UDC 656.7.025(045)
DOI: 10.18372/2306-1472.85.15137

Yelizaveta Sahun

EVALUATION OF THE INTEGRATED MULTICRITERIAL AIRCRAFT LOAD OPTIMIZATION MODEL

Flight Academy of the National Aviation University
1, Dobrovolskogo Street, Kropivnitsky, 25005, Ukraine
E-mail: ielyzavetamaliukova723@gmail.com

Abstract

Purpose: *presenting of results evaluation after implementation of the new developed load optimization model and model adequacy analysis in order to prove the efficiency by reducing of the main loading time criteria.* ***Methods****: experiment, heuristics, statistics, imitation modeling.* ***Results****: the developed load optimization model passed all verification procedures and the experimental data analysis enhanced its relevance in an aircraft load optimization process.* ***Discussion****: Some parametric statistical adequacy criteria were analyzed to point, that the aircraft load optimization model cannot be checked with their help. Thus, an optimization model with time criteria can be analyzed for adequacy with non – parametric T- Wilcoxon criteria. The article presents the experimental data research that demonstrates the difference between model parameters and real duration of loading / unloading procedures in real time conditions. The imitation model shows the minimization of an aircraft loading time after model's implementation. So, the following verification results can be considered as a final part of the integrated multicriterial load optimization model's effectiveness.*

Keywords: aircraft load optimization model, aircraft loading time, multicriterial optimization, statistic criteria, T – Wilcoxon criterion.

1. Introduction

In optimization tasks in an aircraft cargo transportation industry, the accuracy index is a synonym of the adequacy, which can be characterized as a coherence of the parameters of the model and the original process. Such characteristic can be a fragmentation value, average value or the other statistical evaluation [4, 10].

However, the accuracy in aircraft loading models cannot be a goal itself, as a loading process can face with systematic errors, for example last minute cargo and its handling operations. Therefore, the accuracy checking criterion cannot be considered as dogma. But the author implements another valuation of adequacy – consistency. It implies the identical changes of input and output data and the right functional relationships of the loading process.

For testing the developed optimization model for adequacy, the verification process should be executed. The verification procedure contains two sorts of data: data, collected before the optimization model implementation procedures and data produced as a result of the imitation modeling in Blender 2.83 Beta Version in area of Microsoft Visual Studio Code but in real time conditions, implying the series of different flights and schemes of cargo loading. Technically and formally, the model is verified, as it matches the main requirement – loading time reduction (Table).

2. Review of publications

The verification aspects in aircraft optimization models were mentioned in a few scientific researches [1-3].

The M. Kublanov mentions in his research the heuristic approach towards the aircraft flight dynamics that uses the detailed "physical" analysis of the high quality relationship of ruling impacts and parameters of aircraft movements with the aim of getting closer and more accurate results [6]. This approach should take into account the requirements to the finite results without pursuing to answer the countless questions about the statistically balanced sample's distribution. The approach is based on the priority of the "physical" data rather than the statistical value.

I. Štimac analyzed the existing capacity of the airport infrastructure, ground handling equipment and aircraft type implementation with vertical assessment refers to verifying the introduction of a particular type of aircraft according to predefined criteria in accordance with the availability of airport infrastructure and ground handling and horizontal assessment, which includes variable criteria and relates to the selection of an airline business model, and depends on weight factors [8].

Various works are being tested by the mathematical optimizers as in works of V. Lurkin & M. Schyns [7].

3. The aim of the research

The aim of this work is the representing of the results of the integrated multicriterial load optimization model, and highlighting its value by presenting the evaluation results after model's implementation.

Research tasks:

- the selection of the adequacy criteria;
- optimization model evaluation.

4. The selection of the adequacy criteria

The statistics contain a large amount of criterion that evaluates various models' characteristics. But in our finite case, we can use only a few of them. Student's t-test does not fit for developed model's evaluation. The main criterion – the aircraft loading time and model processing time can be linked only between each other. If the real and modeled loading time are in different selections, they are non-dependent and it becomes non feasible to analyze a connection between them.

Fisher criterion also cannot be used in model evaluation. This is not an absolute criterion, and, it should be associated with the statistical correlation together to get feasible results [5, 9]. Fisher criterion provides the similar dispersions of two selections that were not provided by our case.

Since research criterion (aircraft loading time and model processing time) are based on frequency utilization and does not include assignment parameters, non parametric criteria will be more feasible for model adequacy evaluation.

Mann-Whitney U-test also does not match with the model requirements as the selection is dependant. Therefore, the T – Wilcoxon criterion for load optimization model's evaluation will be more appropriate as it compares a few weights of the dependant selection (weights before and after the model implementation). Decision- making algorithm for load optimization model adequacy's evaluation (shift's evaluation) is shown on Fig.1.

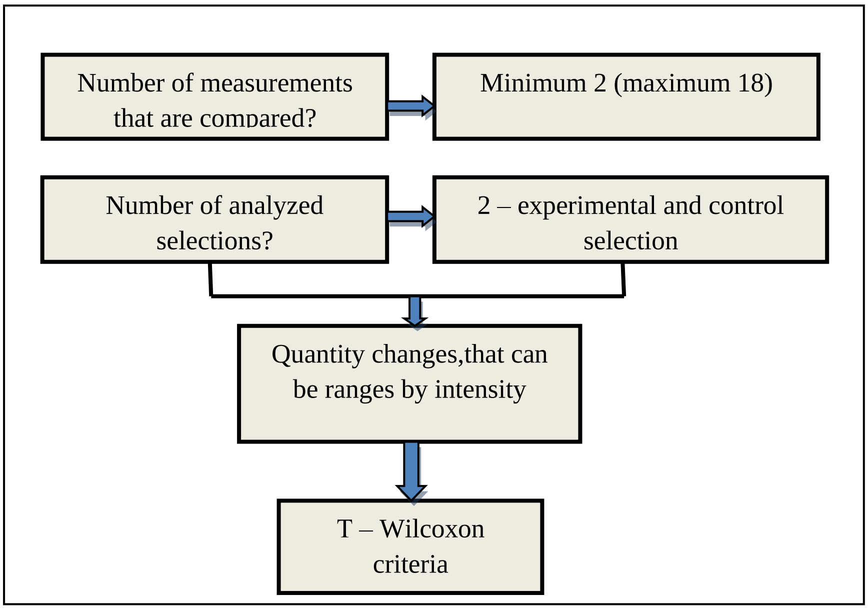

Fig. 1. Decision- making algorithm for load optimization model adequacy's evaluation

5. Model evaluation

There are 2 types of hypothesis:

H_0: Parameters after the experiment are less than the parameters after experiment.

H_1: Parameters after the experiment exceed the parameters after experiment.

The sum according to the rank column is ∑=171 The correctness of matrix is checked based on a control sum computation:

$$\sum x_{iy} = \frac{(1+n)n}{2} = \frac{(1+18)18}{2} = 171 , \qquad (1)$$

The sum of the column and the control sum are equal. It means that the ranging was processed correctly. Now, we point the directions that are non typical, in our case – positive. Table shows these directions and their respective ranks are marked. Sum of ranks of these «occasional» directions represents the empirical value of T – criterion:

$$T=\sum R_t =10+8.5+12+1=31,5 , \qquad (2)$$

The table of critical values for T–Wilcoxon test for n=18:

$$T_{emp} =32 \ (p\leq 0.01),$$

$$T_{kr} =47 \ (p\leq 0.05).$$

In current model the empirical value falls into the T value area: $T_{emp} < T_{kr}$ (0, 01).

Hypothesis H_0 is accepted. The parameter after the experiment does not exceed the parameters after it.

Table

The matrix of rank parameters according to T-Wilcoxon criterion

Before t_{before}	After, t_{after}	$\Delta(t_{before}-t_{after})$	Absolute value of difference	Rank number of difference
1.96	1.75	-0.21	0.21	15
1.5	1.45	-0.05	0.05	2.5
1.55	1.50	-0.05	0.05	2.5
1.1	0.83	-0.27	0.27	18
1.08	0.83	-0.25	0.25	17
1.8	1.92	**0.12**	0.12	**10**
1.28	1.17	-0.11	0.11	8.5
1.14	1.25	**0.11**	0.11	**8.5**
1.33	1.50	**0.17**	0.17	**12**
1.9	1.67	-0.23	0.23	16
1.85	1.75	-0.1	0.1	7
1.5	1.42	-0.08	0.08	6
1.56	1.50	-0.06	0.06	4
0.8	0.73	-0.07	0.07	5
1.1	0.92	-0.18	0.18	13
1.08	0.93	-0.15	0.15	11
1.2	1.00	-0.2	0.2	14
1.5	1.5	**0**	0	**1**
Sum				171

As the approval of the model adequacy, the results of an experiment were demonstrated on Fig. 2. and final dynamics of average parameters of loading/unloading operations were provided (Fig. 3.) The experimental loading time before the model implementation is located in the column 1, loading time processed in the program – is located in the column 2, experimental loading time after the model implementation is located in the column 3.

The results after integrated multicriterial aircraft load optimization model are shown on the Fig. 3. The average time of loading/ unloading procedures for 18 flights was minimized to 7%, on multileg flights – to 12%.

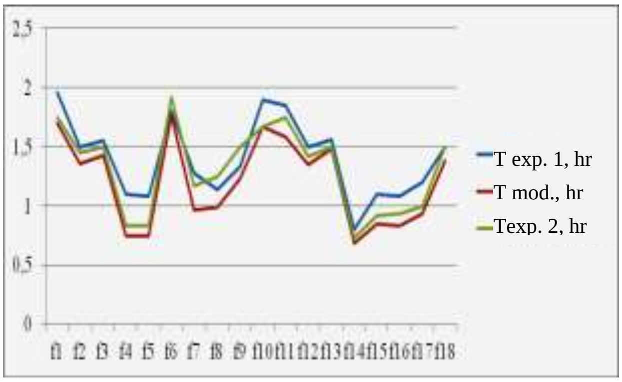

Fig. 2. The experimental results of loading / unloading operations IL-76 TD

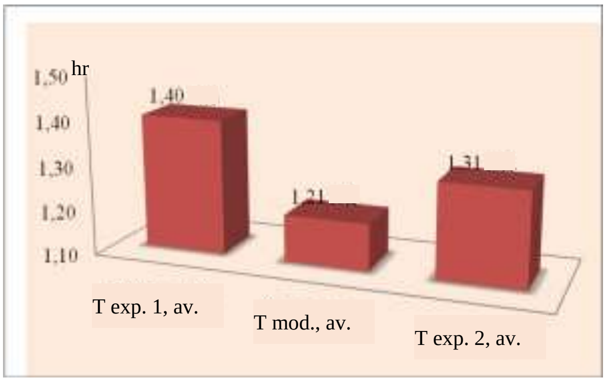

Fig. 3. Dynamics of the average parameters of loading/unloading operations

6. Conclusions and future research directions

The following integrated multicriterial load optimization model was created in order to exclude the bottle necks that appear in cargo load planning procedure. In this case, author considers some contradictory aspects on the assignment stage, so the model seeks to simplify the cargo loading procedures in such a way, to predict their destination according to the multi leg avoiding the overweight and reloading procedures. The efficiency of the model was proved by the 18 experiments and checked for adequacy by T – Wilcoxon non parametric criterion. The experimental data defines that the load optimization process, which includes the working 3 – D model on the planning stage substantially reduces the time for loading and consequently cuts operation costs.

References

[1] Bischoff E.E., Marriott M.D. (1990). A Comparative Evaluation of Heuristics for Container Loading. *European Journal of Operational Research, 44*, pp. 267-276. DOI:10.1016/0377-2217(90)90362-F

[2] FOK K. (2004). *Optimizing Air Cargo Load Planning and Analysis*. International Conference on Computing, Communications and Control Technologies, 6 p.

[3] Garey R. M., Johnson D. S. (1979). *Computers and intractability. A Guide to the Theory of NP-Completeness.* San Francisco, Publ. Freeman, 338 p.

[4] Hald A. (1956). *Matematicheskaya statistika s tehnicheskimi prilozheniyami*. [Matematical statistics with technical annexes]. Moskow, Foreign literature, 664 p. (In Russian)

[5] Kamkin A.S. (2018). *Vvedeniye v formalniye metody verifikatsiy program: uchebnoye posobiye* [Introduction to program formal verification methods]. Moskow, Publ. MAKS press, 272 p. (In Russian)

[6] Kublanov M. (2000). *Adekvatnoye matematicheskoye modelirovaniye.* Dissertatsiya [Adequate mathematical modeling. Dissertation]. Moskow, MSTU of Civil Aviation Publ., 420 p. (In Russian)

[7] Lurkin V., Schyns M. The airline container loading problem with pickup and delivery. *European Journal of Operation Research 244 (3),* pp. 955–965.

[8] Štimac I., Vidovic A., Mihetec T., Drljaca M. Optimization of Airport Capacity Efficiency by Selecting Optimal Aircraft and Airline Business. *Sustainability 2020, 12(10),* pp. 1-18. DOI:10.3390/su12103988

[9] Yang J., Yang J., Zhang D. (2002). What's wrong with Fisher criterion? *Pattern Recognition 35(11),* pp. 2665-2668. DOI: 10.1016/S0031-3203(02)00071-7

[10] Zvonarev S.V. (2019). *Osnovy matematicheskogo modelirovaniya: uchebnoye posobiye* [The basics of mathematical modeling] Yekaterinburgh, Publ. Ural university, 112 p. (In Russian)

Є.С. Сагун

Оцінювання інтегральної мультикритеріальної моделі оптимізації завантаження повітряних кораблів

Льотна академія Національного авіаційного університету, вул. Добровольського, 1, Кропивницький, Україна, 25005
E-mail: ielyzavetamaliukova723@gmail.com

Мета: представлення результатів оцінювання після впровадження розробленої моделі оптимізації завантаження та аналіз адекватності цієї моделі з метою доведення її ефективності, за допомогою зменшення головного критерію – часу завантаження. **Методи**: експеримент, евристика, статистика, імітаційне моделювання. **Результати**: розроблена модель оптимізації завантаження пройшла усі процедури верифікації, а аналіз експериментальних даних підвищив її значущість у процесі авіаційного завантаження. **Обговорення**: Розглянуто деякі параметричні критерії оцінки адекватності моделей для зазначення, що ефективність моделі оптимізації завантаження не може бути оцінена саме за цими критеріями. Тому, оптимізаційна модель з часовими критеріями має бути проаналізована на предмет адекватності лише за непараметричними критеріями, а саме – за Т–критерієм Вілкоксона. Стаття надає результати аналізу експериментальних даних, що демонструють різницю між параметрами моделі та реальною тривалістю процедури завантаження / розвантаження у реальних умовах. Імітаційна модель підтверджує мінімізацію часу завантаження після імплементації оптимізаційної моделі. Отже, результати верифікації моделі можуть розцінюватися як заключна частина дослідження ефективності впровадження інтегрованої мультикритеріальної моделі оптимізації завантаження повітряних кораблів.

Ключові слова: модель оптимізації завантаження повітряних кораблів, час завантаження, мультикритеріальна оптимізація, статистичні критерії, Т– критерій Вілкоксона

Е.С. Сагун

Оценка интегральной мультикритериальной модели оптимизация загрузки воздушных кораблей

Летная академия Национального авиационного университета, ул. Добровольського, 1, Кропивницкий, Украина, 25005
E-mail: ielyzavetamaliukova723@gmail.com

Цель: представление результатов оценки после внедрения разработанной модели оптимизации загрузки и анализ адекватности данной модели с целью подтверждения её эффективности, с помощью уменьшения главного критерия – времени загрузки. **Методы**: эксперимент, эвристика, статистика, имитационное моделирование. **Результаты**: разработанная модель оптимизации загрузки прошла всевозможные процедуры верификации, а анализ экспериментальных данных подчеркнул её значимость в процессе авиационной загрузки. **Обсуждение**: Рассмотрены некоторые параметрические критерии оценки адекватности моделей и отметить то, что эффективность модели оптимизация загрузки не может быть оценена именно по этим критериям. Поэтому, оптимизационную модель с временными критериями следует анализировать на предмет адекватности лишь с помощью непараметрических критериев, а именно – по Т– критерию Вилкоксона. Статья предоставляет результаты анализа экспериментальных данных, которые демонстрируют разницу между параметрами модели и реальной длительностью процедуры погрузки / разгрузки в реальных условиях. Имитационная модель подтверждает минимизацию времени загрузки после имплементации оптимизационной модели. Таким образом, результаты верификации модели могут быть расценены как заключительная часть исследования эффективности внедрения интегрированной мультикритериальной модели оптимизации загрузки воздушных кораблей.

Ключевые слова: модель оптимизации загрузки воздушных кораблей, время загрузки, мультикритериальная оптимизация, статистические критерии, Т– критерий Вилкоксона

Yelizaveta Sahun (1992). Doctoral Student.
Education: Management Faculty, Flight Academy of National Aviation University, Kirovohrad, Ukraine (2014).
Research area: aircraft load optimization processes.
Publications: 15
E-mail: ielyzavetamaliukova723@gmail.com.