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A RESEARCH ON AUDIENCES' EVACUATION IN OLYMPIC GAME GYMS

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Abstract: The article builds an evacuation network made of two kinds of districts-fixed district and unfixed district which divide the network into several small evacuation networks according to the flow and location of the exits. Next, based on safety, speed and order as the whole objective i.e. smaller audiences' congestion degree and smaller total evacuation time, the writer sets up improved max entropy model to distribute evacuation flow to each districts, and then produce the programs that simulate the stream of people in these districts and draw out the graphs according to the simulation model. Consequently, handlers may find out bottleneck of lanes and other else dissatisfied parts to supply with appropriate management and improvement by modifying the parameter values, as a result people can go smooth and feel ease.

Key words: audiences' evacuation; improved max entropy model; simulation

1. EVACUATION INTRODUCTION

In general there are mainly three methods in evacuation articles that concentrate on evacuation time of people in the building. One is exit capacity method which based on the exit velocity according to the crowd and the exit capacity. Those who stand for this method are Predtechenskiand Milinski from Soviet Union, Togawa from Japan and Melinek from England at the beginning of 1950s. The second is network optimize method. It took each function units in the building as nodes, then takes advantage of the flow-limit principals between the nodes in network to reckon the total evacuation time in the building. This method of researches includes Chalmet，Francis，Gunnar，MacGregor from the USA. The third is gridding method. It divided the inside of building into small gridding, took persons as movable particle which can adept its own velocity and orientation according to the changes of circumstance, and as a result traced the moving tracks of the persons, at last came to the results of evacuation time which can be put into computers for dynamic displaying. So far some scholars and research institute have developed calculating software. Some famous include Building Exodus from Greenwich University and Simulex from Edinburgh University in England, EXITT of NIST in American, FIRECAL software of country scientific institute

research organization (CSIRO) from Australia etc, but because of complex of psychology physical factors in the evacuation, especially with the thick smoke filled in the building, it's complicated and incertitude to describe the action of personal character for circumstance varies that time. So it's hard for us to point out which model is more successful. Together with the customs, culture backgrounds and area character, each country still takes great effort to develop their own evacuation model.
In Olympic history some accidents happened because of overcrowded trend and the fires, the researchers show more and more inclination on evacuation. However, existed articles mainly concentrate on the simulation of people flee or the design of the evacuation facility by the simulation results, moreover, they seldom concern how to evacuate more quickly, safe and comfortable when there's no emergency or fail to work out management in designed building.
When Olympic Games convene and a great many people come to the games, it's important to manage efficiently in case that audiences don't come into chaos during the evacuation especially large amount appeared in the ceremony.

Then for the sake of upwards have said, the article brings out something new to improve this situation. The improvements that conclude three main viewpoints for contribution are mainly as followings. First, the writer does a research on audiences' evacuation in Olympic gyms when there is no emergency for example no fire existed in big buildings, which add up the common parts to current evacuation researches that now made up of only emergency evacuation. Second, in addition to build and solve the model, the article also obtains evacuation management and relative actions to take, which fill the blank space of formed researches that no management and actions were adopted. Third, the paper divides the inside building into two kinds of districts-fixed district and unfixed district, and then introduces "the max entropy" model before it simulates the audiences' evacuation. With this pretreatment step, the results can perfectly overcome the disadvantages that stream of people may come into chaos based on the traditional model.

2. EVACUATION REQUIREMENT AND PRINCIPLES IN OLYMPIC GAME

2.1 Evacuation Requirement for Stream of People in Olympic Game

According to the demands of applicant for Olympic and the level that transport facility in Beijing can get to, the Olympic committee set guideline for the transportation service of Olympic games are as follows:

(1) The max gathering or evacuation time that in Olympic ceremony/closure: entrance continual gathering time that comes to the ceremony must be less than 150min. as well as the evacuation time when it's over won't exceed 120min.
(2) When large games such as soccer, track and field are over, audiences should leave in 25min, the max time they took the vehicle permit can't exceed 90min.
(3) In case that the weather changes or transportation accidents, the time permit morra or before limit generally is less than 20min when taking the transportation scheme for emergency.

2.2 The General Principles Relative to Evacuation in Olympic Game:

(1) make sure that traffic –flow move exactly and easily to control
(2) tale effective actions for the safety, park nearby and apart the vehicle and people
(3) plan the special lane, avoid different directions of people to cross or back forwards, shorten the personal walking distance and make sure the staying time of spectator won't exceed the stated limit

3. EVACUATION THEROY

3.1 Concepts about Evacuation Models

Some relative concept in evacuation models:
(1)Density of stream of people (DSP) DSP refers the dense degree that people distributed in stream of people. In the general idea, it means distributed population in unit area. In the article, DSP is level-projection area of people in the unit area of the evacuation lane. Hence the differences between bodies condition (age, gender), the personal level-projection is not one capita of level-projection but reflects complicated level-projection in the whole steam of people.
(2)Velocity of stream of people: It means that the walking velocity of the whole stream, while the value is walking velocity of people who stand at first of the stream. Research verifies that velocity of the stream is the function of the density of the stream.
(3)Flow quantity. We define flow quantity as evacuation persons of projection area that go through the lateral of the certain evacuation lanes in the unit time. Flow quantity is also the function of the stream density.
(4)Capacity of the evacuation lanes: Thus the width of the evacuation lane is stated, and then changes of the flow quantity only follow with that of stream of people. From the anterior analysis, the stream of flow quantity that go through the evacuation exist an max which is just the capacity of the evacuation lane. If the flow quantity exceeds the capacity of the lane when stream go through one evacuation passage, it's will be crowded and congested, as well as stream density will also cone to its max 0.92. Stream flow quantity also exist a max when people go through the safety-exit that served as an important part of evacuation system.

3.2 Troop Theory

When Olympic Games are over, because of the audiences are crowed and serried, it also leads to slow evacuation and congestion, then these action are called troop behavior.
Troop theory: single person walk velocity is at 1~2 m/s or so in the free interspaces. When the population grows to troop, the walking velocity lies on the density of the crowd. When density is less than 1.5 capita/m^2, the velocity for the troop equals to the walking velocity of people who walk slowly, and when it's more than 1.5 capita/m^2, the velocity will be lower. In general, we use coefficient of trooping flow to describe the flowing circumstance when troop go through lateral interspaces. Troop coefficient means the population who go through the unit width in unit minutes.

4. SIMULATION MODEL

4.1 Model Apophasis:

(1) Audiences are reasonable enough to choose the nearest way leaving in his own opinions

(2) Before evacuation, audiences scatters symmetrical in the seats, omitting the stayers in the aisle, stairs and passage lanes. When the evacuation starts, all audiences can go through the evacuation passage or lanes made up of aisle, stairs etc to the parking, bus stop subway outside on his own decision

(3) The total number of evacuation:

The population=capacity of the gyms × 85% × ratio of tickets selling × revise coefficient

(4) Under the service provided, there are no sudden affairs happened such as chaos, congestion caused by terror and nerve. Hereinto, service includes transportation control, volunteer conduction and distributaries.

(5) We take the whole walking people in evacuation as flow system. The state of troop varies and evacuation time is different when populations go through the different interspaces.

4.2 Pretreatment-Fixed District and Unfixed District

The article takes the audiences' passageway as links, the crossings and exits as nodes to make up of a big evacuation network. In the big network two kinds of districts-fixed district and unfixed district which are show in the following diagram divide the network into several small evacuation networks according to the quantities and location of the exits. People near the exits surly choose this lane to get out and they won't head for other lanes far away from them, even the lane turn into congestion or moves slowly for they already in the queue waiting and difficult to jump out to another lane. Consequently, we called these areas fixed districts which contains the areas around each lane to ascertain distance. Except fix districts the left areas are called unfixed where audiences may have different choices to go out judging by the evacuation circumstances and the location of the exits. And if they choose one lane to go out and they already inside the queue, it also turn out difficult for them to jump when congest occurred, but the back of the queue can move around freely if possible. The improved max entropy model put assigned stream of people to each side of small evacuation networks.

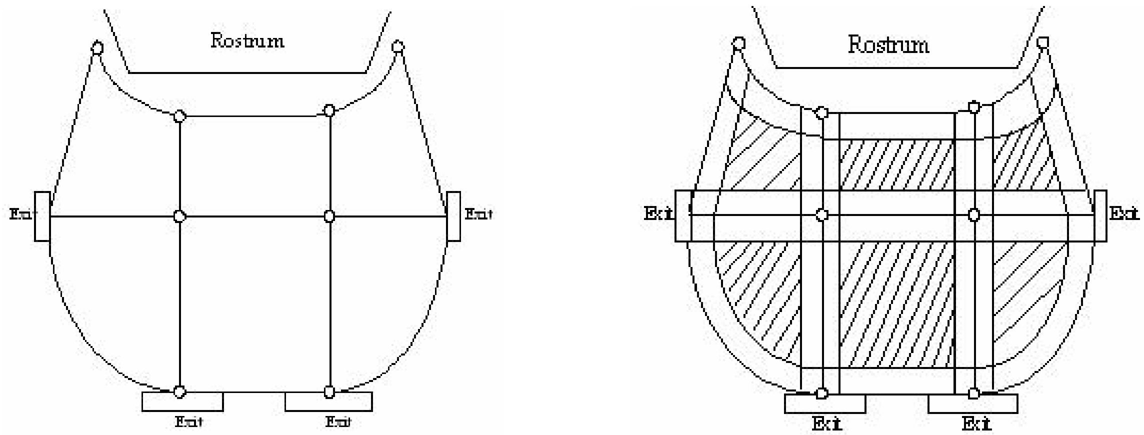


Figure 4.1 (a) Layout of the Network Inside the Gym (b) Fixed and Unfixed District Area

We take T.Y. auditorium as example whose outline of inside evacuation network is shown in

Fig 4.1. Blank areas stand for fixed district and shadow for unfixed district. With this pretreatment step, the results can avoid the disadvantages that stream of people may come into chaos based on the traditional model.

4.3 Simulation Algorithms

The Wardrop first principle: the network will come to equilibrium based that the road uses are certain that traffic conditions of the network and they try to choose the shortest way to travel. In this network, where the impression of the congestion to the travel time was taken into account, and when the networks come to equilibrium, every path used in its OD pair has the same and the least travel time; while travel time of unused path is more than or equal to the least travel time.

But "the max entropy" model is a static model and has its limits while it is used in dynamic audiences evacuation, then its improved max entropy model is as following.

Its general model is: $$\min Z(x) = \sum_a \int_0^{x_a} t_a(w)dw, \qquad (1)$$

$$s.t \begin{cases} \sum_k f_k^{rs} = q_{rs} \\ f_k^{rs} \geq 0 \\ x_a = \sum_r \sum_s \sum_k f_k^{rs} \delta_{a,k}^{rs} \end{cases} \qquad (2)$$

We denote by q_{rs} the flow demand for O-D pair, by x_a the flow and y_a the new flow after calling Dial algorithms for loading , by f_k^{rs} the flow on path, by t_a the flow cost, where $\delta_{a,k}^{rs}$ =1 is path utilizes links and 0 otherwise.

Based impedance varies multi-path distribution algorithms:

Step 1 initialize: based zero- flow initialized impedance $\left\{t_a^0 = t_a(0), \forall a \in A\right\}$, then flow 0-1 distribution we can get the section flow $\left\{x_a^1, \forall a\right\}$, and make repeated number $k=1$;

Step 2 renew impedance of each section, make $\left\{t_a^k = t_a(x_a^k), \forall a \in A\right\}$;

Step 3 on the fundament of new impedance, call Dial algorithms to load flow in random then obtain the flow of each section $\left\{y_a^k, \forall a \in A\right\}$;

Step 4 make $\left\{x_a^{k+1} = (1-\frac{1}{k})x_a^k + \frac{1}{k}y_a^k, \forall a \in A\right\}$;

Step 5 convergence judgment: if it satisfies $\frac{\sqrt{\sum_a (x_a^{k+1} - x_a^k)^2}}{\sum_a x_a^k} \leq \varepsilon$, then stop; or else $k = k+1$, go to step 2.

Applied the algorithms:

Here in the network 1 stands for O and 9 for D between which flow is 1000. Then we applied the algorithms to distribute the flow, the network and results are shown in following figures.

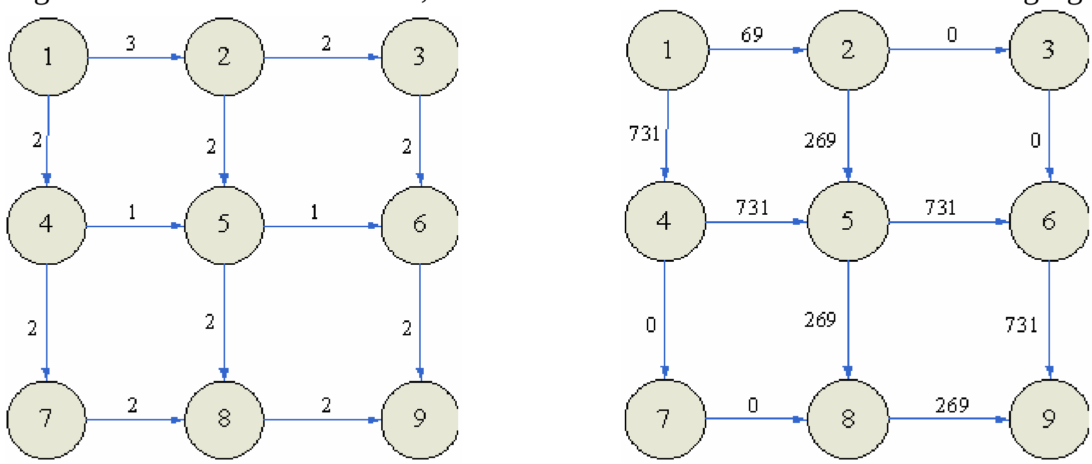


Figure 4.2 (a) O-D Pair Network with Fees (b) Flow Distribution Result

The results are also used in simulation part and each flow on the path will be restricted terms of $v(l)$ and influence the population remained $N(t)$.

4.4 Evacuation Simulation

From the initial time, there is none in the evacuation lane and later people from the paths and nodes swarm into evacuation exits, then evacuation residue (still need to be evacuated) lead to that exit can be described as

$$N(t)=N(t-1)-v_{eva}\Delta t+\sum v(l)\Delta t+\sum v_{border}\Delta t \qquad (3)$$

where $N(t)$ is the population of evacuation that remained on the path which lead to the one exit at time t and $N(t-1)$ is the population of evacuation that lead to the one exit at time t-1; $v_{eva}\Delta t$ refers to during the time of the evacuation population under the evacuation velocity that come out of the exit which varies with $N(t)$ (v_{eva} variety tendency has expatiated in 3.2); $\sum v(l)\Delta t$ refers to during the time, total new increased population under the velocity that people flow into paths which connected directly with the exits, $v(l)$ varies with the path length and $N(t)$; $\sum v_{border}\Delta t$ refers to during the time, total new increased population under the velocity that people move from relative nodes which links the paths directly heads for the exits, v_{border} varies with $N(t)$ and its own v_{eva} in that distraction it belongs.

Simulation:

1. Initialize $N_0 = 0$

2. Propel function: $N(t)=N(t-1)-v_{eva}\Delta t+\sum v(l)\Delta t+\sum v_{border}\Delta t$ (3)

Parameters disposal:

(1) v_{eva}: for v_{eva} decrease when $N(t)$ increase, especial when $N(t)$ is large. v_{eva} will come to quite lower velocity which is the situation that population come into heavy congestion and move roughly, then the author uses conic to imitate this circumstances.

(2) $v(l)$: if we don't take building design into consideration, the path length is fixed and can't changed for improvement whether there is in trouble or not. Then it varies mild with $N(t)$. So the writer utilizes linear function for its description.

(3) v_{border}: the new increased population is equal to the population that evacuated out of the linking node which belongs to the exits of another district. $\sum v_{border}\Delta t=\sum v_{eva}\Delta t$ Besides the v_{eva}, it also varies with $N(t)$ tending opposite direction. Because when $N(t)$ is large, people can't evacuate from its exit node to the gateway district hence the writer also take advantage of linear function to simulate the impression that $N(t)$ gives to v_{border}.

The author takes the left exit in the middle belonged to the top left corner network of Fig. 4.1(b) as the evacuation district example which flow has been distributed in Fig.4.2 (in which show a more detailed network)and gains the simulation results that contain the figure 4.3 (a). From the figure we saw that at the beginning, there is none needed evacuation and people need move a distance before they get out, so the $N(t)$ increase before population come out of the exit. Afterwards $N(t)$ still increase hence people from the seat and linked nodes pouring into the path while v_{eva} decrease little with $N(t)$ grows. After a period of time, the population goes down and people move quickly, however this circumstances attract relative nodes evacuation population and near the end of the evacuation, a lower small peak shows on the figure from which it reflects that people go unstable and roughly.

The congestion degree is density of stream of people (DSP), since its figure is similar to that of $N(t)$, then the writer doesn't show it any more.

Figure 4.5 of v_{eva} curve is shown above and it proves that at first people pour on the pathway lead to v_{eva} decrease sharply but at the last of the period v_{eva} get back slow.

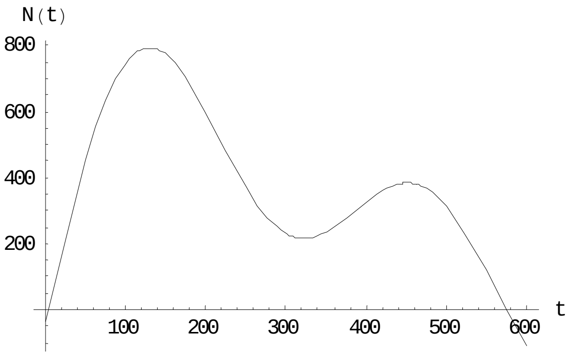
4.5 Change the Values of the Parameters for Improvement

From figure 4.3(a) we know that the max $N(t)$ in the evacuation is up close to 800, in other words, nearly 800 people have ever moved on the path at the same time, thus people won't feel comfortable that time. Consequently we need improve the condition in order to evacuate smoother.

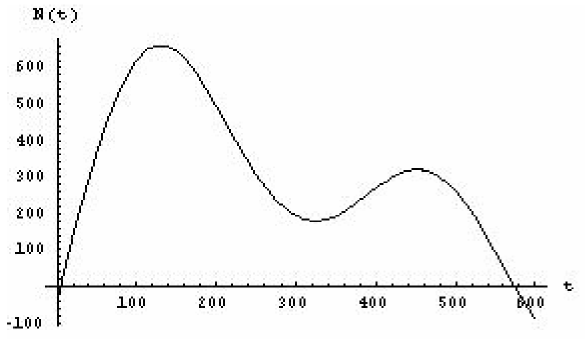
Management & improvement actions:

1.Decrease the flow

The direct method is to open the spare exits, so the total flow for distribution in Fig. 4.3(b) will go down, however the total exits is limited and this actions' effect prove restricted.



(a)



(b)

Figure 4.3 Compared Graphs of Population Remained when the Action 1 Adopted

From the compared graphs we can see that this management can change the extent of the figure.

2. Management mainly based on service

(1) v_{eva} inducement service: including digital notice board or notice sign and locale managing missionary introduction the stream of people. In general, not all people obey the message given by the notice board and sometimes some even inclined opposite behavior among whom we think people based certain probability obey the message given:

$$P_k^{rs} = P_r(C_k^{rs} \le C_l^{rs}), \forall l \ne k, \forall k, r, s$$
$$f_k^{rs} = q_{rs} \bullet P_k^{rs} \tag{4}$$

where C_k^{rs}, C_l^{rs} are vectors of path travel costs for O-D pair.

Then in equation (4), the distribution changes because of the probability changes.

Furthermore, service provided by missionary or volunteers contains that giving direction in order to diminish the intersect or making a detour behavior aimed for smooth walking, sending out the message that moving faster and taking order can obtain quick and ease evacuation, take it easy and do not crowd in case of congestion occurred.

(2) $v_{border} / v(l)$: service contains that encouraging people still in seats into evacuation goes well and prevent coming into the bottleneck lane and persuading them to stay when population grows on the evacuation lanes.

All the service mentioned can modified the parameter's values which cause the figure altered in order to make sure that people take order and move more comfortable in the evacuation meanwhile most prevent the congestion even chaos occurred.
After renew the parameter's setup together with providing the service and the management, the compared result figures are:

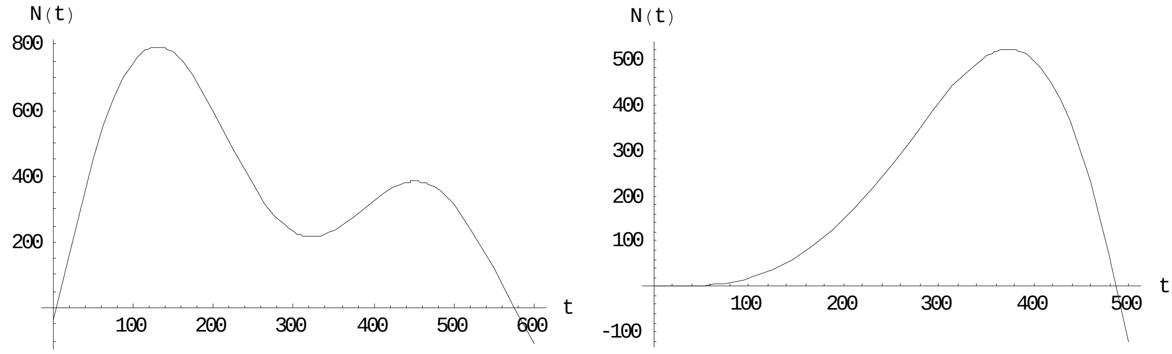


Figure 4.4 Compared Graphs of Population Remained when the Action 2 Adopted

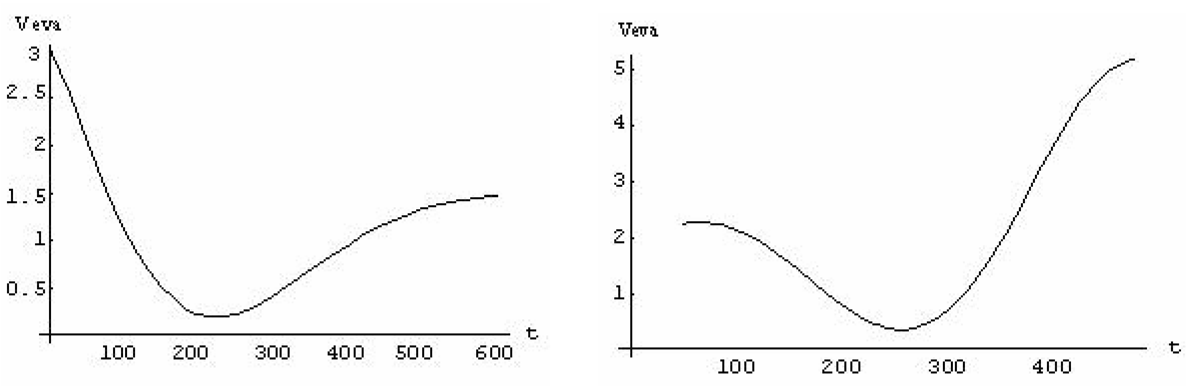


Figure 4.5 Compared Graphs of Moving Velocity when the Action 2 Adopted

From the compared graphs we can see that the wave crest in Fig. 4.4 disappeared and the velocity curve shift. Before the improvement the velocity went down sharply yet revived slowly, in contrast, after the management it went down slowly and got back quickly which indicates that people move more easily and stable. And the new results can well achieve the demand required in anterior section.

5. CONCLUSION

(1) The paper divides the inside building into two kinds of districts-fixed district and unfixed district, and then introduces improved max entropy model before it simulates the audiences' evacuation. With this pretreatment step, the results can perfectly overcome the disadvantages that stream of people may come into chaos based on the traditional model.
(2) Furthermore, the article overcomes the disadvantages that former evacuation's population was quite small at a hundred or so for a visualized reason, by contrast with several thousand population evacuated in the paper.

(3) Next, in addition to set up and solve the model, the article also obtains evacuation management and relative actions for improvement, which fill the blank of formed researches that no management and actions were adopted. That is to say, based the results given, handler may find out bottleneck of lanes and other else parts to strengthen. If he dissatisfies with the results, he can provide relative service or modify the number of the exits and locations. For the unready built up gyms, the governor can change lane-width to revise the design of the building judging by the simulation outcome. Once again using the simulation model mentioned to attain new results until he satisfies, finally the system sends out results and management scheme. When games begin, the supervisor may choose to simulate again to make some adjustment for a better smooth and comfortable evacuation.

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