

Evaluation of Urban Economic Resilience Under Different Earthquake Magnitudes——Based on Tsinghua Community

地震灾害下城市经济韧性评价研究——以清华园社区为研究对象

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0.Introduction

0.1.Tsinghua Community

In our research, Tsinghua Community is chosen as the objective. It is located in Haidian District, Beijing, and covers the campus of Tsinghua University. It consists mainly of students, faculty, and a small number of community members. The number of students in the campus at the end of 2018 (including undergraduate and graduate students) is 48,739, accounting for more than 70% of the community.

Tsinghua Community has a sound infrastructure system and a community organization structure. In addition to the prominent educational functions of the university, it shows considerable community representation in terms of urban functions such as study, work and life. For instance, the map below displayed several kind of service system including dining halls and banks in the community.

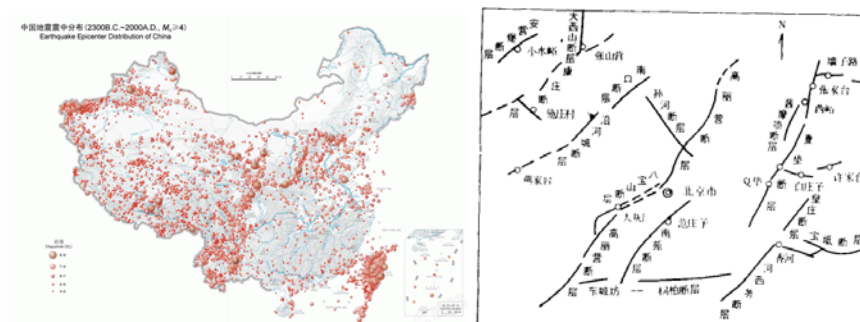
0.2.Challenge of Sustainability

0.2.1 Threat of Earthquake

We have been consulting and having discussion with Professor Wang Fei from Beijing Earthquake Agency and Doctor Wang Fei, Pan Shengjie from Department of Construction Management in September 23, and we have learnt that one of the

greatest threats on Beijing is earthquake. First of all, as the capital of China, Beijing is located in the seismic belt of the North China Plain. Since ancient times, there have been many records of earthquake. The largest earthquake recorded was the Sanhe-Pinggu earthquake in 1679. The magnitude was estimated to be 8. And Tangshan M7.8 earthquake in 1976 caused 242,000 deaths.

And the figure below illustrates faults across the city, some of which are still in active mode. It is necessary to notice that the threat of earthquake has always been a Sword of Damocles to communities in Beijing.



As one of the top institutions in China, Tsinghua University is a highly concentrated area of knowledge-based talents and state assets, for example national labs. Once a severe earthquake occurs, campus functions could not restore right away, which would cause significant losses to the study, work and life of faculties, students and national interests.

0.2.2 Community Resilience

Community resilience is defined as the community system's ability to resist, recover and evolve in response to disturbances. It has been an important reference for resource allocation in urban planning and emergency response.



- **韧性定义** 在灾害研究语境下，韧性指的是能够在灾害中存活并且将灾害影响及损失降到最小的能力。
- **韧性测量** 社区中特定系统的功能在灾害过程中随时间不断变化，范围在0-100%之间。根据Bruneau的定义，功能恢复曲线与横坐标围成的面积（以下简称面积）是韧性。考虑到不同条件下韧性基准不同，笔者将系统的韧性水平定义为预期功能（Anticipated Performance）恢复曲线的面积与目标功能（Desired Performance）恢复曲线的面积之比。

Resilience and Sustainability have been 2 important topics of urban development. Sustainability aims at the long-term development of cities and communities, while resilience focuses on relatively short-term performance before and after disasters. Hence, the resilient community provides a stable environment of development for the four pillars of sustainability, ensuring the continuity of community function over a long period of time so that disasters will not cause significant casualties and interruption of community development.

1.Scope

From the academic perspective, we want to evaluate economic resilience of economic unit under different magnitudes in Tsinghua community, and to provide support for the research of the partner Beijing Earthquake Agency.

From the community member perspective, we want to provide research basis for the preparation of community earthquake emergency plan, and to enhance the defensive and rescue capability of a community, and improve the Earthquake risk awareness of community members.

Our cooperative institution is Beijing Earthquake Agency. Our consultant expert is Fei Wang(王飞). Our consultant doctors are Shengjie Pan(潘胜杰), Fei Wang(汪飞), Quan Mao(茅权)

2. Implementation plan

To achieve our goals, we will do the following steps.

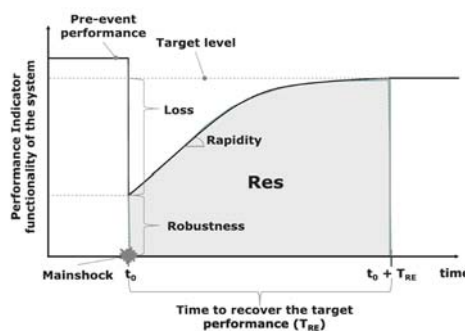
- Define economic unit and urban economic resilience

- b) Ask partners for materials and do investigation
- c) Calculation and modeling
- d) Feedback preliminary conclusions to partners and update
- e) Produce exhibits and related materials brought to Stanford

2.1 Define economic unit and urban economic resilience

Economic unit refers to the unit of management activity such as family, enterprise and company that organize production in certain way. Our research focuses on the canteen and the food processing plant in Tsinghua university.

Urban economic resilience, showed as the following picture. The three key points is the shock, recover and area ratio.



2.2 Ask partners for materials and do survey

2.2.1 Ask partners for materials

We have get some materials from our partners. Such as The acceptance report of Tsinghua community seismic safety resilience assessment demonstration project construction (phase I) (清华园街道地震安全韧性评估示范工程建设(一期)项目验收报告), and Buildings' resilience data and recovery time under different earthquake magnitudes.

We want to do survey to clarify the distribution of economic unit in Tsinghua university

2.2.2 Survey

2.2.2.1 Research Contents

According to the statement before, what we require in our modeling and analysis are the input and output of various economic units within the Tsinghua University, as well

as the relations between them. For the researching target we concentrate on the canteen issues, so we must figure out the economic data of both canteens and food processing plants. Then we should decide the damage condition of Tsinghua Buildings under the circumstances of different magnitude of earthquakes. The fluctuation in function and efficiency should also be assessed to build our economic resilience model.

To sum up the previous contents, a form will be given as the detailed research contents we should gain from the survey.

	Research Contents
1	The input and the output of different canteens and food processing plants. (If no definite number can be acquired, at least the ratio of different sections should be got)
2	The financial relation of various economic buildings, including the flow of the products.
3	The alternation in the flow of the input and output and the damage buildings suffered from after the earthquake.

In order to gain these essential contents, a particular survey methodology is significant.

2.2.2.2 Survey Methodology

The best information resource for canteen message is the Food Service Center within Tsinghua University, which accumulates the data of canteens' operation condition and records the purchase and sell. These detailed data can greatly accelerate our modeling process and accuracy. However, the Food Service Center is not compulsory to provide us with certain accounting statement, as commercial secrets may remain in the relevant information., making the survey a bit sensitive.

To solve this problem we may lay emphasis on the ratio rather than data. We may consult experts at the Food Service Center for estimation of the ratio, for instance about what percent of the output of food processing plant A is sent as the input of

canteen C. Our model is still complete with only the ratio, and the economic resilience standard can also be set. Furthermore, the canteen manager and staff can also be good interviewees. Eventually, we still have on-site investigation as a final method, which includes the estimation of the stream of people and average consumption method to decide the selling condition. However, the most direct and accurate information source is still the Food Service Center, and maybe professor's introduction letter may decide this point.

Survey methodology can be summarized as the following form.

	Research Contents	Survey Methodology
1	The input and the output of different canteens and food processing plants. (If no definite number can be acquired, at least the ratio of different sections should be got)	Consult the Food Service Center for purchase and sell. Interview canteen manager to further understand the situation. Estimate through on-site selling condition.
2	The financial relation of various economic buildings, including the flow of the products.	Inquire the Food Service Center managers about financial relations. Have access to the public knowledge of university canteens.
3	The alternation in the flow of the input and output and the damage buildings suffered from after the earthquake.	Assess the damage through the already developed city resilience model.

We also design a rational questionnaire to launch our survey to the Food Service Center. We will summarize our need and requirement in a good manner, trying our best to persuade the Food Service Center to send us the information we want.

清华大学经济韧性研究——食堂

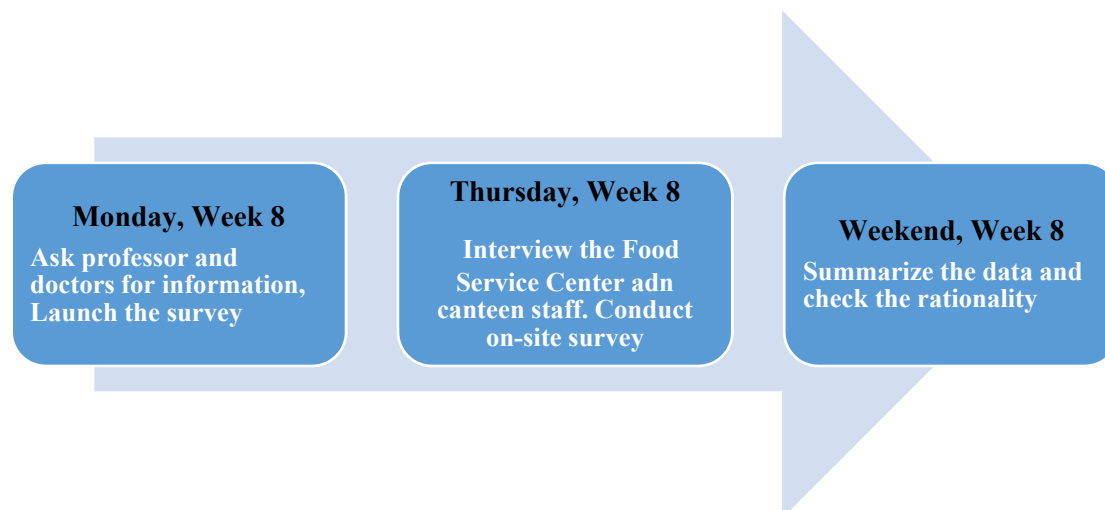
尊敬的负责人您好，我们是清华大学建管 6 班学生。现在我們正在进行一个关于校园经济韧性的调研研究，研究目的是探查在地震发生的情况下，清华大学的食堂和食品加工厂等经济建筑恢复的速度。为完成此研究我们需要了解一下清华大学内的食堂、食品加工厂一天的进货量和销售量，以及彼此之间的大概经济关系。

我們非常希望您能为我们的研究提供一些资料。如果您觉得不方便提供具体的数字，也可以根据经验提供大致的比例（例如 100 代表全校内流量最大，0 则完全没有流量）。十分感谢您的理解与支持！

		进货来源	大致进货量	送货/销售方	大致送货/销售量
食堂	紫荆				
	桃李				

2.2.2.3 Schedule Setting

To ensure that our whole process can be just on the trail, we set definite schedule to minimize the possible procrastination. We decide that all our tasks should be accomplished before the weekend of week 8. That’s why we design the following schedule to ensure our efficiency.



After the survey, the data and relations will be applied in our model. Then our analysis and suggestions can be given according to the results.

2.2.2.3 Survey Process

After the discussion, we consider the most appropriate place for us to conduct research and accumulate data is the Food Service Center, as it gathers detailed food supplement and distribution service information. What we are seeking is the ratio of food distribution from food processing plants to various canteens. With the phone contact in advance and introduction letter from professor, we successfully get the admission of interviewing.



The Food Service Center consists of several offices:

1. General Affairs Office
2. Operation and Management Office
3. Supervisory Office
4. Purchase and Supply Office
5. Device and facilities Management Office

	4	人事管理	2
	5	人事管理	1
	6	人事管理	2
	7	餐饮服务	2
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	99	餐饮服务	2
	100	餐饮服务	2

After brief discussion and consideration, we choose the General Affairs Office to start our interview. This is because the General Affairs Office has the operation system controlling the food supplement in Tsinghua University. We hold the belief that by gathering information from the General Affairs Office we can proceed our data.

Unfortunately, administrator was absent, we altered our plan to interviewing Purchase and Supply Office (or buying office and packing house). It's another place different from the Food Service Center and is responsible for buying and sending food. The place of it is on the opposite side of the Literature and Social Science Library. The Purchase and Supply Office consists of 60+ employees, the biggest department of Food Service Center. Food bought from outside of the campus are gathered and processed here, then departed to different canteens. It can be said that the Purchase and Supply Office is the pivot of the whole food system.

We are kindly welcomed by the manager and get the permission of interview. The possible data we get from the manager are the distribution amount of rice, wheat, meat, vegetable, etc. As a result, another problem emerges: which target can be the best research item for building our city economic resilience index. Our target is narrowed to five possible food: rice, wheat, beverage, meat and vegetable.

We eliminate beverage from the choices at once, for the simple reason that beverage is not necessity within the food system. What we want to decide is the recovery of system function after the strike of earthquake, that's why we prefer more essential food. For rice and wheat, we decide this as complex to decide to proportion of each staple food on the campus, as they are both widely supplied in each canteen. Eventually for vegetable, there are too many varieties to make a clear category. What we require is a kind of food that is both of great importance, of concrete data resource and can be easily analyzed. Meat is the only choice for us.

We interviewed the staff of the meat processing plant, getting complicated data of meat of chicken, beef and mutton. The data is especially suitable for our survey and the result is given in 2.3.4.1, *Investigation Result* part.

2.3. Calculation and modeling

2.3.1 Assumptions

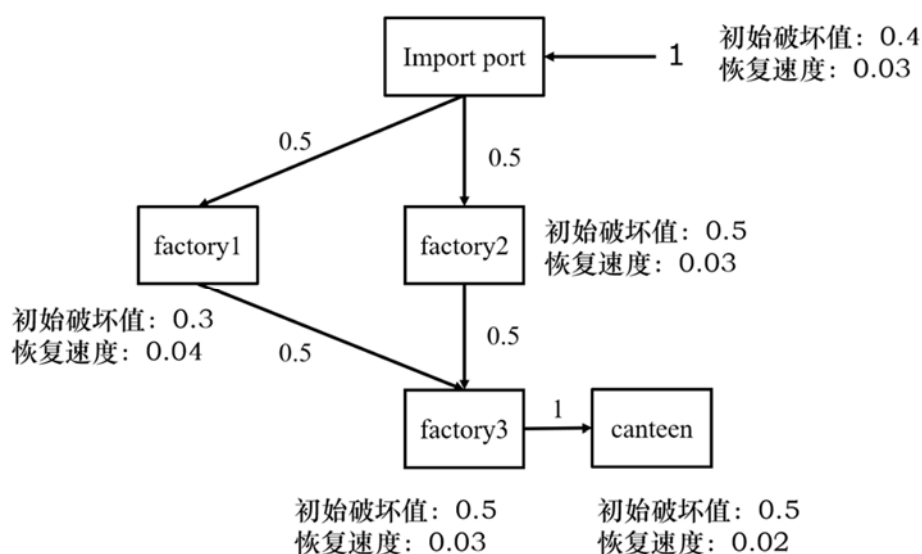
(1) Economic function change is equal to structure function change. We can acquire data which describe the change of building structure function from Beijing earthquake agency. Using the data to describe economic function change is common in the previous literature which studied urban economic resilience.

(2) Economic function recovery is linear. The assumption derives from building structure function recovery process since it is also included in the study of Beijing earthquake agency.

(3) The supply from outside remains the same. We think that Tsinghua community would get enough resource or supportive from outside after earthquake in a short time.

(4) The effect of conversion rate is not considered. It's hard to make clear about the conversion rate of every economic unit in a short study time.

2.3.2 Data



In order to get a better understanding about the calculation and modeling process, we give a simple example here. The main function of every economic unit as following:

(1) Import port: get all the resource from outside and allocate them to the next economic unit.

(2) Factory: process the food and ship the food to the next economic unit.

(3) Canteen: accept the food from the former economic unit and provide them to students.

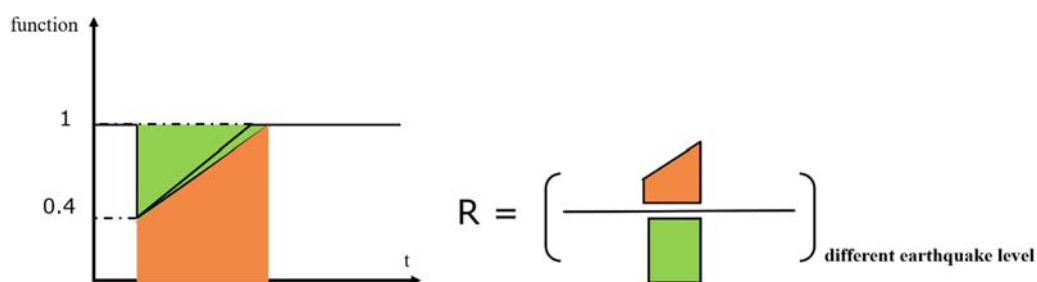
We also give the value of different attributes(initial destroyed value and recovery speed) of every economic unit and relationship(including allocation proportion) among them. Therefore, the data we need as following:

- (1) initial destroyed value
- (2) recovery speed
- (3) relationship among economic units
- (4) allocation proportion

2.3.3 Calculation

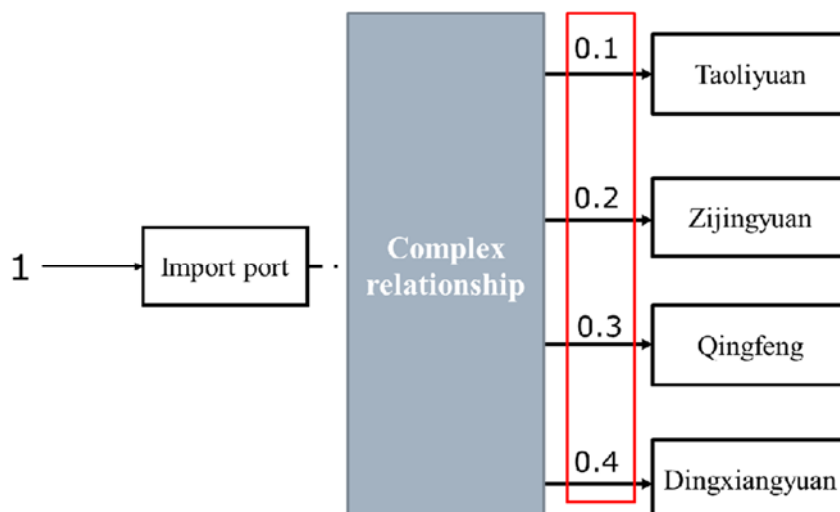
2.3.3.1 Calculate the economic resilience of canteens

For every economic unit, it will have undisturbed performance and supplier performance. The undisturbed performance is only influenced by recovery speed while supplier performance is influenced by supplier. Actually, what we need is actual performance which is equal to minimal value between undisturbed performance and supplier performance. For instance, the undisturbed performance is 40% but the supplier performance is 30%, so the actual performance is the smaller one, that is 30%.



As the picture shown, the actual performance is equal to the orange figure area. And the green figure area is the normal performance if there is no earthquake. Therefore, the economic resilience of canteens is as right picture shown.

2.3.3.2 Take advantage of allocation proportion as their weight to calculate the economic resilience of Tsinghua community.



The sum of allocation rate of canteens will be 1 if we consider the resource from outside is 1 and we do not consider the conversion rate. Therefore, the economic resilience of Tsinghua community is as the following formula shown.

$$R_{ThuC} = \sum_{i=1}^k (weight_i \times R_i)$$

2.3.4 Results

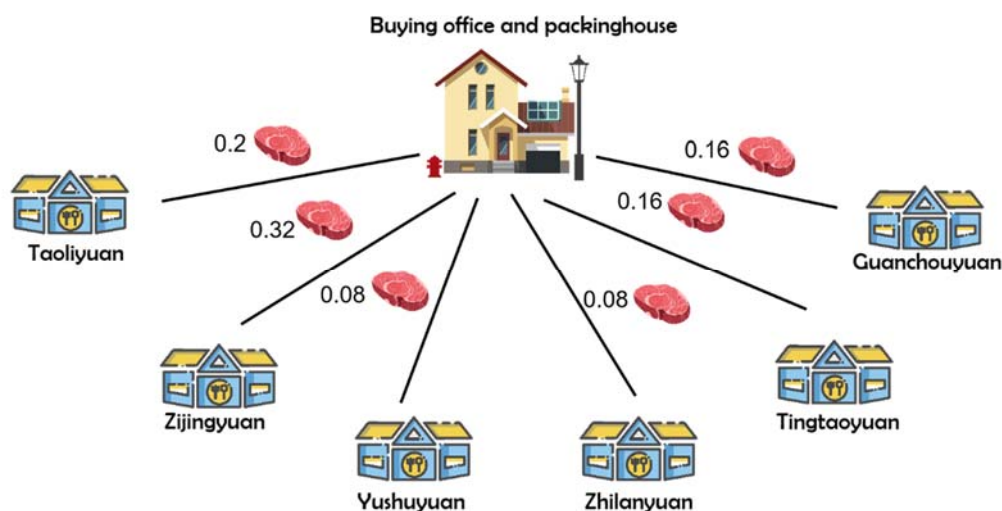
2.3.4.1 Investigation results

We investigated Tsinghua university food service center and found out that:

- (1) Buying office and packinghouse are in the same building. Its responsibility is to provide different canteens with different proportions of meat.
- (2) Supply rates of canteens are as following form.

Canteen	Supply rate
Taoliyuan	0.2
Zijingyuan	0.32
Zhilanyuan	0.08
Yushuyuan	0.08
Tingtaoyuan	0.16
Guanchouyuan	0.16

- (3) Relationships among them are as following picture:



2.3.4.2 Calculation results

With the system dynamics tool in netlogo, we can simulate the situation with different peak accelerations. The results are as follows:

Canteens	Weight	0.2g	0.3g	0.4g
Taoliyuan	0.20	94.57	87.89	80.53
Zijingyuan	0.32	85.13	82.28	68.15
Zhilanyuan	0.08	94.40	86.70	82.55
Yushuyuan	0.08	94.40	86.70	82.55
Tingtaoyuan	0.16	78.93	78.87	78.87
Guanchouyuan	0.16	90.00	78.75	78.75
Economic resilience	-	88.29	83.00	76.34

We can see that economic resilience declines with the increase of peak accelerations.

2.4 Feedback preliminary conclusions to partners and update

To have a good communication with our partner and to be better understood, after we finish our model, we will feedback preliminary conclusions to partners and update our model.

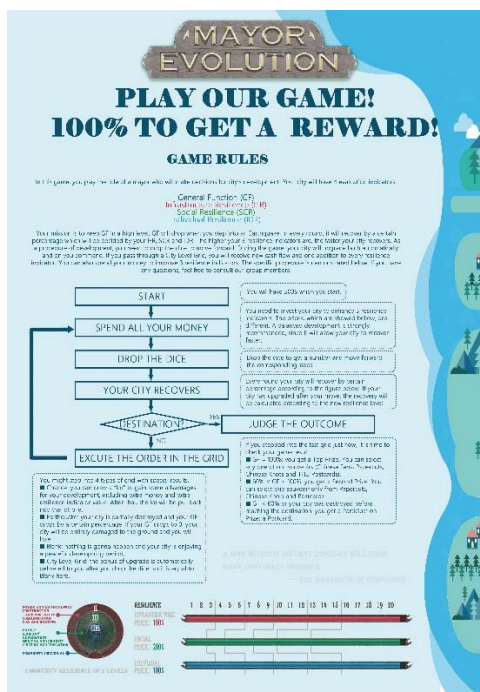
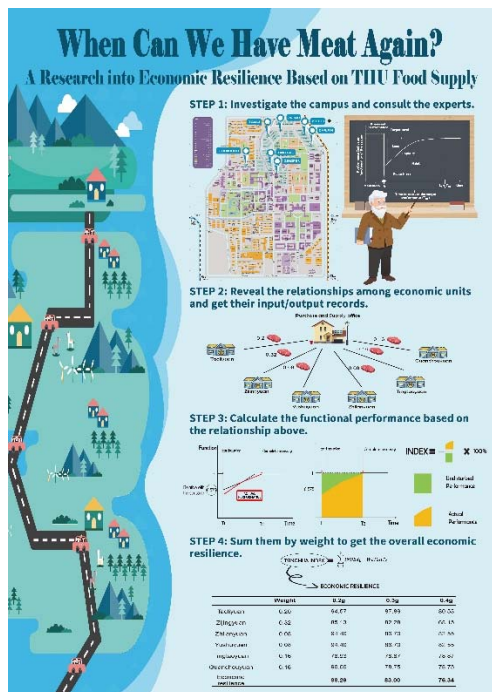
2.5 Produce exhibits and related materials brought to Stanford

In order to make our participation in the Expo, plans have been made including the design of display materials and an interactive game. It is our hope to make people understand our research more easily through some display staffs. They can meanwhile decorate our expo booth. And with an interactive game, we expect to attract people to gather and keep them staying longer around our site.

2.5.1 Display materials

2.5.1.1 2 Posters

With the intention to better illustrate our research to the participants of Expo, we have finished designing 2 A2 posters. The first is to give a thorough introduction to our research process while the other is a detailed explanation to our interactive game.



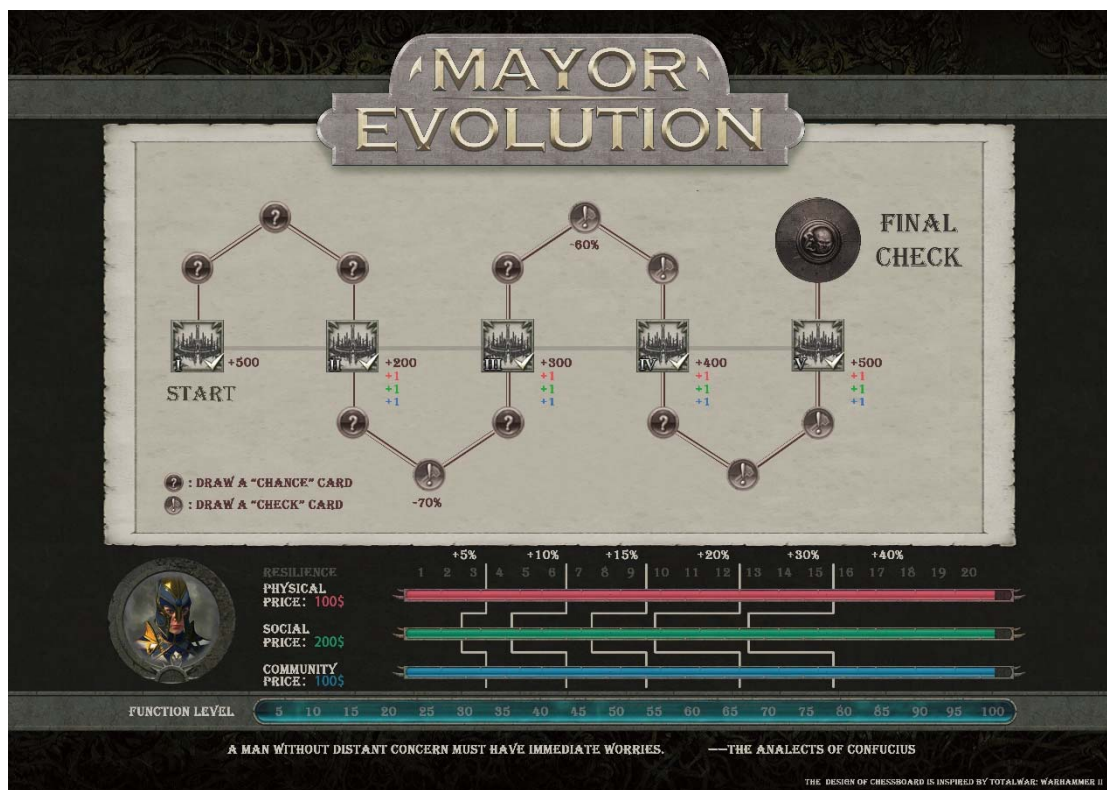
2.5.1.2 A video to present game rules

In order to make others quickly understand our game, we made a brief video to thoroughly illustrate the procedure of our game. Within it, we displayed all the game elements and possible choices for the potential participants.

2.5.2 Interactive Games

2.5.2.1 A full-sized chess board

We have designed a board game called “Mayor: Evolution”, which is similar with Monopoly, though less time-consuming. The aim of players is to upgrade their city, earn and spend money to develop its resilience and survive earthquakes. Initially we imagined a game played on a table and we even designed a board for it.



But later we pursued a more interactive formation. This was when we decided to transform our chess board into a larger size. We designed 36 30*30cm grids to replace the board above, which means that players can actually step onto them and play longer. We even designed our faked cash.



In this game, you play the role of a mayor who will make decisions for city’s development. Your city will have 4 evaluation indicators:

- General Function (GF)
- Infrastructure Resilience (IFR)
- Social Resilience (SCR)
- Individual Resilience (IDR)

Your mission is to keep GF in a high level. GF will drop when you step into an Earthquake. In every round, it will recover by a certain percentage which will be decided by your IFR, SCR and IDR. The higher your 3 resilience indicators are, the faster your city recovers. As a procedure of development, you need to drop the dice to move forward. During the game, your city will upgrade both automatically and on your command. If you pass through a City Level Grid, you will receive new cash flow and one addition to every resilience indicator. You can also spend your money to improve 3 resilience indicators. The specific procedure is demonstrated below.

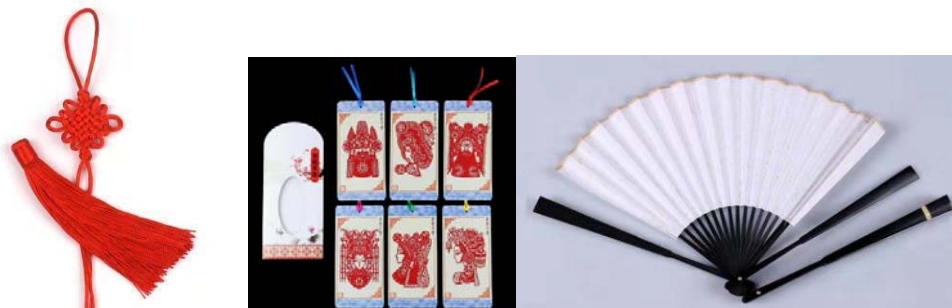
NO	Action	Detailed information
1	Start	You will have 500\$ when you start.
2	Spend all your money	You need to invest your city to enhance 3 resilience indicators. The prices, which are showed bellow, are different. A balanced development is strongly recomanded, since it will allow your city to recover faster.
3	Drop the dice	Drop the dice to get a number and move forward the corresponding steps.
4	Your city recovers	Every round your city will recover by certain percentage according to the figure below. If your city has upgraded after your move, the recovery will be calculated according to the new resilience level.
5	Are you at the destination?	Y: forward to step 6; N: forward to step 7
6	Judge the outcome	<p>If you stepped into the last grid just now, it is time to check your game result.</p> <ul style="list-style-type: none"> ■ GF = 100%: you get a Top Prize. You can select any one of our souvenirs (Chinese Fans, Papercuts, Chinese Knots and THU Postcards). ■ $60\% \leq GF < 100\%$: you get a Second Prize.

		<p>You can select one souvenir only from Papercuts, Chinese Knots and Postcards.</p> <ul style="list-style-type: none"> ■ GF < 60% or your city was destroyed before reaching the destination: you get a Participation Prize: a Postcard.
7	Execute the order in the grid	<p>You might step into 4 types of grid with special results.</p> <ul style="list-style-type: none"> ■ Chance: you can draw a “lot” to gain some advantages for your development, including extra money and extra resilience indicator value. After that, the lot will be put back into the lot pile. ■ Earthquake: your city is partially destroyed and your GF drops by a certain percentage. If your GF drops to 0, your city will be entirely damaged to the ground and you will lose. ■ Blank: nothing is gonna happen and your city is enjoying a peaceful developing period. ■ City Level Grid: the bonus of upgrade is automatically delivered to you after you drop the dice, so it is equal to Blank here. <p>After finishing the execution above, forward to step 2.</p>

2.5.2.2 Souvenirs

To encourage more people to participate, we planned to take some souvenirs to Expo. And to make our game more exciting and challenging along with to attract more participants, we ordered 3 levels of souvenirs. The finest level is Chinese Fans, which will be delivered to those who win the first prize in the game. The second level is

Chinese knots and paper cuts which will be granted to winners of second prize. And the paper cuts are third level which will be given to those who played the game without winning.



3. Contributions

Enhance the defensive and rescue capability of a community. Through the construction of emergency command system, the construction of rescue forces, scientific and reasonable reserve of emergency materials and so on to enhance the community's defense and rescue capabilities.

Arouse earthquake risk awareness. Through the publicity and education of earthquake prevention and disaster reduction, emergency drill, earthquake risk source identification and disaster assessment to arouse the government and the public's awareness of earthquake risk prevention.

4. Plans

	Content(工作内容)	Outcome(产出)
Week7	Planning	PPT
Week8	1. Get material from our partners 2. Investigate relative economic unit (Catering service center, canteen)	Model parameter
Week9	Calculation and modeling	Model and result
Week10	1. Feedback preliminary conclusions to partners and update 2. Start to design our exhibits	1. PPT 2. Meeting with our partners

Week11	1.Continue to produce our exhibits 2.Continue to update our model	1.Exhibits 2.Updated model
Week12	Refine the model and report to community partners	PPT
Week13	Time for Stanford	Exhibits