Journal of Mechanical Engineering *Vol 18(3), 233-245, 2021*

Design Selection for New In-Flight Food Delivery and Waste Collection System of Commercial Passenger Transport Aircraft using TOPSIS

*Farah Diana Ishak, Fairuz Izzuddin Romli**
Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
**fairuz_ir@upm.edu.my*

ABSTRACT

One of the important airline services that can influence the passengers' loyalty is the in-flight meal service. In this study, the conceptual design process of new in-flight food delivery and waste collection system is carried out using the standard engineering design method to improve the current system. A critical step in this process is the design concept evaluation and selection where the best alternative design concept solution is chosen for further development. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is applied to facilitate the selection process of the best design concept for the new improved in-flight food delivery and waste collection system. The design evaluation criteria for the TOPSIS assessment procedures are taken from previous work done on design requirements analysis for the new in-flight food delivery and waste collection system. Similarly, five alternative design concepts for the new system are taken from the results of the previous research work done. Furthermore, an online public survey is conducted to acquire the assessment rating of all alternative design concepts for each design evaluation criterion. The assessment rating is assigned using a simple Likert rating scale. From the resultant TOPSIS ranking, Concept 3 has emerged as the best design concept with a closeness rating of 0.9589, which is very close to 1. For future research work, this selected final design concept for the new in-flight food delivery and waste collection system will be forwarded to the next engineering design stage for further development.

ISSN 1823-5514, eISSN 2550-164X

Received for review: 2020-12-27
Accepted for publication: 2021-05-19
Published: 2021-09-15

Keywords: *In-flight meal; TOPSIS; Commercial transport aircraft; Passenger cabin; Waste collection; In-flight services*

Introduction

In-flight meal services have been indicated as one of the essential services that can shape up the flying passengers' loyalty towards a particular airline for their offered flight services. The in-flight dining experience does not only influence the overall satisfaction level of passengers for the flight services but also their re-flying intentions with the same airline [1]. A similar notion has been shared and highlighted through the findings in a few other conducted studies including Han et al. [2] and Dolekoglu et al. [3]. This realization underlines the ongoing need to offer better in-flight meal services for airlines to positively differentiate their services from their market competitors. It can be observed that, while the meal options have been significantly improved over time to better serve the passengers, the method or mechanism applied onboard the cabin to deliver the meals and collect the waste afterward from seated passengers is still largely like when the in-flight services were first offered decades ago [4]. This creates a good opportunity for better service competitiveness to the airlines if they can enhance their cabin process of food delivery and waste collection during flight.

Thus far, several improvements to in-flight meal services have already been proposed or studied. For instance, the design pattern of a "moving cabinet system" has been filed in 1965 [5], which closely resembles the current service carts, but its movement is supported by tracks along the aisle. This invention is not automated, and it still requires the cabin crew to manually push it along the track during the food delivery and waste collection process. On the other end, an automated mechanism for in-flight meal services has been patented in 2016 [6], where the meals are delivered, and wastes are collected through a conveyor system underneath the cabin floor. The outlet for this system is proposed to be placed at aisle seats of each row, requiring assistance from occupants of those seats to get the meal or discard waste materials afterward for other passengers in the same seat row. Moreover, another conceptual proposal of an automated system design for the in-flight meal services has been described in Ishak et al. [7] and based on the accompanied survey results from the same study, it has been shown that 63.7% of respondents agreed that current food delivery and waste collection process can be further improved.

Overall, though these improvement efforts have yet to make it into cabin implementation at this moment, they nevertheless highlight the ongoing needs and motivations for progress in the offered in-flight meal services, which become the main objective of this study. In this case, a systematic engineering design approach is undertaken to derive a new proposal for an improved system or mechanism of in-flight food delivery and waste collection process onboard the aircraft cabin.

Methodology

The engineering design process often involves multi-criteria decision-making steps, which require the designer to make essential design decisions in the presence of multiple, often conflicting, evaluation criteria [8]. In general, there are some methods that can be used to support the multi-criteria decision-making process for designers and one of the commonly applied methods is Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). For the engineering design process, one of the most crucial decisions to be made is during design concept evaluation and selection since the chosen design concept greatly influences the success of the final product development [9]. A poorly chosen design concept often causes costly compensation at later design stages as the direction of most activities in the product development has already been tailored to it, with any changes made will subsequently lead to increased development cost and time [10]. This puts a big emphasis on the need to select a good design concept for development during the early stages. In this perspective, TOPSIS method helps to systematically rank available alternative design solutions according to their assessment ratings of the evaluation criteria and the best concept is taken to be the one with the farthest Euclidean distance from the negative ideal solution and the shortest Euclidean distance from the positive ideal solution [11]. This method is largely popular primarily because it has the advantages of being simple, easy to understand, and easy to compute [12]. In addition, although it is simple, it can provide an indisputable ranking or order of preference for the considered alternatives to assist the decision-making process [13].

The effectiveness of TOPSIS method in facilitating good quality design decisions has been demonstrated in many products development studies such as for dry soybean cracking machines [14] and car bumpers [15]. The main steps in the typical design concept selection process using TOPSIS are shown in Figure 1. In short, the process starts with the establishment of the design evaluation criteria and the identification of considered alternative design concepts to be assessed. Each of the alternative design concepts is given the assessment rating for every design evaluation criterion. Based on the given rating, the TOPSIS evaluation procedure is performed to rank the alternative design concepts and determine the best among them.

The numerical computations involved in the TOPSIS method have been discussed and explained in many published studies including Kumar and Singh [16], Azis et al. [17], and Jasri et al. [18]. It should be noted that although some small variations for the computations can be found between these studies such as the inclusion of importance weighting for the evaluation criteria, the fundamental of the TOPSIS method in ranking alternative solutions remains similar. In this study, the evaluation process is started with the creation of the decision matrix, which denotes all alternative design concepts that are being considered and the assessment ratings that they received for each of the design evaluation criteria.

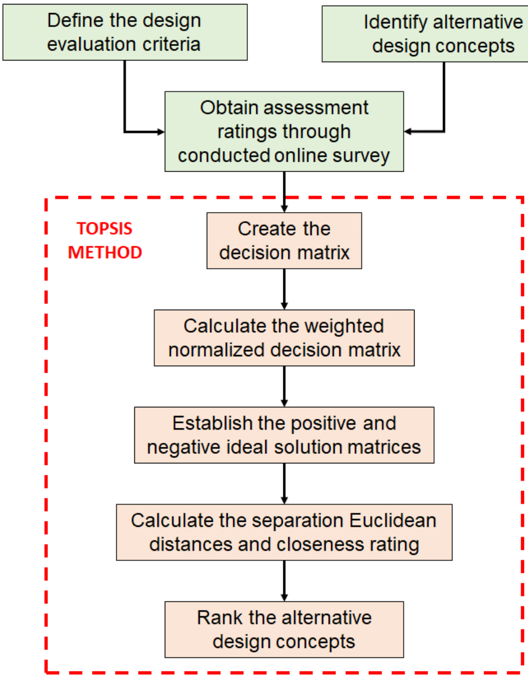


Figure 1: Methodology flowchart for design concept selection.

As indicated in Equation (1), the decision matrix $\boldsymbol{D}$ consists of elements $\boldsymbol{x_{ij}}$ that correspond to the obtained rating of the alternative design concept $\boldsymbol{X_j}$ for design evaluation criterion $\boldsymbol{Y_i}$. Note that the assessment ratings can also be initiated in the form of qualitative measures and in such cases, they need to be converted into quantitative measures for the TOPSIS computations by using a standard numerical scale such as a simple Likert rating scale.

$$D = \begin{matrix} & X_1 & X_2 & \cdots & \cdots & X_j \\ A_1 & x_{11} & x_{12} & \cdots & \cdots & x_{1j} \\ A_2 & x_{21} & x_{22} & \cdots & \cdots & x_{2j} \\ \vdots & \vdots & & & & \vdots \\ \vdots & \vdots & & & & \vdots \\ A_i & x_{i1} & x_{i2} & \cdots & \cdots & x_{ij} \end{matrix} \tag{1}$$

The next step is to normalize the decision matrix. Equation (2) is applied for the normalization of each element inside the decision matrix, which is denoted by $\boldsymbol{r_{ij}}$. Furthermore, given the importance weightage for each design evaluation criterion $\boldsymbol{A_i}$, as denoted by $\boldsymbol{W_i}$, then the weighted normalized elements $\boldsymbol{w_{ij}}$ for the decision matrix can be calculated using Equation (3).

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{j} x_{ij}^2}} \tag{2}$$

$$w_{ij} = W_i(r_{ij}) \tag{3}$$

In TOPSIS evaluation, the positive ideal solution $\boldsymbol{A^+}$ matrix is derived from a combination of the best values for each evaluation criterion regardless of the alternative design concepts. On the contrary, the matrix for the negative ideal solution $\boldsymbol{A^-}$ is derived from a combination of the worst values for each evaluation criterion. Based on the positive and negative ideal solution matrices, separation distance from them, $\boldsymbol{S^+}$ and $\boldsymbol{S^-}$, is calculated for each alternative using Equation (4) and Equation (5), respectively.

$$S_j^+ = \sqrt{\sum_{i=1}^{i} \left(w_{ij} - A_i^+\right)^2} \tag{4}$$

$$S_j^- = \sqrt{\sum_{i=1}^{i} \left(w_{ij} - A_i^-\right)^2} \tag{5}$$

Finally, the closeness rating for each considered alternative design concept, $\boldsymbol{C_j}$ is calculated using Equation (6). This closeness rating will be used to rank the alternative design concepts whereby the best solution has the highest rating value that is closest to 1.

$$C_j = \frac{S_j^-}{S_j^+ + S_j^-} \tag{6}$$

Results and Discussion

For this study, the design requirements for the improved in-flight food delivery and waste collection system have been previously established by conducting focus group study, public survey, and interview sessions with several consulted experts in the aviation field. Table 1 lists these design requirements, which become the design evaluation criteria for the TOPSIS evaluation, and their importance rating. Detailed discussions on the establishment of these design requirements can be found in [19].

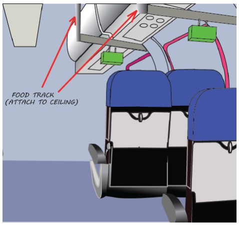
Table 1: Established design requirements for new in-flight food delivery and waste collection system

Requirement	Importance Rating	Importance Weightage
Passenger safety perception	4	0.10
Privacy level	4	0.10
Flexible waste disposal time	3	0.08
Low waiting time	3	0.08
Flexible meal time	3	0.08
Operational safety	5	0.13
Operational reliability	4	0.10
Cleanliness	5	0.13
Weight	4	0.10
Operational Cost	4	0.10

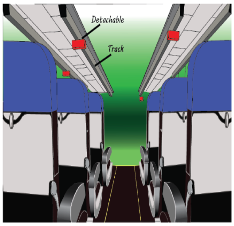
Table 2: Likert rating scale for design concept assessment

Description	Rating
Very poor	5
Poor	4
Neutral	3
Good	2
Very Good	1

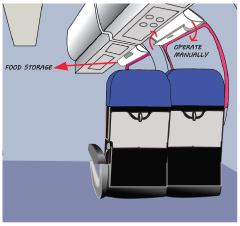
Based on the requirements analysis, several alternative design concepts for new in-flight food delivery and waste collection systems have been derived through the Quality Function Deployment and Morphological Matrix methods. The alternative design concepts are shown in Figure 2. A detailed discussion on the derivation of these alternative design concepts and their design descriptions are available in [20]. For the TOPSIS evaluation, each of these five considered alternative design concepts has to be assessed for all design evaluation criteria. The assessment ratings for the alternative design concepts are obtained through a conducted online public survey and the rating process is done using a simple Likert scale as shown in Table 2.



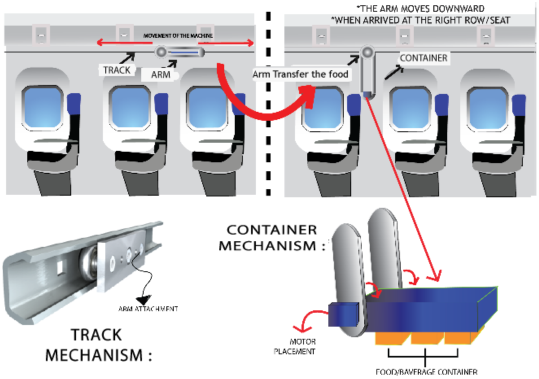
(a) Concept 1



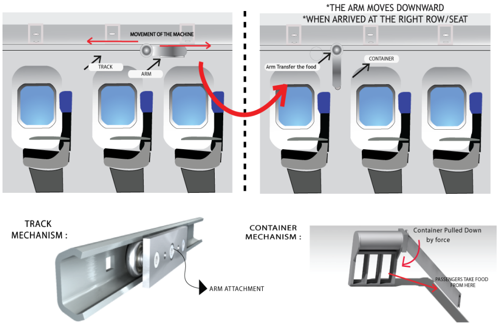
(b) Concept 2



(c) Concept 3



(d) Concept 4



(e) Concept 5

Figure 2: Considered alternative design concepts [20].

In total, 240 respondents have participated in this survey, which is taken as sufficient in reference to the total participants in a rather similar study in [21]. It should be noted that the involvement of the public in assessing the alternative design concepts enables unbiased evaluation and selection of the best design concept. From the collected survey responses, the resultant decision matrix for TOPSIS evaluation is presented in Table 3.

Table 3: Decision matrix for TOPSIS evaluation

Evaluation Criteria	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Passenger safety perception	2.8500	3.1833	4.2091	3.0250	2.9833
Privacy level	2.7667	3.1917	4.1091	3.2167	3.1167
Flexible waste disposal time	3.5333	3.4917	3.5083	3.2500	3.2250
Low waiting time	3.6417	3.5083	3.6500	3.2000	3.2750
Flexible meal time	3.6250	3.5417	3.7167	3.2917	3.2250
Operational safety	2.9167	2.9833	3.4000	2.8333	3.1000
Operational reliability	3.1500	3.3667	3.4167	2.9667	3.0083
Cleanliness	3.2424	3.2750	3.2000	3.1917	3.0417
Weight	3.1750	3.2833	3.2917	3.1583	3.1750
Operational Cost	3.1167	3.2833	3.6333	3.0500	2.9333

Using the importance weightage for the design evaluation as presented in previous Table 1, the weighted normalized decision matrix can be calculated using Equation (3) and it is as presented in Table 4. Subsequently, the positive and negative ideal solution matrices can now be derived. For this study, from the Likert rating scale that is used for the assessment of each alternative design concept as described in previous Table 2, it is inferred that the most preferable solution is the one with the highest assessment rating while the worst possible solution is the one with the lowest assessment rating. With this notion, positive and negative ideal solution matrices have been defined and they are as shown in Table 5.

Finally, the separation Euclidean distances and the closeness rating for each of the alternative design concepts can be evaluated as indicated in Table 6, using Equation (4), Equation (5), and Equation (6), and the closeness rating values are used to determine the ordered ranking of the design concepts. From the ranking in Table 6, alternative design Concept 3 has emerged as the clear winner with a closeness rating value of 0.9589. Design Concept 2, which is ranked second, has the closeness rating value of only 0.3782 and is far behind the rating for design Concept 3.

Table 4: Weighted normalized decision matrix

Evaluation Criteria	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Passenger safety perception	0.0398	0.0444	0.0587	0.0422	0.0416
Privacy level	0.0383	0.0442	0.0569	0.0446	0.0432
Flexible waste disposal time	0.0357	0.0353	0.0355	0.0328	0.0326
Low waiting time	0.0362	0.0349	0.0363	0.0318	0.0326
Flexible mealtime	0.0358	0.0350	0.0367	0.0325	0.0318
Operational safety	0.0548	0.0560	0.0639	0.0532	0.0582
Operational reliability	0.0453	0.0485	0.0492	0.0427	0.0433
Cleanliness	0.0583	0.0588	0.0575	0.0573	0.0546
Weight	0.0453	0.0468	0.0469	0.0450	0.0453
Operational Cost	0.0445	0.0469	0.0519	0.0435	0.0419

Table 5: Positive and negative ideal solutions

Evaluation Criteria	$\boldsymbol{A}^{+}$	$\boldsymbol{A}^{-}$
Passenger safety perception	0.0587	0.0398
Privacy level	0.0569	0.0383
Flexible waste disposal time	0.0357	0.0326
Low waiting time	0.0363	0.0318
Flexible mealtime	0.0367	0.0318
Operational safety	0.0639	0.0532
Operational reliability	0.0492	0.0427
Cleanliness	0.0588	0.0546
Weight	0.0469	0.0450
Operational Cost	0.0519	0.0419

Table 6: Separation distances, closeness rating, and final ranking

Alternative Design Concepts	$\boldsymbol{S}^{+}$	$\boldsymbol{S}^{-}$	$\boldsymbol{C}$	Rank
Concept 1	0.0293	0.0086	0.2266	3
Concept 2	0.0214	0.0130	0.3782	2
Concept 3	0.0014	0.0320	0.9589	1
Concept 4	0.0265	0.0074	0.2193	4
Concept 5	0.0267	0.0073	0.2140	5

Another illustration of the best Concept 3 is depicted again in Figure 3 for better clarity. This result can be rather expected by looking at the obtained assessment rating for Concept 3 through the conducted survey, in which it has been consistently rated with the highest score for nearly all design evaluation criteria. It is believed that Concept 3 is greatly favored by survey respondents mainly due to its simple design and the fact that its implementation inside the cabin does not involve any significant additions of mechanism that may affect their perception of safety during flight. This is also in line with the preference in the design of other cabin features. For instance, as indicated by Akl et al. [22], the design of in-flight entertainment components for passengers is often made very simple and easy to use. This notion is also supported by Syakirah et al. [23], who have established that passengers tend to favor simple, easy to use and safe design while designing their child-restraint system for aircraft use. Overall, it can be taken that the choice of Concept 3 is highly consistent with the design characterization of most aircraft cabin features.

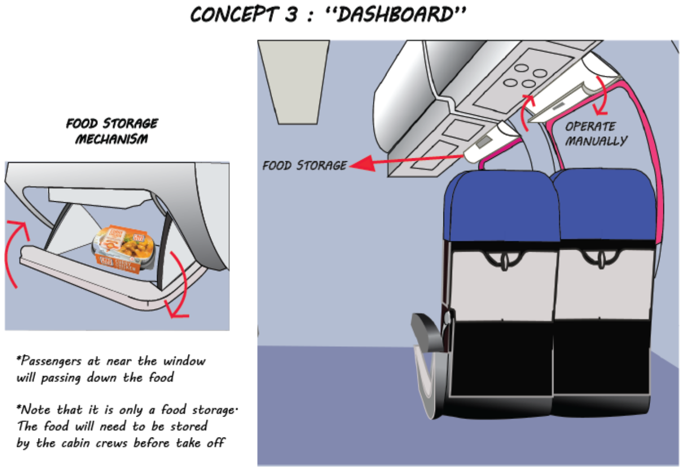


Figure 3: Selected Concept 3 [20].

Conclusion

Based on findings from previous studies, the improvement of the in-flight food delivery and waste collection process is necessary to address some of the issues highlighted with the current cabin meal services. In conjunction to this, a new development of in-flight food delivery and waste collection systems is pursued through systematic engineering design methodology. One of the critical steps in the engineering design and development process is the evaluation and selection of the best alternative concept. In this study, the TOPSIS method has been used to facilitate the decision-making process in selecting the best alternative design concept for the improved in-flight food delivery and waste collection system. The inputs from the potential passengers have been included in the assessment process through the conducted online survey, which is done to avoid any biasness in deciding the final design concept selection. From the TOPSIS results, design Concept 3 is chosen as the best alternative design concept for the new in-flight food delivery and waste collection system, with a closeness rating of 0.9589. With this decision, design Concept 3 will be forwarded to the next stage of the process for further development in future research work. In general, in the following design step, the concept will be ergonomically sized and preliminary analysis such as finite element analysis and ergonomic analysis can be done to ensure that it comfortably meets the operational requirements.

Acknowledgment

The authors like to acknowledge that this research is funded by Universiti Putra Malaysia through research grant GP/2018/9591600.

References

[1] M. S. Mohd Zahari, N. K. Salleh, M. S. Y. Kamaruddin and M. Z. Kutut, "In-flight meals, passengers' level of satisfaction and re-flying intention," *International Journal of Humanities and Social Sciences*, vol. 5, no. 12, pp. 1777-1784, 2011.

[2] H. Han, K. Lee, B. Chua, S. Lee and W. Kim, "Role of airline food quality, price reasonableness, image, satisfaction and attachment in building re-flying intention," *International Journal of Hospitality Management*, vol. 80, pp. 91-100, 2019.

[3] C. O. Dolekoglu, P. Veziroglu and S. Keiyinci, "Analyzing passenger behavior towards perception on in-flight food safety and quality," *New Trends and Issues Proceedings on Humanities and Social Sciences*, vol. 4, no. 10, pp. 417-425, 2017.

[4] F. I. Romli, K. Abdul Rahman and F. D. Ishak, "In-flight food delivery and waste collection service: the passengers perspective and potential improvement," *IOP Conf. Series: Materials Science and Engineering*, vol. 152, no. 012040, 2016.

[5] U. Martin, *U.S. Patent No. US3179208 A*, 20 April 1965.

[6] B. Appolt, M. Bitter and M. Novak, *U.S. Patent No. US20160200439 A1*, 14 July 2016.

[7] F. D. Ishak, F. I. Romli and K. Abdul Rahman, "Public survey on new in-flight food delivery and waste collection system," *Journal of Mechanical Engineering*, vol. SI 5, no. 4, pp. 142-152, 2018.

[8] E. K. Zavadskas, A. Mardani, Z. Turskis, A. Jusoh and K. Md Nor, "Development of TOPSIS method to solve complicated decision-making

problems: an overview on development from 2000 to 2015," *International Journal of Information Technology and Decision Making*, vol. 15, no. 3, pp. 645-682, 2016.
[9] M. Augustine, O. Yadav, R. Jain and A. Rathore, "Concept convergence process: a framework for improving product concepts," *Computers and Industrial Engineering*, vol. 59, pp. 367-377, 2010.
[10] R. Ullah, D. Zhou and P. Zhou, "Design concept evaluation and selection: a decision making approach," *Applied Mechanics and Materials*, vol. 155-156, pp. 1122-1126, 2012.
[11] N. O. Aminian and F. I. Romli, "Study on the potential of airships as urban mass public transport in Malaysia," *Journal of Mechanical Engineering*, vol. SI 4, no. 2, pp. 221-232, 2017.
[12] Syamsudin and R. Rahim, "Study approach technique for order of preference by similarity to ideal solution (TOPSIS)," *International Journal of Recent Trends in Engineering and Research*, vol. 3, no. 3, pp. 268-285, 2017.
[13] R. Szpotowicz and C. Toth, "Revision of sustainable road rating systems: selection of the best suited system for Hungarian road construction using TOPSIS," *Sustainability*, vol. 12, 8884, 2020.
[14] R. A. Anugraha, N. M. Darmawan and M. Iqbal, "Best concept selection for dry-soybean cracking machine process optimization using TOPSIS method," *IOP Conf. Series: Materials Science and Engineering*, vol. 528, 012005, 2019.
[15] M. Davoodi, S. Sapuan, D. Ahmad, A. Aidy, A. Khalina and M. Jonoobi, "Concept selection of car bumper beam with developed hybrid bio-composite material," *Materials and Design*, vol. 32, no. 10, pp. 4857-4865, 2011.
[16] R. Kumar and S. Singh, "Selection of vacuum cleaner with Technique for Order Preference by Similarity to Ideal Solution method based upon multi -criteria decision-making theory," *Measurement and Control*, vol. 53, no. 3-4, pp. 627-634, 2020.
[17] A. Azis, B. A. Kusuma and A. Maselia, "Support system for determination of low-income students' scholarship with Technique for Order Preference by Similarity to Ideal Solution," *International Journal of Informatics and Information System*, vol. 3, no. 1, pp. 1-11, 2020.
[18] Jasri, D. Siregar and R. Rahim, "Decision support system best employee assessments with Technique for Order of Preference by Similarity to Ideal Solution," *International Journal of Recent Trends in Engineering and Research,* vol. 3, no. 3, pp. 6-17, 2017.
[19] F. D. Ishak, F. I. Romli, M. Y. Harmin and A. S. Mohd Rafie, "Design requirements for new food delivery and waste collection system onboard commercial transport aircraft," *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, no. 3, pp. 2207-2212, 2020.

[20] F. D. Ishak and F. I. Romli, "Conceptual design alternatives for new in-flight food delivery and waste collection system in commercial transport aircraft," *International Journal of Advanced Science and Technology*, vol. 29, no. 4, pp. 10165-10175, 2020.
[21] N. Dasuki and F. I. Romli, "Quality function deployment for new standing cabin concept of commercial transport aircraft," *Journal of Mechanical Engineering*, vol. SI 5, no. 2, pp. 247-257, 2018.
[22] A. Akl, P. Berthou and T. Gayraud, "Key factors in designing in-flight entertainment systems", in *Recent Advances in Aircraft Technology*, InTech, London, 2012, pp. 331-360.
[23] K. Syakirah, A. Faeiza and I. Fairuz, "Conceptual design of the ergonomic child restraint system for infants in the aircraft using TRIZ method", *International Journal of Advance Research in Science and Engineering*, vol. 4, pp. 64-73, 2015.