Sustainability analysis of the management strategy in a shopping centers

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Abstract. The managers’ strategic behaviour of shopping centers in a competitive environment is discussed. Sensitivity analysis was made by using the methods of mathematical and experimental game theory. The stability of the strategy to the opponents' actions was investigated. Also, we investigated the stability of the strategies to the environment, expressed in the level of consumption. The level of consumption in our study is characterized by: the share of visitors, making purchases in the shopping centre (the conversion rate); the average amount of purchases that make visitors shopping centre (size of the average check). These parameters describe changes of the environment. All cases of the shopping centre management strategy stability are illustrated. The novelty is that at allocation costs of the Manager for the development and promotion of shopping centres, the strategies of managers are resistant to each other's actions, in contrast to changes in the external environment is shown.

1. Introduction

The task of management of shopping centers (SC) [6] is one of behavioral control in organization problems [1-5]. The competitive and implementation of SC managed autonomously requires a study of the strategic behavior of SC managers. This study makes is possible with using game theory and experimental game methods. The game-theoretical formulation of the competitive SC management problem corresponds to the zero-sum game, because the total number of visitors is constant, in other words, managers entice visitors from each other by changing the quality of SC.

Mathematically possible to determine the theoretically predicted behavior of the SC managers is showed in the theoretical section of this article. An experimental study of this problem in the form of a business simulation game will make it possible to find out – to which strategy the real people will come. Statement of experimental research of the shopping centers’ managers’ strategic behavior is described in experimental section. In particular, layout of a software module based on MS Excel used in preliminary experiments is shown. Results of preliminary experiments of strategic behavior managers of SC allow to found two aspects: with the apparent cognitive complexity of the problem, players were able to find the optimal distribution without using the decision support system in a fairly short period of time, in other words, players came to a theoretically predicted strategy; the optimal strategy, in turn, was resistant to the actions of the opponent, and therefore the players did not change their strategies, which led to a very rapid completion of the experiments.
2. An example of a decision theoretic game problem with two players engaged in the management of a competing SC

2.1. Raw data for solving the problem of competing SC management

The internal parameters characterizing the shopping center for the consumers are include: $x_1$ – square, $x_2$ – range of goods, $x_3$ – transport availability, $x_4$ – aesthetic parameter, $x_5$ – promotions and discounts, $x_6$ – quality of goods, $x_7$ – availability of brands and $x_8$ – events (here are the results obtained by sociological (marketing) survey of the SC in the Perm city\(^1\)). The sociological (marketing) survey was interviewing of visitors (consumers) of shopping centers and main question was “what parameters are more important for you when you are visiting shopping centers?” Consumers (about 600 peoples) didn’t have answers options and that so they answered about parameters for themselves. All answers were aggregate to 8 quality parameters because answers often repeated. For this study used this four parameters: $m = 4, 6, 7, 8$ as those which we will operate, and other remained parameters: $o = 1, 2, 3, 5$.

To predict the attendance of the commercial real estate object, the modified [6] Huff model [7-9] (1) can be used, which allows to estimate the consumer attractiveness of the commercial property:

$$A_j = \frac{Q_j}{T_{ij}}^{\lambda} ,$$

(1)

$i$ – the number of the buyer (the $i$-th consumer means the consumer located in the point of $i$); $j$ – number of the commercial property; $A_j$ – the attractiveness of the $j$-th property for the $i$-th consumer; $Q_j$ – the quality of the property; $T_{ij}$ – time spent by the $i$-th consumer on the road to the $j$-th property; $\lambda \in [0; 1]$ – parameter reflecting the effect of different types of objects on the perceived time spent (this parameter is empirically); $\{\}$ – the numerical value of the parameter. Quality in this study calculate by qualimetric model:

$$Q = \prod Q_m^q \cdot Q_o ,$$

(2)

$Q_m$ – quality of using parameters, $q_m$ – importance of using parameters and $Q_o$ – quality of others internal parameters with taking into account their importance. These parameters are constant and don’t depend on costs in development. In this study $Q_o$ have next values: $Q_{o1} = 0.885$; $Q_{o2} = 0.803$. These ones were calculated based on results of sociological (marketing) survey (table 1).

The time of correspondence ($T$) of consumers from the place of residence to the commercial object has a significant impact on the assessment of consumer attractiveness of shopping centers. The so-called pedestrian-transport zones [6] and corresponding parameters $\lambda$ are formed to commercial real estate objects: for the first zone (from 45 to 80 min walk) – $\lambda = 0$; for the second zone (from 80 to 160 min walk) – $\lambda = 0.5$; for the third zone (over 160 min walk) – $\lambda = 1$. At the intersection of these zones, depending on the location of the studied commercial real estate objects, it is possible to allocate several sectors $K$ (Fig. 1), each one are differently affects for consumers’ time spent to property.

![Figure 1. Allocation of sectors on the example of two shopping centers (SC).](image)

\(^1\) Advantages the Results presented in tablet form. Retried from https://goo.gl/enasqb (creation date: 18.09.2013)
Having calculated attractiveness of SCs according the modified Huff model (1), we can determine the probability of a potential consumer's choice of a trade object (3):

\[ P_{ij} = \frac{A_{ij}}{\sum_{j=1}^{n} A_{ij}} \]

and we can calculate the number of expected visitors (n) in the shopping center, knowing the number of residents in each sector k:

\[ n = \sum_{k=1}^{K} \left( P_{ij}^k \cdot N_k \right) \]

\( P_{ij}^k \) – the probability of visiting the i-th visitor from the k-th sector of the j-th property; \( N_k \) – number of residents of k-th sector; \( K \) – number of sectors for the example with two shopping centers: \( K=10 \) (see figure 1).

Let there be two competing SC (\( j \in J \), \( J = \{1, 2\} \)), each of them has three pedestrian-transport zones and their intersection forms ten sectors (\( K \)). The task of SC management is formulated as a constrained optimization problem, where profit (5) or index of profitability (6) can be used as a objective function (OF). Constrained optimization problem have inequality constraints to the costs of SC development and promotion. These costs are members of set of feasible values \( c_m C_m, mc \in M \), where \( M \) – set of using parameters.

\[ OF_1 = P_j(c_{jm}; c_{-, jm}) = \mu \cdot Ar \cdot n_j \left( c_{jm}; c_{-, jm} \right) - \sum_{m \in M} c_{jm} - TFC_j, \]

\[ OF_2 = RR_j \left( c_{jm}; c_{-, jm} \right) = \mu \cdot Ar \cdot n_j \left( c_{jm}; c_{-, jm} \right) + \sum_{m \in M} c_{jm} + TFC_j - 1, \]

where \( TFC_j \) – total fixed costs of the Manager of the j-th SC; \( \mu \) – customer conversion ratio (the percentage of visitors who purchase something); \( Ar \) – the average amount of purchases that visitors make; \( c_{jm} \) – costs of managing j-th SC for the development of managed parameters of the object; \( n_j \) – the number of attracted visitors in the j-th SC, determined by the equation:

\[ n_j = \sum_{k=1}^{10} N_k \cdot \prod_{m=1,2} Q_j(c_y)^{q_m} \cdot Q_o \cdot T_k^{-\lambda_k} \]

\( Q_j(c_m) \) – quality of using parameters of object j; \( Q_o \) – quality of other parameters of object j; \( T_k \) – correspondence time to i-th SC of visitors to k-th sector; \( \lambda_k \) – parameter that affects the importance of correspondence time for visitors; \( N_k \) – amount of residents in sector k, \( k=\{1,\ldots,10\} \); \( q_m \) – importance of m-th parameter, \( m = 4, 6, 7, 8 \). The game-theoretical formulation of the competitive SC management problem corresponds to the zero-sum game, because the total number of visitors is constant \( n_1+n_2=\text{const} \), in other words, managers entice visitors from each other by changing the quality of SC.

The solution of the optimization problem is the cost distribution for SC management, defined by the equation:

\[ c_{jm}^* = \arg \max_{c_{jm}} \left( OF(c_{jm}, c_{-, jm}) \right), \]

which corresponds to the game-theoretic formulation of the control problem, taking into account that the result of the Manager's activity depends on the actions of the opponent, and vice versa. The game
situation is denoted by \( a - j \) according to the theory of games [10, 11]. Accordingly, in the equation (8) \( c - j_m \) is the opponent’s costs to develop his SC.

The data presented below are the initial ones, at which the authors conducted theoretical and experimental research of strategic behavior of SC managers.

**Table 1.** Evaluation of quality parameters SC and values their importance, compiled by the authors based on the results of a survey of visitors SC, and brought to a scale [0; 1].

| \( i \) | Parameter                  | \( Q_1 \) | \( Q_2 \) | \( q_i \) |
|--------|---------------------------|-----------|-----------|----------|
| 1      | Area                      | 0.947     | 0.740     | 0.12     |
| 2      | Range of goods            | 0.853     | 0.648     | 0.15     |
| 3      | Transport accessibility   | 0.851     | 0.887     | 0.15     |
| 4      | Aesthetic parameter       | 0.861     | 0.842     | 0.12     |
| 5      | Promotions, discounts     | 0.660     | 0.516     | 0.11     |
| 6      | Quality of goods          | 0.789     | 0.759     | 0.15     |
| 7      | Availability of brands    | 0.884     | 0.748     | 0.12     |
| 8      | Events, concerts          | 0.681     | 0.605     | 0.08     |

This survey was conducted among visitors of SC in the Perm city. They were offered to estimate SC in quality parameters (in a scale from 1 to 10 where 1 – poor quality, 10 – excellent quality) and to estimate (on a scale from 1 to 10 where 1 – it isn't important at all, 10 – it is very important) as far as him this parameter at the choice of this or that SC is important. Average values of parameters were brought to a scale [0; 1] for using the qualimetric model (2).

The next initial parameters (Table 2) need for using equations (1) and (4).

**Table 2.** The values of the parameter \( \lambda \), the time correspondence to the SC and the number of residents, depending on the sectors

| Initial parameters | Sectors (k) | \( \lambda_1 \) | \( \lambda_2 \) | \( \lambda_3 \) | \( \lambda_4 \) | \( \lambda_5 \) | \( \lambda_6 \) | \( \lambda_7 \) | \( \lambda_8 \) | \( \lambda_9 \) | \( \lambda_{10} \) |
|-------------------|-------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Value parameter \( \lambda \): for SC1 | 0            | 0              | 0.5            | 0.5            | 0              | 1              | 0.5            | 1              | 1              | 1              | 1              |
| for SC2            | 0            | 0.5            | 0.5            | 0.5            | 0              | 1              | 0.5            | 1              | 0              | 0.5            | 1              |
| Nk                | 5182         | 8292           | 8292           | 6215           | 6215           | 20729          | 20729          | 31094          | 31094          | 50000          |
| T1                | 45           | 45             | 80             | 80             | 80             | 45             | 160            | 80             | 160            | 160            |
| T2                | 45           | 80             | 45             | 80             | 80             | 160            | 45             | 160            | 80             | 160            |

In the discrete case, the total number of control strategies will be determined by the equation:

\[
U = \prod_{m=1}^{M} u_m, \tag{9}
\]

\( m \) is the ordinal number of the parameter that can be controlled by the SC Manager; \( M \) – total number of parameters to be managed; \( u_m = \{1, 2, \ldots, \bar{u}_m\} \), \( \bar{u}_m \) – the maximum number of options for changes to the parameter \( m \), \( m = 4, 6, 7, 8 \).

The first assumption is sets of the costs for the development of individual SC parameters \( m \) have values presented in Table 3.
Consider an example where the strategy of SC managers depends on four cost options for changing four using parameters. In this case (∀m: \( m_u = u = 4 \)) the number of strategies of each manager will be determined by the equation:

\[
U = u^m = 4^4 = 256.
\]  

(10)

The next assumption was made in this study – the dependence between quality of the each managed parameter and costs to its development is linear. The quality values belongs to interval from 0 to 1, where 0 – bad quality, 1 – excellent quality. The costs to development the used parameter \( m \) belongs to interval from \( C_{m} \) to \( c_{m} \). That is why the suggested cost function determined as the ratio of the difference between the current cost value and the minimum to the cost range. However, according to equation (2) the quality of shopping center calculated as product of quality values of the used parameters and the quality value of other parameters. So if one of the managed parameters quality values will be zero, then quality of shopping center value will be zero too. For exclude such a situation the cost function equation is logic and determine as:

\[
Q(c_{m}) = \begin{cases} 
\frac{c_{m} - c_{m}}{C_{m} - c_{m}}, & c_{m} \in C_{m} \\
0.001, & \text{if } c_{m} = c_{m}
\end{cases}
\]

(11)

\( c_{m} \) – the minimum value of \( C_{m} \) and \( c_{m} \) – the maximum value.

Figure 2. The optimal strategy for the first player.

Note for figure 2: at \( \mu = 0.1 \) the purchase is made every tenth visitor SC; AR – 0.5 th.r.; competitor's quality SC \( (Q) = 0.663 \), in relative scale [0;1].
According to the equation (8), the optimal solution to the management problem of the SC is to allocate the management budget to change the used parameters, which provides the maximum of their personal profit [6] or index of profitability. The optimal strategy of the SC Manager by profit maximization criterion (orange columns) and index of profitability maximization (gray columns) is shown below (Figure 2).

It is worth noting that these solutions are obtained with a known strategy of the opponent and a given level of consumption. The level of consumption is characterized by: the share of visitors, making purchases in the SC (the conversion rate - \( \mu \)); the average amount of purchases that make visitors SC (size of the average check – \( AR \)). These parameters describe changes of the environment. Examples of the dependence of the optimal strategy of the SC’s managers on the changing environment are given below (Fig. 3, 4).

![Figure 3](image-url)

**Figure 3.** The optimal strategy distribution of development costs SC when the target profit function and the average bill is equal to 0.1 thousand of rubles (th.r.) at different conversion ratios.

Note for figure 3: at \( \mu=0.01 \), the purchase is made by every hundredth visitor of SC; at \( \mu=0.05 \), the purchase is made by every twentieth visitor of SC; at \( \mu=0.1 \), the purchase is made by every tenth visitor of SC; at \( \mu=0.5 \), the purchase is made by every second visitor of SC.

![Figure 4](image-url)

**Figure 4.** The optimal strategy distribution of development costs SC when the target profit function and the average bill is equal to 0.5 thousand of rubles (th.r.) at different conversion ratios.

Note for figure 4: at \( \mu=0.01 \), the purchase is made by every hundredth visitor of SC; at \( \mu=0.05 \), the purchase is made by every twentieth visitor of SC; at \( \mu=0.1 \), the purchase is made by every tenth visitor of SC; at \( \mu=0.5 \), the purchase is made by every second visitor of SC.
Allocations costs for SC development show that, when the level of consumption becomes costs of the development and promotion of SC becomes too, which is almost obvious. However, the task of searching for the optimal allocation of costs at the SC's management is not a trivial task and its solution is quite time-consuming. This fact makes necessary the management decision support system (DSS). It should also be noted that strategy is the most sensitive to changes in the external environment. For the purposes of this study, devoted precisely to the study of strategic behavior of competitive managers of SC, environment is fixed.

2.2. An example of solving a game-theoretic problem with two players managing the competitive SC
In this paper, we illustrate an example of the solution of the game-theoretic problem in the simplest formulations, where the participants in the game are two players that manage the competitive SCs and their strategies are determined by the costs of their development.

In a situation where the player does not know the opponent's strategy, it is suggested to search for strategies according to the concept of the maxmin (or also called maximum guaranteed result (MGR)). This situation is typical for players with the first rank of strategic reflection. The second rank of reflection means that the player calculates his Best Response (BR), knowing the opponent's strategy. The third rank of reflection means that the player uses the strategy corresponding to Double Best Response (DBR), with the known opponent’s Best Response [11]. Comparative analysis strategies obtained based on these concepts is presented in Table 4. All solutions in table are present by number of player’s strategy. It one is determined according to the equation:

\[
1 \cdot (u_{m-8} - 1) + 4 \cdot (u_{m-6} - 1) + 16 \cdot (u_{m-4} - 1) + 64 \cdot (u_{m-7} - 1).
\]

Table 4. Matrix of strategies of players in the formulation of a game with two managers when using profit as an objective function.

| Strategies  | 2nd player |
|-------------|------------|
|             | MGR2 | BR2 | DBR2 |
| 1st player  |       |     |      |
| MGR1        | 151  (MGR1) | 151  (MGR1) | 151  (MGR1) |
| BR1         | 151 (BR1(MGR2)) | 151 (BR1(MGR2)) | 151 (BR1(MGR2)) |
| DBR1        | 151 (DBR1(BR1(MGR2))) | 151 (DBR1(BR2(MGR1))) | 151 (DBR1(BR2(MGR1))) |

The solution game-theoretic formulation of two SC players-managers shows that with an increase in rank of reflection, the players share the same strategies (Table 4). It is important to note that the solution depends on the level of consumption, which in this study deliberately not investigated.

In Table 4 the player's choice of strategy 87 corresponds to the following costs: for advertisement 60 th.r., for aesthetic appearance – 120 th.r., for the quality of goods – 200 th.r. and for holding events – 55 th.r.; strategy 151 corresponds to: an increase in advertising costs – 90 th.r., costs for aesthetic appearance – 120 th.r., costs for the quality of goods – 200 th.r. and increase the cost of events up to 70 th.r.

Thus mathematically possible to determine the theoretically predicted behavior of the SC managers and becomes relevant experimental study of strategic behavior through a series of business games. An experimental study of the above problem in the form of a business simulation game will make it possible to find out – to which strategy the people will come.

According to the authors of the experiment, these switches are necessary to visualize the optimal allocation of costs for the development of SC, as well as comparing the strategies of players at different ranks of reflection (see table 4). When switching, the histogram visualizes the solution for the corresponding mode, and in the area 4 the optimal values of the quality of the player and his opponent
are displayed. Also in the layout there is a switch showing the optimal allocation of the objective function OF (profit maximization (5) or index of profitability (6)) selected by the rules of experiment.

At the end of the step, each player tells the experimenter the number of the strategy he selected and the value of the quality of his SC in the implementation of this strategy. At the beginning of the next step, each player replaces the quality of the opponent on the value that reached the opponent on the last step.

The end of the game is the situation when a certain number of steps is end in the game or the players do not change their strategies for the second consecutive step. The latter also takes into account the situation in which players would be beneficial (advisable) to change their strategy. This will show the difference between theoretically predicted and actual people behavior.

Before starting the experiment, players are informed of all the theoretical information about the essence of the game and methods of solving the SC management problem. The experimenter must be convinced that each player correctly understood the rules of the game and his role, through feedback.

Preliminary experiments were conducted in the Center of business simulation game of Perm national research polytechnic university (PNRPU). Participants in this study were master students of PNRPU, exactly, students of 1-st and 2-nd courses of master programs “Technologies of real estate property management” and “Risk management in civil engineering”. During one experiment session students were divided in 4 groups, each of one included 2 students. Total amount of participants’ token part in the preliminary experiments is 32 students. One of the purposes of the preliminary experiments was testing software module and that’s why the experiment didn’t incentivize.

In despite of preliminary character of the experiments two aspects were found: players were able to find the optimal allocation without using the decision support system in a fairly short period of time (see Figure 5 and Table 5), in other words, players came to a theoretically predicted strategy; the optimal strategy, in turn, was resistant to the actions of the opponent, and therefore the players did not change their strategies, which led to a very rapid completion of the experiments.

![Figure 5. Results of a preliminary experiment.](image)

Note for figure 5: In the figure preliminary results of a game of 4 groups of students (on 2 players in everyone) are presented. In other groups, similar results have turned out.

The resistance of the optimal strategy is explained by the experimental assumptions, including the values of used parameters of the costs to development and promotion SC (see table 3) and about the type of cost functions (see equation (11)). As it turned out, the costs are too large a change step and when the opponent tries to attract additional consumers to itself, the player's costs for their preservation in its SC exceed the expected economic effect, determined by the product of the average
check (AR) on the number of visitors (nj) and the conversion rate (µ). This fact make necessary for additional theoretical study of the SC management problem with different cost functions.

Table 5. Matrix of strategies of players in the formulation of a game with two managers when using profit as an objective function.

| Groups   | Players          | Steps |
|----------|------------------|-------|
|          | 1-st player      | 2     | 3     | 4     | 5     | 6     |
| 1-st group | 167              | 151   | 31    | 151   | 151   |
| 2-nd player | 148              | 150   | 55    | 42    | 151   |
| 2-nd group | 100              | 99    | 98    | 146   | 151   |
| 2-nd player | 151              | 151   | 151   | 151   | 151   |
| 3-rd group | 149              | 149   | 157   | 151   |
| 2-nd player | 218              | 150   | 150   | 151   |
| 4-th group | 242              | 242   | 151   |
| 2-nd player | 106              | 135   | 169   |

2.3. Change of functions of costs for development and promotion of controlled parameters of SC in a computational experiment

To conduct the experiment in the mathematical model, the ranges of cost functions were increased (table 6). The conversion ratio is changed by 0.05, the average check is assumed to be 500 th.r.

Table 6. Example of allocation of increased cost options to manage four criteria.

| Variants of distribution of management costs | Advertising | Aesthetic appearance | Quality of goods | Events |
|---------------------------------------------|-------------|----------------------|------------------|--------|
| m=7                                         | m=4         | m=6                  | m=8              |
| u=1                                         | 100         | 100                  | 100              | 100    |
| u=2                                         | 200         | 200                  | 200              | 200    |
| u=3                                         | 300         | 300                  | 300              | 300    |
| u=4                                         | 400         | 400                  | 400              | 400    |

By increasing the range of costly functions, a stable strategy of player behavior and optimal resource allocation was revealed (number of optimal strategy – 0, in which m=4, m=6, m=7, m=8 correspond to the level of costs u=1). The resulting optimal strategy can be interpreted as follows: at the maximum cost functions should adhere to the minimum costs in the development and promotion of the SC.

The next stage was to reduce the range of cost functions (table 7). The conversion rate and the average check are the same.

Table 7. An example of the distribution of reduced variants of the cost of four criteria.

| Variants of distribution of management costs | Advertising | Aesthetic appearance | Quality of goods | Events |
|---------------------------------------------|-------------|----------------------|------------------|--------|
| m=7                                         | m=4         | m=6                  | m=8              |
| u=1                                         | 5           | 0                    | 3                | 8      |
| u=2                                         | 10          | 10                   | 6                | 16     |
| u=3                                         | 15          | 20                   | 9                | 24     |
| u=4                                         | 20          | 30                   | 12               | 32     |
When reducing the range of cost functions, it was also revealed a stable strategy of player behavior and optimal allocation of costs (number of optimal strategy – 255, in which \( m=4, m=6, m=7, m=8 \) correspond to the level of costs \( u=4 \)). The resulting optimal strategy can be interpreted as follows: with minimal cost functions should adhere to the maximum cost in the development and promotion of the SC.

The last stage was the replacement of the quality evaluation function from geometric (2) to arithmetic in the mathematical model, with the cost functions adopted in section 2.2 (see table 3). As a result, the optimal strategy (without reflection) was for the first player – 5, for the second (with the first rank of reflection) – 196, for the first (with the second rank of reflection) – 151. As it turned out, the strategies of the players are resistant to the actions of opponents and, accordingly, to the quality of competing SCs, that is, the resistance of strategies does not depend on the function describing the quality of the object.

With the costs that were taken in the computational experiment, it turned out that there is an allocation that shows their optimal value. We can assume that the adopted objective function, the model adopted to assess the consumer attractiveness and quality of the SC, adopted in the experiment, the cost functions are adequate. Thus, it can be said that if in real practice of management, the quality of SC, which affects the choice of the consumer object to visit, would be described using a geometric weighted model, the strategy of the Manager would be resistant to the action of his opponent, but not resistant to changes in the environment, in the form of conversion ratio and average check. Previously the authors [6] showed on the example of SC of Perm city that the geometric model gives more accurate results of forecasting the consumer flow to real data than other recommended weighted models.

3. Conclusion
Sensitivity analysis showed resistance of SC management strategy to the opponent's behaviour, but sensitivity to environmental changes and consumer behaviour. The strategy of the players is resistant to changes in the cost functions (decrease or increase values) and to change the function describing the quality of the used parameters of the SC. The result of this study is: at the maximum cost functions should adhere to the minimum costs in the development and promotion of the SC; with minimal cost functions, adhere to the maximum cost in the development and promotion of the SC. As it turned out, the strategies of the players are resistant to the actions of opponents and, accordingly, to the quality of competitive SC, that is, the stability of the object. Thus, it can be said that if in real practice of management, the quality of the SC, which would be described using a geometric weighted model, of his opponent, but not of change in the environment, in the form of conversion.

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