Development of top-level requirements for regional aircraft based on the needs of the Russian market

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Abstract. The share of regional flight traffic is estimated as 10% of all air transport network in Russian Federation. According to the federal plans on infrastructure improvement, the regional aviation in Russia should provide public transport accessibility of remote areas. Thus the actual task is to provide economically efficient aircraft for local airliners in one hand, and to satisfy the upcoming regulations on ecology standards. One of the solutions is seen in development of regional aircraft with hybrid electric power engine. The paper includes the analysis of current state and trends of the interregional air transport system of Russia for the period 2030 – 2035. It gives, in addition, a composition and a volume of commercial traffic performed by the regional fleet. Also, some results of operational requirements assessment and the analysis of technical excellence of commercial regional aircrafts are presented. The assessment of the environmental requirements for this class of aircraft was carried out on the basis of ICAO standards.

1. Scope of the problem

One of the key economic tasks in Russia is to provide the acceptable transportation net in the nearest future. Due to the low density of areal development also influenced by geographic specifics (country size, landscape variations, climate conditions) the land transport infrastructure cannot provide the desirable access to small towns and settlements. The obvious but highly expensive solution is to cover the country with the airport net for operation of typical civil fleet. Transportation system considers air routes with the focus on the Northern regions, Siberia and the Far East regions. From economy point of view those regions do not have the desirable level of return on investments and are limited with paying capacity of local people. The situation is aggravated by severe climatic conditions that lead to higher operational costs. One of the rational solution is seen in the development of regional aviation with the airfield maintenance and optimized operational characteristics. Considering the average flight route parameters and climatic aspects, the first task for the current study was to obtain the typical mission requirements for the advanced regional aircraft. The task was spitted on two types of passenger regional aircraft (RAC) with the capacity below 50 seats and below 100 seats.

It should be noted that one of the differences in mission requirements for Russian and European markets arises from the typical route distance for small regional aircraft. The typical European local flight is considered to be in the range of 500-600 km, while Russian market typical distance is considered as 1000 - 1,500 km.

The second principal difference is in the amount of operated airports and airfields. Thus the essential market requirement for Russia is the ability to take off and land from unpaved runways. That obviously leads to the complication of the RAC airframe, aerodynamics and lift characteristics etc. imposing additional technical requirements.
Third, due to logistic limitations of distant settlements in Russian Federation, the operational goals could impose more severe or additional requirements for the maintenance of the airplane. The variant of the airfield maintenance could lead to additional issues related with the structural repair accessibility and possibility to perform standard/typical procedures by less qualified personnel. The variant that considers longer maintenance/service check intervals will lead to the increase of the structural weight, performance etc., for the airframe as well as for the engine and the aircraft systems.

Finally, according to the existing practice, the operator of RAC would like to have the ability for the fast conversion of the passenger cabin into a cargo-passenger one. The operation of ATR-42 with such options shows the higher efficiency in comparison with traditional schemes. Such cargo-passenger conversion option will also lead to the complication of the RAC structure.

2. Short overview of operated aircraft types

According to the market research data [1] the operated fleet in 2019 was dominated by regional jets, Fig. 1. The most intensive traffic in Russia is performed by regional jet aircraft between several big cities, percentage of turboprop aircraft is still not sufficient. As estimated by the United Aircraft Corporation the total Russian market in the next 20 years is about 3.5% of global market, dominantly by 180-200 seats jets. It could be assumed that in case of the intensive development of domestic and short distant regional air transportation the barriers related with the substitution of the existing fleet with advanced hybrid electric passenger RAC are quite small.

![Composition of current regional fleet by AC types](image)

**Figure 1** Composition of current regional fleet by AC types

Domestic lines still remain unloaded with the rate of cabin seats occupancy about 65%. Considering that the prevailing aircraft capacity is about 100 – 120 seats the optimal sizing is assumed to be about 70 passenger seats aircraft. Nevertheless the demand for domestic short distant flights has increased for last two years. According to the forecasts [2,3] Russian airliners will need about 300 airplanes within next 20 years. The considered passenger capacity was within the range of 30 -110 seats. The amount of small size local aircraft was estimated as 500 units of less than 30 pax capacity. Also according to Rosaviation forecast the amount of airplanes to be retired within the next 10 years is estimated as 130 airplanes, mainly Yak-40, An-24 and An-2 types. Figure 2 gives the current amount of different type regional aircraft that are operated in Russia, where ‘a’ shows the amount of the passenger airplanes with less than 6 tons the payload (less than 50 pax) and ‘b’ shows the amount of the passenger airplanes with more than 6 tones payload (more than 50 pax). The total number amount for the beginning of 2020 is 282 airplanes and 285 airplanes correspondingly. These data were taken from open source publications of Russian Federal Agency of Air Transport, (Rosaviation) with some corrections [4]. Figure 3 gives the estimated fleet basing on the analysis of the announced market needs for 2025 and 2035 years.
Figure 2 Current passenger regional fleet in Russian Federation

Figure 3 Market needs estimation for regional fleet in Russia

3. Geographic aspects for market needs
The Figures 4, 5 and 6 below show the current distribution of flight routes for both turboprops and turbojets. It could be noted that for the routes presented the mean distance is considered about 800 km. The increase of the distance to 1200 km will cover about 80% of the existing routes as it was mentioned before.
The data on passenger share distribution on for regional flights was analyzed, Figure 6 gives the actual request for passenger aircraft fleet was also taken into account.

4. Top-level requirements overview.
As the main directions of increasing the competitiveness of aircraft in the classes mentioned the following priorities should be considered:
- reduced cost of operation
- all-weather conditions of use
- safe operation at low-class airports (G class airfields)
- improved comfort level
- improved environmental impact.
Basing on the vision of air transport system of RF [5,6] for 2030-2035 period, acceptable flight frequency is considered as minimum as one flight per day for the routes mentioned. Taking into account the forecast of local flight intensity and possible new directions, top level requirements could be stated as following.

4.1. Passenger capacity / payload
Optimal passenger capacity was derived basing on the data given above, considering additional factors such as the mean flight occupancy rate. Based on actual timetables, an analysis was made of the current distribution of regional traffic by flight range for an aircraft capacity of up to 56 seats, operated in the Russian Federation by aircraft with turboprop and turbojet engine. As a result, the optimal passenger capacities were defined as:
• 65 seats for the routes between big regional centers (cities with more than 1 mln. population)
• 40 seats for other regional centers.

These capacity is derived basing on current market data. The mean passenger weight was considered as 100 kg and the mean baggage as 10-15 kg per passenger. Thus for the given seat capacity of 65 units the requirement for max payload would be 7500 kg and for 40 seats it would be equal to 4300 kg.

Following requirements have been stated basing on assumption that the flight characteristics of the perspective hybrid electric propulsion aircraft are close to the similar existing aircraft types, e.g.

• ATR-42-600: speed – 556 km/h, range – 1555 km, payload– 5450 kg, runway – 1165 m;
• ATR-72-600: speed – 510 km/h, range – 1540 km, payload–7050 kg, runway –1200 m.

4.2. Flight distance

Currently the distance of 1000 -1200 km should cover about 70% - 80% of existing traffic needs. Taking into account the extension of flight routes net for regional transportation, the range for perspective aircraft would be defined from the requirement to cover the distance within one region or connecting two neighbour regions.

Figure 7 Distribution of the potential flights in RF by distance

Basing on the distribution, the requires flight range for the 40 seats regional aircraft should not exceed 2000 km and for 65 seat aircraft –2500 km. Taking into account the flights with intermediate landing the required distance could be diminished to 1500 km. Longer flights could be covered by SSJ-100, and its modification for 70 seats and hybrid electric power unit could perform the flight for 3000 km.

4.3. Cruise speed

Due to development of a new type of the powerplant, it is quite difficult to state strict requirements for cruise flight speed (since on interregional routes its influence on the total travel time is not decisive). But in the considered promising regional air transport system of the Russian Federation, the flight speed can already significantly affect the performance indicators of transport operations. Based on this, as well as taking into account the data of current analogues (ATR42/72, Bombardier Q400, Embraer 170) and estimates of the acceptable travel time at the considered ranges for regional aircraft, it is proposed to establish the following requirements.

• For the 40 seats AC the max cruise speed of 550 km/h is treated as adequate. Maximum flight duration would not exceed 3,5 hours.
• For the 65 seats AC the higher speed is preferable with the values about 800 km/h the flight duration at max distance of 3000 km would be about 4,5 hours. Such an aircraft is potentially more interesting for the airliner, also taking into account the fuel adaptiveness for hybrid electric power plant, giving commercial advantages in comparison with the traditional AC.
4.4. Requirements for permissible operating conditions

It is necessary to provide the regular operation of regional aircraft in severe climatic conditions. The practical need of such requirements has already been confirmed by the experience of ATR aircraft operation in cold climates and intense icing. Therefore, the requirements for the operating conditions can be adopted by analogy with the requirements for perspective hybrid AC, namely:

- provide the operational range of air temperatures near the ground from –55 °C to + 45 °C;
- maintenance of the aircraft and its systems after a long ground parking at low temperatures down to –60 °C;
- provide start-up without heating at temperatures down to –40 °C;
- ensure all-weather and round-the-clock operation of the aircraft;
- provide takeoff and landing in conditions: wind with a lateral component of 12 m/s, a tail component of 5 m/s, a counter component of 25 m/s;
- barometric altitudes of the location of airfields (take-off capability) from -300 to 3660 m;
- no restrictions on flights over the sea;
- hangar-free storage during hurricane winds with gusts;
- meteorological minimum of the aircraft when landing up to ICAO category IIIc, if appropriate systems are available at the aerodrome.

4.5. Required runway length

Even the concept for regional aircraft in modified transport system of the RF does not require the operation from unequipped landing sites, for small-capacity aircraft it is reasonable to provide the ability of operation on unprepared and snowy runways. The take-off and landing characteristics of modern analogues such as the ATR-42-600s modification were taken as benchmark basis, considering modification for flights with runways of 800 m. Thus it is proposed to provide take-off/landing for small-capacity aircraft with a runway from 1300 m with a maximum take-off weight and with a runway from 1000 m with a load of up to 70%.

For an aircraft with a capacity of 65-70 passengers, the required length of the airborne air transport for the maximum take-off weight at a cruising speed of 800 km/h should be 1600-1800 m. Safe operation at airports located within city limits requires the ability to approach on a steep glide path (similar to London City Airport). An important issue is the minimum permissible strength of the surface of unpaved runways; stringent requirements can affect the operational efficiency of the runway. At the initial stages of research, it is proposed to provide for the minimum allowable strength of unpaved runways at the level of 6/7.5-8 kg/cm² for aircraft with a capacity of 40-65 passengers.

4.6. Requirements for the passenger / cargo cabin

Characteristics of the transport cabin with the maximum number of passengers should not yield to comfort of existing analogues in the corresponding classes. The characteristics of the ATR-42 / 72-600 or Bombardier Q400 aircraft could be taken as reference. The volume of the cargo compartment is determined from the average density of air cargo recommended by ICAO and equal to 161 kg/m³, but an increase is desirable to compete with the segment of turbojet aircraft of similar capacity. Aircraft layouts must provide luggage compartments for associated cargo (free and paid) with a total mass of at least 30 kg per passenger. The aircraft cabin under consideration (40 seats/65 seats) should be:

- the minimum step for installing passenger seats is not less than 765/790 mm;
- the minimum width of the seats is not less than 460-470 mm;
- the minimum passage width is not less than 460-470 mm;
- cargo compartment (with basic layout) not less than 7.5 / 13 m³;
- the height of the passage in the passenger compartment is not less than 1.9 / 1.95 m;
- the volume of the cabin is not less than 1.1 / 1.2 m³ / pass.

The noise level in the cabin (which is a significant for regional turboprops) should be less than 80 dBA. The requirements for the functional flexibility of the passenger compartment are defined in a way that for the development of new interregional routes incomplete loading is possible even with a reduced capacity,
therefore it is advisable to provide the partial transformation of passenger places for freight and post cargo. In order to improve the transport service of the regions, as well as to increase the loading of the cabins and the profit of operation it is rational to provide routes (chain, carousel, etc.) with intermediate landings. This, in turn, will help in competition with land transport. Such solutions are not a novelty, for example, there is now a route Nizhny Novgorod - Chelyabinsk - Omsk, where the CRJ-200 plane makes the next flight 50 minutes after arriving in Chelyabinsk. To maintain acceptable comfort for passengers, it is proposed to establish a requirement for aircraft preparation for a second departure within 30 minutes after landing. Also, during this time, it is necessary to ensure the possibility of prompt unloading of some passengers with their luggage and partial loading at intermediate landing points.

4.7. Requirements for service life and maintenance
To provide more rational regular traffic the capacities should be close to the average value and with the increased intensity of operation in comparison with analogs of bigger capacity. For ATR-42/72 operated in RF the average values are close to 2500 hours. Therefore, it is necessary to provide the higher intensity of operation up to cumulative annual operation of 3000 flight hours. The certified service life should be at least 20,000 flight hours or even higher. The A-check interval already for manufactured aircraft should be about 700 flight hours as compared to ATR-42. It is advisable to focus on this level when formulating requirements for the minimum frequency of the first form of periodic maintenance. In spite of custom discussions and arguments on fuel saving, increased service life and extended maintenance intervals are the key parameters for economically efficient operation. Application of new approaches for the airframe design and structural health monitoring could sufficiently improve those characteristics.

4.8. Ecology requirements
In addition to the global ICAO requirements the upcoming ones should be definitely considered providing greener and more quiet air transportation. Taking into account high European standards for urban transport, both flight safety and flight performance should be in compliance with environmental requirements, bringing design optimization for extended iterations while development. For the hybrid electric aircraft under study it is advisable to consider the long-term goals of ICAO for the generalized segment of regional aircraft. Prospective field noise targets by 2037 correspond to -17 EPNPdB (with an accuracy of +/- 6 EPNdB) in relation to the noise level of the base aircraft with 2017 technologies. Figure 8 shows a graph of ICAO requirements for CO₂ emissions for regional aircraft and an achievable target that ICAO predicts by 2037.

According to these goals, the AC with a maximum take-off weight of 15 to 25 tons it is planned to reduce specific CO₂ emissions by 1.3-1.4 times compared to the current requirements (2020) for perspective aircraft. In general, it is assumed that next-generation aircraft should provide a 20% reduction in specific fuel / energy consumption (per seat-kilometer) relative to the closest foreign counterparts for the segments under consideration.
5. Generalized TLARs

All mentioned above allow to generalize the results of the study and to present parameters for perspective regional aircraft for Russian market as given in the table below.

| Parameter                        | < 40 seats | < 70 seats |
|----------------------------------|------------|------------|
| Passenger capacity               |            |            |
| Min passenger capacity           | 1.1 m³/nac | 1.2 m³/nac |
| Cargo conversion                 | Required   | Not required |
| Max payload, kg                  | 4300-4500  | 7500-7700  |
| Range, km                        | 1000       | 1500       |
| Cruise speed, km/h               | >550       | >650       |
| Runway, kg/cm²                   | D class, 5 | C class, 6 |
| Add. operational requirements    | Secondary departure interval within 30 min after landing. Partial pax/baggage embankment and dismemberment at intern. landing within 30 min. |
| Barometric height of airport, m | (~300; 3660) | (~300; 3660) |
| Operation temperatures, C       | (~55°C; +45°C) | (~55°C; +45°C) |
| Hangar free parking              | Required for wind 55 m/sec | Not required |
| Cabin noise level , dBA          | < 80       | < 80       |
| Environmental noise, EPNdB       | -25        | -20        |
| Decreased emission NOx (reg. CAEP/6 ) | 45-60% | 45-60% |
| Operation costs, seat-km         | -20% reg. ATR42 | -20% reg. ATR72 |
| Annual flights hours             | 2000-2500  | 2500-3000  |
| Min A-check interval             | 2500 flight hours | 2500 flight hours |
| Service life                     | 25000 flight hours | 25000 flight hours |

6. Summary

The application of the innovative and disruptive technologies in the structure of new regional aircraft should provide in the future sufficient competitive advantages for the airliner in comparison with the traditional technical solutions. Taking into account the top-level requirements defined and presented in this paper, the rational selection and optimal combination of these technologies should bring the aircraft design to a new level. The analysis of these applicable technologies, key technologies roadmap and concept design are the next stages for the research.

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