

A Review of Split Delivery Vehicle Routing Problem Using Adaptive Large Neighborhood Search

Abdullah Alwhibi, Faisal Almalki, Nader Alkathiri, Abdullah Almasad and Mohammed Alkahtani

Industrial Engineering Department
King Saud University
Riyadh, Saudi Arabia

443101137@student.ksu.edu.sa, 442100219@student.ksu.edu.sa,
443100713@student.ksu.edu.sa, aalmasad@ksu.edu.sa, moalkahtani@ksu.edu.sa

Abstract

This paper reviews the literature within the use of Adaptive Large Neighborhood Search (ALNS) for the Split Delivery Vehicle Routing Problem (SDVRP) and related Vehicle Routing Problem (VRP) cases. Across many settings such as time windows, split deliveries, multi-depot, two-echelon networks, EV charging, parcel lockers, zone pricing, synchronized visits, and loading rules, ALNS usually finds solutions close to the best-known and sometimes new best solutions. It also runs in a short time and works well on large, realistic instances. The papers were grouped into five areas: core SDVRP, network extensions, practical innovations, green goals, and ALNS design. Notably, the right destroy, and repair operators make the search faster and more stable. Still, there are clear gaps. Most studies test only on benchmarks instead of real retail data. Few models look at cost, service, and emissions together. It is not always clear which operators help. Only a small number of papers deal with quick replanning when plans change. It is worth noting that it is recommended to use real cases, testing operators, sharing code with common KPIs, and building models that combine cost, service, and emissions. In general, for retail replenishment and last-mile delivery, ALNS is practical and strong.

Keywords

Adaptive Large Neighborhood Search (ALNS), Split Delivery Vehicle Routing Problem (SDVRP)

1. Introduction

The Vehicle Routing Problem (VRP) is a common topic in logistics and operations research. In simple terms, it is about planning routes for a fleet of trucks or vans that start from a depot and then visit a set of customers, then return to the depot. The objective is to set up routes by reducing total cost, distance, or travel time, and following basic constraints like vehicle capacity and customer availability. For example, in a grocery chain sending trucks to many stores every day, the VRP shows the stores each truck should visit and in what order. (Hemmelmayr et al. 2012).

VRP is important because transportation is one of the biggest costs in a supply chain and it directly impacts service quality. Better routes result in less fuel consumption, fewer kilometers, and fewer trucks on the road, which saves money and helps deliveries arrive on time. When running routes every day, a little improvement makes a big difference. Saving a few minutes or a few kilometers on one route can become hours and hundreds of kilometers across many trucks and weeks. This means lower fuel use, lower cost, and fewer delays, which helps deliveries arrive on time and keeps customers happy. Because of that, both companies and researchers pay close attention to the VRP and keep working on simpler, smarter ways to plan routes that fit real-life conditions. (Keskin et al. 2021, Wen et al. 2022).

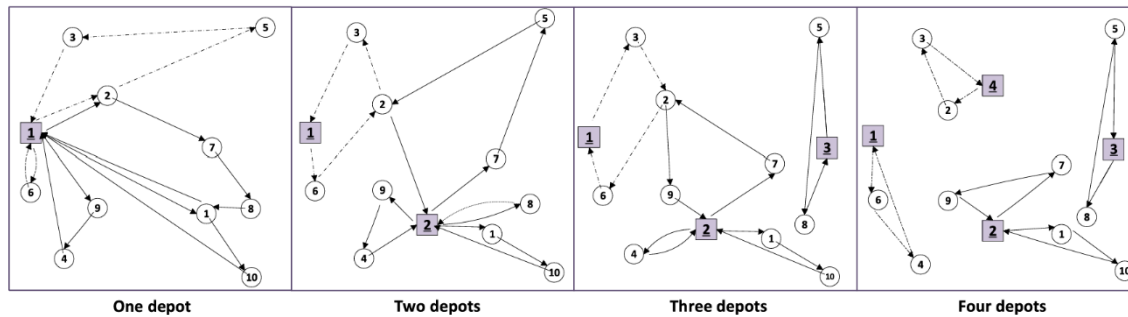


Figure 1. Example of vehicle routing with various number of depots (Alinaghian and Shokouhi, 2018).

VRP has been changed and extended in many ways to reflect real world cases more clearly. For example, VRP can include time windows, pickup and delivery, split deliveries, or even multiple depots where vehicles start from different locations. Figure 1 shows how routing changes when moving from one depot to multiple depots (Alinaghian and Shokouhi, 2018). More depots make the problem more difficult, but they also make the model more realistic.

In Split Delivery Vehicle Routing Problem (SDVRP), one customer can get deliveries from several vehicles instead of just one (Hof and Schneider 2019, Gu et al. 2019). This option makes the routing more flexible and allows better use of the fleet. But this also makes the problem more complicated since there are many more possibilities. That's why researchers usually use heuristics and metaheuristics to solve VRP and SDVRP. Among these approaches, the Adaptive Large Neighborhood Search (ALNS) has proven to be one of the most effective (Voigt et al. 2022). ALNS works by destroying and repairing parts of an initial solution, to identify which operators give better results. This makes it strong and flexible enough to deal with complex VRP cases such as multi-depot systems, green routing, and parcel locker integration.

The motivation for this review is that even though ALNS has been widely applied to SDVRP and related VRP variants, there is still a need to review the literature and highlight the current gaps. Most studies rely only on benchmark data, while real retail data is rarely used. In addition, environmental aspects and customer service measures are often missing in existing research.

1.1 Objectives

The objective of this paper is to explore in detail how Adaptive Large Neighborhood Search (ALNS) has been used to solve the Split Delivery Vehicle Routing Problem (SDVRP). This problem is one of the more complex versions of VRP, and ALNS has proven to be a strong approach to deal with such complexity. By reviewing the studies that applied ALNS, the paper aims to understand the progress made so far and how effective the method has been when compared to other techniques. This gives a better idea of how ALNS is used to solve routing problems in real life.

At the same time, the review also highlights the gaps that still exist in the literature. Many studies mostly use benchmark data, and this makes them less connected to real logistics problems. Little attention is also given to environmental and sustainability aspects, even though they are becoming more important in supply chains today. In addition, customer service factors like delivery reliability and flexibility are often not included in the analysis. By pointing out both the achievements and the gaps, this paper gives a clearer picture of the current state of research and suggests future directions that can make the results more practical and useful, especially by linking cost, sustainability, and service quality together.

2. Methodology

The goal of this paper is to review the most related research papers that have applied ALNS to SDVRP and similar routing problems. This review shows what researchers have already achieved, what is still missing, and what directions future studies should take, especially to link cost, environment, and service.

The process of selecting the scientific papers for this review was done step by step in a clear and systematic way, following guidelines that are often used in literature reviews. The idea was to make sure that the papers included in this review are both trustworthy and useful for fulfilling the research objectives.

The first step was to select papers only from reliable databases and well recognized scientific journals. The databases used for the search were ScienceDirect and Scopus, as they are among the most reliable sources for industrial engineering and operations research topics. These databases provide access to high-quality journals and conference papers that match the scope of this review. This was important because using peer reviewed and well known sources makes the review stronger and more reliable. By focusing on these academic sources, this avoid information that might not be accurate or of low quality.

After that, a keyword search was done using terms directly related to the research topic. This step helped to find the most relevant studies and narrow down the huge amount of available research. The keywords were carefully chosen to match different variations of the topic so that important studies would not be missed. The keyword search included the following combinations to ensure wide coverage of the topic: Adaptive Large Neighborhood Search (ALNS), Vehicle Routing Problem (VRP), Split Delivery Vehicle Routing Problem (SDVRP), ALNS metaheuristics for logistics, These combinations were tested in both ScienceDirect and Scopus databases, which helped identify the most relevant papers.

The papers were prioritized once they were collected. The prioritization on: (1) the amount of citations, because a paper that is cited a lot usually has a big impact on the research community, and (2) the innovation, because newer studies often have fresh ideas and new approaches. This made sure that the review had a balance between classic reference studies and the latest developments.

Then, the final selection of papers, keeping only those that matched the topic closely and supported the goals of this review. Papers that were less relevant or repeated information were excluded so that the focus stayed on the most valuable sources.

Finally, the selected papers were grouped into themes. It is easier to compare studies, identify patterns, and highlight similarities and differences when organizing the papers. It also helped in creating a structured discussion of the results and showing the research gaps more clearly.

This whole procedure is in line with the guidance provided by Carrera-Rivera et al. (2022), who explained the importance of using a step by step framework when conducting systematic literature reviews in computer science and engineering. Their method highlights how planning, selection, and grouping all play an important role in creating a clear and useful review.

Figure 2 below shows a simple summary of the steps followed in this methodology

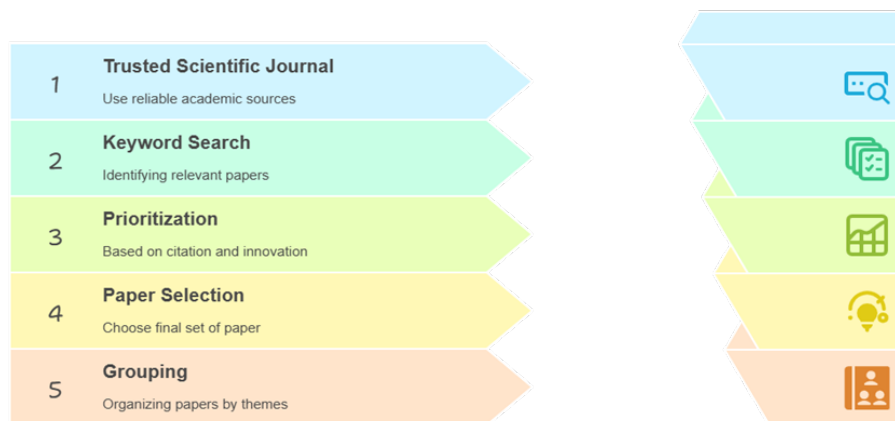


Figure 2. Papers Selection

3. Literature Review

In the last ten years, there's been a huge increase in studies on the Split Delivery Vehicle Routing Problem (SDVRP) using Adaptive Large Neighborhood Search (ALNS). The reason is so clear: split deliveries can reduce the total distance and make planning more flexible, but at the same time they make the problem complex and harder to solve exactly. That's why ALNS became such a popular option, it plans its destroy and repair operators during the search and can solve lots of the details that show up in real world logistics. In this section, the papers were grouped to show how the research improved over the time and what each group of studies added.

3.1 Core SDVRP and Time-Window Problems

The first group of papers showed that ALNS works well for split deliveries, especially when time windows or pick up and delivery constraints included. Li et al. (2016) showed that ALNS can handle routing together with request selection, which matters when not all requests have to be served. Hof and Schneider (2019) looked at split deliveries under time windows and found solutions close to the best known ones, showing how useful split loads can be when timing is important. For SDVRP with commodity limits, Gu et al. (2019) designed strong ALNS components and got competitive results. Overall, these papers proved that ALNS is reliable for the "core" versions of the problem.

3.2 Network Structure: Multi-Depot, Two-Echelon, and Multi-Compartment

When research moved to bigger and more complex problems, the problems became tougher but also more realistic. Hemmelmayr et al. (2012) was one of the first to try this and used level aware operators for two echelon settings. Grangier et al. (2016) extended this idea by having multiple trips and synchronization at satellites that made the problem closer to real problems. Alinaghian and Shokouhi (2018) worked on multi depot and multi compartment routing with a hybrid ALNS-VNS, proving ALNS could handle several product types and depots at the same time. Voigt et al. (2022) mixed ALNS with genetic operators for multi depot and two echelon problems and showed stable results. These papers show that ALNS can still perform well with complex problems.

3.3 Practical Innovations: Lockers, Pricing, Transshipment, Incompatible Loading, and Drayage

More recent papers have focused on making ALNS useful for real delivery systems. For example, Saker et al. (2023) added parcel lockers and showed that costs can go down compared to exact models, which is important for e-commerce. Shi et al. (2023) added zone based pricing and did a pricing aware moves, linking delivery costs and customer threshold. Friedrich and Elbert (2022) applied on city logistics with transshipment points, where shipments can switch between vehicles. Guo et al. (2021) dealt with incompatible loading and built special heuristics and S-ALNS. On the heavy transport side, Bustos-Coral and Costa (2025) used ALNS for drayage with long combination trucks and suggested a new acceptance rule that made the results more stable. These papers show that ALNS can be designed to match different constraints.

3.4 Sustainability and Electric Vehicle Problems

Sustainability and EV routing started to be more popular. Keskin and Çatay (2016) modeled partial recharging in the Electric Vehicle-Routing Problem with Time Windows (EVRPTW) and used metaheuristic ideas similar to ALNS to handle charging. Later, Keskin et al. (2021) looked at time dependent and random waiting at charging stations and added learning and simulation ideas to ALNS so schedules would stay realistic. Wen et al. (2022) designed emission focused operators for multi depot Vehicle Routing Problem with Time Windows (VRPTW), reducing emissions while keeping costs affordable. Altogether, these papers show that ALNS can balance between cost and green goals if the operators and acceptance rules are designed with emissions in mind.

3.5 Search Design and Hybridization (What Makes ALNS Strong)

Another stream of research has focused more on how to make ALNS itself better. By combining constraint programming with ALNS for synchronization, Hojabri et al. (2018) combined constraint programming with ALNS for synchronization, showing that exact tools can guide heuristics. Pan et al. (2021) used a hybrid adaptive large neighborhood search (ALNS) and variable neighborhood descent (VND) (ALNS-VND) for time dependent and multi trip problems, which helped improve local search. Liu et al. (2019) worked on synchronized visits in VRPTW and showed that careful feasibility checks and operator tuning gave good results. Hintsch (2021) introduced a multiple neighborhood search for soft clustered VRP, proving that adding more destroy and repair options improves exploration. Finally, Voigt (2025) reviewed many VRP studies and ranked ALNS operators, finding that sequence based removals and regret style insertions were especially effective and helpful advice for designing SDVRP-focused ALNS models in the future. Table 1 is a summary of the problem types in the studies, showing their features like time

windows, split deliveries, or other constraints. It reviews of how each study looked at the VRP and which aspects they relied on.

Table 1. A summary of the reviewed papers

*Note: The last paper Voigt (2025) is a review paper that covers all VRP types.

Year	Author	VRP Type							
		Time Window	Split Delivery	Heterogeneous	Pickup Delivery	Two Echelon	Multi Depot	Multi Compartment	Synchronization
2012	Hemmelmayr et al.					✓			
2016	Li et al.	✓			✓				
2016	Grangier et al.	✓				✓			✓
2018	Keskin and Çatay	✓							
2018	Alinaghian and Shokouhi		✓				✓	✓	
2018	Hojabri et al.	✓		✓					✓
2019	Hof and Schneider	✓	✓		✓				
2019	Gu et al.		✓					✓	
2019	Liu et al.	✓							✓
2021	Guo et al.		✓	✓					
2021	Keskin et al.	✓							
2021	Pan et al.	✓							
2021	Hintsch		✓						
2022	Wen et al.	✓					✓		
2022	Voigt et al.		✓			✓	✓		
2022	Friedrich and Elbert	✓		✓					
2023	Saker et al.						✓	✓	
2023	Shi et al.			✓					
2025	Bustos-Coral and Costa	✓		✓	✓				
2025	Voigt	✓*	✓*	✓*	✓*	✓*	✓*	✓*	✓*

Table 2 is more about the solution side. It lists the destroy and repair operators used in ALNS and shows how frequently each one was used in the 20 studies, to see which operators are the most common in the studies and how the researchers built their algorithm.

Table 2. ALNS operators diversity among the 20 papers

Destroy Operator	Frequency	Repair Operator	Frequency
Random removal	17	Regret-k insertion	18
Shaw removal	16	Cheapest insertion	15
Worst customer removal	14	Randomized insertion	9
Route removal	9	Split load aware insertion	7
Sequence removal	8	Least slack insertion	6
Time window critical removal	5	Multi depot / two echelon aware insertion	5
Zone removal	5	Synchronized service insertion	4
Pair removal	4	Compartment aware insertion	3
Commodity removal	3	Charging aware insertion	3
Emission aware removal	3	Emission aware insertion	2
Transshipment removal	2	Transshipment insertion	2
Locker removal	2	Locker assignment insertion	2
		Pricing aware insertion	1

Together, the two tables are useful for the literature review because they connect the characteristics of the problems with the solution strategies applied. This makes it easier to understand what kinds of VRP settings in the literature, and also which ALNS components are most frequently used to solve them.

4. Results and Discussion

Overall, the results are strong. In the twenty papers reviewed, ALNS often found solutions that were very close to the best known ones, and in some cases it even set new best results. It also showed savings in cost, number of vehicles, or amount of distance when compared to older heuristics or exact MILP models, while keeping short runtimes and has high scalability. The method stayed effective under many real problems, time windows, two echelon and multi depot networks, EV charging, parcel lockers, zone based pricing, synchronization, and special loading rules without a drop in the quality. In the green cases papers reached low emissions with good cost. In profit focused cases, ALNS increased profit considering baselines. Some of the studies also improved stability and speed with the best operator choices and hybrid ideas. Overall, ALNS showed that it is reliable and high performing approach for SDVRP and related VRP variants.

4.1 Graphical Results

As shown in Figure 3, After reviewing 20 papers and grouped them into five types. Practical Innovation (5 papers) shows the newest ideas used in real life (parcel lockers, zone pricing, transshipment, drayage) because these features cut cost, raise on time delivery, and boost customer satisfaction and profit. ALNS Design (5 papers) is also large: choosing destroy and repair operators, makes it faster and more stable, and gives better solutions on many problems with less effort. Network Extension (4 papers) (multi depot, two echelon) brings models closer to real retail networks, which helps plan actual operations and improves service quality. Core SDVRP (3 papers) covers the base models that everything else builds on. they anchor the field and show why ALNS is a strong choice. Green Objectives (3 papers) is smaller simply because there is still a gap (fewer studies combine emissions goals with split deliveries) so this is a good space for future work. Overall, as the field moved forward, we focused more on innovative ideas and strong ALNS design because they deliver clear real world value, smother operations, happier customers, and better business results.

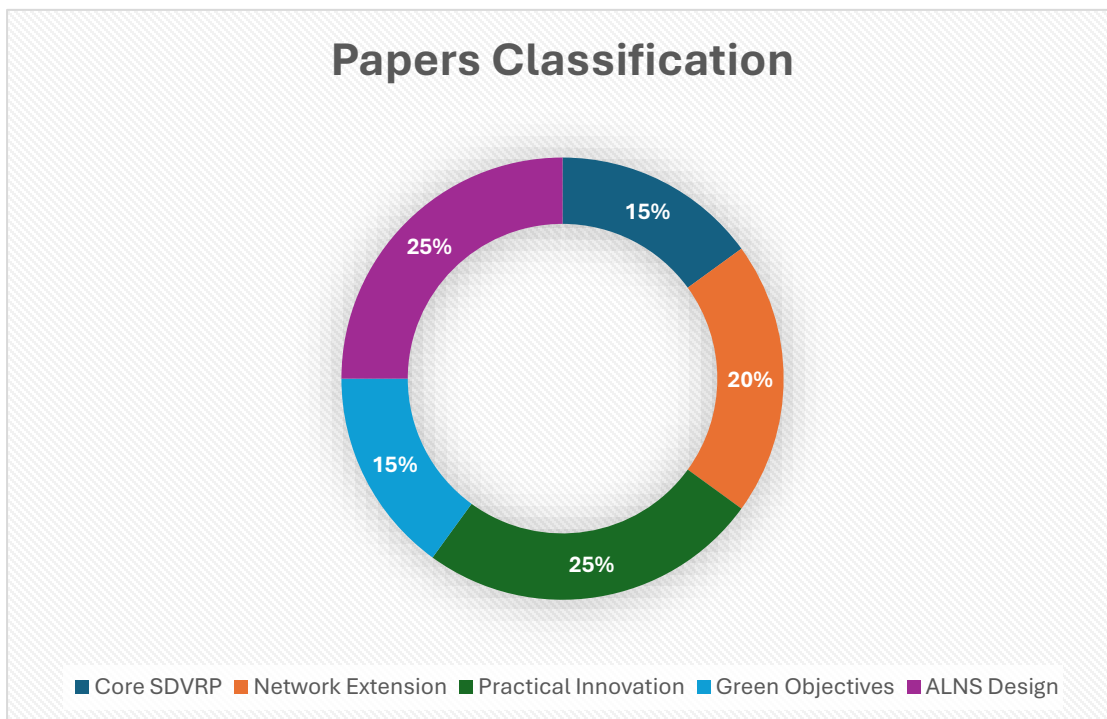


Figure 2. Papers Classification

Below is Table 3 (Papers Result). It summarizes the 20 papers by variant, main outcome, and overall ALNS performance level.

Table 3. Papers Result

Paper (Author, Year)	Problem Variant	Reported Performance	Level
Hemmelmayr et al. (2012)	Two echelon	Many new best-known results	High
Li et al. (2016)	Pickup–delivery, Time windows	Higher profit and faster than MILP	High
Grangier et al. (2016)	Two echelon, Synchronization	Much faster	High
Keskin and Çatay (2018)	Electric vehicles, Time windows, Fast charging	Less vehicles and lower total cost	Medium
Alinaghian and Shokouhi (2018)	Multi depot, Multi-compartment	Good results on large benchmarks	Medium
Hojabri et al. (2018)	Time windows, Synchronization	Consistent improvements	High
Hof and Schneider (2019)	Pickup–delivery, Time windows, Divisible deliveries	Several new best results	High
Gu et al. (2019)	Split deliveries, Commodity constraint	Many new best-known solutions	High
Liu et al. (2019)	Time windows, Synchronized visits	Strong benchmark results	High
Guo et al. (2021)	Incompatible loading	Competitive results on larger cases	Medium
Keskin et al. (2021)	Electric vehicles, Time windows	Lower cost than deterministic planning	High
Pan et al. (2021)	Multi trip, Time dependent travel, Time windows	Robust and efficient results	Medium
Hintsch (2021)	Soft-clustered vehicle routing	Many new best solutions	High
Wen et al. (2022)	Multi depot, green VRP	Lower emissions with competitive cost	High
Voigt et al. (2022)	Two echelon, Multi depot	Very strong results	High
Friedrich & Elbert (2022)	Transshipment facilities, Time windows, Heterogeneous fleet	Strong result on benchmarks, includes real world study	High
Saker et al. (2023)	Parcel lockers	High cost reduction	High
Shi et al. (2023)	Zone-based pricing	higher profit and fast	High
Bustos-Coral and Costa (2025)	Drayage, Heterogeneous fleet	New best-known solutions	High
Voigt (2025)	ALNS operator guidelines	General insights only	N/A

Note: High = $\leq 2\%$ cost gap or $\geq 10\%$ improvement (or new BKS), Medium = 2–5% gap or 5–10% improvement, Low = $> 5\%$ gap or $< 5\%$ improvement, N/A = no numerical results.

Figure 4 shows a bar chart as a visual summary of the table above. For every paper, the level was converted into a score (High = 3, Medium = 2, Low = 1, and N/A = 0) so taller bars show a stronger level. Most bars having 2 or 3 high and medium, which shows the same result with the table: ALNS is effective and important for these routing problems, giving strong solutions in many cases with reasonable time.

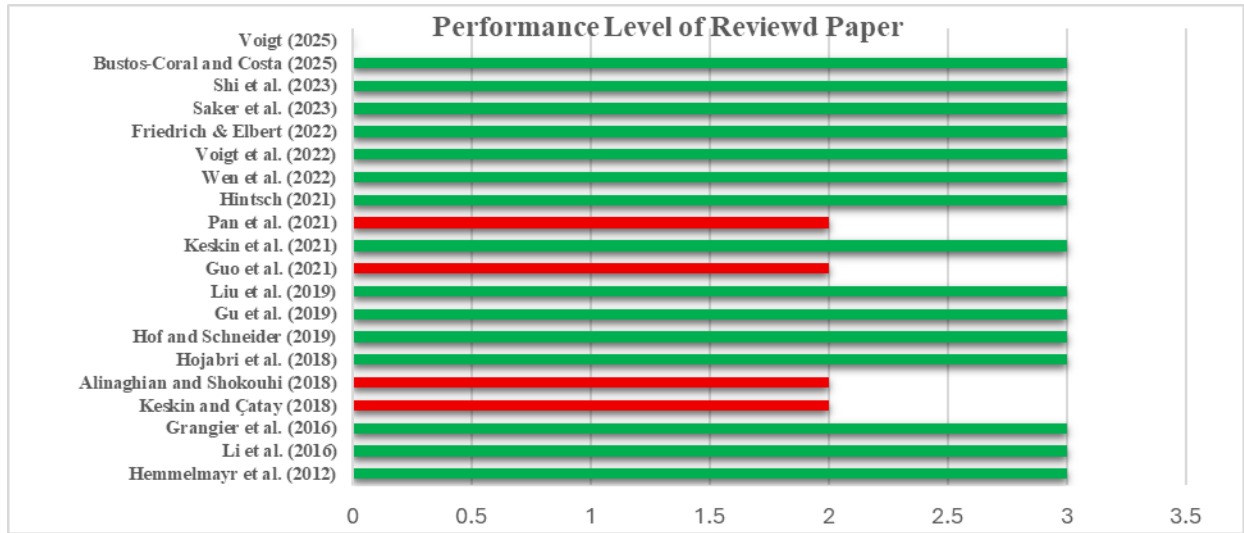


Figure 3. Papers Performance

Figure 5 shows the timeline of how the field kept changing to be like real life and why ALNS is important. It starts in 2012, where ALNS showed that it can handle two echelon networks well which set the base. In 2016, they focused on profit and time windows more, so routing was not only about serving everyone but serving the right requests. In 2018, electric vehicle routing introduced, bringing charging into this plan. In 2019, split deliveries became important to use fleets better. In 2021, more constraints introduced (incompatible items, time dependent travel, multi trip), and the methods still worked. In 2022, the focus was on the sustainability using multi depot (green) routing to reduce emissions with keeping cost performance. In 2023, innovative ideas were added like parcel lockers and pricing, which clearly help today's last mile operations. Finally, in 2025, there has been faster and more stable ALNS with better operator choices. In these steps all 20 papers showed that ALNS adapts to new constraints and economy goals (cost, service, emissions, profit) and keeps delivering strong, practical results.

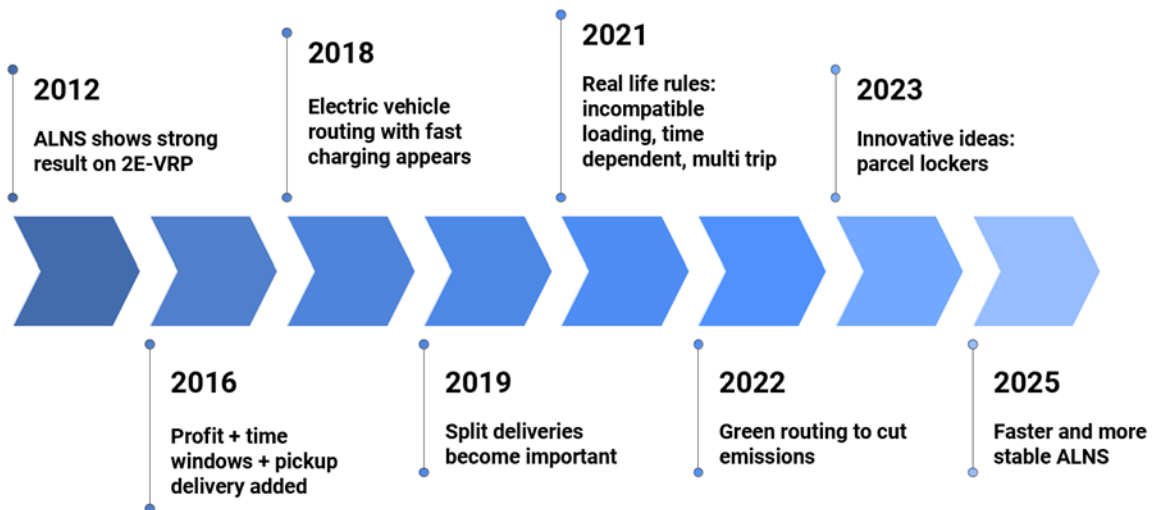


Figure 4. Papers Timeline

Figures 6a and 6b show a quantitative analysis of the most used destroy and repair operators identified in the 20 reviewed studies. This analysis was included to make the review clearer and more transparent by providing real numerical evidence of how often each operator was applied. It also helps to understand which operators researchers trusted the most when developing their ALNS models for solving vehicle routing problems. Showing these

percentages gives a more complete picture of the role and impact of different operators in improving ALNS performance.

The results show that Regret-k insertion was used in 90% of the studies, Cheapest insertion in 75%, and Randomized insertion in 45%. For destroy operators, Random removal appeared in 85%, Shaw removal in 80%, and Worst customer removal in 70% of the studies. These findings show the most important and effective operators that contribute to better optimization performance, helping ALNS find higher quality solutions in a shorter time and with more stable results.

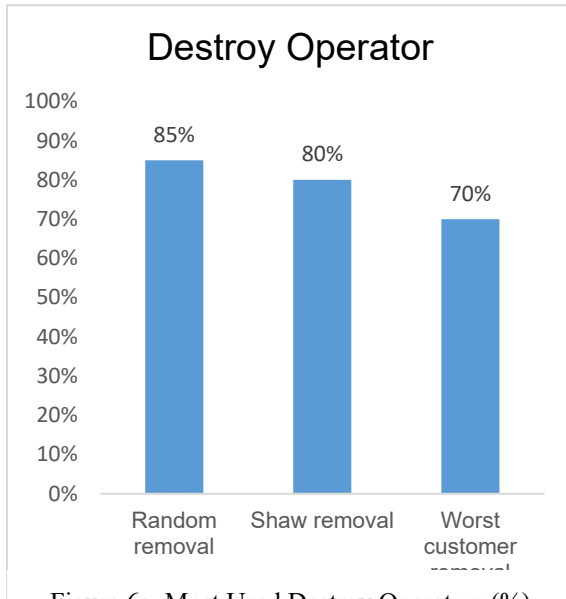


Figure 6a. Most Used Destroy Operators (%)

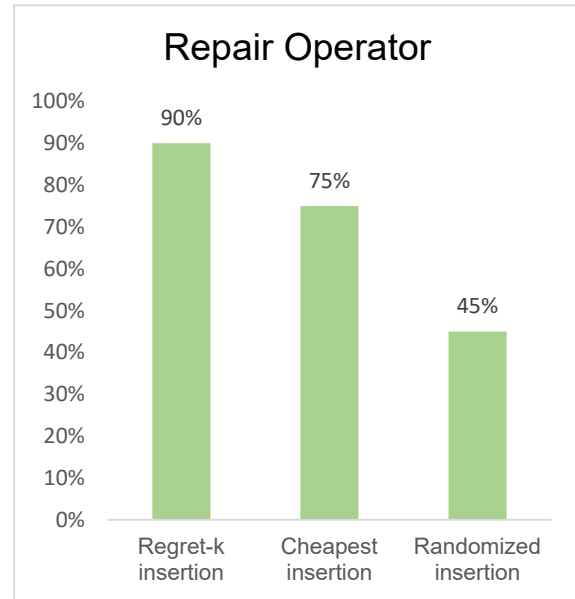


Figure 6b. Most Used Repair Operators (%)

4.2 Proposed Improvements

After reviewing 20 papers, it is clear that ALNS is a strong approach, but there are still some noticeable gaps that have not yet been explored. First, most papers used benchmark data instead of real-world data, so it is unclear how ALNS performs with weekly demand changes, store hours, promotions, or late trucks. Second, many papers optimize cost only, we need to combine service (on time delivery, shelf availability) and emissions with cost in the same model especially the mix of green goals with split deliveries, which is still rare. Third, method details are not always clear, papers should show in a clear way which destroy/repair operators actually help. Fourth, routing should be updated during the day when new orders come or any delays happen, so it's important to replan faster. Finally, results need to be easier to compare, for example by showing common KPIs such as cost per stop, vehicles used, and CO₂ per order. Doing this would make future research more realistic while keeping ALNS practical and high-performing.

5. Conclusion

This review looked at 20 papers that applied Adaptive Large Neighborhood Search (ALNS) to the Split Delivery Vehicle Routing Problem (SDVRP) and close VRP variants. The key point is that ALNS has proven to be both strong and dependable. In many cases like time windows, split deliveries with extra rules, two echelon and multi-depot systems, EV charging, parcel lockers, zone pricing, synchronization, and loading limits ALNS often found solutions close to the best known, and sometimes even discovered new best ones, while still keeping the runtime reasonable. The results were not only shown on small test cases, some studies also applied ALNS to large instances and still achieved good solution quality. Recent studies also became more practical, showing that ALNS can be applied to real ideas in the field, such as parcel lockers and pricing in last mile delivery, or drayage using longer trucks. At the same time, choosing proper operators and adding small hybrid adjustments helped make the search quicker and more stable, which is very useful for larger problems.

The papers were chosen with a clear and consistent method to make the review more organized and fairer. Papers were included if they directly applied ALNS to SDVRP or a very similar problem and provided real experiments with

results. The final selection includes older studies that cover the basics and benchmarks along with newer papers that offer fresh ideas and more powerful search methods. By grouping the papers into five themes and arranging them on a short timeline, it became clearer how the research moved from basic structures to more practical applications and improved ALNS designs.

From these twenty studies, a few broad gaps stand out. First, using real retail data and case studies can show how ALNS works with weekly demand changes, store hours, and daily disruptions. Second, models that combine cost, service, and emissions would give a more realistic view of how decisions are made in practice. Third, in real operations routes often change during the day, so having fast updates and replanning on the spot is very important. Finally, providing clearer details for example, showing which operators were used and which ones had the most impact together with sharing more datasets and using common KPIs (like cost per stop, number of vehicles, and CO₂ per order) would make it easier to compare and apply the results. Overall, the results show that ALNS is a strong and flexible method, and if the current gaps are addressed, it can become even more useful for retail supply and last mile delivery.

References

- Alinaghian, M. and Shokouhi, N., Multi-depot multi-compartment vehicle routing problem, solved by a hybrid adaptive large neighborhood search, *Omega*, vol. 76, pp. 85–99, 2018.
- Bustos-Coral, D. and Costa, A.M., Adaptive large neighborhood search for drayage routing problems involving longer combination vehicles, *Computers & Operations Research*, vol. 173, no. 106826, 2025.
- Carrera-Rivera, A., Ochoa, W., Larrinaga, F. and Lasa, G., How-to conduct a systematic literature review: A quick guide for computer science research, *MethodsX*, vol. 9, no. 101895, 2022.
- Friedrich, C. and Elbert, R., Adaptive large neighborhood search for vehicle routing problems with transshipment facilities arising in city logistics, *Computers & Operations Research*, vol. 137, no. 105064, 2022.
- Grangier, P., Gendreau, M., Lehuédé, F., and Rousseau, L.-M., An adaptive large neighborhood search for the two-echelon multiple-trip vehicle routing problem with satellite synchronization, *European Journal of Operational Research*, vol. 254, pp. 80–91, 2016.
- Gu, W., Cattaruzza, D., Ogier, M., and Semet, F., Adaptive large neighborhood search for the commodity constrained split delivery VRP, *Computers and Operations Research*, vol. 112, no. 104761, 2019.
- Guo, F., Huang, Z., and Huang, W., Heuristic approaches for a vehicle routing problem with an incompatible loading constraint and splitting deliveries by order, *Computers and Operations Research*, vol. 134, no. 105379, 2021.
- Hemmelmayr, V.C., Cordeau, J.-F., and Crainic, T.G., An adaptive large neighborhood search heuristic for Two-Echelon Vehicle Routing Problems arising in city logistics, *Computers & Operations Research*, vol. 39, pp. 3215–3228, 2012.
- Hintsch, T., Large multiple neighborhood search for the soft-clustered vehicle-routing problem, *Computers & Operations Research*, vol. 129, no. 105132, 2021.
- Hof, J. and Schneider, M., An adaptive large neighborhood search with path relinking for a class of vehicle-routing problems with simultaneous pickup and delivery, *Networks*, vol. 74, pp. 207–250, 2019.
- Hojabri, H., Gendreau, M., Potvin, J.-Y., and Rousseau, L.-M., Large neighborhood search with constraint programming for a vehicle routing problem with synchronization constraints, *Computers and Operations Research*, vol. 92, pp. 87–97, 2018.
- Keskin, M. and Çatay, B., A metaheuristic method for the electric vehicle routing problem with time windows and fast chargers, *Computers and Operations Research*, vol. 100, pp. 172–188, 2018.
- Keskin, M., Çatay, B., and Laporte, G., A simulation-based heuristic for the electric vehicle routing problem with time windows and stochastic waiting times at recharging stations, *Computers and Operations Research*, vol. 125, no. 105060, 2021.
- Li, Y., Chen, H., and Prins, C., Adaptive large neighborhood search for the pickup and delivery problem with time windows, profits, and reserved requests, *European Journal of Operational Research*, vol. 252, pp. 27–38, 2016.
- Liu, R., Tao, Y., and Xie, X., An adaptive large neighborhood search heuristic for the vehicle routing problem with time windows and synchronized visits, *Computers and Operations Research*, vol. 101, pp. 250–262, 2019.
- Pan, B., Zhang, Z., and Lim, A., Multi-trip time-dependent vehicle routing problem with time windows, *European Journal of Operational Research*, vol. 291, pp. 218–231, 2021.
- Saker, A., Eltawil, A., and Ali, I., Adaptive Large Neighborhood Search Metaheuristic for the Capacitated Vehicle Routing Problem with Parcel Lockers, *Logistics*, vol. 7, no. 72, 2023.

- Shi, Y., Liu, W., and Zhou, Y., An adaptive large neighborhood search based approach for the vehicle routing problem with zone-based pricing, *Engineering Applications of Artificial Intelligence*, vol. 124, no. 106506, 2023.
- Voigt, S., Frank, M., Fontaine, P., and Kuhn, H., Hybrid adaptive large neighborhood search for vehicle routing problems with depot location decisions, *Computers & Operations Research*, vol. 146, no. 105856, 2022.
- Voigt, S., A review and ranking of operators in adaptive large neighborhood search for vehicle routing problems, *European Journal of Operational Research*, vol. 322, pp. 357–375, 2025.
- Wen, M., Sun, W., Yu, Y., Tang, J., and Ikou, K., An adaptive large neighborhood search for the larger-scale multi depot green vehicle routing problem with time windows, *Journal of Cleaner Production*, vol. 374, no. 133916, 2022.

Biographies

Abdullah Alwhibi is a final-year B.Sc. student in Industrial Engineering at King Saud University (Riyadh, Saudi Arabia). During his studies he explored manufacturing, quality, ergonomics, simulation, supply chains, and data analytics, but operations research is the area that grabbed his attention most. He enjoys turning real logistics problems into simple, useful models that save cost and improve service. His current interests include vehicle routing, split deliveries, and metaheuristics such as Adaptive Large Neighborhood Search (ALNS), with applications in retail replenishment and last mile delivery. Abdullah is a hardworking, passionate student who cares deeply about his major and its different branches. He also competed in the department's Linear Programming Competition, earning second place with his teammates it is an experience that strengthened his modeling, teamwork, and presentation skills. Beyond the classroom, he stays active in small projects and short courses to sharpen his skills, and he enjoys translating ideas into tools that planners can actually use. His aim is straightforward, apply industrial engineering to cut costs, improve on time delivery, and build clear dependable solutions for daily operations.

Faisal Almalki is a final-year Industrial Engineering student at King Saud University, Saudi Arabia. He is passionate about his major and especially interested in Operations Research, where he enjoys exploring optimization and modeling techniques to address complex real-world problems. His academic journey has given him experience in diverse areas such as manufacturing processes, quality systems, human factors, and engineering design, yet he finds the analytical and problem-solving nature of Operations Research the most inspiring. Faisal has participated in several projects that combine theory with practice, including simulation studies, CAD/CAM applications, and quality improvement initiatives, which helped him strengthen his teamwork, critical thinking, and decision-making skills. In addition, he and his teammates achieved second place in the department's Linear Programming Competition, further confirming his enthusiasm for optimization and decision sciences. Looking ahead, Faisal aspires to expand his expertise in Operations Research and contribute to innovative solutions that improve efficiency, sustainability, and service quality in industrial and business environments.

Nader Alkathiri is in his final year of a Bachelor's degree in Industrial Engineering at King Saud University, Riyadh. He enjoys the practical side of operations research using simple, fast models to help real logistics decisions and he is especially interested in vehicle routing, network design, and heuristic methods such as Adaptive Large Neighborhood Search (ALNS). This semester, his graduation project studies the same topic as this review: ALNS for the Split Delivery Vehicle Routing Problem (SDVRP), where he compares operator choices and tracks clear planning metrics. Nader likes hands on work, building quick prototypes, cleaning data, and explaining results in a way planner can use. He and his teammates also earned second place in the department's Linear Programming Competition, which strengthened his modeling and presentation skills. After graduation, he plans to join a logistics analytics team and turn OR models into simple tools for routing and planning, with a focus on cost, service, and sustainability.

Mohammed S. Alkahtani is a Professor of Industrial Engineering, King Saud University (KSU), Riyadh, Saudi Arabia. He served as the chairman of the Industrial Engineering Department at the College of Engineering, KSU, and as a vice-dean of Advanced Manufacturing Institute, KSU. He earned his B.Sc. degree in Industrial Engineering from KSU, a M.Sc. in Industrial Engineering from the University of Central Florida (Orlando, FL, USA), and a Ph.D. in Manufacturing Engineering from Loughborough University (Loughborough, UK). He has diverse expertise in the analysis, modeling, simulation and design of manufacturing systems, supply chains, and operations management, as well as responsiveness measurement, lean manufacturing, and agility in manufacturing and supply chains.

Dr. Abdullah A. Almasad is an Assistant Professor in the Industrial Engineering Department at King Saud

*Proceedings of the 3rd GCC International Conference on Industrial Engineering and Operations Management
Tabuk, Saudi Arabia, February 2-4, 2026*

University. He holds a Ph.D. in Industrial Engineering from Pennsylvania State University. Dr. Almasad specializes in artificial intelligence, deep learning, and data analytics with applications in energy, healthcare, and smart cities.