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THE IMPACT OF DIGITAL TECHNOLOGIES ON NONPERFORMING LOANS IN THE BANKING SECTOR

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Abstract. The digitalisation of the banking sector is changing the way borrowers are assessed, loans are granted, and debt is being tracked. At the same time, the expansion of remote services is accompanied by the risks of accelerated accumulation of debt burden, misclassification of clients and fraudulent loan processing. The purpose of the article is to assess how digital technologies affect banks' debt problems in Kazakhstan and to identify indicators to verify the effectiveness of their use. The study is based on official data from the Agency of the Republic of Kazakhstan for Regulation and Development of the Financial Market for 2021-2025, payment statistics from the National Bank, an analysis of regulatory measures, and international scientific literature. The study applies dynamic and structural analysis, calculates the rate of debt change, and compares technological tools by stages of the credit process. It was found that the volume of loans overdue for more than 90 days increased from 669 billion tenge at the end of 2021 to 1,575 billion tenge at the end of 2025. In 2025, its growth reached 44.0%, while the loan portfolio grew by 21.3%; the share of NPL90+ increased from 3.1% to 3.6%. The paper shows differences between household and business

debt, as well as between payment digitalisation and automation of credit risk management. A scheme for the interaction of scoring, early warning, biometric identification and digital debt settlement has been developed. The scientific contribution consists in combining stock analysis and relative debt indicators with a system for verifying technological results. Suggestions for assessing the quality of new outputs, sustainability of restructuring, and independent validation of models are of practical importance. The results obtained characterise sectoral trends; the causal effect of individual technologies requires data from banks and loan agreements.

Keywords: digital technologies; banking sector; nonperforming loans; NPL90+; credit scoring; machine learning; credit risk

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ЦИФРЛЫҚ ТЕХНОЛОГИЯЛАРДЫҢ БАНК СЕКТОРЫНДАҒЫ ПРОБЛЕМАЛЫҚ БЕРЕШЕККЕ ӘСЕРІ

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Аннотация. Банк секторын цифрландыру қарыз алушыларды бағалау, кредит беру және берешекті басқару тәсілдерін өзгертеді. Қашықтан қызмет көрсетудің кеңеюі қарыз жүктемесінің жылдам өсуі, клиенттерді қате жіктеу және алаяқтық жолмен кредит рәсімдеу тәуекелдерімен қатар жүреді. Мақаланың мақсаты цифрлық технологиялардың Қазақстан банктерінің проблемалық берешегіне ықпал ету тетіктерін бағалау және олардың нәтижелілігін тексеруге мүмкіндік беретін көрсеткіштерді

айқындау болып табылады. Зерттеу Қазақстан Республикасының Қаржы нарығын реттеу және дамыту агенттігінің 2021–2025 жылдардағы ресми деректеріне, Ұлттық Банктің төлем статистикасына, реттеушілік шараларды талдауға және халықаралық ғылыми әдебиетке негізделген. Динамикалық және құрылымдық талдау, берешектің өзгеру қарқынын есептеу, кредиттік үдеріс кезеңдері бойынша технологиялық құралдарды салыстыру әдістері қолданылды. Төлем мерзімі 90 күннен астам кешіктірілген қарыздар көлемі 2021 жылдың соңындағы 669 млрд теңгеден 2025 жылдың соңында 1 575 млрд теңгеге дейін ұлғайғаны анықталды. 2025 жылы бұл көлемнің өсімі 44,0%-ға жетті, ал несие портфелі 21,3%-ға өсті; NPL90+ үлесі 3,1%-дан 3,6%-ға көтерілді. Халық пен бизнес берешегінің ерекшеліктері, сондай-ақ төлемдерді цифрландыру мен кредиттік тәуекелді басқаруды автоматтандыру арасындағы айырмашылықтар көрсетілді. Скоринг, ерте ескерту, биометриялық сәйкестендіру және борышты цифрлық реттеу құралдарының өзара байланысы ұсынылды. Ғылыми үлес берешектің абсолюттік және салыстырмалы көрсеткіштерін талдауды технологиялық нәтижелерді тексеру жүйесімен ұштастырудан тұрады. Жаңа кредиттердің сапасын, қайта құрылымдаудың тұрақтылығын және модельдердің тәуелсіз валидациясын бағалау жөніндегі ұсыныстардың практикалық маңызы бар. Нәтижелер секторлық үрдістерді сипаттайды; жекелеген технологиялардың себептік әсерін анықтау үшін банктер мен кредиттік шарттар деңгейіндегі деректер қажет. Ұсынылған тәсіл кредит беру жылдамдығын тәуекелді төмендетудің дәлелі ретінде қабылдауды шектейді.

Түйін сөздер: цифрлық технологиялар; банк секторы; проблемалық берешек; NPL90+; кредиттік скоринг; машиналық оқыту; кредиттік тәуекел

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ВЛИЯНИЕ ЦИФРОВЫХ ТЕХНОЛОГИЙ НА ПРОБЛЕМНУЮ ЗАДОЛЖЕННОСТЬ БАНКОВСКОГО СЕКТОРА

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Аннотация. Цифровизация банковского сектора меняет способы оценки заемщиков, выдачи кредитов и сопровождения задолженности. При этом расширение дистанционного обслуживания сопровождается рисками ускоренного накопления долговой нагрузки, ошибочной классификации клиентов и мошеннического оформления займов. Цель статьи состоит в оценке механизмов влияния цифровых технологий на проблемную задолженность банков Казахстана и определении показателей, позволяющих проверить результативность их применения. Исследование основано на официальных данных Агентства Республики Казахстан по регулированию и развитию финансового рынка за 2021–2025 годы, платежной статистике Национального Банка, анализе регуляторных мер и международной научной литературы. Применены динамический и структурный анализ, расчет темпов изменения задолженности и сопоставление технологических инструментов по этапам кредитного процесса. Установлено, что объем займов с просрочкой свыше 90 дней увеличился с 669 млрд тенге в конце 2021 года до 1 575 млрд тенге в конце 2025 года. В 2025 году его прирост достиг 44,0%, тогда как ссудный портфель вырос на 21,3%; доля NPL90+ повысилась с 3,1% до 3,6%. Показаны различия между задолженностью населения и бизнеса, а также между платежной цифровизацией и автоматизацией управления кредитным риском. Разработана схема взаимодействия скоринга, раннего предупреждения, биометрической идентификации и цифрового урегулирования долга. Научный вклад заключается в соединении анализа запасов и относительных показателей задолженности с системой проверки технологических результатов. Практическое значение имеют предложения по оценке качества новых выдач, устойчивости реструктуризации и независимой валидации моделей. Полученные результаты характеризуют секторные тенденции; причинный эффект отдельных технологий требует данных банков и кредитных договоров.

Ключевые слова: цифровые технологии; банковский сектор; проблемная задолженность; NPL90+; кредитный скоринг; машинное обучение; кредитный риск

Introduction. Digital technologies affect problem debt through decisions made throughout the entire loan agreement. Before issuing a loan, the bank evaluates the borrower's solvency and verifies the borrower's identity; after issuance, it monitors changes in the borrower's financial condition, offers repayment options, and manages delays. An error at any of these stages can increase losses, even if the rest of the operations are performed faster and cheaper. Therefore, the impact of digitalisation should be assessed through the quality of credit decisions and debt service. For Kazakhstan, the issue has a specific empirical basis. By the end of 2025, the share of non-cash transactions reached 98.3% by number and 87.2% by payments and transfers among the population. At the same time, the share of bank

loans overdue for more than 90 days increased to 3.6%, and their volume amounted to 1,575 billion tenge (NBK, 2026a; RFBR, 2026). These trends together require an explanation of which technological changes relate to credit risk and how their outcomes are verified.

The development of digital services expands the bank's information base but also increases the scale and speed of interaction with borrowers. A more accurate model may select clients with a lower probability of default, but the bank can use the efficiency gains to increase disbursements and change the acceptable risk. As a result, improved forecasting at the contract level and the dynamics of problem debt across the sector may have different directions. Additional importance is given to the stability of household incomes, the cost of credit and the timing of delinquency.

The study aims to assess the mechanisms by which digital technologies affect problem debt in Kazakhstan's banking sector and to develop a system to verify their effectiveness. To achieve this goal, the study compares the absolute and relative dynamics of NPL90+, differences between lending to households and businesses, the functions of digital tools, and the observed results of their use. The research question is under what conditions digitalisation improves debt management and what indicators make it possible to separate this result from the expansion of the credit market. The object is the banking sector of Kazakhstan; microfinance organisations as a separate sector are not included in the quantitative sample.

Literature review. Research on digital lending links its advantages primarily to the reduction of information uncertainty. Berg et al. (2020) show that a user's digital footprints contain information for predicting default and complement credit bureau information. This justifies the use of new data sources, but it does not mean that any set of behavioural features is equally useful. What matters is their relationship to solvency, accessibility at the time of decision-making, and sustainability beyond the training sample. For banks in Kazakhstan, this provision involves checking the added value of digital attributes relative to the credit history already in use.

Jagtiani and Lemieux (2019) consider alternative data and machine learning on the consumer lending platform LendingClub. The work shows that assessments of borrowers change when lenders use additional sources of information. Berg et al. (2022) link technological advantages to the organisation of lender-client interaction, information processing, and competition. Therefore, the remote interface and the quality of the credit model relate to different characteristics of digital lending: the convenience of applying alone does not determine the accuracy of estimating the probability of non-repayment. The results of more complex models also vary for different customer groups. Fuster et al. (2022) use data from the US mortgage market to identify the distributional consequences of the transition to machine learning: improved forecasting does not ensure an even gain for borrowers. Bartlett et al. (2022) show that differences in lending conditions may persist among

technology lenders. These studies relate to specific markets and do not provide a ready-made assessment for Kazakhstan. Their methodological significance lies in the need to analyse errors and access conditions by customer groups, including customers with a short credit history.

Gambacorta et al. (2025) study the joint use of artificial intelligence and information accumulated in banks' relations with enterprises based on Italian data. The authors show that the result of technological implementation depends on the state of the economy and the nature of the bank's interaction with the client. For debt management, this supports combining automated analysis with professional assessment in situations where digital signals do not reflect business seasonality, contract changes, or temporary interruptions in cash flows. International regulators are expanding the analysis beyond the accuracy of individual algorithms. The Basel Committee on Banking Supervision (2024) considers digitalisation possibilities alongside operational risks and dependence on external suppliers. The European Banking Authority (2023) highlights the need for careful application of machine learning in internal rating models. The Financial Stability Board (2024, 2025) highlights model risks, the concentration of technological services, and gaps in monitoring the implementation of artificial intelligence. These provisions are important for banks that outsource data processing and model development to external organisations.

A separate aspect is related to the moment of recognition of credit losses. The International Accounting Standards Board (2014, 2024) considers the IFRS 9 expected credit loss model a tool for more timely accounting for asset-quality deterioration. For the present study, this means distinguishing between the long-term delay already observed, a significant increase in credit risk, and expected losses. The literature review provides an analytical framework in which the results of digitalisation are assessed simultaneously in terms of decision accuracy, borrower stability, and loan portfolio dynamics.

Materials and methods. The study is based on open sector data for 2021-2025. The main source of indicators of problem debt is the annual reports of the Agency of the Republic of Kazakhstan for Regulation and Development of the Financial Market. Indicators as of January 1 of the following year are interpreted as the state at the end of the corresponding reporting year. For 2023, we use a comparable NPL90+ value of 864 billion tenge, as given in the message for 2024; the initial publication reported a rounded value of 863 billion tenge. The payment indicators are taken from the National Bank's 2024-2025 publications. The date of access to electronic sources is October 6, 2026.

The main category measured is loans with overdue debts of more than 90 days, designated NPL90+. They characterise a certain part of the problem debt. The broader concept also includes loans with deteriorating solvency before a long delay occurs. Table 1 distinguishes the indicators used. This distinction avoids substituting the regulated indicator NPL90+ with accounting categories and operational fraud statistics.

Table 1 — Differentiation of indicators of problem debt

Indicator	Content	Importance for technology assessment
NPL90+	Loans with overdue debts over 90 days	Long-term delay observed; the main sector indicator
Stage 2 under IFRS 9	Significant increase in credit risk; expected losses over the entire term	Early deterioration of quality before actual impairment
Stage 3 under IFRS 9	Credit-impaired assets; expected losses for the entire term	Accounting category, the coverage of which may differ from NPL90+
Expected credit losses	Probabilistic assessment of losses based on the timing of cash flows	Checking the timeliness of risk accounting and the quality of the forecast
Fraud incidents	Operations or handling of signs of misconduct	Operational risk; not every incident is related to a bank loan
Sources: RFBR (2026); International Accounting Standards Board (2014, 2024); NBK (2026b). The categories are used according to their own definitions and are not summarised.		

The NPL90+ share is calculated relative to the corresponding loan portfolio:

$$r_t = \frac{N_t}{L_t} \times 100 \quad (1)$$

Here, N stands for the volume of NPL90+ loans, L stands for the volume of the loan portfolio, and t stands for the reporting year. The indicator "loans to the economy", also published by the regulator, has a different statistical scope and is not used instead of L when calculating the share. The article presents officially published values for the share and the rate of change of the loan portfolio. Monetary volumes are expressed in current tenge; their increase characterises the nominal stock of debt and is not interpreted as an increase after excluding inflation.

The rate of change in the volume of NPL90+ is determined by successive annual observations.:

$$g_{N,t} = \left(\frac{N_t}{N_{t-1}} - 1 \right) \times 100 \quad (2)$$

The analysis additionally compares changes in the population and business entities, as well as the coverage of non-performing loans with provisions. Calculations are performed based on the published rounded data. The difference of one billion tenge between the sum of the segments and the total is accounted for as rounding. The composition of the banking sector is not fixed: at the end of 2025, 23 banks were operating, compared to 21 at the end of 2024. This limits the interpretation of aggregate growth as a change in the quality of a single unchanged set of loans (RFBR, 2025a, 2026).

The technological part is a comparison of verification mechanisms, results, and conditions. Payment indicators characterize the development of the digital environment, but do not directly measure the proportion of loans issued using machine learning. Five annual observations and the lack of comparable data on

technology adoption for individual banks do not allow us to assess a reliable causal regression. Therefore, empirical results describe the dynamics and structure of debt, and the flow chart generates verifiable explanations and indicators for subsequent analysis of loan agreements.

Results. The dynamics of NPL90+ shows that changes in the share and volume of problem loans give different information about the quality of the portfolio. At the end of 2021, their volume amounted to 669 billion tenge with a share of 3.3%. By the end of 2025, the volume reached 1,575 billion tenge, and the share reached 3.6%. Over four annual intervals, the nominal stock increased by 135.4%. At the same time, the minimum share was observed in 2023 and amounted to 2.9%. Table 2 compares these indicators with the growth of the loan portfolio.

Table 2 — Dynamics of NPL90+ and loan portfolio of banks in Kazakhstan

Year	NPL90+, billion tenge	NPL90+ share, %	NPL90+ Volume Growth, %	Loan portfolio growth, %
2021	669	3,3	—	—
2022	815	3,4	21,8	20,1
2023	864	2,9	6,0	23,1
2024	1 094	3,1	26,6	20,0
2025	1 575	3,6	44,0	21,3

Sources: RFBR (2023, 2024, 2025a, 2026); calculations by the authors.

In 2023, the share of NPL90+ decreased by 0.5 percentage points, although their volume increased by about 6.0%. The loan portfolio increased by 23.1%, that is, significantly faster than the numerator of the ratio. This shows the impact of the expansion of the lending base on the relative indicator: a decrease in the share was consistent with an increase in the amount of long-overdue loans. This result is important for evaluating digital solutions. A drop in the relative indicator cannot automatically serve as confirmation that the bank has prevented the emergence of new problem loans.

In 2024-2025, the ratio of rates has changed. In 2024, the volume of NPL90+ increased by 26.6% with a 20.0% increase in the loan portfolio. In 2025, the corresponding changes were 44.0% and 21.3%. The gap reached 22.7 percentage points, and the official share of NPL90+ increased by 0.5 points. With the continued expansion of lending, the relative indicator no longer compensated for the rapid increase in problem loans. Figure 1 shows this change in the ratio without combining monetary values *and percentages on the same scale*.

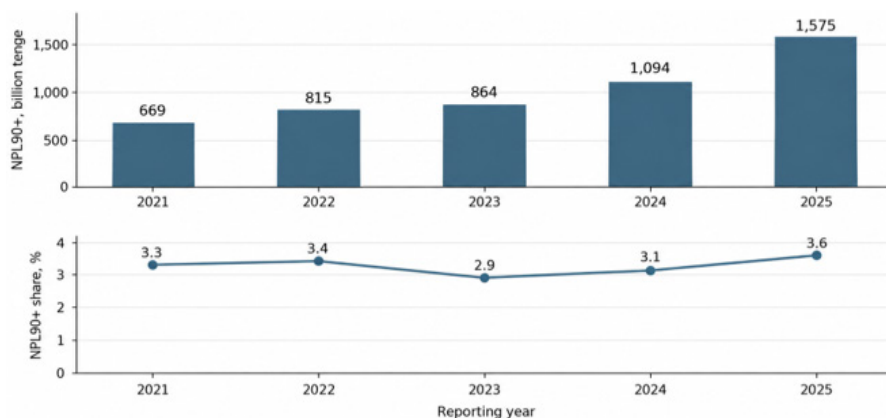


Figure 1 — Volume and share of NPL90+ in the banking sector of Kazakhstan
Sources: RFBR (2023, 2025a, 2026).

An important limitation of the sector dynamics is related to the life of loans. The rapidly growing portfolio contains a significant proportion of new contracts for which delays of more than 90 days have not yet occurred. Therefore, the digital scoring assessment should compare issues of the same age, for example, six and twelve months after issue. The indicator for the entire current portfolio mixes the quality of the selection, the duration of supervision and the volume of new loans. For practical control, the bank needs data on the months of issue, the transitions between the delay intervals and the actual repayment.

The digital payment environment remained developed during the period under review. The volume of non-cash transactions of the population increased from 166.1 trillion tenge in 2024 to 188.4 trillion tenge in 2025, or by 13.4% according to published values. The shares in terms of the number and volume of transactions are shown in Table 3. These indicators confirm the wide range of digital channels through which the bank can receive information about cash flows and interact with the client. At the same time, payments include transactions that are not related to lending, and their volume includes repeated transfers of funds.

Table 3 — Kazakhstan's digital payment environment in 2024-2025

Indicator	2024	2025
The volume of non-cash transactions of the population, trillion tenge	166,1	188,4
Percentage of non-cash transactions by number, %	98	98,3
Share of non-cash transactions by volume, %	87	87,2

Sources: NBK (2025, 2026a).

A comparison of tables 2 and 3 shows that the high prevalence of non-cash transactions coexists with an increase in long-term delays. The data does not establish that payment digitalization has caused this growth. They show the limited use of payment activity as the only indicator of the quality of a bank's

digital transformation. Information about the actual implementation of scoring, the proportion of solutions without the participation of a specialist, and the coverage of borrowers with early monitoring are more directly related to the subject of the study. This approach is in line with the recommendations of the Financial Stability Board (2025) to distinguish between direct implementation indicators and indirect indicators.

The structural analysis clarifies where the debt growth is formed. According to comparable data, the volume of NPL90+ population increased from 575 billion tenge at the end of 2023 to 790 billion tenge at the end of 2024 and 1,072 billion tenge at the end of 2025. For business entities, the corresponding values amounted to 289, 304 and 504 billion tenge. Table 4 summarizes the volumes and shares within each segment. It uses segment definitions adopted in the regulator's publications.

Table 4 — NPL90+ population and business in 2023-2025

Segment	2023 billion tenge. / %	2024 billion tenge. / %	2025 billion tenge. / %	Volume growth in 2025, %
Population	575 / 3,4	790 / 3,8	1 072 / 4,3	35,7
Business entities	289 / 2,3	304 / 2,1	504 / 2,7	65,8

Sources: RFBR (2025a, 2026); calculations by the authors.

In 2024, the NPL90+ population growth amounted to 215 billion tenge, or about 93.5% of the total increase of 230 billion tenge. In 2025, population growth reached 282 billion tenge, and business growth reached 200 billion tenge. The population accounted for about 59% of the increase in the total. Consequently, the retail segment retained the largest monetary volume of long-term delays, but the acceleration in the corporate segment also became significant: its NPL90+ increased by 65.8% over the year against 35.7% for the population. Risk management requires different data sources and procedures for these groups of borrowers.

For the population, a digital assessment should take into account proven income, current obligations and their maintenance. The frequency of application usage or the amount of account receipts can complement the analysis, but they are not a substitute for checking income stability. The transfer of borrowed funds between own accounts can create the appearance of turnover without increasing solvency. The cumulative burden of obligations to different creditors is also important. In a situation of rapid reissues, the delay in updating information becomes an independent source of risk assessment error.

The seasonality of revenue, revenue from key customers, and the concentration of payments are important for a business. An algorithm trained on stable daily trade turnover may misjudge an enterprise with irregular large contracts. Therefore, model signals require industry interpretation and verification by documents. The study by Gambacorta et al. (2025) supports the analysis of the combination of digital information and information obtained in the bank's relationship with the

customer. The practical point is to preserve the possibility of expert review of cases for which the standard features do not describe the financial situation of the enterprise.

An additional result concerns the coverage of non-performing loans with provisions. The published figure decreased from 76.0% at the end of 2023 to 67.0% at the end of 2024 and 60.6% at the end of 2025. This change needs to be considered together with the composition of the collateral, the expected return and the rules for assessing losses. One coefficient does not establish the sufficiency of reserves. For technological management, the timeliness of recognizing the deterioration of risk and updating expected losses is essential, since a late signal reduces the time to restore the client's solvency (APPR, 2025a, 2026; International Accounting Standards Board, 2024).

At the issuance stage, digital scoring can reduce information costs and improve customer ranking based on the probability of default. An economic result appears when a more accurate forecast is used to change the amount, term, or decision on the issue. The very increase in the statistical accuracy of the model does not determine the quality of the actually accepted portfolio. The bank can simultaneously improve accuracy and expand lending to more risky groups. Therefore, verification requires recording approval criteria and comparing losses at a comparable level of accepted risk (Berg et al., 2020, 2022).

After the loan is issued, digital monitoring allows you to notice changes in the financial condition before a long delay. A decrease in regular receipts, skipping payments, and an increase in the use of credit limits may serve as reasons to contact the customer. The usefulness of such a signal depends on whether it leads to action.: clarifying the reasons, changing the schedule, or limiting further issuance. A warning system without the agreed authority of employees is able to increase the number of notifications without changing the debt. Therefore, the response time and the proportion of signals that resulted in a steady recovery of payments are important.

Digital debt resolution expands the availability of contact and gives the borrower the opportunity to provide information about temporary difficulties. However, postponing the payment deadline may reduce the apparent delay without restoring income. The effectiveness of the restructuring should be assessed by repeated delays after six and twelve months, the return of funds and the continuation of servicing obligations. To compare a digital and a conventional channel, it is necessary to take into account the initial severity of the difficulties. Customers with fewer problems can use the app more often on their own, so a simple comparison of channel totals can overestimate the advantage of digital service.

Transactions with signs of fraud form a separate channel of influence. As of January 1, 2026, the Anti-fraud Center registered 80,871 incidents of transactions with signs of fraud and ensured the timely blocking of 2.8 billion tenge. These data characterize the accumulated performance of the infrastructure as of the specified date, and not solely the flow of prevented credit losses for 2025. Some

of the operations relate to transfers and other actions that do not directly increase NPL90+. Therefore, the blocked amounts cannot be added to the amount of the repaid debt or subtracted from the bank indicator NPL90+ (NBK, 2026b).

The link between fraud prevention and problematic debt is through checking the legality of the contract and preventing the disbursement of funds based on unlawful statements. Biometric identification, device verification, and interbank signal exchange complement each other. An identity check does not replace an assessment of the ability to repay a loan, and a positive credit rating does not confirm the voluntary nature of the registration. The results of the digital transformation of regulators in 2025 reflect the development of biometric services and anti-fraud infrastructure. This creates organizational conditions for joint control, but does not determine the magnitude of the effect for each bank (NBK, 2026c).

The regulatory changes of 2025 show the importance of a manageable online lending rate. A cooling-off period has been introduced for certain unsecured online consumer loans since September 30, 2025. For bank loans from 150 to 255 MCI, at least eight hours are provided, over 255 MCI — at least twenty-four hours; transfer is allowed after obtaining the consent of the borrower after this period. There are exceptions, including commodity loans, internal refinancing, and individual loans within the card limit. These parameters relate to the rules introduced in 2025 and are not presented as a universal scheme for all loans (RFBR, 2025b).

The economic sense of such a measure is to provide time to verify the decision and prevent actions under the influence of fraudsters. When evaluating the result, it is necessary to distinguish between loan cancellation during the cooling-off period, an identified fraudulent episode, and a future delay in the loan actually issued. These events have different denominators. Comparing the short period after the measure was introduced with previous issues requires taking into account the seasonality and age of the contracts. The final annual share of NPL90+ for 2025 does not allow us to single out a separate effect of the norm introduced at the end of September.

Table 5 compares digital tools with their impact channels and verification indicators. It combines the findings of debt analysis and international research. The proposed indicators relate to the results of the loan process; the processing speed of the application is considered as an operational characteristic that must be evaluated together with subsequent loan servicing.

Table 5 — Digital tools and their performance indicators

The tool	The channel of influence	Result indicator	Verification condition
Digital scoring	Assessment of solvency before issue	Delays and losses on payments of the same age	Comparable risk and approval rate
Early warning	Identification of cash flow deterioration	Reaction time; transition to a long delay	Fixing actions after a signal
Digital settlement	Debt service recovery	Refund; repeated delay after 6 and 12 months	Comparable severity of the initial problems

Biometrics and anti-fraud	Preventing illegal transactions	Confirmed losses; false locks	Separate accounting of credit and payment incidents
Data exchange via API	Clarifying income and obligations	Completeness and relevance of information about the load	Legitimate access; data quality control
Model control	Testing the stability of forecasting	Calibration and errors on late issues	Independent validation; saving versions

Source: development by the Government of Berg et al. (2020, 2022), the European Banking Authority (2023), the Basel Committee on Banking Supervision (2024) and the Financial Stability Board (2024, 2025).

The interaction of the tools is shown in Figure 2. Data expansion and automation enable the bank to recognize risk earlier. At the same time, remote issuance increases the rate of new obligations and identification requirements. The total debt depends on how these opportunities and risks translate into decisions made on specific contracts. Professional judgment is necessary in cases where the model features differ from the confirmed financial situation of the borrower.

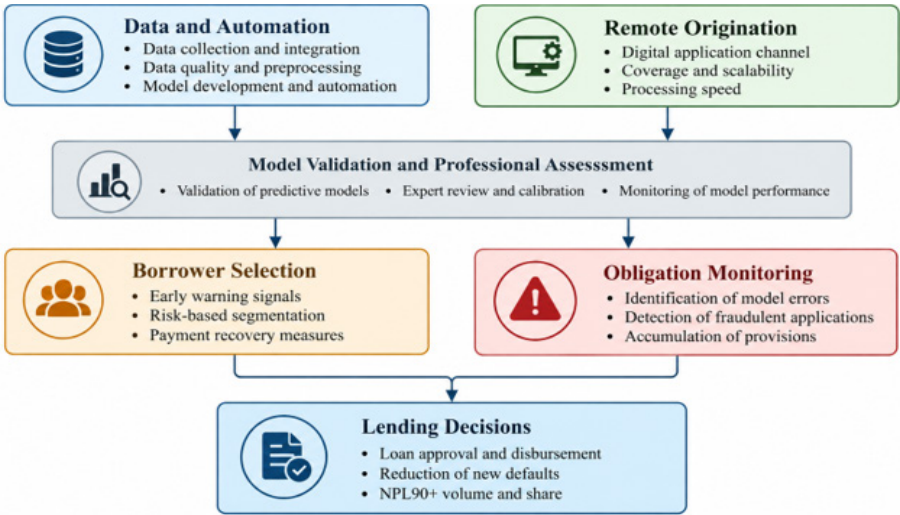


Figure 2 — Channels of influence of digital technologies on distressed debt
Source: the author's analytical scheme. The arrows indicate the intended relationships; the magnitude of the causal effects is not estimated.

Discussion. The implementation of the proposed approach begins with data comparability. The Bank must keep the version of the model used in the issuance, the date of the decision, the channel of circulation and the factors that changed the final approval. Training features are formed only from information available before the decision: including information about a subsequent delay would create a data leak and overestimate the accuracy of the model. Checking for later disbursements

allows you to identify a deterioration in the quality of forecasting with changes in customer income and loan costs. Independent validation should cover both the algorithm and the procedure for its application by employees.

The next level of verification is related to access to credit and error differences. For groups with a short credit history, unstable employment, or irregular incomes, it is necessary to separately analyze unjustified refusals and approvals that ended in default. Stricter screening can reduce NPL90+ by excluding a wide range of paying customers. Therefore, the result is evaluated together with the share of approval, the cost of the loan and subsequent maintenance. Conclusions of Fuster et al. (2022) and Bartlett et al. (2022) substantiate such an analysis, but specific group differences for Kazakhstan require independent research.

Dependence on external suppliers is also included in the credit risk assessment. Termination of data access, service failure, or algorithm change can affect multiple solutions at once. The Bank needs a change log, quality control of incoming information, and the ability to continue servicing if the digital channel fails. Generative artificial intelligence can be used to prepare messages and process documents with mandatory verification of significant findings. The decision on creditworthiness should be based on reproducible information, since the convincingly formulated response of the model does not confirm the reliability of financial facts (Basel Committee on Banking Supervision, 2024; Financial Stability Board, 2024).

For further empirical verification, a selection of contracts is preferable, which makes it possible to compare clients before and after the implementation of a particular instrument in the presence of a comparable control group. The product, age of the loan, income, initial debt burden, and changing macroeconomic conditions should be taken into account. With step-by-step implementation, it is possible to analyze differences in dynamics between departments or products while checking previous trends. The sectoral data in this article defines the directions of such verification: accelerating the growth of NPL90+ in 2025, differences between the population and businesses, and the need to observe new issues before the risk manifests.

Conclusion. An analysis of the banking sector in Kazakhstan for 2021-2025 showed that the spread of digital services is accompanied by a heterogeneous dynamics of problem debt. The nominal volume of NPL90+ increased from 669 to 1,575 billion tenge. In 2023, its share decreased with an increase in monetary volume, and in 2024-2025, the volume of long-term delinquencies grew faster than the loan portfolio. In 2025, the growth of NPL90+ reached 44.0% with a 21.3% increase in the portfolio. These results establish the need for a joint assessment of absolute and relative indicators.

The impact of digital technologies depends on the stage of the loan process. Scoring can improve the selection of borrowers, monitoring can reduce the delay in detecting difficulties, digital settlement can facilitate the recovery of payments, and anti-fraud tools can prevent illegal transactions. At the same time, accelerated

issuance, incomplete assessment of the total load, and model errors can increase the risk. Therefore, the result of digitalization is determined by the quality of solutions and the sustainability of repayment, and its payment indicators describe only a part of the technological environment.

A practical recommendation is to evaluate digital projects based on the quality of loans of the same age, overdue payments, actual repayment of funds, and sustainability of restructuring. For the public, load checking and protection against illegal registration are priorities, for businesses, cash flow analysis and a combination of model signals with industry assessment are priorities. Independent validation and reproducibility of solutions make it possible to link technological implementation with the observed result for the portfolio.

The scientific contribution of the article is to combine the NPL90+ sector analysis with a system for distinguishing indicators and verifying digital tools. Open aggregated data does not establish the size of the causal effect of individual technologies. The next stage of the study requires data from banks and loan agreements, including the dates of implementation of the tools, terms of issue and subsequent maintenance. Such a database will allow you to check which solutions reduce the expected losses while maintaining the availability of credit for paying customers.

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