НАУЧНО-ТЕХНИЧЕСКИЙ ВЕСТНИК ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ, МЕХАНИКИ И ОПТИКИ
март–апрель 2023 Том 23 № 2 http://ntv.ifmo.ru/
SCIENTIFIC AND TECHNICAL JOURNAL OF INFORMATION TECHNOLOGIES, MECHANICS AND OPTICS
March–April 2023 Vol. 23 No 2 http://ntv.ifmo.ru/en/
ISSN 2226-1494 (print) ISSN 2500-0373 (online)

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ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ И КОГНИТИВНЫЕ ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ

ARTIFICIAL INTELLIGENCE AND COGNITIVE INFORMATION TECHNOLOGIES

doi: 10.17586/2226-1494-2023-23-2-323-330

Information model of the essential goods purchase duration

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Abstract
The task of reducing the time for the purchase of essential goods is especially relevant in cases of shortage of free time of buyers. To do this, it is necessary to predict and estimate the time required to purchase goods. Traditional approaches based on cartographic systems do not provide estimates and forecasts, but only allow you to build a route to the right place based on an assessment of the traffic situation. For this reason, the problem of developing a more modern model is relevant, taking into account such factors as the infrastructural location of the store, user evaluation, and the workload of the store. The paper proposes an information model that includes such time costs of the buyer as the search for goods, the route to the place of sale of goods, the purchase of goods. The time spent on the purchase of goods is described using elements of queuing theory. Statistical and direct methods for assessing the workload and queues in the store are highlighted. The developed generalized model contains the parameters necessary to estimate the required time using statistical methods which include traffic forecasting based on user ratings and reviews, analysis of the infrastructure location and public video surveillance cameras, public Application Programming Interface of stores, and Internet services. Correction coefficients have been introduced to adjust the estimation of model parameters depending on the infrastructure location of the store and user ratings. A new information model has been formulated that allows taking into account the dependence of the time required to purchase emergency goods on the workload of the store, its infrastructure location, ratings and user reviews. The simulation model is developed in the AnyLogic environment. An example of using the model to estimate the average time spent on the purchase of emergency goods is demonstrated. The simulation results are consistent with the conducted experiment in which purchases of emergency goods were made in various stores in Saint Petersburg. The developed model can be used when searching for the optimal route to the place of sale of essential goods when planning the construction of stores as well as in the areas of marketing and delivery of goods.

Keywords
model, optimal route, time estimation, cartographic system, purchase of goods

Acknowledgements
This research is financially supported by The Russian Science Foundation, Agreement No. 17-71-30029 with co-financing of the "Bank Saint Petersburg".

For citation: Khlyupina Yu.M., Kuznetsov D.A., Laptev A.A. Information model of the essential goods purchase duration. *Scientific and Technical Journal of Information Technologies, Mechanics and Optics*, 2023, vol. 23, no. 2, pp. 323–330. doi: 10.17586/2226-1494-2023-23-2-323-330

УДК 004.021, 004.942

Информационная модель продолжительности покупки товаров первой необходимости

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Аннотация

Предмет исследования. Задача сокращения времени на покупку товаров первой необходимости особенно актуальна в случаях дефицита свободного времени покупателей. Для этого необходимо спрогнозировать и оценить время, которое требуется для покупки товаров. Традиционные подходы на основе картографических систем не дают оценки и прогноза, а лишь позволяют строить маршрут до нужного места на основе оценки дорожной ситуации. По этой причине актуальной является проблема разработки более современной модели с учетом таких факторов как инфраструктурное расположение и загруженность магазина, а также оценка пользователей. **Метод.** В работе предложена информационная модель, которая включает в себя такие временные затраты покупателя как поиск товара, маршрут до места реализации товара и покупка товара. Время, затрачиваемое на покупку товара, описано с помощью элементов теории массового обслуживания. Выделены статистические и прямые методы для оценки загруженности и очереди в магазине. Разработанная обобщенная модель содержит параметры, необходимые для оценки требуемого времени с помощью статистических методов, к которым относятся прогнозирование посещаемости на основе рейтингов и отзывов пользователей, анализ инфраструктурного расположения и общедоступных камер видеонаблюдения, общедоступные Application Programming Interface магазинов и интернет-сервисов. Введены поправочные коэффициенты, позволяющие скорректировать оценку параметров модели в зависимости от инфраструктурного расположения магазина и оценок пользователей. **Основные результаты.** Сформулирована новая информационная модель, позволяющая учитывать зависимость времени, необходимого на покупку товара экстренной необходимости, от загруженности магазина, его инфраструктурного расположения, рейтингов и отзывов пользователей. Имитационная модель разработана в среде AnyLogic. Продемонстрирован пример использования модели для оценки среднего времени, затрачиваемого на покупку товаров экстренной необходимости. Результаты моделирования согласуются с проведенным экспериментом, в котором были совершены покупки товаров экстренной необходимости в различных магазинах Санкт-Петербурга. **Практическая значимость.** Разработанная модель может быть использована при поиске оптимального маршрута к месту продажи товаров первой необходимости при планировании строительства магазинов, а также в сферах маркетинга и доставки товаров.

Ключевые слова

модель, оптимальный маршрут, оценка времени, картографическая система, покупка товаров

Благодарности

Исследование выполнено при финансовой поддержке Российского научного фонда, соглашение № 17-71-30029 при софинансировании Банка «Санкт-Петербург».

Ссылка для цитирования: Хлюпина Ю.М., Кузнецов Д.А., Лаптев А.А. Информационная модель продолжительности покупки товаров первой необходимости // Научно-технический вестник информационных технологий, механики и оптики. 2023. Т. 23, № 2. С. 323–330 (на англ. яз.). doi: 10.17586/2226-1494-2023-23-2-323-330

Introduction

High congestion of transport routes, a busy work schedule strongly constrains a person in his right to freely dispose of his personal time. A person is forced to adapt to the changing pace of life in modern cities, sharply limiting his free time. Thus, modern living conditions dictate the need for rational use of time.

Trips to shops/pharmacies are an integral part of every person's daily life. At the same time, the delivery of goods is not always possible for technical or other reasons. In addition, according to research[1], more than 45 % of the Russian population has never used delivery services (Fig. 1).

Studies of the time spent in queues[2] indicate that on average people spend up to 9 days a year waiting in line. Thus, in conditions of a shortage of free time, it is an unacceptable luxury to waste precious time on everyday purchases.

It is especially worth noting the need to purchase emergency goods, such as medicines, some types of household and food products. In this case, the buyer is keenly interested in speeding up the process of buying goods. Therefore, it is necessary to develop a unified mechanism for estimating the time required to make a purchase to speed up the purchase process and rational use of time.

In order to purchase an emergency product, you need to perform the following actions:

— Find an emergency product in stock at the place of its sale;
— Build a route to the place of sale of the goods and arrive at the place of sale of the goods;
— Buy goods at the place of sale.

Based on these points, we will analyze existing solutions that allow us to estimate the time spent on their implementation.

To date, there are many cartographic solutions on the market. The study analyzed such services as Google Maps, Apple Maps, Yandex.Maps, 2GIS, Microsoft Bing Maps, OpenStreetMap, Wikimapia, Qwant Maps, HERE WeGo[3].

Among these solutions, only Google Maps, Yandex.Maps and 2GIS represent the API (Application Programming Interface) for software developers, and also

1 The audience of Russian online stores 2021: portrait of the customer. Available at: https://решение-верное.рф/sites/default/files/2021-10/Исследование_Почта_России_финал_5_10_0.pdf (accessed: 20.11.2022).

2 Time spent in queues. Available at: https://rus-opros.com/about/articles/vremia-v-ocherediah (accessed: 19.11.2022).

3 Yakubova D.R. Comparative analysis of GIS: Yandex. Maps, Google.Maps and 2GIS // All-Russian Scientific and Practical conference "Geoinformation systems in the modern world". Available at: http://econf.rae.ru/article/10967 (accessed: 21.11.2022).

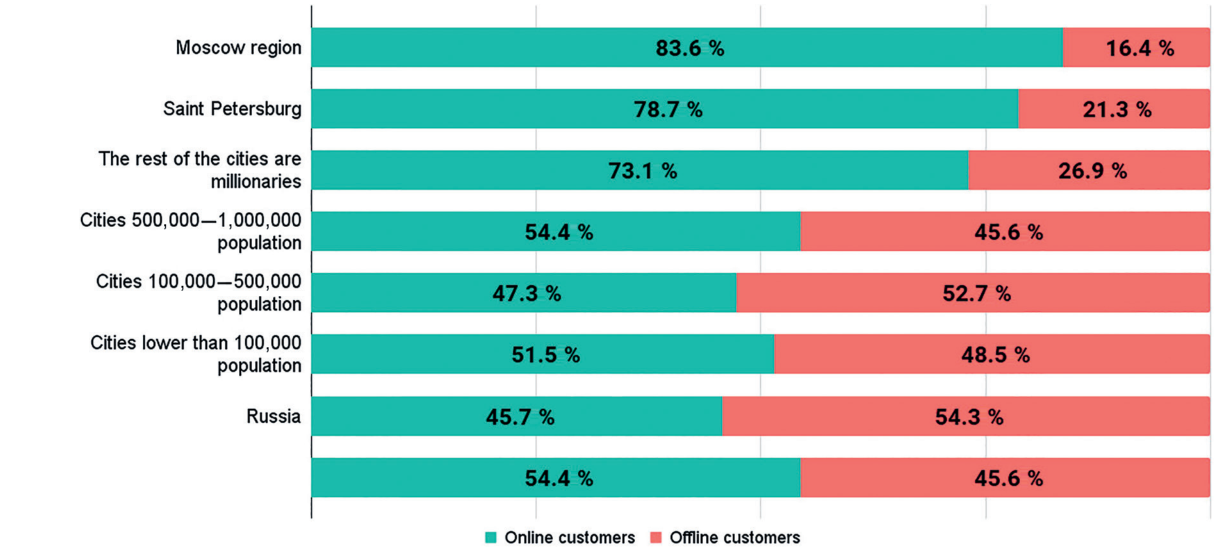

Fig. 1. The share of online buyers by cities of residence

have the greatest detail and coverage for the territory of Russia [1].

A study of the proposed services found that only 2GIS has the ability to search for goods and install their availability in all cities of Russia[1]. 2GIS receives information about goods and medicines, their availability and prices in two ways: from the stores and pharmacies themselves or from the 2GIS Check application, with which users scan receipts to get cashback for purchases.

In addition to the API of Internet services, the search for goods and the installation of its availability can be carried out using the API of Stores, however, this method requires considerable time: you must first find the goods in the search aggregator, for example, in Yandex.Products, then select a store from the suggested ones and go to the store website where it is already possible to establish the fact of the availability of goods in a particular store.

As part of solving the problem of finding the optimal route of movement, popular services (Yandex.Maps, 2GIS, Google Maps) use Dijkstra's algorithm[2] [2]. With its help, the system calculates the fastest travel option — based on the length of each segment of the graph and the speed of movement on this section. If the user builds a driving route without taking into account traffic jams, then the algorithm uses the average speed of movement on the site. If the user wants to know how to get to the place the fastest, taking into account the situation on the road, the algorithm uses data about the current situation on the road. However, such services do not take into account passenger traffic [3] and cannot accurately predict the time for walking sections of the route. In addition, the existing solutions do not take into account a number of significant characteristics of the space that affect the choice of the route by the user of the system [4]. Such characteristics include the presence of pedestrian paths, openness of space, street lighting, etc.

Among the services under consideration, only Yandex.Maps and Google Maps provide an assessment of the workload of the place of sale of goods. However, this information is represented by a set of relative values of workload and their corresponding qualitative characteristics, for example, "average workload", "a lot of visitors", etc., from which it is impossible to make an estimate of the time required to purchase goods in the store.

In existing studies in the field of estimating the time spent on purchases, attempts are being made to form a time model.

For example, in the study [5], the authors assess the influence of various variables, such as age, gender, demographic characteristics, individual factors of visual merchandising, on time costs. It was found that only gender and age significantly affect the time spent. The article also notes that the longer customers stay in the store, the more they will be exposed to incentives to purchase unplanned goods, and the more they will be delayed in the store.

The study [6] shows the relationship of various aspects of experience (social, pragmatic, emotional, intellectual) [7] to consumer engagement. Based on studies of the effects of these factors, the coefficients of their influence on the involvement of the buyer and, as a result, the impact on the time spent on the purchase of goods were obtained.

Also, the study [8] shows the influence of the smell of the environment on the mood of the buyer, and thereby affects the time spent in the store.

In addition, an indirect estimation of time can be made by analyzing customer behavior through the creation of a Customer Journey Map [9]. Such a map shows the history of the customer's interaction with the store by identified points of contact, such as the application/the store website, the store delivery services, the store support service, the store itself, etc.

The analysis of these models shows that they take into account the signs that are essential for daily visits to stores when the buyer is not limited by the need for

[1] Search for goods and medicines in 2GIS: how it works: Available at: https://web.archive.org/web/20220129021728/https://help.2gis.ru/question/poisk-tovarov-i-lekarstv-v-2gis-kak-rabotaet (accessed: 19.11.2022).

[2] Routing. Available at: https://yandex.ru/company/technologies/routes (accessed: 20.11.2022).

urgent purchase of emergency goods. Such models can be used to predict the time spent on buying goods in a store based on the free nature of his visit. However, these models cannot be applied in predicting the average time spent on the purchase of emergency goods when the buyer is not affected by the involvement in purchases, but is a rational buyer.

Thus, existing cartographic solutions and developed models in the field of estimating the time spent on the purchase of goods cannot fully provide the calculation of the average time required to purchase an emergency product. Therefore, it is necessary to develop a model that allows you to estimate the specified time.

The model of the average time spent on the purchase of goods in the store

The time spent on the purchase of goods in the store consists of:
— Time spent on service at the checkout;
— Time spent waiting for a queue.

To estimate the time spent on the purchase of goods, we describe a scheme for estimating this time in terms of Queuing Management Systems. In this case, the store service system in Kendall's notation [10] will look like M/M/S — a multi-channel CFR with an unlimited queue [11]. Such a system will be characterized by zero probability of denial of service $p_{den} = 0$, service probability $Q = 1$, absolute service efficiency $A = \lambda$ and the number of n service channels with service intensity μ. The relationship of the parameters of such a system is shown in Fig. 2.

The time spent on the purchase of goods will be the service time of the application (buyer) in the Purchase order. Thus, the required time will be calculated according to the formula:

$$T_{queuing\ system} = t_{queue} + t_{service}, \tag{1}$$

where t_{queue} — average waiting time in the queue; $t_{service}$ — time spent on servicing one customer.

The service time of one customer will depend on the time spent on processing a unit of goods — t_{proc}, quantity of goods in the basket — k_g, and the time spent on other actions of the cashier — t_{other}:

$$t_{service} = t_{proc} \times k_g + t_{other}. \tag{2}$$

The time spent on processing a unit of goods and other actions of the cashier can be estimated by empirical observations and data from electronic cash registers[1].

The average queue waiting time can be calculated by the formula:

$$t_{queue} = \frac{L_{que}}{\lambda}, \tag{3}$$

where L_{que} is the average queue length, λ is the intensity of the input stream.

The average queue length is found by the formula:

$$L_{que} = \frac{\rho^{n+1}}{n \times n! \times \left(1 - \frac{\rho}{n}\right)^2} \times p_0, \tag{4}$$

where ρ is the load intensity calculated as:

$$\rho = \frac{\lambda}{\mu} \tag{5}$$

and p_0 is the probability of finding the system in the initial state when all service channels are free and determined by the formula:

[1] What I Would Do With This: Groceries. [Electronic resource]. Access mode: https://blog.mrmeyer.com/2009/what-i-would-do-with-this-groceries (accessed: 22.10.2022).

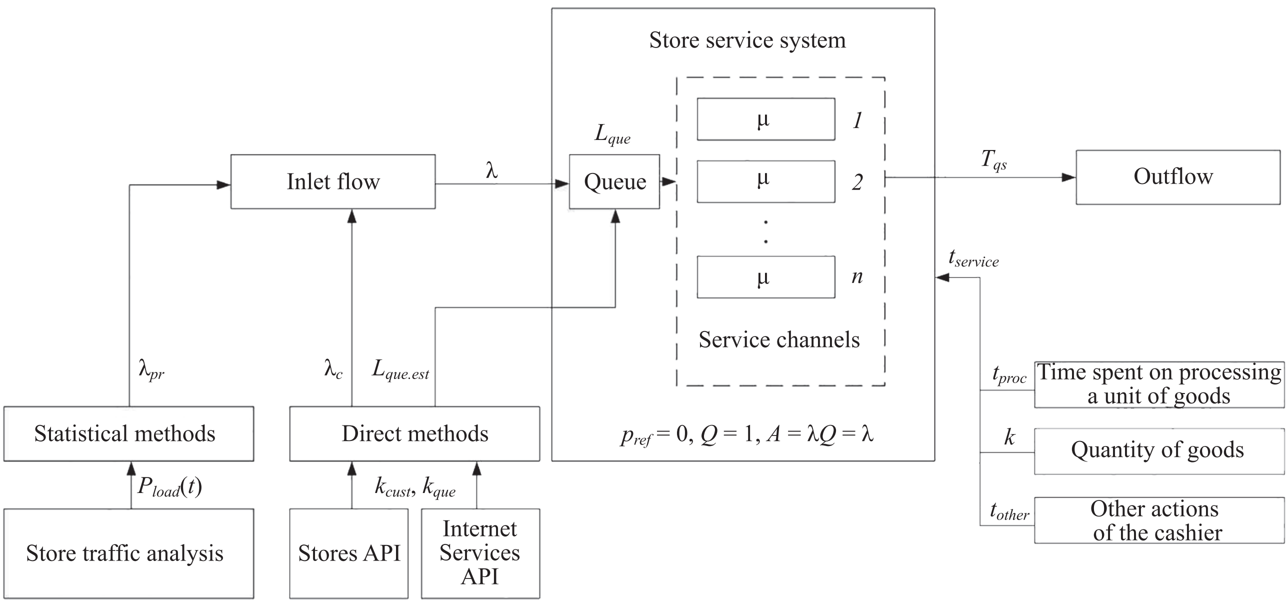

Fig. 2. An information model for estimating the average time spent on the purchase of goods, where: λ_{pr} — predicted input flow rate; λ_c — calculated input flow rate; p_{ref} — probability of denial of service; T_{qs} — queuing system spent time; k — quantity of goods

$$p_0 = \frac{1}{\sum_{k=1}^{n} \frac{\rho^k}{k!} + \frac{\rho^{n+1}}{n! \times (n - \rho)}}, \quad (6)$$

where $k = 0$ and is the number of applications.

Thus, the average queue L_{que} can be found based on the intensity λ of the input stream, or can be calculated using direct queue estimation methods that directly count the number of visitors in the queue.

To estimate the number of people in the queue, you can use direct methods that allow you to give accurate data on the number of people in the queue k_{queue} at a given time. These can be store APIs (if available) that allow you to access calculated data on the number of people in the queue, or access video cameras to make such a calculation as well as Internet service APIs that implement these calculations and provide quantitative information about the cashier's workload.

Obviously, the number of people in the queue is proportional to the workload of the store. Thus, for a

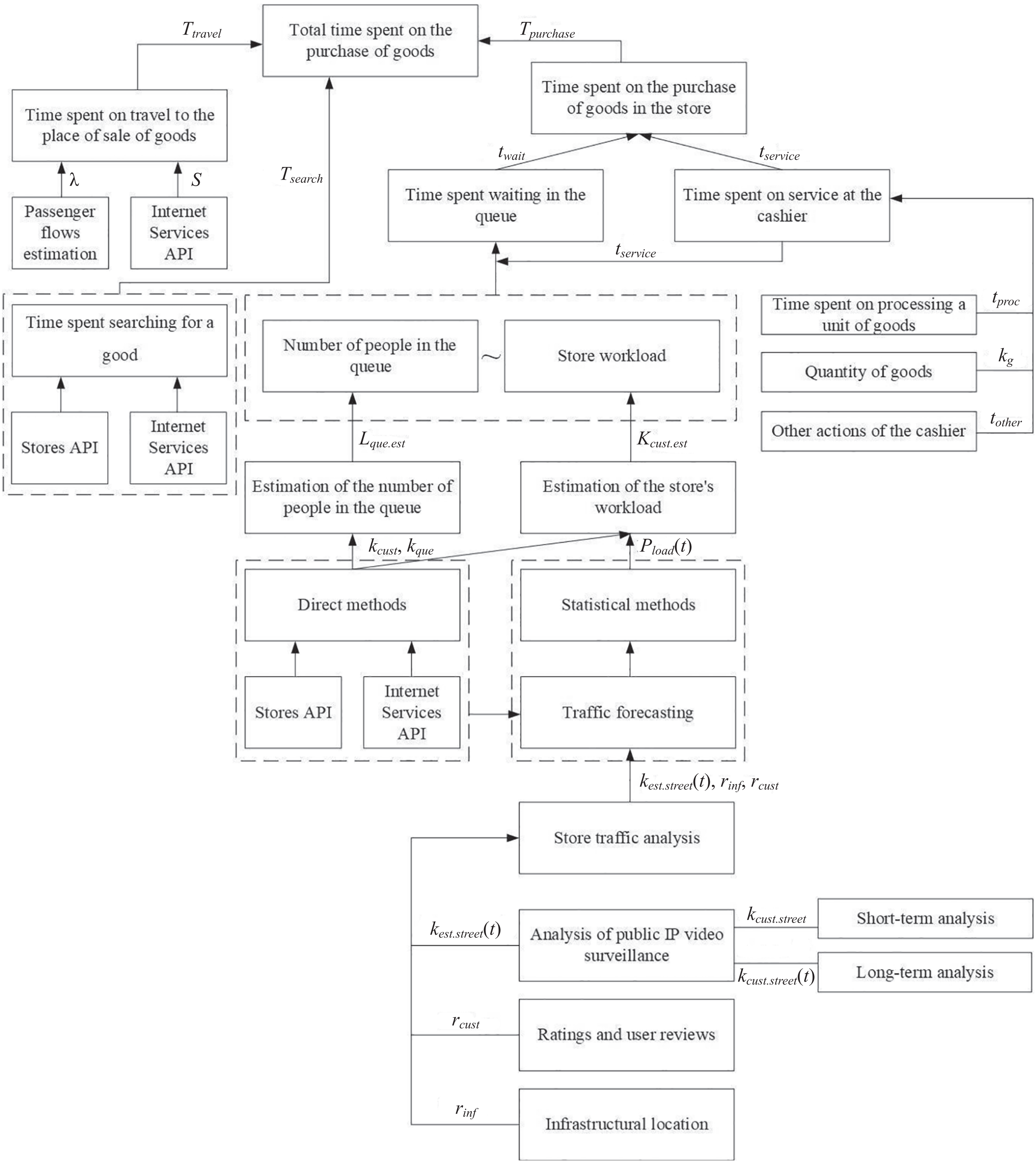

Fig. 3. Information model of the average time spent on the purchase of goods

qualitative assessment of the queue $L_{que.est}$, you can use the methods of assessing the workload of the store. Such an assessment can be carried out using direct methods that provide accurate data on the number of visitors to the k_{cust} store as well as using statistical methods based on the analysis of store attendance, giving a probabilistic estimate of the $P_{load}(t)$ of the store workload at time t, on the basis of which it is possible to quantify the workload of the $K_{cust.est}$.

Traffic analysis is carried out by collecting and analyzing data from publicly available IP surveillance cameras. At the same time, an instant data analysis is possible, estimating the number of people on the $k_{cust.street}$ street next to the store, and a long-term analysis that allows us to judge the seasonal and daily quantitative visits to the $k_{cust.street}(t)$ [12, 13].

In addition, when predicting the workload of the store, it is necessary to introduce coefficients that provide an adjustment for the rating and evaluation of users r_{cust}, and an adjustment for the infrastructure location of the r_{inf}.

The presence of these coefficients is explained by the dependence of the store attendance on the quality of its reviews and ratings as well as on the infrastructure location. Obviously, the more positive the reviews and the high rating of the store, the greater the likelihood of its high workload and with the help of infrastructure analysis it is possible to determine the alternative of the buyer's choice. For example, if there is only one pharmacy in a certain area, you can make a forecast about its high workload.

The time spent searching for a product is calculated based on the time spent using the API of stores and online services to search for a product. The specified time can be obtained, for example, by averaging the results of the experimental search time for a certain product range.

The time spent on the way to the place of sale of the goods is calculated based on the assessment of passenger traffic λ and the way S provided by Internet services. This time can be obtained from cartographic services such as Yandex.Maps.

Based on the above, we will build an information model for estimating the average time spent on the purchase of goods (Fig. 3).

The average time spent on the purchase of a product will be defined as:

$$T_{aver} = T_{search} + T_{travel} + T_{purchase}. \qquad (7)$$

The presented model reflects the main essential parameters necessary to calculate the average time spent on the purchase of goods.

Based on the data collected in the web version of the 2GIS service using the Selenium WebDriver software library, using model (1)–(7), we will build a simulation model in the AnyLogic environment [14] (Fig. 4) to estimate the average time to purchase essential goods for the following conditions:

— Product search time varies from 1 to 5 min;
— Travel time to the place of sale varies from 10 to 40 min;
— Shop 5 support services;

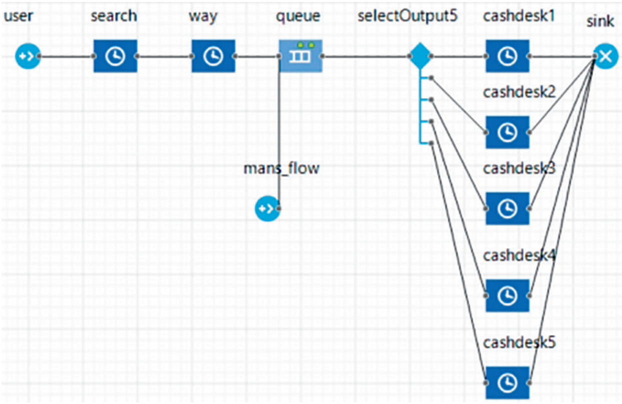

Fig. 4. Simulation model of the average time spent on the purchase of goods developed in the AnyLogic environment

— The speed of customer service at the checkout from 40 s to 2 min;
— The incoming flow of applications is characterized by an exponential distribution.

These conditions are typical for the places of sale of essential goods of one of the pharmacy chains in Saint Petersburg.

As a result of modeling the flow of users buying emergency goods for 10 h (the duration of the pharmacy), we get the dependencies shown in Fig. 5 and 6.

For this example, the average time spent on the purchase of emergency goods was 1935 s. The average queue length is 10 people, the average waiting time in the queue is 340 s.

To verify the simulation results, an experiment was conducted in which 10 control purchases of emergency goods were carried out in various stores. The results of the experiment are presented in Table.

The results of the experiment show their consistency with the simulation data based on the proposed information model.

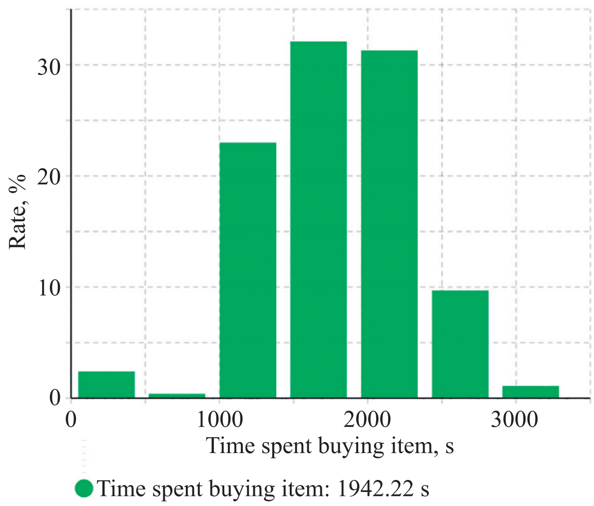

Fig. 5. The results of estimating the average time spent on the purchase of goods using a simulation model developed in the AnyLogic environment

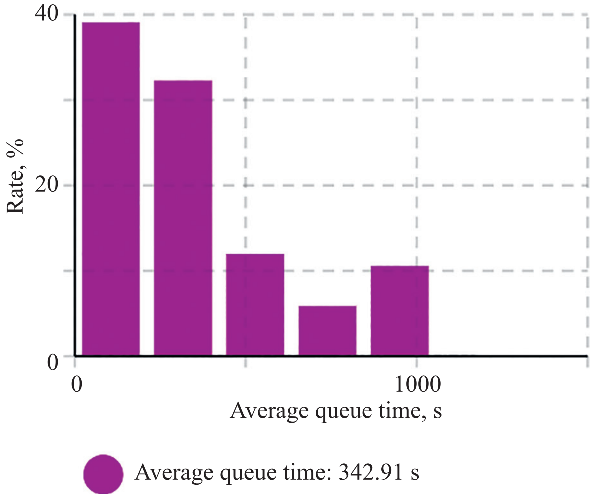

Fig. 6. The results of estimating the average queue length using a simulation model developed in the AnyLogic environment

Table. Results of the experiment

Purchase number	Waiting time in the queue, s	Time of purchase of the product, s
1	301	1752
2	473	2015
3	287	1871
4	358	1618
5	387	2533
6	271	1670
7	421	2758
8	317	1896
9	295	1752
10	288	1482
Average time	340	1935

Thus, if the necessary parameters are available, using the proposed model, it is possible to model the user's behavior under certain conditions and, using the data of cartographic services on the travel time, estimate the time required to purchase an emergency product.

Conclusion

Based on the above, it can be concluded that the existing models do not fully reflect the nature of the behavior of the buyer of the emergency goods. In addition, they do not take into account the overall workload of the store and the length of queues, their impact on the time spent on the purchase of goods, but only allow you to assess the impact of individual characteristics of the buyer on the time spent by him on visiting the store.

The developed model proceeds from the rationality of the buyer of the emergency goods. It takes into account the actual and predicted workload of the store, the length of queues, the time spent on cash customer service. In addition, the time spent searching for the necessary emergency goods using various services is also taken into account as well as the time spent on the way to the place of sale of the goods.

Thus, the specified model sufficiently reflects the essential parameters necessary to estimate the average time spent on the purchase of emergency goods. The developed model can be used when searching for the optimal route to the place of sale of goods, taking into account the time spent on the purchase of goods in the store, which will greatly increase the accuracy of modern cartographic systems that do not take into account this time.

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Received 02.12.2022
Approved after reviewing 19.12.2022
Accepted 28.03.2023

Статья поступила в редакцию 02.12.2022
Одобрена после рецензирования 19.12.2022
Принята к печати 28.03.2023