + L_{qt1}} = \frac{\sum_{k=1}^{n_1} w_{1k}}{n_1 + \frac{n_1}{k_1}} = \frac{k_1 \times \left[\sum_{k=1}^{n_1} w_{1k}\right]}{n_1 \times [k_1 + 1]} \tag{24}$$

Substituting the expression of:

$$\sum_{k=1}^{n_1} w_{1k}$$

in the above equation yields the following expression for average waiting time, i.e. $w^1_{(\text{ave})}$:

$$w^1_{(\text{ave})} = \left[\frac{k_1}{k_1 + 1}\right]\left[\left(\frac{n_1 \times A}{S_{t1}}\right) \times \left(\frac{1}{2} + \frac{1}{k_1}\right) + A - \frac{t_1}{2}\right] \tag{25}$$

Generalizing the above equation yields the following equation, i.e. $w^i_{(\text{ave})}$ for, $i = 1, 2$. The "I" can accommodate any "n" number of sessions, i.e. $i = 1, 2, 3, \ldots, n$:

$$w^{i}_{(\text{ave})} = \left[\frac{k_i}{k_i+1}\right]\left[\left(\frac{n_i \times A}{S_{ti}}\right) \times \left(\frac{1}{2}+\frac{1}{k_i}\right) + A - \frac{t_i}{2}\right] \quad (26)$$

For $i = 1, 2, 3, \ldots, n$.

Analysis and validation of model

Field data collection

Data collection was organized with a list of around 50 service centers, both authorized and specialized service centers in Chennai. Response rate was 21 service centers (42 percent) and the survey furnished the following information:

- machine base;
- average daily demand for customer support services [field service demand];
- field service force size;
- average service and travel times per customer (in hours); and
- daily working hours (in hours) and demand fluctuation.

Service times and travel times are random and varying with the size of the market territory served by the service provider. The Table I gives the profile of the data collected from the 21 service centers of various manufacturers of IT-hardware in Chennai (Figure 3).

Theoretical values of customer waiting times

Study considered different levels of fluctuations to estimate the theoretical customer waiting time values using the derived model. Field interviews elicited following levels of daily demand fluctuation.

Lower value of $1/k = 0.1$; upper value of $1/k = 0.6$.

All the intermediary values and the extreme values of fluctuation namely, 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 were uniformly distributed within the extreme values. The Table II gives machine-base (sales) of service centers, field staff strength and the computed theoretical customer waiting times for different fluctuation levels.

Total average waiting time: 5.55 hours (sample estimate).

Waiting time preferred in the industry: 5 hours (population parameter).

Statistical analysis

The exhibit shows the results of statistical analysis performed on the theoretical and contractual waiting times. The results were computed using MS-excel (Table III).

Inference. The average theoretical customer wait differs significantly from the contractual time (complying with the customer's annoyance as elicited from the field). *Reason*. On the days with lower fluctuation levels, the customers wait for less than 5 hours. Contrarily, the customers wait exceed five hours at higher levels of fluctuation.

Further analysis

To know the customer wait when the fluctuation reaches its peak, the above analysis was repeated with hiked "contract times" (test times), viz. 5.1 hours, 5.2 hours and so on. The analysis was continued till "no significant difference" arise between theoretical and test waiting times for all levels of demand fluctuations (Table IV).

SI No.	Service center names	Machine base	Average number of customer calls received per day	Number of field service men	Average service time (hrs)	Average travel time (hrs)	Daily working hours
1	RMST	1,000	12	10	3.5	0.75	10
2	Infotech	6,000	60	29	4	1	10
3	HCLinfo	49,000	180	75	5	0.75	10
4	Spicenet	50,000	125	56	6	0.75	10
5	SBAComp	10,000	45	25	4	0.5	11
6	Vel	25,000	100	46	4	1	12
7	Skylark	5,000	45	26	4.5	1.5	10
8	HP	9,000	70	35	4	0.5	11
9	CCS	4,000	35	19	3.5	0.75	10
10	GCM	3,000	40	24	3	1	10
11	*Citicomp*	3,500	20	13	2.5	1	9
12	*Landmark*	2,000	25	16	2.5	0.75	11
13	*SK Interntl*	5,000	32	18	3.5	0.5	12
14	*SatvaOpen*	6,000	30	19	3.5	1	10
15	*Sensar*	4,000	25	14	3	0.75	10
16	*Solaris*	3,000	20	12	3.5	0.5	10
17	*Netlinx*	2,500	15	11	3.5	0.8	11
18	*New version*	1500	20	12	3	0.75	10
19	*ORG*	3000	20	13	3	1	10
20	*PCS*	3500	20	12	3	0.75	9
21	*RV*	4000	25	14	4	0.5	10

Table I. Field data collection

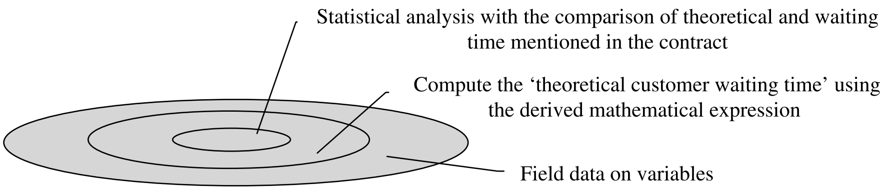

Figure 3. Analysis and validation of the model

Inference. Only when the fluctuation levels are 0.1 and 0.2 the manufacturers meet the industry standard namely 5 hours waiting time. Even when the fluctuation reaches an average level between the observed range of 0.1-0.6, the service provider is unable to keep the average waiting time below 5 hours.

Inference. On raising the population parameter to 5.9 hours, the analysis shows that service providers meet the customer's requirement for all the fluctuation levels.

Outcomes of the statistical analysis

Statistical analysis was performed with the "theoretical waiting times" and the contractual waiting time of 5 hours (Table V):

- service centers respond to customers within 5 hours during days when daily demand fluctuation registers 0.1 and 0.2 levels;

Machine base	Number of field service men	Theoretical customer waiting times for different levels of fluctuation 0.1	0.2	0.3	0.4	0.5	0.6	Average waiting time
1,000	7	3.83	4.16	4.44	4.67	4.88	5.06	4.51
6,000	26	5.3	5.73	6.09	6.41	6.68	6.92	6.19
49,000	72	5.77	6.24	6.63	6.97	7.26	7.52	6.73
50,000	53	5.42	5.86	6.24	6.55	6.83	7.07	6.33
10,000	22	4.19	4.62	4.98	5.28	5.55	5.78	5.07
25,000	43	4.43	4.94	5.37	5.74	6.07	6.35	5.48
5,000	23	4.43	4.8	5.11	5.38	5.62	5.82	5.19
9,000	32	4.54	4.99	5.37	5.7	5.98	6.23	5.47
4,000	16	5	5.41	5.76	6.06	6.31	6.54	5.85
3,000	21	4.3	4.66	4.97	5.23	5.46	5.66	5.05
3,500	10	4.99	5.33	5.62	5.87	6.08	6.27	5.69
2,000	13	3.89	4.29	4.63	4.93	5.18	5.4	4.72
5,000	15	3.96	4.43	4.84	5.18	5.48	5.75	4.94
6,000	16	4.23	4.58	4.88	5.14	5.37	5.56	4.96
4,000	11	5.21	5.64	6	6.3	6.57	6.81	6.09
3,000	9	5.08	5.5	5.85	6.16	6.42	6.65	5.94
2,500	8	3.77	4.17	4.5	4.79	5.04	5.25	4.59
1,500	9	5.08	5.5	5.85	6.16	6.42	6.65	5.94
3,000	10	4.53	4.91	5.23	5.51	5.75	5.96	5.32
3,500	9	5.54	5.92	6.24	6.51	6.75	6.96	6.32
4000	11	5.21	5.64	6	6.3	6.57	6.81	6.09
Standard deviation	0.64	Standard error			0.14		Mean	5.55

Table II.
Theoretical customer waiting times for the field data

Population mean	5.00
Average of all waiting times	5.55
Standard deviation	0.64
Standard error of mean	0.14
Difference between means	*− 0.55*
t-value	*− 3.94*
p-value(two-tailed)	0.000809

Table III.

One-sample test
Test value = 5

	t	Df	Sig. (two-tailed)	Mean difference	99 percent confidence interval of the difference Lower	Upper
OBSTIFL1	−2.263	20	0.035	−0.3000	−0.6771	0.0771
OBSTIFL2	0.815	20	0.424	0.1105	−0.2750	0.4959
OBSTIFL3	3.308	20	0.004	0.4571	0.0640	0.8503
OBSTIFL4	5.353	20	0.000	0.7543	0.3534	1.1552
OBSTIFL5	7.068	20	0.000	1.0129	0.6051	1.4206
OBSTIFL6	8.473	20	0.000	1.2390	0.8230	1.6551
OBSTIAVE	3.936	20	0.001	0.5462	0.1514	0.9410

Table IV.
Estimating the significant difference between customer waiting times for different fluctuation levels and industry standard time of 5 hours

- on an average service centers make their customers wait for 5.5 hours under conditions encountering moderate to high levels of demand fluctuations; and
- during days with very high fluctuation of daily demand (0.6), service centers meet customer requirement in 5.9 hours.

Analysis on difference between mean waiting times for different fluctuation levels

ANOVA, tests the differences between the means does not reveal which population means differ from which others. In this research we need to know which level of fluctuations result in highest disturbances in the customer waiting time. For this purpose, Fisher's LSD, Tukey HSD and Newman-Keuls test were performed (Lane, 1993) (Table VI).

Theoretical values of customer waiting times when the field force size is increased by 2 units for the field observed data

Methodology. Computing the theoretical waiting time was performed with addition of two more field service men to the existing field force strength. This was done for all the 21 service centers contacted in the survey.

Analysis performed. As done earlier, the following analyses were performed on the data:

- How far the average customer waiting time differs from the industry standard of 5 hours?
- What is the impact of daily demand fluctuation on the waiting time when field staff strength is added by 1 more staff? (Table VII and VIII).

Inference. The average value of customer waiting time, i.e. 4.828 hours does not show significant difference from the industry standards namely 5 hours. In fact, it is well within the industry standards (Table IX).

Inference. The service provider can confidently meet the customer requirements within industry specification even under adverse conditions (Table X).

Inference. An overall view of the output shows the following characteristic observations in wake of adding two staffs to existing field force:

- analysis project that customer waiting times at fluctuation levels of 0.1 and 0.2 are close to the waiting time encountered at fluctuation level 0.3;

One-sample test

	Test value = 5.9					
					99 percent confidence interval of the difference	
	t	Df	Sig. (two-tailed)	Mean difference	Lower	Upper
OBSTIFL1	−9.053	20	0.000	−1.2000	−1.5771	−.8229
OBSTIFL2	−5.828	20	0.000	−0.7895	−1.1750	−.4041
OBSTIFL3	−3.205	20	0.004	−0.4429	−0.8360	−.0497
OBSTIFL4	−1.034	20	0.313	−0.1457	−0.5466	0.2552
OBSTIFL5	0.788	20	0.440	0.1129	−0.2949	.5206
OBSTIFL6	2.319	20	0.031	0.3390	−0.0770	.7551
OBSTIAVE	−2.550	20	0.019	−0.3538	−0.7486	.0410

Table V. Estimating the significant difference between customer waiting times for different fluctuation levels and industry standard time of 5.9 hours

		OBSWT				
		Subset for $\alpha = 0.01$				
INFLEV	*N*	1	2	3	4	5
Student-Newman-Keuls[a]						
0.10	21	4.7000				
0.20	21	5.1105	5.1105			
0.30	21		5.4571	5.4571		
0.35	21		5.5462	5.5462		
0.40	21			5.7543	5.7543	
0.50	21			6.0129	6.0129	
0.60	21				6.2390	
Sig.		0.039	0.073	0.028	0.040	
TukeyHSD[3]						
0.10	21	4.7000				
0.20	21	5.1105	5.1105			
0.30	21		5.4571	5.4571		
0.35	21		5.5462	5.5462	5.5462	
0.40	21		5.7543	5.7543	5.7543	
0.50	21			6.0129	6.0129	
0.60	21				6.2390	
Sig.		0.369	0.023	0.079	0.010	
Duncan[3]						
0.10	21	4.7000				
0.20	21	5.1105	5.1105			
0.30	21		5.4571	5.4571		
0.35	21		5.5462	5.5462	5.5462	
0.40	21			5.7543	5.7543	5.7543
0.50	21				6.0129	6.0129
0.60	21					6.2390
Sig.		0.039	0.037	0.158	0.025	0.020
ANOVA						
OBSWT						
	Sum of squares	*Df*	*Mean square*	*F*	*Sig.*	
Between groups	34.754	6	5.792	14.193	0.000	
Within groups	57.137	140	0.408			
Total	91.891	146				

Note: Means for groups in homogeneous subsets are displayed. [a]Uses harmonic mean sample size = 21.000

Table VI.
ANOVA and tests for mean differences

- customer waiting times at fluctuation. 0.35 levels does not show very significant difference with that of extreme fluctuations like 0.5 and 0.6; and
- the manufacturing organization can confidently assume that even under worst situation the customer wait does not exceed 5 hours.

Results

The table constructed below summarizes the entire analysis in terms of customer waiting times under different staffing levels. Results show an improvement of close to one hour with addition of two field staffs (Table XI).

Machine base	Number of field service men	Theoretical customer waiting times for different levels of fluctuation 0.1	0.2	0.3	0.4	0.5	0.6	Average waiting time
1,000	9	2.88	3.15	3.37	3.56	3.73	3.87	3.43
6,000	28	4.89	5.29	5.63	5.93	6.18	6.4	5.72
49,000	74	5.61	6.06	6.44	6.77	7.06	7.31	6.54
50,000	55	5.21	5.64	6	6.31	6.57	6.81	6.09
10,000	24	3.77	4.17	4.5	4.79	5.04	5.25	4.59
25,000	45	4.18	4.67	5.09	5.44	5.75	6.02	5.19
5,000	25	4.04	4.38	4.68	4.93	5.14	5.33	4.75
9,000	34	4.23	4.65	5.01	5.32	5.59	5.83	5.11
4,000	18	4.4	4.77	5.08	5.35	5.58	5.78	5.16
3,000	23	3.89	4.22	4.51	4.75	4.96	5.14	4.58
3,500	12	4.16	4.45	4.69	4.89	5.07	5.23	4.75
2,000	15	3.26	3.61	3.92	4.18	4.4	4.6	4
5,000	17	3.33	3.77	4.14	4.45	4.72	4.96	4.23
6,000	18	3.71	4.03	4.3	4.54	4.74	4.92	4.37
4,000	13	4.34	4.71	5.02	5.28	5.51	5.72	5.1
3,000	11	4.08	4.43	4.73	4.98	5.2	5.39	4.8
2,500	10	2.84	3.17	3.45	3.69	3.9	4.08	3.52
1,500	11	4.08	4.43	4.73	4.98	5.2	5.39	4.8
3,000	12	3.71	4.03	4.3	4.54	4.74	4.92	4.37
3,500	11	4.54	4.85	5.11	5.34	5.53	5.7	5.18
4,000	13	4.34	4.71	5.02	5.28	5.51	5.72	5.1
							Mean	4.828
	Standard error	0.163			Standard deviation			0.747

Table VII. Theoretical customer waiting times when field force is increased by two units in the field data

One-sample statistics

	N	Mean	SD	Std. error mean
TH2TFLAV	21	4.8263	0.74703	0.16301

One-sample test

	Test value = 5				99.5 percent confidence interval of the difference	
	T	Df	Sig. (two-tailed)	Mean difference	Lower	Upper
TH2TFLAV	−1.065	20	0.299	−0.1737	−0.6877	0.3404

Table VIII. Statistical analysis for deviation from industry standard, i.e. 5 hours

Findings

- Current field staffing levels deployed by the service centers in Indian IT hardware industry is sufficient to meet the industry standards under conditions of lower daily demand fluctuation. This fact is synchronous with the customer complaints on delayed customer response.
- At highest level of fluctuation, i.e. 0.6, average customer wait inflates to 5.8 hours.
- By adding two more staffs in the field force, the lower limit of customer wait drastically reduces to near four hours and adverse demand could be met in 5 hours.
- Under hectic competition, there is tremendous scope of raising service standards.

Table IX.
Estimating the significant difference between customer waiting times for different fluctuation levels and industry standard time of 5 hours

	One-sample test Test value = 5					
					99.5 percent confidence interval of the difference	
	T	df	Sig. (two-tailed)	Mean difference	Lower	Upper
TH2TFLAV	− 1 .065	20	0.299	− 0.1737	− 0.6877	0.3404
TH2TFL1	− 6.226	20	0.000	− 0.9290	− 1.3995	− 0.4584
TH2TFL2	− 3.615	20	0.002	− 0.5624	− 1.0529	− 0.0719
TH2TFL3	− 1.563	20	0.134	− 0.2524	− 0.7616	0.2567
TH2TFL4	0.080	20	0.937	0.0134	− 0.5128	0.5397
TH2TFL5	1.418	20	0.172	0.2436	− 0.2982	0.7854
TH2TFL6	2.526	20	0.020	0.4453	− 0.1107	1.0014

Table X.
Tests for mean differences

TH2WT				
		Subset for $\alpha = 0.005$		
INFLEV	*N*	1	2	3
Student-Newman-Keuls[a]				
0.10	21	4.0710		
0.20	21	4.4376	4.4376	
0.30	21	4.7486	4.7486	4.7486
0.35	21	4.8276	4.8276	4.8276
0.40	21		5.0143	5.0143
0.50	21		5.2438	5.2438
0.60	21			5.4462
Sig.		0.007	0.006	0.025
TukeyHSD[a]				
0.10	21	4.0710		
0.20	21	4.4376	4.4376	
0.30	21	4.7486	4.7486	4.7486
0.35	21	4.8276	4.8276	4.8276
0.40	21		5.0143	5.0143
0.50	21		5.2438	5.2438
0.60	21			5.4462
Sig.		0.023	0.012	.047
Duncan[a]				
0.10	21	4.0710		
0.20	21	4.4376	4.4376	
0.30	21	4.7486	4.7486	4.7486
0.35	21		4.8276	4.8276
0.40	21		5.0143	5.0143
0.50	21			5.2438
0.60	21			5.4462
Sig.		0.006	0.023	0.006

Note: Means for groups in homogeneous subsets are displayed. [a]Uses harmonic mean sample size = 21.000

SI No.	Field staffing level	Maximum customer waiting time	Minimum customer waiting time	Observations from the statistical analysis
1.	As observed in the field	5.8 hours	5 hours	Minimum waiting time can be achieved only under lower fluctuation of daily demand levels for field services (0.1 and 0.2)
2.	Increasing the field staff strength by two personals	5 hours	4.07 hours	The minimum waits achieved under lower fluctuation levels (0.1 and 0.2)

Table XI. Results

Conclusion

Hectic competition in emerging markets necessitates the manufacturer to offer best "after sale services" complying with customer requirements. Manufacture has to configure customer support networks with authorized centers and specialized centers to deliver these services. Growing customer base, product reliability has tremendous impact on the daily demand for support services. The staffing decisions under stochastic demand conditions have profound influence on customer response.

This study has modeled the situation to relate customer response and staff strength considering stochastic demand limited server availability. This methodology aids an organization to engage right number of staffs in customer support.

Following aspects form the study's highlight:

- The mathematical expression determines the relation between customer wait and staffing levels based on stochastic principles.
- In addition, the statistical analysis show that with higher staffing levels significant differences examined in waiting times as a result of demand fluctuation can be brought down considerably.

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Corresponding author
R. Shankar can be contacted at: rkravishankar@imt.edu