Possibilities of implementation *fuzzy* decision making models in process of airport privatization

Amsterdam 3-4. July 2008.
Aviation Research Workshop

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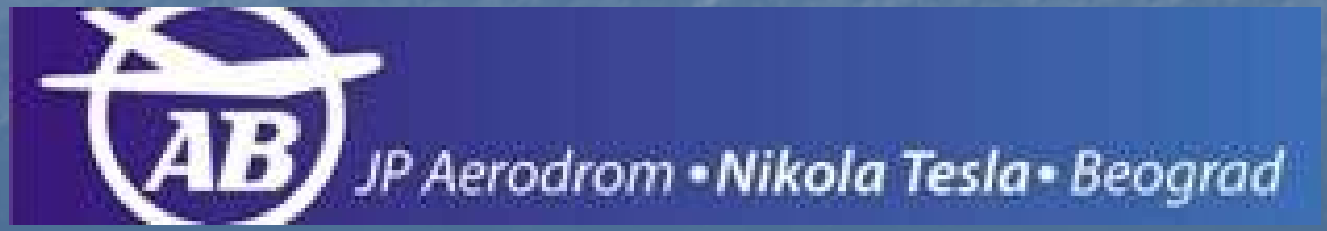

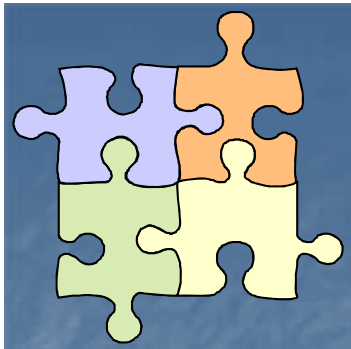

Scope

- Privatization is global trend in all industries, widely used concept in airport business
- Classical decision making is congested with numerous parameters to be assessed
- *Fuzzy* multi criteria analysis solves complex transportation economics problems more efficiently
- Contents: airport sector drivers, airport privatization models and risks, basics of *fuzzy* decision making, and finally *fuzzy* multi criteria analysis model for decision making on airport privatization.

Introduction

- Since the first airport privatization took place, private sector participation became worldwide trend, especially in countries unable to maintain, finance or develop their own airports.
- Privatization is process of transforming enterprise ownership from public to private, as response to increased competition pressure and need to find capital funds for infrastructure development.
- Only in year 1997, worldwide privatizations gathered almost €160 billion. It became golden economy rule, no matter of political constitution of states.
- Goal is to find necesarry investments for development projects and to improve business performances like in private sector.

Global trends and drivers in airport sector

Air transport of today basically belongs to global industry with following strong factors in airport market:

- Globalization- Air transport system is the main globalization catalyst, simultaneously failing to adapt to it, because globalization induced forces change competition dynamics of this industry.
- New technologies- As innovations pioneer, air transport industry rushed to implement many "science fiction" technologies, directly linking to cost expenditure for modern infrastructure and technology.
- (De)regulation- ICAO bilateral regulation in air transport changed for more efficient and competitive free market and full competition model.
- Sustainable mobility- Air transport became victim of its own success in all of three aspects: social (terrorism, culture, human resources, quality perception), financial (fiscal policy, tariff system, energy, taxes), and environmental (flora and fauna, human life, noise, air pollution).

Global trends and drivers in airport sector (cont'd)

- "Open skies"- Without ballast of regulation in competitive environment, it means non-restricted routes, capacities, frequencies, tariffs and agreements (especially *charter* and *cargo*), *code sharing*, non-discriminatory reservation system etc.
- Low cost sector- Services diversified and many different low budget airlines and airports were born, thus attracting passengers who didn't use air transport before, widening airport population.
- Intermodality- Congestion along most wanted air corridors and constrained number of airport slots became significant problem, partially solved by popularization of other modes of transport (rail and multimodal).
- Privatization- Financial reasons (lack of budget for infrastructure investments) and pressure for greater profit (airports focus on commercial activities, less depending on aeronautical revenues) moved investment and management responsibilities to private sector.

Airport privatization concept

- Airports remained public during the most years of their history, by ownership, management and financially.
- Recesion in economy resulted in change of thinking, involving modern transportation management and private participation.
- 1985-2000 forecasts showed doubling pax figures, which put high preassure on airport infrastructure.
- 1998 assessed additional $350 billions for airport infrastructure development for traffic up to 2010.

Privatization is way out to handle this financial burden.

History of airport privatization

- Great Britain- year 1987, 16 local airports plus 7 in BAA commercialled for £1.2 billion. Airport operator could increase profit only by non-regulated activities.
- USA- Airport market is mixture of public and private owned and operated airports, only two state- owned. From 1970, state funds only for airside development.
- Developing countries keeping in progress with developed ones. Best practices are in Asia (especially China and India) and Latin America (Argentina).

Models of private sector involvement in airports

Options	OPTION 1	OPTION 2	OPTION 3
Allocation of responsibility	**Public ownership and investment; Private airport management and operation**	**Public ownership; Private investment, management and operation**	**Responsibility for ownership, operation and investment lies on private sector**
Ownership **Investments** **Management**	State State Private sector	State Private sector Private sector	Private sector Private sector Private sector
Private sector participation models	(Multi) Concessions, Outsourcing, Management Contracts	BOT models, Long-term lease, Master concessions	BOO models, Strategic Sale, Capital markets
Case studies	Aeroports de Cameroon, Pittsburgh Int'l, Hong Kong	Athens Int'l, Lester B Pearson, La Chinita (Venezuela)	BAA, Sangster Int'l (Jamaica), Belfast Int'l

Total sale, Partial privatization, Concession agreement
Public Private Partnership: Contracting out, Management contract, Long-term lease, Joint venture

Secondary sale of early privatized airports to more competitive specialized investors.

Risks of airport privatization

Changes are the only constant of our times.

- Higher risks in airport privatization than in any other industry, because of great monopoly value. Nevertheless, history has not shown unsuccessful airport privatization.
- Observation has various perspectives (economy, social aspect, ecology, safety, security) of all relevant stakeholders (state, private sector, airlines, passengers, employees, concessionaires) and wide range of organizational, social, technological and environmental concerns to preserve public interests.
- Risk elements: air transport forecasts, income / cost forecast, airport development plans, business risk, organizational culture, institutional influences and privatization aspects.

Risks are to be identified, measured, forecasted and lowered at acceptable level.

Fuzzy approach in decision making

- Very hard to find precise universal parameters and even harder to quantify them, so that approximate reasoning is tool better than classical complicated mathematics.
- In transportation management decisions are made on the basis of decision maker's experience, intuition and subjective evaluation. *Fuzzy* approach advantage is the possibility to use experience rules, intuition or descriptions, without need to model the process itself.
- Qualitative e.g. *fuzzy* nature of human reasoning process encouraged engineers to develop *fuzzy* controllers based on imprecise, qualitative data in combination with linguistic set of rules.
- First practical application in 1975 proved that controller can be exclusively logical one. Numerous applications in industrial and transportation processes, recently managerial decision making.

Fuzzy approach in decision making (cont'd)

- Road traffic management, freeway ramp metering, human sense for distance and angles in garage parking, automatic control of traffic signals at intersection of two one-way streets, automated railway *fuzzy* controller
- Route problems, network „loading" algorithm, vehicle routing and transshipment, dispatching models in road, river, rail and air transport
- Selection of transportation investment projects, performance, safety, quality, efficiency and privatization models.

Fuzzy in airport privatization process

- Multi objective problem with many conflicting goals; big challenge.
- *Fuzzy* is very interesting tool, proved very effective in tackling problems of transportation management.
- Multi criteria analysis has been widely used, although there is no best approach and quite often outcomes vary on concept used. There is evident need to develop simple, comprehensible and reliable approach, to get consistent outcomes.
- To overcome this problem in airport privatization field, it is proposed effective *fuzzy* multi criteria analysis approach, which generates a crisp (satisfaction) performance index for each alternative based on the concept of the ideal solution.
- Suggested model is to be tested in near future, and more or less modified, it can be used in any related privatization decision making.

Proposed *fuzzy* model

- Multi criteria *fuzzy* decision making model
- Two-phased: first phase using *fuzzy* numbers to express decision maker's assessment on alternative' performance with respect to each criterion (Chen and Hwang, 1992; Ribeiro, 1996). After criteria weighting, overall utilities of alternatives are aggregated by *fuzzy* arithmetic (Kaufmann-Gupta approach). Second phase ranks the alternatives, comparing their corresponding *fuzzy* utilities (Zeleny, 1998; degree of optimality).
- Two-leveled: basic level (consideration of sub-criteria) and higher level (approximate reasoning).
- Supposing, in accordance with specifics of airport privatization process, it is possible to use *fuzzy* linguistic approach instead of traditional one, that way by-pass numerical quantifying of hard-to-get decision parameters.

Proposed *fuzzy* model (cont'd)

basic level

- Airport privatization problem involves a set of n different possible models (alternatives) $A_i\ (i= 1, 2, \ldots, n)$. These alternatives are to be evaluated based on a set of m independent criteria $C_j\ (j= 1, 2, \ldots, m)$. Each criterion C_j may be broken down into p_j sub-criteria $C_{jk}\ (k= 1, 2, \ldots, p_j)$.
- The decision matrix for m criteria and n alternatives is given by experts or aggregated from the corresponding lower-level decision matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1m} \\ x_{21} & x_{22} & \ldots & x_{2m} \\ \ldots & \ldots & \ldots & \ldots \\ x_{n1} & x_{n2} & \ldots & x_{nm} \end{bmatrix}$$

Proposed *fuzzy* model (cont'd)

basic level

- If sub-criteria Cj_k $(k= 1, 2, \ldots, p_j)$ are used for criterion C_j, a lower-level decision matrix is:

$$Y_{C_j} = \begin{bmatrix} y_{11} & y_{21} & \cdots & y_{n1} \\ y_{12} & y_{22} & \cdots & y_{n2} \\ \cdots & \cdots & \cdots & \cdots \\ y_{1p_j} & y_{2p_j} & \cdots & y_{np_j} \end{bmatrix}$$

- The weighting vectors for the evaluation criteria or sub-criteria W and W_j $(j= 1, 2, \ldots, m)$ can be given directly by decision maker or obtained hybrid (pairwise comparison, etc), are represented as:

$$W = (w_1, w_2, \ldots, w_j, \ldots, w_m),$$
$$W_j = (w_{j1}, w_{j2}, \ldots, w_{jk}, \ldots, w_{jpj}).$$

Proposed *fuzzy* model (cont'd)

higher level

- Ranking procedure is based on the generation of the *fuzzy* performance matrix, which is the multiplication of the criteria weighting vector and the decision matrix. If criterion C_j consists of sub-criteria C_{jk}, the decision vector $(x_{1j}, x_{2j}, \ldots, x_{nj})$ across all the alternatives with respect to criteria C_j is determined by:

$$\left(x_{1j}, x_{2j}, \ldots, x_{nj}\right) = \frac{W_j Y_{Cj}}{\sum_{k=1}^{p_j} w_{j,k}}$$

- *fuzzy* maximum (M_{maxj}) and *fuzzy* minimum (M_{minj}) can be determined on the real line R to respectively represent the best and the worst *fuzzy* performance ratings among all the alternatives with respect to criterion C_j. Their membership functions are respectively:

$$\mu_{Mmax^j}(x) = \begin{cases} \dfrac{x - x_{\min}{}^j}{x_{\max}{}^j - x_{\min}{}^j} & x_{\min}{}^j \le x \le x_{\max}{}^j \\ 0 & \text{otherwise} \end{cases}$$

, $x_{maxj} = \sup \{x, x \in R \text{ and } 0 < \mu_{w_i x_{ij}}(x) < 1\}$

$x_{minj} = \inf \{x, x \in R \text{ and } 0 < \mu_{w_i x_{ij}}(x) < 1\}$.

$$\mu_{Mmin^j}(x) = \begin{cases} \dfrac{x_{\max}{}^j - x}{x_{\max}{}^j - x_{\min}{}^j} & x_{\min}{}^j \le x \le x_{\max}{}^j \\ 0 & \text{otherwise} \end{cases}$$

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Proposed *fuzzy* model (cont'd)

higher level

- The degree to which alternative A_i is the best / worst alternative with respect to criterion C_j can be calculated by comparing its weighted fuzzy performance ($w_i x_{ij}$) with the fuzzy maximum (M_{maxj}) / minimum (M_{minj}), as:

$$U_{Rj}(i) = \sup x \in R\,(w_i x_{ij} \cap M_{maxj}),$$ optimistic view

$$U_{Lj}(i) = 1 - \sup x \in R\,(w_i x_{ij} \cap M_{minj}).$$ pessimistic view

- An optimism index $\lambda \in (0, 1)$ indicates the relative preference between $U_{Rj}(i)$ and $U_{Lj}(i)$. The degree of optimality of alternative A_i in respect to criterion C_j is represented by:

$$r_{ij} = \frac{\lambda u_{rj}(i) + (1-\lambda) u_{lj}(i)}{2}, \qquad i = 1, 2, \ldots, n, \qquad j = 1, 2, \ldots, m.$$

Proposed *fuzzy* model (cont'd)

higher level

- A *fuzzy* singleton matrix is obtained from the *fuzzy* performance matrix, given as:

$$R = \begin{bmatrix} r_{11} & r_{12} & \ldots & r_{1m} \\ r_{21} & r_{22} & \ldots & r_{2m} \\ \ldots. & \ldots. & \ldots. & \ldots. \\ r_{n1} & r_{n2} & \ldots & r_{nm} \end{bmatrix}$$

- To rank alternatives, concept of positive or negative ideal solutions (alternatives) is used. The most preferred alternative should not only have the shortest distance from the positive ideal solution A+, but also the longest distance from the negative ideal solution A-, determined as:

$$r^{+} = (r_1^{+}, r_2^{+}, \ldots, r_m^{+}), \qquad r^{-} = (r_1^{-}, r_2^{-}, \ldots, r_m^{-}),$$, where

$$r_j^{+} = \sup(r_{1j}, r_{2j}, \ldots, r_{nj}) \qquad r_j^{-} = \inf(r_{1j}, r_{2j}, \ldots, r_{nj})$$

Proposed *fuzzy* model (cont'd)

higher level

- Distance between alternative A_i and the positive ideal solution and the negative ideal solution

$$s_i^+ = \sum_{j=1}^{m} (r_j^+ - r_{ij}), \qquad s_i^- = \sum_{j=1}^{m} (r_{ij} - r_j^-),$$

- And finally, crisp (satisfaction) value overall performance index of alternative A_i across all the criteria can be determined by:

$$P_i = \frac{s_i^-}{s_i^+ + s_i^-}$$

- After calculation the overall performance index for each alternative, alternatives are ranked in descending order of their performance index.

Future considerations

- Another 120 airports waiting privatization. Trend doubled in Y2K. Two issues to cover: infrastructure development and system management.
- Airport privatization is to ensure continuous, effective, efficient, safe and secure services provided to the public by private sector. An multi objective assessment is to be made against specific criteria and sub-criteria.
- Presented approach provides structured framework for decision maker to handle privatization model evaluation problem systematically from a wide variety of viewpoints added to the traditional economy and operation criteria. It is in preliminary stage.
- Research so far reached selection of evaluation criteria: safety, security, environmental concerns, efficiency and social duty. Sub-criteria that constitute each of them are being developed.
- The next step is to obtain a set of operation objectives to achieve project goal (formulation of objectives and assessment of their weights). Further, model will be tested. Appropriate comments will be made after thorough computing and sensitivity analyses. Results will be known hopefully by the end of the year.

Conclusion

- About airport privatization success- still new trend, but old enough to have positive impression.
- Privatization model choice involves subjective and imprecise assessments.
- Paper presented effective *fuzzy* multi criteria analysis approach with outcomes ranking. The model is two-phased (assessment of alternative performance and alterative ranking) and two-leveled (consideration of sub-criteria and approximate reasoning).
- This approach so far not investigated in airport privatization field. Developed model can add value to transportation economics and air transport management.

Thank you for your kind attention!

- Any questions?

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