The main criterion of paper selection in this survey was the presence of an innovative problem formulation or solution method. While each of the baseline VRP aspects mentioned in the introductory section (time frame, loading constraints, open routes, etc.) single-handedly adds a new layer of complexity to the plain VRP/CVRP formulation, such one-dimensional VRP extensions are, nevertheless, well-researched in the literature and gradually give ground to more complex problem variants. On a general note, the mainstream VRP research is developing in the three following directions:
在这次调查中，论文选择的主要标准是有一个创新的问题公式或解决方法。虽然导论部分中提到的每个基线 VRP 方面(时间框架、加载约束、开放路径等)单枪匹马地为普通 VRP/CVRP 公式增加了一个新的复杂层，但是这种一维 VRP 扩展是，在文献中得到了很好的研究，并逐渐为更复杂的问题变体奠定了基础。总的来说，主流的 VRP 研究正朝着以下三个方向发展：

new challenging problem extensions reflecting contemporary technical and societal challenges, demands and opportunities, e.g. Green VRP, ad-hoc delivery, or last-mile delivery,
新的挑战性问题扩展反映了当代技术和社会挑战、需求和机遇，例如绿色 VRP、点对点交付或最后一英里交付,

synergetic combinations of several VRP aspects which lead to essentially new problem formulations, usually practically-motivated, e.g. VRP with backhauls or various formulations of Rich VRP,
多个 VRP 方面的协同组合，导致基本上新的问题公式，通常是出于实际动机，例如，VRP 与回程或 rich VRP 的各种公式,

new problem formulations addressing specific business or industry settings, e.g. VRP for transportation of hazardous materials, humanitarian transportation in post-disaster settings, or local VRP in large industry or cargo plants.
针对特定商业或行业环境的新问题配方，例如用于危险材料运输的 VRP、灾后环境中的人道主义运输，或大型工业或货运厂中的本地 VRP。

带回程的：

One of the fast developing variants of the VRP in recent years is VRP with Backhauls (VRPB), initially proposed in [14], which includes, as one of its main subcases, VRP with Simultaneous Pick-up and Delivery (VRPSPD). Simultaneous pick-up and delivery assumes that both linehauls (delivering goods) and backhauls (pick-up tasks) are requested simultaneously at a client ' s site [15] – [17]. While this situation is quite frequent in real-life scenarios, there are also two other VRPB formulations which gained momentum in recent years [18]. In the first one, known as VRP with Delivery Before Pick-up (VRPDBP) [19], [20],linehauls must be served before backhauls. In the other one, referred to as VRP with Backhauls and Mixed-load (VRPBM) or VRP with Mixed Pickup and Delivery (VRPMPD) [21], linehauls and backhauls can be served in any order.
近年来快速发展的 VRP 变体之一是回程 VRP（VRPB），最初在文献[14]中提出，它包括作为其主要子类之一的同时提货的 VRP（VRPSPD）【同时派送/收集的车辆路线规划问题】。

同时提货和交货假设在客户现场同时请求联运（交货）和回运（提货任务）[15]-[17]。虽然这种情况在现实生活中相当常见，但还有另外两种 VRPB 公式近年来获得了发展势头[18]。在第一种情况下，即所谓的“先交货后提货”（VRPDBP）[19]，[20]，必须在回程运输之前提供货物运输服务。在另一种情况下，称为具有回程和混合装载（VRPBM）的 VRP 或具有混合取货和交货（VRPMPD）[21]的 VRP，可以按任何顺序提供直线运输和回程运输。

The three above-mentioned variants of VRPB were initially introduced as stand-alone extensions of the VRP. Lately, they started to serve as a basis for new VRPB versions that address specific business requirements, most notably, loading constraints described below.
Two-dimensional loading VRP with clustered backhauls (2LVRPB), which assumes that both types of demands (pickups and deliveries) are composed of non-stackable items, was proposed in [22]. Quite surprisingly, despite relatively high commonness in everyday transportation logistics, the problem has not been formally considered in the literature until recently [22]. The problem is approached with the Large Neighborhood Search (LNS) metaheuristic, with dedicated routing and packing local search heuristics.
上述三种 VRPB 变体最初作为 VRP 的独立扩展引入。最近，它们开始成为解决特定业务需求的新 VRPB 版本的基础，尤其是下面描述的加载约束。
文献[22]提出了具有集群回程的二维装载 VRP（2LVRPB），假设两种需求（提货和交货）都是由不可堆叠的物品组成。令人惊讶的是，尽管在日常运输物流中具有较高的共性，但直到最近才在文献中正式考虑到这个问题[22]。采用大邻域搜索（LNS）元启发式算法、专用路由和打包局部搜索启发式算法对该问题进行求解。

VRPSPD is extended by adding constraints related to the transportation of non-stackable rectangular items was also proposed in [23] under the name VRP with Simultaneous Pick-ups and Deliveries and Two-Dimensional Loading Constraints (2LSPD). A combination of 2L-CVRP [24] and VRPSPD makes the resulting problem truly demanding as 2D loading feasibility must be verified for each arc of the traveled routes. The problem can be further extended by imposing LIFO (Last In, First Out) constraints which prohibit the rearrangement of items on the route. Both versions (with and without LIFO) are solved with a two step approach: first a heuristic initial solution is constructed, which is then optimized with the help of three local exchange operators, previously used and evaluated by the authors in [25]. Also a new set of benchmarks [26] corresponding to 2L-SPD formulation is proposed in [23].

VRPSPD 的扩展是通过增加与不可堆叠矩形物品的运输相关的约束，在文献[23]中也以 VRP 的名义提出了同时提货和交货以及二维装载约束（2LSPD）。2L-CVRP[24]和 VRPSPD 的结合使得所产生的问题真正需要解决，因为必须验证每个行驶路线弧的二维加载可行性。这个问题可以通过强制后进先出（Last-In，First-Out）约束进一步扩展，这些约束禁止重新排列路线上的项目。两个版本（有和没有后进先出）都采用两步方法求解：首先构造一个启发式初始解，然后在三个局部交换算子的帮助下进行优化，作者以前在[25]中使用和评估过。文[23]还提出了一组新的与 2L-SPD 公式相对应的基准[26]。

An extension along the lines of the classical VRPSPD formulation consisting in adding three-dimensional loading constraints, denoted as 3L-VRP, was proposed in [27]. The specification of the problem assumes that each demand is in the form of a set of 3D rectangular items (boxes) which must be carried by vehicles with a given 3D rectangular loading space. Furthermore, it may additionally be assumed that boxes, once loaded, must not be moved before the final unloading, i.e., no reloading effort is required while serving the customers (which is a variant of the LIFO constraint). This problem version is abbreviated as 3L-PDP. The solution method combines a routing procedure and a packing heuristic. The former is an extension of the LNS method used for the 1D-PDP (i.e. VRPSPD). The latter relies on a specific tree search problem representation. The authors propose a new set of 54 benchmark problems which are available.

文献[27]提出了一种沿经典 VRPSPD 公式的扩展，该公式包括添加三维载荷约束，即 3L-VRP。问题的具体说明假设每个需求都是一组三维矩形物品（盒子），这些物品必须由具有给定三维矩形装载空间的车辆携带。此外，还可以假设，箱子一旦装载，在最终卸载之前不得移动，即在为客户服务时不需要重新装载（这是后进先出约束的一种变体）。此问题版本缩写为 3L-PDP。该求解方法结合了路由过程和包装启发式。前者是用于 1D-PDP（即 VRPSPD）的 LNS 方法的扩展【A quick large neighborhood search（LNS）algorithm 快速大规模领域搜索】。后者依赖于特定的树搜索问题表示。

Another interesting extension of VRPB was proposed in [29], where the problem is combined with Multiple-Trip VRP (MTVRP) [30] (which assumes that a vehicle may perform several trips within a given time period), leading to the MT-VRPB variant. A MILP formulation is proposed and solved with the IBM ILOG CPLEX 12.5 optimizer for small and mid-size MTVRPB instances. For large-size problems the Two-level VNS algorithm is applied which alternately switches between the two stages: outer and inner. The former is responsible for the construction of the transitory solution and the later aims at its local search-based improvement. The algorithm is tested on a new set of 168 MT-VRPB benchmark problems [31] proposed by the authors.

文献[29]提出了 VRPB 的另一个有趣的扩展，其中该问题与多行程 VRP（MTVRP）[30]相结合（假设车辆在给定的时间段内可以执行多个行程），从而导致 MT-VRPB 变体。针对中小型 MTVRPB 实例，提出了 MILP 公式，并用 ibmilogcplex12.5 优化器求解。对于大尺寸问题，采用两级 VNS 算法，在外部和内部两个阶段之间交替切换。前者负责构建临时解决方案，后者则以局部搜索为基础进行改进。该算法在作者提出的 168mt-VRPB 基准问题[31]上进行了测试。