User Characteristic-Based Analysis and Strategies for Electricity Bill Collection—Postprint of Electric Power Knowledge Transformation Engineering Practice

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Abstract

[Purpose/Significance] With the development of knowledge management theories, various industrial sectors, particularly those that have completed informatization, are facing an increasingly urgent need for knowledge-based transformation. In addition to knowledge management theories, the knowledge-based transformation process also requires the extraction of a relevant knowledge management tool system. [Method/Process] This study primarily investigates the application of knowledge management tools in the marketing domain of the electric power industry, extracting characteristic factors affecting payment users from data routinely encountered by power business personnel, and forming key knowledge related to user payment and arrears habits to guide future work of business staff. First, electricity consumption and payment data of nearly 100,000 households in Gansu Province were collected from the power system, and data obtained through questionnaire surveys were compiled; second, principal component analysis and regression methods were employed to construct a user on-time payment model; finally, based on model analysis, factors that promote user on-time payment were identified, and targeted marketing strategies were proposed to reduce electricity bill delinquency rates and lower electricity fee collection costs. [Results/Conclusion] Through analysis, key factors such as user creditworthiness, customer satisfaction, and collection frequency were identified, effectively achieving knowledge-based transformation in the electric power sector.

Full Text

Introduction

Although power information systems have accumulated vast amounts of multi-dimensional customer data—including electricity consumption records, payment bills, complaint and maintenance logs, user demographic information, and payment channel records—this data remains largely underutilized. Analysis of user electricity consumption patterns and strategies for arrears recovery currently rely primarily on the subjective experience of frontline personnel, constituting tacit knowledge acquired through long-term customer interaction and observation of usage data. Veteran staff can leverage their experience to identify potential electricity theft or malicious arrears from consumption patterns, and assess recovery difficulty based on billing and complaint records to formulate appropriate collection strategies. New employees lacking such experience struggle to perform these tasks effectively, resulting in low efficiency and high difficulty in electricity bill collection. If accumulated user data could be effectively harnessed to extract insights about electricity needs, payment habits, and compliance capabilities, it would significantly aid collection strategies while saving substantial resources and reducing costs for power enterprises.

According to payment information provided by State Grid Gansu Electric Power Company, the actual average electricity price is far lower than the theoretical price, indicating that collected revenue cannot guarantee 100% recovery. The user arrears situation is severe, with widespread delinquency causing annual economic losses of 20 billion yuan to grid companies—a figure that continues rising yearly. Research on electricity bill recovery has become urgent. Shen Ji and Yin Li argue that serious arrears problems stem from three main factors: weak legal awareness among users who prioritize benefits over regulations; corporate profit-driven behavior that retains working capital by withholding payments; and protectionism for industrial users that encourages malicious arrears. Huang Wensi et al. analyzed historical payment data to uncover hidden risk patterns, categorizing customer characteristics into basic information, billing data, and payment history. Building on this work, we further divide influencing factors into payment ability, payment willingness, and payment habit based on user attitudes and behavioral characteristics.

Research Methodology

This study proceeds through three sequential stages. First, to identify primary factors influencing payment behavior while reducing data processing complexity, Section 3 employs both subjective user interviews and objective literature review to screen factors, providing a foundation for questionnaire design. Drawing upon existing literature and Gansu Province's operational characteristics, we identified twelve indicator variables: user income, electricity consumption, electricity price, household size, region, behavioral awareness, power supply stability satisfaction, power quality satisfaction, service satisfaction, electricity bill

credibility, electricity price satisfaction, and payment channel, with on-time payment as the dependent variable. Second, we collected data and applied principal component analysis to extract three-dimensional user characteristics—payment ability, payment willingness, and payment habit—then used regression analysis for knowledge mining to determine their influence on payment behavior. Finally, based on these results, we assessed user arrears rates and formulated tailored recovery strategies.

Data sources consist of two components: electricity consumption and payment data for nearly 100,000 Gansu households from the power information system, and questionnaire survey data. System data provides indicators such as monthly consumption, payment proactiveness, on-time payment status, and channel type (categorized as door-to-door collection, counter payment, bank card automatic deduction, or third-party online platforms). Survey data captures household economic status, residential satisfaction, and awareness of arrears consequences, with specific indicators detailed below.

3.1 User In-Depth Interviews

The interview stage extracts objective elements from tacit knowledge through focused discussions. To identify initial influencing factors, we conducted in-depth interviews with dozens of representative users from different regions using structured questionnaires supplemented by unstructured inquiries. Key reasons affecting on-time payment included: lack of electricity information understanding, absence of reasonable payment cycles, insufficient payment awareness, regional/payment channel limitations, dissatisfaction with power supply/voltage/service, and overly lenient arrears consequences.

Representative interview records include: User A, a rural resident paying through a local cooperative, reported voltage instability, frequent outages, and difficult restoration, resulting in low payment enthusiasm despite small consumption and timely monthly payments. User B, from a large rural household with working children, lacked mobile payment skills and experienced disconnection due to forgotten payments. User C, an urban resident with tenants, faced proportional billing complications and frequent reminders due to delayed tenant payments.

Reasons for arrears were categorized as shown in Table 1 and Figure 1 [Figure 1: see original paper], including non-malicious arrears, service dissatisfaction, poor economic conditions, channel limitations, weak payment awareness, and irregular payment cycles.

3.3 Variable Refinement

Based on thirteen proposed variables, we conducted a pilot survey and standardized the data. Analysis revealed that electricity price and price satisfaction had no significant impact on on-time payment, with no regional differences in payment behavior. Regarding satisfaction, power quality perceptions focused on

outage frequency and restoration speed, essentially reflecting power supply stability satisfaction, making the power quality variable redundant. Consequently, we removed region, power quality satisfaction, electricity price, and price satisfaction indicators. Combined with literature review, this yielded eleven indicator variables and one dependent variable, as shown in Table 2 .

Data Analysis

4.1 Data Collection

Using electricity consumption data from State Grid Gansu Electric Power Company, we conducted an empirical study on payment behavior to uncover tacit knowledge factors. The questionnaire surveyed household economic status (including monthly income), residential satisfaction (encompassing power supply satisfaction, service satisfaction, bill credibility, payment convenience, and channel satisfaction), and arrears consequence awareness (including consequence awareness and behavioral awareness regarding late or missed payments). Basic demographic information including gender was also collected.

The questionnaire was distributed through social media, yielding 334 responses (54.19% female, 45.81% male) from 28 provinces/municipalities, indicating minimal regional bias. After screening for validity—removing incomplete responses, submissions under 34 seconds, logical inconsistencies, and duplicate answers—45 questionnaires were eliminated, retaining 289 valid responses (86.5% validity rate).

4.2 Reliability Testing

Reliability refers to measurement consistency across repeated applications. The most common coefficient is Cronbach's α, calculated as:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum S_i^2}{S_T^2}\right)$$

where k is the number of items, S_i^2 is item variance, and S_T^2 is total score variance. Our data yielded $\alpha = 0.752$, exceeding the 0.7 threshold and indicating acceptable reliability.

4.3 Correlation Analysis

Pearson correlation coefficients measured linear relationships between variables. Eight independent variables showed significant correlations at the 0.05 level, except for on-time payment with electricity consumption and bill credibility. Monthly income correlated significantly only with on-time payment. Electricity consumption showed no significant correlations with any variable. Payment proactiveness correlated significantly with on-time payment. The remaining seven variables—power supply satisfaction, service satisfaction, bill credibility,

payment convenience, channel satisfaction, behavioral awareness, and consequence awareness—were all significantly intercorrelated. Since electricity consumption demonstrated no significant relationships, it was removed from further analysis.

4.4 Principal Component Analysis

Principal component analysis yielded the component matrix shown in Table 4 . Three components with eigenvalues exceeding 1 were extracted. The first component featured high loadings for power supply satisfaction (0.815), bill credibility (0.800), service satisfaction (0.799), channel satisfaction (0.752), payment convenience (0.711), consequence awareness (0.621), and behavioral awareness (0.618). These represent attitudes toward electricity usage, payment processes, and payment behavior, leading us to characterize this component as **payment willingness**.

The second component showed high loading for monthly income (0.876), representing total household disposable income and effectively reflecting economic status. Research indicates account balance significantly negatively affects arrears behavior, confirming that economic circumstances determine **payment ability**.

The third component exhibited highest loading for payment proactiveness (0.954), defined as the time interval between receiving payment notice and completing payment. This habitual pattern led us to designate this component as **payment habit**.

4.5 Regression Analysis

Regression analysis using the principal components yielded results shown in Table 5 . All three component coefficients were positive and significant ($p < 0.01$). Payment willingness, payment ability, and payment habit all demonstrated significant positive effects on residential on-time payment rates.

Letting Y represent on-time payment, X_1 payment willingness, X_2 payment ability, and X_3 payment habit, the principal component regression equation is:

$$ZY = 0.137 \times X_1 + 0.381 \times X_2 + 0.380 \times X_3$$

Variance homogeneity tests across payment channels yielded an F-statistic of 1.514 ($p = 0.211 > 0.05$), indicating no significant channel differences in on-time payment behavior.

Electricity Bill Recovery Strategies

Based on the relationship between payment ability and on-time payment rates, we formulate targeted recovery strategies. Since payment ability significantly

positively affects on-time payment, and income contributes most to payment ability (loading = 0.876), strategies should prioritize users with poorer economic conditions.

Strategies by Economic Status

Affluent users: For those in developed regions where electricity expenses represent a small proportion of monthly spending, arrears typically result from forgetfulness rather than financial constraints. Strategies should increase reminder frequency while reducing payment frequency. We recommend implementing prepaid package systems offering quarterly, semi-annual, or annual plans with proportional discounts. Insufficient consumption can be supplemented with additional purchases, while surplus rolls over to subsequent periods.

Economically constrained users: These users prioritize energy conservation and carefully scrutinize bill accuracy, often delaying payment within allowable limits. To improve their on-time payment rates, power companies should enhance information transparency and implement incentive measures. Provide accessible channels for querying consumption and tariff information, and offer rewards such as 5% discounts for the first 1,000 monthly payers or maximum 20% discounts for three consecutive months of timely payment. Balance preferential strategies across economic tiers through staged incentives.

Enhancing Payment Willingness

Payment willingness significantly positively affects on-time payment, with major contributions from power supply satisfaction (0.815) and bill credibility (0.800). The seven contributing elements divide into user satisfaction and arrears consequence awareness. Higher satisfaction and greater awareness correlate with higher on-time payment rates.

Improving satisfaction: Meet user needs for power products. The five satisfaction elements (power supply satisfaction, bill credibility, service satisfaction, channel satisfaction, payment convenience) show highest factor loadings for power supply satisfaction and bill credibility, as these most directly affect user experience. To improve power supply satisfaction, companies should enhance voltage stability, reduce outages, and accelerate restoration through demand-side management and peak-shaving strategies. For bill credibility, minimize information asymmetry by leveraging smart meters to provide real-time consumption data, helping users understand exactly where each kilowatt-hour and each cent is spent.

Improving service satisfaction: Since user interactions with power companies are limited primarily to service installation, equipment maintenance, and complaint handling, companies should enhance service personnel capabilities by accelerating installation and maintenance speeds and improving customer service professionalism and responsiveness.

Enhancing consequence awareness: Since arrears within allowable limits don't directly harm users but cause company losses, education and publicity become crucial. Power companies should promote the benefits of timely payment and consequences of arrears, increasingly linking delinquency to personal credit scores, which can affect travel, loans, and housing purchases. This raises consequence awareness and encourages timely payment.

Optimizing Payment Habit

Payment habit's significant positive impact indicates that shorter intervals between receiving payment notice and completing payment correlate with higher on-time payment probability. Currently, over 19 payment channels exist, divided into cash and non-cash methods. Non-cash methods reduce collection costs and improve efficiency.

Promoting automatic deduction: Bank card automatic deduction offers the highest timeliness, with smart meters monitoring consumption and automatically deducting payments when thresholds are reached, while alerting users to maintain sufficient balances. This synchronizes notification and payment, effectively reducing losses from delayed payments. Companies should vigorously promote this method through community outreach, property management coordination, and bank partnerships.

Non-cash channels: Users paying via Alipay, WeChat, or websites experience short notification-to-payment intervals and low transaction costs. Companies need only prevent missed payments through timely reminders. For cash payers facing high transaction costs and low proactiveness, companies should reduce payment costs through timely reminders and consider door-to-door collection, though this increases company costs. Overall, lower user payment costs yield higher proactiveness and on-time payment rates.

Conclusion

This study demonstrates that knowledge management theories and tools can effectively support the transformation from informatization to knowledge-based operations in China's power sector. Our "data collection and survey—data mining analysis—knowledge extraction" methodology applies not only to power but also to broadcasting, banking, telecommunications, and traditional manufacturing. Industries can enhance efficiency in product development, production, and logistics through knowledge-based approaches, charting a new path toward intelligence.

However, this remains a challenge without standard solutions, requiring continued attention and collaborative effort from domestic experts and scholars.

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Author Information and Abstract

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Abstract: [Purpose/significance] With the development of knowledge management theories, all relevant industrial sectors, especially those that have completed informatization, face an increasingly urgent transformation toward knowledge-based operations. In this transformation process, both knowledge management theories and tool systems require refinement. [Method/process] This paper takes the power industry as an example to explore the application of knowledge management tools in power marketing. Experienced practitioners can leverage tacit knowledge to analyze key marketing factors. This study attempts to make tacit knowledge explicit through explicit knowledge management tools, investigating factors that prompt on-time payment to propose targeted marketing strategies, reduce arrears rates, improve recovery methods, and lower collection costs. Using principal component analysis and regression, we constructed an on-time payment model based on electricity consumption and payment data from nearly 100,000 Gansu households and questionnaire survey data. [Result/conclusion] The analysis identified key factors including user performance focus, customer satisfaction, and collection frequency, achieving effective explicit representation of tacit knowledge.

Keywords: power system knowledge; data intelligence; power marketing; user characteristics

Note: Figure translations are in progress. See original paper for figures.