**Improving the efficiency of passenger railway transportation based on e-commerce technologies and dynamic pricing**

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**Abstract.** In this article, current trends in the development of passenger railway transportation in Uzbekistan under the conditions of digitalization are presented. The role of e-commerce technologies in improving the quality of passenger service and stimulating demand is studied. The application of dynamic pricing based on the principles of Revenue Management is described, and its impact on ticket sales, carriage occupancy, and railway revenue is analyzed. The results confirm the efficiency of flexible tariff regulation for increasing the competitiveness of passenger railway transportation.

**INTRODUCTION**

Passenger railway transportation today is one of the key components of the transport sector. It ensures population mobility and contributes to economic development. Understanding its dynamics is essential for developing management strategies and improving transport infrastructure [1].

Despite the overall decline in the number of passengers transported by all modes of transport, passenger turnover on the national railway network in 2023 exceeded the 2010 level by 11%, reaching 3,926 million passenger-kilometers. This was achieved after a sharp drop to 1,794.9 million passenger-kilometers (–59%) during the COVID-19 year of 2020 and a subsequent recovery growth of 119% over the following three years. The railway segment is gradually regaining its position but has not yet reached the pre-crisis level of 2019 (4,385.2 million passenger-kilometers). In absolute terms, 9.7 million passengers were transported in 2023 compared to 9.0 million in the previous year (+7.7%), whereas in 2020 the figure fell to only 6.2 million (–26.9% compared to 2019). The share of the population actually using railway transport declined from 59.5% to its minimum in 2020 but increased by 50.2% over the next three years, confirming the existence of a stable pent-up demand [2].

The regional structure remains highly uneven: more than half of the total passenger flow is generated by the Tashkent, Syrdarya, and Jizzakh regions (approximately 5.1 million passengers in 2023), while the least served remain Karakalpakstan (0.42 million passengers) and several southern regions. At the same time, competition from air transport has intensified significantly. Its share in passenger turnover grew most noticeably during 2021–2023, while the railway segment reduced its relative share [3].

**EXPERIMENTAL RESEARCH**

The industry has already overcome the pandemic downturn; however, to achieve full recovery and further growth, it is necessary to maintain the positive dynamics of passenger turnover (currently +10.6% compared to 2022) and restore the pre-crisis level of 2019 no later than 2026 [4]. The main reserve for growth lies in expanding regional coverage and increasing the competitiveness of services: the least developed regions account for only 15% of total transportation volumes, while the average carriage occupancy remains at 65%, which indicates significant growth potential without capital expansion of the rolling stock [5].

Online sales are carried out through e-commerce systems. An online store expands the market without opening physical branches, while small businesses can easily enter the nationwide market through marketplaces without dealing with logistics issues. Order management systems remind customers of abandoned shopping carts and offer subscriptions to news and updates, thereby stimulating repeat purchases [6-10].

E-commerce systems simplify the purchasing process: customers pay for goods online, after which the product is either delivered to their home or digital access is provided. This not only accelerates the purchasing process but also makes shopping more accessible for people with disabilities, allowing them to place orders without the need to visit physical stores [11].

According to reports by international experts, the share of retail e-commerce in global retail trade amounted to 24.0% in 2022. According to this report, the top five countries included China (45.3%), the United Kingdom (35.9%), South Korea (30.1%), Indonesia (28.1%), and Singapore (17.2%) [12].

Interest in railway transportation in Uzbekistan is growing: in 2024, 9.8–11 million passengers were transported compared to 5 million in 2019. At the same time, tariffs remain fixed (approximately 200,000 UZS), while the average carriage occupancy is only about 65%. As a result, popular routes are sold out in advance, leading to lost revenue, whereas less popular routes operate with a high share of empty seats. Dynamic pricing addresses this issue by flexibly adjusting prices to demand.

The proposed model is based on the principles of revenue management and takes into account a variety of factors. The Pdyn ticket price changes dynamically relative to the Pbase base fare depending on the following parameters.

Time before departure. Early booking discount: a lower price is set for tickets purchased well in advance of departure (discount for advance purchase). As the departure date approaches, the discount decreases and the price increases. The bottom line is that the ticket price is highest immediately before departure and lowest when sold well in advance of the flight [13]. If there is very little time left before departure and there are still many seats available, the system may decide to temporarily lower the price or run a promotion, but in general, the closer to departure, the higher the fare (all other things being equal).

Current demand for the route. The model assumes that prices depend on the popularity of the destination and seasonal demand. For each route and train, a base fare plan is set, taking into account the distance of the trip, the season (e.g., summer holiday peak or public holidays), the day of the week, and the departure time. These factors determine the starting base price 𝑃base. The dynamic system then applies real-time coefficients to it: if there is increased demand (many requests and bookings for a given train), the price rises more quickly to the next level. When demand is low, the price increase slows down or stops in order to stimulate sales. The main principle is: "the higher the demand and the fewer seats available, the higher the price."

Carriage load (percentage of seats sold). The model continuously tracks the proportion of tickets sold 𝑤 relative to the train's total capacity. The price depends directly on this indicator: while few seats are sold, the maximum discount applies. When sales reach a certain percentage 𝛼 (for example, the first 40–50% of seats), the price returns to the base level 𝑃base. Further, as the number of available seats decreases, a surcharge may be applied to the base price [13]. For example, when >80% of seats are sold, the fare may exceed the original price by a certain percentage. Thus, as the train fills up, the price gradually increases. If tickets are selling slowly and a significant number of seats remain empty before departure, the system may keep the price below the base level until the end of sales in order to increase occupancy.

Formally, dynamic pricing can be represented as a function:

 (1)

Where: t – days (or hours) until departure,w – percentage of tickets sold at the current time. Functions  and  determine discounts or surcharges depending on the time of advance purchase and current seat occupancy,  – seasonality coefficient (>!1 during peak periods and <!1 during low season), and  – adjustment for user behaviour (for example, it may slightly reduce the price when online purchasing activity is low). The objective function of the model is to maximise total revenue.

 (2)

Where: *Q* – number of tickets sold), with capacity restrictions and subject to maintaining customer satisfaction. Demand forecasting and iterative price revision methods are used to solve this optimisation problem. The basis is balance: to sell as many seats as possible, but at the highest price that passengers are willing to pay for each specific ticket.

**RESEARCH RESULTS**

An example of ticket price dynamics as departure approaches for flights with high and low demand. When demand is high (yellow line), tickets are cheapest when sales open (90 days in advance), after which the price rises rapidly and exceeds the base fare by the time of departure. When demand is low (orange line), the price remains close to the minimum for a long time and only reaches the base price on the date of departure.

**FIGURE. 1.** Example of price dynamics depending on demand

The example above shows how the model responds to different situations: when the train is full, the price increases (encouraging early purchases and increasing revenue from the last seats), and when it is underfilled, the price remains relatively low (encouraging additional demand through price). In both cases, a more even load is ensured: high surcharges curb excessive demand for popular flights (spreading bookings over time), while continuing discounts attract passengers to half-empty destinations.

Modelling the scenario of implementing a dynamic pricing strategy shows tangible improvements in key indicators. Below are the expected changes after the introduction of a dynamic pricing system (conditionally, in 2025), compared to the current situation.

Thus, a flexible pricing policy not only increases revenue by 20–25% and the average ticket price by 8–10%, but also provides a win-win effect: affordability of travel for different categories of passengers and optimal use of railway resources.

The overall forecast is that the carrier will see growth in both revenue and traffic volume, i.e. improved operational efficiency. The key indicators before and after the introduction of dynamic pricing are summarised below:

**TABLE 1.** Comparison before and after implementation of the system

|  |  |  |
| --- | --- | --- |
| **Indicator** | **before (static price)** | **After (dynamic price)** |
| Average ticket price, sum | 200 000 | 220 000 (+8-10%) |
| Average wagon load | 65% | ~75–80% |
| Passengers transported per year | 11 million | ~12,5 million (+10–15%) |

Dynamic pricing in passenger rail transport will create a win-win situation: passengers will get flexible fares, and the carrier will get a stable financial model and better train utilisation. A phased launch is recommended, with an information campaign, staff training and IT system improvements. The key is to monitor the "before/after" (revenue, load factor, satisfaction) and make operational adjustments. With competent implementation, a noticeable increase in revenue and passenger traffic can be expected within a year, strengthening the digital transformation and competitiveness of Uzbekistan Railways JSC in the long term. The Afrosiyob train has a total of 286 seats, of which 216 are economy class (base price 270,000 sum), 48 are business class (base price 396,000 sum) and 22 are VIP class (base price 545,000 sum). The total occupancy rate of the train is 85%, i.e. 0.85•286 ≈ 243 seats have been sold. The model of phased dynamic pricing is set by occupancy ranges (a single scale for all classes):

• 0–20 % from the location – base price,

• 20–50 % – +5 % to the base price,

• 50–80 % – +10 %,

• 80–100 % – +15 %.

Distribution of seats sold by stage: Let's calculate the number of seats in each range (from 286 seats):

**TABLE 2.** Phased distribution of seats sold by occupancy ranges

|  |  |  |
| --- | --- | --- |
| **Filling range** | **Capacity (seats)** | **Sold seats** |
| 0–20 % (basic) | 57 | 57 |
| 20–50 % (+5 %) | 86 | 86 |
| 50–80 % (+10 %) | 86 | 86 |
| 80–100 % (+15 %) | 57 | 14 |
| **Итого (85 %)** | 286 | **243** |

Distribution by class: For simplicity, let us assume that sales by class are proportional to their share of seats on the train (216:48:22). Then, out of 243 sold: economy – 184, business – 40, VIP – 19 seats (243 in total). Accordingly, we will distribute these sales across ranges with the same ratio:

**TABLE 3.** Sales structure by type of location and occupancy level

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Class/range** | **0–20 %** | **20–50 %** | **50–80 %** | **80–100 %** | **Итого** |
| **Economy (270 000)** | 43 | 65 | 65 | 11 | 184 |
| **Business (396 000)** | 10 | 14 | 14 | 2 | 40 |
| **VIP (545 000)** | 4 | 7 | 7 | 1 | 19 |
| **Total** | 57 | 86 | 86 | 14 | 243 |

Here, for example, 43 economy tickets were sold at the base price (range 0–20%), 65 at a price of +5%, etc.

 (3)

Revenue with dynamic pricing: We calculate revenue for each class as the sum of the products of the number of tickets and the price with a surcharge in each range.

**TABLE 4.** Comparative analysis of revenue by service class

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Class** | **Tickets sold** | **Static average price, sum** | **Static revenue, sum** | **Average price dynamics, sum** | **Revenue dynamics, sum** |
| Economy | 184 | 270 000 | 49 680 000 | 287 800 | 52 758 000 |
| Business | 40 | 396 000 | 15 840 000 | 419 800 | 16 790 400 |
| VIP | 19 | 545 000 | 10 450 000 | 584 700 | 11 110 000 |
| **Total** | **243** | **≈ 312 600** | **75 970 000** | **≈ 331 900** | **80 658 400** |

**CONCLUSIONS**

Thanks to tariff optimisation, a significant increase in total railway revenue is expected. Calculations show a potential increase in annual revenue of approximately 20–25% relative to the static tariff. In absolute terms, this is equivalent to an increase from, for example, ~2.2 trillion soums to ~2.7 trillion soums per year. The sources of growth will be: (a) a moderate increase in the average ticket price (due to a surcharge for the most popular seats) and (b) an increase in the number of tickets sold due to better train load factors. The second factor is particularly important – by attracting additional demand through price incentives, the company sells more seats that previously remained empty. For example, instead of selling 65 out of 100 seats at a single fare of 200,000 soums (revenue of 13 million soums), the dynamic model will allow, say, 80 seats to be sold at an average price of 185,000 soums, generating 14.8 million soums, which is ~27% more. International experience confirms these calculations: on routes where revenue management has been implemented, passenger turnover has increased by ~8.8%, and total revenue has increased by a comparable amount. In other words, dynamic pricing allows you to generate additional revenue with virtually no increase in transport capacity and no direct increase in base fares, by more effectively monetising existing demand.

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