Flood damage in Bangkok

Disaster or an opportunity for creative destruction

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Abstract

We attempt to evaluate the paths to recovery following the devastating floods in 2011 in Thailand, which submerged a large part of the country for five months and severely damaged the infrastructures and the economy. We use system dynamic to simulate the impact of flood and test the performance of post-flood recovery effort. Since most of Thailand's economic activities are located in the capital, we set the boundary of our study to Bangkok metropolitan area. We build on Saeed's model of Schumpeter's concept of creative destruction, which he has posited as fore-runner to Forrester's Urban Dynamics model (Saeed 2010). We extend Saeed model to subsume the infrastructure aging chains and land constraints of the Urban Dynamics model. We also added to the model mechanisms for taxation and service provision as on ground in Bangkok. We study the damage recovery policies implemented by Thai government as well as those alluded to in Urban Dynamics. We find that encouraging new investment and reducing cost of capital help recovery to some degree. These policies paired with increasing demolition of old infrastructure seem to facilitate the recovery process.

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Introduction

The Merriam-Webster's dictionary defines "disaster" as something that happens suddenly and causes much suffering or loss to many people. The causes of disaster are recognized in two types: natural disaster and man-made disaster. While man-made disasters usually affect a small number of people, natural disasters such as flood, drought, and tsunami can be in a much larger scale. Regardless, disaster leads to vast loss of life and property. Furthermore, it affects people's mental, physical, and social well-being.

Flood is one of the most common and costly disasters affecting human race throughout the history. It occurs when water overflows the land. Conditions that cause flood include precipitation, rise of sea level, and dam failure (Nelson, 2013). The effects of flood can be devastating: loss of lives, infrastructures damages, insufficient water and food supplies, diseases, and species extinction. In long term, flood also affects mental health and the economy.

Our project begins with an idea to simulate the impact of 2011 flood to Thai economy and find effective policies to fasten the recovery. Since system dynamics is an effective tool for policy analysis and design in various fields, we decide to use system dynamics to create a model of Thai economy and analyze alleviation policies.

Synopsis of flood in Thailand

In 2011, one of the biggest floods in Thailand's history occurred. The flood was caused by the Noktane Cyclone, which approached Thailand from the Northeast then move to the South. This caused extremely heavy rainfall as well as tidal waves that flowed into the densely populated urban/industrial areas. The flood last for 175 days, from 25 July 2011-16 January 2011. More than three quarters of the country was affected and approximately 6 million hectors of land came under water. In terms of population, 4 million families (13.5 million people) were affected and about ten thousand houses were destroyed or damaged. (Thaiwater, 2011)

Not only the flood caused damaged to people and infrastructure, it also greatly impact Thai economy. The World Bank approximated that more than 500 billion dollars was lost. According to fiscal policy office, the growth of GDP in 2011 had drop from 4.52 percent to 2.71 percent. This is because the major industries – producing cars, electronics, and hard drive – were heavily damaged. In addition, Bangkok – the capital of Thailand – was flooded. This caused a serious break in commerce and production of all types.

For 4 months, the water level in Bangkok was over a meter high, confining most families to their houses. Boats became the primary means of transportation. All activities in Bangkok stopped. After the floodwater receded, a large proportion of the infrastructures remained damaged and unusable for an extended period of time.

Bank of Thailand predicted that the economy will return to normal within 4 months. It has been almost 2 years after the flood, however, the economy had not yet returned to normal. In addition, there has been little restoration of damaged infrastructures due to poor planning and ineffective action on part of the government.

Boundary

Our project focuses on studying the impact of flood on the economy by combining the models that were developed by Saeed (2010) and Forrester (1969). We simulate the flooding in the model by disturbing the equilibrium and implement policies to study the alleviation of the economic damage created by floods. These alleviation policies are not only current policies implemented by Thai government but also those we explored. Although the 2011 flood impacted several provinces in Thailand, we scope the area of our study within Bangkok and its surrounding provinces since they are the center of Thailand's economic activities. In addition, most infrastructures and businesses that were destroyed during the flood are located in this area. Our model will focus on the impact of flood on the economy. Other factors that may affect the economy of Thailand during our research such as political policies, corruption, and recession in Europe are outside of the scope of our study.

Literature Review

Previous Work

Although it has been almost 2 years after the 2011 flood, only a small amount of research has been published. The published research was mostly done by the Bank of Thailand. Bank of Thailand used econometric, a traditional economic modeling method, to evaluate the impact of flood to the economy and predict the alleviation.

The result shows that 16.7 billion dollars was lost because of the flood. This is approximately 2.3 percent decrease in GDP. Of the 16.7 billion dollars lost: 69.2 percent was industry sector's, 24.3 percent was service sector's, and 6.6 percent was agricultural sector's (Chantapong, 2012). The industry sector was most heavily impacted because the flood had hit 7 major industry districts, which is approximately 17 percent of Thailand's industries (Bank of Thailand, 2012).

Regarding the workforce, since 7 major industry sectors and Bangkok (the capital) were flooded, 7.3 million workers were affected (Chantapong, 2012). This is approximately one fifth of Thailand's workers. Nevertheless, Bank of Thailand predicted that most of the employers will not layoff their employees in order to resume production when the factories are restored.

Bank of Thailand estimated that the economy will be back to normal by the 2nd quarter of 2012 as shown in Figure 1. However, this has proven to be inaccurate since the economy has not been fully restored by early 2013, the time this paper is written. This is because Bank of Thailand did not take into account of the destruction of capital infrastructures, which is a permanent decrease in production capacity.

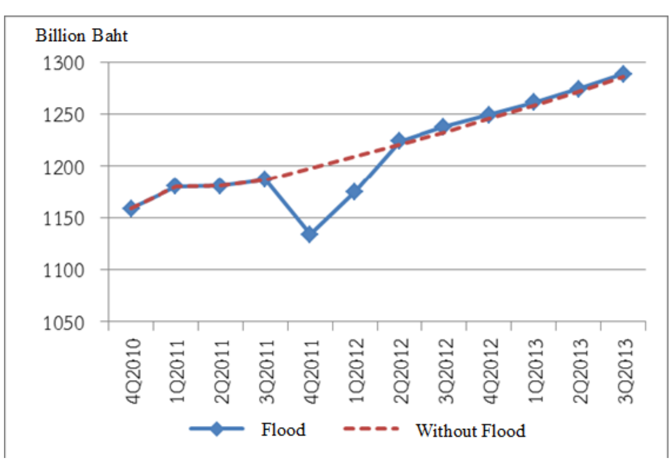

Figure 1: The effect of flood on Thailand's GDP (Suracht, 2011)

By using system dynamic, our work will take into account of how the permanent damages caused by flood have affected the economy. We will build upon Forrester's urban Dynamic model and Schumpeter's idea of Creative Destruction, which is created into a system dynamic model in Saeed (2010).

Forrester

Jay Wright Forrester, known as the founder of System Dynamics, has published a book called Urban Dynamics in 1969. The book represents a system dynamic model of urban structure. Forrester explained that the model is a theory of urban structures and internal relationships.

Forrester's model consists of third-order aging structure of industry, third-order aging structure of housing units, and three classes of workforces. The model covers several factors which represents relationship between those structures such as job constraint, land constraint, taxation, and how they affect the workforce growth and the aging processes of industry and housing. Forrester's simulation starts with an empty land area and reaches the equilibrium point by the generation the flows. Forrester explains in his book that the growth process would lead to a new equilibrium.

In the later chapter of the book, Forrester has used his model to simulate the result of applying policies in his virtual urban area. The simulation shows that any improvement policies applied to the model will not be effective as intended unless combined with policy to destroy old business or housing structures (which Forrester called "Slum-Clearance").

Schumpeter

Joseph Schumpeter, one of the most influential economists of the 20th century, explained the concept of "Creative Destruction" in one of his books called *"Capitalism, Socialism and Democracy."* Contrary to Karl Marx who viewed class struggle as responsible for moving history, Schumpeter viewed entrepreneur as the agent provocateur of capitalism who created new products, opened new markets, promoted new capitals, and destroyed old ones in the process (Lipartito, 2008).

Schumpeter said that the growth of capitalism is inevitable due to the process of Creative Destruction – the endless process in industry by which innovative mechanical products replace outdated one. The instability of capitalist process is not merely due to the fact that the economic life goes on in the social or natural changes such as semi-automatic growth in workforces and capital, the unpredictability of monetary systems, wars, revolutions, and so on. These changes only condition industrial change. However, the fundamental impulse that drives capitalism comes from the constant creation of entrepreneurs who produce: new consumers' goods, new methods of production, new method of transportation, new markets, and new forms of industrial organization (Schumpeter, 1942).

Saeed

Schumpeter idea of creative destruction was modeled by Saeed (2010) using system dynamic. His model illustrates mobility between classes of workforces – meaning labor and unemployed can become potential entrepreneurs. These entrepreneurs will create investments that increase the amount of capital. In his model, technology and saving are the implicit factors that determine the amount of investment.

Saeed also posited that there are similarities between Schumpeter's theory and Forrester's Urban Dynamic. They both model a mature economic system. In addition, these models suggest that, in order to transform the economy from stagnation into high welfare homeostasis, not only formation of new capitals but demolition of old capitals is also needed. This is a process Schumpeter called "Creative Destruction" and Forrester called "Slum Clearance."

Methodology

Since Saeed (2010) saw the link between Forrester's Urban Dynamics and Schumpeter's concept of creative destruction, we decided to extend Saeed's model of Schumpeter's Creative Destruction to subsume in it the aging chains representing infrastructure in Forrester's Urban Dynamics model. We believe that the model resulting from this extension will best represent Bangkok, which is our system of interest.

We built on Saeed's model by extending his capital sector into third-order aging capital structure: new capitals, mature capitals, and old capitals – like Forrester's. In addition, we implement Urban Dynamics' land constraint to limit the growth of capitals. We also create a mechanism for workforce to grow – based on number of jobs available. Finally, we added a service sector into the model. We use service to represent the infrastructures provided by the government. These services are funded by taxation from workforce and industry.

We adjust several parameters in the model in order to set the model to equilibrium. We disturbed the equilibrium by destroying a large fraction of the infrastructure, simulating the impact of floods. We then simulated the interventions made by the government to mitigate the impact of floods. Finally, we explored policies that would change of the model's behavior for better.

The policies we tested are from two main sources. First, we used the policies which have been tried by the Thai government. Second, we used the policies which have been proposed in the literatures such as Urban Dynamics.

Model

We will begin this section by describing the overview of our model. Later, we will explain the details of model structure in each sector.

Model overview

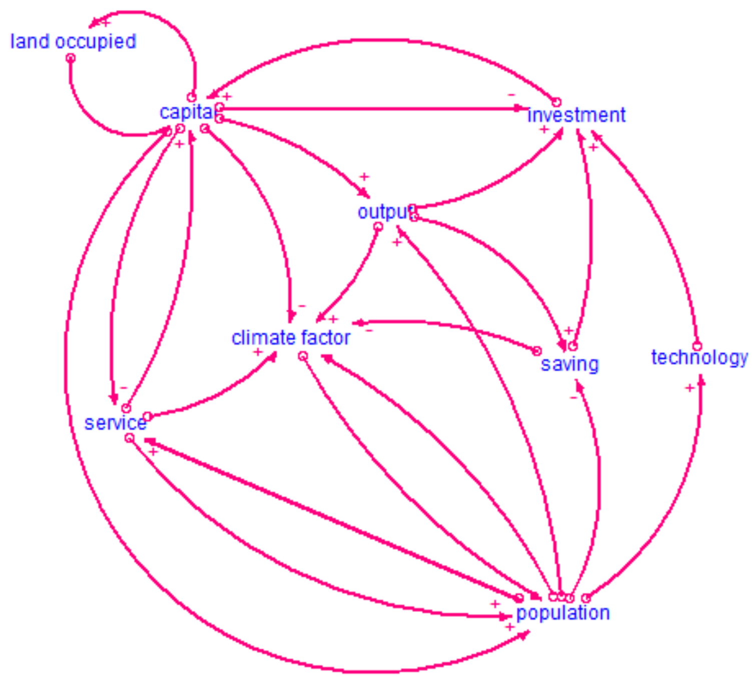

Figure 2: Logical Model

Our model consists of: population sector, climate factor sector, service sector, technology sector, saving sector, investment sector, capital sector, output sector, and land sector. These sectors are interconnected, creating feedback loops as shown in Figure 2.

In this model, the capital infrastructures are constructed by investment of entrepreneurs. Services provided by the government also encourage entrepreneur to construct more capital. However, the growth of the capital is limited by land constraint. As the capital increases, more jobs will be available. The job availability and service provided by the government will then attract more immigrants to the city.

We assume that the government spends tax to service capital more than population. As a result, capital will generate more service demand than service supply; therefore, decreases service ratio. On the contrary, more population will create more service supply than service demand; therefore increases service ratio.

Population Sector

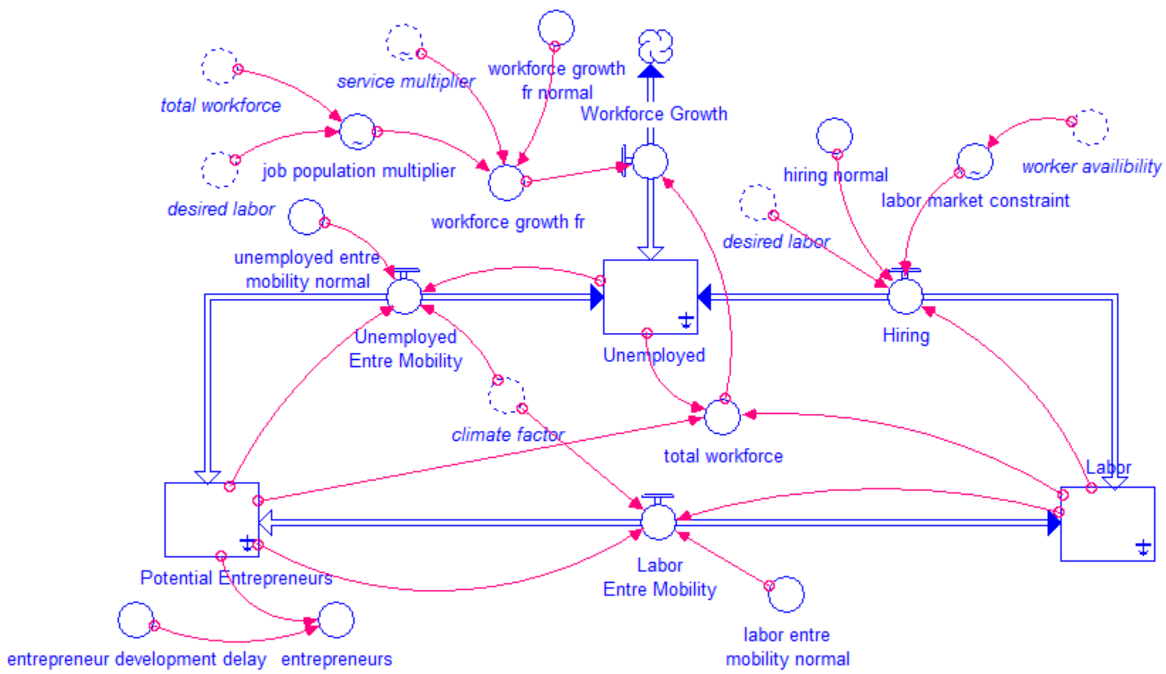

Figure 3: Population Sector

The population sector consists of three stocks representing three types of workforce: Potential Entrepreneurs, Labor, and Unemployed. These three types of population can freely change their status when there are shifts in the economy. The change process is represented by the following flows: Labor Entre Mobility, Unemployed Entre Mobility, and Hiring.

Labor and Unemployed can move to Potential Entrepreneurs if the climate factor is high while the number of current Potential Entrepreneurs is low. On the other hand, Unemployed will become Labor if the Desired Labor is high, current Labor is low, and Labor Market Constraint is high. As Worker Availability increases the Labor Market Constraint increases at a declining rate (Saeed, 2010).

In this model, new workforce – by birth or immigration – is assumed to be unemployed. The growth of the workforce is represented in the Workforce Growth flow, which depends on the Job Population Multiplier.

The Job Population Multiplier is a function of Total Workforce and Desired Labor. At 1, the Job Population Multiplier is at equilibrium. Before equilibrium, there is low need of labor (low Desired Labor compared to Total Workforce); therefore, the multiplier increases at a declining rate. After equilibrium, there is a high demand for labor; therefore, the multiplier increases at an exponential rate.

Climate Factor Sector

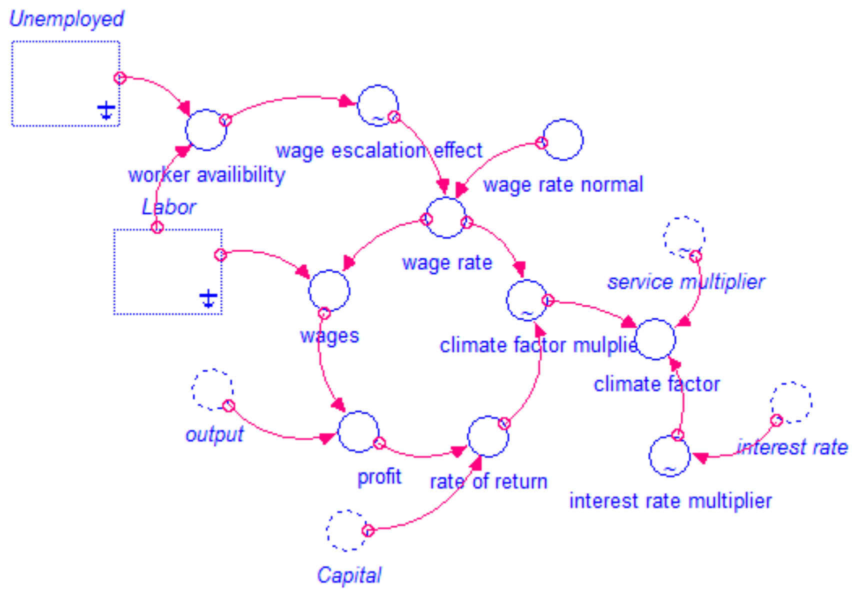

Figure 4: Climate Factor Sector

The Climate Factor can be defined as the environment that encourages entrepreneurial activity. It is the product of Interest Rate Multiplier, Climate Factor Multiplier, and Service Multiplier.

In this section, we will explain how the Interest Rate Multiplier and Climate Factor Multiplier are calculated while the calculation of Service Multiplier will be explained in the service sector.

Interest Rate Multiplier:

The Interest Rate Multiplier is a reverse s-curve function of Interest Rate. It shows that as the interest rate decreases, entrepreneurs will be less likely to invest (high interest rate multiplier).

Climate Factor Multiplier:

In order to define climate factor multiplier, we first need to know that Worker Availability is defined by Unemployed divided by Labor. In addition, Worker Availability is also directly related Wage Escalation Effect. As the Worker Availability declines, the Wage Escalation Effect decline with a declining rate (Saeed, 2010).

Wage Escalation Effect is positively correlated with Wage Rate. By multiplying Wage Rate by Labor, we can then determine the Wages. Respectively, Profit can be calculated by subtracting Output from Wages. Finally, dividing Profit by Capital will yield the Rate of Return.

Knowing all the contributed factors, Climate Factor Multiplier can be defined as an s-curve function of Wage Rate and Rate of Return (Saeed, 2010).

Service Sector

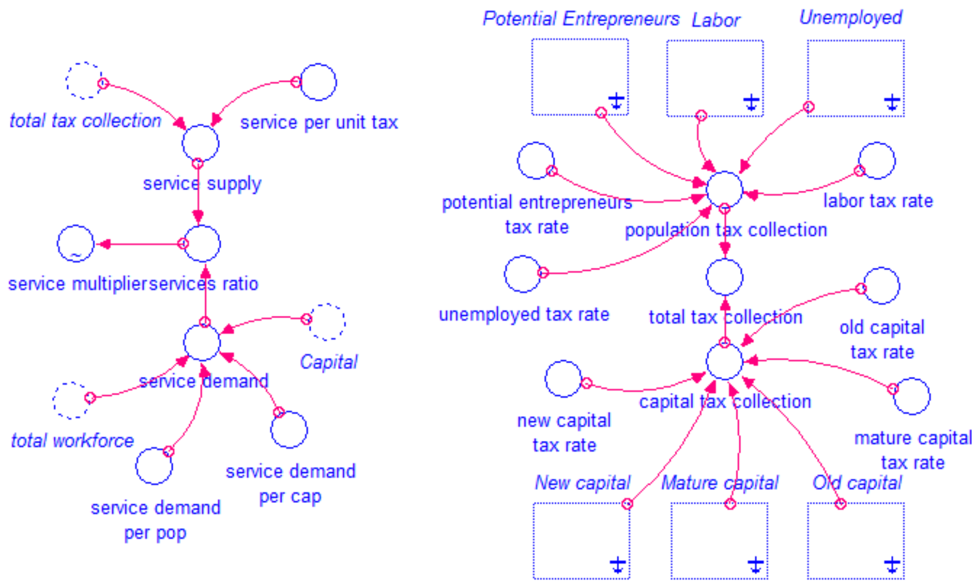

Figure 5: Service Sector

In our model, the service sector represents services provided by the government. The government finances service supply by taxing from its citizens and capital. The Population Tax Collection consists of taxes collected from Potential Entrepreneurs, Labor, and Unemployed. Since progressive tax is assumed, potential entrepreneur is taxed twice as labor's while unemployed is not taxed due to the lack of income. The Capital Tax Collection consists of taxes collected from New Capital, Mature Capital, and Old Capital. Since new capital earns more profit than the old one, the newer capital is taxed more than the older one. Note that, based on Thailand's tax system; we assume that the government collects tax from people more than capital.

On the other hand, population and businesses in the city desire for better services to improve their living conditions. In this model, Service Demand is defined as the sum of the demand from both capital sector and population sector.

We use Service Supply and Service Demand to calculate the Service Ratio and Service Multiplier. We defined Service Ratio as the ratio of Service Supply to Service Demand. The Service Ratio value less than one means there is an excess of Service Demand with respect to Service Supply and vice versa.

The Service Multiplier is positively associated with the Service Ratio. The Service Multiplier reflects the living condition of people and the economic situation of capital in the city. A high Service Multiplier will create incentive for people to move into the city, to become entrepreneurs, and to construct more capital infrastructures.

Technology Sector

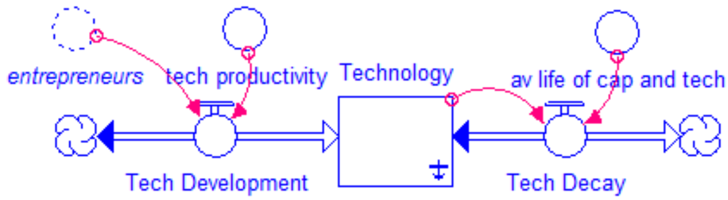

Figure 6: Technology Sector

The technology sector consists of Technology stock and two flows – inflow and outflow. The inflow is called Tech Development while the outflow is called Tech Decay.

The higher the number of Entrepreneurs and Technological Productivities, the higher the Technological Development will be. On the other hand, Technology will decay at a higher rate if its Average Life is low and vice versa.

Saving Sector

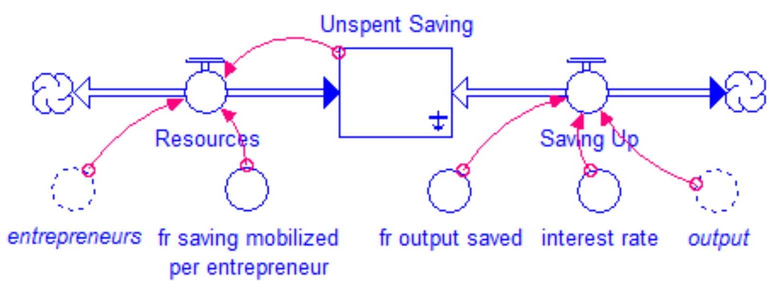

Figure 7: Technology Sector

The saving sector consists of Unspent Saving stock, inflow, and outflow. The Saving Up inflow is a function of Output, Fr Output Saved, and Interest Rate. It represents the rate which capital is being accumulated. More money will be saved when the interest rate is high.

The Resources outflow is a function of Entrepreneurs, Fr Saving Mobilized per Entrepreneur, and Unspent Saving. It represents the rate which capital is used for investment. More entrepreneurs and current capital will contribute to higher investment.

Investment Sector

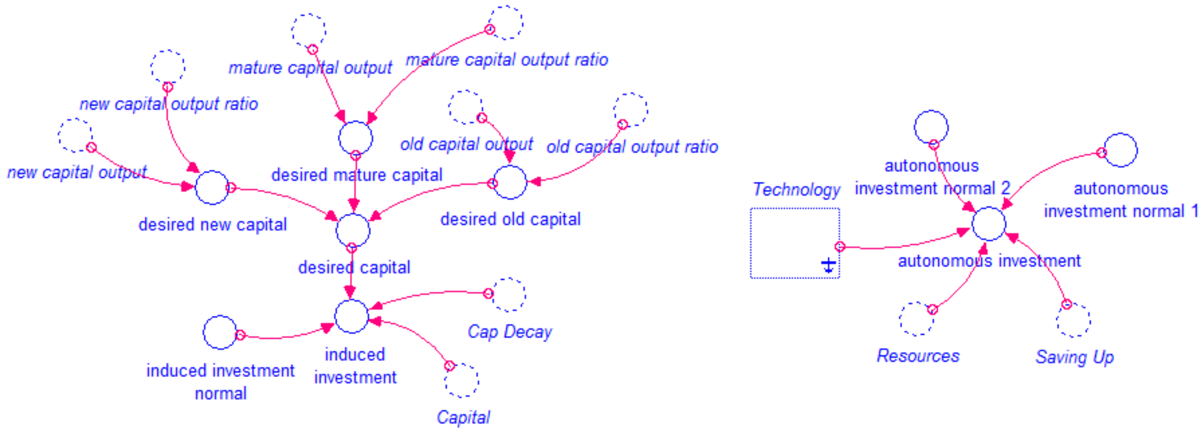

Figure 8: Investment Sector

There are two kinds of investment which generates the inflow of new capital: Induced Investment and Autonomous Investment. The Induced Investment depends on the difference between the amount of supply (actual) and the demand (Desired Capital) (Saeed, 2010). On the other hand, Autonomous Investment is the investment from resources and technology created by entrepreneurs. (Saeed, 2010)

Capital Sector

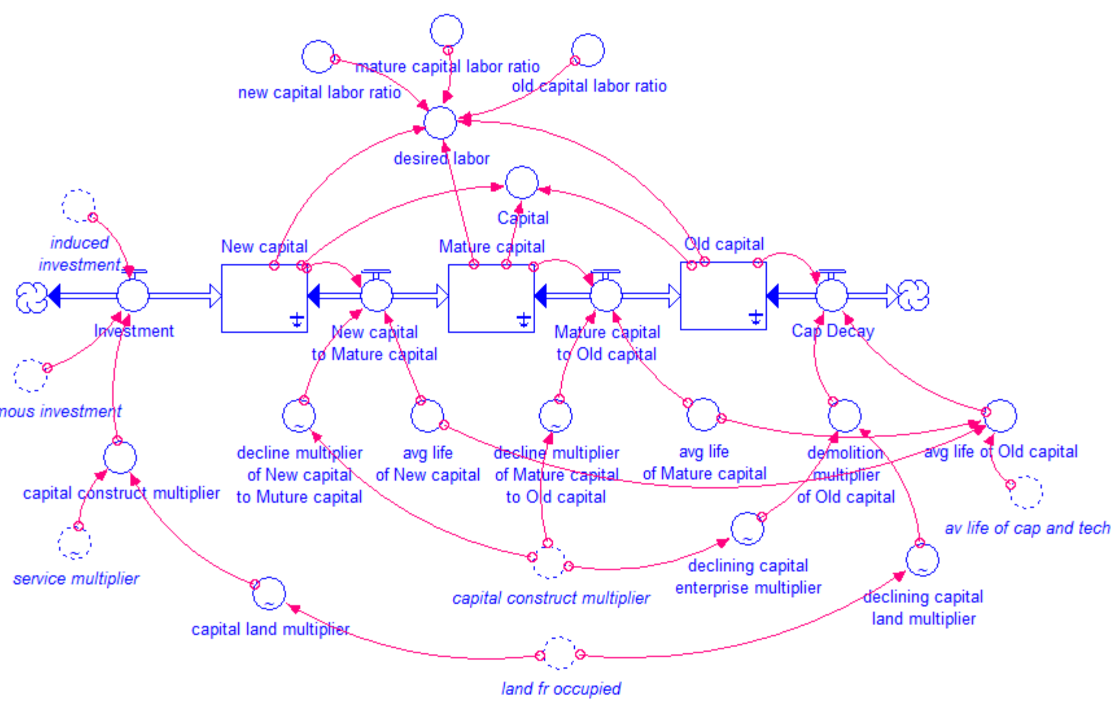

Figure 9: Capital Sector

The capital sector shows a third-order aging structure of capital infrastructures. When capital infrastructure is constructed, it is considered New Capital. In time, it becomes Mature Capital, and then Old Capital respectively.

Investment, an inflow of New Capital, is the product of Capital Construct Multiplier and the sum of Induced Investment and Autonomous Investment. Capital Construct Multiplier is the facilitation for a new capital to be constructed. As the multiplier goes up, the more capital can be constructed within the same amount of investment. As the multiplier decreases, spending the same amount of investment can construct less new capital (Saeed 2010).

Capital Construct Multiplier depends on two factors: Land Fraction Occupied and Service Multiplier. When Land Fraction Occupied is very low, the area has not yet been developed. As Land Fraction Occupied increases, the area has been more developed, which makes the construction of new capital infrastructures easier to be done. When Land Fraction Occupied reaches 0.4, the land becomes rare and more expensive, therefore discourages investor to buy more land and construct new capital. (Alfeld, 1976)

A high Service Multiplier means the government will support and help entrepreneurs to construct new capital infrastructures. On the contrary, the low Service Multiplier means that the government barely supports entrepreneurs. (Forrester, 1979)

According to Urban Dynamics' model, the ratio of average lifetime of each kind of capitals is approximately 2:3:5. In this model, the New Capital's lifetime is 2 years; therefore, the lifetime of Mature Capital and Old Capital will be 3 years and 5 years respectively.

The Average Lifetime is used to calculate the outflow. The normal outflow rate of each capital is calculated by dividing the total amount of each capital by the average lifetime of that capital (Forrester, 1979).

Output Sector

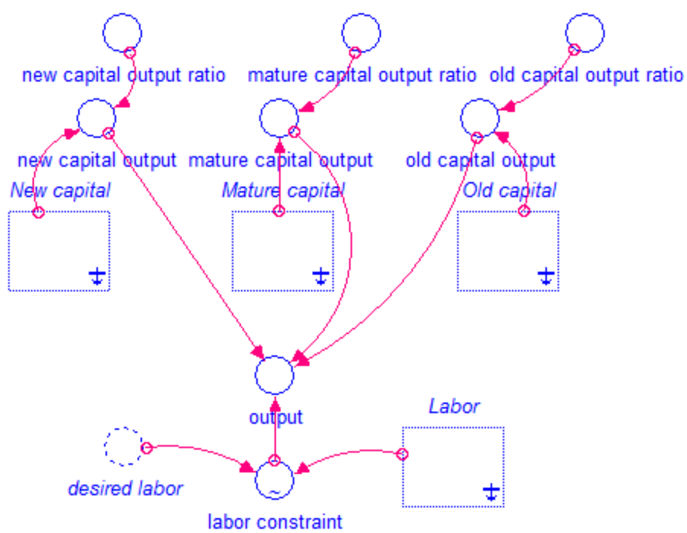

Figure 10: Output Sector

According to Saeed (2010), the output is produced by capital and labor. In our model, the output is derived by multiplying the Labor Constraint with the sum of New Capital, Mature Capital, and Old Capital.

Land Sector

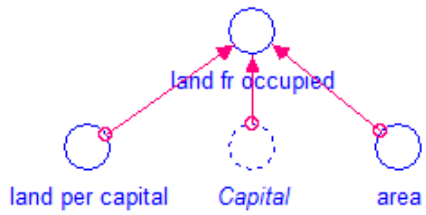

Figure 11: Land Sector

The land sector represents the amount of land available in the city. Land availability is illustrated by Land Fraction Occupied, which is one of constraints obstructing the growth in the city.

Flood Simulation

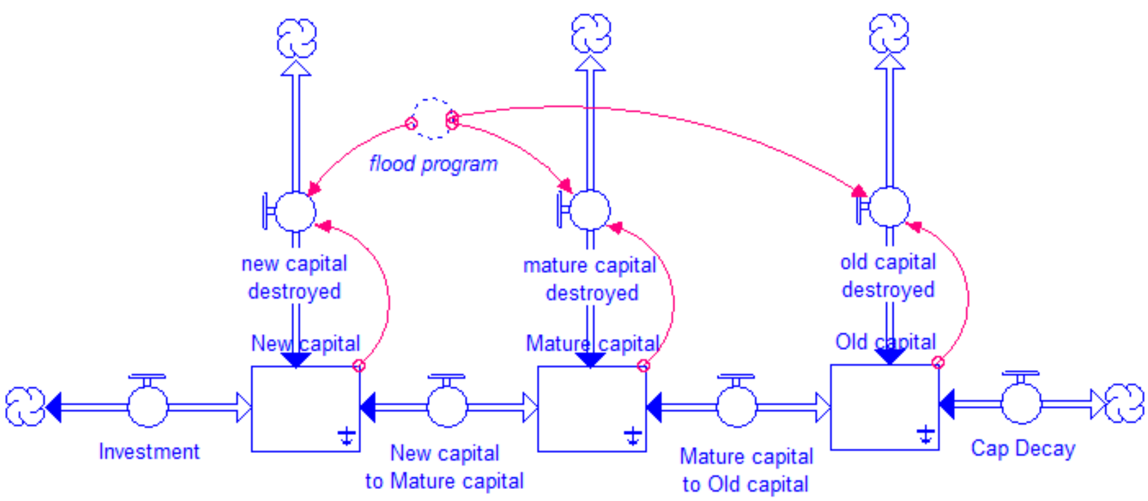

Figure 12: Flood Simulation

The effect of flood is represented in the capital sector, as shown in Figure 12. When flood occurs, every type of capital is permanently destroyed. As a result, flood is represented in the model by using 3 outflows at New Capital, Mature Capital, and Old Capital.

In this model, we use pulse function to indicate that 30 percent of each capital is destroyed; therefore, the higher the capital, the more it is destroyed.

Policies

In this section we will analyze polices that might fasten the economic alleviation. These policies are based on both literature and Thai government's policies.

New Capital Construction Policy

This policy aims to increase new capitals by increasing government's investment. In the model, the policy is implemented by increasing the inflow of the new capital by 12%

Variable	Base Run (Without Policy)	Year 64 (With Policy)
Total Capital	100.0000	123.5019
New Capital	20.0000	18.4879
Total Workforce	14.0000	15.9803
Potential Entrepreneurs	2.0000	2.2553
Ratio of New Capital to Old Capital	0.4000	0.2392
Ratio of Potential Entrepreneurs to Total Workforce	0.1429	0.1411
Ratio of Unemployed to Total Workforce	0.1429	0.1443
Service Ratio	1.0000	0.9330

Table 1: Output from New Capital Construction Policy

Table 1 shows that, by implementing this policy, Total Capital increases from the base run. The total amount of capital increases because of the higher capital inflow. Yet, Table 1 shows that New Capital decreases. An increase of capital inflow causes a rapid growth of New Capital, however, soon land becomes full thus limiting the growth. As a result, the New Capital overshoot then decreases more than the normal recovery. Since the age of Old Capital is much longer than New Capital's, more fraction of land is occupied by Old Capital instead of being available for New Capital construction.

Table 1 shows that more people move into the city because an increase of Total Capital creates more jobs. In addition, entrepreneurs also increase proportionately.

In conclusion, this policy improves the economy of the city by increasing the amount of capital; therefore, create more jobs for both its citizens and immigrants. However, most fraction of the land is occupied by old capital instead of new capital, which has more productivity.

Decrease Interest Rate Policy

The objective of this policy is to speed up the economic recovery by encouraging potential entrepreneurs to construct more new capital infrastructures. By decreasing interest rate, saving money in the bank becomes less attractive. On the other hand, taking investment loan will be more attractive. As a result, it is easier for potential entrepreneurs to construct new capital infrastructures. This program can be implemented in the model by changing the value of interest rate parameter. Our policy will decrease interest rate from originally 10% to 5%.

Variable	Base Run (Without Policy)	Year 64 (With Policy)
Total Capital	100.0000	108.2250
New Capital	20.0000	19.2234
Total Workforce	14.0000	14.6427
Potential Entrepreneurs	2.0000	2.2570
Ratio of New Capital to Old Capital	0.4000	0.3195
Ratio of Potential Entrepreneurs to Total Workforce	0.1429	0.1541
Ratio of Unemployed to Total Workforce	0.1429	0.1323
Service Ratio	1.0000	0.9863

Table 2: Output from Decrease Interest Rate Policy

Compare the result of this policy to the base run, Table 2 shows that Total Capital increases. Decreasing the interest rate will create incentive for entrepreneurs to invest money in capital infrastructure construction rather than saving. However, Table 2 shows that New Capital decreases. Since entrepreneurs invest more money constructing capital infrastructures, the amount of New Capital go up rapidly. Soon, land becomes full and limits the growth. As a result, New Capital overshoots then decrease to lower than the normal recovery's – without applying this policy. Similar to previous policy, the age of Old Capital is much longer than New Capital; therefore, more land fraction is occupied by Old Capital instead of being available for New Capital construction.

Table 2 shows that more people will move into the city because more jobs become available from an increase of capital. Entrepreneurs also increase proportionately.

In conclusion, this policy improves the economy of the city by giving an incentive for people to become entrepreneurs and construct more capital infrastructures. An increase of capital will create more jobs – creating incentive for people to move into the city. However, most fraction of the land is occupied by old capital instead of new capital, which have more productivity. Bank of Thailand can implement this policy by announcing a decrease of national interest rate.

Import Technology Policy

This policy encourages potential entrepreneurs to import new technology from outside the country. The goal of this policy is to allow new technology to facilitate construction of new capital infrastructures. In this model, the policy will be implemented by increasing the Tech Productivity from 5 to 6.

Variable	Base Run (Without Policy)	Year 64 (With Policy)
Total Capital	100.0000	103.4389
New Capital	20.0000	19.7020
Total Workforce	14.0000	14.2733
Potential Entrepreneurs	2.0000	2.0343
Ratio of New Capital to Old Capital	0.4000	0.3636
Ratio of Potential Entrepreneurs to Total Workforce	0.1429	0.1425
Ratio of Unemployed to Total Workforce	0.1429	0.1431
Service Ratio	1.0000	0.9876

Table 3: Output from Import Technology Policy

According to Table 3, comparing the result of the policy to the base run, Total Capital is a little higher; however, the New Capital is a little lower.

Note that an increase of technology barely affects the inflow of the new capital. Since the autonomous investment is defined as "$\text{Resources}^{0.5} * \left(\frac{\text{Technology}}{10}\right)^{0.5} - \text{Saving Up}$" (Saeed, 2010), increasing Tech Productivity by 20% will not increase the Autonomous Investment by 20% but only less than 10% (from 1 to $1.20^{0.5}$).

Table 3 shows that the number of entrepreneurs and total workforce only increase by a small amount. The increase of capital, even small amount, leads to a small increase of jobs available; therefore more people moves into the city. As a result, entrepreneurs also increase proportionally.

The government can implement import-technology policy by encouraging private companies to import technology from foreign countries. However, since this policy only improves the economy by a small amount, it might not be effective for the government to implement.

Service Supply Policy

The service-supply policy is implemented in the model by directly adding a step function "step(0.1,2)" to increase the Service Supply parameter. By increasing the Service Supply, the Service Multiplier will also raise. The increased Service Multiplier will then increase the Climate Factor, Capital Construction Multiplier, and Workforce Growth Fraction. Therefore, increasing service supply is expected to provide incentive for people to become entrepreneurs, encourage capital construction, and allow the city to expand. Yet, the result after applying the service-supply policy is not as effective as we expected.

Variable	Base Run (Without Policy)	Year 64 (With Policy)
Total Capital	100.0000	102.3979
New Capital	20.0000	20.4491
Total Workforce	14.0000	14.3288
Service Supply	152.5000	137.9500
Service Demand	152.5000	141.8343
Service Ratio	1.0000	1.0443
Ratio of New Capital to Old Capital	0.4000	0.3988
Ratio of Potential Entrepreneurs to Total Workforce	0.1429	0.1440
Ratio of Unemployed to Total Workforce	0.1429	0.1418

Table 4: Output from Service Supply Policy

As shown in Table 4, the service-supply policy results in a slight increase of the capital and workforce. At first, the service ratio significantly increases due to an increase of Service Supply. However, as the time passes, the raise in workforce and capital will increase the Service Demand; therefore, minifies the increasing rate of the Service Ratio. Eventually, the Service Ratio will return to nearly one. As a result, the service-supply policy can only support the economic growth for a short amount of time.

In reality, the government can only implement this policy in short run due to limited budget. If the government is to implement this policy in long run, it would constantly require more money to maintain the constructed service supply. As a result, this policy is not sustainable, especially for Thai government.

Training Program Policy

The training program policies are implemented in order to encourage more people to become entrepreneurs. By having more entrepreneurs, more capital will be built and therefore fasten the recovery from the flood. The training program policies can be categorized in two categories: Labor Training Program and Unemployed Training Program. Both programs are represented in the model by directly increasing the Labor Entre Mobility and Unemployed Entre Mobility respectively.

Variable	Base Run (Without Policy)	Labor Training Program at year 64	Unemployed Training Program at year 64
Total Capital	100.0000	100.4558	99.8219
New Capital	20.0000	20.0063	20.0258
Total Workforce	14.0000	14.0455	13.9877
Potential Entrepreneurs	2.0000	2.0404	1.9830
Ratio of New Capital to Old Capital	0.4000	0.3967	0.4025
Ratio of Potential Entrepreneurs to Total Workforce	0.1429	0.1453	0.1418
Ratio of Unemployed to Total Workforce	0.1429	0.1411	0.1417
Service Ratio	1.0000	1.0018	1.0008

Table 5: Output from Training Program

The result shows that implementing the labor training program will slightly fasten the recovery. The number of entrepreneurs and capitals will also increase, as shown in Table 5. When labor is trained, more labors will become entrepreneurs; therefore increase capital. In addition, the existing labor jobs will be freed. This will allow Unemployed to become Labor.

However, by implementing unemployed training program, Table 5 shows that the number of entrepreneurs and capital slightly decreases. This program has an opposite effect as intended. When unemployed training program is implemented, more Unemployed will initially become Potential Entrepreneurs. This will create an overshoot in Potential Entrepreneurs; therefore, a lot of Potential Entrepreneurs will exit the market. However, since the Potential Entrepreneurs are skilled individuals, they become Labor instead of Unemployed. The Worker Availability (ratio of Unemployed over Labor) will go down, resulting in an increase in Wage Rate which in return leads to a decrease in Climate Factor. As a result, entrepreneurs and capital will decrease respectively.

As shown in Table 5, both training programs result in only a small change in entrepreneurs and capitals. This is because Potential Entrepreneurs, Labor and Unemployed are linked by flows. When the training program policy disturbs one of the flows, the other two flows change accordingly to adjust the model to initial equilibrium. It can be concluded that both training programs are not effective.

The unemployed training program was implemented by Thai government in 2009. The program called "Ton Kla Archeap" was designed to train unskilled-unemployed people. Three hundred million dollars was invested in the program to train approximately 400,000 people (Thairath, 2009). The program was discontinued in 2010 since the result of the program was not as successful as anticipated. The money invested in the program was too high while the program only helped a small group of people.

According to our model, the labor training program will be slightly better than the unemployed training program. However, it is also not as effective compared to the money that needed to be invested. In addition, the concept of implementing a labor training program is not very feasible. The government will not be able to justify training skilled labor while unemployed worker still exists.

Increase Wage Rate Policy

The increase wage rate policy is intended to stimulate the economy by increasing the money supply – the household income. In addition, by increasing workers' wage rate, they will have more money to rebuild their properties. This policy is implemented by adding step function "step(1, 2)" at the Wage Rate parameter.

Variable	Base Run (Without Policy)	Year 64 (With Policy)
Total Capital	100.0000	92.2119
New Capital	20.0000	19.9560
Total Workforce	14.0000	13.2326
Potential Entrepreneurs	2.0000	1.4268
Labor	10.0000	9.4728
Unemployed	2.0000	2.3331
Ratio of New Capital to Old Capital	0.4000	0.4025
Ratio of Potential Entrepreneurs to Total Workforce	0.1429	0.1418
Ratio of Unemployed to Total Workforce	0.1429	0.1417
Service Ratio	1.0000	1.0008

Table 6: Output from Wage Rate Policy

The outcome of this policy is not as intended. Table 6 shows that the numbers of entrepreneurs, labors, and capital decrease while the number of unemployed increases significantly. With an increase in Wage Rate, the Climate Factor will go down. As a result Potential Entrepreneurs will decrease which lead to a decrease in capital.

Thai government implemented the increase wage rate policy in 2012. The program intended to help individuals with low income. However, the program was not as successful as expected. By increasing Wage Rate, a large amount of labors was laid off since the business owners (entrepreneurs) were not able to afford hiring the same amount of workers. Not long after the laid off, a lot of business – especially small businesses – were closed down (Matichon, 2013). The result of this policy is the same as the prediction from our model. It is likely that capital will continue to decrease and more people will be unemployed until the government discontinues the policy.

Old Capital Demolition Policy

From previous section, we found that New Capital Construction Policy and Decrease Interest Rate Policy were effective alleviation policies. However, we also found that, for both policies, the level of New Capital is low compared to the Old Capital. Therefore, we decide to free up the occupied land by destroying Old Capitals, hence simulating Proactive Creative Destruction. In this sector we will illustrate the result of pairing Old Capital Demolition Policy with New Capital Construction Policy and Decrease Interest Rate Policy.

The old capital demolition policy is implemented in the model by decreasing the Average Life of Capital and Technology by 2, from 10 to 8 years.

Combination of Decrease Interest Rate Policy and Capital Demolition Policy

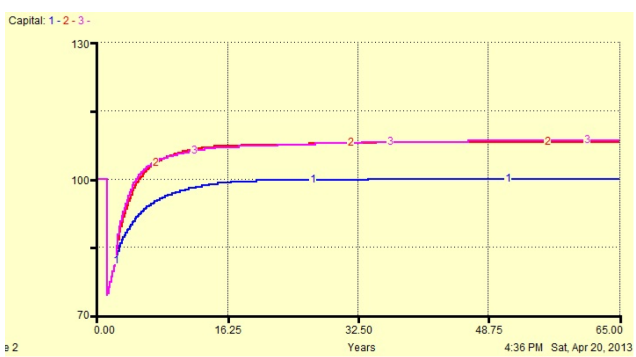

Figure 13: Total Capital (DIRP&OCDP)

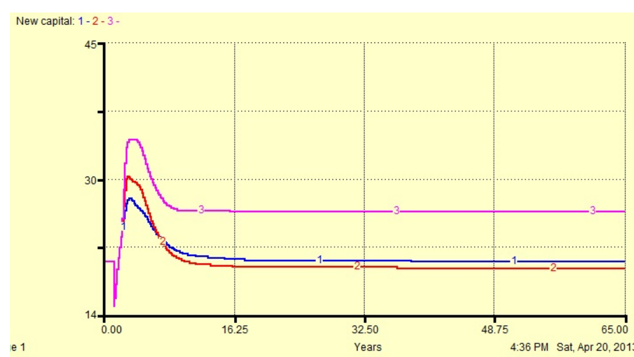

Figure 14: New Capital (DIRP&OCDP)

Comparing line 2 and line 3, the combined policy (line 3) increases the level of new capital (Figure 14), whereas the level of total capital remains almost the same (Figure 13). By decreasing the average life of capital and technology, the outflow of old capital increases; therefore, more fraction of land will be available for constructing new capital infrastructures.

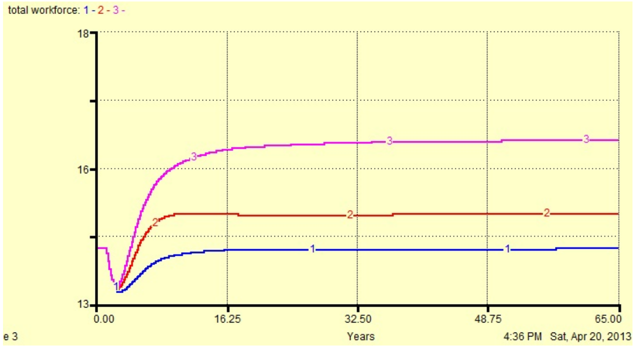

Figure 15: Total Workforce (DIRP&OCDP)

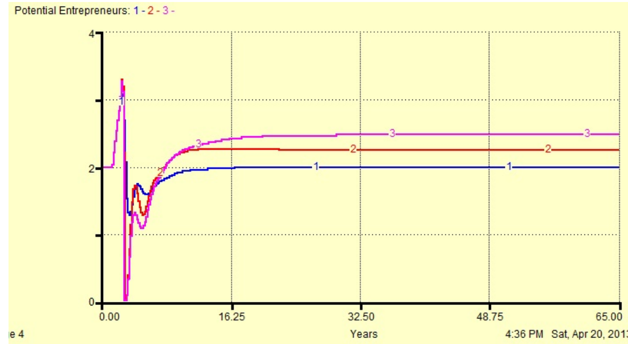

Figure 16: Potential Entrepreneurs (DIRP&OCDP)

According to Figure 15 and Figure 16, the level of workforce and entrepreneurs also increase from line 2 to line 3. This is because, even though the amount of total capital is the same, new capital creates more jobs than old capital. More people will move into the city, meaning entrepreneurs will also increase proportionally.

Variable	Year 64 (Decrease Interest Rate Policy)	Year 64 (Combined with Old Capital Demolition Policy)
Total Capital	108.2250	108.3346
New Capital	19.2234	25.6222
Total Workforce	14.6427	15.9971
Potential Entrepreneurs	2.2570	2.4888
Ratio of New Capital to Old Capital	0.3195	0.5787
Ratio of Potential Entrepreneurs to Total Workforce	0.1541	0.1556
Ratio of Unemployed to Total Workforce	0.1323	0.1309
Service Ratio	0.9863	1.0625

Table 7: Output from the combination of Decrease Interest Rate Policy and Old Capital Demolition Policy

Combination of New Capital Construction Policy and Old Capital Demolition Policy

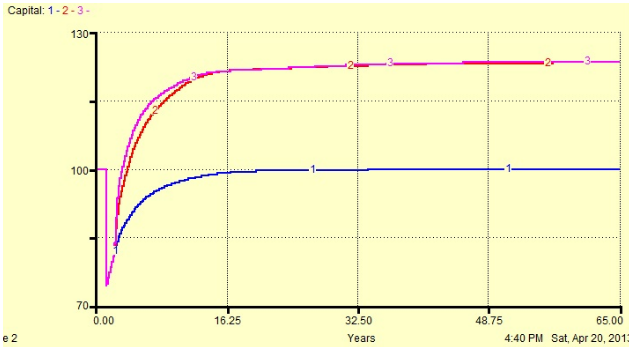

Figure 17: Total Capital (NCCP&OCDP)

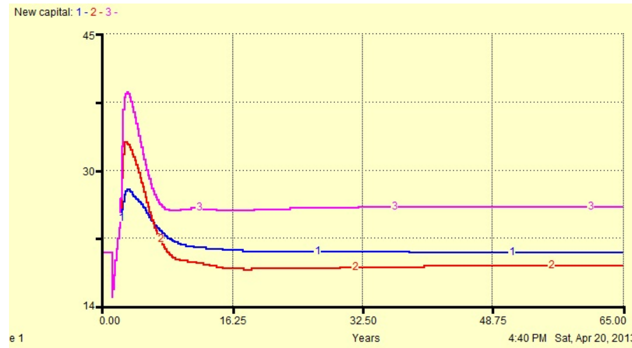

Figure 18: New Capital (NCCP&OCDP)

The result of using both Old Capital Demolition Policy and New Capital Construction Policy is similar to previous combination's. New capital increases from line 2 to line 3 (Figure 18) while total capital remains the same (Figure 17). This is because decreasing the average life of capital and technology increases the outflow of old capital; therefore, more land will be available for new capital construction.

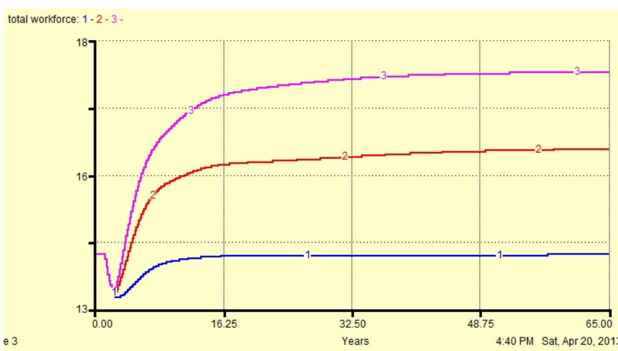

Figure 19: Total Workforce (NCCP&OCDP)

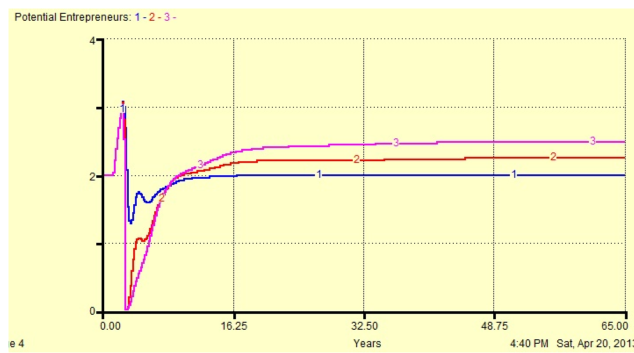

Figure 20: Potential Entrepreneurs (NCCP&OCDP)

As illustrated in Figure 19 and Figure 20, total workforce and entrepreneurs increase from line 2 to line 3. By freeing up land with the Old Capital Demolition Policy, the amount of new capital increases. Since new capital requires more workers than old capital, more jobs will be available. More people will move into the city; therefore, proportionately increase the number of entrepreneurs.

Variable	Year 64 (Only New Capital Construction Policy)	Year 64 (Combined with Old Capital Demolition Policy)
Total Capital	123.5019	123.6186
New Capital	18.4879	25.2735
Total Workforce	15.9803	17.4195
Potential Entrepreneurs	2.2553	2.4903
Ratio of New Capital to Old Capital	0.2392	0.4182
Ratio of Potential Entrepreneurs to Total Workforce	0.1411	0.1430
Ratio of Unemployed to Total Workforce	0.1443	0.1427
Service Ratio	0.9330	1.0057

Table 8: Output from the combination of New Capital Construction Policy and Old Capital Demolition Policy

In conclusion, combining Old Capitals Demolition Policy with Decrease Interest Rate Policy or New Capital Construction Policy will significantly fasten the alleviation. Without applying Proactive Creative Destruction – destroying old capital – the economic recovery will not be as effective. In reality, the Old Capital Demolition policy can be implemented by establishing tax structure that provides incentive for removal of aging structures (Forrester). The tax will encourage entrepreneurs to replace old capital with new capital.

Conclusion

In 2011, Thailand was flooded for five months. The flood severely damaged not only infrastructures but also the economy. It has been almost 2 years since the flood; however, the economy has not fully recovered. The goal of our project is to use system dynamic to simulate the impact of flood on Thai economy and alleviation policies. Since most of Thailand economic activities are located in the capital, we decided to set the boundary of our study to only Bangkok, where most of the economic damage occurred.

We created our model by combining Forrester's Urban Dynamics model with Saeed's Creative Destruction model (concept by Schumpeter). We used Saeed's model as a base model then add the following structures from Forrester's to Saeed's: third-order-aging capitals, land constraint, job sector, and service sector. After the combination, the model was set to equilibrium in order to simulate the flood and alleviation policies.

We studied the alleviation policies from both literature and Thai government's. Increase New Capital Policy, Decrease Interest Rate Policy, Import Technology Policy, and Service-Supply Policy are drawn from the literature while Training Program Policy and Wage Rate Policy were implemented by

Thai government in 2009 and 2012 respectively. After the analysis, we found that only Increase New Capital Policy and Decrease Interest Rate Policy are effective. Both policies generated positive outcomes: increases in entrepreneurs, total workforce, and total capital. However, we noticed that, due to the land constraint, higher portion of existing capital is old capital instead of new.

Since the high proportion of old capital is the obstacle that impede the alleviation, we decided to destroy old capital so more land will be available for new capital construction. We paired the old capital demolition policy with both new capital construction policy and decrease interest rate policy. With these combinations, the alleviation rate of the initial policies will increase significantly. As a result, we can conclude that, in combination with alleviation policy, Creative Destruction is a crucial factor for economic recovery.

Our project can be improved by taking into account of the economic damage from agriculture sector, which is located in the rural areas. Even though the damage is small compared to the industry sector in Bangkok, simulating the impact of agriculture sector will better represent Thai economy.

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Appendix

Model Parameters at Equilibrium

Labor(t) = Labor(t - dt) + (Hiring - Labor__Entre_Mobility) * dt
INIT Labor = 10
INFLOWS:
Hiring = ((desired_labor-Labor)*hiring_normal)*labor_market_constraint
OUTFLOWS:
Labor__Entre_Mobility = (Labor*.05*climate_factor*(1+training_labor_program)-
Potential_Entrepreneurs*.25/climate_factor)*labor_entre__mobility_normal
Mature_capital(t) = Mature_capital(t - dt) + (New_capital__to_Mature_capital - Mature_capital__to_Old_capital - mature_capital__destroyed) * dt
INIT Mature_capital = 30
INFLOWS:
New_capital__to_Mature_capital =
decline_multiplier__of_New_capital__to_Muture_capital*New_capital/avg_life__of_New_capital
OUTFLOWS:
Mature_capital__to_Old_capital =
decline_multiplier_of_Mature_capital_to_Old_capital*Mature_capital/avg_life_of_Mature_capital
mature_capital__destroyed = Mature_capital*mature_capital__decay_normal*flood_program
New_capital(t) = New_capital(t - dt) + (Investment - New_capital__to_Mature_capital - new_capital__destroyed) * dt
INIT New_capital = 20
INFLOWS:
Investment =
(autonomous_investment+induced__investment)*capital_construct_multiplier*(1+new_cap__construct_program)
OUTFLOWS:
New_capital__to_Mature_capital =
decline_multiplier__of_New_capital__to_Muture_capital*New_capital/avg_life__of_New_capital
new_capital__destroyed = New_capital*new_capital__decay_normal*flood_program
Old_capital(t) = Old_capital(t - dt) + (Mature_capital__to_Old_capital - Cap_Decay - old_capital__destroyed) * dt
INIT Old_capital = 50
INFLOWS:
Mature_capital__to_Old_capital =
decline_multiplier_of_Mature_capital_to_Old_capital*Mature_capital/avg_life_of_Mature_capital
OUTFLOWS:
Cap_Decay = demolition__multiplier_of_Old_capital*Old_capital/avg_life_of_Old_capital
old_capital__destroyed = Old_capital*old_capital__decay_normal*flood_program
Potential_Entrepreneurs(t) = Potential_Entrepreneurs(t - dt) + (Labor__Entre_Mobility + Unemployed__Entre_Mobility) * dt
INIT Potential_Entrepreneurs = 2

INFLOWS:
Labor__Entre_Mobility = (Labor*.05*climate_factor*(1+training_labor_program)-Potential_Entrepreneurs*.25/climate_factor)*labor_entre__mobility_normal
Unemployed__Entre_Mobility = (Unemployed*0.1*climate_factor*(1+training_unemplyed_program)-Potential_Entrepreneurs*0.1)*unemployed_entre__mobility_normal
Technology(t) = Technology(t - dt) + (Tech_Development - Tech_Decay) * dt
INIT Technology = 100
INFLOWS:
Tech_Development = entrepreneurs*tech_productivity
OUTFLOWS:
Tech_Decay = Technology/av_life_of_cap_and_tech
Unemployed(t) = Unemployed(t - dt) + (Workforce_Growth - Unemployed__Entre_Mobility - Hiring) * dt
INIT Unemployed = 2
INFLOWS:
Workforce_Growth = total_workforce*workforce_growth_fr
OUTFLOWS:
Unemployed__Entre_Mobility = (Unemployed*0.1*climate_factor*(1+training_unemplyed_program)-Potential_Entrepreneurs*0.1)*unemployed_entre__mobility_normal
Hiring = ((desired_labor-Labor)*hiring_normal)*labor_market_constraint
Unspent_Saving(t) = Unspent_Saving(t - dt) + (Saving_Up - Resources) * dt
INIT Unspent_Saving = 20
INFLOWS:
Saving_Up = output*fr_output_saved*interest_rate/.1
OUTFLOWS:
Resources = entrepreneurs*fr_saving_mobilized_per_entrepreneur*Unspent_Saving
area = 100
autonomous_investment = Resources^.5*(Technology/10)^.5*(autonomous__investment_normal_1)^.5-Saving_Up*autonomous__investment_normal_2
autonomous__investment_normal_1 = 1
autonomous__investment_normal_2 = 1
avg_life_of_Mature_capital = 3
avg_life_of_Old_capital = av_life_of_cap_and_tech-avg_life__of_New_capital-avg_life_of_Mature_capital
avg_life__of_New_capital = 2
av_life_of_cap_and_tech = 10+old_cap_decline_program
Capital = Mature_capital+New_capital+Old_capital
capital_construct_multiplier = capital_land_multiplier*service_multiplier
capital_tax_collection =
Old_capital*old_capital__tax_rate+Mature_capital*mature_capital__tax_rate+New_capital*new_capital__tax_rate
climate_factor = climate_factor_mulplier*service_multiplier*interest_rate_multiplier
demolition__multiplier_of_Old_capital =
declining_capital_enterprise_multiplier*declining_capital_land_multiplier
desired_capital = desired_new_capital+desired_mature_capital+desired_old_capital

desired_labor =
New_capital/new_capital_labor_ratio+Mature_capital/mature_capital_labor_ratio+Old_capital/old_capital_labor_ratio
desired_mature_capital = mature_capital_output*mature_capital_output_ratio
desired_new_capital = new_capital_output*new_capital_output_ratio
desired_old_capital = old_capital_output*old_capital_output_ratio
entrepreneurs = SMTH3(Potential_Entrepreneurs,entrepreneur_development_delay)
entrepreneur_development_delay = 5
flood_policy = PULSE(.3,1,10000)
flood_program = flood_program_switch*flood_policy
flood_program_switch = 0
fr_output_saved = .2
fr_saving_mobilized_per_entrepreneur = .25
hiring_normal = 2
import_tech_policy = step(1,2)
import_tech_program = import_tech_policy*import_tech_program_switch
import_tech_program_switch = 0
induced_investment__normal = 1/2
induced__investment = (desired_capital-Capital)*induced_investment__normal+Cap_Decay
interest_policy = step(-0.05,2)
interest_program = interest_policy*interest_program_switch
interest_program_switch = 0
interest_rate = .1+interest_program
labor_entre__mobility_normal = 1
labor_tax_rate = 7.5
land_fr_occupied = Capital*land_per_capital/area
land_per_capital = .7
mature_capital_labor_ratio = 1/.11
mature_capital_output = Mature_capital/mature_capital_output_ratio
mature_capital_output_ratio = 2
mature_capital__decay_normal = 1
mature_capital__tax_rate = .5
new_capital_labor_ratio = 1/.16
new_capital_output = New_capital/new_capital_output_ratio
new_capital_output_ratio = 4/3
new_capital__decay_normal = 1
new_capital__tax_rate = 1
new_cap_construct_policy = step(1.12,2)
new_cap_construct_program_switch = 0
new_cap__construct_program = new_cap_construct_policy*new_cap_construct_program_switch
old_capital_labor_ratio = 1/.07
old_capital_output = Old_capital/old_capital_output_ratio
old_capital_output_ratio = 2.5
old_capital__decay_normal = 1

old_capital__tax_rate = .25
old_cap_decline_policy = step(-2,2)
old_cap_decline_program = old_cap_decline_policy*old_cap_decline_program_switch
old_cap_decline_program_switch = 0
output = (new_capital_output+mature_capital_output+old_capital_output)*labor_constraint
population_tax_collection =
Unemployed*unemployed_tax_rate+Labor*labor_tax_rate+Potential_Entrepreneurs*potential_entrepreneurs__tax_rate
potential_entrepreneurs__tax_rate = 15
profit = output-wages
rate_of_return = profit/Capital
services_ratio = service_supply/service_demand
service_demand = Capital*service_demand__per_cap+total_workforce*service_demand__per_pop
service_demand__per_cap = 1
service_demand__per_pop = 3.75
service_per_unit_tax = 1
service_supply = service_per_unit_tax*total_tax_collection+service_supply_program
service_supply_policy = step(6.75,2)
service_supply_program = service_supply_policy*service_supply_program_switch
service_supply_program_switch = 0
tech_productivity = 5+import_tech_program
total_tax_collection = capital_tax_collection+population_tax_collection
total_workforce = Labor+Potential_Entrepreneurs+Unemployed
training_labor_policy = step(0.2,2)
training_labor_program = training_labor_program_switch*training_labor_policy
training_labor_program_switch = 0
training_unemployed_policy = step(0.4,2)
training_unemplyed_program = training_unemplyed_program_switch*training_unemployed_policy
training_unemplyed_program_switch = 0
unemployed_entre__mobility_normal = 1
unemployed_tax_rate = 0
wages = Labor*wage_rate
wage_policy = step(1,2)
wage_program = wage_program_switch*wage_policy
wage_program_switch = 0
wage_rate = wage_rate_normal*wage_escalation_effect+wage_program
wage_rate_normal = 3
worker_availibility = (Unemployed/Labor)/(2/10)
workforce_growth_fr = workforce_growth__fr_normal*job_population_multiplier*service_multiplier
workforce_growth__fr_normal = 0.1
capital_land_multiplier = GRAPH(land_fr_occupied)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.45), (0.5, 1.40), (0.6, 1.30), (0.7, 1.00), (0.8, 0.7), (0.9, 0.4), (1, 0.00)
climate_factor_mulplier = GRAPH(((rate_of_return/.2)/(wage_rate/3)))

(0.00, 0.001), (0.2, 0.06), (0.4, 0.18), (0.6, 0.35), (0.8, 0.67), (1.00, 1.00), (1.20, 1.49), (1.40, 1.75), (1.60, 1.89), (1.80, 1.96), (2.00, 2.00)
decline_multiplier_of_Mature_capital_to_Old_capital = GRAPH(LOG10(capital_construct_multiplier)/LOG10(2))
(-3.00, 2.00), (-2.00, 1.80), (-1.00, 1.50), (0.00, 1.00), (1.00, 0.7), (2.00, 0.5), (3.00, 0.5)
decline_multiplier__of_New_capital__to_Muture_capital = GRAPH(LOG10(capital_construct_multiplier)/LOG10(2))
(-3.00, 2.00), (-2.00, 1.80), (-1.00, 1.50), (0.00, 1.00), (1.00, 0.7), (2.00, 0.5), (3.00, 0.5)
declining_capital_enterprise_multiplier = GRAPH(LOG10(capital_construct_multiplier)/LOG10(2))
(-3.00, 0.4), (-2.00, 0.5), (-1.00, 0.7), (0.00, 1.00), (1.00, 1.60), (2.00, 2.40), (3.00, 4.00)
declining_capital_land_multiplier = GRAPH(land_fr_occupied)
(0.8, 1.00), (0.85, 1.20), (0.9, 1.60), (0.95, 2.20), (1.00, 6.00)
interest_rate_multiplier = GRAPH(interest_rate)
(0.00, 2.00), (0.025, 1.90), (0.05, 1.73), (0.075, 1.41), (0.1, 1.00), (0.125, 0.51), (0.15, 0.24), (0.175, 0.06), (0.2, 0.00)
job_population_multiplier = GRAPH((desired_labor/10)/(total_workforce/14))
(0.00, -1.58), (0.2, -1.54), (0.4, -1.36), (0.6, -1.04), (0.8, -0.58), (1.00, 0.00), (1.20, 0.58), (1.40, 1.04), (1.60, 1.36), (1.80, 1.54), (2.00, 1.58)
labor_constraint = GRAPH(Labor/desired_labor)
(0.00, 0.00), (0.2, 0.45), (0.4, 0.69), (0.6, 0.83), (0.8, 0.92), (1.00, 1.00), (1.20, 1.06), (1.40, 1.11), (1.60, 1.14), (1.80, 1.17), (2.00, 1.19)
labor_market_constraint = GRAPH(worker_availibility)
(0.00, 0.00), (0.1, 0.435), (0.2, 0.655), (0.3, 0.765), (0.4, 0.85), (0.5, 0.895), (0.6, 0.935), (0.7, 0.96), (0.8, 0.975), (0.9, 0.995), (1, 1.00)
service_multiplier = GRAPH(LOG10(services_ratio)/LOG10(2))
(-2.00, 0.3), (-1.00, 0.5), (0.00, 1.00), (1.00, 1.80), (2.00, 2.80), (3.00, 3.60), (4.00, 4.00)
wage_escalation_effect = GRAPH(worker_availibility)
(0.00, 4.00), (0.2, 2.76), (0.4, 2.04), (0.6, 1.62), (0.8, 1.28), (1.00, 1.00), (1.20, 0.74), (1.40, 0.54), (1.60, 0.4), (1.80, 0.28), (2.00, 0.22)

Model Parameters' Changes for Polices Implementation

Policy	Parameter Name	Changed Value
Flood Simulation	flood policy	PULSE(.3,1,10000)
New Capital Construction Policy	new cap construct policy	step(1.12,2)
Decrease Interest Rate Policy	interest policy	step(-0.05,2)
Import Technology Policy	import tech policy	step(1,2)
Service Supply Policy	service supply policy	step(6.75,2)
Labor Training Program Policy	training unemployed policy	step(0.2,2)
Unemployed Training Program Policy	training labor policy	step(0.4,2)
Increase Wage Rate Policy	wage policy	step(1,2)
Old Capital Demolition Policy	old cap decline policy	step(-2,2)