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# Power Reduction Policy and Its Impact on Cellular Network Performance under GSM-R Interference: A Case Study of KCJB-Indosat

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**Abstract:** This research aims to evaluate the impact of transmitter power reduction policies implemented to mitigate spectrum interference between the GSM-R system and cellular networks on the Jakarta–Bandung High-Speed Railway (KCJB), with a specific focus on Indosat. Employing a quantitative descriptive method complemented by strategic management analysis (SWOT, IFE–EFE, QSPM), this study analyzes technical parameters (RSRP, traffic volume, active users) and business indicators (daily revenue, customer churn rate). Findings indicate significant service quality degradation, marked by a 35.7% decrease in RSRP coverage, 34% reduction in daily traffic volume, and 33% decrease in active users. Additionally, business performance suffered, reflected by 5.8% drop in daily revenue and a substantial rise in customer churn. Strategic analysis suggests joint spectrum management and installation of band-pass filters on the GSM-R side as the optimal mitigation strategy. This study underscores the necessity of coordinated technical and regulatory solutions to balance interference mitigation with telecommunication service sustainability.

**Keywords:** GSM-R; Spectrum Interference; Power Reduction; QoS; Strategic Management.

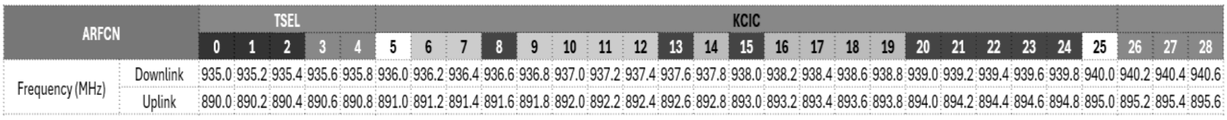
## INTRODUCTION

Digital transformation and infrastructure acceleration constitute two fundamental pillars supporting Indonesia's recent economic growth. According to data from Statistics Indonesia (BPS RI, 2024), the Information and Communication sector recorded robust growth of 7.59% in 2023, underlining its strategic role in facilitating various sectors. Concurrently, the transportation and warehousing sector rebounded post-pandemic, expanding by 13.96% within the same period. This synergistic relationship between telecommunications and transportation is crucial for achieving national digital transformation objectives, particularly given that reliable cellular network communications are essential for successful technology-based transportation services (BPS RI, 2024; Kementerian PPN/Bappenas, 2023; Putri & Santosa, 2022; World Bank, 2023).

Railway transportation, specifically the Jakarta–Bandung High-Speed Railway (*Kereta Cepat Jakarta–Bandung*/*KCJB*), has experienced rapid user adoption. It is highlighted by the substantial growth of the *Whoosh* service, with passenger volume increasing by approximately 44.08% in April 2025 compared to the previous year. This trend emphasizes growing public reliance on integrated, high-speed transportation networks supported by advanced digital communication systems (KCIC, 2025; Antara News, 2025; Kominfo, 2024; Hapsari & Nugroho, 2023).

Parallel to the national trends, the global expansion of High-Speed Rail (HSR) infrastructure has accelerated significantly. Data from the International Union of Railways (UIC, 2023) indicate global HSR track length exceeded 55,000 km by the end of 2021 (UIC, 2023; OECD, 2022; Zhao et al., 2021; Chen & Haynes, 2020), with an annual growth projection of 4–5%. This rapid expansion, especially driven by significant investments in China since 2007, culminated in approximately 58,800 km of operational track globally by 2021. Essential to this development has been the implementation of the Global System for Mobile Communications–Railway (GSM-R), a dedicated communication standard critical for operational safety, reliability, and interoperability in railway services. GSM-R operates within allocated frequency bands (876–880 MHz uplink, 921–925 MHz downlink), standardized by the European Telecommunications Standards Institute (ETSI) to minimize interference with public cellular networks (ETSI, 2021; ITU, 2022; Liu et al., 2020; European Commission, 2020).

In Indonesia, the *KCJB* project, managed by PT *Kereta Cepat Indonesia China* (*KCIC*), represents Southeast Asia's first high-speed rail initiative. *KCJB* operates along a 142.3 km corridor at speeds reaching 350 km/h. The GSM-R system deployed for *KCJB* occupies the 936–940 MHz frequency range, closely adjacent to commercial cellular bands (particularly the 900 MHz frequency used by Indosat). This proximity raises significant concerns regarding potential spectrum interference impacting critical railway communications and public cellular service quality (see Figure 1).



| ARFCN | | TSEL | | | | | KCIC | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 |
| Frequency (MHz) | Downlink | 935.0 | 935.2 | 935.4 | 935.6 | 935.8 | 936.0 | 936.2 | 936.4 | 936.6 | 936.8 | 937.0 | 937.2 | 937.4 | 937.6 | 937.8 | 938.0 | 938.2 | 938.4 | 938.6 | 938.8 | 939.0 | 939.2 | 939.4 | 939.6 | 939.8 | 940.0 | 940.2 | 940.4 | 940.6 |
| | Uplink | 890.0 | 890.2 | 890.4 | 890.6 | 890.8 | 891.0 | 891.2 | 891.4 | 891.6 | 891.8 | 892.0 | 892.2 | 892.4 | 892.6 | 892.8 | 893.0 | 893.2 | 893.4 | 893.6 | 893.8 | 894.0 | 894.2 | 894.4 | 894.6 | 894.8 | 895.0 | 895.2 | 895.4 | 895.6 |

**Figure 1. Frequency Allocation**

Joint field measurements involving *KCIC*, cellular operators (Indosat and Telkomsel), and the Indonesian Ministry of Communications and Informatics (*Kemkominfo*) identified 48 initial interference points ("bad spots") along the *KCJB* corridor. Technical mitigation trials demonstrated that increasing GSM-R transmitter power to 60 W, combined with cellular operators reducing their power by up to 12.2 dBm within a 500-meter radius, effectively decreased bad spots from 48 to 15. Consequently, *Kemkominfo* implemented a phased transmitter power reduction policy (3 dB, 6 dB, and 9 dB) for cellular operators, including Indosat, aimed at mitigating GSM-R interference while attempting to maintain acceptable service quality levels (see Table 1).

**Table 1. Field Measurement Scenario**

| Test Condition | Number of Bad spot |
|---|---|
| GSM-R Power at 30 W with ODD-EVEN scenario | 48 spot |
| All GSM-R BTS active (30 W) | 32 spot |
| Power increased to 60 W (selected BTS) | 25 spot |
| GSM-R Power at 60 W + Operator reduced power (12.2 dBm within 500m radius) | 15 spot |

Despite its technical justification, this policy has resulted in substantial negative impacts on Indosat's service quality. Empirical data revealed notable service degradation, including signal strength reduction (RSRP), diminished data traffic, and increased customer churn risks within affected areas. Prior studies primarily addressed GSM-R feasibility and interference mitigation from technical standpoints, lacking comprehensive analyses on impacts to cellular network quality and business performance (Riyantika & Gunawan, 2023; Anwar et al., 2019). Benchmarking international cases, particularly from Germany and the United Kingdom, suggests coordinated, multi-stakeholder approaches including technical solutions such as band-pass filtering and joint spectrum management are effective for balancing interference mitigation and service continuity (Ofcom, 2022; ERA, 2022).

Previous research on the integration of GSM-R communication systems into high-speed rail networks, such as studies by Riyantika and Gunawan (2023), primarily focused on the technical aspects of GSM-R interference mitigation. While these studies provided important insights into the feasibility of GSM-R deployment and potential mitigation strategies, they largely overlooked the broader commercial implications for cellular providers. Specifically, they did not assess how power reduction policies and interference from GSM-R affect cellular network performance, including signal strength (RSRP), data traffic, or customer churn. Similarly, Anwar et al. (2019) addressed GSM-R communication and interference issues but did not explore the impact of these technical challenges on the business operations of cellular networks. Both studies emphasize the need for technical solutions but fail to link these solutions to real-world business outcomes, particularly in the highly competitive telecommunications industry.

Given the complexity of balancing technical mitigation with commercial sustainability, this study combines quantitative technical assessments with strategic management frameworks (SWOT, IFE–EFE, and QSPM analyses). The study specifically aims to: (1) quantify the technical impacts of power reduction policies on cellular service parameters (RSRP, traffic volume, active users); (2) evaluate associated business impacts (daily revenue and churn rates); and (3) propose balanced technical and strategic recommendations for effective spectrum management between railway operators and cellular providers. The findings will offer valuable recommendations for policymakers and industry stakeholders on managing spectrum allocation in a way that balances the needs of both sectors, promoting sustainable growth for both high-speed rail systems and telecommunications providers.

## METHODOLOGY

This study employed a quantitative descriptive approach supported by strategic management analysis, using a case study design focused on PT. *Indosat Tbk* during the implementation of transmitter power reduction in the *KCJB* corridor. The research combined technical network performance measurements, business performance indicators, and strategic analysis frameworks (SWOT, IFE–EFE, and QSPM) to assess the impact of GSM-R spectrum interference and formulate data-driven mitigation strategies.

The study utilized both primary and secondary data. Technical data were obtained from drive test measurements conducted by Indosat's managed service partner (Huawei). The measurements covered key network indicators: Reference Signal Received Power (RSRP), traffic volume (GB), and the number of RRC connected users across 18 affected BTS sites. Business performance data, including daily revenue and churn rate, were processed from Indosat's internal dashboards and billing systems. Additional documentation such as regulatory letters, network reconfiguration notes, and collaborative interference assessment reports involving the Ministry, *KCIC*, and cellular operators were used to validate the technical context of policy implementation.

Three variable categories were used:

(1) Technical variables: RSRP (dBm), data traffic volume (GB), and RRC connected user count.

(2) Business variables: Total Daily Revenue (TDR, in IDR) and customer churn rate (% of lost users).

(3) Strategic variables: Derived from internal and external factors identified through Focus Group Discussion (FGD) and used in SWOT and IFE–EFE matrices.

Quantitative data were analyzed using descriptive statistical comparison between pre- and post-policy implementation (before-after analysis). Mean differences, percentages, and traffic patterns were evaluated to quantify the impact of power reduction on both technical and business performance. Bad spot rate was calculated using predefined RSRP thresholds (e.g., $< -105$ dBm). Simultaneously, churn trends were plotted using monthly customer exit data from selected sites with high service degradation.

The strategic evaluation was conducted using three steps:

(1) SWOT analysis to qualitatively identify internal strengths/weaknesses and external opportunities/threats;

(2) IFE–EFE Matrix to assign weights and scores to the SWOT components, resulting in a positioning plot within the IE matrix framework;

(3) Quantitative Strategic Planning Matrix (QSPM) to compare alternative mitigation strategies based on Total Attractiveness Score (TAS) and enable selection of the most appropriate strategy.

## RESULTS AND DISCUSSION

The discussion is structured into three sub-sections: (1) technical impact, (2) business performance implications, and (3) strategic response formulation.

### Technical Impact on Cellular Network Performance

The implementation of the power reduction policy directly affected signal coverage and quality across the 18 BTS sites studied. Based on the drive test results before and after the policy was applied, the percentage of samples in the "Excellent" signal category (RSRP > –95 dBm) dropped from 75.5% to 39.8%, while "Good" signal levels (–95 to –105 dBm) slightly increased due to the shift from stronger signal zones. Notably, there was a significant rise in weak signal areas: samples in Poor (–110 to –115 dBm) and No Signal (< –115 dBm) categories grew from 9.6% to 11.9%. This signal degradation indicates the policy's tangible effect on perceived coverage, especially in dense or critical transit zones (see Table 2).

**Table 2. RSRP Result**

| Q_Rsrp DT | Before 20-Sep | | After 18-Oct | |
|---|---|---|---|---|
| | # of sample | Ratio (%) | # of sample | Ratio (%) |
| 0 to -95 | 1,578 | 75.50% | 830 | 39.77% |
| -95 to -105 | 238 | 11.39% | 880 | 42.17% |
| -105 to -110 | 73 | 3.49% | 121 | 5.80% |
| -110 to -115 | 45 | 2.15% | 99 | 4.74% |
| -115 to -150 | 156 | 7.46% | 157 | 7.52% |
| **Grand Total** | **2,090** | **100.00%** | **2,087** | **100.00%** |

Field measurement also confirmed that signal degradation was not distributed evenly. Urban sites in Jakarta, Karawang, and Bandung experienced sharper losses due to their proximity to GSM-R towers and greater overlap in the 900 MHz band. These findings align with international studies indicating that co-channel and adjacent-channel interference, particularly in legacy LTE Band 8 (900 MHz) can severely impact RSRP and service retainability if guard bands or mitigation filters are not deployed (CEPT ECC Report 2022; Ofcom 2021).

Furthermore, LTE traffic volume measured on L900 sites fell by 34% post-implementation from 1,639.35 GB to 1,081.98 GB (see Figure 2). This reflects reduced utilization caused by signal weakening and possibly user displacement to other bands or technologies. This trend was corroborated by the 33% decrease in RRC connected users, which indicates that fewer devices maintained active data sessions in the affected layer. These findings imply not only reduced user connectivity but also network inefficiency, where spectrum resources remain underutilized despite high demand (see Figure 3).

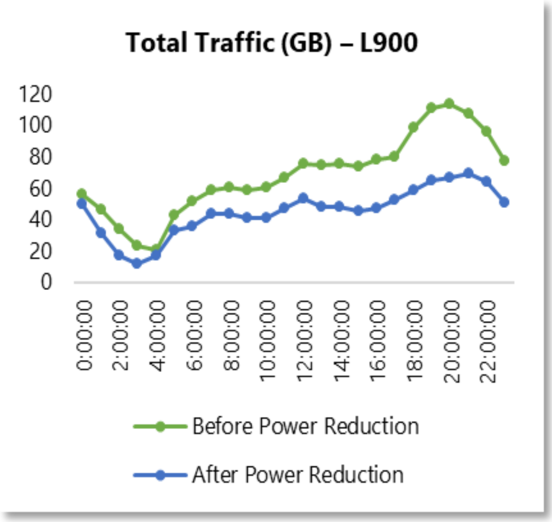


**Figure 2. Traffic Result**

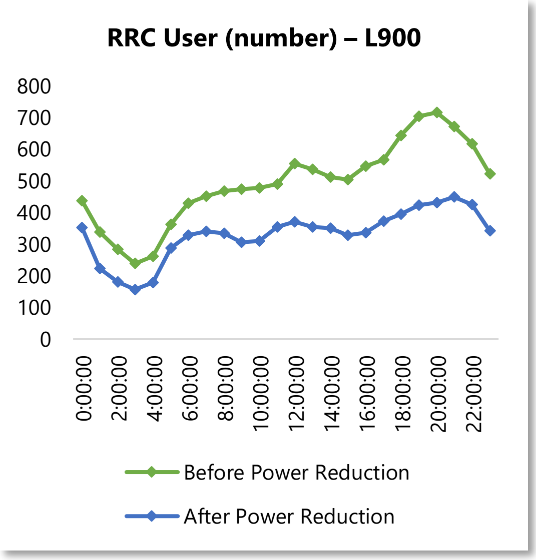


**Figure 3. RRC Result**

The correlation between RSRP, user activity, and data traffic affirms the well-documented link between radio signal degradation and decreased network performance. In high-density transport corridors, even a slight increase in drop zones can lead to amplified user frustration and negative user experience (QoE), particularly when real-time services such as streaming or navigation are disrupted.

## Business Impact: Revenue and Customer Churn

The technical degradation translated into measurable economic consequences. Total Daily Revenue (TDR) from the 18 observed sites (A-R) decreased to maximum by 5.8%. Five sites are particularly experienced consistent reductions above this threshold. For example, site A saw a drop from IDR 4.85 million to IDR 4.56 million daily, implying an annualized revenue loss of over IDR 100 million if left unaddressed (see Table 3).

**Table 3. Daily Revenue Result**

| Site | Average of Daily Revenue (before) | Daily Revenue (After) |
|---|---|---|
| A | IDR 4.849.391 | IDR 4.568.126 |
| B | IDR 4.608.761 | IDR 4.341.453 |
| C | IDR 4.178.204 | IDR 3.935.869 |
| D | IDR 3.178.431 | IDR 2.994.082 |
| E | IDR 2.137.294 | IDR 2.013.331 |

While revenue reduction is partially driven by lower usage, its significance is compounded by long-term effects on customer behaviour, notably churn. Three sites (D, F, and G) were monitored for churn rate fluctuations over 12 months post-policy implementation. Site D, which experienced severe RSRP decline and traffic loss, saw its churn rate spike from a baseline of ~6% to 29.47% in January 2025 (see Figure 4). These patterns are consistent with customer behaviour studies which link decreased signal reliability and coverage consistency with increased likelihood of service discontinuation (Mustafa et al., 2021).

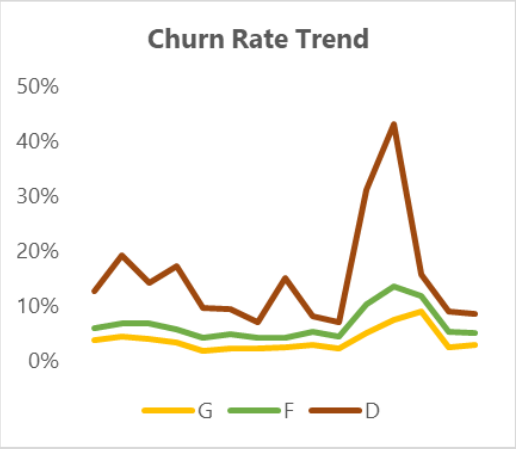


**Figure 4. Churn Rate Trend**

Churn behaviour was not immediate but showed a 1–2-month lag, suggesting a threshold of tolerance before user abandonment occurs. This insight is critical for operators and regulators, as it highlights the importance of early intervention and proactive network adjustment before customer dissatisfaction materializes as revenue loss (Statistik, 2024).

Moreover, the combination of traffic loss and rising churn erodes Average Revenue Per User (ARPU), raises customer acquisition costs (CAC), and may damage Net Promoter Score (NPS). All of which are fundamental to sustaining long-term business performance. When considered in the broader market context, these risks are magnified, especially in Indonesia's already saturated mobile market where user retention is more cost-effective than acquisition (Committee, 2022; Ofcom, 2021; Statistik, 2025; (UIC), 2023).

### Strategic Implications and Mitigation Pathways

Given the dual pressure of technical and financial degradation, strategic response formulation becomes imperative. The study's SWOT analysis identified critical strengths in infrastructure and technical readiness but also exposed weaknesses such as excessive dependence on the 900 MHz spectrum and limited automation in power management systems. External opportunities, notably the policy focus on quality of service (QoS) and spectrum reform (e.g., Dynamic Spectrum Sharing/DSS), present strategic levers for long-term resolution. Conversely, regulatory asymmetry and lack of national interference mapping mechanisms were key threats to sustainable mitigation.

From the IFE–EFE analysis, the organization's internal score was 3.20 (strong), while the external environment scored 3.48 (favourable). This placed Indosat in Quadrant I (Grow and Build) of the IE matrix, indicating that the company possesses the capabilities and opportunities to proactively shape its mitigation strategy through assertive technical and regulatory engagement (see Figure 5).

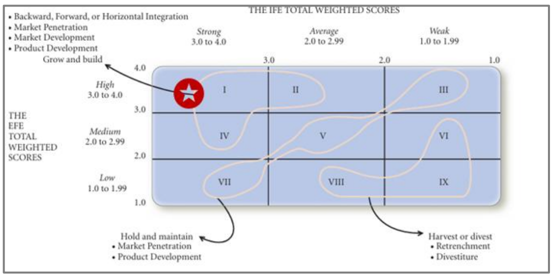


**Figure 5. The IE Matrix**

Three alternative strategies were evaluated through the Quantitative Strategic Planning Matrix (QSPM) (see Table 4):

**Strategy A**: Joint spectrum coordination with KCIC and the installation of bandpass filters on GSM-R receivers.

**Strategy B**: Internal optimization via dynamic spectrum management (DSM) and adaptive power adjustments.

**Strategy C**: Regulatory advocacy for compensation or relaxation of power reduction mandates, based on measurable service loss.

**Table 4. QSPM strategies**

| Factor | Strategy A | Strategy B | Strategy C |
|---|---|---|---|
| | **TAS** | **TAS** | **TAS** |
| Main Internal Factor [Strength] | 1.90 | 1.90 | 1.65 |
| Main Internal Factor [Weakness] | 2.00 | 1.92 | 1.58 |
| Main External Factor [Opportunity] | 1.92 | 1.67 | 1.61 |
| Main External Factor [Threat] | 2.08 | 2.08 | 1.74 |
| STAS | **7,90** | **7,57** | **6,58** |

QSPM results show Strategy A scored highest (TAS = 7.90). This strategy was deemed superior due to its practicality, technical effectiveness, and alignment with international best practices. Bandpass filtering, already proven in other interference cases (e.g., Indosat–Smartfren coordination). It enables precise attenuation of out-of-band emissions while preserving operator power levels. Meanwhile, joint coordination reduces the regulatory burden on a single sector and promotes cross-institutional ownership of interference risks.

By contrast, Strategy B, while technologically sound, may be limited by infrastructure maturity and lack of centralized real-time coordination platforms. Strategy C, while politically and ethically compelling, faces challenges in policy enforcement and realization timeframe.

The results reinforce the need for collaborative and data-informed spectrum governance. As seen in Europe, co-management models between railway and telecom sectors under frameworks such as ERA's spectrum coexistence protocols are more sustainable than unilateral mandates. This study advocates adopting a similar model in Indonesia, where technical innovation (e.g., filters, DSM) is accompanied by institutional reform (e.g., cross-sector committees, SOP alignment) (Creswell, 2018; David, 2011; Zhang Liu K. and Yu S., 2020).

While power reduction can act as a rapid emergency mitigation tool. It often results in collateral degradation of mobile service quality, network efficiency, and business performance particularly in urban corridors with high user density (Anwar Kartiko B. and Sugiarto A., 2019; (ERA), 2022; Ma Lin X. and Huang Y., 2020; Mustafa Irwan H. and Syahputra D., 2021; Riyantika D., 2023). Sustainable and equitable spectrum coexistence requires a more holistic and forward-looking approach, including the deployment of advanced interference mitigation technologies such as bandpass filters, dynamic power control algorithms, and adaptive spectrum allocation frameworks. Moreover, institutional arrangements such as regulatory co-governance structures, standardized cross-sector protocols, and National interference mapping systems are essential to ensure that spectrum policies are not only technically sound but also operationally fair and commercially viable.

## CONCLUSION

Based on a technical perspective, the study revealed a significant decline in signal quality. The proportion of "Excellent" RSRP decreased by 35.7%, daily traffic volume dropped by 34%, and active user sessions (RRC) fell by 33%. These results indicate that coverage area and signal integrity in affected zones, particularly urban transit corridors, were severely compromised. This degradation in technical performance led to a 5.8% decline in daily revenue and an increase in customer churn, with some areas experiencing churn rates exceeding 29% monthly. From a strategic standpoint, the organization remains well-positioned internally, with favorable external conditions, as reflected in the IFE and EFE scores of 3.20 and 3.48, respectively. The QSPM analysis identified the most effective mitigation strategy as a dual approach, combining joint spectrum coordination with GSM-R stakeholders and the implementation of bandpass filters at the source of interference. This strategy aligns with international best practices and ensures a balance between railway safety and mobile service continuity.

Ultimately, the study highlights the importance of cross-sector collaboration and evidence-based policymaking in managing radio frequency spectrum. In scenarios where infrastructure systems with different public service goals coexist, such as the *KCJB* project, unilateral technical mandates, like transmitter power reductions, may offer temporary relief but are unsustainable in the long run. The findings of this research provide a benchmark for similar spectrum coexistence situations, especially as Indonesia continues to expand its infrastructure projects, including MRT, LRT, and high-speed rail systems. This study suggests that for long-term sustainability, a more coordinated approach is needed, where continuous monitoring, adaptive mitigation strategies, and cross-industry collaboration are prioritized to prevent service degradation and financial losses in shared spectrum environments.

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