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IMPROVING DELIVERY SERVICE PERFORMANCE USING DISCRETE EVENT SIMULATION MODELING

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Abstract. *The rapid growth of on-demand food delivery services has posed significant challenges in logistics optimization. This study focuses on a formerly leading food delivery company in Uzbekistan, which faced difficulties in meeting customer expectations due to high demand and inefficiencies in courier allocation. The research applied Discrete Event Simulation (DES) theory to analyze courier utilization, waiting times, and delivery performance. The model incorporated district-based clustering, queueing theory, stochastic simulation modeling, model validation and performance evaluation to evaluate various operational scenarios. Findings reveal that integrated models reduce delivery times by 1.6 times, enhance throughput, and provide actionable strategies for urban delivery optimization. The results contribute to both academic literature and managerial practice in emerging markets.*

Keywords: *management science, simulation modeling, discrete event simulation, prescriptive analytics, delivery service optimisation, e-business.*

DISKRET HODISALARNI SIMULYATSION MODELLASH ASOSIDA YETKAZISH XIZMATLARINING SAMARADORLIGINI OSHIRISH

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Annotatsiya. *Raqamli texnologiyalarning jadal o'sishi yetkazib berish xizmatlarining jiddiy raqobat muhitida samaradorligini oshirish va logistik jarayonlarni optimallashtirish kabi muammolarni keltirib chiqardi. Ushbu tadqiqot O'zbekistondagi yetkazib berish xizmatlari bo'yicha yetakchi bo'lgan kompaniya biznes jarayonlarining tahliliga qaratilgan. Tadbirkorlik korxonasi yuqori talab va kuryerlarni taqsimlashdagi samarasizlik tufayli mijozlar talablarini qondirishda qiyinchiliklarga duch kelgan. Tadqiqotda kuryerlikdan foydalanish, kutish vaqtlari va yetkazib berish samaradorligini tahlil qilish uchun Diskret Hodisalarni Simulyatsiyasi (DHS) nazariyasi qo'llanildi. Model turli operatsion senariylarni baholash uchun tumanga asoslangan* *klasterlash, navbat nazariyasi va stoxastik simulyatsion modellash, modelni validatsiyalash va natijalarni chuqur tahlil qilishni oʻz ichiga olgan. Natijalar shuni koʻrsatadiki, integratsiyalashgan modellar etkazib berish vaqtlarini 1,6 baravar qisqartiradi, oʻtkazish qobiliyatini oshiradi va shahar doirasida yetkazib berishni optimallashtirish uchun harakatga asoslangan strategiyalarni taqdim etadi. Natijalar akademik adabiyotga va rivojlanayotgan bozorlardagi boshqaruv amaliyotiga hissa qoʻshadi.*

Kalit soʻzlar: *boshqaruv fani, simulyatsion modellashtirish, diskret hodisalar simulyatsiyasi, reseptiv analitika, yetkazib berishni optimallashtirish, e-biznes.*

УЛУЧШЕНИЕ ПРОИЗВОДИТЕЛЬНОСТИ СЛУЖБЫ ДОСТАВКИ С ИСПОЛЬЗОВАНИЕМ ДИСКРЕТНО-СОБЫТИЙНОГО ИМИТАЦИОННОГО МОДЕЛИРОВАНИЯ

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Аннотация. *С развитием цифровых технологий стремительный рост услуг доставки еды по запросу создал серьезные проблемы в оптимизации логистики. Данное исследование посвящено ведущей компании по доставке еды в Узбекистане, которая столкнулась с трудностями в удовлетворении ожиданий клиентов из-за высокого спроса и неэффективного распределения курьерских услуг. В исследовании применялась теория дискретно-событийного моделирования (ДСИ) для анализа использования курьерских услуг, времени ожидания и эффективности доставки. Модель включала кластеризацию по районам, теорию очередей и стохастическое моделирование, валидация модели и анализ производительности для оценки различных операционных сценариев. Результаты показывают, что интегрированные модели сокращают время доставки в 1,6 раза, повышают пропускную способность и предлагают действенные стратегии для оптимизации доставки в городах. Результаты вносят вклад как в научную литературу, так и в управленческую практику на развивающихся рынках.*

Ключевые слова: *наука управления, имитационное моделирование, дискретно-событийное моделирование, предписывающая аналитика, оптимизация доставки продуктов питания, электронный бизнес.*

Introduction.

Consumer demand for online food delivery has grown significantly since the global pandemic, transforming the industry into a market worth over USD 150 billion (McKinsey, 2020). Physical-distancing requirements accelerated the adoption of delivery platforms, which became a vital support for the restaurant industry. In Uzbekistan, Express24 (acquired by Yandex Eda) emerged as the leading delivery platform, doubling sales for its partner restaurants to 21 percent (Inoyatova, 2020) while the restaurant sector was experiencing approximately 10 percent annual growth before the crisis.

The pandemic established a long-term trend toward convenience, with food delivery demand continuing to rise through 2021 (Deloitte Touche Tohmatsu, 2021). Key factors influencing competitiveness include geographic coverage, delivery times, and platform integration. Efficient driver distribution and reduced delivery times remain decisive for cost reduction and customer satisfaction.

The company, operated in Tashkent, Samarkand, Bukhara, and Fergana, provided fast and reliable delivery services, enabling restaurants to expand their e-commerce capabilities

(Ruzmetova, 2021). Acting as an intermediary between restaurants, couriers, and customers, the platform facilitates seamless transactions and timely delivery.

This study aims to develop a simulation model to diagnose service length, waiting times, and efficiency, as well as to optimize driver allocation and scheduling. Simulation supports logistics management, staff scheduling, and resource planning, while reducing congestion and delays.

The proposed model offers a resource allocation strategy that considers geographic location, peak hours, and weekends, ultimately improving customer satisfaction and enhancing the company service quality in Tashkent, Uzbekistan.

Literature review.

On-Demand Food Delivery Service (OFDS). The demand for delivery services has grown significantly in recent years, largely due to the COVID-19 pandemic. Businesses lacking in-house delivery capabilities increasingly relied on third-party platforms as their main customer acquisition channel (Deloitte, 2021). Delivery websites and mobile applications have become integral to both business operations and customer preferences. Since 2017, the global market for perishable product delivery has tripled in value (McKinsey, 2021), with continued growth in online food orders among consumers (Collison, 2022). OFDS benefits both customers and restaurant owners by providing rapid access to food (Gupta and Paul, 2016) and offering comprehensive information on menus and reviews (Alalwan, 2020). These platforms enhance throughput, improve order accuracy, attract new customers, and reduce marketing costs (Gavilan et al., 2021; Collison, 2022).

Outcomes of Inefficient Resource Use in OFDS**.** Despite its economic benefits, OFDS faces challenges including dynamic demand, strict time constraints, long waiting lines, and highly perishable products (Allen et al., 2018). Furthermore, logistics issues such as transport conditions, seasonality, and traceability significantly impact supply chain performance (Lei and Yang, 2010). Insufficient personnel allocation often leads to workload imbalances, reduced service times, and lower quality (Ingaldi, 2019). Such inefficiencies can result in errors in food placement, delivery delays, and reduced product quality, ultimately causing customer dissatisfaction.

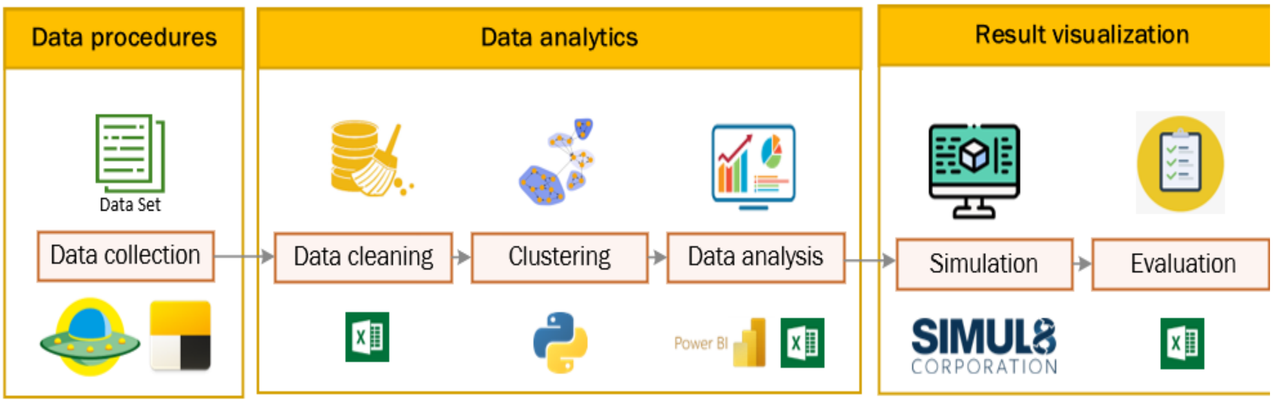
Simulation Models for OFDS**.** Simulation is widely used to optimise resource allocation and improve delivery services. It enables predictions of system performance and tests changes before implementation (Banks, 2010; Yousri, 1978). Discrete Event Simulation (DES) is particularly suitable for OFDS as it focuses on logically separate processes and supports dynamic, time-based modelling (Heavey, 2022; Wei et al., 2022). In the case of "*Express24*", a stochastic DES model was developed, accounting for random user orders and system constraints from 00:00 to 23:59. Such models allow testing transportation networks, scheduling strategies, and resource distribution without committing physical resources (Thiers, 2014; Padilla et al., 2014; Ren et al., 2021; Hofmann et al., 2022).

Optimizing Courier Dispatch and Delivery Efficiency**.** Researchers have also explored methods for courier routing, dispatching policies, and optimal resource allocation to reduce waiting times and improve delivery reliability (Sungur, 2006; Novoa & Storer, 2009; Chen & Hu, 2020). Additional solutions include zone-based courier assignment, location selection, and autonomous vehicle management (Toth & Vigo, 2002; Al-Kanj et al., 2020). Efficient timing is especially critical during lunch and dinner peaks, when delays can directly affect food freshness and customer satisfaction (Ingaldi, 2019; Sungur, 2006).

Analysis and discussion of results.

Theoretical Framework.

This study employed a quantitative, descriptive research design to develop and evaluate discrete event simulation (DES) models for optimizing on-demand food delivery service (OFDS) operations. Data collection integrated secondary data (five months of delivery logs, CSV and GeoJSON files) and primary data from expert interviews with "*Express24*" managers and analysts. Key operational times, courier routes, and customer interactions were analyzed using Python libraries (pandas, geojson, numpy, matplotlib, seaborn, geopy, folium, minisom, scipy) and Power BI for preprocessing, clustering, and visualization (Pic. 1).



Picture 1. Computing resources representation

Source: *developed by authors.*

Data cleaning involved removing null and duplicate values, correcting geospatial coordinates, and validating timestamps. Clustering was conducted using K-means with centroid calculation:

$$c(S_i) = \sum_{r=1}^{[S_i]} (d(x^{-1}, x_r^i))^2$$

District-level classification was refined with polygon-based GeoJSON mapping. Six simulation models were constructed for each district (original, integrated, variants with altered courier numbers, and reduced restaurant waiting time). Comparative performance evaluation was based on delivery time, service length, and orders delivered.

Distributional assumptions were tested using chi-square (^{2}) goodness-of-fit test:

$$\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Gamma distribution, $\Gamma(\beta) = (\beta - 1)(\beta - 1)$, defined as β greater than zero, and thought as generalization of all positive numbers, not just integers:

$$\beta = \frac{s^2}{\mu},$$

where s^2 is variance and μ is mean and if beta is an integer, the gamma distribution is related to the exponential distribution:

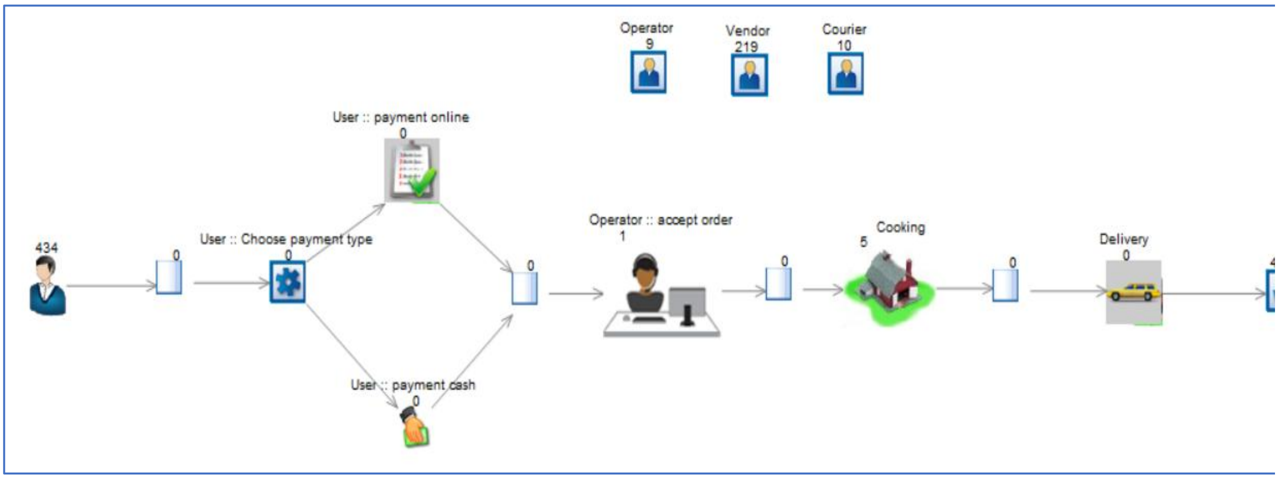
$$F(x)\begin{cases} 0, \\ \int_0^x \lambda e^{-\lambda e}\, dt = 1e^{-\lambda x}, x \leq 0, \end{cases}$$

were it is applied to restaurant and delivery times. Where only minimum, maximum, and most-likely values were known, triangular distribution was used:

$$F(x) = \begin{cases} 0, & x \leq a \\ \frac{(x-a)^2}{(b-a)(c-a)}, & a < x \leq b \\ 1 - \frac{(c-x)^2}{(c-b)(c-a)}, & b < x \leq c \\ 1, & x > c \end{cases}$$

If no parametric fit was possible, empirical distributions were adopted. Simulation models were implemented in Simul8 software application, integrated with Excel for parameter calculation, and validated via Turing test and confidence-interval estimation: $\boldsymbol{Y} \pm \boldsymbol{t} \times \boldsymbol{S}\sqrt{\mathbf{1}+\frac{\mathbf{1}}{\boldsymbol{n}}}$

Modeling. The modeling stage of this study focused on replicating the operational processes of the delivery business as a Discrete Event Simulation (DES) system. The delivery process was decomposed into a sequence of interrelated activities, namely order placement, payment selection, order confirmation by operators, restaurant preparation, courier dispatch, and delivery to the customer. Each activity was treated as an event occurring at discrete points in time, leading to state changes in the system such as order status updates, courier allocation, or queue formation.



Picture 2. Original data model diagram representation in Simul8 software application

Source: developed by authors using SIMUL8 software application.

Simulation models. Six different models were implemented for each district (Mirzo Ulugbek and Shaykhontohur):

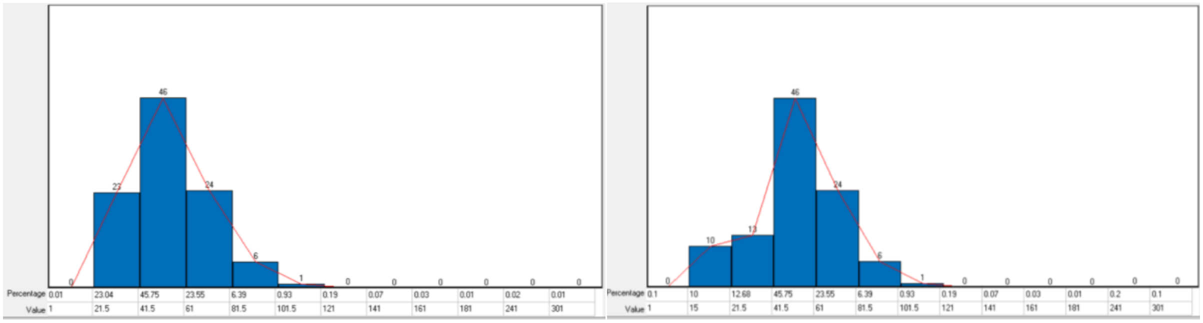
1. Original DES model using empirical times and current courier numbers.
2. Integrated DES model incorporating simulated routing and parking.
3. Integrated DES model without restaurant waiting time.
4. Original DES model with an additional 20 couriers.
5. Original DES model with an additional 40 couriers.
6. Original DES model with an additional 100 couriers.

All share demand inputs and operator settings; resources follow day/night shifts.

Picture 3. Illustration of original, original with k number of couriers and integrated models

Source: developed by authors.

Time distribution. Arrival intensity exhibits clear peaks between 12:00–14:00 and 18:00–21:00. The baseline mean delivery time is approximately 15.5 minutes. Adding 20, 40, or 100 couriers reduces the total delivery time accordingly. Delivery and restaurant preparation times did not fit gamma or exponential distributions according to the chi-square test, so empirical distributions were used instead. For integrated routing, a triangular cumulative distribution function F(x) was employed, with parameters (a,b,c) derived from observed minimum, mode, and maximum values.



Picture 4. The delivery time distribution created for MU (a) and S (b) using Simul8.

Source: *developed by authors using SIMUL8 software application.*

These distributions were derived from historical transaction data provided by "*Express24*", ensuring that the simulation closely mirrored actual system behavior. For example, order arrivals were modeled as time-dependent, with peak demand occurring at lunch and dinner hours, while delivery times were fitted to gamma and exponential distributions to reflect variability in traffic and courier availability. By incorporating stochastic properties, the model was able to simulate not only average performance but also fluctuations and extreme cases that affect service quality.

District-level clustering. The geospatial dimension of delivery operations was also integrated into the model. Orders were clustered by district using k-means and GeoJSON polygon classification, allowing separate sub-models to be created for high-density (Shaykhontohur) and medium-density (Mirzo Ulugbek) areas. This spatial modeling enabled the simulation to account for geographic differences in order density, restaurant concentration, and travel times. Courier allocation strategies were evaluated at the district level, ensuring a more precise assessment of resource requirements across locations.

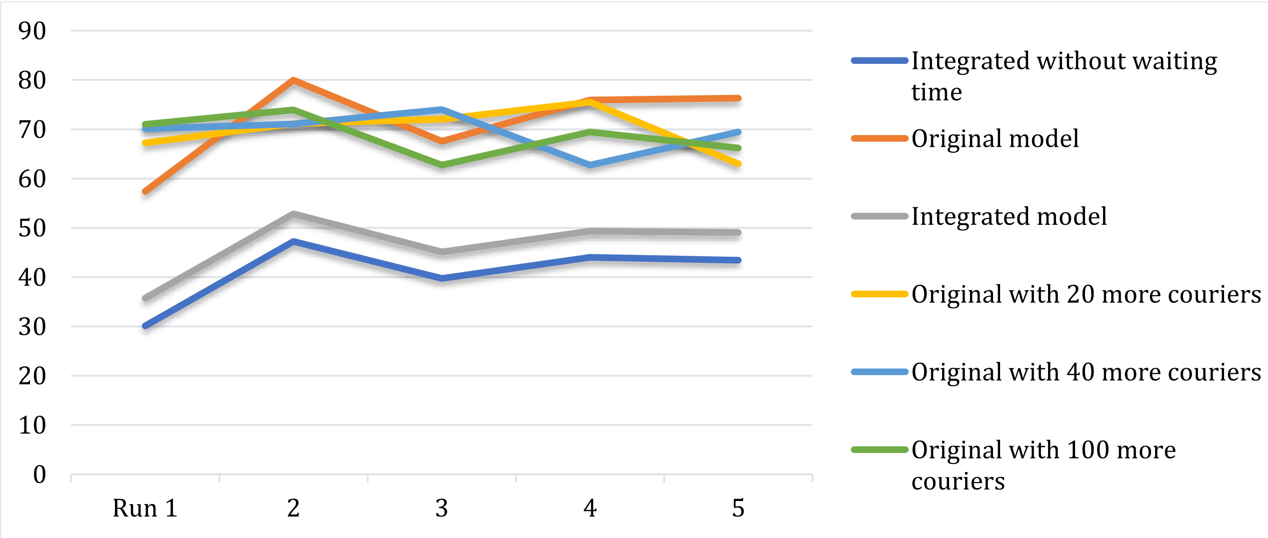
Solution. The Discrete Event Simulation (DES) model revealed that delivery time is a key determinant of operational efficiency. Integrated models with routing logic reduced average delivery time by 9–10%, from a baseline of 15.5 minutes to approximately 14 minutes in Shaykhontohur. Hiring 20 to 40 additional couriers resulted in the greatest reduction in delivery times, decreasing them by approximately 2.4 to 3.2 minutes, while further increases produced only marginal improvements. District-level clustering allowed tailored sub-models and showed higher efficiency in resource allocation by zone.

The financial analysis was based on two key approaches: Activity-Based Costing (ABC) and Total Cost of Ownership (TCO). Average revenue per delivery was $1.50, with each minute of restaurant waiting reducing revenue by $0.70. Marginal courier cost was $10.00 per day, and overhead was $1,000 per day. Annual income in Shaykhontokhur could reach 307 million UZS, assuming 236,393 deliveries. Weekly profits from adding 20, 40, and 100 couriers were estimated at $4,828, $6,228, and $10,428 respectively, before taxes. However, increased staff and parking infrastructure incur land, property, and income taxes as outlined in Uzbekistan's Tax Code.

Overall, the results suggest that placing courier parking stations by district and moderately increasing staff are cost-effective strategies. However, adding too many couriers leads to higher costs without a matching increase in revenue, highlighting the value of simulation in finding the right balance between performance and cost.

Outcomes. The implementation of the simulation-based optimization model led to measurable improvements in the delivery performance.

District-level clustering and integrated routing significantly reduced system time, particularly during peak hours (12:00–14:00 and 18:00–20:00), which account for over 50% of daily orders. Shaykhontohur, with 2.5 times more orders than Mirzo Ulugbek, required higher courier allocation and demonstrated greater delivery inefficiencies.



Picture 5. Performance evaluation of six simulation models

Source: developed by authors.

Simulation outputs showed (figure 5) that the integrated model reduced average delivery time by 1.6 times, improving both product freshness and customer satisfaction. Excluding restaurant wait times further decreased total delivery time to 40.9 minutes. A courier shift schedule by hour and district enabled optimal workforce distribution based on demand. Overall, delivery was identified as the most time-consuming process, averaging 73.5 minutes, emphasizing the need for district-based parking and courier allocation. These outcomes confirm that simulation-driven planning can enhance responsiveness, resource efficiency, and service quality in on-demand delivery systems.

Table 1

Schedule for couriers of the company

No	Daily Shift Time	Number of couriers in MU	Number of couriers in S
1	00:00-04:00	10-15	20-25
2	04:00-08:00	5-10	10-15
3	08:00-12:00	25-35	60-70
4	12:00-15:00	40-50	80-100
5	15:00-18:00	30-45	60-95
6	18:00-21:00	40-50	80-110
7	21:00-23:59	20-25	50-60

Source: developed by authors.

Table 1 demonstrates peak hours of the day with red, more flexible hours with yellow and less flexible hours with green color. According to data analysis, lunch and dinner times are considered as peak hours that require 40-50 and 80-110 number of couriers in MU and S districts. While midnight to mid-morning time is considered more flexible due to lower order volume and requires fewer drivers in the company.

Conclusion and suggestions.

This study applied Discrete Event Simulation (DES) and geospatial clustering to optimize courier allocation and improve delivery performance for the delivery service company in Uzbekistan. Using real operational data, six models were developed to evaluate the effects of courier numbers, routing, and restaurant waiting time across two key districts in Tashkent. The integrated model with routing and district-based parking achieved the greatest reduction in delivery times—up to 1.6 times faster than the original model. Hiring 20 to 40 additional couriers provided the most effective time savings, reducing delivery time by approximately 2.4 to 3.2 minutes, while further increases delivered diminishing returns.

Financial analysis, combining Activity-Based Costing (ABC) and Total Cost of Ownership (TCO), demonstrated that moderate courier increases and district-level parking stations are cost-effective strategies. Simulation results confirmed that delays occur mostly during peak hours, particularly in high-demand zones like Shaykhontohur. Overall, the study confirmed that simulation-driven planning can improve efficiency, enhance customer satisfaction, and guide better decision-making in on-demand delivery operations.

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