LONG TERM INTERVAL DEMAND FORECASTING FOR AIR TRANSPORTATION NETWORKS

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ABSTRACT

In this study we consider the problem of generating long term predictions of demand for an air transport network linking a set of domestic airports so that long term capacity investments at these airports can be planned accordingly. In the considered area the concurrent as well as complementary transport modality is ground transportation. Based on demographic and economic projections, generation and attraction studies are available at different stages of the considered horizon, providing for passengers and freight flows prediction intervals. These intervals are modelized as fuzzy dual numbers allowing the development of specific modal assignment and trip distribution problems. Modal choice and traffic flows distributions are imbedded in an entropy maximization scheme which is solved along the successive stages of the planning process where traffic predictions at airports are then given by real intervals. This process can be coupled with a Dynamic Programming scheme to generate the corresponding additional capacity components to the network of airports.

Keywords: Air transport planning, networks, long term demand forecasting, entropy maximization, fuzzy intervals.

1. INTRODUCTION

As the world economy goes through successive periods of economic downturns and upturns, the airline industry is expected to continue to grow remarkably in the coming decades. Following this trend, the Airport System will expand accordingly. Airports are an essential component of the transport system infrastructure both at national and global level, offering a service with features primarily complementary to those of land transport modes.

In the Brazilian case, the air transport system has seen a remarkable development over the last decades, offering a modern and relatively efficient transportation service, partially compensating the deficiencies of the modalities of terrestrial transport presenting today an important deficit in terms of infrastructures (motorway network, inter-urban and inter-regional rail transport networks and high-speed trains). It is expected that in the next decades this deficit of infrastructures of terrestrial transport must be partly compensated to guarantee the full economic development of the Brazilian space. This will impact both the pace of development and the composition of domestic and international air transport activities.

The construction of new Airports, including their accesses, or more frequently the expansion of existing airports, requires significant investments. One characteristic of these projects is the uncertainty about the financial and environmental impacts in the medium to long term, another is the multi-stage nature of this type of projects. Airports are significant economic drivers with multiplier effects in national and regional economies. At the same time, airports are at the center of a dynamic and complex system, facing constant changes in a very competitive environment. The management and operation of airports carrying public passenger and freight transport were traditionally considered to be on the responsibility of governments, in accordance with their economic policies. In the more recent economic environment, a paradigm shift occurred in which private stakeholders emerged as investors, evolving from outsourced service providers to full-scale operators, often BOT (Built, Operate and Transfer). For the latter, the financial trajectory of their airport projects being of paramount importance, the assessment of the level of risk becomes an essential issue.

2. LONG TERM AIRPORT DEMAND MODELS

While public authorities choose economically and socially beneficial investments, the question of financial profitability is even more crucial for private investors. In the last decades, private investors have become more involved in transport infrastructure investments while financial profitability is essentially based on expected traffic. Models for forecasting travel demand are therefore a key issue.

Let us recall that the theoretical foundations of transport demand forecasting are based on the neoclassical microeconomic theory of consumer choice. The application to the transport sector has been developed since the sixties by authors such as Ben-Akiva, McFadden, Domencich or Manheim, which are the main formalizers of the theoretical foundations of the transposition of the microeconomic approach to consumer choice in transport. However, the demand model can only be a simplified representation of reality, intended to better understand or act upon it. In a mathematical model, this simplification can be divided into two operations:

- First, at the level of the construction of the theoretical model that leads to retaining only a part of the variables and causal relations that can influence the studied phenomenon.
- Then the mathematical formalization leads to a second simplification for questions of choice of mathematical functions, measurability of variables, internal coherence or complex calculations.

The value of a transport demand forecast model is linked to its operability. This depends on three conditions: its relevance, its coherence and its measurability.

Broad generic categories of models can be considered where the first distinction that is usually made refers to the structure of choice of the individual (passengers) or the company (freight). In the case of sequential models, they divide the choice of displacement characteristics into a sequence of elementary choices such as destination, mode, path, schedule, etc. The second distinction concerns the level of aggregation. In the disaggregated approach, each individual / company is considered in isolation with its individual characteristics leading to particular transport choices. On the other hand, in the aggregate approach, an average individual representative of a group or a class of individuals / companies is considered. The third commonly accepted distinction concerns the deterministic or probabilistic character attached to utility.

3. SEQUENTIAL MODELS

The sequential approach breaks the process of choice into a sequence of choices. Most of the time, four types of choices are identified:

- generation/attraction. This step corresponds to the choice of the individual to move or not. The generation/attraction stage allows to define the displacement volume reached. Most of the time, the result of the generation model is to determine the number of displacements emitted or attracted by each zone of the study area;
- distribution. This step corresponds to the quantification of trips by origin-destination pairs. The result of this step is to construct the origin-destination matrix of the displacements, while the previous one allowed to calculate the margins of this matrix;
- modal split. This step corresponds to the choice of the transport mode to carry out the movement between an origin and a destination. The result of this step is to construct as many origin-destination matrices as the modes of transport taken into account;
- assignment. This step corresponds to the choice of the route to carry out the displacement between a source and a destination with a certain mode. The result of this step provides the traffic load on each of the network segments.

Among the various techniques to solve the distribution problem which gets a central place in the sequential approach, the entropy model stands out especially when we refer to the expected properties of relevance, consistency and measurability of the model.

4. THE ENTROPY MODEL

Consider a system composed of a large number of distinct elements. A complete description of such a system requires a specification of all microstates, that is, an enumeration of all individuals with a description of the characteristics of each of the movements performed. Such enumeration is out of reach and further unnecessary, since often only the aggregate or meso-states description is sufficient. Such meso-states may correspond to sums of origin-destination matrix of microstates while macro-states of the system can be also considered. In the present case, it can be the total number of trips or the number of trips issued or received per zone.

The basic hypothesis of entropy maximization approaches is that all system microstates are equiprovable, unless otherwise available information. This hypothesis seems acceptable insofar as we do not know the system at the level of its microstates. The principle of the method is then to find the meso-state most likely to satisfy the knowledge one has about the macro state of the system. That is, the most likely meso-state, given the restrictions on the macro-state, that is, the constraints mathematically translate the knowledge we have about the macro-state of the system.

5. FUZZY NUMBERS

Beginning with Lofti Zadeh's seminal work in 1965, fuzzy logic and fuzzy set theory have evolved in many directions, with applications in very diverse fields of research where conventional techniques are obsolete to deal with very complex definitions or very vague. By providing the basis for a systematic approach to approximate reasoning, fuzzy set theory has had a significant impact on research domains such as economics, medicine, decision analysis, and artificial intelligence. The term soft computing or computational intelligence entered the literature in 1992, including the theory of fuzzy sets, neural networks, and evolutionary computation. The umbrella of soft computing brings together tools to deal with imprecision and uncertainty, however, many times this leads to cumbersome computations. More recently, fuzzy dual calculus, which corresponds to a trade-off between complexity of representation and calculation has been introduced, allowing effective resolution of uncertain mathematical programs.

6. SOLUTION APPROACH

Here a sequential approach is adopted and considering the long term forecasting horizon, it is supposed that the result of the generation/attraction produces expected interval values for the global generated and attracted volumes at each node of the transportation network. Investment scenarios with respect to ground transportation infrastucture are considered with direct influence on air transportation demand. To predict the distribution of air transportation flows, the mode assignment (ground and air) and the trip distribution problems are melted together in a new formulation of the entropy model where ground and air flows are considered simultaneously. The interval uncertainty of generated and attracted flows at each node is introduced as fuzzy dual constraints for the maximum entropy problem. This problem can be solved directly by considering the fuzzy dual optimality conditions associated to this problem which remains in essence convex.

The solution of this problem produces fuzzy dual flows for each transport modality between each pair of nodes of the transport network, i.e coherent interval predictions of demand.

7. CONCLUSION

The proposed approach to generate long term prediction of demand over an air transportation network presents two main specific characteristics :

-It produces level of demand predictions where the degree of uncertainty is explicit

-It takes into account at the network level of the evolution of the concurrent/complementar transportation modes.

This approach, coupled with fuzzy dynamic programming techniques should allow to define relevant long term investment plans for domestic air transportation.

8. REFERENCES

KINCAID, I., TRETHEWAY, M., GROS., S., LEWIS, D., ACRP REPORT 76: ADDRESSING UNCERTAINTY ABOUT FUTURE AIRPORT ACTIVITY LEVELS IN AIRPORT DECISION MAKING, TRANSPORTATION RESEARCH BOARD, WASHINGTON D.C., 2012.

GELHAUSEN M., PETER BERSTER AND DIETEZR WILKEN. , A NEW MODEL OF LONG TERM FORECASTING AIR DEMAND PASSENGER AND THE NUMBER OF AIR TRANSPORT MOVEMENTS OF GERMANY, CONFERENCE: AIR TRANSPORT RESEARCH SOCIETY (ATRS) WORLD CONFERENCE, JANUARY 2016.

KWAKKEL, J., WALKER, E., WIJNEN, R.A.A, THE TREATMENT OF UNCERTAINTY IN AIRPORT STRATEGIC PLANNING: THE CASE OF SCHIPHOL AIRPORT'S LONG-TERM VISION, 12TH AIR TRANSPORT RESEARCH SOCIETY WORLD CONFERENCE, ATHENS, GREECE, 2008.

OACI, SEARCH RESULTS FOR: 'GLOBAL AIR TRANSPORT OUTLOOK TO 2030 AND TRENDS', 2040 CIRCULAR 333, 2013.

COSENZA, C., A., N., MORA-CAMINO, F., 'FUZZY DUAL ENTROPY AND TRIP DISTRIBUTION IN TRANSPORTATION SYSTEMS', PROCEEDINGS OF THE 17TH INTERNATIONAL CONFERENCE OF HONG KONG SOCIETY FOR TRANSPORTATION STUDIES, HONG KONG, 15-17 DEC. 2012.

NIVEN R. K., M. ABEL ET M. SCHLEGEL, 'MAXIMUM ENTROPY ANALYSIS OF TRANSPORT NETWORKS', AIP CONFERENCE PROCEEDINGS, JUNE 2017.

KACPRZYK, J., 'MULTISTAGE DECISION MAKING UNDER FUZZINESS', VERLAG TÜV, RHEINLAND, COLOGNE, 1983.

PARIDA, P., K., 'FUZZY DYNAMIC SYSTEM APPROACH TO MULTISTAGE DECISION MAKING PROBLEMS', ULTRA SCIENTIST VOL. 25(2)A, 350-360, 2013.