Optimization of Courier Delivery Route among Hubs in Johor by Using Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization

Vevina Yau Jing Rou, Suliadi Firdaus Sufahani*

Department of Mathematics and Statistics, Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Edu Hub, 84600, Johor, Malaysia

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.910000481

Received: 02 November 2025; Accepted: 08 November 2025; Published: 17 November 2025

ABSTRACT

The quick growth of e-commerce has significantly increased demand for courier services, creating pressure on logistics infrastructure to manage delivery operations efficiently. This study focuses on the optimization of courier delivery routes for GDex Express to determine the optimal delivery route based on distance and time travelled among hubs in Johor. Mixed Integer Programming, Genetic Algorithm, and Ant Colony Optimization were proposed in this study in order to solve the travelling salesman problem (TSP) by using Python software. This study mainly focuses on 13 GDex Express delivery hubs in Johor with the data based on total distance travelled and average time travelled that selected into three different time periods at 8.00 a.m., 1.00 p.m. and 6.00 p.m. for weekdays and weekends. There are two optimal delivery routes generated respectively in terms of total distance travelled and average time travelled. The results shows that Mixed Integer Programming provided optimal solution as benchmarking, while Genetic Algorithm outperformed Ant Colony Optimization in comparing which algorithm is more closer to the optimal solution. Thus, this study provides solutions to the GDex Express in order to improving the delivery effectiveness and reducing the operating costs by reducing the travel time and distance.

Keywords – Courier services, GDex Express, Optimization, Mixed Integer Programming, Genetic Algorithm, Ant Colony Optimization, Travelling Salesman Problem

INTRODUCTION

The quick growth of e-commerce has significantly impacted global logistics and delivery systems. E-commerce, defined as the online purchasing and selling of products and services, has enabled businesses to reach more customers through cost-effective and efficient means. The proliferation of digital devices such as computers, tablets, and smartphones has further facilitated this trend. As a result, traditional business operations have undergone radical changes, with the transportation and delivery sectors being among the most affected (1). The need for reliable, fast, and efficient courier services has risen dramatically to meet the demands of customers purchasing goods online (2).

Courier services play a crucial role in this ecosystem, offering specialized shipping solutions that prioritize speed, reliability, and security. Unlike traditional postal services, courier services provide enhanced features such as real-time tracking, customization options, and faster deliveries (3). In Malaysia, the evolution of courier services dates to the British colonial era, with the establishment of Pos Malaysia in 1985 to facilitate communication and package delivery. The advent of private courier companies in the 1980s brought more efficient and professional delivery options, driven by technological advancements and growing economic demands (4). Today, major courier service providers in Malaysia, such as GDex Express, Pos Laju, and DHL Express, operate in a highly competitive market.

However, the rapid expansion of e-commerce has introduced challenges to the logistics infrastructure, including bottlenecks in warehouses, sorting facilities, and delivery networks. Route optimization, a critical aspect of courier operations, has become increasingly complex due to factors such as multiple hubs, variable delivery quantities, and geographic constraints (5). Addressing these challenges requires innovative solutions like the travelling salesman problem (TSP), an optimization problem focused on determining the optimal courier delivery route among hubs in Johor based on distance and time. Previous studies have applied methods such as Mixed Integer Programming, Genetic Algorithm, and Ant Colony Optimization to solve TSP, demonstrating significant improvements in route planning and cost efficiency (6).

This study aims to determine the optimal delivery routes among courier hubs in Johor using advanced optimization techniques. There are four objectives in this study, as gathering the data of distance and time travelled among hubs for courier delivery of GDex Express in Johor, applying the modelling of mixed integer programming, genetic algorithm and ant colony optimization to find the optimal delivery route in Johor. The study also seeks to determine the optimal courier delivery route among hubs in Johor based on distance and time and compare the performance of approximate algorithm against the benchmark optimal solutions provided by mixed integer programming method on which provides solutions closet to the optimal outcomes. By achieving these objectives, this research will provide valuable insights for enhancing operational efficiency, reducing costs, and improving service reliability in Malaysia's courier industry.

Materials and Methods

In this study, the location of 13 GDex Express delivery hubs in Johor were collected from the GDex Express website (https://gdexpress.com/), while the distance and time travelled data among hubs were collected from the Google Maps (https://www.google.com/maps). The distance travelled data among hubs is illustrated in kilometer (km), while the time travelled data among hubs is illustrated in minutes (min). The time travelled data were collected at three different times which are 8.00 a.m., 1.00 p.m. and 6.00 p.m. for weekdays and weekends. The average time travelled data among hubs on weekdays is calculated by using the data from Sunday to Thursday, while the average time travelled data among hubs on weekends is calculated by using the data on Friday and Saturday. Then, the distance and time travelled data were used for future analysis.

Data Description

This study mainly focused on the courier delivery hubs in Johor state. There was a total of 13 courier delivery hubs in the Johor area to be considered. The list of transit hubs is shown in Table 1, while the location of the listed hubs is illustrated in Figure 1.

Table 1 List of Transit Hubs

Node	Name of Hub
1	Tangkak Hub
2	Muar Hub
3	Batu Pahat Hub
4	Pagoh Hub
5	Segamat Hub
6	Yong Peng Hub
7	Kluang Hub
8	Kulai Hub

INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

9	Senai Hub
10	Tampoi Hub
11	Pasir Gudang Hub
12	Kota Tinggi Hub
13	Pontian Hub

Fig. 1 Location of The Listed Hubs on Google Maps

Travelling Salesman Problem (TSP)

In this study, the travelling salesman problem (TSP) known as an optimization problem that aims for determining the optimal delivery route with the least amount of travel distance, time, and cost in travelling every location and returning to the beginning point at the end (7). The distance or time to travel between two hubs is d_{ij} where i is the origin and j is the destination. The binary variable that considers value 1 if the salesman travel from i to j and 0 as otherwise is x_{ij}. The general TSP model in this study is constructed as below which was mentioned by (8):

Objective function:

$$Min\ z = \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}x_{ij} \quad \text{Eq. 1}$$

Subject to:

$$\sum_{i=1}^{n} x_{ij} = 1, for\ i = 1, 2, \dots, n \quad \text{Eq. 2}$$

$$\sum_{j=1}^{n} x_{ij} = 1, for\ j = 1, 2, \dots, n \quad \text{Eq. 3}$$

where

$$x_{ij} = \begin{cases} 1; if\ the\ salesman\ travel\ from\ city\ i\ to\ city\ j \\ 0; otherwise \end{cases}$$

$d_{ij} = Distance\ or\ time\ to\ travel\ from\ city\ i\ to\ city\ j$

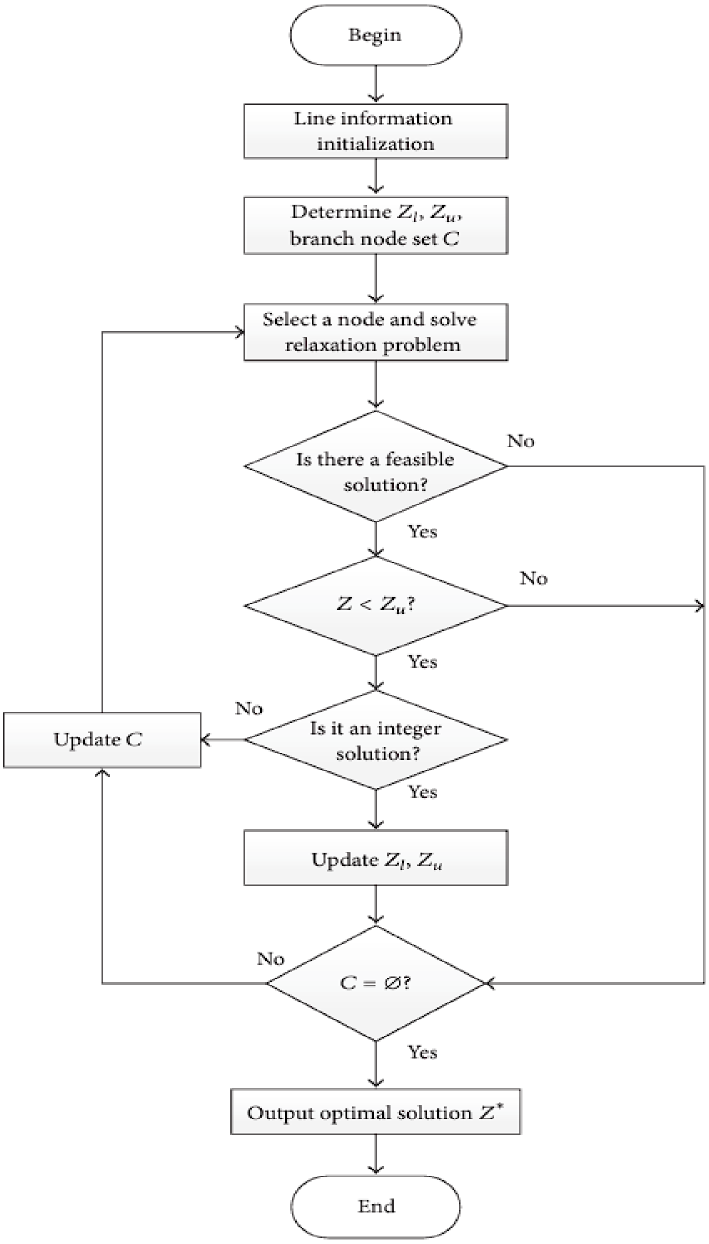
$z = Minimize\ the\ total\ distance\ or\ time\ of\ the\ matrix$

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

Mixed Integer Programming

Mixed Integer Programming known as a mathematical optimization method that used for solving the optimization problem applied in this formulation where the determination of the optimal solution depends on the discrete integer values of some of the decision variables and continuous values of others (9). The objective of mixed integer programming is to find the optimal values of the decision variable that in turn either minimize or maximize an objective function constraint that subject to certain number of constraints. Solving Mixed Integer Programming problems involves specialized algorithms and software tools, such as Branch-and-Bound. Branch-and-Bound is known as a general algorithmic technique which is mainly used for optimization problems, especially those based on combinatorial optimizations and mathematical programming. It systematically explores the solution space of a problem to find the optimal solution or prove its infeasibility or optimality. Figure 2 showed the general flow chart of Branch-and-Bound which was mentioned by (10).

Fig. 2 Flowchart of Branch-and-Bound



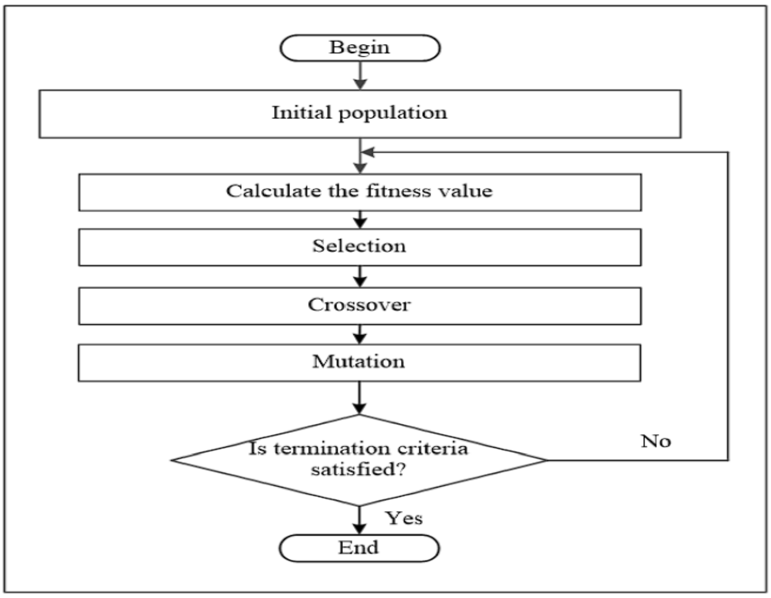
Genetic Algorithm

Genetic Algorithm is a type of metaheuristic algorithm that gets inspiration from the principles of genetics and natural selection. It aims to mimic the process of evolution observed in natural systems, so that it will solve the optimization and search problems (11). There are five steps in the process of Genetic Algorithm which are

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

initial population, fitness function, selection, crossover, and mutation. Figure 3 showed the process of Genetic Algorithm which was mentioned by (12).

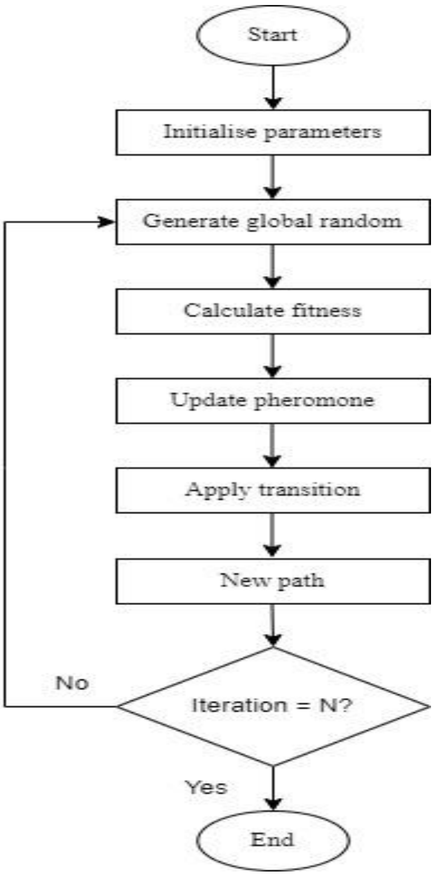
Fig. 3 Process of Genetic Algorithm



Ant Colony Optimization

Ant Colony Optimization is known as a metaheuristic algorithm extracted based on the strategy of ants searching for food sources (13). It is a probabilistic technique used for solving computational problems that can be reduced to finding good paths through graphs. Figure 4 showed the process of Ant Colony Optimization which was mentioned by (14).

Fig. 4 Process of Ant Colony Optimization



RESULTS AND DISCUSSION

Delivery Route Based on Distance Travelled

In this study, three methods were used to determine the delivery routes based on distance travelled among hubs in Johor which are Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization. The delivery route with the minimum distance travelled and fulfilling all the travelling salesman problem (TSP) constraints is the optimal delivery route for the distance factor. Table 2 showed the total distance travelled of Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization.

Table 2 Total Distance Travelled of Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization

Method	Total distance travelled (km)
Mixed Integer Programming	569.7
Genetic Algorithm	569.8
Ant Colony Optimization	582.4

Based on Table 2, the total distance travelled of Mixed Integer Programming is 569.7 km. Next, the total distance travelled of Genetic Algorithm is 569.8 km. Then, the total distance travelled of Ant Colony Optimization is 582.4 km. The overall results showed that Mixed Integer Programming obtained the minimum total distance travelled in this study with the delivery route sequence from Muar - Tangkak - Segamat - Yong Peng - Kluang - Kota Tinggi - Pasir Gudang - Tampoi - Senai - Kulai - Pontian - Batu Pahat - Pagoh - Muar.

Delivery Route Based on Time Travelled

In this study, three methods were used to determine the delivery routes based on time travelled among hubs in Johor which are Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization. The delivery route with the minimum total time travelled and fulfilling all the travelling salesman problem (TSP) constraints is the optimal delivery route for the time factor. There was total six different sets of time travelled data based on three different time periods at 8.00 a.m., 1.00 p.m. and 6.00 p.m. for both weekdays and weekends. Table 3 showed the total time travelled of Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization at 8.00 a.m., 1.00 p.m. and 6.00 p.m. for both weekdays and weekends.

Table 3 Total Time Travelled of Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization at 8.00 a.m., 1.00 p.m. and 6.00 p.m. for Both Weekdays and Weekends

Total time travelled (min)		Mixed Integer Programming	Genetic Algorithm	Ant Colony Optimization
Weekdays	8.00 a.m.	608.8	611.0	612.0
	1.00 p.m.	625.4	629.2	631.8
	6.00 p.m.	635.6	640.8	640.0
Weekends	8.00 a.m.	606.5	609.5	607.5
	1.00 p.m.	666.0	672.0	685.5
	6.00 p.m.	676.5	677.5	682.5

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

Based on Table 3, the minimum total time travelled for the optimal delivery route at 8.00 a.m. on weekdays was 608.8 min which was produced by using Mixed Integer Programming. The minimum total time travelled for the optimal delivery route at 1.00 p.m. on weekdays was 625.4 min which was produced by using Mixed Integer Programming. The minimum total time travelled for the optimal delivery route at 6.00 p.m. on weekdays was 635.6 min which was produced by using Mixed Integer Programming. Moreover, the minimum total time travelled for the optimal delivery route at 8.00 a.m. on weekends was 606.5 min which was produced by using Mixed Integer Programming. The minimum total time travelled for the optimal delivery route at 1.00 p.m. on weekends was 666.0 min which was produced by using Mixed Integer Programming. The minimum total time travelled for the optimal delivery route at 6.00 p.m. on weekends was 676.5 min which was produced by using Mixed Integer Programming. By comparison between each different time, the results showed that the most suitable time for delivery is 8.00 a.m. in weekends based on time factor since the total time travelled is the least compared to other time. The delivery route sequence is Tangkak - Muar - Batu Pahat - Pontian - Kulai - Senai - Tampoi - Pasir Gudang - Kota Tinggi - Kluang - Yong Peng - Pagoh - Segamat – Tangkak.

Comparison Among the Algorithms

Based on the results, Mixed Integer Programming is the most suitable algorithm for solving the travelling salesman problem (TSP) in this study with 13 delivery hubs, due to it can generated the optimal solution for total seven different sets of distance and time travelled data.

Since the exact algorithm, Mixed Integer Programming can provide the optimal solution as benchmarking, therefore the performances of the approximate algorithms, Genetic Algorithm and Ant Colony Optimization will be compared. The comparison was summarized in Table 4.

Table 4 Comparison Among the Algorithms

			Mixed Integer Programming	Genetic Algorithm	Ant Colony Optimization
Total distance travelled			569.7 km	569.8 km	582.4 km
Total time travelled	Weekdays	8.00 a.m.	608.8 min	611.0 min	612.0 min
		1.00 p.m.	625.4 min	629.2 min	631.8 min
		6.00 p.m.	635.6 min	640.8 min	640.0 min
	Weekends	8.00 a.m.	606.5 min	609.5 min	607.5 min
		1.00 p.m.	666.0 min	672.0 min	685.5 min
		6.00 p.m.	676.5 min	677.5 min	682.5 min

According to Table 4, it clearly shows that Genetic Algorithm provided the solutions that better than the Ant Colony Optimization based on total seven different sets of distance and time travelled data. This is because the results obtained from Genetic Algorithm is closer to the optimal solution compared to the results obtained from Ant Colony Optimization, especially Genetic Algorithm has obtained five solutions that are closer to the optimal solution. Thus, it can be concluded that Genetic Algorithm can obtained better solution than Ant Colony Optimization.

CONCLUSION

This study successfully demonstrated the application of Mixed Integer Programming, Genetic Algorithm and Ant Colony Optimization for optimizing the courier delivery routes based on distance and time travelled among hubs in Johor. The results shows that Mixed Integer Programming provided optimal solution as benchmarking, while Genetic Algorithm outperformed Ant Colony Optimization in comparing which algorithm is more closer to the optimal solution. Thus, Mixed Integer Programming was the most effective method for GDex Express to plan their delivery routes followed by Genetic Algorithm and Ant Colony Optimization in order to improving the delivery effectiveness and reducing the operating costs by reducing the travel time and distance.

Additionally, this study provides solutions to the courier companies in improving their delivery routes by reducing the travel time and distance for 13 delivery hubs in Johor. The delivery effectiveness is improved by shorter delivery times, while the operating costs are reduced by shorter distance. Since this study uses the real-world data from GDex Express, therefore the results are practical and reliable. The models can help the courier companies in selecting more efficient routes. Besides, the models developed in this study are not just for courier companies. They can also be used for other industries that require optimization, such as food delivery, waste collection, and supply chains logistics. These models can be modified to improve the operations of the companies in various types of industries.

ACKNOWLEDGEMENT

This research was supported by University Tun Hussein Onn Malaysia (UTHM) through Tier 1 (vot H785). The authors are extremely thankful to the reviewers for their beautiful remarks.

REFERENCES

1. Lin, B., Zhao, Y., & Lin, R. (2020). Optimization for courier delivery service network design based on frequency delay. Computers & Industrial Engineering, 139, 106144. https://doi.org/10.1016/J.CIE.2019.106144
2. Otim, S., & Grover, V. (2006). An empirical study on Web-based services and customer loyalty. European Journal of Isssssssnformation Systems, 15(6), 527-541. https://doi.org/10.1057/PALGRAVE.EJIS.3000652
3. Ejdys, J., & Gulc, A. (2020). Trust in Courier Services and Its Antecedents as a Determinant of Perceived Service Quality and Future Intention to Use Courier Service. Sustainability 2020, Vol. 12, Page 9088, 12(21), 9088. https://doi.org/10.3390/SU12219088
4. Izzah, N., Rifai, D., & Yao, L. (2016). Relationship-Courier Partner Logistics and E-Commerce Enterprises in Malaysia: A Review. Indian Journal of Science and Technology, https://doi.org/10.17485/IJST/2016/V9I9/88721 9(9), 1–10.
5. Gonzalez-Feliu, J. (2013). Models and Methods for the City Logistics: The Two Echelon Capacitated Vehicle Routing Problem POLITECNICO DI TORINO. https://theses.hal.science/tel-00844731
6. Chauhan, C., Gupta, R., & Pathak, K. (2012). Survey of Methods of Solving TSP along with its Implementation using Dynamic Programming Approach. In International Journal of Computer Applications (Vol. 52, Issue 4).
7. Davendra, D. (2010). Traveling Salesman Problem , Theory and Applications Edited by Donald Davendra. An Efficient Solving the Travelling Salesman Problem : Global Optimization of Neural Networks by Using Hybrid Method, 37, 120. https://books.google.com/books/about/Traveling_Salesman_Problem.html? id=gKWdDwAAQBAJ
8. Taha;, H. A. (2007). Operations Research 670–678. an Introduction. //172.0.0.24%2Felibrary%2Findex.php%3Fp%3Dshow_detail%26id%3D2 5122
9. Kleinert, T., Labbé, M., Ljubić, I., & Schmidt, M. (2021). A Survey on Mixed Integer Programming Techniques in Bilevel Optimization. EURO Journal on Computational Optimization, https://doi.org/10.1016/J.EJCO.2021.100007
10. Ma, J., Yang, Y., Guan, W., Wang, F., Liu, T., Tu, W., & Song, C. (2017). Large scale demand driven design of a customized bus network: A methodological framework and beijing case study. Journal of Advanced Transportation, 2017. https://doi.org/10.1155/2017/3865701
11. Alam, T., Qamar, S., Dixit, A., & Benaida, M. (2020). Genetic Algorithm: Reviews, Implementations, and Applications.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue X October 2025

12. Albadr, M. A., Tiun, S., Ayob, M., & Al-Dhief, F. (2020). Genetic Algorithm Based on Natural Selection Theory for Optimization Problems. Symmetry 2020, Vol. 12, Page 1758, 12(11), 70 1758. https://doi.org/10.3390/SYM12111758
13. Dorigo, M., & Stützle, T. (2019). Ant Colony Optimization: Overview and Recent Advances. International Series in Operations Research and Management Science, 272, 311–351. https://doi.org/10.1007/978-3-319 91086-4_10
14. Ighohor Okonta, C., Edokpia, R., Gideon Monyei, C., & Okelue, E. (2016). A heuristic based ant colony optimization algorithm for energy efficient smart homes. https://www.researchgate.net/publication/308911799