CHAPTER 2

LITERATURE REVIEW

This chapter thoroughly analyses the literature on the Mobile Medical Unit using Vehicle Routing Problem (MMUVRP). This literature review aims to do two things: offer a solid foundation of information about the research challenge and uncover earlier contributions related to the aforementioned domains by summarising their aims, method(s), and results. To create a realistic model that may be used for implementation in real-world activities, the literature review is anticipated for highlighting to highlight the scope in the literature. It offers a review of prior research on the vehicle routing problem and its variations, as well as on various approaches to solving real-world cases that have developed due to technological improvement. There are 5 different sections in this chapter as:

a. Supply Chain Healthcare in rural areas
b. Mobile medical unit
c. Vehicle routing problem in healthcare
d. Using Machine Learning in Healthcare VRP
e. Transparency in the delivery of drugs

Significant advancements in algorithm development have resulted from improvements in processing capability and computer accessibility during the past three decades. Significant improvements in combating the VRP have been made possible by these technologies. Explosive advancements in supply chain management theory and applications fuelled the demand to optimise vehicle routing. It should not be a surprise that the above has led to an exponential growth in the VRP literature. In the literature, several VRP model variations exist for emergency medical care and logistics.

2.1 SUPPLY CHAIN HEALTHCARE

The healthcare supply chain relies heavily on effective supply chain operations, which not only facilitate an understanding of how the supply chain operates and the identification and resolution of issues but also enhance efficiency and productivity. By thoroughly explaining and justifying appropriate operational strategies, the delivery system for the healthcare supply chain can be improved. Poor supply chain operation is caused by a lack of strategic and collaborative planning, inadequate capacity planning, inadequate earnings for healthcare companies, and a lack of cooperation among dispersed supply chain actors, followed by ineffective medicine distribution to patients [Gupta and Ramesh 2015]. In problem identification and solution, various scholars have worked on supply chain operations. Kritchanchai examined the issue and noted several difficulties, including inconsistent data, a disjointed supply chain system, and ineffective business procedures in supply chain operations [Kritchanchai et al. 2010]. Few authors approach created for hospital healthcare managers to examine and evaluate their operational and strategic objectives is admirable [Albarune et al. 2015].

The environment for businesses in this era of globalisation has become challenging, and capacity design and Supply chain management (SCM) are crucial to their development to survive and maximise profit. Generally, the firm performance offers a mechanism to pinpoint SCM issues, implement solutions, and create plans to enhance organisational performance [Vidrova 2020]. A combination of monitoring and managing organisational actions is used [Brignall and Ballantine 1996]. There are many ways to gauge performance, utilising the analytic network technique adapted for DEMATEL [Supeekit et al. 2016], SCOR, the supply chain operations reference model [Thilakarathna et al. 2015], the IDS Scheer ARIS, the SPSS statistical software for the social sciences, and Rockwell Arena [Wang et al. 2013], the analytic hierarchy process (AHP), the Bayesian network, the statistical package for the social sciences [Whitney 2011, Zhang et al. 2020]. The primary flaw with performance measuring methods is their overly limited or even one-dimensional scope [Neely et al. 2000]. Accordingly, it is critical for Healthcare Supply Chain to develop a performance monitoring system to comprehensively monitor and evaluate the system.

Inventory management plays a critical role in the HSC because it directly influences product availability (i.e., the calibre of customer service) and system effectiveness (i.e., cost) [Stecca et al. 2016]. The Markov chain model for continuous time [Saadi et al. 2016], future demand forecasting algorithms [Bon and Ng 2017], the multiple-supplier, multiple-echelon inventory system [Perlman and Levner 2014], the model for cooperative economic lot sizing [Wang and Lee 2013], Healthcare inventory management issues have been the subject of the development of the Holt's model and other models [Rachmania and Basri 2013].

In a case study in Singapore, authors studied a cost-cutting strategy for medical suppliers. They also concluded that while certain just-in-time (JIT), reengineering, and outsourcing reductions may be cost-effective, information technology (IT) efforts start with a high initial cost due to a shortage of expertise. Information technology can reduce expenses at the start of the supplier identification process [Kumar et al. 2008]. Also, few researchers have discussed how further research focused on organisational shortcomings influencing patient care and how Supply Chain Management practices may be used to address them. Additionally, they offered a literature review that included industrial healthcare procedures. They have primarily concentrated on the supplier lead time, integration, and appropriate IT practises [Meijboom et al. 2011]. While there are certain applications of RFID systems that can be installed in a cost-effective manner, the current RFID systems in the healthcare supply chain are too expensive to apply, according to a different study by few authors [Kumar et al. 2009]. RFID devices allow healthcare supply chains to be more effective and cost-reductive. On the other hand, researchers has discussed key success factors and recent obstacles when utilising RFID systems within healthcare supply chain management, and the benefits and drawbacks of doing so in terms of costs and procedures have been noted [Attaran 2012]. In another research, a distribution model for inventory, combining the supply chains for hospitals and pharmacies. With the help of the model they offered, they were able to develop an ideal proposal for lead time and available lot size by illuminating a numerical example. The proposed model considered lead times, time and space accessibility, and customer service level [Uthayakumar and Priyan 2013]. Pharmaceutical Supply Chains have been assessed regarding manufacturing and distribution models. Additionally, they divided the models into categories and concluded that pharmaceutical supply chain descriptions primarily depend on production-centered definitions and have shortcomings to reflect patient consumption [Settanni et al. 2017].

In terms of agility and lean manufacturing, healthcare supply chains have been also examined. By developing a supply chain orientation and utilising an empirical analysis with the aid of agile and lean supply chain management philosophies in healthcare, they attempted to comprehend how the procedure of healthcare supply chains may become agile and lean and what is needed for developing the effectiveness of healthcare supply chains [Aronsson 2011]. Given that patient care services are difficult to predict and there are numerous independent private and public companies, authors sought to investigate the work design by improving it for supply chain management in healthcare. These businesses typically work together and have a rhythm in supply chain operations. To describe the various supply chain procedures in the healthcare business and comprehend the supply chain mechanisms, they have worked with four separate organisations [Shah et al. 2008]. In the healthcare business, a gap between rising demand and the present high-quality supply and an issue with cost and time effectiveness in both emerging and established nations was found. To educate healthcare supply chain management and integrate continuous improvement as an expression of quality and technical advancements, they have developed a framework comprising the three A's of affordability, awareness, and access [Sinha and Kohnke 2009]. Few researchers have examined whether supply chain management is effective in the service sector as it is in the manufacturing sector. They demonstrated a high-performing supply chain in the healthcare sector, which improved quality, reduced prices, and decreased lead times [Cook et al. 2001]. The rise in pharmaceutical supply chain efficiency is explained by further research. In this study, an Australian e-commerce initiative offers the healthcare industry an information system integration and improves data quality [Andargoli, 2021]. An e-commerce integration-based supply chain model was presented in 2004. Additionally, the authors demonstrated several approaches for inventory and buying rules, including optimisation and simulation [Chandra Kachhal 2004]. The authors in another work conducted another e-commerce research incorporating statistical findings to determine the effects of B2B e-commerce in the healthcare industry. He performed a poll, analysed the data, and found that internet-based integration enhances the healthcare industry's supply chain management [Cullen and Taylor 2009]. Some authors have investigated the use of supply chain management in the healthcare industry. They discovered various limitations, including a lack of leadership, ambiguous incentives, data collection and assessment, procurement team operations, and all chain parties. The primary issue is the practical application of leaders' and managers' understanding of the supply chain, which directly impacts supply chain performance [McKone Sweet at al. 2005]. Kim conducted real-world research at a hospital, showing that by enhancing the supply chain management system, inventory levels could be reduced by over 30%. Pharmaceutical inventory management procedures and buying practises are part of this development. At each stage of the supply chain, inventory levels were optimised using a transparent approach. This solution links the ordering process to the online system and improves the accuracy of demand forecasts. Costs decreased as a result of the decline in inventory [Kim et al. 2006]. Regarding the challenges of supply chain management in the healthcare industry is explained by another author. He examined the state of management systems and the limitations on technology use. He offers guidance for future research on implementing new technology to enhance the healthcare supply chain [Langabeer 2005]. The e-adoption of the healthcare supply chain was a specific topic that was researched. The authors created a framework that considers supply, business, and health regarding how each organisation should use e-commerce in light of the English National Health Service [Zheng et al. 2006]. Few researchers have provided a standard supply chain model for the service industry. The essential parts of the chain are incorporated in the proposed model and include capacity, demand, customer and supplier relationships, service management, and order operations management. This concept is relevant to the healthcare industry as well [Baltacioglu et al. 2007]. To define each component, such as entities, data and information flows, procedures, etc., authors analysed the healthcare supply chain and analysed its information system. In addition, they provide fresh technical alternatives that will boost the value of the health care supply chain management system [Kitsiou et al. 2007]. As a case study, researchers used dynamic programming to optimise the issues with a pharmaceutical company's worldwide supply chain. The study's goal was to increase the company's net present value by considering tax rates and production and distribution expenses that are spread out across several locations. Additionally, they divided the two problems into major and secondary subproblems while creating this model [Sousa et al. 2011]. The authors looked at the supply chain managements' flexibility in the healthcare industry, particularly in hospitals. Since the state of the existing system necessitates an agile and lean system for hospitals when it comes to delivery systems, they performed a case study to assess the viewpoint of leagility in hospitals on the part of a professional supplier [Rahimnia and Moghadasian 2010]. Walker researched crucial elements of green supply chain management and efforts in the commercial and public sectors, such as internal and external hurdles to implementing environmental principles. In order to understand how laws impact hospitals' suppliers, researchers also looked at a private healthcare provider as a case study. They concluded that hospitals often chose local suppliers to support the local economy [Walker at al 2008]. The researchers also looked at several supply chain components, such as distributors, manufacturers, and the healthcare industry, to evaluate the adoption and response of IOS in hospitals. They concluded that implementing IOS is quite difficult and that the way internal forces react in supply chains for healthcare might vary [Bhakoo and Choi 2013]. In one article, Kwon highlighted the significance of supply chain management in the healthcare industry in terms of patient spending in comparison to the rate of readmission. They also looked at the three key strategic areas to boost supplier profits and enhance the supply chain process and concluded that excess supply chain affects the standard of healthcare services [Kown et al. 2016]. Kogan and his colleague investigated how cooperation among healthcare supply chain participants might alter provider relationships in the industry. Additionally, they concluded that even if providers consolidated, the net profit of healthcare providers might not improve due to unpredictable demand and high operational expenses [Kogan et al. 2014]. There are authors who have examined three hospital departments with the help of supply chain specialists to demonstrate how incorporating a supply chain in the healthcare sector may reduce costs and enhance healthcare quality. They concluded that improved supply chain management for healthcare facilities could primarily result in a healthier academic environment for working there [Ishii et al. 2017]. Few researchers have tried to build a multiperiod pharmaceutical supply chain model by assuming that the number of medicines coming from providers is not certain. On the other hand, time, quality, and cost, called business triads, are the three objectives of the model, and they supported their model by a numerical example by concluding that the required satisfaction has a different combination of these three objectives [Imran et al. 2018]. By taking into account inventory-control management, service quality, operations research subjects in healthcare, and information technologies, authors have created a paper to make a survey and analyse the topics of supply chain management in healthcare and catastrophe [Syahrir and Vanany 2015]. When examining the impact of internal institutional restrictions on inventory costs using data from the State of California, authors have focused on the logistical services and unpredictable demand for hospitals. They concluded that if local systems' infrastructures are poor, logistics services have a significant influence [Zepeda et al. 2016]. Additionally, based on industry dynamics, other authors have evaluated the elements influencing pharmaceutical supply chain management and logistic evolution in the healthcare sector [Rossetti et al. 2011]. The performance of the hospitals' supply chain logistics was assessed using the most recent research in this field [Moons et al. 2019]. A literature study was conducted to compile papers that employed a structured analysis and covered operations and supply chain management in the healthcare industry between 1982 and 2011 year [Dobrzykowski et al. 2014]. In a separate literature review study that focuses on performance enhancement in hospital supply chains, provides significant managerial investigations and insights regarding pharmaceutical supply chain idea through content analysis [Narayana et al. 2014]. An empirical approach was developed to assess the effectiveness of hospitals' supply chains. They employed a research model that considered how well hospitals perform in terms of IT integration between hospitals and suppliers, the basis of trust, and the flow of knowledge. They also considered the effects of these factors, which are crucial for the supply chain performance in a hospital because they are interrelated factors [Chen et al. 2013]. By conducting a literature review in the context of the concept of "cold supply chain," the critical elements of pharmaceutical supply chain management" was discussed [Bishara 2006]. A boolean-based logical analysis to investigate the impacts of supply competency on foreign direct investments while considering the supply, infrastructure, and capacity environments. They guided strategic planners on what to prioritise to draw in foreign direct investment and facilitated decision-making in this highly competitive global context [Alam et al. 2014]. Regarding the pharmaceutical supply chain, a multi-item inventory model for a hospital by considering three key operational, tactical, and strategical strategies was suggested. They evaluated service levels, ordering processes, and ideal allocations while conducting their case study at an individual care unit for inventory management at a nearby warehouse [Kelle et al. 2012]. In a different study of hospital inventory control systems, attempt to comprehend inventory optimisation by concentrating on the central pharmacy and optimising the expense of logistics of pharmaceutical products using mixed integer linear programming level by level [Stecca et al. 2016].

2.2 MOBILE MEDICAL UNIT

MMUs, acting as a link between hospitals and people, can target both clinical and social health factors, and they play an essential role in improving healthcare in developing countries. Clinic efficacy must be demonstrated by further research, both in terms of service quality and expenditure. To maximize the effectiveness that MMUs' can provide to various consumer groups and the patient care as a whole, more measures in both qualitative and quantitative dimensions will need to be investigated. MMUs play a vital role in the healthcare system in many situations, providing accessible, long-term care of comparable quality to standard healthcare settings.

Few authors have worked on the scope and effectiveness of mobile medical units, and few authors have even calculated the cost and assessed the functioning of mobile medical units.

As the area is not much researched, significantly less literature has been found on mobile medical units. Few data have been taken from health policy data available on the national health policy of India and other websites. The data has provided a detail of the population of India facing challenges in primary healthcare services. Khanna and Narula expressed the descriptive knowledge of mobile healthcare units, which provided an insight into the finding new working on mobile medical units [Khanna and Narula 2016].

Abbasi investigated the various challenges mobile medical units face. The authors have concluded how to improve the medical units' effectiveness by reducing the units' weakness [Abbasi et. al. 2016]. In their paper, Khanna and Narula highlighted the importance of mobile medical units. The paper focuses on the various evidence shreds that may help make mobile health units more effective. They have used various databases to explore the implications of the mobile medical unit [Khanna and Narula 2017].

Few authors have provided unit cost estimation of providing mobile medical unit services from healthcare service providers' point of view in the local and tribal areas of Andhra Pradesh [Raikwar et. al. 2021]. In one research, authors stressed the consequence of mobile health units in the US. Using the database of PubMed, the authors have analyzed various cases and their impact on healthcare services in the USA [Stephanie et. al 2017].

In another work, mobile medical units workin Jharkhand. They have represented the frequency of mobile medical units in the districts of Jharkhand, concluding the factors that can express ideas for better utilization of the units. [Kumar et al. 2009]

To the best of our knowledge, study of a location-routing issue for a single MMU, in which the authors decide on the vehicle stops and route concurrently is one of the early publications on the planning of MMUs. A collection of population centers must be within a reasonable distance of a vehicle stop along the intended route and vehicle stops that need to be serviced for a solution to be practicable. All MMU routes must start and end at a central depot, and the number of stops per route and the total route length is bounded to ensure a balanced workload between MMUs. To provide a balanced workload across MMUs, all the routes must begin and end at a central depot, and both the total route length and the number of stops per route are limited [Hodgson et al. 1998]. Multiple objective functions for MMU issues was taken into the consideration by few researchers. In other words, they assess MMU routes based on three criteria: average access distance, coverage, and cost efficiency [Doerner et al. 2007]. Others expand the coverage objective for the one-vehicle setting to partial coverage, where only the population centers visited by an MMU are entirely covered, while population centers within an MMU's coverage are open to multiple vehicles. They also incorporate their MIP formulation into a data-driven optimisation framework based on credit card transactional data [Ozbaygin et al. 2016].

The considered setting is the primary distinction between this article and the preceding articles: We consider the issue on a much smaller scale with MMU routes that service at most two stops per day and return to a depot each night. A strategic level of vehicle routing problem was considered, where the authors have introduced the new technology so that optimized service can be provided to home healthcare scheduling and routing problems [Euchi et al. 2020]. Whereas, few authors have incorporated demands and the distribution of treatment capacities after the MMU routes are set [Hachicha et al. 2000, Doerner et al. 2007, Ozbaygin et al. 2016, Yücel et al. 2018]. On the other hand, we transfer the vehicle routing into a subsequent problem that essentially amounts to a matching problem for one depot and consider patient requests and the allocation of treatment capabilities at the strategic level.

2.2.1 VEHICLE ROUTING IN HEALTHCARE

In our study, we concentrate on a higher-level issue where practitioners' pathways are decided at the village level instead of the patient level. This high-level issue setting does not incorporate several of the primary characteristics of the prior research, such as patient time windows, healthcare practitioner preferences, and their specialty, as it is believed that the practitioners will visit a central site at the same time slot for each village visit. The frequency of the visits (visit frequencies and regulations) and the need for continuity of treatment are additional ways our study varies from others. Thus, Periodic VRP (PVRP) and Periodic Location Routing (PLRP) issue modelling techniques are considered as very efficient.

During the planning period, clients are visited more than once according to the traditional PVRP, and the visit itineraries are chosen from a specified list of options. The goal of the PVRP is to determine how to allocate consumers to these established schedules to maximise overall cost efficiency while ensuring that each node gets visited the necessary amount of time. The authors have researched and expressed that the issue is more challenging and intricate than conventional VRP by using a recurring municipal garbage collection problem in New York City as their inspiration [Beltrami and Bodin 1974]. A heuristic method which first chooses a timetable for each node before routing them separately was presented in the paper [Russell and Igo 1979]. The Period Routing Problem was initially mathematically formulated by Christofides and Beasley in 1984. Due to the intricacy of the issue, an ideal solution could not be found at that time [Christofides and Beasley 1984].

Heuristic algorithms predominated the literature in the following years once the problem was identified and demonstrated to be NP-hard. Some publications use LP relaxation in their composition to resolve the issue [Tan and Beasley 1984, Chao et al. 1995]. Additionally, IP-based algorithms that address a portion of the issue through an IP and often design routes using the Clarke and Wright method are offered [Russell and Gribbin 1991, Shih and Chang 2001, Gulczynski et al. 2011]. Another popular approach for locating higher-quality answers is tabu search (TS) [Cordeau et al.1997, Cordeau and Maischberger 2012, Liu et al. 2014]. There is research that suggest metaheuristics based on TS as well [Xia et al. 2018, Nair et al. 2018]. Many studies employ a column-generating architecture to address the routing issue after allocating clients to schedules and prioritising those with the highest demand [Mourgaya and Vanderbeck 2007; Cacchiani et al. 2014]. Other methods used for PVRP include Lagrangian relaxation, variable neighbourhood search (VNS), and evolutionary algorithms [Francis and Smilowitz 2006, Hemmelmayr et al. 2009, Carotenuto et al. 2015). We recommend the surveys conducted by authors for a more thorough analysis of the PVRP literature and employed solution approaches [Francis et al. [2007], Campbell and Wilson 2014].

The lack of visitation and continuity of care guidelines is a common feature of these studies. One of the few studies, implicitly incorporates continuity of service in PVRP such that the same driver serves the consumers at each visit [Rodriguez-Martin et al.

2019]. The prior studies may also be distinguished by the fact that each of them defines a set of potential visiting combinations and uses a solution approach to select the best option from this set. However, defining all such combinations is time-consuming and ineffective, especially when their number grows rapidly. Therefore, it is simple to understand that the solutions could not be ideal unless they are entirely deliberately determined. Several research studies in the literature illustrate this problem for different PVRP applications. Working on a scheduling issue for teaching assistants for impaired students in the Netherlands. The writers consider a few visiting regulations but do not mandate continuity of care. The schedules of the nurses performing HHC in Korea are determined by Nasir and Kuo. It considers continuity of care but does not include any visitation guidelines, such as uniformly spaced-out interval visits [Nasir and Kuo 2020]. Also, the issue with a general allocation plan is that an outcome variable determines how many goods are delivered throughout each time period. Neither visit guidelines nor continuity of care are included in this research [Archetti et al. 2017]. Therefore, it can be said that no study in the PVRP literature completely corresponds to the criteria of our issue setting.

The PLRP has the same goal as the PVRP, and it also locates the warehouses where the vehicles begin and concludes their tours. Due to its recent study, the PLRP literature is less extensive than PVRP's. Since PLRP is much more complex than PVRP, it is likewise NP-hard and heuristic methods rather than precise solution algorithms are used in the literature. The PLRP setup, it should be noted, is the type that most closely resembles our issue structure.

Prodhon established PLRP, and a metaheuristic technique is suggested to resolve it. In this approach, sites and routes are chosen and enhanced by a local search [Prodhon 2011]. For PLRP, a memetic algorithm with control over the population. It has been shown that this methodology performs better than the prior iterative heuristic strategy in terms of the solutions' accuracy and calculation speed. A local ecological search (ELS) method is created by Prodhon (2009) and Prodhon (2011). By enhancing the customer assignments to the visiting combinations, both investigations aim to identify the best periodic decisions. Prodhon (2011) has made the effort to formulate the mathematical model with predetermined timings of the vehicle. In the paper it was suggested that heuristics are required to manage huge instances, whereas the IP can handle tiny ones.

A similar issue is addressed by Savaser (2017), who created a heuristic based on VNS. The authors vary the daily routes by eliminating and adding clients while repeatedly changing the depot locations and visit pairings in the solution method. Hemmelmayr (2015) uses a modified LNS algorithm that essentially ruins a solution by excluding customers and fixes it by including them in yet another path or visit combination. It has been shown that using this strategy considerably raises the quality of the solutions in PLRP cases. A Unified-Adaptive LNS (U-ALNS) metaheuristic is used by Koc (2016) to solve the large-scale cases of heterogeneous PLRP and its variation with temporal frames. Hemmelmayr et al.'s (2017) research is the most recent to address this issue. Hemmelmayr (2015) found that in each ALNS iteration, a destroying operator eliminates a portion of the current solution before a repair operator rebuilds it.

2.2.2 USING MACHINE LEARNING IN HEALTHCARE VRP

New services utilising new technology are continually being provided, in addition to the classic routing services suggested in the scientific literature throughout the years. The most often utilised technique to enhance the efficiency of the algorithms as mentioned above is machine learning (ML). An overview of routing options that incorporate ML is given in the following sentences.

Utilising ML-based approaches, study aims to solve the CVRP. The "Learn to Improve" (L2I) learning-based CVRP method, which outperforms Operation Research (OR) algorithms in terms of solving speed, was proposed by the authors. The authors specifically presented a learning-based approach for the CVRP and proposed a framework that could divide heuristic operators into two groups to speed up the operation and focus reinforcement learning (RL) on those operators that were found to be improvement operators. Finally, they introduced an ensemble approach that teaches RL rules concurrently, producing better results at the same computing cost [Lu, Zhnag, Yang, 2019].

Few authors have created a database of the best answers for sampling circumstances and traits. The aforementioned information is used to train machine learning (ML) models that can predict characteristics of the best solutions for unseen scenarios and generate branching scores for assessment, a procedure that mimics the actions of an expert. As a result, the Sampled Vehicle Routing Problem with Time Windows (SVRPTW), a novel variant of the VRPTW, is created. According to experiments, the above-mentioned approach outperforms traditional algorithms regarding the quantity of nodes processed during the request and the needed runtime [Goel et al. 2019].

In another study, the authors suggested Deep Policy Dynamic Programming (DPDP), which combines established neural heuristics with DP techniques. Based on a deep neural network trained to estimate edges from sample solutions, DPDP prioritizes and restricts DP state space. Testing was performed on three different variants of routing problems. We used and evaluated three distinct routing problem versions. The traveling salesperson problem (TSP) was presented first, followed by the VRP, the most straightforward vehicle routing issue, and then the TSP with time windows (TSPTW), a variant of the original TSP. The trials showed that the algorithms' performance had been substantially improved, and as a result, they could outperform several other well-known solutions [Kool et al. 2022].

The Electric Vehicle Routing Problem with Chance Constraints (EVRP-CC) and partial recharge are the subjects of study. Two distinct steps make up the technique that the writers provided. While the first identifies the routes between each node to be visited, the second decides the best order for the journey to save energy and make arrangements for the vehicle to be charged as needed. The algorithm then determines the least energy-consuming routes that start and conclude at the depot and make stops at all clients and charging stations as necessary. Customers, charging stations, and depots are considered nodes in the road network since they are situated near intersections. All of the aforementioned use a probabilistic Bayesian ML model that the author created. A high level of accuracy for the energy projection, as well as energy improvements and improved route reliability, are revealed by the experiments carried out in the city of Gothenburg, coupled with a number of realistic simulations. More particular, no total consumption exceeded the prediction's 95% confidence interval, according to the trial data. Additionally, it was possible to conserve energy on the ten routes by up to 19.5%, with an average of 10.6% [Basso et al. 2021].

One of the most complicated variations of the VRP, the multi-objective VRP with stochastic demand (MO-VRPSD), is attempted to be addressed by the authors of research. The aforementioned problem faces two substantial obstacles: first, the unpredictability of customer demands; and second, the potential for competing goals. The authors offer a decision tree-based ML model to address MO-VRPSD, which helps in developing acceptable populations based on the knowledge gathered from prior search processes and considerably reduces the number of iterations, in order to meet the aforementioned issues. Additionally, they gave two inputs about the main issues with the MO-VRPSD. 2023 in Analytics, 29 In order to properly handle route failure, they first introduced a unique method of encoding and decoding the route and chromosome. They then used a powerful multi-objective optimisation algorithm to deal with the conflicting objectives in the MO-VRPSD. Utilising modified Solomon VRP benchmark instances, their method is evaluated. The experimental results show that the proposed evolution model outperforms earlier evolutionary techniques and can identify solutions with a superior Pareto front [Gee et al. 2016].

The Energy Minimising Vehicle Routing Challenge (EMVRP), which focuses on finding vehicle routes that utilise the least amount of energy when serving a group of cities or clients, is solved in work. The authors provide a genetic algorithm implementation that is enhanced by ML techniques to adjust its parameters in a later phase. The method being discussed is the use of k-means clustering, which has shown that identifying different data clusters significantly improves the performance of the genetic algorithm being used [Cooray et al. 2017].

The authors of the study proposed a ground-breaking extended neighbourhood search (LNS) architecture for routing-related issues that creates novel results using learned heuristics. The learning method was developed expressly for inclusion into an LNS search environment and is based on a deep neural network with an attention mechanism. The presented system, NLNS, is an addition to LNS that uses a guided heuristic search to find and deploy repair operators for VRP instances. The approach was explored in relation to CVRP and the Split Delivery VRP (SDVRP). The suggested technique significantly outperforms an LNS that uses only hand-crafted heuristics as well as a well-known heuristic algorithm from the literature in CVRP cases with about 297 consumers. The authors also showed that the aforementioned procedure surpasses existing ML techniques and methodologies for the CVRP and the SDVRP [Hottung and Tierney, 2019].

The study's authors offer a comprehensive methodology for using RL to resolve the VRP. This approach trains a single policy model to suggest the best options for a wide range of issue scenarios of comparable size by identifying reward signals and taking into account feasibility constraints. The trained model creates the solution as a sequence of subsequent actions in real-time without needing to be retrained for each new issue occurrence, thanks to the evaluation of a parameterized stochastic policy by the authors and the use of a policy gradient approach to maximise its parameters. In terms of solution quality for the CVRP, the proposed technique outperforms conventional heuristics and Google's OR-tools on mild examples with comparable computing time. The authors also illustrated how the solution under consideration might address delivery issues and looked into how divided shipments affect the system's dependability. Finally, several iterations of the VRP may be implemented using the aforementioned paradigm [Kalakanti et al. 2019].

Using a value-function-based DRL scheme and a combinatorial action space, the authors of proposed a framework in which the action selection problem is explicitly characterised as a mixed-integer optimisation problem. They used the CVRP as an illustration for using this paradigm. Each action is defined as the establishment of a single route, and a deterministic policy is created using the basic policy iteration approach. On medium-sized standard library instances, the authors claim that the proposed methodology achieves comparable performance to state-of-the-art OR methods and is competitive with current RL approaches [Koh et al. 2020].

The CVRP, a research team, employed a recursive method of the k-means clustering algorithm coupled with the Dijkstra shortest path algorithm to address one of the most prevalent issues in the areas of logistics and supply chain distribution. The suggested remedy breaks the CVRP into pieces to choose the best path. The overall capacity of the fleet of vehicles is considered first in order to optimise the capacity of the whole route; then, the k-means algorithm is executed while taking into consideration the trip time, distance travelled, and vehicle capacity; The ideal capacity of the vehicles is guaranteed in the following phase, and in the last stage, the Dijkstra's algorithm determines the fleet's shortest path [Yan et al. 2022].

2.2.3 BRINGING TRANSPARENCY IN DRUG DELIVERY

Access to essential medicines is an important aspect of public health. However, delivering medicines to rural areas can be challenging due to factors such as distance, infrastructure, and socio-economic barriers. In this literature review, we will explore the different strategies used for the delivery of medicines at rural areas, and the challenges associated with them.

A comprehensive search of relevant literature was conducted using databases such as PubMed, Medline, and Google Scholar. Keywords used included “medicine delivery”, “rural areas”, “healthcare access”, “low-resource settings” and “healthcare delivery”. Studies published between 2010 and 2022 were included in this review.

Several strategies have been employed to improve medicine delivery to rural areas. These include:

Mobile clinics: These are vehicles equipped with medical supplies and staffed by healthcare professionals that visit rural areas on a regular basis to provide medical services and dispense medicines. Mobile clinics have been shown to increase access to healthcare services in rural areas, including the delivery of medicines.

Telemedicine: This involves the use of technology such as videoconferencing, teleconsultation, and remote monitoring to provide healthcare services to patients in remote areas. Telemedicine has been shown to improve access to healthcare services and the delivery of medicines to rural areas.

Community health workers: These are individuals who are trained to provide basic healthcare services in their communities, including the delivery of medicines. Community health workers have been shown to be effective in improving access to healthcare services in rural areas, including the delivery of medicines.

Supply chain management: This involves the efficient management of the distribution of medicines from the central warehouse to the last mile, including rural areas. Effective supply chain management can ensure that medicines are available when and where they are needed.

Challenges associated with the delivery of medicines to rural areas include inadequate infrastructure, lack of transportation, and limited resources. In addition, there may be socio-cultural barriers, including lack of awareness, distrust of healthcare providers, and traditional beliefs and practices.

The delivery of medicines to rural areas is a complex issue that requires a multi-pronged approach. Strategies such as mobile clinics, telemedicine, community health workers, and effective supply chain management can help to improve access to healthcare services in rural areas, including the delivery of medicines. However, these strategies need to be tailored to the specific needs and challenges of each community.

Blockchain has evolved as a cutting-edge technology that securely, fault-tolerantly, and transparently transports and stores data. The technology based on distributed ledgers makes this possible. Any organisation may become safe, effective, transparent, and decentralised thanks to the blockchain. Researchers have been working to expand blockchain uses outside of finance since before the blockchain gained notoriety through Bitcoin. The healthcare sector is one of the non-financial sectors that has demonstrated a greater influence on the blockchain. However, research on creating blockchain-assisted apps is still fairly young and evolving quickly. Scientists in the healthcare sector have so been working hard to stay abreast of the research fronts in this area.

There has only ever been one prior literature evaluation that specifically addresses blockchain technology applications in the pharmaceutical sector [Fernando 2019]. No other study based on a literature review was found in this field, and no studies that addressed the problems, difficulties, and solutions connected to the implementation of blockchains in the pharmaceutical business were found, with the exception of Fernando. As a result, our work is the first thorough literature assessment in this field, including key blockchain technologies in the pharmaceutical industry, several major sectors of the pharmaceutical business, as well as current research constraints, issues, solutions, and future prospects.

The goal of Fernando's literature research was to pinpoint the elements that would make blockchain technology applications in the pharmaceutical sector successful. The authors conducted a meta-analysis of 15 studies and presented information on 21 success variables. Of these, they chose the five that they felt were most crucial: trust, tracking, transparency, traceability, and real-time. Notably, these five elements were only briefly covered, with no reference to the uses of blockchain or the problems specific to the field.

The appraisal of blockchain applications to advance the pharmaceutical business was covered in another review study [Alshahrani & Alshahrani 2021]. Data collection techniques for quantitative analysis were utilised by the authors. They discovered that the opinions of healthcare experts, a lack of cooperation, and economic disparity were the primary barriers to blockchain adoption in the pharmaceutical business in Saudi Arabia. The authors also noted a number of elements that may support blockchain applications, such as system stability, data security, enhanced supply chain management, decentralisation, interoperability, and governmental regulations. In contrast to Fernando, Alshahrani & Alshahrani notably avoided talking about blockchain-related problems and concerns.

The designs and difficulties of utilising blockchain for drug traceability were covered by the authors. They discussed problems with product traceability in the pharmaceutical supply chain and emphasised ways to use blockchain technology effectively for monitoring and tracing to reduce the use of fake medicines. The blockchain technology and the problems and difficulties associated with other sectors of the technology's uses in the pharmaceutical business were not discussed by the authors outside of the pharmaceutical supply chain in [Uddin et al. 2021].

For the early implementation of cryptocurrencies (such as Bitcoins) and other financial services, blockchain technology gained popularity. Later, other blockchain applications were proposed in numerous industries, and with the addition of smart contracts, blockchain gained in strength. Numerous concepts have been put out to utilise Blockchain's incredible flexibility in the fields of medical and healthcare. The authors have described how using blockchain can raise the calibre of clinical research. The application of blockchain in healthcare and medicine has generally been explored, but the use of blockchain in the medication supply chain has not been explained [Benchoufi and Ravaud 2017]. Another proposal, MedShare, seeks to leverage blockchain technology in the healthcare industry to transmit medical data from one institution to another in a trust-less environment. Healthcare data is extremely valuable and vulnerable to numerous forms of assaults. A technique for secretly preserving medical data and making it available to researchers for study purposes in the future is introduced in the white paper MedRec. By adding blockchain security, it offers a mechanism for storing patient data and making it simple to retrieve that data [Azaria et al. 2016]. Although M. Mettler did not provide specific implementation information, she also addressed using blockchain in the pharmaceutical supply chain [11].

Generally, the previous studies give the insight of vehicle routing and scheduling as well as the application of blockchain technology used in healthcare supply chain management. There are many challenges in the integration of MMUs along with the different parameters and maintaining the transparency in the system. However, there are several gaps witnessed in healthcare supply chain optimization as:

a. The calculation of accurate distance from one location to another relies on the many other parameters such as traffic conditions, road networks, etc.

b. Also, data for supply chain comes from various sources and system, thereby challenging the transparency in the supply chain.

c. Supply chain can be guaranteed for static data but in case of real time data, it may lead to suboptimal decisions.

d. There is absence of routing algorithm for real time data that considers all the different real time parameters.

e. Healthcare supply chain management must account for unpredictable demands that rapidly changes the circumstances and becomes difficult for the optimization models.

f. Healthcare supply chains involves multiple stakeholders, including manufacturer, distributor, etc. These entities may not have transparency into one other's operations, thereby making it difficult to optimize the model.

g. Another important concern is the cost and efficiency of the supply chain management. As sustainability is an important concern, healthcare supply chain needs to optimize the model which is not only cost efficient and efficiency of the system, but also for environmental impact.

These gaps help in finding out the objectives for this research.