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Interaction Model of Regional Air Transportation Market Participants under the Conditions of Limited Competition

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ABSTRACT

The objective of the article is to build a model of interaction between participants in the regional air transportation market, considering the peculiarities of internal competition in Russia.

The paper discusses the main parameters of the consumer behaviour model in the regional air transportation market, suggests options for the dependencies of consumer decisions depending on the cost, geography of the route network, flight schedules and the total transportation capacity in specific directions.

Also, a model of the behaviour of the air carrier is proposed, that includes the parameters of the costs of transportation, additional costs for paying for the services of auxiliary and supporting participants. Functions are formed that describe the interaction of participants based on an effective combination of behaviour models and a possible conflict of interest.

Keywords: *air transport, regional transportation market, consumer behaviour model, airline behaviour model, limited competition, interaction between participants in the air transportation market.*

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INTRODUCTION

Interaction in the regional air transportation market is carried out under a three-sector scheme. The main sectors of air transportation as of a market product are:

1) Participants in the process of producing air transportation as a product (manufacturers of the product).

2) Consumers of the air transportation product, which include passengers (for passenger air transportation) and cargo owners (for air cargo transportation).

3) Auxiliary and supporting market participants who are not directly involved in air transportation but create the necessary conditions for smooth functioning of the market.

We propose to include, for example, airlines, airports, air traffic control and air navigation services in the list of the main participants in the process of producing air transportation as a product. Then the auxiliary and supporting market participants are maintenance and repair factories, catering businesses, divisions providing services to passengers and visitors of the transport infrastructure (meeting and assisting personnel, public and personal transport, etc.), transport security services, cleaning services, etc. Accordingly, on the other side of the product is the consumer.

Obviously, in a broader interpretation of the air transportation market, it is also necessary to consider the state as a regulator and controller of the activities of market participants, the population, which is exposed to various factors that arise during the process of product manufacturing, as well as other interested parties, including aircraft manufacturers, civil engineering (construction) organisations, etc. However, the key market participants are the sectors discussed earlier. From the point of view of interaction zones, the diagram of air transportation as a product has the shape of a triangle, the vertices of which are groups of participants, and the sides represent emerging relationships (Pic. 1).

It is important to understand here that not only economic relations exist in such a scheme. In addition to the product «purchase-sale» relationship, social relationships arise between sectors, for example, in the form of brand loyalty, as well as stable links between specific companies in terms of involvement in regular and one-time actions, co-branding initiatives aimed at promoting a brand in an unusual area of consumption.

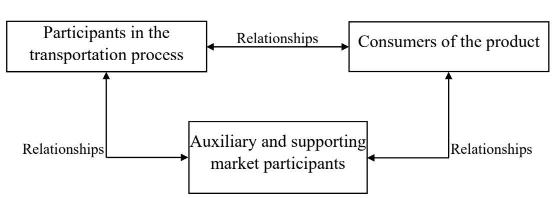
The objective requirement for a balance of economic activity assumes that all market participants strive to establish a mutually beneficial equilibrium, when air transportation on a specific route uses such a volume of resources (aircraft, infrastructure, personnel) that allows them to fully satisfy effective demand. In this situation, the most important guideline for establishing strategic priorities for market development is correct identification of the set of consumers.

Thus, the issues discussed in the article are of high relevance in the Russian transport sector and can be applied in other countries. Therefore, the main *objective* of the article is to develop a methodology for correctly assessing the quantity and quality of potential passengers who are motivated to purchase products on the regional air transportation market, which will improve the management efficiency of this sector of the transport industry. Due to the high capital intensity of business and the low level of capital productivity of participants in the air transportation market, the issue of improving the quality of forecasts of potential demand becomes extremely important.

The main research *methodology* includes the apparatus of set theory, theories of mathematical modelling, decision-making theories, principles of utility, graphical and tabular methods.

LITERATURE REVIEW

The issues of analysing air transportation markets of various sizes are quite often considered by modern authors. For example, among recent



Pic. 1. Main sectors of relationships in the process of consumption of air transportation as a product [performed by the authors].

publications, works [1–6] should be noted. However, most analytical works tend to consider general statistical indicators of the entire market conditions without dividing the market into individual segments. This approach does not allow us to assess trends in fluctuations in consumer preferences, as well as the problems of carriers.

Mechanisms and models of relations between various groups of stakeholders in the air transportation market are discussed in works [7–12]. It should be pointed out here that in most works there is no analysis of the interaction mechanism, the target indications of stakeholders in the decision-making process are not considered, therefore, in the process of making marketing decisions, the main source of interests is the air carrier. Also, under modern conditions, it is necessary to consider the change in the nature of the market and the transformation of relations within the «buyer's market» paradigm.

The economic basis for functioning of the air transportation market is considered by the authors of such works as [13–19]. However, most works in this subject area do not consider the realities of the post-Covid and further transformation of the air transportation market, and that significantly reduces the range of analysed risks and sources of threats to the domestic regional air transportation market.

MAIN RESEARCH RESULTS

In our studies, we have examined in some detail passenger transportation and the structure of consumption of this product [20–22]. As we stated earlier, a consumer is an individual, household, or group of individuals with common interests who chooses and implements a plan for consuming a particular product. When choosing and implementing his consumption plan, any consumer is guided by the existing objective restrictions on choice and by subjective selection criteria. In our opinion, there are two main types of constraints:

1) «A priori constraints, for example, geographical preferences or the time period of product consumption» [21].

2) Consumer budget as the amount of funds initially allocated by the consumer for the purchase of a product.

We believe that, other things being equal, the total cost of a consumer plan should not exceed the consumer's budget. Thus, the imposition of all constraints leads to the fact that the consumer gets a single consumption plan. Let's consider the possibilities of assessing the interaction pattern between participants from the consumer's point of view [21].

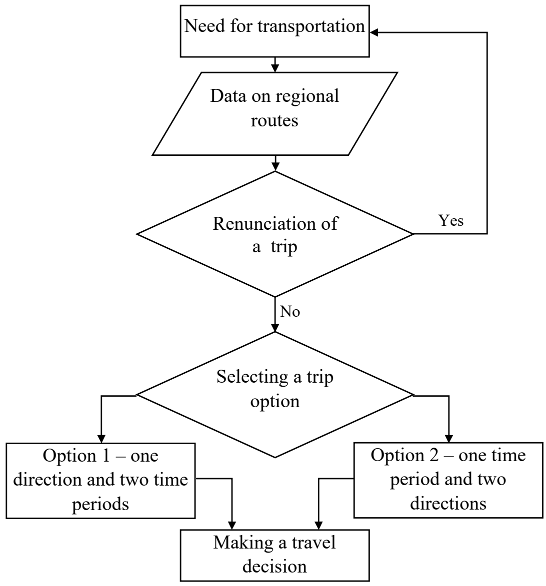
Let the number m be fixed (m is a positive integer), characterising the number of consumers in the regional air transportation market. Each consumer receives an index i: $i = 1, \ldots, m$. Each consumer has his own consumption plan, which is described by element x, which is a regional route included in a predetermined product space R^l. We call this product space a regional route network. Moreover, for the i-th consumer, a specific consumption plan x_i is either acceptable or unacceptable.

Then for the i-th consumer, a consumer set X_i can be formed, including all routes acceptable for this consumer. Let x be the demand of the i-th consumer, described by a point in the product space. If all consumers are given consumption plans x_i, the vector $x = \sum_{i=1}^{m} x_i$ describes aggregate consumption or aggregate demand in a given regional air transportation market. Then $X = \sum_{i=1}^{m} X_i$ this is the total consumer set.

Here it is important to use certain generalisations, which are illustrated by examples. We propose to fix a local agreement on the signs of variables. Let all numbers describing the inputs of a particular consumer have a *positive* sign, and all outputs are negative numbers. For example, the inputs for any consumer are the products of the regional air transportation market, that is, existing and available regional routes. Then let us suppose that the outputs for the consumer will be the various types of labour he performs.

It is also necessary to understand that each consumer can choose from all the options available to him in the market. In turn, the market supply consists of the production plans of all manufacturers. That is, if the consumer's input is the h-th product, its smallest value is 0, for example when the product is not available in the market. At the same time, this same h-th product is an output for the manufacturer (air carrier). It is obvious that for a given amount of labour there is a corresponding maximum value of product. Options for a specific consumer to choose various consumer plans are shown in Pic. 2.

In fact, in the regional air transportation market, the i-th consumer cannot reach the saturation point. That is, whatever his initial choice from the consumer set X_i may be, it is



Pic. 2. Flowchart of consumer travel decision making [performed by the authors].

always possible to form an alternative consumption that the consumer will prefer to the original one. Thus, the first function is introduced to describe consumer behaviour in the regional air transportation market. As «a measure of the quantitative preference of the *i*-th consumer from a set of regional routes x_i, let us use the utility function u_i» [21]. This function characterises the quantitative meaning of the degree of satisfaction with choice x_i for the *i*-th consumer.

Further, the budgetary constraint regarding a particular consumer begins to play an important role in the selection process. We adhere to the principles of classical economics, therefore, in the categories of set theory, this limitation is described as follows: let a set of prices *p* and consumption x_i be given, then the direct costs of the *i*-th consumer will be $p{*}x_i$. At the same time, costs cannot exceed the budget of a particular consumer w_i.

Then, «for a given price system *p* on the regional air transportation market and for a given budget w_i, the costs of the *i*-th consumer $p{*}x_i$ for their consumption (regional route) x_i from their own consumer set X_i satisfy the budget constraint $p{*}x_i \le w_i$» [21]. In this case, the budget distribution $w = (w_i)$ is described by a single element of the set of admissible budgets R^m. Then the typical pair «price – budget» is an element (p, w) of the set R^{l+m}.

We believe that in some cases, after choosing the pair (p, w_i), the set of consumer plans x_i will be empty. Therefore, it is advisable to select a set S_i, which includes only those «price – budget» pairs (p, w_i), when choosing which the set of consumer plans contains at least one element. Then for each pair (p, w_i) from the set S_i there exists a non-empty set $\gamma_i(p, w) = \{x_i \in X_i \mid p{*}x_i \le w_i\}$ of admissible consumer plans that satisfy the budget constraint specifically for the selected pair (p, w). That is, there is a uniquely defined mapping of γ_i from S_i to X_i.

This display must be presented in such a way that the individual demands of different consumers can be summed up. Then, using the utility function u_i to evaluate regional routes, any consumer in the regional air transportation market will choose the best element in accordance with his preference, that is, the option with the maximum value of the function u_i on $\gamma_i(p, w)$, or the feasible consumer plan that is optimal with regard for constraints imposed by his budget.

Moreover, any single-factor demand functions fit correctly into this model of demand on the regional air transportation market. «Curves of the form $y_i = f_i(Z)$ corresponding to these functions are called Engel curves» [23]. In our opinion, regional air transportation is not an essential product, so demand arises only after the consumer reaches a minimum threshold of his own income. On the other hand, regional air transportation is not a luxury item either. Consequently, regional air transportation is a non-essential (durable) good, «the demand for which is described by the Tornquist function» [24]. For durable goods, «the function has the following form:

$D = a^*(I_1 - I_2) / (I + b)$,
where I – income, if $I_1 \geq I_2$, a, b – parameters of the model» [21].

Typically, the usefulness of such products is assessed only by consumers who have reached the required income threshold. Moreover, the saturation of demand for such a category of products always has an asymptotic character and cannot be limited in advance.

The prerequisites for the developed model of functioning of the regional air transportation market were models of aggregated and disaggregated demand. In particular, in aggregated models, the accuracy of some dependencies is insufficient, therefore, to absorb the accumulative error and describe dependencies that are unimportant for the purposes of the study, appropriate variables are included in the equation. Then the demand function has the following form:

$Y = F(X) + \varepsilon$,

where Y – demand;

X – vector of arguments influencing the demand;

$F(X)$ – form of dependence;

ε – parameter to consider the influence of accumulated error and minor variables.

In turn, disaggregated (behavioural) models of demand for transport services are based on the results of an analysis of consumer parameters that form the consumer plan. For example, one type of disaggregated model is discrete choice models. In such models, the decision-making consumer n always has a set of discrete alternatives $j = 1, \ldots, J$, from which he chooses the option that maximises the utility of the choice. The function looks like:

$U_{jn} = V(z_{jn}, s_n; \beta) + \varepsilon_{jn}$,

where $V()$ – type of systematic utility function;

z_{jn} – vector of alternative solutions;

s_n – vector of consumer characteristics;

β – vector of unknown parameters;

ε – unobservable utility component.

Regardless of the chosen type of model, it is necessary to predict the values of the aggregated quantities that make up the set of independent variables of a particular demand equation. In particular, for the air transportation market, such variables are the size of the total passenger traffic on a particular route or the total passenger traffic between specific travel points. The task of assessing the impact of each variable on a model requires that the variable be explicitly included in the model.

Thus, to collect the necessary information, it is necessary to change the forms of statistical accounting in air transport. For example, panel data, which is easy to collect in the air transportation system, is quite informative for generalisation. Moreover, panel data allows one to analyse the dynamics of behaviour and the factors of choice of any sample of consumers in the regional air transportation market, not only at a given point in time, but also over several periods, providing the necessary reliability and the ability to analyse seasonality. Panel data provides the opportunity for its verification during the formation of all the topological sets described above.

In addition to consumers, product manufacturers also participate in the air transportation market. In our opinion, «a manufacturer in the regional air transportation market is a specialised enterprise that has passed a qualifying selection and is endowed by the state authorities of the Russian Federation with the legal right to carry out activities for the transportation of passengers by air, confirmed by the presence of a Commercial Aviation Operator Certificate» [21]. For simplicity, we will call such a manufacturer «airline». In fact, the manufacturer in the regional air transportation market is an economic agent that forms and implements its own production plan by offering consumers a set of air transportation options as its main product.

Let the number of manufacturers in the regional air transportation market be given by the number n (n is a positive integer), and each manufacturer is assigned an index j: $j = 1, \ldots, n$. Then the totality of products as individual elements y constitutes the production plan of any manufacturer. Moreover, y_j is a regional route included in the product space R^l, i.e., the airline's regional route network.

For the j-th airline, a specific production plan y_j is either technologically acceptable or technologically unacceptable, for example, due to the lack of aircraft of a certain type, the inability to fly to a given range or to airfields of certain classes. Then the production set of the j-th airline is the set Y_j of all its production plans, that is, feasible regional routes.

The offer of the j-th airline is represented by element y_j, which is a point in the space of products offered by the j-th airline in the regional air transportation market. If the production plan y_j is fixed, then the sum of the form $y = \sum_{j=1}^{n} y_j$ is called total production or total supply of the airline.

A set $Y = \sum_{j=1}^{n} Y_j$ is a set of total production possibilities. Therefore, if $y_j \in Y_j$ for all $j = 1, ..., n$, then $y \in Y$. Moreover, the power of the set of production capabilities of the regional air transportation market is clearly greater than the power of the set of R^l products.

Based on the listed parameters and sets, a system of consumer plans and production plans of airlines, quantitative estimates of input and output are formed, and the total quantity of each product available to participants in the regional air transportation market is estimated. The result is an estimate of the total amount of resources of the market under consideration (total resources) ψ.

Here it is also necessary to agree on signs. Let negative numbers describe all the inputs of a particular manufacturer, then all its outputs are positive numbers. Let's consider regional routes of a regional route network as outputs of a manufacturer on a given market. Here, each type of product not only certainly contains the corresponding characteristics and price but is also the single one. That is, the consumer always chooses a specific regional route as the most useful product for himself.

The interaction between the airline and the airport is also described by set theory. The airport is not a producer in the regional air transportation market, since it does not create an independent product consumed in this market. Therefore, the airline is the only type of producer when building set of producers in the regional air transportation market, since only the airline produces the product the consumer needs.

At the input, any airline receives the resources necessary for its operation: aircraft technical resources, aviation fuel, aircraft take-off and landing control services, air traffic control services, meteorological services, airline employee labour, etc. Moreover, the airline's production plan is chosen so as to maximise profit at given product prices, that is, the difference between the cost of the airline's output and the cost of providing input.

Let us consider in more detail the individual properties of the regional air transportation market model. The first property is additivity. Let the j-th airline have two different regional routes y^1_j and y^2_j –by definition, non-empty sets of admissible production plans, then the sum
$y^1_j + y^2_j$
is also a valid production plan, that is:

$(Y^1_j + Y^2_j) \subset Y_j$.

Indeed, if it is possible for an airline to operate flights on two independent regional routes (two production plans are separately admissible), then their sum is also an admissible production plan. One consequence of product additivity is cost additivity.

Another property is multiplicativity, that is, the possibility of multiplying the set y_j by a non-negative number t. For the airline, this means the ability to change the scale of its operations. If $t > 1$, the scale of the airline's operations increases. If $t < 1$, the scale of the airline's activities decreases accordingly. Thus, if it is possible to increase the scale of an airline's operations within the production plan y_j, this indicates that non-diminishing returns to scale have emerged.

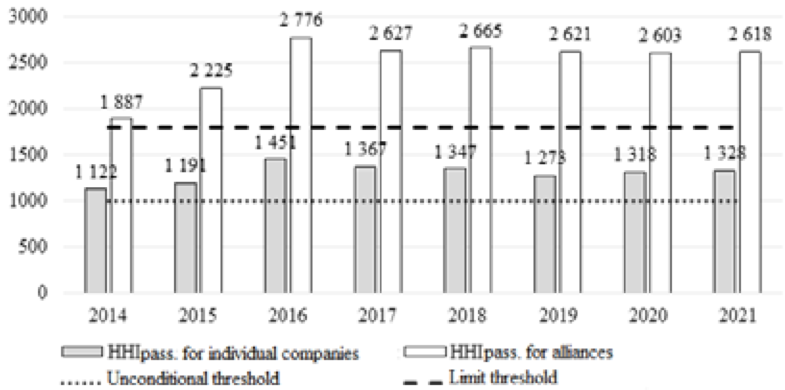
Accordingly, if it is possible to reduce the scale of the airline's activities within the framework of the production plan y_j, then we can talk about the formation of non-increasing returns to scale. Let's consider the situation for the j-th airline. If there are two independent production plans y^1_j and y^2_j, then there is a weighted average $t * y^1_j + (1 – t) * y^2_j$, for any t $(0 \le t \le 1)$.

This is how the nonincreasing returns to scale described above manifest themselves. This particular case of a mathematical description clearly explains the possibility of using the considered theory of the local air transportation market for the civil aviation of the entire country.

The price system p was introduced above. Then, if the price system p (the final price of an air transportation unit for a specific consumer x_i) and the cost of the production plan y_j (the cost of flying on a regional route y_j) are known, then the income of the j-th airline is $p * y_j$, and its total income is calculated as $p * y$.

In market conditions, any airline acts to maximise its own profits. In accordance with this assumption, the choice of a production plan by each j-th airline as a certain set of regional routes from the available production set Y_j means that the airline will maximise its profit on each regional route.

Since the total maximum profit may not exist for an arbitrary p, then there is a set T'_j of elements p from R^l for which the profit is maximum. Also, in the entire set of routes, there is always a certain number of regional routes that generate maximum profit for the airline. Let us take as an axiom the fulfilment of the inequality $p * y_j > 0$ in a strict form, that is, the impossibility of the existence of both a «cornucopia» and a «perpetual motion machine» for an airline.



Pic. 3. Dynamics of Herfindahl-Hirschman index values for individual companies and airline alliances [performed by the authors based on their own calculations].

Then for each price system p included in the set T'_j, there is a non-empty set $\eta_j(p)$ of feasible production plans, under which the airline generates maximum profit. That is, in the space of products of the regional air transportation market that make up the regional route network R^l, each j-th airline has production sets Y_j, which represent the entire set of regional routes of the airline in question, and only some of them are the set $\eta_j(p)$, bringing airline profit at price level p. This price system p, maximising the airline's profit, constitutes the set T'_j. That is, the regional route network of each airline includes obviously profitable and unprofitable routes.

Let us consider the profit function of the j-th airline. The profit function of the j-th airline is a function π_j on the set of prices p ($\pi_j(p)$), for which there is a maximum profit in the price system p from the set of prices of regional routes T'_j within the regional route network R^l. Mathematically, this means that a maximum profit exists in a given price system p for $j = 1, \ldots, n$, if $p \in \bigcap_{j=1}^{n} T'_j$, and the function π from $\bigcap_{j=1}^{n} T'_j$ is a function of total profit.

The analysis of the structure of the Russian air transportation market shows that this market is currently highly concentrated. Pic. 3 presents data on the value of the Herfindahl-Hirschman index (HHI), the values of which were calculated both for individual airlines and for airline alliances using panel statistics on the number of passengers carried in 2014–2021.

As can be seen from Pic. 3, currently there is a high concentration in the Russian market for air passenger transportation, which reduces the level of market competition. An analysis of the dynamics of structural changes in market segments shows that the number of airlines offering routes at the local, regional and interregional levels, with non-constrained passenger traffic, is clearly insufficient under the current conditions.

The models proposed above for describing the main participants in the air transportation market allow us to form a single model of the system of relations between them as a description of the general state of the regional air transportation market E. Let each consumer be characterised by a consumer set X_i, and each manufacturer – by a production set Y_j. Moreover, the specific actions of economic agents – consumers and airlines – determine the current state of the regional air transportation market E.

Then, to describe the state of the market E, it is necessary to use a set of elements (x_i, y_j) in the space R^l, of size $(m + n)$. Let any element $(x\text{-}y)$ describing the result of pairwise interaction of all agents be pure demand. By definition, net demand $x\text{-}y$ is an element of the set $X\text{-}Y$. Then excess demand is the actual excess of the net aggregate demand of all agents over the resources of the regional air transportation market ($x\text{-}y\text{-}\psi$), which is denoted by z. Excess demand constitutes set Z.

By market equilibrium we will understand the state of the regional air transportation market when excess demand is equal to 0. From the definition of equilibrium, it is clear that the net demand of all agents corresponds to the total resources, that is: $x\text{-}y = \psi$. Moreover, the state of market equilibrium, by definition, is not unique.

For example, any specific state (x_i, y_j) of the economy E of the regional air transportation market is acceptable if there is an infinitely large set of combinations of demand for regional routes, a desired price system has been established, there are no consumer budget constraints, regional routes have been developed that can be operated by the airline in the desired price system at absence of excess demand. Let us denote the set of market equilibria of the economy E of the regional air transportation market by M.

The manufacturer of the product in the regional air transportation market is the airline. Each airline has beneficiaries interested in making a profit in proportion to the airline's share of capital ownership. Then δ_j is the share of capital of the j-th airline owned by a specific beneficiary.

Accordingly, the profit shares of the j-th airline can be written as $\delta_1, ..., \delta_j$, where $j \in [1, n]$, and δ_j are real numbers ($\delta_j \geq 0$, $\sum \delta_j = 1$ for each j). The symbol j in share δ refers it to a specific airline but does not identify the owners of the capital. The profit function of the j-th airline was described earlier. The profit arising in the economy E of the regional air transportation market is the sum of all products of the profit of the j-th airline by the share of $\delta_j : \sum_{j=1}^{n} \delta_j * \pi_j(p)$. The profit of the j-th airline is always contained in the budget of the i-th consumer. Therefore, the mathematical description of the budget of the i-th consumer is as follows:

$w_i = p * \psi_i + \sum_{j=1}^{n} \delta_j * \pi_j(p)$.

We believe that in the established price system, in the process of the consumer choosing the offer of the j-th airline (x_i, y_j), the budget constraint will have the form of a non-strict inequality:

$p * x_i \leq p * \psi_i + \sum_{j=1}^{n} \delta_j * p * y_j$ for each i.

Summing for all i, we get:

$p*x \leq p*\psi + p*y$.

Here the economic meaning of equilibrium in the regional air transportation market becomes clear, which is the goal of managing the industry on any scale. In our opinion, the task of regulation is to balance the elements p_i of the set of prices P_i of the consumer and the elements p_j of the set of prices P_j of the airline. Then the target control function is to minimise the difference between the sets P_j and P_i, that is, to eliminate the complement of the set P_i to the set P_j, which is denoted by L_{ji}:

$L_{ji} = P_j / P_i = \{ p_j \in P_j \mid p_j \notin P_i \}$.

In fact, air travel promotions at any market size are deliberate actions by decision makers to increase demand by increasing market resources, decreasing budget constraints, and reducing airline entry costs.

CONCLUSIONS

The economy of the regional air transportation market E is closed in nature, therefore, if the conditions described above are met, a market equilibrium can be ensured that is beneficial for all market participants. It is necessary to ensure a situation where consumer demand is satisfied from a set of regional routes, there is always a specific regional route feasible for air travel, the airline provides a regional route from its production plan.

In the absence of excess demand, the establishment of market equilibrium is the result of the choice of a pairwise connection by both agents of the regional air transportation market. Therefore, the price system must be such that both economic agents of the market do not strive to make a different choice. Equilibrium is achievable if, under the chosen price system, no consumer can change the transportation budget without increasing its costs, and no airline can increase its profit.

On an intuitive level, it is clear that if the consumer's budget for air transportation on a regional route is exceeded, it is necessary to introduce a regulatory mechanism to compensate for the airline's losses. It is this conclusion that is fundamental when considering the economics of the regional air transportation market in a quasi-open private property economy.

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