2.LITERATURE SURVEY

There are numerous studies in the field of order picking and warehousing. To present classifications of order picking systems and routing heuristics for single block warehouses, review of [1], which is about manual order picking processes regarding layout design, storage assignment techniques, order batching, zoning, routing strategies, order accumulation and sorting methods, is analyzed. A taxonomy developed by [2] is also considered to classify order picking systems into five categories as "Picker-to-parts", "Pick-to-box", "Pick-and-sort", "Parts-to-picker" and "Completely automated picking". [3] provides a literature review about order picking systems as well. Categorization of order picking systems, components of order picking time, factors affecting order picking process and routing heuristics are topics covered by the survey which is broadly used for the introduction part of this study.

This study is focused on improving order picking performance of a multi-block warehouse so a performance basis for multi-block warehouses is needed to compare the proposed solution. To analyze solution approaches for multi-block warehouses, various studies for multi-block warehouses are examined. [4] considers a parallel-aisle warehouse. Average travel time is compared for warehouses with and without a middle aisle, through a simulation. Three factors are taken into account: warehouse size, warehouse layout (the presence or absence of a middle aisle; the number of aisles), pick list size. A routing algorithm is proposed where aisle changing is allowed, due to cross aisles. Also [5] introduces combined and combined+ routing heuristics in this study for warehouses with more than two cross aisles where items are stored

randomly. The proposed heuristics use dynamic programming. The performance of the proposed heuristics is compared to a branch-and-bound algorithm under different warehouse layouts and pick list sizes. [6] studies order picking problem and compare optimal and heuristic algorithms, in terms of average travel time and total route time (which includes other activities such as administrative tasks, acquisition and dropping off pick carriers, in addition to travel time). [7] describes routing policies and storage assignment policies for multi-block warehouses. A simulation study takes place to evaluate several storage assignment policies and routing policies for various layouts.

To analyze different management decision problems that warehouse managers encounter to improve warehouse productivity, reviews and studies based on main warehouse activities and policies are examined. [8] mention basic warehouse functions, order picking strategies, automation, classification of order picking systems and warehouse equipment. [9] presents a literature review including classification of warehouses, strategic-tactical-operational warehouse decisions, storage location assignment problem, order batching, routing and sequencing issues. Storage location assignment is considered as an intermediate range management decision whereas routing, sequencing and order batching are considered as short range operational decisions. [10] reviews literature on warehouse design and control systems, focusing internal warehouse structure and operations. Warehouse characteristics regarding warehouse processes, warehouse resources, warehouse organization issues are covered. Warehouse design problems at strategic, tactical and operational level are examined. [11] presents a

review and categorize operational level warehouse operation planning problems, based on four warehouse activities: receiving, storage, order picking and shipping. [12] compares several picking, storage and routing policies in manual order picking systems via a simulation study. The effect of these three decisions are examined on order picker travel time, with regards to reduction in total picking time by comparing to a baseline policy. The baseline policy refers to the actual policy of the firm which employs traversal routing and random storage. A sensitivity analysis is also conducted to explore the effect of order size, warehouse shape, location of pick-up/drop-off point, and demand distribution on order picker travel time.

[13] focusses joint order batching and order picking problems. A mathematical formulation is proposed for the joint problem, based on integrating bin packing problem and TSP. It is stated that bin packing problem is equivalent to order batching problem where bin represents the order picking vehicle and items to be packed are items to be picked. The aim is to find the assignment of orders to batches to minimize the number of batches subject to not exceeding the capacity of the vehicle. TSP is equivalent to obtaining the sequence of items to be picked. Moreover, two heuristic algorithms are suggested to be able to solve the problem within reasonable running time. This is because order batching and order picking problems are said to be two key operational problems which must be solved frequently and require fast solutions. [14] considers order picking problem where items can be stored in multiple locations, as opposed to general setting. A model is suggested for simultaneous determination of location assignments and picking

sequence. However, given the complexity of the problem, TSP heuristics such as nearest neighbor and shortest arc are modified for the problem setting. Also, a tabu search algorithm is developed for the problem.

In terms of studies that describe and implement GA, [15] examines evolutionary algorithms, in specific, genetic algorithms. Steps and process of genetic algorithm, genetic operators, advantages of genetic algorithms and selection methods are explained. This study is mainly used to have a brief introduction to GA and to understand the functioning of GA. Among diverse applications of GA to solve different problems in literature, studies proposed for warehousing problems using GA are concerned majorly. To be able to decide on selection method, crossover and mutation operators and to determine the value ranges of parameters to be used in GA in parameter tuning for crossover and mutation probability, the following studies are examined. [16] considers order picking problem in an automated single-block warehouse by taking travelling time into account. A GA is implemented which uses roulette wheel as selecting strategy, with the optimal individual preserving strategy (in other words, elitism). Solutions' convergence situation in terms of total travel time is reported under different iteration times. [17] considers order batching problem where customer orders are grouped into batches optimally to minimize total travel distance by the help of a GA. The proposed algorithm can be applied to not only single-aisle or rectangular but any type of warehouse layout. [18] proposes an order batch picking model which takes earliness and tardiness penalties into account, in addition to travel cost. Retrieving items earlier than their due date leads to piled up items around the

warehouse. Retrieving items after their due date leads to transportation delays and customer dissatisfaction. Roulette wheel selection approach is employed. A multiple-GA method, which consists of two different GA-based algorithms, is constructed to solve the proposed model. The first GA algorithm is used to find an optimal order batching plan to minimize earliness and tardiness penalties and travel cost. The second GA algorithm is utilized to obtain the optimal travel path within an order batch to minimize travel distance. A parameter tuning takes place to find best parameter combinations,regarding maximum number of iterations, crossover probability, mutation probability and population size. [19] focuses on order batching problem in a low-level, picker-to-parts, single-block rectangular warehouse. A GA is presented which applies parameterized uniform crossover operation that mixes the information of two parents according to a fixed mixing ratio. An immigration operator is employed, instead of a mutation operator, by generating some new chromosomes as initial solution generation phase in order to provide genetic diversity and not to get stuck in local optima. [20] considers storage allocation and order picking problems in a single-block fast-moving consumer goods warehouse. Elitism is implemented by copying the first best two chromosomes to the next generation. [21] focuses on order picking multi-objective optimization problem. The number of order pickers per shift and the best retrieving sequence of items are to be determined. Roulette wheel is used as a parent selection technique and order crossover is employed to generate offspring. Inversion mutation is incorporated. [22] proposes a dynamic mathematical model to solve small-size order picking problems by

taking product life, customer importance, probabilistic demand and backordering strategy into account. A GA is proposed to solve similar large-size problems. Three metrics are used for performance comparison of two methods: Elapsed CPU time, number of fulfilled orders, quality of objective function. [23] examines order picking problem in a multi-aisle automated warehouse to minimize total travel time of storage/retrieval machine. In the warehouse, each item can be retrieved from several storage locations. A GA is constructed which uses roulette wheel as selection method and partially matched crossover as crossover operator. Two performance measures, CPU time and travel time, are analyzed. [24] considers the problem of a film-copy deliverer, as an extension of TSP. There is an analogy between order picking problems and TSP such that order picker is analogous to salesman whereas items to be picked are analogous to cities to be visited. Therefore, film-copy delivery problem is also similar to order picking problem. In this problem, there are several cinemas and only one film-copy. The duty of the deliverer is to bring the film-copy to each cinema based on the predetermined show times. A GA is developed for which a new crossover operator is designed to prevent illegal offspring and a new mutation operator is designed to mutate offspring. [25] investigates the relationship between order picking problem inside warehouse and vehicle routing problem outside warehouse for conventional single-block and multiple-cross aisle warehouses. A GA-based approach is proposed to solve these problems in a hierarchical manner. [26] solves order batching and pick routing problems simultaneously via GA based methods. Two new GA-based methods are

proposed that can be employed for both conventional single block and multi-block warehouses. Roulette wheel is used as selection method.