

# Performance Analysis Of Traffic Congestion In A Developed Mobile Communication Network In Oduke, Delta State, Nigeria

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## Abstract:

**Background:** Evaluation of the performance of a mobile communication network is very necessary to judge the networks QoS standard. Percentage traffic congestion (PCONG) is one of the major metrics used by network operators to determine their QoS. In this work, we analyzed the percentage traffic congestion in the different sectors/cells of a developed mobile communication network around the metropolitan area of Oduke, Nigeria. Our result shows that most of the sectors in the different cells analyzed cannot cope with high traffic i.e. they have mean traffic congestion values far greater than the 5% KPI standard. These sectors need further optimization to increase quality of service especially during period where high traffic is generated for the network.

**Materials and Methods:** Traffic data were collected from the operator's performance management system over a defined observation period. Key performance indicators—including call setup attempts, successful call completions, handover attempts, handover failures, and congestion events—were extracted for each sector/cell. The dataset was analyzed using descriptive statistics and comparative KPI evaluation against the 5% congestion benchmark. Graphical trend analysis and sector-by-sector performance comparison were also conducted to identify congestion-prone areas and underlying causes.

**Results:** Analysis shows that several sectors consistently recorded PCONG values far exceeding the acceptable 5% KPI limit. Congestion events were strongly associated with high call setup attempts and increased handover activities. Sectors with poor handover success rates exhibited the highest congestion levels, indicating that mobility-related failures significantly contribute to network degradation. The results further show that dropped calls due to unsuccessful handovers accounted for a major proportion of congestion-related issues.

**Conclusion:** The results of the study show the studied sectors / cells cannot perform optimally when the amount of traffic unusually increases. So, it is advisable for the network operator to carry out further optimization on all the sectors / cells. This will ultimately improve the QoS of the network provider, increase customer satisfaction and thereby generate more revenue for the operator. Consequently, we have seen that congestion is as a result of handover and setup. Also, from the analysis more of congestion related problems are as a result of calls being dropped due to handover.

**Key Word:** Mobile Network Performance, Percentage Traffic Congestion, QoS, KPI, Handover Failure, Call Setup, Oduke Nigeria, Network Optimization

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## 1.0 Introduction

The rapid advancement in mobile communication technology has redefined the global telecommunications landscape over the past few decades. With the proliferation of smart devices, real-time applications, and the increasing dependency of individuals, businesses, and governments on mobile networks, there has been an exponential increase in demand for faster, more reliable, and more efficient mobile communication services. This surge in usage has placed significant pressure on mobile communication networks, resulting in one of the most persistent and complex challenges facing the telecommunications industry today. Even in developed mobile communication networks, which are equipped with advanced infrastructure and the latest technologies such as LTE-Advanced, 5G NR (New Radio), and intelligent traffic management systems, the issue of traffic congestion remains a major concern that affects service quality and user satisfaction (Aliu et al., 2013; Cisco, 2020).

Traffic congestion in mobile communication networks occurs when the volume of traffic surpasses the network's designed capacity, leading to performance degradation across various service parameters. This manifests in the form of increased latency, call drops, reduced data throughput, call setup failures, poor voice quality, and general decline in Quality of Service (QoS) and Quality of Experience (QoE) (Feng et al., 2014; Salahuddin et al., 2015). As mobile networks strive to accommodate the growing user base and increasingly data-intensive applications such as video conferencing, mobile gaming, social media streaming, and cloud services, managing and analyzing congestion becomes critical for maintaining network reliability and user trust.

Developed mobile networks are often assumed to have robust systems capable of handling high user densities and large-scale traffic demands. However, real-world scenarios reveal that traffic congestion still occurs,

particularly during peak usage periods, special events, or in high-density urban centers where the demand for mobile connectivity often outpaces capacity expansions (ITU, 2017). For example, major cities in Europe, Asia, and Africa have reported frequent mobile network slowdowns and service interruptions despite having state-of-the-art mobile infrastructure (Zhang et al., 2017). These recurring issues highlight the limitations of even the most advanced network deployments and underscore the need for continual performance evaluation and optimization.

The complexity of traffic congestion in mobile communication networks stems from a multitude of factors. These include user behavior patterns, mobility, network architecture, capacity planning, spectrum limitations, and external environmental conditions. Unlike traditional circuit-switched networks, modern mobile networks use a packet-switched paradigm where numerous data sessions from different users are handled concurrently. This makes congestion highly dynamic and often unpredictable, necessitating real-time traffic monitoring and intelligent resource allocation techniques (Kumar et al., 2018). Additionally, the transition from 4G LTE to 5G brings about new challenges, such as managing ultra-dense small cell deployments, millimeter wave propagation issues, and integration with heterogeneous network elements, all of which can contribute to localized congestion if not effectively managed.

Performance analysis serves as a fundamental tool in addressing the challenges of traffic congestion. By evaluating Key Performance Indicators (KPIs) such as Call Setup Success Rate (CSSR), Handover Success Rate (HOSR), Drop Call Rate (DCR) etc, network operators can gain insights into how congestion is affecting different components of the network. These metrics allow for the identification of congestion hotspots, assessment of traffic patterns, and the formulation of targeted interventions such as cell splitting, load balancing, and dynamic spectrum allocation (ITU, 2017; Cisco, 2020). Moreover, with the integration of machine learning and big data analytics, performance analysis is becoming more predictive, enabling proactive congestion management rather than reactive troubleshooting.

This research aims to analyze and determine if the services provided by network operators equal acceptable standard and if not suggest possible ways to attain such standard.

### **1.1 Statement of the Problem**

In recent years, Nigeria has experienced a dramatic increase in mobile communication usage, driven by a growing population, digital transformation, and the proliferation of smartphones. As of 2023, the Nigerian Communications Commission (NCC) reported over 220 million active mobile subscriptions, making Nigeria one of the largest telecommunications markets in Africa (NCC, 2023). Despite the rollout of advanced technologies such as 3G, 4G LTE, and more recently 5G, traffic congestion remains a persistent challenge, even in well developed mobile communication networks.

Users across major cities and semi-urban areas continue to experience frequent call drops, poor voice quality, slow internet access, and high latency which are all indicators of network congestion (Adebayo & Salihu, 2022; Onuoha & Eze, 2021). These issues are often most severe during peak usage periods, when the demand for network resources exceeds available capacity. While mobile network operators have made efforts to expand coverage and increase bandwidth, the performance efficiency of developed mobile networks under high traffic load has not been adequately studied or optimized.

Moreover, existing research tends to focus on access, affordability, and technology adoption, with limited emphasis on traffic-related performance degradation in matured infrastructures (Ndukwe, 2020). Without a comprehensive analysis of traffic congestion and its effect on key performance indicators (KPIs) which include throughput, call setup success rate, and packet loss, network optimization efforts remain reactive and insufficient. This study therefore aims to address this gap by conducting a detailed performance analysis of traffic congestion in a developed mobile communication network in Nigeria, with a view to proposing data-driven recommendations for enhanced network efficiency and user satisfaction.

### **1.2 Relevance of the Study:**

This research is significant because it addresses traffic congestion, a major factor affecting both the Quality of Service (QoS) and the overall user experience in mobile communication networks. In Nigeria—one of Africa's largest and fastest-growing telecommunications markets—millions rely on mobile networks daily for communication, business, education, and digital services..

Using real data from Oduke, Delta State, the study demonstrates that even developed mobile networks continue to experience serious congestion challenges, particularly during peak usage periods. By identifying critical congestion hotspots (sectors 1, 4, and 6), the study highlights the importance of sector-specific optimization, which is more efficient and cost-effective than broad, network-wide upgrades.

The study further contributes to telecommunication engineering and policy development by demonstrating how metrics such as Percentage Congestion (PCONG) can be effectively applied to monitor network efficiency and guide targeted improvements. Its findings are therefore valuable not only to network operators but also to regulators such as the Nigerian Communications Commission (NCC), as well as policymakers and researchers.

Finally, the study aligns with the objectives of Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure) by promoting stronger and more reliable mobile communication infrastructure capable of enhancing digital inclusion, fostering innovation, and supporting economic growth.

### 1.3 Objective of the Study:

The objective of this study is to analyze the performance of traffic congestion in a developed cellular network in Oduke, Delta State, Nigeria, with the aim of identifying key performance challenges and proposing strategies to optimize network efficiency.

## 2.0 Literature Review

### 2.1 Traffic

Traffic is a term that quantifies usage (Rogers, 2004). The traffic unit is in Erlang; an Erlang defines the efficiency of a traffic resource and represents the total time in hours to carry all calls or the number of simultaneous occupations during a specific period of time. Traffic can be measured in either Erlang or Centrum-call second (CCS). The relationship between Erlang and Centrum-call second (CCS) used in North America (<http://www.computer.org/ieee>, Boulmalt M. et al, 2009) is given by the equation

$$1 \text{ Erlang} = 1 \text{ call hour} = 3600 \text{ call second} = 36 \text{ ccs} \quad (1)$$

The Erlang (E) is a unit of measurement of traffic. It can be calculated with the following relation:

$$A = N * T / 3600 \text{ Erlang} \quad (2)$$

Where

A = offered traffic from one or more users in the system

N = number of calls per second

T = average call time in seconds

(CPO2, 2002; Cornel et al, 2010).

The best traffic indicators used in traffic analysis are

Call completion rate (CCR). It is defined as the ratio of the number of successive calls to the number of call attempts. This indicator measures the ease with which calls are established or setup in the mobile network. The CCR parameter is used in dimensioning the network capacity.

$$\text{Call completion rate} = \text{Number of successful calls} / \text{Number of call attempts} \quad (3)$$

**The Grade of Service (GoS).** This is a measure of the ability for a user to access a traffic system during the busiest hour. The busiest hour occurs during rush hour. GOS is the traffic related part of network performance (Rappaport, 2003). Grade of service (GOS) expresses the probability of blocking calls, a typical grade of service is  $P=0.02$ , (Roger, 2004).

$$\text{Grade of Service (GoS)} = \text{Number of blocked calls} / \text{Total number of offered calls} \quad (4)$$

Additional factors are offered and carried traffic in Erlang channels utilization rate etc. (Jahanger et al, 2000; Alexei et al, 2009). To determine the traffic per subscriber using equation (2) (Ericsson recommends traffic per subscriber between 0.025 Erlang and 0.033 Erlang when planning GSM network).

Therefore, if assumed number of subscriber (N) = 1

Average call time in seconds (T) = 90 seconds

Traffic =  $1 * 90 / 3600 = 0.025$  Erlang. In addition, if we assume this following data exist for a network

- Number of subscribers = 10 000
- Average frequencies = 24

- call pattern: 4/12 (means that there are four, three-cell sites supporting twelve calls using twelve frequency groups)
- GoS: 2%
- Traffic per subscriber 0.025 Erlang. (<http://www.sup.com> Mincom to mediation articles).

## **2.2 The Telephone Network**

The telephone network has traditionally been built up as a hierarchical system. The individual subscriber is connected to a subscriber switch or sometimes a local exchange (LEX). This part of the network is called access network. The subscriber switch is connected to a specific main load exchange which again is connected to a transit exchange (TEX) of which there is normally at least one for each area code. The transit exchanges are normally connected into a mesh structure. These connections between the transit exchanges are called the hierarchical structure. There exist further, more connections between two local exchanges (subscriber switch) belonging to different transit exchanges (local exchange) if the traffic demand is sufficient to justify it. In the discipline of network planning, the objective is to optimize network structures and traffic routing under the consideration of traffic demands, service and reliability requirements etc.

## **2.3. Sectorization**

Sectorization is the process whereby a cell is divided into different sectors covered by a number of directed antennas.

Sectorization Technique is a widely used technique to reduce co-channel interference in cellular mobile system. There are two important factors that influence the system performance when using sectorial technique.

- i. The number of sectors per cell; the more the sectors in a cell, the less interference in the system. However, too many sectors at a cell will increase the interference to other cells and require excessive handover and the more sectors in a cell increases the base station cost. Therefore, most base stations in current cellular systems have three to six sectors at a cell.
- ii. The beam width of directional antenna used in each sector; commonly used directional antennas in sectorial cellular systems have a 3db beam width for 60° to 120°.

Because of limited frequency spectrum availability, current cellular mobile radio systems adopt the frequency reuse concept to utilize the same frequency band repeatedly in different locations. A large reuse distance enhances the channel quality due to less interference, but decreases the system capacity. One challenge for cell engineering is to determine the optimal tradeoff between frequency reuse distance and system capacity, while not increasing the cost of the infrastructure and user terminals.

Two common 3 – sector techniques used in current mobile systems studied are the Wide – Beam Tri-sector Cell (WBTC) and the Narrow – Beam Tri-sector Cell (NBTC).

A WBTC is defined as a cell composing of three 100° - 120° directed antennae, while an NBTC, on the other hand is a cell with 3 – sectors and each of which is served by a 60° - 70° directed antennae.

It has been shown that the Narrow Beam Tri-sector Cell (NBTC) system performs better than the Wide-Beam Trisector Cell (WBTC) system (Wang, Chawla, and Greenstein, 1998).

A six-sector cellular system using six 60° antennas at a cell is proposed to improve the capacity of the Global System for Mobile communication (GSM) (Xiang, 1996).

Wong and Prabhu showed that a cell with four 60° antenna can optimize the interference performance for Cell Division Multiplexing (CDMA) system (Wong and Prabhu, 1997).

Even though the sectorization technique with 60° antenna have been studied for the CDMA system (Wang and prabhu, 1997), the performance and potentials of this kind of sectorization technique was relatively unknown for a TDMA/FDMA system.

For ease of rotation, we use  $N*\beta(\alpha^\circ)$  to represent a system with reuse factor N, in which each cell has  $\beta$  sectors and each sector is covered by a directional antenna with a beam width of  $\alpha$  degree. For example, for reuse factor = 2, an NBTC, WBTC and Wide-Beam Quad-sector Cell (WBQC) system are denoted as  $2*3(60^\circ)$ ,  $2*3(120^\circ)$  and  $2*4(60^\circ)$  system respectively.

The traditional WBTC architecture uses three 100° to 120° antennas at each cell site, in which each antenna is designed to cover a diamond-shaped sector, as a result, a WBTC forms a coverage area with the shape of a hexagon.

There is a sectorial scheme called Narrow Beam Quad-sector Cell (NBQC). Here the cell is divided into 4 sectors, and each sector is covered by a 60° antenna.

The NBQC structure allows implementing the concept of Interleaved Channel Assignment (ICA) which can take full advantage of antenna directivity. With ICA, the NBQC system can enhance the system performance from several perspectives. It can improve the system capacity and quality of radio links.

The 4 – sector cell always perform better than the 3 – sector cells for three different antenna beam width of 60°, 90° and 120°. The coverage performance improvement of the 4-sector cell, over the 3-sector cell, result from the fact that the 4-sector cell provides more site diversity gain and more uniform coverage area.

### 3.0 Methodology

In this work, real data was collected using a software called network management system (NMS) for a month from one of the leading telecommunication companies in Nigeria. NMS is a program for providing detection and configuration for systems to automatically connect to a network. It is a set of co-operative tools that make networking simple and straight forward. The data collected were based on two GSM traffic cells with three sectors each for a total of Six sectors. About 10,000 calls were monitored. All data came from Okwe Road Oduke Metropolis, Delta State, Nigeria. Traffic has been measured every hour of the day for the month. In order to obtain numerically significant data, the six sectors have been considered. In particular, these Sectors were chosen as representative of the whole network taking into account cell extension, number of served subscribers in the area, and traffic load. We were interested in the percentage traffic congestion whereby their any given situation we expected that some calls may be rejected for one reason or another. In our computation, we used what is known as the percentage traffic congestion; this is the ratio of the number of call rejected to the number of incoming calls multiplied by one hundred (100).

$$PCONG = \frac{\text{No of Rejected Calls}}{\text{Total No of incoming Calls}} \times 100$$

The percentage traffic congestion is then compared with what is called the key performance indicator (KPI). The KPI is given as five percent (5%) for congestion, i.e. the percentage traffic congestion should be less than this key performance index, otherwise the cell or sector as the case may be is said to have a traffic congestion problem.

**Table 1:** Statistical estimation of traffic congestion (%) in Six sectors (two cells) in the month of December 2024.

Cell(s)	Sector No	No of call setup cong.	No of handover cong.	Tcongs	Total incoming Calls	Pcong [%]
1	1	160	277	437	1855	24
	2	5	56	61	1534	4
	3	3	66	69	1325	5
2	4	50	230	280	2234	13
	5	25	12	37	685	5
	6	172	237	409	2168	19

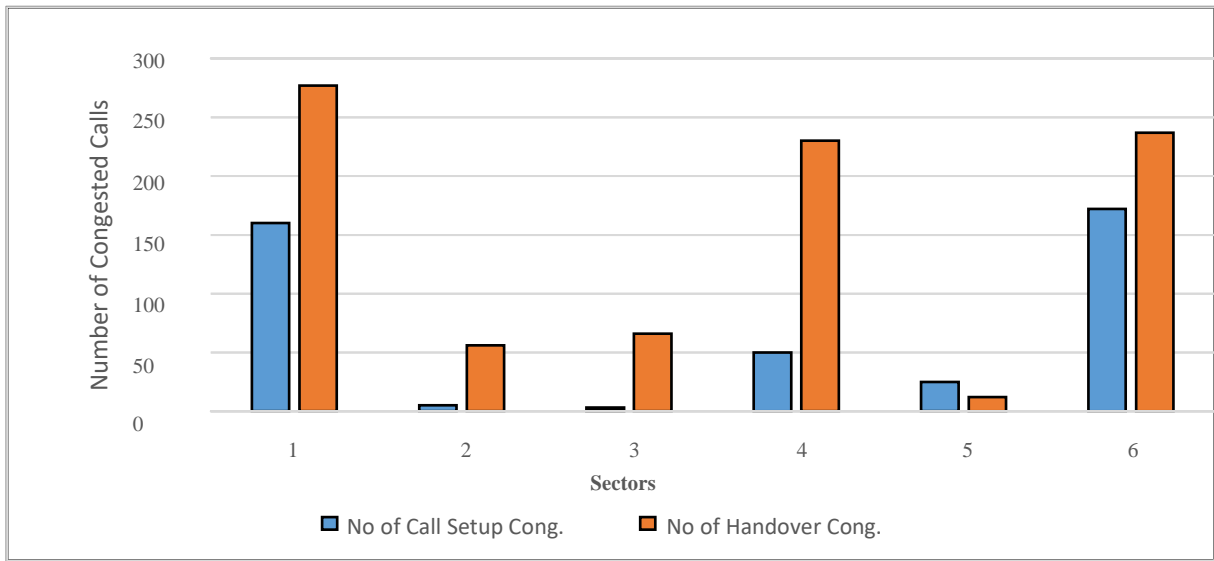


Figure 1: Total number of Congested calls based on setup and handover failure on each sector for the month of December 2024.

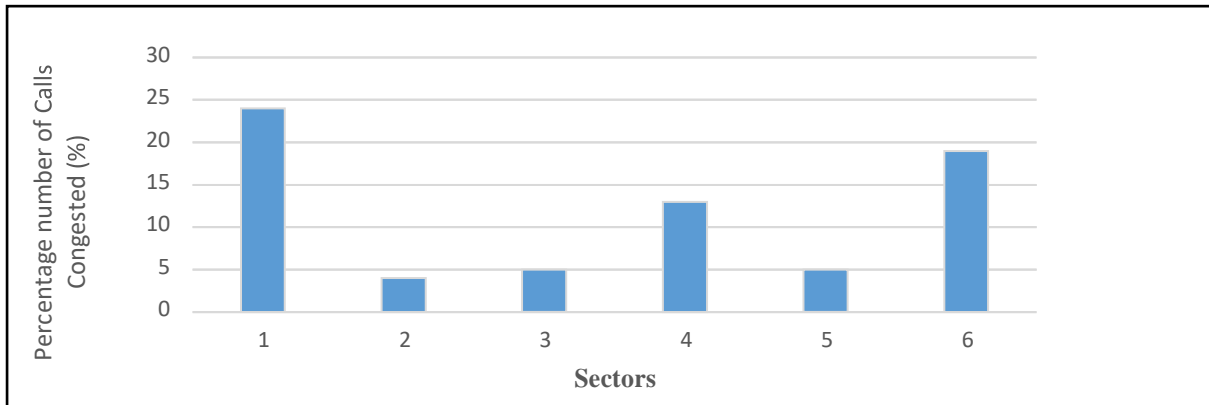


Figure 2: Graph of mean traffic congestion (%) on each sector for the month of December 2024.

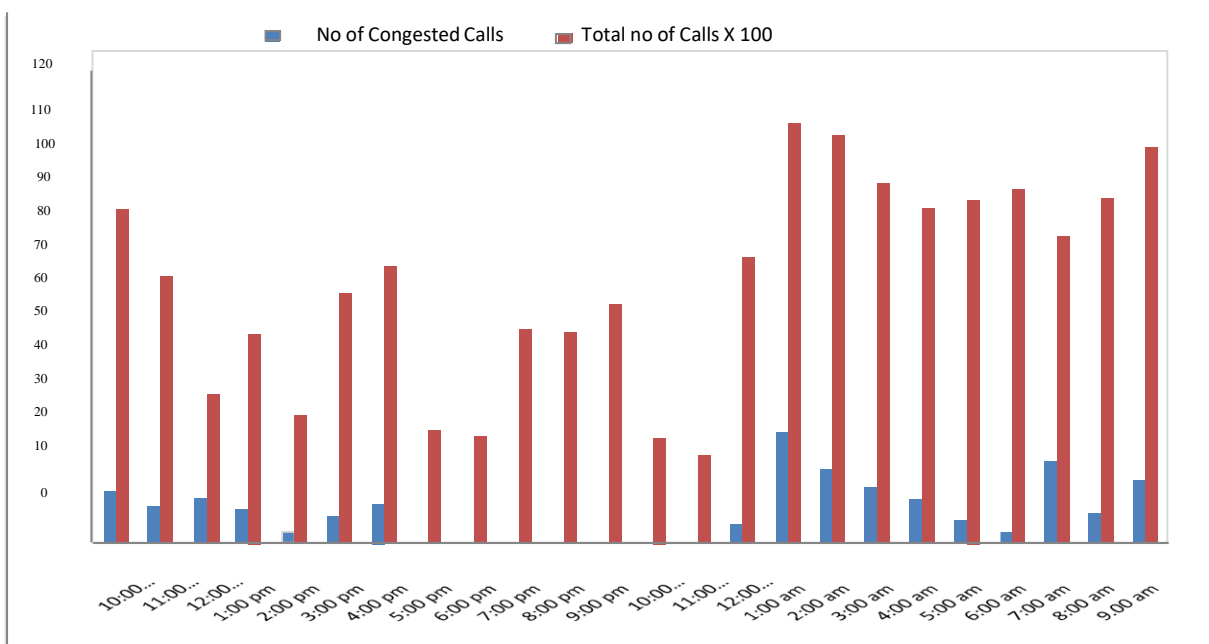


Figure 3: Daily variation of congestion on the 25<sup>th</sup> of December (Christmas Day), 2024 on sector

**Fig 1** shows the two types of traffic congestion; unsuccessful call setup due to congestion in a cell and unsuccessful handover due to congestion in a sector or cell. It shows that more calls were dropped during handover than setup.

**Fig 2** shows that sectors 1, 4 & 6 with percentage traffic congestion values of 24%, 13%, & 19% were above the key performance index (KPI) of 5% which goes to show that they need sector specific optimization so as to save cost, time and labour. It also shows that the generated traffic for the month of December exceeded the capability of the facilities and equipment for the affected sectors (1, 4, 6).

**Fig 3** shows the variations of congestion from 24<sup>th</sup> - 25<sup>th</sup> of December 2024. Data were taken at every one hour which goes to show that at 1:00am, more calls made compared to other times which indicate congestion was very high. increase (+8.17%).

#### 4.0 Conclusion

The results of the study show the studied sectors / cells cannot perform optimally when the amount of traffic unusually increases. So, it is advisable for the network operator to carry out further optimization on all the sectors / cells. This will ultimately improve the QoS of the network provider, increase customer satisfaction and thereby generate more revenue for the operator. Consequently, we have seen that congestion is as a result of handover and setup. Also, from the analysis more of congestion related problems are as a result of calls being dropped due to handover.

#### 5.0 Recommendation

Based on the findings of the study, the researchers recommended sectors 1, 4 & 6 for optimization to reduce the congestion value to the accepted KPI value of 5% and that future traffic congestion analysis should be sector-specific. Furthermore, more network providers should also provide raw data from their database for traffic analysis so as to enhance network performance and increase customers satisfaction and revenue for the company.

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