Unified Optimization of Assortment Selection and Courier Routing for Meal Delivery Platforms

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Short summary

Meal delivery platforms are reshaping urban logistics, connecting customers, restaurants, and couriers in complex and competitive markets. This paper introduces an integrated optimization model that simultaneously determines which restaurants should be offered on a meal delivery platform and how couriers are routed and compensated. We show that this joint approach can increase overall profits and reduce the required courier workforce compared with conventional planning methods. In addition, we explore trade-offs between pay-per-service and fixed employment policies, illustrating how platforms can fine-tune their compensation strategies to balance cost stability, service quality, and driver retention. Our findings highlight the value of bridging tactical and operational decisions in on-demand delivery, and they set the stage for future research on scaling these methods to larger networks.

Keywords: Assortment optimization, Courier routing, Meal delivery platforms, Service design

1 Introduction

Meal delivery platforms, such as Uber Eats, Deliveroo, JustEatTakeaway, and Grubhub, have revolutionized access to restaurant meals by offering extensive assortments and rapid delivery services. Despite their success, these platforms face persistent operational challenges, particularly in managing courier positioning and rebalancing couriers to meet fluctuating demand while controlling costs. Rebalancing often requires deadhead trips, in which couriers travel without orders, introducing inefficiencies that increase costs and complicate workforce planning. These inefficiencies not only elevate operational expenses but also disrupt delivery reliability, undermining the competitive advantage of speed and convenience that defines these platforms.

Recent studies primarily approach these challenges from an operational perspective, emphasizing routing, dispatching, and courier assignment. For example, Reyes et al. (2018) developed online dispatching algorithms for crowd-shipping that utilize external courier capacity to enhance routing efficiency. Similarly, Ulmer et al. (2021) examined routing under uncertainty, accounting for random restaurant preparation times and unpredictable customer order arrivals to improve delivery reliability. While these studies offer valuable insights into courier management, they overlook the impact of assortment configurations on operational efficiency.

From a tactical perspective, Yildiz & Savelsbergh (2019) proposed optimal delivery radii for restaurants to maximize profitability. While this approach accounts for spatial demand distribution, it assumes demand is exogenous and neglects the interdependencies between customer demand, the inclusion of restaurants in the platform's assortment, and routing decisions. Customer demand, defined as the potential number of customers entering the system, is shaped by the assortment of restaurants and menu items offered. Routing decisions, in turn, depend on the geographic distribution and volume of demand generated by these assortment choices. Despite these interdependencies, these planning dimensions are often treated independently. Assortment decisions are typically made first, guided by marketing insights, with courier operations subsequently arranged. This sequential, decoupled approach reduces operational flexibility and fails to leverage the interplay between assortment configurations, demand generation, and routing efficiency, often resulting in higher operational costs and constrained profitability.

This research proposes a unified modeling framework that simultaneously integrates assortment optimization with courier dimensioning, allocation, and routing decisions. By addressing these elements jointly, the framework captures how restaurant availability shapes customer demand and how demand patterns, in turn, affect courier utilization and routing efficiency. Additionally, the model incorporates courier compensation policies, comparing pay-per-service arrangements with fixed employment contracts, to evaluate their implications for both profitability and operational performance. Rather than viewing assortment decisions as an upstream planning task disconnected from operational considerations, this integrated model allows for the simultaneous pursuit of cost-effective routing solutions and profit-maximizing assortments.

Our contributions are threefold. First, we develop a non-linear optimization model that integrates assortment planning with courier dimensioning and routing decisions, incorporating customer behavior through a nested logit framework. Second, we examine how varying courier employment structures impact the system's performance under this unified framework. Third, we design computational methods capable of solving larger problem instances, addressing the model's inherent complexity while ensuring practical applicability. The results demonstrate that a fully integrated treatment can yield higher profitability than current sequential approaches, guiding meal delivery platforms toward more profitable and operationally robust configurations.

2 Methodology

We consider a meal delivery platform operating in an urban area divided into distinct service districts $d \in D$, each offering a curated assortment of restaurants tailored to local customer preferences. The platform's primary objective is to maximize expected profit by balancing expected revenues from customer orders against the costs of courier operations. Customers are distributed across the urban area that seek timely delivery and diverse restaurant options. Each restaurant $r \in R$ offers a specific cuisine type $q \in Q$ and is characterized by known attraction parameters v_{qr}^{d} and an average profit margin p_{qr}^{d}. The service districts are defined a priori based on the socio-economic characteristics and marketing analysis of the area, while the assortment offered in a district is to be determined by the model. The operating area is further partitioned into hexagonal zones $m \in M$, allowing for more granularity in the modeling of couriers.

The platform relies on couriers to fulfill orders. Two employment policies are considered: a pay-per-service (PPS), where couriers are compensated per delivery (c_{qr}^{d}), and an employed-couriers (EC), where couriers receive hourly wages c^{t} and incur hiring costs c^{h}. For both policies, the couriers must meet service requirements, including delivery deadlines and satisfaction of all demand, and shift duration constraints while operating over a spatial-temporal network defined by zones m and time periods $t \in T$. Within this network, couriers can move freely between zones, even without active deliveries, to anticipate or respond to emerging demand patterns. Couriers are modeled as homogeneous continuous flows and we exclude order bundling. We construct the spatial-temporal network $G(N, A)$, where nodes $(m, t) \in N$ represent a spatial-temporal combination and arcs $a \in A$ correspond to possible courier movements between nodes based on the travel time $\tau_{mm'}$ between zones m and m'. When customers place an order, couriers may pick-up the order after the meal preparation time η and must deliver the order within the delivery deadline ρ. Figure 1 illustrates the hexagonal zones, colored service districts and a three-zone-four-period spatial-temporal network for the zones highlighted.

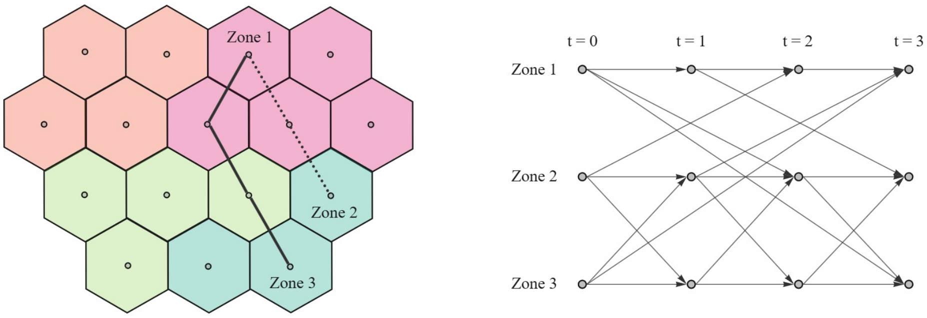

Figure 1: Hexagonal zone structure with colored service districts (left) and three-zone-four-period spacial-temporal network example where the arcs represent possible courier flows.

Customers arrive at known deterministic rates λ_{mt} per zone $m \in M$ and time period $t \in T$, with their purchasing decisions depending on the available restaurant assortment. We assume that customer purchasing behavior follows a nested structure: customers first select a cuisine category and then choose a restaurant within that category. This hierarchical process is modeled using a nested logit framework that captures within nest correlations in customer preferences using known dissimilarity parameter γ_q^d. Representing each service district's assortment as a subset of restaurants r for every cuisine type q denoted S_q^d, the total attraction value of a cuisine category combines all attraction values v_{qr}^d of included restaurants plus a no-purchase option v_{q0}^d, i.e. $V_q^d(S_q^d) = v_{q0}^d + \sum_{r \in S_q^d} v_{qr}^d$. For each district, let v_0^d be the no-purchase option at the cuisine level. Given that each restaurant offers one cuisine exclusively, the probability that a customer chooses a particular restaurant is the product of the probability of choosing its cuisine category and the conditional probability of selecting that restaurant:

$$\mathbb{P}_{qr}^d(S_q^d) = \mathbb{P}_q^d(S_q^d) \cdot \mathbb{P}_{qr|q}^d(S_q^d) = \left(\frac{V_q^d(S_q^d)^{\gamma_q^d}}{v_0^d + \sum_{q \in Q} V_q^d(S_q^d)^{\gamma_q^d}} \right) \cdot \left(\frac{v_{qr}^d}{V_q^d(S_q)} \right) = \frac{v_{qr}^d \cdot V_q^d(S_q^d)^{\gamma_q^d - 1}}{v_0^d + \sum_{q \in Q} V_q^d(S_q^d)^{\gamma_q^d}} \quad (1)$$

These probabilities yield expected orders per restaurant, which in turn influence courier flows. To ensure consistency with the spatial-temporal model of courier movements, we aggregate restaurant-level demand at the zone level. Specifically, for each time period and pair of zones, the expected courier flow is determined by multiplying the total customer orders originating in one zone by the probability that these customers select restaurants located in another zone. In doing so, we translate individual restaurant choices into continuous zone-to-zone flows, reflecting the movement of couriers through the network to meet anticipated demand.

Mathematical Formulation

We formulate the platform's decision-making problem as a non-linear optimization model that aims to maximize expected profit, defined as the total expected revenue from customer orders minus courier operating costs. The binary variables z_{qr}^d indicate whether a restaurant r of cuisine q is included in district d's assortment, while continuous variables w_a represent courier flows along arcs a and $W(in)_m^t$, $W(out)_m^t$ track courier entries and exits at zone m in period t. The binary parameter b_m^d links each zone m to a service district d. We only present the model for the employed couriers (EC) policy, the model with the pay-per-service (PPS) policy can be derived by removing arc and hiring costs and adjusting the profit margin per restaurant to include a delivery fee c_{qr}^d. The objective function (2) combines the revenue term derived from the nested logit structure including total potential demand $\sum_{m \in M} \sum_{t \in T} \lambda_{mt} b_m^d$ across all zones m and periods t in district d, with cost terms representing courier movements and hiring:

$$\max \quad \sum_{d\in D}\left(\frac{\sum_{q\in Q}(v^d_{q0}+\sum_{r\in R_d} v^d_{qr}z^d_{qr})^{\gamma^d_q-1}(\sum_{r\in R_d} v^d_{qr}p^d_{qr}z^d_{qr})}{v^d_0+\sum_{q\in Q}(v^d_{q0}+\sum_{r\in R_d} v^d_{qr}z^d_{qr})^{\gamma^d_q}}\cdot\sum_{m\in M}\sum_{t\in T}\lambda_{mt}b^d_m\right) - \sum_{a\in A} c_a\cdot w_a - \sum_{m\in M}\sum_{t\in T} c^h\cdot W(in)^t_m \tag{2}$$

Let e^r_q be a binary parameter indicating if restaurant r belongs to cuisine type q. Constraint (3) ensures r can only be included in the assortment for q if it matches the cuisine type. Constraint (4) enforces a minimum number of restaurants per cuisine q in district d, ensuring sufficient variety if preferred by the platform.

$$z^d_{qr} \le e^r_q \qquad \forall r\in R,\quad q\in Q,\quad d\in D \tag{3}$$

$$\sum_{r\in R_d} z^d_{qr} \ge K^d_q \qquad \forall q\in Q,\quad d\in D \tag{4}$$

$$z^d_{qr}\in\{0,1\} \qquad \forall r\in R,\quad q\in Q,\quad d\in D \tag{5}$$

The flow conservation constraint (6) ensures courier inflow equals outflow at each node (m,t), where sets δ^- and δ^+ represent adjacent origin and destination nodes respectively. Constraint (7) maintains balance between total incoming and outgoing couriers in the network. Constraint (8) enforces average courier shift duration limits $\theta_{\min}$ and $\theta_{\max}$. Constraint (9) ensures enough couriers are available to meet expected demand within delivery time frames, allowing some flexibility in timing. Constraint (10) ensures all demand is met across the network.

$$\sum_{(m',t')\in\delta^-_{(m,t)}} w_{(m',t')(m,t)} + W(in)^t_m = \sum_{(m',t')\in\delta^+_{(m,t)}} w_{(m,t)(m',t')} + W(out)^t_m \qquad \forall (m,t)\in N \tag{6}$$

$$\sum_{t\in T}\sum_{m\in M} W(in)^t_m = \sum_{t\in T}\sum_{m\in M} W(out)^t_m \tag{7}$$

$$\theta_{\min}\cdot\sum_{m\in M}\sum_{t\in T} W(in)^t_m \le \sum_{a\in A} w_a \le \theta_{\max}\cdot\sum_{m\in M}\sum_{t\in T} W(in)^t_m \tag{8}$$

$$\sum_{\substack{t'=t+\tau_{mm'}\\ t+\eta\le t'\le t+\rho}} w_{(m,t)(m',t')} \ge \lambda_{m't}\sum_{d\in D} b^d_{m'}\cdot\frac{\sum_{q\in Q}(v^d_{q0}+\sum_{r\in R_d} v^d_{qr}z^d_{qr})^{\gamma^d_q-1}(\sum_{r\in R'_m} v^d_{qr}z^d_{qr})}{v^d_0+\sum_{q\in Q}(v^d_{q0}+\sum_{r\in R_d} v^d_{qr}z^d_{qr})^{\gamma^d_q}} \tag{9}$$

$$\forall m,m'\in M,\quad t\in T\setminus\{T_{max}-\rho-\eta,...,T_{max}\}$$

$$\sum_{a\in A} w_a \ge \sum_{m\in M}\sum_{m'\in M}\sum_{t\in T}\lambda_{m't}\sum_{d\in D} b^d_{m'}\cdot\frac{\sum_{q\in Q}(v^d_{q0}+\sum_{r\in R_d} v^d_{qr}z^d_{qr})^{\gamma^d_q-1}(\sum_{r\in R'_m} v^d_{qr}z^d_{qr})}{v^d_0+\sum_{q\in Q}(v^d_{q0}+\sum_{r\in R_d} v^d_{qr}z^d_{qr})^{\gamma^d_q}} \tag{10}$$

$$w_a\in\mathbb{R}_+ \qquad \forall a\in A \tag{11}$$

$$W(in)^t_m\in\mathbb{R}_+,\quad W(out)^t_m\in\mathbb{R}_+ \qquad \forall m\in M,\quad t\in T \tag{12}$$

Resolution approach

The underlying non-convex optimization problem can be reformulated as a set-partitioning problem by enumerating possible restaurant assortments for each cuisine type and service district. Introducing binary variables for each potential assortment and subsequently linearizing yields a mixed-integer linear program (MILP) that in principle, can be solved using standard optimization software. However, enumerating all possible subsets leads to an exponential growth in the number of variables, making direct solution approaches computationally prohibitive for larger instances. To address this scalability issue, we propose a decomposition-based strategy that combines column generation and Benders decomposition.

Column generation dynamically generates only those assortments that prove beneficial, avoiding the combinatorial explosion caused by enumerating all subsets from the start. Beginning with a restricted master problem that considers only a manageable set of columns, we iteratively solve a pricing subproblem to identify and introduce new assortments that improve the current solution. Simultaneously, we employ Benders decomposition to partition the problem into an assortment master problem and independent routing subproblem. We derive Benders cuts that strategically refine the feasible region and accelerate convergence. Together, these advanced solution approaches enable handling more realistic problem sizes.

3 Results and Discussion

This section presents computational experiments demonstrating the benefits of integrating assortment planning and courier routing decisions in a meal-delivery platform, and compares the cost and revenue structures of pay-per-service (PPS) and employed-courier (EC) policies. The results show the impact of the research, leading to higher expected profits and reducing necessary fleet size. The experiments consider a four-hour time horizon divided into 20 periods of 12 minutes each, with a spatial network of 15 hexagonal zones grouped into two service districts. Meal preparation requires one time step, and the maximum delivery time is five time steps. Couriers work shifts of two to four hours. The platform offers two cuisine types across ten restaurants (four of type 0 and six of type 1) without minimum assortment requirements, allowing the model to select any subset of restaurants. Customer arrivals follow Poisson distributions with an average of five orders per zone and time step. Restaurant attraction parameters and no-purchase options are drawn from uniform distributions and normalized, while revenues range uniformly from 5 to 10 units. Delivery costs per unit flow and time period are set to 1 unit, and hiring costs are 10 units per courier. We consider two restaurant location scenarios: centered (C), where all restaurants cluster in the central region, and distributed (D), where restaurants are spread across the area.

Table 1: Preliminary results comparing the separated and integrated model.

	Separated Model		Integrated Model	
	Distributed (D)	Centered (C)	Distributed (D)	Centered (C)
Objective value	**5963.17**	**7495.34**	**7238.50**	**7654.04**
Revenue	9544.85	9544.85	9126.50	9536.78
Cost (hiring)	1432.81	803.00	667.45	667.94
Cost (delivery)	2148.86	1246.42	1120.55	1214.81
Number couriers	143.28	80.31	66.75	66.79
Included restaurants	r_0, r_4, r_5, r_7, r_9	r_0, r_4, r_5, r_7, r_9	r_0, r_4, r_5, r_9	r_0, r_5, r_7, r_9

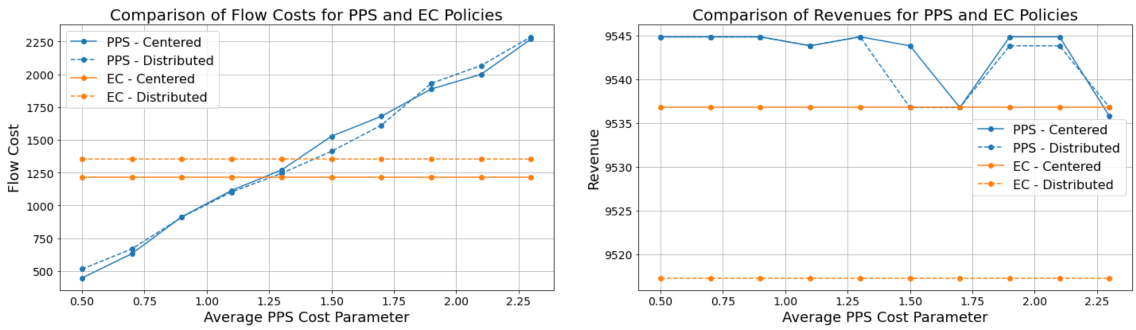

Figure 2: Comparison of PPS and EC policies for costs (left) and revenues (right).

Preliminary results in Table 1 compares a *separated* model, where assortments are chosen first and followed by routing, with an *integrated* model, where assortment planning and routing decisions are optimized simultaneously. The integrated approach increases total profit (objective value) in both scenarios, but to different extents. In the distributed setting, the objective value rises by 21% (from 5963.17 to 7238.50), primarily due to a 50% drop in combined courier hiring and delivery costs, albeit with about a 4% reduction in revenue. In the centered scenario, the objective value improves by 2% (from 7495.34 to 7654.04), reflecting an 8% reduction in total courier costs and almost no change in revenue. Despite the smaller improvement compared to the distributed case, the centered scenario underscores that even in simpler geographic configurations, integrated planning still provides measurable gains. Furthermore, the integrated model cuts the required number of couriers by 53% in the distributed scenario and 17% in the centered scenario, highlighting substantial operational savings and workforce flexibility..

Figure 2 shows how costs and revenues differ between PPS and EC compensation policies. We fix EC's per-unit flow costs and gradually increase the service fee in the PPS model. As expected, PPS flow costs rise with higher fees, whereas EC costs remain constant. At certain fee levels, the two cost curves intersect, suggesting cost-equivalence points where switching from one policy to the other does not materially affect overall costs. This strategic flexibility enables the platform to evaluate non-cost factors such as driver retention or reliability when selecting a compensation model. The revenue curves for PPS occasionally exhibit sudden jumps, triggered by re-optimization of the restaurant assortment in response to changing cost parameters; these abrupt adjustments alter demand patterns, thereby influencing operating costs.

In summary, the integrated framework outperforms the conventional separated approach in both distributed and centered scenarios, achieving up to 21% greater total profit and reducing the courier workforce by more than half under certain conditions. Our comparison of compensation policies further underscores how cost structures can be fine-tuned to balance profitability, workforce stability, and service quality. Overall, these findings underscore the substantial added value of a unified model that captures both through assortment planning and operational routing and scheduling.

4 Conclusions

This research demonstrates that a unified framework for optimizing assortment planning and courier routing decisions can significantly enhance profitability and operational efficiency for meal delivery platforms. By capturing how assortment choices shape demand, and in turn influence courier allocation, routing, and compensation, the integrated model consistently outperforms the conventional separated approach. The integrated framework yields up to 21% higher total profits while reducing the required courier workforce by as much as 53% for small instance examples. These improvements stem from a balanced interplay between demand generation and cost control, achieved by selecting restaurant assortments that align better with courier routing constraints.

In the coming months we will focus on improving scalability. By implementing advanced solution techniques we aim to handle larger instances efficiently, making the model more applicable to realistic large-scale delivery networks. As meal delivery services continue to evolve in competitive and dynamic environments, the insights and methodologies presented here offer valuable tools for integrating tactical and operational decision-making that can ultimately reshape how platforms operate and grow.

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