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The effects of COVID-19 pandemic on the performance of airport renovation projects: the case of Pulkovo Airport

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Abstract

This paper explores the effects of the COVID-19 pandemic on the performance of airport renovation projects. The research examines the case of the renovation project of the Saint Petersburg's Pulkovo Airport in Russia, which started in 2010 within the concession agreement of the Northern Capital Gateway and the Government of Saint Petersburg until 2040, and raises the question of how this pandemic influenced the performance of Pulkovo airport renovation project. A Cost-benefit analysis and its sensitivity analysis were used to determine how restrictive measures against the spread of COVID-19 affected the profitability and social indicators generated by Pulkovo Airport. The social effect of infrastructure renewal was determined in accordance with the Efficient Time Allocation and Generalized Cost of Travel theories. The study reveals a decrease in the Net Present Value (NPV) of the renovation project due to changes in the trends of passenger traffic and the number of take-off and landing operations, a decrease in the growth rate of airport revenue and a partial reduction in operating costs. The expected Social NPV of the project decreased by 94.32 percent, and the benefit-cost ratio drastically reduced to 1.33, from a 4.06, had the pandemic not developed. The sensitivity analysis suggests a shift in the key variables that affect the performance of the analysed infrastructure project.

Keywords: cost-benefit analysis; infrastructure project; airport renovation project; investment project; aeronautics; aviation

1. Introduction

Airports are social infrastructure facilities, generating both positive and negative externalities (Small, 2013). Airport renovation projects allow increasing the positive social effect, by solving problems of matching airline

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schedules and reducing waiting times in the air and at the airport, specifically, to modernize air traffic control systems, allowing aircraft to take-off and land more quickly, having planned all the details; furthermore, to modernize aircraft maintenance and passenger screening systems. This also results in reduced fuel consumption and gas emissions (Sheina et al., 2022). However, it is also necessary to consider the impact of infrastructure renovation (Shami, 1996), including the creation of the project, on the time passengers spend traveling to, staying at the airport, and going through all the security procedures, and onboard waiting for the aircraft maintenance, as well as the flight itself on the airplane.

In 2020, the COVID-19 pandemic greatly affected the air transportation industry. According to the International Air Transport Association (IATA), the total number of air passengers dropped from about 4,500 million in 2019 to just under 2,000 million in 2020 (Statista, 2023). The changes have altered different aspects of the industry: airlines (Mumbower, 2022), airports (Vasilj et al., 2021), passengers (Linden, 2021), markets (Warnock-Smith et al., 2021), sector economics (Zhang and Zhang, 2021), workforce (Wu & Shila, 2021), and sustainability (Gössling & Lyle, 2021).

Recent research note irregular trends in the air transportation industry, such as a sharp and significant decline in passenger traffic, increased costs for airport and aircraft security, additional staff training, dealing with psychological problems of employees caused by the situation, and others (Sun et al., 2022). This indicates that in the case of major social infrastructure projects, the impact of COVID-19 can greatly change the social cash flows, affecting the payback of these projects, as profits are reduced, and costs are increased. Consequently, it is necessary to reassess such projects, and their potential social effect with consideration of the pandemic effect.

The purpose of this study is to evaluate the results of airport renovation in Russia (focusing on Pulkovo Airport in St. Petersburg as a case study), examining the positive social effects associated with reduced congestion and travel times for regular and business passengers in view of the impact of the COVID-19 pandemic. A research question answered to achieve the goal: how do investments in airport capacity expansion impact the overall well-being of the Russian society, considering the effects of the COVID-19 pandemic? How does it affect the welfare of airline operators and airports?

Since the Pulkovo airport was reconstructed in 2010-2015 (Airport Pulkovo, 2015) we analyse the generated social effects for the period based on data up to 2021 inclusive with projections up to 2040, which is the last year of the concession agreement (Airport Pulkovo, 2023a). To account for the impact of only one significant event — the coronavirus pandemic — without taking into consideration the sanctions pressure on the industry, which increased substantially in 2022, and to avoid confusing the effects of two events that are different, it was decided to consider data until 2021.

Consequently, this study examines the problem, little studied at the moment, associated with the profitability and efficiency of large social infrastructure projects, in terms of the social effect they generate and taking into account the negative effects of the pandemic of COVID-19. The case study of Pulkovo Airport, a major international airport in Russia, connecting the countries of Europe and Asia, with a large flow of international passengers, allows to use the results and validation of the methodology for assessing such projects to be used in the case of other international airports in terms of return on their renovation projects in the context of formation of social benefits to the users of these airports.

2. Literature Review

Performance evaluation of aviation infrastructure considers time savings for passengers resulting from infrastructure renovations. The time allocation theory, proposed by Becker (1965), integrates time into utility functions for goods, services, and activities within a household. Becker's model considers labour and leisure time but is criticized by Pollak (2012) for its limited representation of behaviour and preferences. Oort (1969) research advocates including travel time in utility functions, reflecting reduced labour or leisure time due to travel. Jara-Diaz et al. (2000) emphasize the subjective nature of valuing travel time, suggesting assessing opportunity costs using wage rates and the value of foregone activities. Truong and Hensher (1985), and Biddle and Hamermesh (1990) highlight the value of time, influenced by salary level, leisure or work time, travel purpose, income, gender, and marital status. Travellers perceive their time as more valuable when working more than desired and less valuable when working less. Metz (2008), however, questions the theory of travel time conservation, arguing that minor time reductions may not be perceived as savings. Short trips' time reductions may lead to increased demand for additional trips, challenging the effectiveness of cost-benefit analysis (CBA) in reflecting real behaviour.

A constantly and uninterrupted air transport sector provides significant economic development for countries and regions, especially those without dense road and sea or river connections, with low population densities (Amos, 2004). When the demand for passenger air travel and cargo transportation increases, there is more pressure on all the links in the logistics chain: both, on airports and airlines. As a result of this pressure, there are situations when the capacity limit is reached, resulting in congestion. Therefore, to avoid such situations, it is necessary to transform the infrastructure, increase the capacity (Zou et al., 2015; Saldıraner, 2013). The growing demand for air transportation services has led to significant pressure on existing airport infrastructure (Gelhausen et al., 2013), resulting in the need for airport renovation, increased square footage, expansion and renewal of infrastructure and a change in the approach to managing airport, airline and aircraft planning and maintenance. When traffic becomes very high, intense, and reaches a level close to the limit capacity of the take-off and landing system, the airport faces several operational and system challenges. First, it becomes difficult to maintain consistently good quality operations, without errors or overlaps. And there is also a high risk that future traffic growth may lead to increased traffic, and the airport eventually faces the fact that future traffic growth can no longer be accommodated (Gelhausen et al., 2013). Moreover, even now, some important airports that are major international hubs have been struggling for years with capacity constraints and excessive congestion, problems of rising traffic costs due to high demand from carriers and passengers; such airports include: Heathrow, Charles de Gaulle, London, Frankfurt, and New York LaGuardia (Gelhausen et al., 2013).

In air transportation, time is a crucial factor affecting the overall cost of the entire route, including processes such as airport services, carrier and passenger services, check-in procedures, waiting times, baggage handling, pre-flight services, take-off and landing (Gillen et al., 2016). The capacity of the airport also influences these factors and the flight itself. Researchers emphasize the significance of operational maintenance and logistics for aircraft. The efficiency of preflight maintenance, aircraft readiness checks, and operators' planning and execution impact the flight's final time (Lonzius and Lange, 2017). Atomistic models, which describe the impact of airport congestion, highlight tight time barriers and the strong effect of flight delays on other flights (Brueckner, 2002). Transforming airport infrastructure can reduce congestion and time costs for passengers and airlines. However, the cost of airport renovation falls on the operators, airlines, and passengers. Alternatively, the state could share the burden if social benefits outweigh renovation costs. A cost-benefit analysis (CBA) should assess the renovation's effects, including potential reductions in congestion and passengers' travel time, which could lead to increased productivity and benefits.

In short, airports play a vital role as complex infrastructural social projects, facilitating both ordinary and business trips via air transport. However, these trips involve considerable time spent on flights and various pre- and post-flight procedures. Factors like airport congestion, flight schedule overlaps, maintenance issues, and infrastructure decay can further increase travel time for passengers and cargo. Such time losses are significant since they represent missed opportunities for engaging in productive activities or work, leading to potential financial gains.

Evaluating the costs associated with existing airport infrastructure is essential, particularly during periods of increased demand and technological advancements. Mitigating these costs while considering technological progress and airport development potential becomes crucial for passengers, airlines, operators, and carriers.

Airport renovation has the potential to enhance the overall welfare of society by reducing transportation and cargo service costs. However, investors, including businesses and the state, must carefully assess the existing costs and potential profits, both tangible and intangible, such as social effects or cash flows. The Cost-Benefit Analysis (CBA) method can be employed to conduct this assessment effectively.

3. Data Sampling

This study uses the operations data of Pulkovo airport in St. Petersburg for the period from 2007 to 2021. Pulkovo airport was selected for this research as a case study as it is a major regional hub that provides large flows of passengers on both domestic and foreign flights and allows to use a tested methodology on similar airports in Russia and abroad.

The data was collected on the airport's domestic and international passenger traffic, the number of take-off and landing operations, and financial statements. The sources of all these data were: reports and the official website of Pulkovo (Northern Capital Gateway. Disclosure: Airport Services, 2023), financial and annual reports of Fraport

(Fraport AG, 2023), reports and statistical data of the Federal Air Transport Agency (Rosaviation, 2023), ICAO (2023) and IATA (2023) publications.

4. Research Design

The goal of this research is to identify the effect of a generalized pandemic on the efficiency of airport infrastructure renovation projects. In this paper, the study was conducted on the example of Pulkovo airport, since this airport is an object of socially important infrastructure that provides services mainly to residents of two Russian regions (the city of federal status of St. Petersburg and the Leningrad region), as well as to tourists and business travellers from other regions of Russia and foreign countries. The airport belongs to the Government of St. Petersburg through JSC Pulkovo Airport, though the property of the airport was transferred to the management of the Northern Capital Gateway LLC (NCG LLC) under the agreement on public-private partnership subscribed in 2010 (Airport Pulkovo, 2023a).

As part of the agreement, the management company, the NCG LLC consortium, was to reconstruct the airport, renovate the existing terminal and build a new one. The airport was large even before the renovation, but it was necessary to meet the growing demand and implement the project of a major international aviation hub in Russia. Regional budgets and federal transfers would not have been enough to implement this project, private capital was needed (Airport Pulkovo, 2023b).

Therefore, there are two global research objectives: to evaluate the effectiveness of the Pulkovo airport renovation project and to assess specifically the impact of the pandemic on efficiency. The present research adopts a methodology aimed at evaluating the efficacy of airport infrastructure renovation projects by a cost-benefit analysis.

The main benefit indicators are calculated on the basis of the effective time allocation and generalized cost of travel (GCT) theories, which allow to present the social effect in a monetary form: the benefit to society by reducing the travel time in air transport, as well as the waiting time and passing all procedures before and after the flight, the time were evaluated as an opportunity cost in monetary form.

The study identifies the economic effects of implementing the airport renovation project on the welfare of society, which is defined in equation (1), as the changes in the private effect for the concession holder (NCG LLC), the economic effect for the public authority (The Government of Saint Petersburg), owner of the infrastructure facility, and the social effect for citizens (passengers):

$$\Delta W = \Delta CS + \Delta GS + \Delta PS \quad (1)$$

where: ΔW– changes in welfare for society; ΔCS – concession holder surplus; ΔGS – government surplus; ΔPS – passenger surplus.

To identify specifically the pandemic effect, this study conducted two performance evaluations of the renovation project: with and without pandemic years. On the basis of several parameters that allow estimating the social effect for passengers in monetary terms and estimating the economic effect for the state and the concession holder for the two scenarios, changes specifically from the implementation of the airport renovation project were calculated in the form of incremental cash flows for the effects of all three participants (2) in the relationship around Pulkovo Airport:

$$\Delta W = \Delta CS + \Delta GS + \Delta PS = CS\left(Q^1_{pas}, Q^1_{op}, g^1, t^1, t^1_{p.sh}, r^1_{ex}, w^1_{SL}, c^1_{works}, g^1_{OPEX}, g^1_{REV}, SP^1\right) - CS\left(Q^0_{pas}, Q^0_{op}, g^0, t^0, t^0_{p.sh}, r^0_{ex}, w^0_{SL}, c^0_{works}, g^0_{OPEX}, g^0_{REV}, SP^0\right) + GS\left(Q^1_{pas}, Q^1_{op}, g^1, t^1, t^1_{p.sh.}, r^1_{ex}, w^1_{SL}, c^1_{works}, g^1_{OPEX}, g^1_{REV}, SP^1\right) - GS\left(Q^0_{pas}, Q^0_{op}, g^0, t^0, t^0_{p.sh}, r^0_{ex}, w^0_{SL}, c^0_{works}, g^0_{OPEX}, g^0_{REV}, SP^0\right) + PS\left(Q^1_{pas}, Q^1_{op}, g^1, w^1, g^1_w, Q^1_{bus.pas}, Q^1_{other\ pas}, Time^1_{saved}\right) - PS\left(Q^0_{pas}, Q^0_{op}, g^0, w^0, g^0_w, Q^0_{bus.pas}, Q^0_{other\ pas}, Time^0_{saved}\right) \quad (2)$$

where CS, OS, PS are functions of: Q_{pas} – passenger flow; Q_{op} – operations; g – prices; t – taxes; $t_{p.sh}$ – share of taxpayers; r_{ex} – exchange rate; w_{SL} – wages (skilled labour); c_{works} – cost of works; g_{OPEX} – growth rate of OPEX (inflation and tariffs indexation); g_{REV} – growth rate of revenues (inflation, taxation policy changes and tariffs indexation); w – weighted average wages; g_w – growth rate of wages (indexation); $Q_{bus.pas}$ – share of business travellers; $Q_{other\ pas}$ – share of other travellers; $Time_{saved}$ – quantity of time saved by project implementation. For the "with project" situation, the index 1 is used, and a 0 for the "without project" situation.

The final estimates, expressed in monetary form and with the help of financial indicators that reflect the social effect, are compared in section 5 (Table 1).

4.1. Methodology

To assess the impact of the pandemic on the effectiveness of the Pulkovo airport renovation project, a methodology was used to compare the situation with and without the implementation of the renovation project. This methodology was applied twice, to two datasets (two scenarios): with and without pandemic years.

- The "no project" situation was determined which was identical for the two calculations (with and without pandemic years);
- Characteristics of a situation "with project" for two sets of data were determined: costs and benefits;
- On the base of the selected literature and statistical data on the social and economic characteristics of the region, the infrastructure object and its users, assumptions about the costs and benefits were made;
- Costs and benefits were stated in effective prices;
- Social cash flow structures were built for the two data sets under consideration, taking into account the forecasted airport traffic and passenger turnover data;
- The social net present value was calculated for all scenarios considered;
- Social cash flows were built for the "no project" situation (identical for the two scenarios under consideration);
- The "incremental social cash flows" based on cash flows with and without project situations were extracted, and the net present value for these social cash flows was found;
- Sensitivity analysis was performed for NPV in two scenarios to determine the risks of the project, as well as the change in risks, taking into account the transformation caused by the COVID-19 pandemic crisis;
- The final indicators of performance and profitability of the project were calculated specifically for the situation "with project" and separately for "incremental flows" for the two scenarios.

In order to identify the impact of the COVID-19 pandemic, two forecasts (up to 2040) were compared: based on data from 2007 to 2019 and based on data from 2007 to 2021, which include 2 pandemic years. Consequently, by comparing the two calculations, it is possible to conclude how this additional data for the 2 years in which there were significant changes in the pandemic context and airport operations had an effect on airport performance and the utility of the airport to the public.

For each of the scenarios, available historical data up to 2019 or 2021 on operations, passenger traffic, and key financial indicators were used and projections to 2040 were calculated.

4.2. Social cash flows

The calculated cash flows are used to calculate the social NPV according to equation (3) of De Rus (2010), using a social discount rate of 4.4% (Kossova and Sheluntcova, 2016):

$$NPV = -CAPEX - Cost\ of\ capital + \sum_{t=1}^{T}(Project\ Revenues_t - OPEX_t + Social\ Benefits_t)(1+i)^{-t} \quad (3)$$

To calculate the financial indicators and flows for the intermediate calculations, classical formulas were used with the assumptions specified in Appendix A. The concession holder and the public authority profits were calculated based on actual and projected passenger traffic and operations data by equation (4):

$$CR = \big((Op_{d,t} \times Tax_{d,t} + Op_{i,t} \times Tax_{i,t} \times r_{ex,t} + P_{d,t} \times Tax_{d,t} \times P_{NT,\%,d,t} + P_{i,t} \times Tax_{i,t} \times P_{NT,\%,i,t}) \times Rev_{i,\%,t} \times SP_{ex} + \big(Op_{d,t} \times Tax_{d,t} + Op_{i,t} \times Tax_{i,t} \times r_{ex,t} + P_{d,t} \times Tax_{d,t} \times P_{NT,\%,d,t} + P_{i,t} \times Tax_{i,t} \times P_{NT,\%,i,t}\big) \times Rev_{d,\%,t}\big) \times (RTr_{\%,Conc.} + RTr_{\%,(Auth)}) \times g_{REV}^{t} \quad (4)$$

where: CR – Concession holder and public authority revenues, Op – number of flight operations, Tax – airport taxes and fees, r_{ex} – RUB/EUR exchange rate, P – passenger traffic, $P_{NT,\%}$ – number of non-transit passengers who pay taxes, $Rev_{\%}$ – share of revenue from international (i) or domestic flights (d), SP – shadow price conversion factor, $RTr_{\%,Conc.}$ – share of revenue to the concession holder, $RTr_{\%,Auth}$ – share of revenue transferred to the public authority (or aeronautics, region, or port authority) , g_{REV} – revenue growth rate for the forecast years. Indicators for international flights are marked as i, for domestic flights as d; t - time period.

The social effect is considered as time saved, calculated for passengers who board because the renovation mainly affected pre-flight procedures by equation (5):

$$Boarding\ (Taxi)\ Minutes\ Saved = ((Bus.Pas._{\%,t} \times Pas._{board.,t} \times Min.Saved/60min. \times Time\ Value\ per\ Hour) + (Other\ Pas._{\%,t} \times Pas._{board.,t} \times Min.Saved/60min. \times Time\ Value\ per\ Hour)) \times g_{WAGE,t} \quad (5)$$

where: $Bus.Pas._{\%,t}$ – share of business passengers, $Other\ Pas._{\%,t}$ – share of travellers, $Pas._{board.,t}$ – number of passengers boarding the flights, $Min.Saved/60min.$ – number of hours saved, $Time\ Value\ per\ Hour$ – value of time for passengers depending on their status, $g_{WAGE,t}$ – wage growth factor, t - time period.

The projected operating costs were calculated based on the calculated growth rate since project implementation for "with project" situations in equation (6):

$$OPEX_{SL(Work),proj.,t} = OPEX_{SL(Work),t-1} \times g_{OPEX} \times OPEX_{SL(Work),\%} \quad (6)$$

where: $OPEX_{SL(Work)}$ – operating costs for skilled labour or work, raw materials and supplies, g_{OPEX} – operating cost growth factor, $OPEX_{SL(Work),\%}$ – share of operating costs for skilled labour or work, raw materials and supplies in total operating costs.

All cash flows were discounted by the social discount rate (7):

$$CF_D = Act.CF/(1 + r_s)^t \quad (7)$$

where: CF_D – discounted cash flows, $Act.CF$ – real cash flows, r_s – social discount rate.

For the "no project" situation, cash flows were calculated as per equation (8) at the level of the airport's marginal capacity reached by 2013 before the implementation of the first results of the airport renovation project; to take into account the growth of prices and tariffs, the indicator of price and tariff growth - the average annual inflation rate in the air transport sector in Russia - was used as per assumptions in Appendix A.:

$$CF_t = CF_{t-1} \times g_{n/p} \quad (8)$$

where: CF_t – cash flows in each year t, $g_{n/p}$ – cash flow growth rate in the "no project" scenario.

To identify the effect of the renovation project, social incremental cash flows were calculated for the scenarios with and without the pandemic (9):

$$Soc.Incr.CF = CF_{w/p} - CF_{n/p} \quad (9)$$

where: $Soc.Incr.CF$ – social incremental cash flows, $CF_{w/p}$ – cash flows in a "with project" situation, $CF_{n/p}$ – cash flows in a "no project" situation.

4.3. Social Indicators and Sensitivity Analysis

To identify the social effects, social indicators based on social cash flows were calculated: NPV (3), IRR (10), B/C ratio (11).

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t} = 0 \quad (10)$$

$$B/C\ ratio = \frac{Present\ Value\ of\ Benefits}{Present\ Value\ of\ Costs} \quad (11)$$

The Sensitivity analysis based on Monte Carlo simulations allows to estimate the degree of probability of NPV values spread, as well as to highlight those factors that have the greatest influence on the change in the value of this indicator. In this study 10,000 simulations were used for each of the scenarios and 13 parameters (displayed in Fig. 1) that affect the NPV.

5. Results and discussions

In this paper, the pandemic has been used as a quasi-natural experiment, enabling a comparison of two scenarios to assess the project's efficiency and profitability under its powerful shock. Table 1. shows the results of the cost-benefit analysis performed in this study. Based on data from 2007-2019, the social NPV without the pandemic, was estimated to be 885,518 million rubles with a probability of 49.39%. However, considering pandemic years (2007-2021), the social NPV is 292,032 million rubles with a probability of 51.67%. Before the pandemic, the potential NPV ranged from 537,203 to 1,253,473 million rubles with a 94.71% probability. After the pandemic-induced transformation of the business model, the NPV range became 176,140 to 410,992 million rubles with a 98.17% probability. Overall, the airport, both pre- and post-pandemic, remains profitable, with no negative NPV scenarios under consideration, though the possibility of such circumstances are observed.

In a scenario without the pandemic, the renovation project significantly contributes to the airport's performance, accounting for almost three-quarters of its total during the concession period until 2040. The project improves airport efficiency, evident from the higher benefit/cost ratio (B/C ratio) of 4.06 compared to the airport's B/C ratio of 3.89. The airport has a relatively high social Internal Rate of Return (IRR), typical for major international infrastructure projects. Notably, the social effect in terms of benefits to passengers, estimated in saved minutes, constitutes 12.9% of the project's total benefits.

Table 1. Social Profitability Indicators without and with Covid-19 pandemic - Pulkovo Intl. Airport, in millions of Rubles

	Without pandemic		**With pandemic**	
Parameter	With Project (1)	Incremental (2)	With Project (3)	Incremental (4)
CAPEX [Government SPb]	0	0	0	0
CAPEX [NCG LLC]	42472	42472	42472	42472
Cost of Capital	59849	59849	59849	59849
OPEX [Skilled labour]	105695	49561	54824	642
OPEX [Works]	98732	46296	51212	599
Present Value of Costs (a)	**306748**	**198178**	**208357**	**103562**
Revenues [NCG LLC]	963264	620666	365154	44487
Revenues [Government SPb]	125170	80652	47449	5781
Boarding Minutes Savings (b)	48207	48207	40758	40758
Taxi Minutes Savings (c)	55624	55624	47028	47028
Total Benefits Users (b + c)	103832	103832	87786	87786
Present Value of Benefits (d)	**1192266**	**805149**	**500389**	**138054**
Social Net Present Value (d - a)	**885518**	**606971**	**292032**	**34492**
Social Internal Rate of Return	**54.63%**	**17.92%**	**48.39%**	**6.35%**
Benefit/Cost Ratio (d ÷ a)	**3.89**	**4.06**	**2.4**	**1.33**

Note(s): This table shows the Social Net Present Values (NPV) of the renovation project and the incremental cash flows without the pandemic on columns (1) and (2) and with the pandemic on columns (3) and (4). Source: Own calculations.

However, the pandemic led to a significant decline in the airport's performance. The NPV until 2040 decreased by three times mainly due to a 2.38-fold reduction in potential benefits, particularly in revenues. Despite the reduction in benefits, the airport remains socially profitable with benefits exceeding costs by 2.40 times. The renovation project's NPV decreased by 94.32 percent (34,492/606,971-1), and the benefits are now only 1.33 times larger than costs, instead of the 4.06 times had the pandemic not evolved. Additionally, the project's operating costs also decreased significantly due to necessary business model transformations to survive the pandemic crisis's difficult and unstable conditions. Despite the rapid changes in the airport's business model due to the pandemic, the positive social impact for citizens was maintained, and the airport's profitability was sustained.

The sensitivity analysis (Fig. 1) reveals that in the scenario without the pandemic (left side), Pulkovo's NPV was mostly influenced by the revenue growth rate (43.8%), which includes inflation, airport tariffs, and taxes. The social discount rate (-21.6%) and exchange rate (16.9%) also played significant roles. The share of non-transit passengers (15.3%) and other parameters had less influence on NPV uncertainty.

Under the pandemic scenario (Fig. 1, right side), the influence of indicators on NPV changed significantly. The largest contribution to the Social NPV uncertainty came from the share of tax paying passengers (31.9%), resulting in a potential NPV variation from 260 billion to 327 billion rubles with a ±12.8% change in this indicator. The share of non-transit passengers also had a more significant impact, with an elasticity coefficient of 0.9, meaning a 1% increase in the share would lead to a 0.9% increase in NPV.

The pandemic highlighted the importance of the social effect on passengers, leading to increased uncertainty in the social NPV, depending on wage growth and the number of working hours of passengers.

Time saved became even more crucial as a quasi-cash flow that forms project benefits. The concession holder's and City Government's share of revenue decline reduced the influence of revenue growth on the social NPV. Before the pandemic, the NPV elasticity of revenue growth was 1.30, but in the pandemic scenario, it decreased to 0.33.

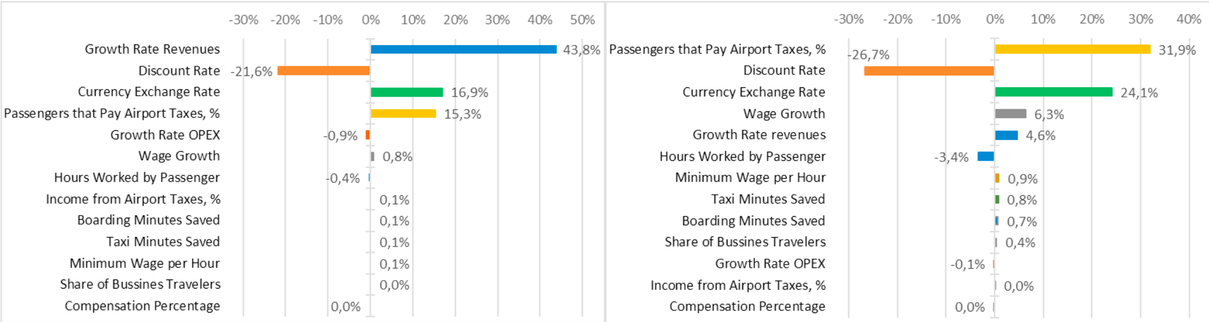

Fig. 1. Sensitivity of airport's project NPV without pandemic (left) and with pandemic (right), as contribution to variance in %

6. Conclusions

The key findings of this research consist in: a) testing an existing economic evaluation methodology to airport renovation projects adjusting it to a quasi-natural experiment such as a generalized pandemic; b) although the pandemic drastically reduced the profitability of the analysed renovation project, it managed to remain profitable after all. c) airport technological innovations turn into a change in the business model of the analysed airport to make it even more efficient in its operations.

Through the cost-benefit analysis performed, it has been possible to account for the change in the ratio of domestic and international passenger traffic, and in the global reduction of operating expenses because of the restrictions caused by the pandemic. These transformations have influenced trends in the airport's key performance and productivity indicators, as well as the potential social effect that can be generated. As a result, the existing renovation project became much less profitable, as the expected Social NPV of the project decreased by 94.32 percent, and the benefit-cost ratio drastically reduced to 1.33, from a 4.06, as a direct result of the pandemic. Yet there is a probability that the social NPV could turn zero or negative, at times of high social risk events such as a pandemic.

Pulkovo airport was forced to change its business model, becoming more cost-efficient. Reductions in expenses have been made in payroll, employee bonuses, maintenance of fixed assets, and associated costs and rent payments. Though these costs may have to be increased, the airport can use the experience gained during the pandemic and use modern technology and resource reduction measures in maintaining the operations of the transportation hub.

A very important effect of this project is that despite the strong reduction in revenue from the project, the effect on passengers has not decreased much due to the impact of the pandemic. Therefore, the renovation project also remains important and necessary in terms of generating public goods. Since the share of benefits from saved time as a result of the pandemic outweighed the share of revenue from the project, the airport's NPV became more influenced by passengers' wages and working hours (i.e., the indicators that adjust the cost of passenger hours). It is important to notice that the airport cannot affect the amount of time saved without an additional renovation project or the implementation of new technology, which would require new investments and possibly a new concession agreement.

In short, the pandemic, due to flight restrictions, has severely impacted both passenger traffic and flight operations, as well as cash flows. Revenues were decreased by reduced flights and by the airport having to lower fares for airlines; and the airport also had to cut operating costs to survive. As a result, the profitability and attractiveness of the project declined; nonetheless, the important social effect remained: the airport provides passenger services with reduced time spent at the airport itself due to the renovation (only time reductions as a result of infrastructure renewal are considered, Appendix A), despite the fact that total passenger traffic will decline over the life of the project through 2040 as a result of pandemic effects. This is the effect that was captured based on current historical data through the end of 2021. However, before the expiration of the concession agreement, other hazards may arise, which may affect the efficiency of both the entire airport and the renovation project itself. One example of such risks are the travel restrictions as a consequence of sanctions due to the Russo-Ukrainian conflict that developed in early 2022, which may have sharply impacted this airport's passenger traffic and flight operations after the first quarter of 2022. Future research should include sufficient data on this particular shock in our methodology and be able to update the results of the economic indicators here calculated.

Appendix A. Assumptions

Assumption	Source
Project life: 30 years	
First year of "with-project" situation: 2016	
First year of project implementation: 2010	
Last year of project life: 2040	
Base years of "without project" situation: 2010-2013	
Base years for projections without impact of COVID-19 pandemic: (2007) 2010-2019	
Base years for projections with impact of COVID-19 pandemic: (2007) 2010-2021	
Project costs (CAPEX): 1190 million euro or 46206 million rubles (exchange rate 38.8283 rubles per 1 euro)	European Bank for Reconstruction and Development, 2023. Bank of Russia (2023).
Project WACC: 13.20%	Lewis et. al, 2011.
Average time savings: 15 minutes	Rincon, 2021.
Minimum wage per hour: 45.59 rubles (2016)	Author's calculation based on Garant (2023), Statista (2023) and Rosstat — Labour market, employment and and wages (2023).
Share of other travellers in national income: 27.03%	
Share of business-travellers in national income: 45.31%	Author's calculation
Share of business-travellers: 68%	Civil aviation in Russia: is flying normal? (2022). Planes first! Russians about civil aviation. (2018).
Share of other travellers: 32%	
Time value per hour of business-travellers: 697.50 rubles	Author's calculation based on Statista (2023) and Rosstat — Labour market, employment and and wages (2023).
Time value per hour of other travellers: 273.56 rubles	
Domestic airport tax: 301 rubles	Airport Pulkovo. (2023c). Aeroflot, 2023.
International airport tax: 21 euro	
Fees for use of boarding bridges on domestic flights: 2407 rubles	
Fees for use of boarding bridges on international flights: 142 euro	
Domestic aerodrome fee: 30284 rubles	
International aerodrome fee: 772 euro	
Share of passengers' taxpayers (2021): 96.83%	Author's calculation based on ATO (2019)
Share of revenue transferred to government: 11.50%	Accounts Chamber of the Russian Federation, 2011
Share of revenue transferred to operator: 88.50%	
Exchange rate rubles per euro: 76.06	Bank of Russia (2023)
Shadow price foreign exchange: 1.090	European Union Regional Policy
Shadow price skilled labour: 0.850	
Shadow price works: 0.794	
Share of skilled labour in OPEX: 50%	
Share of works in OPEX: 50%	
OPEX growth rate (2021): 1.36%	Author's calculation based on airport statistics
Revenue additional growth rate (2021): 3.71%	
OPEX growth rate (2019): 8.04%	
Revenue additional growth rate (2019): 9.76%	
Wage growth rate (2021): 9.29%	Author's calculation based on Rosstat — Labour market, employment and and wages (2023).
Wage growth rate (2019): 9.25%	
Inflation in air transportation sector: 1.5%	Transport of Russia, 2014
Share of revenue under international taxation (2021): 40.45%	Author's calculation based on airport flight statistics, financial statements and taxation policy
Social discount rate: 4.40%	Kossova and Sheluntcova, 2016

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