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Impact of QoS Parameters on the Subscribers Volume of Cellular Operators across Indian States

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Abstract

Over the past decade, the demand for wire-line and wireless services has increased multi-fold. As per India Brand Equity Foundation (IBEF), India ranks second globally in having a vast telecommunication market, with the subscriber base increasing over 1.2 billion, enabling the rapid growth of commercial mobile service providers (CMSP). With the entry of multiple players in the CMSP space, the decision to choose amongst the cellular operators for customers narrows down to theserviceexperienceintermsofthenetwork-relatedparameters and customer service quality encountered by them, resulting in the change in subscriber volumes for each service provider. The paper aims at determining the impact of the Quality of Service (QoS) Parameters on the quantifiable subscriber volumes of the leading CMSPs across various Indian states. Secondary data was extracted and collated from the official website of Telecom Regulatory Authority of India (TRAI). The operator-wise subscriber volumes were collected from the COAI, DoT and TRAI. The QoS parameters are based on the quality of experience that the customer expects from the service provider. From secondary research of available literature, it was found that the various factors affecting customer satisfaction and churn rate are network performance, availability and reliability, thecall drop rate, network congestion, service quality. The significanceof various network related parameters such as the base transceiver downtime, call drop rate, call set-up success rate, accessibility to customer service was determined through a panel data regression on the cross-sectional data of operators across 12 states over a time period of 11 quarters. The findings for the model pertaining to subscribers across the states depicted that there are external factors that might be considered for explaining the variation in customer base. The results of operator-wise subscriber base panel regression model helped in understanding the significance of various network related parameters across operators. These findings will be instrumental in carving suggestions for the cellular operators related to the most critical factors that should be focused on to retain their subscribers and maximize their benefits.

Keywords: *Mobile Service Providers, Network Parameters, Quality of Service (QoS) Parameters, Subscribers*

I. INTRODUCTION

The Indian telecommunication industry has been thriving and exponentially expanding over the past decade, resulting in having one of the largest customer bases in terms of wire line, wireless and internet subscriptions. The wireless segment of the subscribers in the telecom industry comprises around 98% of the total subscribers' base **[1]**,with the cellular segment having varied tele-densities amongst the urban and rural customers.The telecom service provider landscape has seen increased competition with all the leading operators, aiming to get the maximum share of the customer base by switching over from a voice-based to a data-focused network. Therehave been multiple players in the cellular network service provider space, however

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over the last couple of years, we have seen manymobileserviceprovidersgoingdefunctduetomergers, bankruptcy, loss of subscription base, consolidation due to lack of financial backing.

As of December 2019, there are only 3 private mobile operators and 1 public sector operator that provide voice and data services to the 1151.44 strong wireless subscriber base. The customer is the most crucial stakeholder for any cellular operator and every competingprovider hasthe sole aim of acquiring the maximum customer base, which will result in a higher gross annual revenue for the company**. C Panse et., al, (2019) [14]** in their piece of work find out that "factors like Convenience, Control, Technology Anxiety & Ease of Information significantly affect Consumer Satisfaction, which intern significantly affect the Consumer Intentions".The research community has studied the behavioural aspects, where the customer satisfaction is influenced by theexperience and the services offered by different players in thetelecommunication market. **Ashish Das and Suresh Kumar (2011) [2]** in their paper have analyzed the determinants of the subscriber's choice of mobile service providers through primary survey and prioritized the factors with highest preference depicted towards network coverage, customer care service availability and accessibility, call plan or pricing. **Muhammad Turki Alshurideh [3]** intheir paper have examined the constituents influencing the consumer's decision in choosing amongst competing cellular subscription plans and foundthat the service features, size of data offered in terms of minutes of call and messages were some of the deciding factors for a consumer to choose an operator. It is often seen that when the user experience becomes dissatisfactory with a particular operator, one considers switching to another operator leading to an increase in churn rate. In the competitive landscape with a plethora of operators, the customer's decision-making process to select an operator is influenced by the perceived quality of service.**Rastogi, S. (2016) [15],** in his study believes that "In the new world dispensation in 21st century, it is now the turn of third world nations led by China and India to take the lead change with a blistering speed" The technological advancement in telecom industry has opened gateways for the service providers to cater to a foray of services. In 1997, the independent regulatory body of Telecom Regulatory Authority of India was created to forestall the establishment of monopoly in the telecom sector and tofacilitate economy-wide policy changes. As per **[4],**In 2005TRAI had laid down certain Quality of Service Parameters for CMSPs, which served as a checkpoint as itensuresthattheconsumersareprovided with the promised services by the operators and getvalue for the money they spend on the subscription plans. They alsoensured frequent measurement of the quality of service and assess it against a benchmark performance level. In 2009, certain parameters were deleted tomaketheframeworkrelevantinthetechnologicalera. The regulation has been revised over the years, and in2012 it was revised to include the financial disincentives for the operators who exhibit delay in compliance as well as parameters for 3G services. As of 2015, the benchmark has become more stringent to penalize the repetitive non-compliant and rogue operators **[4]** The customer satisfaction has been studied extensively, however there has been limited work done around the impact of the technical characteristics of service on the volume of subscribers. This led us to consider the Quality of Service (QoS) parameters as the variables under study as they ensure that the operators abide by their promise of providing the desired services to the customer. Through this paper we aim to quantitatively determine whether the performance of QoS parameters has significant impact on the subscriberbaseofeachmobileserviceprovider.
Moreover, the performance of not only telecommunication companies but all the companies also depend upon the capital structure (Rastogi, 2011; Rastogi, 2016) **[20, 21].**

II. LITERATUREREVIEW

The advancement of technology has facilitated the dawn of digital age, enabling us to stay connected with each other across the globe. One of the most well-accepted product-service continuums of this age is the mobile telephony and cellular services, which provides users with connectivity and accessibility across the globe. The advent of various mobile operators in the market provides the customers with a plethora options to choose from. However, it also leads to increase in competition

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among service providers as well. The customers are then posed with the choice of choosing the mobileoperator which gives them the expected service. **T.M Valletti [5] i**n his paper on building a model for deciding the sizeof the networks being covered by various operators asserts that network coverage acts as a quality differentiator provided the customers are moving to different areas. **Przemysław Gilski and JacekStefan´ski (2015)[6]**have emphasized onhow controlling service quality ensures the quality of experience (QoE) perceived by the user. They have also dealt with the behavioural aspects of subscribers and other factors that affect the QoE**. Kim, H.-S. and Yoon, C.-H**. (2004) **[7],** in their paper have deduced that it is usually factors like call quality, brand image which is instrumental in gaining customer loyalty and influencing their decision to recommend the operator to a new customer. **Saha, Netai & Islam, Md & Hoque, Asif. (2016)[8] h**ave found a positive correlation between the customer satisfaction in mobile subscribers and the network quality in terms of network coverage, time to establishment of calls, voice clarity, product diversity, customer service facilities. **A. Stafecka, A. Lizunovs and V. Bobrovs (2018) [9]** have closely studied the dependency of signal parameters and QoS parameters on the quality of experience at the end-user premises. It was found that QoS parameters were informative enough to explain the performance of thenetwork.

The International Telecommunication Union (ITU) provides certain recommendations to the National Regulatory Authoritiesof various regions for the QoS and QoE parameters in the Information and Communication Technology sphere. The quality of service is defined in the ITU-T Rec. E. 800 as the "*Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service*." **[10]** TheQoS takes into account the network perspective in terms of its infrastructure as well as the perception of the user which is formed during the telecommunication service experience. The QoS framework for monitoring in the Indian context depends on the end-to-end stakeholders in the network as shown below **[11]**

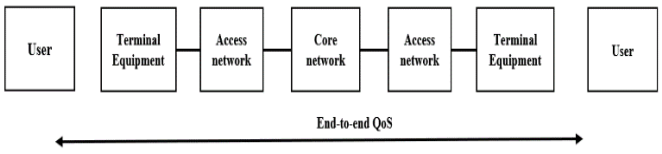

Fig. 1. **Stakeholders for QoS Monitoring and Implementation**

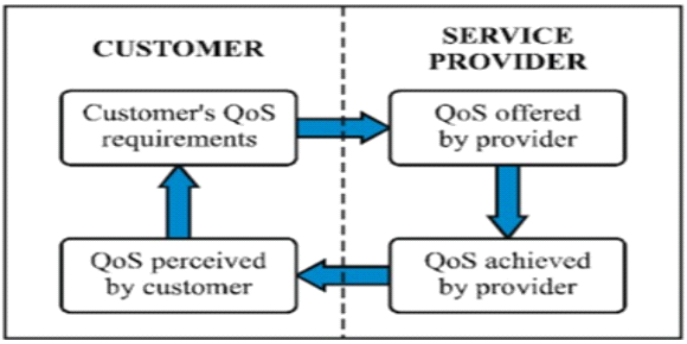

Fig. 2. **Four viewpoints of QoS**

The Quality of Service comprises the network quality related parameters along with the customer service-related parameters. The QoS is determined from four different aspects as shown in the figurebelow *(Source: Quality of Service Regulation Manual)***[10]**

The QoS in India for wireless segment has been bifurcated into **Network Service Quality Parameters** and **Customer Service Quality Parameters**. The Network Service Quality Parameters have four major divisions namely:

- NetworkAvailability
- Connection Establishment/ Accessibility of the Network
- Retainability or ConnectionMaintenance
- CongestionatPointofInterconnection(PoI)

The Customer Service Quality Parameters take into account the accessibility to customer service, the responsiveness of the customer care to complaints, metering and billing facilities. Every cellular mobile telephone services provider is expected to fulfil the performance criteria, barring which financial disincentives are awarded to repeat non-compliant operators. Before enforcing the QoS framework in India, a consumer survey was conducted to identify the pain points and the result depicted that QoS was

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the rationale for selecting a service provider**[10].** The survey also shed light on consumers opinion on requesting financial disincentives for operators that did not provide the pledged services.

Popoola et. Al (**2017**) have studied the performance indicators of the QoS of GSM networks across operators in Nigeria. They have conducted the tests on the "Call Set-Up Success Rate", "Stand-alone Dedicated Channel Congestion" (SDCCH), "Call Drop Rate" and the "Traffic Channel Congestion"**[12]**

Haresh Barot and Namrata Kansara (2015) [13] have studied various factors that help in retaining customers for cellular service providers with network performance, reliability and availability being the most significant variables in their analysis.

III. OBJECTIVE

This paper aims to determine the impact of the performance of Quality of Service (QoS) parameters for cellular mobile service providers, as measured by TRAI, and the number of subscribers in for each of the operators across the states in India.

H_0: The performance of QoS network parameters have significant effect on the subscribers count

H_1: The performance of QoS network parameters do not have a significant effect on the subscribers count.

QoS is considered a relevant parameter in customer's preference, hence it has been chosen as a basis of research.

IV. RESEARCHMETHODOLOGY

For the empirical analysis, we have taken the measured values of QoS Parameters data as provided in the Performance Indicator Reports **[16]** published on the TRAI website starting from quarter ending March 2017 to Sept 2019, encompassing 11 quarters. Although data were extracted for all the 22service areas as listed by TRAI, but the absence of data for a few operators in the each of the states, for the period under study the final analysis was carried out on 12 service areas only. The data was collated and a balanced panel data of operators for 11quarters,fromMarch2017toSeptember2019,wasused.Every State or Service Area, falls under either Category A, B or C based on the population size of the subscriber base to which the operators provide their services.

Owing to the cross-sectional and time-series data, panel regression was chosen as the method for studying the impact on the number of subscribers across 12 states with mobile services being offered by the 4 operators – Reliance Jio, BSNL, Vodafone Idea and Bharti Airtel. The panel data under study consists of various network parameters that have been identified by International Telecommunication Union as crucial for ensuring consumer satisfaction. We considered the period from 2017 onwards, as one of the frontrunners in the telecom industry today – Reliance Jio, came into being in September 2016. We have considered the number of subscribers at the end of each quarter as provided by Cellular Operator Association of India, Department of Telecommunications and TRAI.**[16] [17]**

TABLE I
VARIABLES DESCRIPTION

Variables	Description	Type
Subscribers	Quarterly count of subscribers of each operator in each state	Dependent Variable
Base Transceiver Downtime	Base Transceiver Downtime refers to the accumulated downtime of the transceiving stations which is unplanned, the benchmark for this parameter is <=2%	Independent Variable
Call Set-Up Success Rate	Ratio of Established calls to call attempts, hence an attempt to achieve a connection to one or more devices in the telecommunication network, the benchmark for this parameter is >=95%	Independent Variable
SDCCH Congestion	Congestion in the signalling channel which can lead to non-establishment of calls, the benchmark for this parameter is <= 1%	Independent Variable
Call Drop Rate	Service provider's inability to maintain a call after it is established, the benchmark for this parameter is <= 2%	Independent Variable
% of Good Voice Quality	The quality of voice in cellular mobile telecom services, the benchmark for this parameter is > 95%	Independent Variable
Accessibility CC	Accessibility to customer service, the benchmark for this parameter is > 95%	Independent Variable

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The dummy variable "Location" has been used to assign numeric equivalents to each category as shown in Table II. Some descriptive statistics for the dependent and explanatory variables are shown in Table III.

TABLE II
SERVICE AREA-WISE CATEGORY

States	Category	Location (Dummy Variable)
AP	A	0
Gujarat	A	0
Haryana	B	1
J&K	C	2
Karnataka	A	0
Kerala	B	1
Maharashtra	A	0
Punjab	B	1
Rajasthan	B	1
TN	A	0
UPE	B	1
UPW	B	1

TABLE III
DESCRIPTIVE STATISTICS

Variables	Mean	Min	Max	Std. Dev
Subscribers	12386525	809122	48916041	8797276
Base Transceiver Downtime	0.441875	0.01	8.66	0.615082
CSSR*	98.74537	49.72	99.98	2.360852
SDCCH*	0.296023	0	7.73	0.427468
CDR*	1.16465	0.05	2.26	0.619335
% of Good Voice Quality	98.26677	49.79	100	2.468603
AccessibilityCC	98.78723	83.07	100	1.922178

** CSSR – Call Set-Up Success Rate, SDCCH - Standalone Dedicated Channel Congestion, CDR – Call Drop Rate*

V. DATA INTERPRETATION AND ANALYSIS

Tests for Estimating Model for Panel Data Across States and Operators

The state wise-operator is considered as one cross-section, whose value is taken over a time period of 11 quarters, thus, creating a panel of 48 circles. Before proceeding with regression, we need to estimate the model which best represents the panel data. To arrive at the most appropriate model we perform the "fixed effect" test, "random effect" test and "Hausman" test.

1.3.1 Test for Estimation of Fixed-Effect (within) Regression:

We perform F-statistics test in order to determine whether "Fixed-Effect"Model is to be used for Panel data regression.

H_o*: There is no fixed effect*
H_1*: There is fixed effect*

Group Variable: Circle (State Wise-Operator)

TABLE IV
FIXED-EFFECT TEST RESULTS

	Co-efficient	Std. Error	t-value	p-value
BaseTransceiverDowntime	-2546868	1141113	-2.23	0.026
CSSR	-242364.1	259754.8	-0.93	0.351
SDCCHCongestion	2777116	1269593	2.19	0.029
CDR	1991528	530948.6	3.75	0
% of GoodVoiceQuality	312711.1	263891.8	1.18	0.237
AccessibilityCC	-280030.3	139791	-2	0.046
Constant	0	16600000 3120000	1.89	0.06

** CSSR – Call Set-Up Success Rate, SDCCH - Standalone Dedicated Channel Congestion, CDR – Call Drop Rate*

P>F = 0.000, making it less than 0.05, therefore conclude there is fixed-effect, thus rejecting the null hypothesis.

1.3.2Test for Random-effects GLS Regression:

We then performed the Breusch and Pagan Lagrangian multiplier test in order to check whether "Random Effect"Model istobeappliedforPaneldataregression.

H_o*:There is no random effect*
H_1: *There is random effect*

Group Variable: Circle (State Wise-Operator)

TABLE V
RANDOM-EFFECT TEST RESULTS

	Co-efficient	Std. Error	z	p-value
BaseTransceiverDowntime	-5334608	954999	-5.59	0
CSSR*	-216217.3	249859.7	-0.87	0.387
SDCCH*	5771150	1119944	5.15	0
CDR*	1849340	504873.1	3.66	0
% of GoodVoiceQuality	243966.1	251026.3	0.97	0.331
AccessibilityCC	-208266.5	138264.6	-1.51	0.132
Constant	32700000	1.67E+07	1.96	0.05

** CSSR – Call Set-Up Success Rate, SDCCH - Standalone Dedicated Channel Congestion, CDR – Call Drop Rate*

Prob > chibar2 = 0.00, makes the p-value < 0.05, therefore we conclude there is random-effect by rejecting the null hypothesis.

1.3.3 HausmanTest

As both "Random Effect" and "Fixed Effect" model was found to be significant hence,

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Hausman Test is performed.

H_o:*There is random effect*

H_1: *There is fixed effect*

By running the Hausman command in Stata SE 13 on the stored fixed and random effect values, the following results were obtained:

TABLE VI
HAUSMAN TEST RESULTS

	Fixed effect Values	Random Effect Values	Difference	Standard Error
BaseTransceiverDowntime	-	-	2787740	624593.1
2546868		5334608		
CSSR	-	-	-26146.8	71015.49
242364.1		216217.3		
SDCCH	277711	5771150	-2994034	597990
CDR	199152	1849340	142188	164346
% of GoodVoiceQuality	312711	243966.1	68745	81392.14
AccessibilityCC	-	-	-71763.8	20601.52
280030.3		208266.5		

Hausman test provides confirmation for the appropriate model of estimation

The null hypothesis was rejected as **Prob > chi2 = 0** andacceptthealternatehypothesis.Thus,Hausman test confirms that "Fixed effect" is to be applied to thispanel.

1.3.4 **Consolidated Panel Regression using "Fixed Effect Model"**

From the "fixed effect" test we were able to find the estimated equation to be:

$$31200000 - 2546868\ Base\ Transceiver\ Downtime - 242364.1\ Call\ Set - Up\ Success\ Rate + 2777116\ SDCCH\ Congestion + 1991528\ Call\ Drop\ Rate + 312711.1\ \%\ of\ Good\ Voice\ Quality - 280030.3\ Accessibility\ CC$$

TABLE VII
PANEL DATA REGRESSION RESULTS

	Co-efficient	Std. Error	t-value	p-value
BaseTransceiverDowntime	-	1141113	-2.23	0.026
2546868				
Call Set-UpSuccessRate	-	259754.8	-0.93	0.351
242364.1				
SDCCHCongestion	2777116	1269593	2.19	0.029
CallDropRate	1991528	530948.6	3.75	0
% of GoodVoiceQuality	312711.1	263891.8	1.18	0.237
AccessibilityCC	-	139791	-2	0.046
280030.3				
Constant		16600000	1.89	0.06
	3120000			
0				

Regression Results on impact of network parameters on subscribers' base

The R-square, i.e. the co-efficient of regression was found to be **28.1 %**, that implies in the given panel data, the independent variables are able to explain 28.1 % change in the number of subscribers of the state wise - operators.

With the confidence interval at 95%, it is found that **Base Transceiver Downtime**, **SDCCH Congestion**, **Call Drop Rate** and **Accessibility of Customer Care** have significant impact on the number of subscribers in 12 states that have been taken under study.

1.4Test for Stationarity

The total number of observations over cross-sections are 528 with the cross-sections (N) being 48, and the time series over which the data has been collected is 11 quarters (T) , hence, we do not perform the test for stationarity for the panel data under study, and consider the given dataset as stationary.

1.5Test for Heteroscedasticity

In order to run diagnostics on the given panel data, we performed the Wald test for groupwise heteroscedasticity,

H_o: T*he data is homoscedastic*

H_1:*The data is not homoscedastic*

As the p-value resulted to be less than 0.05 we can conclude that the dataisheteroscedastic.Thisposesasa**limitation**inthestudy.

1.6 Test forAuto-collinearity

We performed the Woolridge test for auto-correlation in the panel data,

H_o: *There is no autocorrelation in the explanatory variables*

H_1: *There is autocorrelation*

The p-value = **0.0104**, which is less than 0.05, hence concluding that there is significant autocorrelation. Thisposesasa**limitation**inthestudy.

1.7Test for Multi-collinearity

In order to test for multi-collinearity amongst the independent variables, we look for the Variation Inflation Factors (VIF) and Correlation Co-efficient as shown below:

TABLE VIII
VARIATION INFLATION FACTOR FOR MULTICOLLINEARITY

Variable	VIF
Base Transceiver Downtime	4.45

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Call Set-Up Success Rate	4.35
SDCCH Congestion	2.21
Call Drop Rate	2.03
% of Good Voice Quality	1.28
AccessibilityCC	1.12

It is found that as the co-efficient in the correlation matrix is less than 0.8 and all the variable inflation factors are less than 6, Hence we can infer that there is no multi-collinearity.

TABLE IX
CORRELATION MATRIX BETWEEN THE EXPLANATORYVARIABLES

Correlation	BTD	CSSR	SDCCH	SDR	GVQ
BTD	1				
CSSR	-0.1947	1			
SDCCH	0.7077	-0.2416	1		
SDR	0.2828	-0.2247		1	
GVQ	-0.1624	0.4141	0.38	-0.2911	1
		0.8656	-		
		0.2107			

** BTD – Base Transceiver Downtime, CSSR – Call Set-Up Success Rate, SDCCH - Standalone Dedicated Channel Congestion, CDR – Call Drop Rate GVQ - % of Good Voice Quality, Acc – Accessibility to Customer Care*

1.8 Operator-Wise Panel DataRegression

We performed an operator-wise panel data regression on the number of subscribers of each operator across the 12 service areas and ran 4 separate regressions for each operator namely, Airtel, Vodafone Idea, Reliance Jio and BSNL with respect to the network related parameters. The Panel consisted of11 quarters and 12 cross-sections for each of the operators, creatingabalancedpanelof132observationseach.

Dependent Variables – Number of Subscribers

Independent Variables[16]– Performance of Quality of Service Parameters as measured by TRAI on a quarterly basis.

We performed the Fixed Effect, Random Effect and Hausman Test in each case. The Hausman test confirmed that for BSNL and Vodafone Idea, the Random Effect Model was appropriate for estimation, whereas for Airtel and Reliance Jio the Fixed Effect Model was the choice of model estimation.

1.8.1 **Hausman Test Results forAirtel**

Owing to the p-value as depicted in the table, we conclude that the "**Fixed Effect"** model for Airtel subscribers is appropriate for estimation model, thus rejecting the null hypothesis.

TABLE X
HAUSMAN TEST RESULTSFOR MODEL ESTIMATION FOR AIRTEL

Correlated Random Effects - Hausman Test Equation: Airtel Subscribers
Test cross-section random effects

TestSummary	Chi-Sq.Statistic	Chi-Sq. d.f.	Probability
Cross-sectionrandom	15.581828	6	0.0162

p-value = 0.0162, this suggests the fixed effect model is more appropriate

Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-51711724	1.04E+08	-0.496547	0.6205
SDCCH_CONGESTION	4511513.	2601767.	1.734019	0.0856
CALL_SET_UP_SUCCESS_RATE	1292807.	719415.1	1.797025	0.0750
CALL_DROP_RATE	2363250.	968208.5	2.440848	0.0162
BASE_TRANCEIVER_DOWNTIME	-5652848.	3656384.	-1.546022	0.1249
ACCESSIBILITYCC	74996.84	180980.6	0.414392	0.6794
_OF_GOOD_VOICE_QUALITY	-721432.1	559613.4	-1.289162	0.2000
Effects Specification				
Cross-section fixed (dummy variables)				
Root MSE	4222885.	R-squared		0.807593
Mean dependent var	16208599	Adjusted R-squared		0.778901
S.D. dependent var	9663860.	S.E. of regression		4544057.
Akaike info criterion	33.62266	Sum squared resid		2.35E+15
Schwarz criterion	34.01577	Log likelihood		-2201.096
Hannan-Quinn criter.	33.78240	F-statistic		28.14679
Durbin-Watson stat	2.418074	Prob(F-statistic)		0.000000

Fig. 3. **Fixed-Effect Model Panel Regression Results for Airtel**

On running the "fixed effect" model of panel data regression in E- Views for 132 observations the following results were observed for Airtel subscribers across the 12 service areas:

The estimated equation for regression model was found to be:

$$Subscribers = -51711724 + 4511513\,SDCCH\ Congestion + 1292807\,Call\ Set-Up\ Success\ Rate + 2363250\,Call\ Drop\ Rate - 5652848\,Base\ Transceiver\ Downtime + 74996.84\,Accessibility\ of\ Customer\ Care - 721432.1\,\%\ of\ Good\ Voice\ Quality$$

It was found that the adjusted R-square value was found to be **77.89%,** with only the **Call Drop Rate** being the significant explanatoryvariable.

The diagnostics tests were run on the dataset, and it was found that data was homoscedastic, with no multi-collinearity between variables.

1.8.2 **Hausman Test Results forBSNL**

On running the Hausman test we conclude that the "**Random Effect"** model for BSNL subscribers is appropriate for estimation and we do not reject the null hypothesis

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TABLE XI
HAUSMAN TEST RESULTSFOR MODEL ESTIMATION FOR BSNL

Correlated Random Effects - Hausman Test Equation: BSNL Subscribers

Test cross-section random effects

TestSummary	Chi-Sq.Statistic	Chi-Sq. d.f.	Probability
Cross-sectionrandom	2.714045	6	0.8438

p-value = 0.8438, this suggests the random-effect model is more appropriate

Results

On running the "random effect" model of panel data regression in E- Views for 132 observations the following results were observed for BSNL subscribers across the 12 service areas:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3944875.	11396198	-0.346157	0.7298
SDCCH_CONGESTION	-235494.7	302260.7	-0.779111	0.4374
CALL_SET_UP_SUCCESS_RATE	51503.65	72643.66	0.708990	0.4797
CALL_DROP_RATE	528899.8	85002.84	6.222143	0.0000
ACCESSIBILITYCC	-12918.97	48431.37	-0.266748	0.7901
BASE_TRANCEIVER_DOWNTIME	227203.6	183349.2	1.239185	0.2176
_OF_GOOD_VOICE_QUALITY	64728.92	63904.38	1.012903	0.3131
Effects Specification			S.D.	Rho
Cross-section random			3700006.	0.9894
Idiosyncratic random			382157.9	0.0106
Weighted Statistics				
Root MSE	366966.3	R-squared		0.283910
Mean dependent var	221933.0	Adjusted R-squared		0.249538
S.D. dependent var	435305.1	S.E. of regression		377101.4
Sum squared resid	1.78E+13	F-statistic		8.259852
Durbin-Watson stat	0.441132	Prob(F-statistic)		0.000000
Unweighted Statistics				
R-squared	-0.000783	Mean dependent var		7129981.
Sum squared resid	1.18E+15	Durbin-Watson stat		0.006653

Fig. 4. **Random-Effect Model Panel Regression Results for BSNL**

The estimated equation for regression model was found to be:

$$Subscribers = -3944875 - 235494.7\ SDCCH\ Congestion + 51503.65\ Call\ Set - Up\ Success\ Rate + 528899.8\ Call\ Drop\ Rate + 227203.6\ Base\ Transceiver\ Downtime - 12918.97\ Accessibility of Customer Care - 64728.92\% of Good Voice\ Quality$$

It was found that the adjusted R-square value was found to be **24.95%,** with only the **Call Drop Rate** being the significant explanatoryvariable.

The diagnostics tests were run on the dataset, and it was found that heteroscedasticity was present in the data which poses as limitation of the study. However, there was no multi- collinearity between variables.

1.8.3 Hausman Test Results forVodafone-Idea

The Hausman test confirms that the "**Random Effect"** model for Vodafone-Idea subscribers is appropriate for estimation and we do not reject the null hypothesis.

TABLE XII
HAUSMAN TEST RESULTSFOR MODEL ESTIMATION FOR VODAFONE-IDEA

Correlated Random Effects - Hausman Test Equation: Vodafone-Idea Subscribers

Test cross-section random effects

TestSummary	Chi-Sq.Statistic	Chi-Sq. d.f.	Probability
Cross-sectionrandom	9.61122	6	0.142

p-value = 0.142, this suggests the random effect model is more appropriate

Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.64E+08	85811005	4.245824	0.0000
SDCCH_CONGESTION	7895867.	3030518.	2.605451	0.0103
BASE_TRANCEIVER_DOWNTIME	-7507529.	2757995.	-2.722097	0.0074
ACCESSIBILITYCC	-3846049.	917512.3	-4.191823	0.0001
_OF_GOOD_VOICE_QUALITY	618299.9	676730.0	0.913658	0.3627
CALL_SET_UP_SUCCESS_RATE	-303591.8	675741.8	-0.449272	0.6540
CALL_DROP_RATE	2216618.	1235826.	1.793633	0.0753
Effects Specification			S.D.	Rho
Cross-section random			6303879.	0.5728
Idiosyncratic random			5444601.	0.4272
Weighted Statistics				
Root MSE	5374258.	R-squared		0.251671
Mean dependent var	3857775.	Adjusted R-squared		0.215751
S.D. dependent var	6236249.	S.E. of regression		5522688.
Sum squared resid	3.81E+15	F-statistic		7.006461
Durbin-Watson stat	0.929781	Prob(F-statistic)		0.000002
Unweighted Statistics				
R-squared	0.258409	Mean dependent var		15308162
Sum squared resid	1.00E+16	Durbin-Watson stat		0.354151

Fig. 5. **Random-Effect Model Panel Regression Results for Vodafone- Idea**

On running "random effect" model for panel data regression run in E- Views for 132 observations the following results were observed for Vodafone-Idea subscribers across the 12 service areas.

The estimated equation for regression model was found to be:

$$Subscribers = 3.64E + 08 + 7895867\ SDCCH\ Congestion - 303591.8\ Call\ Set - Up\ Success\ Rate + 2216618\ Call\ Drop\ Rate - 7507529\ Base\ Transceiver\ Downtime - 3846049\ Accessibility\ of\ Customer\ Care - 618299.9\%\ of\ GoodVoice\ Quality$$

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It was found that the adjusted R-square value was foundto be **21.575%,** with only the **SDCHH Congestion, Base Transceiver Downtime and Accessibility** were found to be the significant explanatoryvariables.

The diagnostics tests were run on the dataset, and it was found that the data was homoscedastic in nature. There was no multi- collinearity between variables, however the data was not normal.

1.8.4 **Hausman Test Results for RelianceJio**

Owing to the p-value as depicted in the table, we conclude that the "**Fixed Effect**" model for Reliance Jio subscribers is appropriate for estimation, thus rejecting the null hypothesis.

TABLE XIII
HAUSMAN TEST RESULTS FOR MODEL ESTIMATION FOR RELIANCE JIO

Correlated Random Effects - Hausman Test Equation: Reliance Jio Subscribers
Test cross-section random effects

TestSummary		**C**
hi-Sq.Statistic		**C**
hi-Sq. d.f.		**P**
robability		
Cross-sectionrandom	22.66601	6

p-value = 0.0009, this suggests the fixed effect model is more appropriate

Results

On running the "fixed effect" model for panel data regression in E- Views for 132 observations, the following results were observed for Reliance Jio subscribers across 12 service areas

On running the "fixed effect" model for panel data regression in E- Views for 132 observations, the following results were observed for Reliance Jio subscribers across 12 service areas.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.66E+09	1.64E+08	-10.09329	0.0000
SDCCH_CONGESTION	19516805	9182552.	2.125423	0.0357
CALL_SET_UP_SUCCESS_RATE	75024.47	1151892.	0.065132	0.9482
CALL_DROP_RATE	-2260805.	1263949.	-1.788683	0.0763
BASE_TRANCEIVER_DOWNTIME	-10140480	2314291.	-4.381679	0.0000
_OF_GOOD_VOICE_QUALITY	16699750	1343491.	12.43011	0.0000
ACCESSIBILITYCC	-30806.71	194135.4	-0.158687	0.8742
Effects Specification				
Cross-section fixed (dummy variables)				
Root MSE	3058439.	R-squared		0.820594
Mean dependent var	10899357	Adjusted R-squared		0.793841
S.D. dependent var	7248248.	S.E. of regression		3291049.
Akaike info criterion	32.97743	Sum squared resid		1.23E+15
Schwarz criterion	33.37054	Log likelihood		-2158.511
Hannan-Quinn criter.	33.13718	F-statistic		30.67244
Durbin-Watson stat	0.805827	Prob(F-statistic)		0.000000

Fig. 6. **Fixed-Effect Model Panel Regression Results for Reliance Jio**

The estimated equation for regression model was found to be:

$$Subscribers = -1.66E+09 + 19516805\ SDCCH\ Congestion + 75024.47\ Call\ Set-Up\ Success\ Rate - 2260805\ Call\ Drop\ Rate - 10140480\ Base\ Transceiver\ Downtime - 30806.71\ Accessibility\ of\ Customer\ Care + 16699750.1\ \%\ of\ Good\ Voice\ Quality$$

It was found that the adjusted R-square value was found to be **79.3%,** with only the **SDCCH Congestion, Base Transceiver Downtime and % of Good Voice Quality**being the significant explanatoryvariables.

The diagnostics tests were run on the dataset, and it was found that heteroscedasticity was present in data. However, there was no multi- collinearity between variables.

1.9 **Diagnostics Tests for Operator-Wise Panel Data Regression:**

The Breusch-Pagan-Godfrey test was performed for Heteroscedasticity and Co-efficient diagnostics was performed for checking the presence of multicollinearity between the independentvariables.

TABLE XIV
DIAGNOSTICS TEST RESULTS FOR OPERATOR-WISE PANEL REGRESSION

Operators	Heteroscedasticity	Multicollinearity	Normality
Airtel	Absent (p-value =0.752)	Absent (All VIF values are less than 6)	Almost Normal (p-value = 0.045)
BSNL	Slightly Present (p-value = 0.03)	Absent (All VIF values are	Normal (p-value = 0.23)

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		less than 6)	
Vodafone Idea	Absent (p-value = 0.221)	Present between variables	Not Normal
Reliance Jio	Present (p-value = 0.01)	Absent (All VIF values are less than 6)	Normal (p-value = 0.234)

VI. RESULTS AND DISCUSSION

This section deals with the results and findings that were obtained from the panel regression which was performed between the number of subscribers across the **48** cross-sections and the Quality of Service (QoS) parameters for the chosen cellular operators in the 12 service areas. The network quality parameters **of Base Transceiver Downtime**, **SDCCH Congestion**, **Call Drop Rateand Accessibility of Customer Care** are found to have significant impact on the number of subscribers across states and operators. Through our analysis it was found that the Base Transceiver Downtime has a **negative** relation with the number of subscribers.It is considered that more the congestion and call drop rate in the network, more the customer dissatisfaction and more the accessibility to customer service better is the customer satisfaction. However, in our model it is found that SDCCH congestion and Call Drop Rate have a positive relation with the number of subscribers and Accessibility to Customer Service is negatively related to the number of subscribers. The model gave an adjusted R-square of 28.1% which means that apart from the factors taken into account in this paper, there could be a presence of external factors which have not been considered in this model

We also conducted separate panel regressions for the four major operators across the 12 service areas. It was found that the number of subscribers for **Airtel** has the most significant impact by the performance metrics of **Call Drop Rate** out of all other parameters. The **BSNL subscribers** also have been significantly impacted by the call drop rates, however the model gave an adjusted R-square of **24.95%.** This indicates that there are external factors that have not been considered by us, and hence, the variation in number of subscribers cannot be fully explained by this model. The Vodafone-Idea subscribers were found to be impacted by the **SDCHH Congestion, Base Transceiver Downtime and Accessibility,** with Base Transceiver Downtime having an unfavourable impact on the number of subscribers. The positive relation of SDCCH can be attributed to the fact that more the number of subscribers, more would be the traffic in the network, and hence more the congestion in the standalone dedicated control channel.

The adjusted R-square was found to be **21.575%,** which suggests that there are external factors which have not been considered for explaining the change in the number of subscribers.

The **Reliance Jio** subscribers were seen to be impacted by **SDCCH Congestion, Base Transceiver Downtime and % of Good Voice Quality** network qualityparameters. The Base Transceiver Downtime coefficient is seen to have a negative value, which depicts that it is inversely related to the subscribers volume across the 12 service areas. The **% of Good Voice Quality** has a **positive** impact on the number of subscribers, hence suggesting that better the fundamental performance of the connections with good quality, more the number of subscribers would increase for an operator.

VII. CONCLUSION

The aim of this paper was to determine the impact of the selected network service quality parameters on the number of subscribers under each operator and it can be concluded that although there is considerable impact of telecommunication network infrastructure on the number of subscribers, there is a possibility of external factors such as word of mouth and behavioural factors which might be instrumental in explaining the variation in the dependent variable better. Additionally, at an operator wise regression, we were able to establish a good model for the Airtel and Reliance Jio subscriber base. It was found that the Airtel subscribers base was significantly influenced by the call drop rate of the network. The Reliance Jio subscribers were influenced by the downtime of network stations, congestion in establishing and connecting a call and the quality of call as well. In case of BSNL and Vodafone-Idea subscribers, there might be external factors at play that influence the number of subscribers. The entry of private players with lucrative subscription plans has inadvertently caused subscribers to switch from the public sector providers like BSNL and MTNL. Similarly, mergers

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and acquisitions due to lack of financial adequacy has led to the fall in subscribers for Vodafone-Idea. There is scope for research for the various external behavioural and functional factors that might affect the subscriber base of each operator.

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