Team Control Number

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Problem Chosen

B

2009 Mathematical Contest in Modeling (MCM) Summary Sheet

Comparing the landlines and cell phones to two kinds of species, they compete with each other for the limited resources (consumers), hence, we build the competitive model to describe the competition between them. According to the model, the species which have the stronger competitive power will either replace the other one or occupy the most resources.

The competitive force is determined by a myriad of factors. If only considering the energy consumption as is required in requirement2, we can derive that the optimal way of providing phone service is to provide 151230000 landlines and 191300000 cell phones. Taking the population and GDP into consideration, we can obtain the relationship between the landlines' and cell phones' competitive force, and the energy needs predicted for the next 50 years are as follows:

Year	2019	2029	2039	2049	2059
Energy Needs (10^7barrels of oil)	2.0936	2.0611	2.0755	2.2051	2.3787

Basing on the data available, we derive that the wasted electricity caused by the improper use of cell phones' recharges is $C = 4.84\times10^5$ barrels of oil, and the wasted electricity caused by the improper use of various rechargers is $C = 6.65\times10^5$ barrels of oil per day

Energy and the Cell Phone

Abstract

Comparing the landlines and cell phones to two kinds of species, they compete with each other for the limited resources (consumers), hence, we build the competitive model to describe the competition between them. According to the model, the species which have the stronger competitive power will either replace the other one or occupy the most resources.

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Introduction

Landlines and cell phones coexist in our society and it is obvious that they are competitors as they compete for the limited resources, consumers. Comparing the landlines and cell phones to two kinds of species, species A and species B, the one which has a stronger competitive force will either replace the other one or occupy the most resources. The competitive force of landlines and cell phones is influenced by a myriad of factors, such as energy consumption, expense for utilizing, convenience of use, security and so on, while the energy consumption is the most important factor as is required in the problem. Based on the energy consumption data, we can derive the competitive force of landlines and cell phones. To obtain the result, namely the balanced state of competition, the competitive model which analyzes the competition between two species is necessary. To build the competitive model, which describes the current competition state, the exponential growth model and the block growth model are also necessary as they describe the competition state before and lay a foundation for the competitive model.

Exponential Growth Model (the Malthus Model)

The model can be used to describe the state when the landlines or the cell phones just emerged.

Assumptions:

- The growth rate of the species is constant.
- There do not exist competitors.
- The resources of the living environment are enough, so there do not exist competitions among the same species.

Symbols and Definitions:

$x(t)$	The population quantity of the species at t
r	The growth rate, which is a constant according to the assumptions

Model Building:

The increment of the population quantity from t to $t+\triangle t$ is:

$$x(t+\triangle t)-x(t)=rx(t)\triangle t \qquad (1)$$

If divided by $\vartriangle t$ both sides,

$$\frac{x(t+\vartriangle t)-x(t)}{\vartriangle t}=rx(t) \tag{2}$$

Let $\vartriangle t \to 0$, we can obtain a differential equation:

$$\frac{dx}{dt}=rx(t) \tag{3}$$

Hence, the model can be described by the differential equation above, if $x(0)=x_0$, we can obtain:

$$x(t)=x_0e^{rt} \tag{4}$$

Model Analysis:

Since the resources in the living environment are enough, there do not exist competitions among the same species, what's more, there are not any competitors, the population quantity of the species will increase quickly.

Block Growth Model (the Logistic Model)

This model describes the negative effect caused by the quick increase of the same species.

Assumptions:

- The growth rate of the species is not constant, but a linear decline function of the population quantity.
- The resources of the living environment are not enough, so there exist competitions between the same species and there is a maximum quantity of the population.

Symbols and Definitions:

$x(t)$	The population quantity of the species at t
$r(x)$	The growth rate, which is no longer a constant, but a function of the population quantity
r	The inherent growth rate, namely the growth rate under the circumstances that there are not any competitors and there do not exist competitions among the same species

x_m The maximum population quantity of the species, which is constrained by the resources of the living environment

Model Building:

According to the assumptions, the growth rate

$$r(x) = r - sx \quad (5)$$

It is obvious that:

$$r(0) = r \quad (6)$$

$$r(x_m) = 0 \quad (7)$$

Then we can deduce:

$$r(x) = r(1 - \frac{x}{x_m}) \quad (8)$$

Substitute formula (8) into the differential equation formula (3) in the exponential model, we can obtain:

$$\frac{dx}{dt} = r(1 - \frac{x}{x_m}) \quad (9)$$

Given $x(0) = x_0$, we can obtain the following formula by solving the differential equation:

$$x(t) = \frac{x_m}{1 + (\frac{x_m}{x_0} - 1)e^{-rt}} \quad (10)$$

Model Analysis:

Since the resources in the living environment are limited, there will be competitions among the same species, which will have a negative effect on the increase of the population. The more the population quantity is, the greater the negative effect will be. Hence, the increasing speed will slow down gradually with the increase of the population quantity. When the increasing speed is zero, the species will reach its maximum number x_m , and will remain the balanced state from then on.

Competitive Model

Assumptions:

- There are two kinds of species A and B. They compete with each other for the resources of the living environment.
- The resources of the living environment are not enough and there is a maximum quantity of the population of each species.

Symbols and Definitions:

x_A	The population quantity of species A
x_B	The population quantity of species B
r_A	The inherent growth rate of species A
r_B	The inherent growth rate of species B
x_{Am}	The maximum population quantity of species A
x_{Bm}	The maximum population quantity of species B
σ_A	The ratio of species A's specific resources consumption by species B of per quantity unit (relative to x_{Bm}) to species A's specific resources consumption by species A of per quantity unit (relative to x_{Am}), which is used to denote the negative effect of species B to species A and can be regarded as the indicator of species B's competitive force
σ_B	The ratio of species B's specific resources consumption by species A of per quantity unit (relative to x_{Am}) to species B's specific resources consumption by species B of per quantity unit (relative to x_{Bm}), which is used to denote the negative effect of species A to species B and can be regarded as the indicator of species A's competitive force

Model Building:

In this model, species A and species B are competitors, so the growth rate of species A is influenced not only by the population quantity of species A, but also by the population quantity of species B, basing on formula (9) in the block growth model, we can obtain:

$$\frac{dx_A}{dt} = r_A x_A (1 - \frac{x_A}{x_{Am}} - \sigma_A \frac{x_B}{x_{Bm}}) \tag{11}$$

Similarly,

$$\frac{dx_B}{dt} = r_B x_B (1 - \sigma_B \frac{x_A}{x_{Am}} - \frac{x_B}{x_{Bm}}) \tag{12}$$

Hence, the following system of differential equations can be used to describe the model:

$$\begin{cases} \dfrac{dx_A}{dt} = r_A x_A (1 - \dfrac{x_A}{x_{Am}} - \sigma_A \dfrac{x_B}{x_{Bm}}) \\ \dfrac{dx_B}{dt} = r_B x_B (1 - \sigma_B \dfrac{x_A}{x_{Am}} - \dfrac{x_B}{x_{Bm}}) \end{cases} \tag{13}$$

To obtain the results of the two kinds of species which have a relationship of mutual inhibition competition, namely the population quantity of the two kinds of species when $t \to \infty$, we just need to analyze the stability of the model's equilibrium points.

Stability Analysis of the equilibrium points:

If $\frac{dx_A}{dt} = 0$ and $\frac{dx_B}{dt} = 0$, both species A and species B will reach a balanced state where the population quantity will remain constant. Solving the following system of algebraic equations:

$$\begin{cases} f(x_A, x_B) \equiv r_A x_A (1 - \dfrac{x_A}{x_{Am}} - \sigma_A \dfrac{x_B}{x_{Bm}}) = 0 \\ g(x_A, x_B) \equiv r_B x_B (1 - \sigma_B \dfrac{x_A}{x_{Am}} - \dfrac{x_B}{x_{Bm}}) = 0 \end{cases} \tag{14}$$

We can obtain four equilibrium points:

$$P_1(x_{Am}, 0), \quad P_2(0, x_{Bm}), \quad P_3(\frac{x_{Am}(1-\sigma_A)}{1-\sigma_A\sigma_B}, \frac{x_{Bm}(1-\sigma_B)}{1-\sigma_A\sigma_B}), \quad P_4(0,0)$$

Local Stability Analysis:

Linearizing formula (13), we can obtain the coefficient matrix

$$A=\begin{bmatrix} f_{x_A} & f_{x_B} \\ g_{x_A} & g_{x_B} \end{bmatrix}=\begin{bmatrix} r_A(1-\frac{2x_A}{x_{Am}}-\sigma_A\frac{x_B}{x_{Bm}}) & -\frac{r_A\sigma_A x_A}{x_{Bm}} \\ -\frac{r_B\sigma_B x_B}{x_{Am}} & r_B(1-\sigma_B\frac{x_A}{x_{Am}}-\frac{2x_B}{x_{Bm}}) \end{bmatrix} \quad (15)$$

The formulas of p and q are as follows:

$$p=-(f_{x_A}+g_{x_B})\big|_{P_i}, i=1,2,3,4 \quad (16)$$

$$q=\det A\big|_{P_i}, i=1,2,3,4 \quad (17)$$

With formula (16) and (17), we can compute the four equilibrium points' values of p and q. Let $p>0, q>0$, we can obtain the stable conditions. The results are shown in the following table:

Equilibrium Points	p	q	**Stable Conditions**
$P_1(x_{Am},0)$	$r_A-r_B(1-\sigma_B)$	$-r_Ar_B(1-\sigma_B)$	$\sigma_B>1$
$P_2(0,x_{Bm})$	$-r_A(1-\sigma_A)+r_B$	$-r_Ar_B(1-\sigma_A)$	$\sigma_A>1$
$P_3(\frac{x_{Am}(1-\sigma_A)}{1-\sigma_A\sigma_B},\frac{x_{Bm}(1-\sigma_B)}{1-\sigma_A\sigma_B})$	$\frac{r_A(1-\sigma_A)+r_B(1-\sigma_B)}{1-\sigma_A\sigma_B}$	$\frac{r_Ar_B(1-\sigma_A)(1-\sigma_B)}{1-\sigma_A\sigma_B}$	$\sigma_A<1,\sigma_B<1$
$P_4(0,0)$	$-(r_A+r_B)$	r_Ar_B	**Unstable**

The stable conditions above can only lead to local stability, what we want is the global stability, that is: no matter what the initial value is, the equilibrium point will always be stable. Hence, based on the local stability analysis, we implement the phase orbit analysis.

Global Stability Analysis:

In the system of algebraic equations, formula (14), let

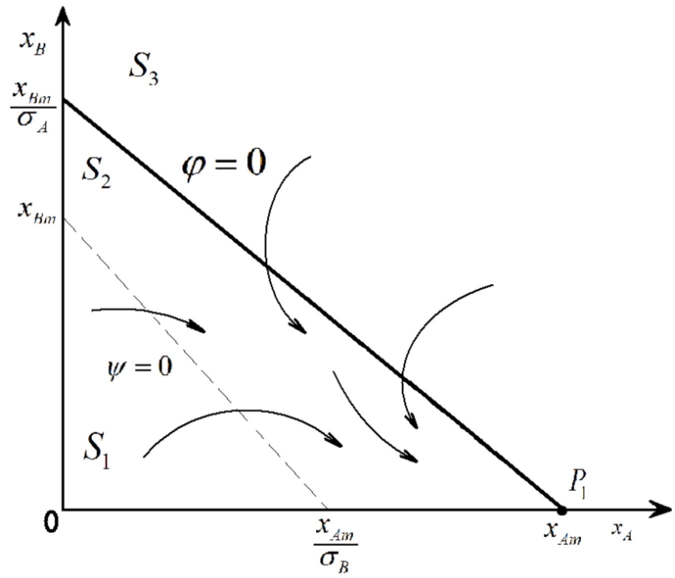
$$\varphi(x_A,x_B)=1-\frac{x_A}{x_{Am}}-\sigma_A\frac{x_B}{x_{Bm}} \quad (18)$$

$$\psi(x_A,x_B)=1-\sigma_B\frac{x_A}{x_{Am}}-\frac{x_B}{x_{Bm}} \quad (19)$$

The positions of the two lines $\varphi(x_A, x_B) = 0$ and $\psi(x_A, x_B) = 0$ vary according to the different values of σ_A and σ_B.

1. $\sigma_A < 1, \sigma_B > 1$

The two lines $\varphi(x_A, x_B) = 0$ and $\psi(x_A, x_B) = 0$ divide the phase plane $(x_A, x_B \geq 0)$ into three areas S_1, S_2 and S_3, as is shown below:



The properties of the three areas are as follows:

$$S_1 : \frac{dx_A}{dt} > 0, \frac{dx_B}{dt} > 0 \tag{20}$$

$$S_2 : \frac{dx_A}{dt} > 0, \frac{dx_B}{dt} < 0 \tag{21}$$

$$S_3 : \frac{dx_A}{dt} < 0, \frac{dx_B}{dt} < 0 \tag{22}$$

- If the path curve starts to move from a point in S_1, according to formula (20), $x_A(t)$ and $x_B(t)$ will increase over time, the path curve will move towards upper right and enter into S_2.
- If the path curve starts to move from a point in S_3, according to formula (22), $x_A(t)$ and $x_B(t)$ will decrease over time, the path curve will move towards lower left and enter into S_2.

• If the path curve starts to move from a point in S_2, according to formula (22), $x_A(t)$ will increase while $x_B(t)$ will decrease over time, the path curve will move towards lower right and it will either enter into S_3 or tend to the point P_1, but it is impossible to enter into S_3, because:

If the path curve enters into S_3 through the line $\varphi(x_A, x_B) = 0$ at time t_1, we can derive :

$$\frac{dx_A}{dt}\Big|_{t=t_1} = 0 \tag{23}$$

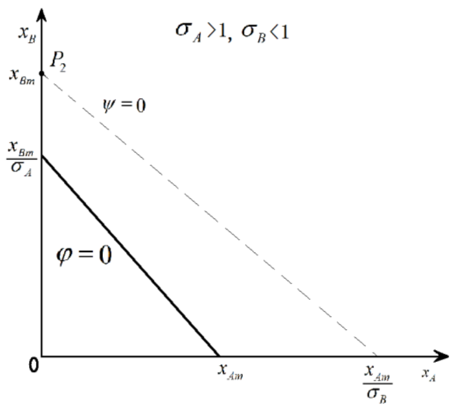
However, computing the derivative of the formula (11) at time t_1, we can obtain

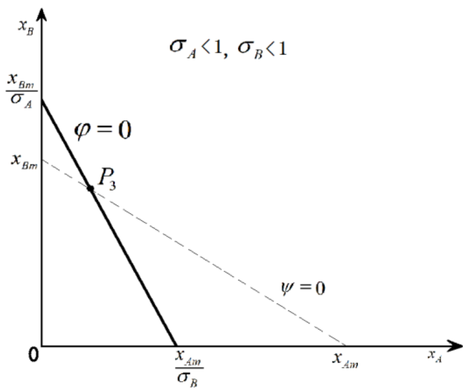
$$\frac{d^2x_A}{dt^2}\Big|_{t=t_1} = -\frac{r_A\sigma_A}{x_{Bm}}x_A(t_1)\frac{dx_B}{dt}\Big|_{t=t_1} > 0 \tag{24}$$

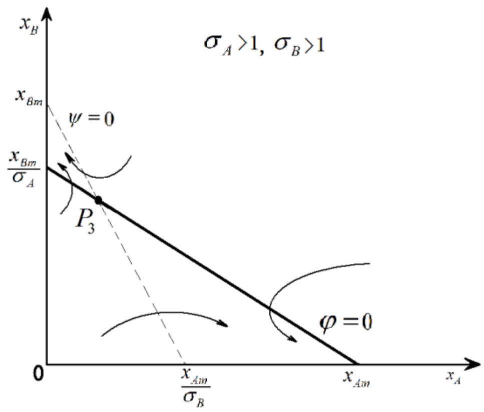
As a result, $\frac{dx_A}{dt}$ will remain increasing and cannot be zero.

From the analysis above, we can conclude that no matter where the path curve starts, it will always tend to the point P_1, namely P_1 will be a equilibrium point of global stability in the condition that $\sigma_A < 1, \sigma_B > 1$.

Similarly we can get the other conditions about the global stability.







The conditions are summarized in the following table:

Equilibrium Points	**Stable Conditions**
$P_1(x_{Am},0)$	$\sigma_A<1,\sigma_B>1$
$P_2(0,x_{Bm})$	$\sigma_A>1,\sigma_B<1$
$P_3(\frac{x_{Am}(1-\sigma_A)}{1-\sigma_A\sigma_B},\frac{x_{Bm}(1-\sigma_B)}{1-\sigma_A\sigma_B})$	$\sigma_A<1,\sigma_B<1$
$P_4(0,0)$	**Unstable**

We compare landlines to species A, cell phones to species B, our society to the living environment and ourselves (consumers) to the resources that species A and species B compete for to live. According to the competitive model above, σ_A can be used to denote the competitive force of the species B, while σ_B can be used to denote the competitive force of the species A.

The Solution to Requirement 1

Overview:

According to the requirement 1, all the landlines will be replaced entirely by the cell phones, so the cell phones have a much stronger competitive force than the landlines. According to the competitive model, if the equilibrium point is $P_2(0,x_{Bm})$, then $\sigma_A>1$ and $\sigma_B<1$.

The electricity utilization by the landlines consists of two parts, the utilization by the phones and the utilization by the telecom operators.

The electricity utilization by the cell phones also consists of two parts, the utilization by charging the batteries and the utilization by cell sites, which are the basic parts of the mobile network.

Cell phones do not last as long as landline phones, if a cell phone get lost or break, according to Jorgen Stig Norgard, it will cause indirect energy consumption. As for landline phones, the probability that a cell phone gets lost or break is quite low, thus we do not take the indirect energy consumption of landline phones into consideration.

Assumptions:

- The cell phones have a much stronger competitive force than the landlines.
- The capacity of a cell phone's battery is 1000mAh on average and the charging voltage is 4.2v .
- The efficiency of a recharger is 33%.
- The batteries of cell phones are recharged every two days on average.
- The recharger of a cell phone is pulled out as soon as the battery is full.
- A cell phone has a probability of 20% to get lost or break, and the indirect energy consumption caused is two times of the usual energy consumption.

Symbols and Definitions:

x_A	The quantity of landline phones
x_B	The quantity of cell phones
C_A	The electricity utilization by the landlines
C_B	The electricity utilization by the cell phones
C_1	The electricity utilization by the phones in a year
C_2	The electricity utilization by the telecom operators in a year
C_3	The electricity utilization by the cell phones' rechargers in a year
C_4	The electricity utilization by the cell phones' cell sites in a year
C_5	The electricity utilization of the indirect energy consumption caused by cell phones' lost and breakdown in a year

P_0 The probability that a cell phone gets lost or break

Computation:

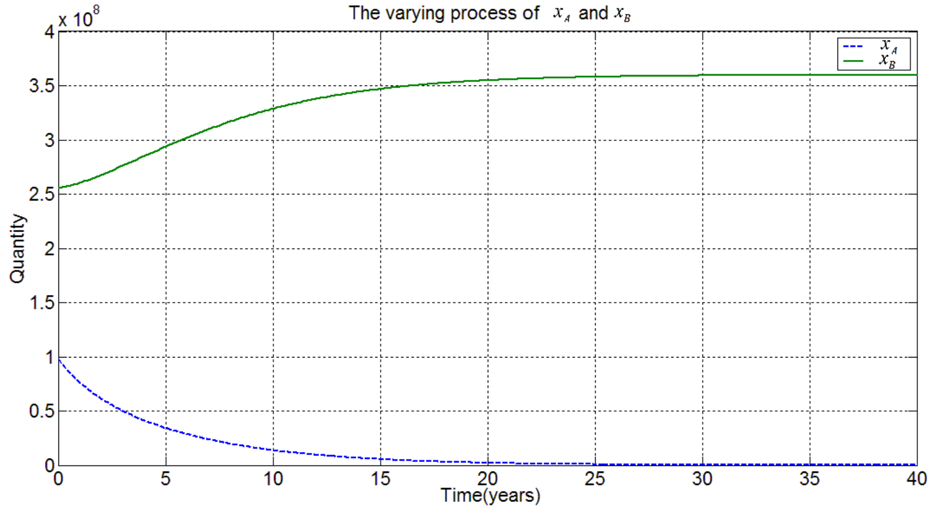
The electricity utilization by the landlines in a year is:

$$C_A = x_A(C_1 + C_2) \tag{25}$$

The electricity utilization by the landlines in a year is:

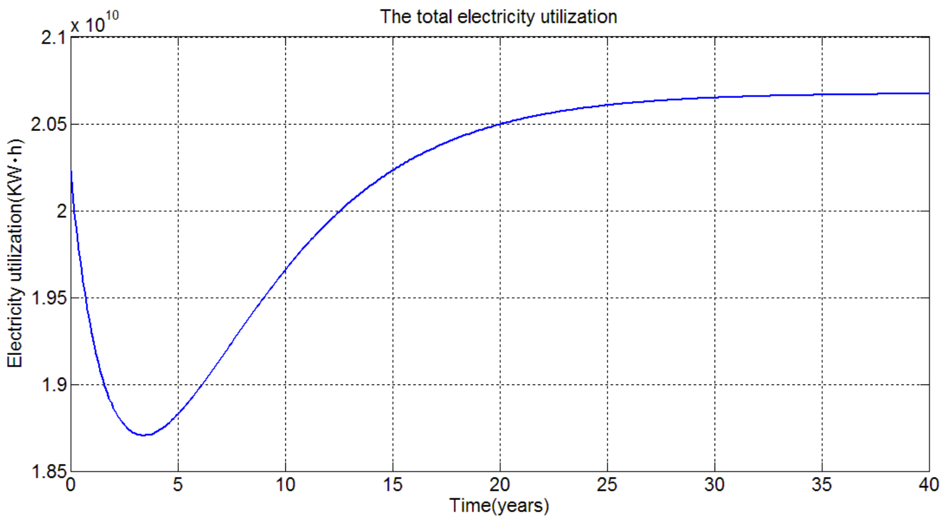
$$C_B = x_B(C_3 + C_4) + x_B P_0 C_5 \tag{26}$$

The varying process of x_A and x_B are as follows:



The varying process of x_A and x_B

The varying process of the total electricity utilization $C = C_A + C_B$ is as follows:



The electricity utilization during the transition and during the steady state is as follows:

Time(year)	2010	2014	2018	2022	2026	2030	2034	2038
The total electricity utilization(10^8kwh)	187.3	191.3	197.9	202.2	204.6	205.6	206.3	206.6

The Solution to Requirement 2

Overview:

We are required to find the optimal way of providing phone service to a second Pseudo US from the energy perspective, so the energy consumption is the most important factor determining the competitive force of the landlines and cell phones. In requirement 1, it is supposed that all the landlines will be replaced by cell phones, which, however, will not take place in reality. Cell phones have many social consequences and uses that landlines do not allow, while landlines also have some advantages that cannot be exceeded by cell phones, such as the permanence that landlines have a much smaller probability to get lost or break. Hence, the landlines will not be replaced by cell phones, nor will cell phones be replaced by landlines, they will coexist with each other. According to the competitive model, the equilibrium point will be $P_3(\frac{x_{Am}(1-\sigma_A)}{1-\sigma_A\sigma_B},\frac{x_{Bm}(1-\sigma_B)}{1-\sigma_A\sigma_B})$, which is the optimal point expected, and we can derive that $\sigma_A<1,\sigma_B<1$.

Computation:

The current electricity utilization by the landlines in a year is:

$$C_A=0.92\times10^{10}kwh$$

The current electricity utilization by the cell phones in a year is:

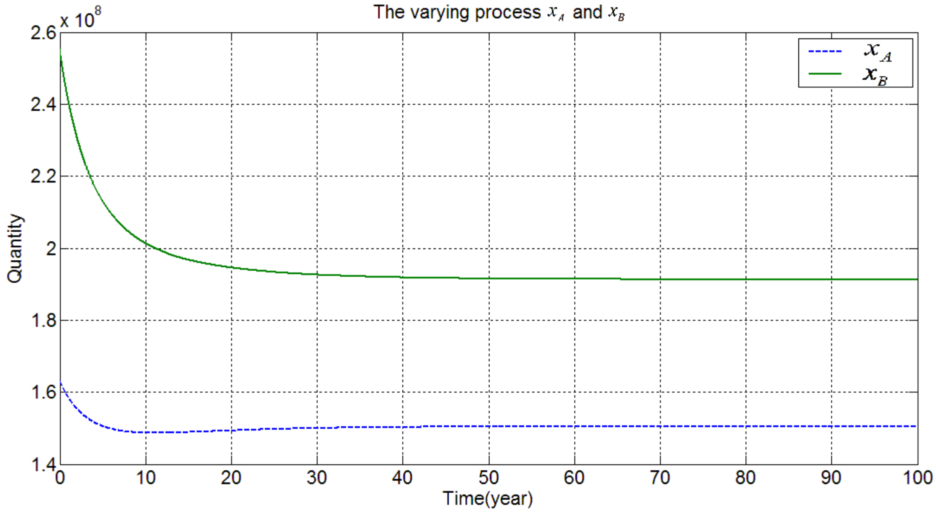
$$C_B=1.36\times10^{10}kwh$$

According to the analysis above, there is a trade-off relationship between σ_A and σ_B, if σ_A increases, σ_B will decrease; if σ_A decreases, σ_B will increase. Suppose $\sigma_A+\sigma_B=1$, we can obtain:

$$\sigma_A = \frac{C_A}{C_A + C_B} = 0.5965$$

$$\sigma_B = \frac{C_B}{C_A + C_B} = 0.4035$$

According to the competitive model, the varying processes of landlines and cell phones are as follows:



The equilibrium point (151230000,191300000) is the optimal point expected, thus the optimal way of providing phone service is to provide 151230000 landlines and 191300000 cell phones.

A Further Discussion:

Although the energy consumption is the most important factor, it cannot determine the competitive force of landlines and cell phones absolutely. According to the data of recent years,

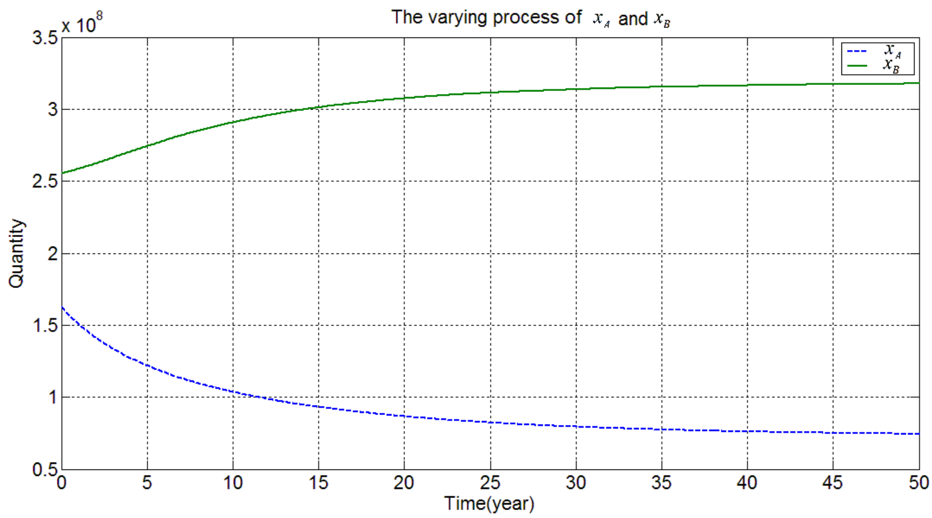
Year	Quantity of landlines	Quantity of cell phones
2000	192513000	109478000
2001	191570800	128500000
2002	189250100	141800000
2003	182933300	160637000
2004	177690700	184819000
2005	175160900	213000000
2006	167459900	241800000
2007	163170400	255395600

The quantity of cell phones keeps increasing, implying that cell phones have the stronger competitive force, which seems contrary with our results above that the quantity of cell phones decreases. However, the results above are obtained basing on the competitive force determined mainly by the energy consumption, whose data of recent years is as follows:

Year	Energy consumption of landlines (10^8kwh)	Energy consumption of cell phones (10^8kwh)	Quantity of cell sites
2000	108.83	60.980	95733
2001	108.29	72.591	114059
2002	106.98	83.396	131350
2003	103.41	93.826	147719
2004	100.45	110.60	174368
2005	99.018	113.70	178025
2006	94.664	126.37	197576
2007	92.240	134.48	210360

From the table above, we can derive that the cell sites increase quickly with the increase of cell phones, which results in the quick increase of cell phones' energy consumption. In the year 2004, the energy consumption of cell phones exceeds the energy consumption of the landlines, as a result, cell phones have the weaker competitive force. So if considering the competitive force just from the energy perspective, the result we obtain above is right.

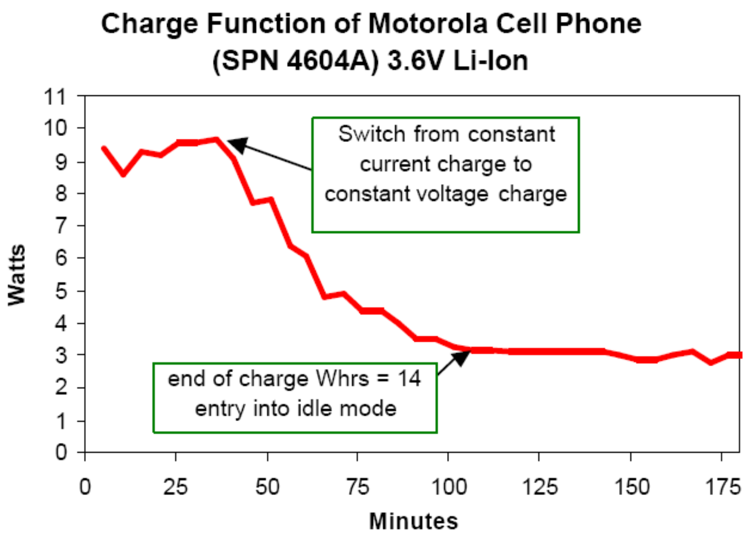
From the analysis above, we can derive that it is unilateral to determine the competitive force just from the energy perspective. In fact, cell phones have many social consequences and uses that landline phones do not allow, such as being very convenient to use, having more kinds of functions than landlines and so on. Thus, the cell phones will have a stronger competitive force, suppose $\sigma_A = 0.7, \sigma_B = 0.3$, we can get a new curve about the varying process of landlines and cell phones.



The Solution to Requirement 3

Overview:

Many people always keep their cell phones' rechargers plugged in, or charge their phones every night even if the battery is full. This wasteful practice is often neglected by many people but causes great electricity waste.



We classify the use of the rechargers into three kinds:

- Proper use: The recharger is only plugged in when charging a battery and it is pulled out as soon as the battery is full
- Idle use: There is a battery in the recharger, but the battery is full.
- Standby use: There is no battery in the recharger, but it is plugged in all the time.

Symbols and Definitions:

t_1 The average charging time of a battery

k The average percent of a battery's electricity quantity left when being charged

η The average efficiency of a charger

c_0 The average capacity of a battery

P_{ca} The average power of a recharger when it is active

P_{ci} The average power of a recharger when it is idle

P_{cs} The average power of a recharger when it is standby

p_i The percent of the rechargers of idle use

p_s The percent of the rechargers of standby use

x_c The quantity of rechargers, which equals the quantity of cell phones x_B

C The total electricity wasted by the rechargers for a year

Computation:

The charging time of a battery is:

$$t_1 = \frac{c_0 k}{p_{ca}\eta} \tag{27}$$

Suppose the average sleeping time is 8 hours, the electricity wasted by a recharger of idle use for a year is:

$$C_i = p_{ci}(8 - t_1) \times 3600 \times 365 \tag{28}$$

The electricity wasted by a recharger of standby use for a year is:

$$C_s = p_{cs}(24 - t_1) \times 3600 \times 365 \tag{29}$$

If a recharger is plugged in when it does not charge a battery and it is not pulled out when charging a battery at night until the user wake up in the morning, even if the battery is full. The electricity wasted by a recharger of this use for a year is:

$$C_{is} = \{p_{cs}(24-8) + p_{ci}(8-t_1)\} \times 3600 \times 365 \qquad (30)$$

The total electricity wasted by the rechargers for a year is:

$$C = x_c(p_i - p_i p_s)C_i + x_c(p_s - p_i p_s)C_s + x_c p_i p_s C_{is} \quad (31)$$

According to the assumptions in requirement 1, the battery is recharged every two days, so $k = 50\%$. $P_{ci} = 2.24w, P_{cs} = 0.14w$, $P_{ca} = 3.68w$, $\eta = 33\%$, supposing $p_i = 60\%, p_s = 50\%$, we can obtain that $C = 4.84 \times 10^5$ barrels of oil.

The Solution to Requirement 4

Overview:

In fact, the electricity wasted by the improper use of rechargers exists commonly. Besides cell phones' rechargers, TV, DVR and other types of rechargers also cause waste of electricity when left plugged in but not charging the device (the standby mode).

Symbols and Definitions:

P_s	The average standby power of a specific recharger
T_s	The time in the standby mode one day

Computation:

The electricity wasted by one given appliance in standby mode one day is:

$$USEC = P_S \cdot T_S$$

The electricity wasted by all the rechargers of the same type of one household one day is:

$$HSEC_i = \sum_{i=1}^{N} USEC_i$$

Where N is the number of the rechargers. Hence, the electricity wasted by all the rechargers in standby mode in the whole country is:

$$E_S = \sum_{N=1}^{U} H_N \cdot HSEC_N$$

Where U is the maximum number of one given appliance in a household, and H_N

is the number of the household which have N units in the whole country.

As there are various types of rechargers, it is difficult to get the complete data of every one, however, we find that the household's standby consumption is 24% of the whole electricity consumption. Hence, we can obtain the total electricity wasted of the current US by the following formula:

$$C_{standby} = \frac{C_{all} \times \eta \times 24\%}{365} \tag{32}$$

Where C_{all} is the US's electricity consumption in a year, and η is the percentage of residential electricity consumption. We can obtain:

$$C_{standby} = 6.65 \times 10^5 \text{ barrels of oil per day}$$

The Solution to Requirement 5

Overview:

To predict the energy needs in the next 50 years, we need to know the competitive force of cell phones and landlines. According to the requirement, the competitive force has a relationship with population and economic, so we regard the competitive force as a function of population and economic, and we write it as:

$$The\ competitive\ force = f\,(population, economic)$$

Implementing the regress analysis with SPSS based on the data of 2000-2007, the results are as follows:

Coefficients(a)

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	**t**	**Sig.**	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	7.370	0.440		16.744	0.000			
	GDP	0.000	0.000	0.211	2.765	0.051	-0.713	0.810	0.127
	Population	0.000	0.000	-1.157	-15.134	0.000	-0.988	-0.991	-0.695

a. Dependent Variable: σ_B

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.084	2	0.042	235.285	0.000
	Residual	0.001	4	0.000		
	Total	0.085	6			

a. Predictors: (Constant), Population, GDP

b. Dependent Variable: σ_B

Coefficients(a)

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Partial	Part
1	(Constant)	-3.298	0.587		-5.621	0.005			
	GDP	0.000	0.000	0.093	0.574	0.597	0.816	0.276	0.056
	Population	0.000	0.000	0.905	5.585	0.005	0.979	0.941	0.544

a. Dependent Variable: σ_A

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.032	2	0.016	50.783	0.001
	Residual	0.001	4	0.000		
	Total	0.033	6			

a. Predictors: (Constant), Population, GDP

b. Dependent Variable: σ_A

The significance of σ_A is 0.000, the significance of σ_B is 0.001, and we can conclude that the two functions are quite significant. Then we can obtain:

$$\sigma_A = 1.62\times10^{-7}\times GDP + 1.16\times10^{-5}\times Population - 3.298 \quad (33)$$

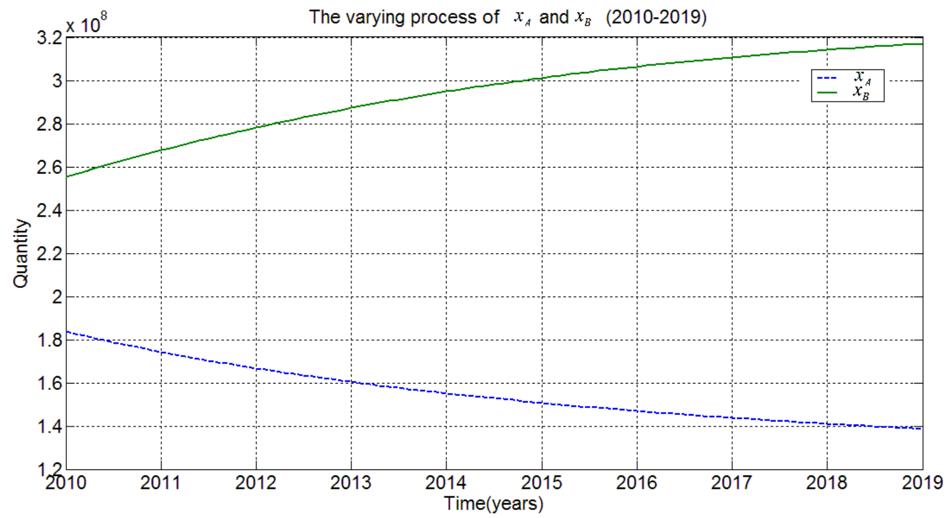
$$\sigma_B = 5.85\times10^{-7}\times GDP - 2.4\times10^{-5}\times Population + 7.4856 \quad (34)$$

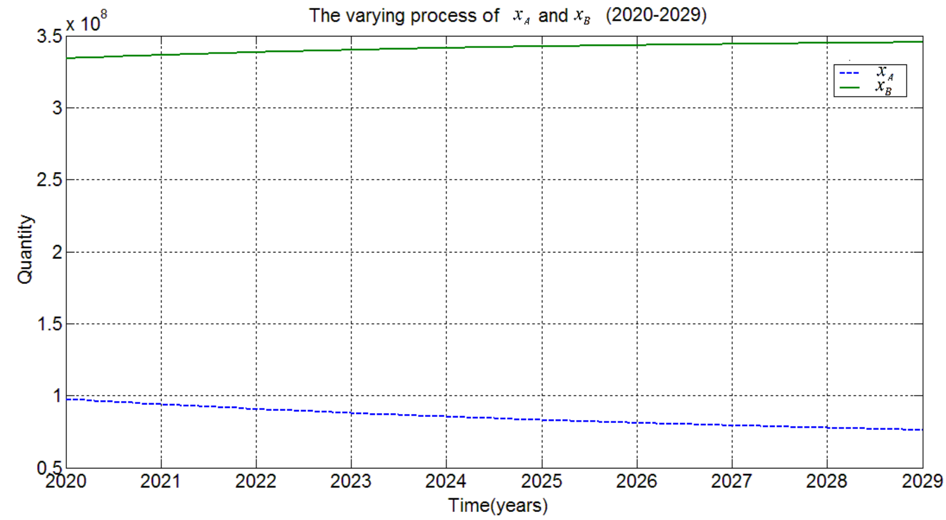
σ_A increases with the growth of population and GDP, implying that the cell phones' competitive force is becoming stronger, while σ_B decreases with the growth of population and GDP, implying that the landlines' competitive force is becoming weaker. According to the analysis above, however, landlines will not be replaced by the cell phones and the cell phones cannot increase without limit. Hence, we suppose that the maximum value of σ_A is 0.9 and the minimum value of σ_B is 0.1.

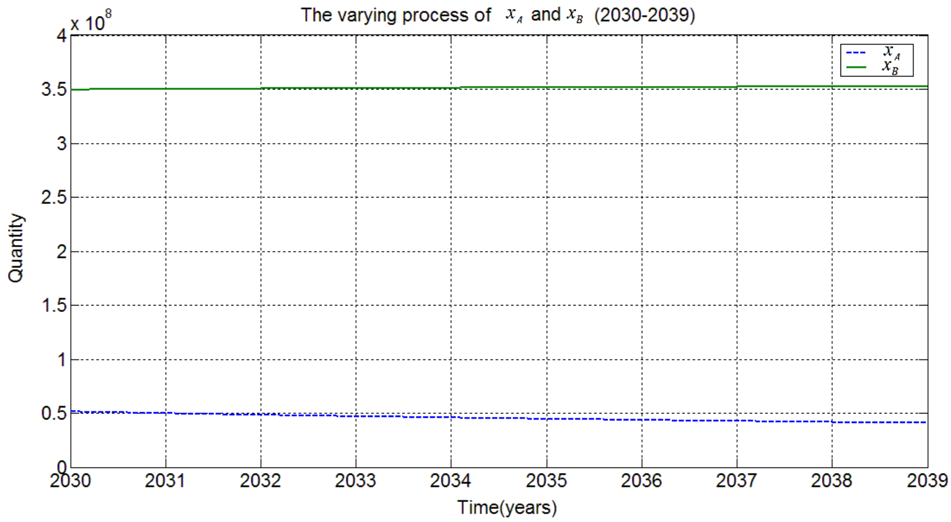
According to ….the data of GDP and population are as follows:

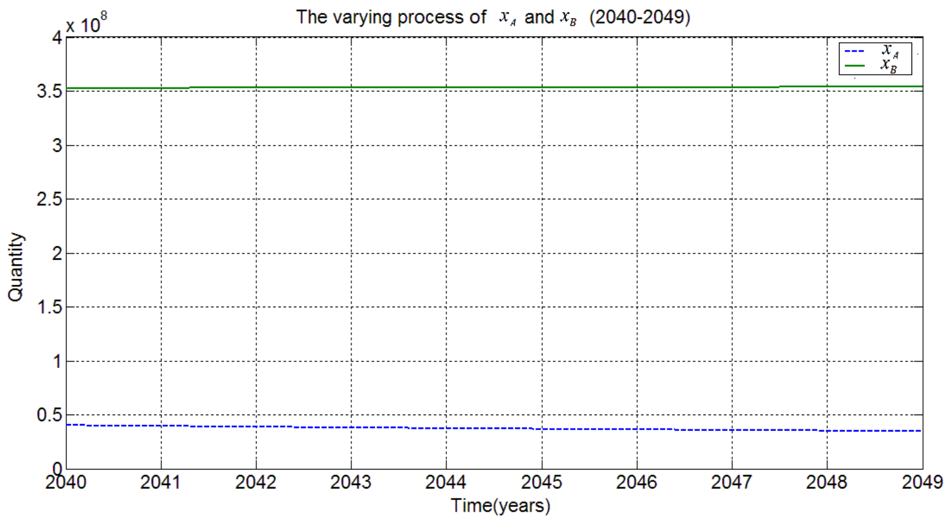
Year	σ_A	σ_B
2008	0.25	0.28
2009	0.28	0.22
2010	0.31	0.15
2011	0.34	0.10
2012	0.37	0.10
2013	0.40	0.10
2014	0.43	0.10
2015	0.47	0.10
2016	0.50	0.10
2017	0.53	0.10
2018	0.56	0.10
2019	0.59	0.10
2020	0.63	0.10
2021	0.66	0.10
2022	0.69	0.10
2023	0.72	0.10
2024	0.75	0.10
2025	0.79	0.10
2026	0.82	0.10
2027	0.85	0.10
2028	0.90	0.10
2029	0.90	0.10
.	.	.
.	.	.
.	.	.
2058	0.90	0.10

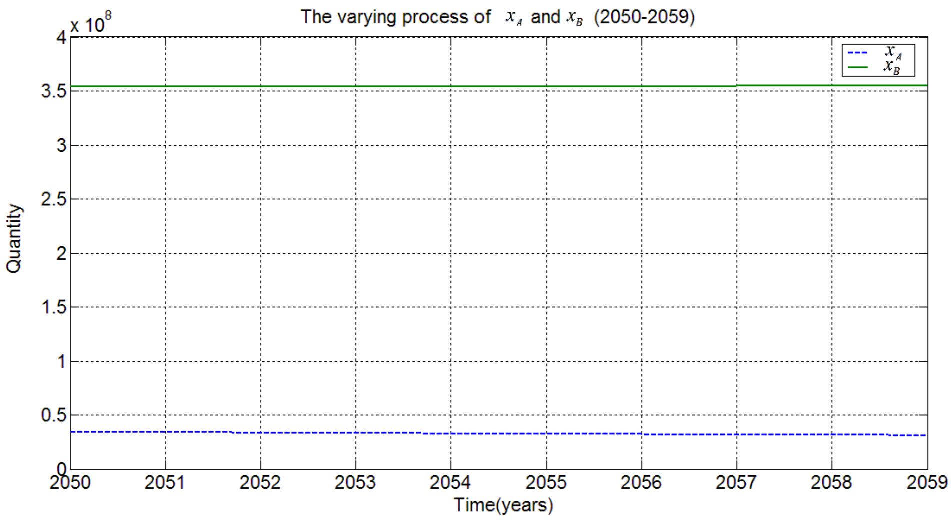
The varying process of x_A and x_B for each 10 years for the next 50 years are as follows:


The varying process of x_A and x_B (2010-2019)
x 10^8
Quantity
Time(years)
x_A
x_B


The varying process of x_A and x_B (2020-2029)
x 10^8
Quantity
Time(years)
x_A
x_B


The varying process of x_A and x_B (2030-2039)
x 10^8
Quantity
Time(years)
x_A
x_B





The varying process of energy needs is as follows:

Year	2019	2029	2039	2049	2059
Energy Needs （10^7barrels of oil）	2.0936	2.0611	2.0755	2.2051	2.3787

Analysis:

From the results above, we can derive that the cell phones have the stronger competitive force and will increase over time. This is a reflection of the fact.

- The cell phones have more functions and they are quite popular.
- As with the development of economic and technology, the cell phones will have a lower cost but higher performance.
- The cell phones are quite convenient to use, which have a positive effect on the

cell phones' competitive force.

Strengths and Weaknesses

Strengths

- All approaches to the problem is base on the main model: competitive model, and the model can be in common use.
- Variety of influences have been discussed to modify the competitive force between cell phone and landline phone
- Use a variety of modeling techniques in getting data.
- Use regression analysis base on economy and population to accurately get the competitive force variation.

Weakness

- Some part of the data is estimated without exact reference material.
- Consider few factor of the pay telephone.
- Does no distinguish various types of cell phone, of which the electricity consumption could vary.

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