A Real-Time Mobile and Web-Based Logistics Management System for Collaborative Urban Freight Transportation

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Abstract: **Logistics management has been considered to be one of the fast growing, flourishing and most lucrative business ventures to grow today in Pakistan and its key strategic geographical location on the commence of major sea trade routes between Europe, Asia, Africa, and the Middle East as well a large untapped market to handle to its vast population. Coordinating logistical operations is a highly complex and onerous task involving activities requiring well-defined routine, systematic procedures and meticulous attention to detail with the success of logistics firms now being directly linked with the quality of the software systems designed to cater to the myriad processes involved. The proposed system provides an innovative and user-friendly solution to all these problems of transportations, and shipments of parcels by providing a smart way of placing orders and tracking shipments with minimal human effort required on the part of the client and maximum satisfaction and ease of mind guaranteed at a reasonably cost-effective price. The proposed system contains four modules that are tailored to provide a complete logistics solution in a single software package, namely the Warehouse Management System, Driver/User Registration System and Booking/Tracking System spread over android applications for customers and ad-hoc drivers as well as a web-based desktop application for management and control of .the overall system**

***Keywords*— Logistics Management; Container Loading Problem; Vehicle Route Problem; 3D Packing Algorithm; .Logistics Warehouse Management; CPEC**

INTRODUCTION

In this paper a hybrid mobile and web application-based courier and parcel delivery system is presented. The main focus is on catering for businesses and industries along the China Pakistan Economic Corridor (CPEC) [1] route as well as between the major cities of Pakistan with provisions for clients importing goods from neighboring countries through third-party shipping companies and then their distribution. It seeks to provide an economic alternative to cross-country shipping based on the use of mobile applications cloud-based data handling without any need for tedious paperwork or physical presence of the customer in any order posting step.

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The proposed system is divided into a series of inter-linked modules, each geared towards a certain special purpose which includes booking, registration, driver panel, administration, and inventory management. Separate administrators will be responsible for over-seeing different systems with ad-hoc drivers and customers being the primary users of these systems. Ad-hoc or voluntary drivers can register to provide delivery services and access a driver panel where they can view details of new orders posted in their area and then choose whether or not to accept them.

Similarly, users also register separately so they can place delivery orders and then further track their own orders. A warehouse management system will be in place to manage parcel transfers into a warehouse for storage or packaging and out towards their intended destinations. Finally, various algorithms will be implemented to create a “smart system” that can automatically calculate optimal transportation routes, maximum freight capacity, and minimum fuel consumption so as to make the whole process of parcel delivery as efficient as possible.

LITERATURE REVIEW

The term Logistics refers to the process of acquiring, storing and transporting the materials or goods from the point of origin to the final point of consumption within time and budget. One of the first definitions of logistics is that it involves an efficient transportation of raw materials [2]. Logistics and supply chain industry is now evolving with the passage of time and countless efforts have been made by people from all over the world to enhance this logistics process. Not only worldwide, but Pakistan is also progressing in logistics industry specially after the initiation of CPEC project. This research paper has undertaken CPEC and logistics management as a research area as these two areas are interlinked with each other. However, despite the fact that CPEC and its logistics management is considered as the game changer for Pakistan for its economic benefits that it offers [3], there are many issues and challenges currently faced by the industry, some of which are described below as follows:

Fuel Expense and Maintenance

This is one of the major problems faced by almost every logistics firm and thus becomes the main reason of the loss of

revenue. According to a survey, there is a report that 95% people responded that high transportation costs is one of the main issue faced by logistics industry [4]. Almost every transportation vehicle consumes massive quantities of fuel, and is prone to mechanical failures due to its complexity and the road infrastructure. All these expenses add up to a handsome amount with increasing number of fleet vehicles of a logistics firm.

Continuous Need for Business Process Improvement

Every organization must constantly update and evolve its business processes in order to remain competent in this digital market, especially logistics and transportation firms where we have huge tech giants such as FedEx [5], DHL [6], UPS [7] and TCS [8] etc. The inability of keeping up the pace of competitors and the new technology has resulted in increasing challenges for the logistics firms to stay on top of market share. Thus constant changes must not only be accepted but also should be encouraged.

Satisfactory Customer Service Mechanism

Satisfactory Customer Service is the utmost need nowadays with increasing number of customers wanting to have their queries resolved instantly, but firms usually lack in providing their customers with this services especially logistics firms do not pay much interest in this area and as a result they lose their share in the market. Thus, customer satisfaction is the best method to gain competitive advantage over other firms. In order to deliver quality services to the customers, it is equally important for organizations to not only to understand their expectations but also continuously interact with them [9].

The March of Technology

In the present era of digitization and automation, many companies are now shifting towards complete automation of their business processes, which on one hand gives them the benefit of cost reduction, more satisfied customers, process optimization, less delay but on the other hand, firms now have to struggle more in order to keep them updated technologically. Especially logistics companies whose objective is less delays and more satisfied customers; these companies now have to constantly struggle to keep evolving their businesses with respect to technology.

Organizational Management and Coordination of Employees

In the recent years, customers prefer online shopping, due to this a rapid growth in the development of logistics industry. But most of the supply chain companies does not provide quality delivery service. This gives supply chain companies a chance to adopt more sophisticated supply chain management [10]. It is another major challenge faced by organizations, especially logistics firm is the efficient management and coordination of employees in order to run a well-organized and systematic process of supply chain activities. This management of processes and coordination of employees becomes extremely difficult for organizations operating from multiple geographical locations. Thus a proper organizational framework to better manage logistics operations and activities as well as to better coordinate the communication amongst the drivers and employees must be articulated.

High Unemployment Rate

The unemployment rate in Pakistan is increasing day by day and due to which Pakistan is facing economic backwardness. According to Pakistan Bureau of Statistics Government of Pakistan stated in "Employment trends in Pakistan", unemployment rate has been increased from 5.1% to 5.7% from 2006-2018. There are a number of people in Pakistan who want to work part time alongside their education or other jobs. There are a number of transportation companies which are addressing this issue by letting them be a part time driver such as Bykea [11], Uber [12], Careem [13] etc. Logistics companies can also incorporate this mechanism by introducing the concept of ad-hoc drivers.

Lack of Communication

Lack of communication between the customers, drivers and the company is a major challenge faced by the logistics companies. Customers want to track their parcels during shipment and there are a number of logistics companies who do not support their customers to do so because of lack of modern services. IT can improve communication and coordination all along the chain by improving the communication processes, as it produces competitive advantage, increases its innovation capability, and in this way, it provides better customer service and consequently increases the number of satisfied customers [14].

Efficient Container Loading and Vehicle Route Optimization

Loading parcels into the container is not only a matter of stuffing the container with boxes; rather it is a well-planned mechanism which involves determining the best solution with maximum volume utilization. In this way, logistics firms can prevent themselves from losses and earn more revenue. The activity of container loading requires continuous and repetitive estimation and simulation of the loading of packages into the container in order to find the best organization of packages with minimized number of containers [15]. Similarly, an effective and optimized routing mechanism is also needed which can help minimize the average number of hours spent per delivery and in turn saves fuel cost incurred. A typical Vehicle Routing Problem (VRP) involves determining the most efficient route for each vehicle from a main supply depot to multi customers and them returning back to the depot within specified shipment time and cost [16]. Thus, specialized algorithms are needed in both the cases for better efficiency of the logistics firms.

Container Loading Problem

Container Loading Problem (CLP) is classified as a Non-deterministic Problem (NP) [17]. NP hard three dimensional rectangular single large object placement problem [18]. There are two types of container loading problem, the first one involves loading of identical boxes into the container namely homogenous loading and the other type involves loading of different types of boxes and it is called heterogeneous loading [19]. These specialized algorithms seek to find a mathematical model of the problem that aims to utilize maximum volume of the container. There are a number of scientists who proposed their own algorithms with George and Robinson being the first to propose a heuristic for container loading problem [20]. In 1997, Gehring and Bortfeldt proposed a genetic algorithm to solve this problem [19], which was recently enhanced by Xianbo Xiang, and Caoyang Yu, He Xu, and Stuart X Zhu in 2018 by using an adaptive genetic algorithm to solve the container loading problem. They utilized a dynamic space division method and a placement heuristic that finds the best position and orientation of a cargo box [21]. In 2001, Erhan Baltacioglu proposed EB-AFIT packing algorithm used to pack parcel boxes into the container with an objective to utilize maximum volume of container. This algorithm builds a new placement of parcel in every iteration and thus chooses the best possible arrangement of cargo boxes [22]. In 2005, Andrew lim, and Xingwen Zhang proposed a greedy heuristic layer building approach to solve the container loading problem [23]. Later in 2010, Tobias Fanslau, and Andreas Bortfeldt proposed a tree based algorithm to solve the CLP. They used a method which involved two stages, one stage packs the weakly heterogonous boxes and the second stage packs the strongly heterogonous boxes [24].

Vehicle Route Problem

Another issue which mostly logistics and transportation companies face is transportation, and path issues and this issue is mostly rendered by a lot of companies, and sometimes it becomes hectic to cope with the whole situation where less fuel has to be used, with respect to the vehicle. Fuel consumption is based on the path, which the vehicle chooses, as the shorter the path is, the more fuel is preserved, and this is only possible if there is a technique at the backend, that is calculating the shortest path in no time. In this problem, there are majorly three variants that are dependent on each other somehow, like the path chosen, fuel consumed and the type of vehicle. With the correct, and accurate simulation of them, it is nearly easier to get the accurate results for solving the problem and getting the definite results.

Vehicle Routing Problem (VRP) is one of the famous type of algorithms that has been used in recent times for filling the gap between theory, and practices. A lot of research work has been done, in easily solving this routing problem, and amazingly this algorithm is one of the biggest and one of the successful implementations of operational research. A lot of live examples, being followed up on the basis of this algorithm, has been proposed in which VRP helps in reducing the transportation cost and has proven it for a lot of giant transportations companies, by making a vibrant decrease in fuel consumption, by rendering the shortest path available [16]. The core purpose of this VRP is to find the optimal path which will take the driver to destination in the smallest span of time possible.

In [25], a general heuristic technique is used to solve in-vehicle routing enigma helps in solving this routing problem. Faced by vehicle in which there are numerous attributes, which play a part in solving the issue. It helps in solving five different variants, like the Vehicle Routing Problem Time Windows (VRPTW), the Capacitated Vehicle Routing Problem (CVRP), the Multi-Depot Vehicle Routing Problem (MDVRP), the Site-Dependent Vehicle Routing Problem (SDVRP) and the Open Vehicle Routing Problem (OVRP). All the mentioned variants are locked up into an enriched pickup, and delivery model which helps in simulating the issue, using Adaptive Large Neighborhood Search, (ALNS) framework which was presented in [25]. Some researcher uses genetic algorithm to find the solution of vehicle routing problem. The main center of attention is paid off to the demands of the customers, that are based on a single depot. Many vehicles are desired to be limited in case of weights a vehicle can bear, and also the distance traveled. The best

results have been put forward by using the tabu search, and simulated annealing. Whereas genetics algorithms have been used to compute various optimization problems, including a lot vehicle routing problems, mostly where the time frame is restricted. This algorithm helps in solving the computational problem of vehicle routing using a hybrid technique that is of Genetic algorithms, in terms of time, and path [26].

In [27], Contraction Hierarchies Algorithm, first proposed in 2008. This is used to find the shortest path in a graph with low time and space complexity. It has various applications in different fields such as car navigation systems, vehicle routing problem, traffic simulations, logistics optimization, travelling salesman problem etc. There are many efficient route finding algorithms like the A* algorithm that may use to find the shortest route in a short span of time but some additional preprocessing can do wonders and thus enable us to cut down shortest path computations from a matter of seconds to milliseconds or even microseconds without any noticeable loss in efficiency.

Contraction Hierarchies (CH) [28] is a two-phase approach namely revolving around a pre-processing phase and a query phase. It is a speed-up optimization method that makes use of the properties of graphs representing road networks which works by creating shortcuts in a preprocessing phase that are then later used in the query phase and it helps find the shortest

path by skipping unimportant vertices which are too far away. These shortcuts help to save the pre-computed distance computed between two important nodes by preventing the algorithm from having to consider the full length between them so that it can readily be utilized at the time of query. The pre-computed routes and shortcuts can then be used to answer as many queries of shortest paths as required and through this way we can save a lot of time and find shortest path near instantaneously [28]. Pre-processing is the first step in the CH algorithm. This phase helps in reducing the search space of vertices and edges representing the road network. Through this step, shortcuts can be created which we can used later to answer the query requests in the queries phase. This can be achieved by performing iterative vertex contractions. In short, when contractions are performed a shortcut is created between each pair of neighboring vertices that is (u, v) vertex u and vertex v. Thus, witness search method is then used to find whether the shortest path between the pair of vertices that is vertices u and v exists or not. The vertices in the graph are contracted in such a way that the edges in the graph are minimized then the pre-processing phase starts by sorting all the nodes to some notion of importance. After this the contractions of nodes are performed in the same order one by one while preserving the shortest paths in the graph, also consecutively adding more edges also called shortcuts. Thus after adding all the shortcuts and removing all the nodes from the actual graph, a new graph G' is created [29]. In the second query phase a slightly modified bidirectional Dijkstra shortest path search [30] is then executed in order to answer a query request, only traversing a few hundred nodes. Thus, shortcuts are unpacked in query phase in order to determine the list of edges in the shortest path [31].

In this paper, better customer service and how to increase the number of satisfied customers are addressed. The proposed system successfully solves these issues and overcomes the challenges faced by logistics organizations. The proposed system includes efficient algorithms proposed by remarkable scientists, two such algorithms are container loading algorithm (EB-AFIT [22]), and route optimization algorithm (Contraction Hierarchies [28]) for better efficiency of the logistics operations.

SYSTEM ARCHITECTURE

The proposed system is based on client server architecture that is the client node requests the services from the server and the server is responsible to manage the network resources and deliver the services as requested by the client. All the services and communications are conducted over a network. The android devices act as the client nodes in the system, thus these devices will request the services from the server through an Android application. Both the client devices and the server communicate through a network. These android applications are available to be used by the drivers and customers in order to request their services immediately. The client and server system interact and communicate with each other using http protocol that is by using an Application Programming Interface (API) that helps the client to connect with the server through an http request. In the Figure 1, system architecture which can easily make the readers understand the business logic in one glance; it has the four main component active roles of the proposed system. Drivers, Customers, Admin and Warehouse staff along with their cause of interaction with each other labeled separately on each flow.

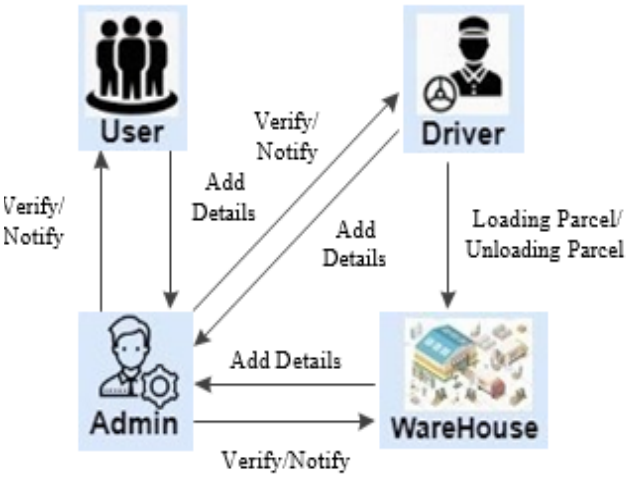

Fig 1: System Architecture shows four main components.

Drivers (both ad-hoc and in-store) have an android application through which they can easily view the details of shipment orders such as the source and destination address, the freight details such as its weight and volume, the pickup date etc. and choose to accept or reject the orders. Drivers can also view the shortest path from one place to another which will help them reduce their operating costs. Customers, on the other hand, can use their android application to request the shipment of their parcels, they can easily track their parcels as well as get notifications regarding the shipment of their parcels from timeto time. Thus, these mobile applications will be a huge benefit for the customers in an attempt to book the shipment of their parcels.

Customers will request the shipment service from the server via android application by providing all the details of the order. These details are transferred to the server side in the Java Script Object Notation (JSON) format and with the help of an API that helps client connect to the server. The server cannot directly communicate with the client; however, it can send notifications/ messages to the client. When the order is accepted, customer on the client side will be notified via android application. Similarly, drivers will make a get request to the server to view all the current shipment orders that have not been accepted by any other driver.

The front-end of the mobile application is built on react native, which can be used to create hybrid applications that is both android and IOS application. However, for now there is only an android application. Admin who is responsible for managing all the operations of the system has a web application whose front-end is built on HTML and CSS. Back- end the proposed system is built on PHP and MySQL, because it is flexible and widely used. Furthermore, Firebase cloud messaging service will be used for push notifications in order to notify the customer about the status of orders. Push notifications will be also be used to notify the drivers about the new posted shipment orders. Email servers will be used to automatically generate email notifications to the customers about the status of their shipment orders. JavaScript is used for validation of data, and payment gateways will be used for online payment of the shipment service.

This paper mainly examines the above-mentioned systems in-depth, both by their working and methodology alongside their overall design. In addition to providing an overview, it also includes a review and discussions on the theoretical literature available related to the field of logistics that this project is built around mainly revolving around the various standardized algorithms, i.e. container loading, shortest path, etc. available for solving common logistics and transportation problems. This paper will seek to provide all the typical services of a high-end logistics carrier at a reasonable cost.

METHODOLOGY

The proposed system is divided into a chain of inter-linked modules shown in the Figure 2, which includes the admin panel for system administration and the warehouse management system for inventory management on the web and the android-based mobile applications for drivers and customers' administration and an inventory management are web application-based. Each module has a separate administrator which is responsible for overseeing different systems with ad-hoc drivers and customers being the primary users of these systems. Drivers, customers and warehouse staff must first register with the system in order to be able to perform their respective roles. The overall registration process is the same for all users with a user providing their info and credentials that are forwarded to an administrator for verification, whereupon access is granted on acceptance. For ad-hoc drivers an additional interview step is added that must be cleared in order to be considered for acceptance.

Users can enter parcel related information such as its net worth (value), type of the content of the parcel etc. into the booking and tracking panel. Which will be verified by the Administrator. So they can place their orders for the shipment of parcels and then also further track their own orders. The administration will accept the user's request and then send it to the drivers. We cater to both in-store drivers as well as ad-hoc drivers. Ad-hoc drivers will be commission based and work on a pay-per-delivery basis and they can also formally sign on as employees of the company themselves. Both in-store drivers and Ad-hoc drivers can access a driver panel where they can view details of every new orders posted in their area and then choose whether to accept them for delivery to a warehouse or destination.

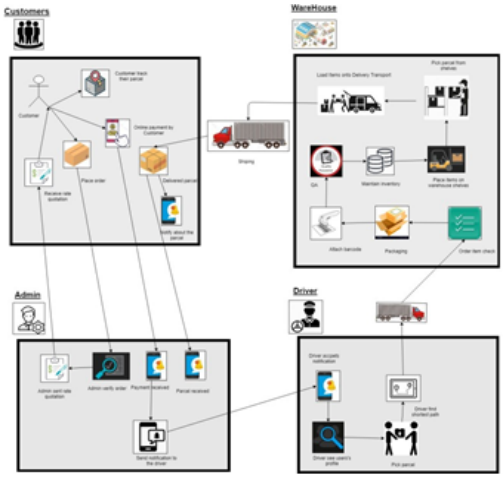

Fig 2: Coordination of different modules of proposed system.

The management of parcels is an important component of the system. That's why warehouse is the foundation of the proposed logistics system and it would be impossible to provide an efficient and dependable delivery service without this system. In warehouse first parcels are unpacked, inspected by the Quality Assurance (QA) team (in terms of measuring dimensions and weights, etc.), bar-code tagged and then placed on shelves for temporary storage. When these parcels need to be moved when their delivery time frame draws near, they are picked up by labor, the inventory is updated and the parcel is loaded in the vehicle for its final shipment to the destination point (that is the receiver). These parcels are delivered from the source warehouse to the destination warehouse (such as from Karachi to Lahore) where the whole process (except unpacking) would be done and the shipment can finally be sent off to its final destination. In Figure 3, an overview of the warehouse management system where all orders pass through on their way to their destination, involving the processes of inspection, barcode tagging and order status

appraisal. A group of administrators oversees the entire system and manages the roles while handling the requests for the other three user types drivers, customers and warehouse staff. This includes registration management, order management, shipment management, report generation and distribution point management all handled through the admin panel which serves as a repository for all information related to the system.

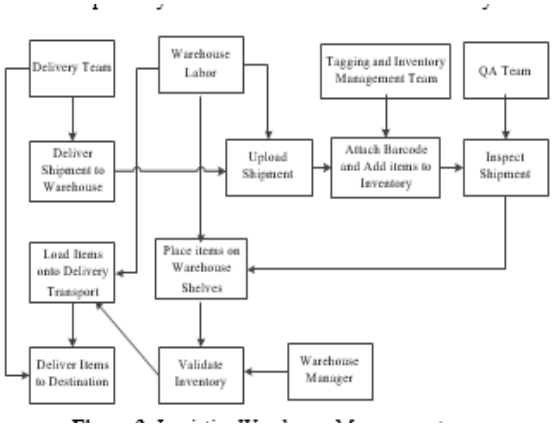

Fig 3: Logistics Warehouse Management.

The Warehouse system incorporates state-of-the-art three dimensional container loading algorithm which enables the warehouse staff to load the parcels into the container in no time and even view the organization of parcels in a three-dimensional model visualization provided by the system. This ability to "see" the exact way to properly load parcels into the container beforehand has greatly improved our logistic operations efficiency as now the warehouse staff has no longer to pre-plan the parcels' organization. The container loading algorithm that is EB-AFIT algorithm [22] is tested for its efficiency and thus the results proved that it is the most efficient, best fit container loading algorithm for the proposed system that can load the parcel into the containers.

The main reason of using CH based VRP algorithm [28] for amongst the established basic ones is its ability to drastically reduced computation time made possible by pre-processing without having to sacrifice efficiency or the accuracy of results. It also helps to conserve computational resources and time by making sure that only the "important" or "relevant" points of a graph are examined instead of having to keep track of everything between two points, both advantages being highly sought after in the highly complex computational problems found in real-time shortest path finding that demand both precision and promptness in its results.

The proposed system also has its own embedded administration system. This system helps manage the overall logistics operations of the other systems. It is the management system that allows the admin to oversee the entire flow of the parcel delivery process. This feature improves the performance of the system and makes it even more efficient. All these features and use cases of proposed system are thoroughly tested for their efficiency and reliability. The proposed logistics system is intended to be a comprehensive logistics solution suitable for the needs of small-medium scale industrial and business clients that helps gives them an edge against competitors in a highly contested business environment. Its easy-to-use mobile application allows comparatively less tech-savvy drivers to hop in and out of shipment deliveries at their leisure, enabling them to make the most of their freight capacity and valuable time without the hassle of having to hunt for prospective clients. At the same time customers are able to comfortably arrange shipment sizes and delivery schedules earning them piece of mind without having to constantly fret about pickup and drop-off. The web- based administration system requires minimal training and effort with a low startup cost to utilize allowing localized support personnel to be hired to widen the service net. The main motto is to stick to the basics by providing a reliable, low-cost shipping solution alternative to those businesses and industries that are not yet large enough to support taking on high-end logistics providers, thus attempting to build a solid foundation that caters to the new industrial and business boom that is expected to follow with the opening of CPEC.

CONCLUSION

The proposed paper's main goal is to offer a viable alternative logistics solution to the wider commercial and industrial market by empowering both customers and drivers through allowing them more influence in their respective areas of concern. By providing an easy-to-use interface with smart route finding and container loading capabilities, it hopes to encourage the further digitization of logistics in Pakistan and open up this untapped market for the benefit of all. While there are many challenges towards the widespread acceptance of such a system by small-medium scale businesses and industries in Pakistan, this paper aims to break the barriers between customers, drivers and logistics firms by fostering better communication alongside smart optimization services in order to provide smaller firms with a more level playing field by which to compete in the highly lucrative and competitive business environment opened up by developments in CPEC.

REFERENCES

[1] "Employment Trends in Pakistan," Pakistan Bureau of Statistics Government of Pakistan, 2018.

[2] I. Meidute, "Comparative analysis of the definitions of logistics centres," Transport, vol. 20, no. 3, pp. 106-110, 2005.

[3] M. Hussain, M. Ilyas, K. Mahmood, and A. Awais, "Pragmatic reality of China Pakistan economic corridor: Impacts on economy and logistics industry of Pakistan," Science International, vol. 29, no. 5, pp. 1073-1078, 2017.

[4] R. Hanif, and E. Kaluwa, "Analysis of transport logistics challenges affecting freight forwarding operations in Malawi," African Journal of Business Management, vol. 10, no. 24, pp. 607-614, 2016.

[5] "Federal Express Corporation," https://www.fedex.

com/ Accessed on: May 18, 2022.

[6] "Deutsche Post DHL Group," https://www.dhl.com/ Accessed on: May 18, 2022.

[7] "United Parcel Service," https://www.ups.com/ Accessed on: May 18, 2022.

[8] "Tranzum Courier Service," https://www.tcsexpress.com/ Accessed on: May 18, 2022.

[9] H. W. Kim, and Y. G. Kim, "Rationalizing the customer service process," Business Process Management Journal, 2001.

[10] R. M. Ali, H. S. Jaafar, and S. Mohamad, "Logistics and supply chain in Malaysia: issues and challenges." pp. 12-13.

[11] "Bykea," https://bykea.com/ Accessed on: May 18, 2022.

[12] "Uber," https://www.uber.com/ Accessed on: May 18, 2022.

[13] "Careem," https://www.careem.com/ Accessed on: May 18, 2022.

[14] G. Fulantelli, M. Allegra, and A. Z. P. Vitrano, "The Lack of Communication and the Need of IT for Supply-Chain Management Strategies in SMEs." pp. 19-21.

[15] H. Iwasawa, Y. Hu, H. Hashimoto, S. Imahori, and M. Yagiura, "A heuristic algorithm for the container loading problem with complex loading constraints," Journal of Advanced Mechanical Design, Systems, and Manufacturing, vol. 10, no. 3, pp. JAMDSM0041-JAMDSM0041, 2016.

[16] J. E. Bell, and P. R. McMullen, "Ant colony optimization techniques for the vehicle routing problem," Advanced engineering informatics, vol. 18, no. 1, pp. 41-48, 2004.

[17] J. Cohen, "Non-deterministic algorithms," ACM Computing Surveys (CSUR), vol. 11, no. 2, pp. 79-94, 1979.

[18] F. Parreño, R. Alvarez-Valdés, J. M. Tamarit, and J. F. Oliveira, "A maximal-space algorithm for the container loading problem," INFORMS Journal on Computing, vol. 20, no. 3, pp. 412-422, 2008.

[19] H. Gehring, "A genetic algorithm for solving the container loading problem," International transactions in operational research, vol. 4, no. 5-6, pp. 401-418, 1997.

[20] J. A. George, and D. F. Robinson, "A heuristic for packing boxes into a container," Computers & Operations Research, vol. 7, no. 3, pp. 147-156, 1980.

[21] X. Xiang, C. Yu, H. Xu, and S. X. Zhu, "Optimization of heterogeneous container loading problem with adaptive genetic algorithm," Complexity, vol. 2018, 2018.

[22] E. Baltacioglu, The distributer's three-dimensional pallet- packing problem: A human intelligence-based heuristic approach, Air Force Institute of Technology, Wright- Patterson AFB OH, School of Engineering and Management, 2001.

[23] A. Lim, and X. Zhang, "The container loading problem." pp. 913-917.

[24] T. Fanslau, and A. Bortfeldt, "A tree search algorithm for solving the container loading problem," INFORMS Journal on Computing, vol. 22, no. 2, pp. 222-235, 2010.

[25] S. Ropke, and D. Pisinger, "An adaptive large neighborhood search heuristic for the pickup and delivery problem with time windows," Transportation science, vol. 40, no. 4, pp. 455- 472, 2006.

[26] I. H. Osman, "Metastrategy simulated annealing and tabu search algorithms for the vehicle routing problem," Annals of operations research, vol. 41, no. 4, pp. 421-451, 1993.

[27] R. Geisberger, P. Sanders, D. Schultes, and D. Delling, "Contraction hierarchies: Faster and simpler hierarchical routing in road networks." pp. 319-333.

[28] R. Geisberger, P. Sanders, D. Schultes, and C. Vetter, "Exact routing in large road networks using contraction hierarchies," Transportation Science, vol. 46, no. 3, pp. 388-404, 2012.

[29] S. Storandt, "Contraction hierarchies on grid graphs." pp. 236- 247.

[30] F. B. Zhan, "Three fastest shortest path algorithms on real road networks: Data structures and procedures," Journal of geographic information and decision analysis, vol. 1, no. 1, pp. 69-82, 1997.

[31] R. Geisberger, and D. Schieferdecker, "Heuristic contraction hierarchies with approximation guarantee."