Team Control Number

33229

Problem Chosen

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T1		F1	
T2		F2	
T3		F3	
T4		F4	

2015 Mathematical Contest in Modeling (MCM) Summary Sheet
(Attach a copy of this page to your solution paper.)

Type a summary of your results on this page. Do not include the name of your school, advisor, or team members on this page.

Sustainable Development Analysis

Summary

Sustainable development, including economy, ecology and society, is of great significance to develop a harmonious and healthy world.

26 significant criteria of 5 categories are selected to build a sustainability measure. We consider correlation between these criteria and sustainable development carefully to obtain weight for each criterion by means of AHP and find out the equation for the measure P. Next, According to the value of P, we rank the state of sustainability into six levels. In this way we quantify the dividing point of sustainable and unsustainable countries.

We select Uganda as our case of study. After normalizing raw data, we came to the conclusion that Uganda is unsustainable country according to its performance in the AHP equation. Considering the capital factors and Uganda's weak points in development comprehensively, we select GNI per capita, Forest area percentage and urban population percentage as main arguments to draw out a plan for ICM. Correspondingly, our plan consists of three parts and provides feasible programs and policies in economy, ecology and society.

When analyzing effects our plan has on Uganda, we considered its current situation carefully, and classified these criteria into three types according to their effects, and quantify their effects separately. When analyzing the investment of each program, we obtain the fitting curve of the criteria to quantify how much aids Uganda needs each year in the next 20 years. According to our plan, we predict the future with the aid of our plan, and compared it with the development tendency without our plan, proving the positive effect our each program and policy has on the sustainability of Uganda. The total influence of all the programs and policies improve the sustainability of development and make Uganda a sustainable country in the next 20 years.

Finally, We define a measure R to evaluate the cost performance of each part of the program, and come to a conclusion that part A gets the "most bang for the buck".

Sustainable Development Analysis

1 Introduction

In the report *Our Common Future*, The United Nations World Commission on Environment and Development defined sustainable development: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Sustainable development emphasizes the balance between economic development and ecosystem. Nowadays, it has been widely accepted that sustainable development consists of environment aspect, social aspect and economic aspect.

How to gauge the degree of sustainability and distinguish more sustainable countries from less sustainable ones? Obviously, it is practical and useful to define a quantitative measure instead of qualitative measure. We will build a model to get the measure and give an example to test its practicality.

Next, we select Uganda, a poor country in East Africa, as the object of study. Based on the present situation of Uganda, we provided a universal plan using our model to help The International Conglomerate of Money (ICM) to invest. We also verify the reliability of the plan with government statistics and draw a conclusion that improvement of Uganda in sustainable development is promising.

2 Basic assumptions

- We quantity the annual help from ICM in unit ‘year’
- ICM influence Uganda at the beginning of the year
- Data collected are reliable.
- The plan is carried out as planned without any interference.

3 Definitions and Key Terms

- P assessing measure of sustainable development
- x' initial figure
- x relative figure(normalized)
- W weight of each criteria
- m year(from curve fitting origin point)
- m' year(from current year2015), $m'=0$ means year 2015
- $E_{m'}$ figure of certain criterion at the end of m' ,without our plan

- $Y_{m'}$ figure of certain criterion at the end of m' ,with our plan
- $T_{m'}$ figure of investment at beginning of m' (in the plan)

4 The Development of Model

4.1 Analysis Preparation

To reserve finite resources for future generations, we tie the carrying capacity of natural system with social, economic, and technological challenges faced by humanity. We propose a method for assessing sustainable development. Our criteria for sustainable development include economic growth, technology advancement, population growth ,energy use, equality, poverty and so on. These criteria are carefully selected after we referred to information about policies and assessment methods worldwide .We set priorities, classify these factors into five groups and use them to evaluate how sustainable a country is .The table below shows different criteria and their priorities.

Table 1

indicators and classifications

<table>
<tr><th>A Highest</th><th>B Middle</th><th>C Lowest</th></tr>
<tr><td rowspan="17">A Sustainable developme nt</td><td rowspan="5">B1 ecosystem &energy</td><td>C11CO2 emissions</td></tr>
<tr><td>C12Nitrous oxide emissions from agricultural biomass burning, industrial activities, and livestock management</td></tr>
<tr><td>C13Forest area</td></tr>
<tr><td>C14 electricity use</td></tr>
<tr><td>C15GEF benefits index for biodiversity[1]</td></tr>
<tr><td rowspan="6">B2 Technology &Population</td><td>C21population density</td></tr>
<tr><td>C22Population growth (annual)</td></tr>
<tr><td>C23 Literacy rate, adult total(% of people ages 15 and above)</td></tr>
<tr><td>C24Ratio of female to male tertiary enrollment</td></tr>
<tr><td>C25 Research and development expenditure</td></tr>
<tr><td>C26 Technicians in R&D (per million people)</td></tr>
<tr><td rowspan="6">B3 Economy and Growth</td><td>C31 GDP per capita</td></tr>
<tr><td>C32 Vehicles(per km of road)</td></tr>
<tr><td>C33 Industry, value added (% of GDP)</td></tr>
<tr><td>C34Services, etc., value added (% of GDP)</td></tr>
<tr><td>C35Urban population (% of total)</td></tr>
<tr><td>C36Total debt service (% of exports of goods, services and primary income)</td></tr>
</table>

[1] GEF benefits index for biodiversity is a composite index of relative biodiversity potential for each country based on the species represented in each country, their threat status, and the diversity of habitat types in each country. The index has been normalized so that values run from 0 (no biodiversity potential) to 100 (maximum biodiversity potential).

	B4Improved living standards	C41Life expectancy at birth, total (years)
		C42Malnutrition prevalence, weight for age (% of children under 5)
		C43 GNI per capita
		C44 Health expenditure per capita
		C45 Improved water source (% of population with access)
		C46 Poverty headcount ratio at national poverty lines (% of population)
	B5 aids	C51Investment in energy with private participation
		C52Net ODA received per capita [2]
		C53Public spending on education, total (% of government expenditure)

4.2 Normalizing Criteria

Since we use different units, different ways of underlying collected criteria ,these figures may not be reliable enough to satisfy our needs. For this reason , we normalized our matrix A by making equal to 1 the sum of the entries .In this way, we are able to evaluate the sustainable development of a country or a region using a relative value from 0 to 1.

Parameters

x' raw data, these figures are showed as we collected.

x the normalized data

$x_{\max}$ The largest figure we collected before being normalized

$x_{\min}$ The smallest figure we collected before being normalized

- If there is a positive correlation between the figure and sustainable development, then we have

$$x = \frac{x' - x_{\min}}{x_{\max} - x_{\min}}$$

We obtain normalized criteria like 'GDP' in this way. In our model, positive criteria include: C13, C14, C15, C21, C22, C23, C25, C26, C31, C32, C33, C34, C35, C41, C43, C44, C45, C51, C52, C53.

- If there is a negative correlation between the figure and sustainable development, then we have

$$x = \frac{x_{\max} - x'}{x_{\max} - x_{\min}}$$

[2] Net official development assistance (ODA) per capita consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by official agencies of the members of the Development Assistance Committee (DAC), by multilateral institutions, and by non-DAC countries to promote economic development and welfare in countries and territories in the DAC list of ODA recipients; and is calculated by dividing net ODA received by the midyear population estimate. It includes loans with a grant element of at least 25 percent (calculated at a rate of discount of 10 percent).

We use this way to get normalized figures like ‘Malnutrition prevalence’. In our model, negative criteria include:C11, C12, C36, C42, C46.

- If the closer indicators are to a certain value, the more sustainable a country is, then we have

$$x = 2\left|\frac{x'}{x'+1} - \frac{1}{2}\right|$$

We use this method to normalize figures with respect to equality. Indicators like‘Ratio of female to male tertiary enrollment ’ are normalized in this way. In our model, this kind of criteria are converted and considered negative criteria, which include C24.

Normalized figure ranging from 0 to 1 make it easier for us to analyze and quantify influence each factor has on sustainable development, as well as guarantee the correctness of the model.

4.3 Method description: The *Analytic Hierarchy Process* (AHP)

We manage to sort out different levels of sustainable development.

It is noticeable that these criteria are not totally exclusive or related and may sometimes vary under different circumstances, so it can be difficult to make complex decisions. According to our pairwise comparisons of the criteria, we generate a weight and a separate score for each evaluation criterion regarding its importance and performance. We obtain a sustainability measure by multiplying all weighed criteria.

4.3.1 Arranging Criteria by Rank

We have already classified criteria and set priorities for each one in our hierarchy structure. The whole structure consists of three ranks; The highest is our final aim to assess how sustainable a country is; The middle (B1-B5)is to describe basic criteria with respect to the different parts they play and their overall areas; the lowest is composed of these different criteria(C11-C15，C21-C26，C31-C36，C41-C46，C51-C53).

4.3.2 Constructing the Matrix of Separate Scores

We normalize those criteria in a certain way(by making equal to 1 the sum of the entries on each column) before computing a m×m real matrix by making pairwise comparisons and assign a score and weight to each entry ajk with regard to its importance and performance. The values in the matrix are decided by pairwise consistent construction, see table 2.

Table 2

Interpretation of Judging Matrix

Values of *ajk*	Interpretation
1	J and k are equally important
3	J is slightly more important than k
5	J is more important than k
7	J is much more important than k
9	J significantly more important than k
2、4、6、8	The importance is between two adjacent rank

We obtain six matrix B1~B5 and A. All these matrix are shown in appendix 1.

4.3.3 The Check for Consistency

Maximum eigenvalue and the vector of criteria weights of matrix A are obtained :

$$\lambda_{mA} = 5.1148$$

$$W_A = (0.2489\ \ 0.1216\ \ 0.3494\ \ 0.2118\ \ 0.0683)^T$$

We estimate the consistency index by computing

$$CR_A = CI_A / RI_5 = 0.0256 < 0.1$$

This result is what we expect: CR is much smaller than 0.1 so that the inconsistency can be tolerated. This means that our decision is reasonable.

To approach more detailed results ,you may refer to appendix 2.

4.3.4 Measure Result

We verify our analytical results ,where we have sustainability measure as

$$W_{AC}\left(Cij\right) = W_A\left(Bi\right) W_{Bi}\left(Cij\right)$$

Comparing the consistency index regarding the sustainability measure, we have

$$CR = 0.0576 < 0.1$$

This result indicates that our entire hierarchical structure meet the demand of consistency.

We have a sustainability measure:

$$P = 0.0918x_{11} + 0.0177x_{12} + 0.0316x_{13} + 0.0723x_{14} + 0.0356x_{15}$$

$$+0.0063x_{21} + 0.0131x_{22} + 0.0345x_{23} + 0.0313x_{24} + 0.0198x_{25} + 0.0167x_{26}$$

$$+0.0245x_{31} + 0.0417x_{32} + 0.0645x_{33} + 0.1029x_{34} + 0.1029x_{35} + 0.0129x_{36}$$

$$+0.0324x_{41} + 0.0851x_{42} + 0.0102x_{43} + 0.0096x_{44} + 0.0259x_{45} + 0.0486x_{46}$$

$$+0.0467x_{51} + 0.0080x_{52} + 0.0136x_{53}$$

This score is used to sort out countries regarding their sustainable development.

4.4 Ranking and Assessment

As each criterion has a group of normalized figure ranging from 0 to 1, and the total weight of 26 criteria adds up to

$$\sum_i \sum_j W(\mathrm{Cij}) = 1,$$

so the measure P should range from 0 to 1.

According to the 26 criteria and countries, we substitute normalized figure into the equation and calculate sustainability measure P of different countries. Then we can rank countries into 6 level by the value of P. You may refer to Table 3 for detailed ranking basis.

Table 3

Ranking Basis of P

Ranking	Assessment Score P	sustainable/unsustainable
I	$0.9 < P \leq 1.0$	sustainable
II	$0.7 < P \leq 0.9$	sustainable
III	$0.5 < P \leq 0.7$	sustainable
IV	$0.3 < P \leq 0.5$	unsustainable
V	$0.1 < P \leq 0.3$	unsustainable
VI	$0.0 \leq P \leq 0.1$	unsustainable

Class-I indicates a high level of sustainable development. A country of class-I may already reaches ideal figure in all criteria. Class- VI indicates a low level on the opposite. A country of class- VI is in desperate needs of aids and measures to improve sustainability of development.

When a country or region has a sustainability measure of $0.0 \leq P \leq 0.5$ (class IV, V and VI), we determine it to be unsustainable. Otherwise, When the sustainability measure reaches $0.5 < P \leq 1.0$ (class I, II and III), we determine it to be sustainable.

Table 4

Example of Sustainable Country and Unsustainable Country

Country	Sustainable Measure	Level	Sustainable?
Chile	0.645464	III	S
Burundi	0.128881	V	U

5 Sustainability of LDC: Uganda

We select Uganda from the 48 LDC countries UN listed as our research subject, which is a landlocked country in East Africa.

5.1 Sustainability of Development

In order to determine whether Uganda is sustainable in development, we normalized massive figure of basic criteria, and used the model previously described to get a sustainability measure P. Due to the fact that raw data of certain years is incomplete, we take 2010 as an example, of which year data is both complete and credible.

Initial and normalized figure of Uganda in 26 criteria is as follow:

Table 5

Initial and normalized figure of Uganda in 2010

CRITERION	INITIAL	NORMALIZED	CRITERION	INICIAL	NORMALIZED
C11	111	0.396047	C33	27.01811	0.240016
C12	11364.2	0.896585	C34	47.30444	0.459929
C13	14.95421	0.158069	C35	14.492	0.059401
C14	14.6	0.132995	C36	1.818127	0.579614

C15	2.768313	0.027545	C41	57.29654	0.325089
C21	170.0977	0.025213	C42	14.1	0.696429
C22	3.359655	0.460049	C43	288.2447	0. 104911
C23	73.21188	0.683157	C44	40.90741	0.036463
C24	79.822	0.424300	C45	73.2	0.586861
C25	0.55794	0.136911	C46	24.5	0.409497
C26	13.17849	0.038724	C51	30000000	0.040854
C31	471.6773	0.01739	C52	50.70937	0.037346
C32	209.2298	0.534181	C53	13.51757	0.366643

5.2 Analysis of Current Situation

The economic development of Uganda is suffering from depression. GDP and GNI is far beneath international average level, and urbanization level is low. Pool living standard is reflected by severe malnutrition as well as poverty. Development of education and technology is also slow. We substitute these figure into the equation and get the assessment score for Uganda:

$$P = 0.34409528,$$

its sustainable is IV, and we determine that Uganda is unsustainable in development.

6 Drawing Out a Plan for Uganda

Based on our model, we intend to launch programs to make raise Uganda a more sustainable country by raising P in a short term. Considering the key criteria for the future development of Uganda and potential investment from ICM, our team make a prediction about its sustainable development in the coming two decades then give some advice to ICM .

6.1 Analysis Preparation: Finding Key Criteria

For each basic criterion , we have sustainability measured in terms of C_{ij} x_{ij} .We choose $x = 0.5$ to do more research in depth as it is the divide point of sustainable and unsustainable development.

In order to find an effective way to raise P in a very short term, we need to improve those criterion which have larger impact on the future development. We select some important criteria by their final weight contributing the sustainable development .These criteria hold the key to improve Uganda in terms sustainable development. So how to get the key criteria ?

We have:

- Method A

  We introduce D

$$D = W(\mathrm{Cij}) \times x$$

We consider it a key criteria if D for C_{ij} is small.

- Method b

To promote the overall sustainable development of Uganda , we attach more importance to those criteria whose performance is not optimistic and come up with a plan to improve them .

- Method c

We consider C_{ij} a key criterion if its $W(\mathrm{Cij})$ is big and chose those biggest ones, then try to raise p by improving these selected criteria.

We mainly adopt the first method and use method b and c as a supplement.We think it more thoughtful to find key criteria in this way.

Considering the three method above, we have

Table 6

D and weight of C_{ij}

C_{ij}	D	weight	C_{ij}	D	weight	C_{ij}	D	weight
C11	0.0363571	0.0918	C25	0.0027108	0.0198	C42	0.0592661	0.0851
C12	0.0176396	0.0177	C26	0.00006466	0.0167	C43	0.00000254	0.0102
C13	0.00001908	0.0316	C31	0.0000426	0.0245	C44	0.000035	0.0096
C14	0.0096155	0.0723	C32	0.0222753	0.0417	C45	0.0151997	0.0259
C15	0.0009806	0.0356	C33	0.015481	0.0645	C46	0.0344816	0.0486
C21	0.00015884	0.0063	C34	0.0473267	0.1029	C51	0.004995	0.0467
C22	0.0060266	0.0131	C35	0.0061123	0.1029	C52	0.0002988	0.0080
C23	0.0235689	0.0345	C36	0.012637	0.0129	C53	0.0049863	0.0136
C24	0.0132806	0.0313	C41	0.0105329	0.0324			

From our table , we have:

Selected by method a: C43 C13 C44

Selected by method b: C43 C13

Selected by method c: C35 C34

And we determine the key points after taking the criteria (selected by three methods respectively) into account. Anther principal we stick to is that we only choose one of those criteria if their performance is similar.

6.2 Correspondent Plan

The main principle of our general plan is to help deprived countries(take Uganda for example)develop in a more sustainable way . These countries may see the advantages of extensive financial resources and influence of ICM. We divide our plan into three parts by three criteria discussed in the last sector .

6.2.1 Part A：Programs and Policies to Improve GNI per Capita

- Economics

●Giving policy support to enterprises and inviting more investment partners home and abroad.

Giant companies or local businesses are more likely to be attracted and invest large amounts of capital when they are supported by policy .for example , giving a tax discount to these potential investors may encourage them to increase their investment , for they are more likely to take the initiative when they don not have to pay more tax if they earn more .

This can help promote the economic development and combat unemployment and poverty . Another way is to adopt new techniques to make the best of infinite resources in Uganda by the aid of developed countries , which results in a more effective way to optimize the use of these resources like copper , cobalt and coffee .

●Enacting regulations on tariffs may also encourage a economic prosperity

As there are less barriers to export and import. For example, copper, cobalt and coffee are rich in Uganda, so it is possible to develop the mining industry and promote farm produce. However , we should make sure that these efforts conserve resources for future generations.

- Building Uganda' system

ICM can play an important role in providing support by fanancial aids and promoting equality .for example ,ICM can help set up a equal managerial system for Uganda.

- Technology improvements and management

Another way is to adopt new techniques to make the best of infinite resources in Uganda by the aid of developed countries , which results in a more effective way to optimize the use of these resources like copper, cobalt and coffee . We also can invite some expertise in environmental engineering if possible to offer guidance to the sustainable development based on their current situation.

6.2.2 Part B: Programs and Policies to Increase Forest Area

- Policies:

●Laws and regulations: ICM can use its influence and communicate with environmental organizations and individual to assist Uganda authority in establishing forest-protect regulations. Educational methods is to be carried out to increase awareness of forest protection.

●System and activity: Comparison activity among cities and areas also contributes to this plan.

- Protect forest with science

Prevent fire and insect pest. Experts' opinion should be propagated and special funds should be established.

6.2.3 Part C: Programs and policies to increase Urban population (% of total)

- Funds:

ICM can set up an underlying fund or low interest loans at the primary stage of urban construction. It can also donate infrastructure, providing an favorable environment for urban construction.

Additionally, programs and policies related to secondary and tertiary industry, which are introduced in Part A, also contributes to this program.

- Establish charitable organization:

ICM can appeal to interested parties to establish charity group, donate infrastructure or start-up capital of large program.

- Setting up a well-funded education system:

We make this decision on the illiteracy rate of Uganda and we hope our plan can make a contribution to eradicating or at least minimizing the illiteracy rates .This will result in a well-educated workforce and these people are like to work with high efficiency,and in turn uganda can become more prosperous.

6.3 Program Implementation and Effectiveness of Each Part

We divide important criteria into 3 categories .

I these criteria can improve their performance with time,but they usually develop at a slow pace. We come up with policies and programs to accelerate their development .

II. these criteria's performance will deteriorate without the aid from ICM .programs and policies aim at reversing the negative trend .

III unpredictable criteria like wars ,natural disasters .To combat these future challenges, ICM and other organizations should join forces to help Uganda .

To simplify our model , we make assumptions.

- ◆We quantity the annual help from ICM in unit
- ◆ICM influence Uganda at the beginning of the year

6.3.1 Part A

This part is aimed at improve GDP(short for GP) . Aids rely on the performance of GP. We obtain

A fitting curve which is consonant with the observation data and use the curve to make a prediction

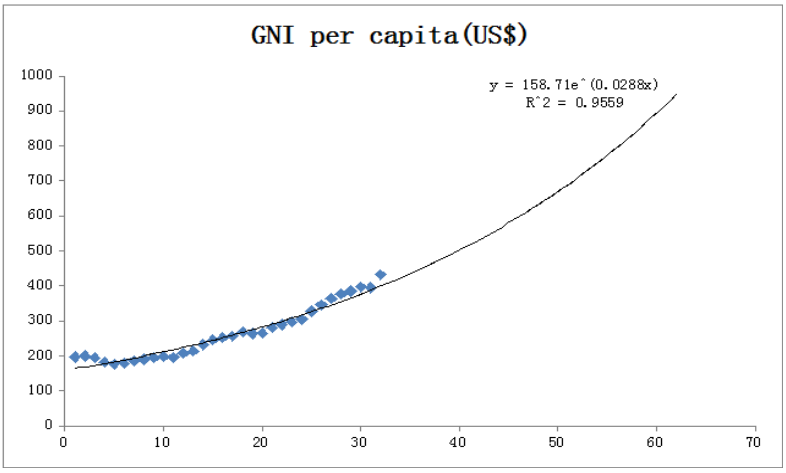

Chart 1 GNI per capita prediction

And we get the fitting curve and correlation coefficent

$$C43 = 158.7e^{0.028m} \qquad R^2 = 0.937$$

Our curve is well consonant with the collected data. We need to improve people's living standards in Uganda based on what we learned.

We hope to shorten the growing time of GP and make the best of its resources . To be more precise, GP reach the expectation of the 60^{th} year in 20 years when we implement plan A. Firstly , we divide 60 years into 20 stages. What is needed to mention is that we do not divide these years evenly but divide them on different performances of different years. after a year , we manage to help GP perform as well as it performs in the 4^{th} year with the help of our plan and so on .we get the input

Table 7

the amounts of investment and results in 20 years

year m'	The amounts of investment at the beginning of the year	GP at the end of the year	Years of Equivalent performance per year
1	13.4601	474.1286	4
2	15.1036	532.0187	4
3	16.9477	596.977	4
4	18.4765	650.849	3
5	20.1437	709.583	3
6	21.9624	773.6183	3
7	23.9444	843.4315	3
8	26.1052	919.5447	3
9	28.4614	1002.527	3
10	31.029	1092.997	3
11	33.829	1191.631	3
12	36.882	1299.167	3
13	39.069	1376.196	3
14	42.594	1500.387	3
15	46.439	1635.786	3
16	50.629	1783.403	3
17	55.198	1944.341	3
18	58.471	2059.624	2
19	61.938	2181.741	2
20	65.61	2311.099	2

Expectations before and after implementing part A

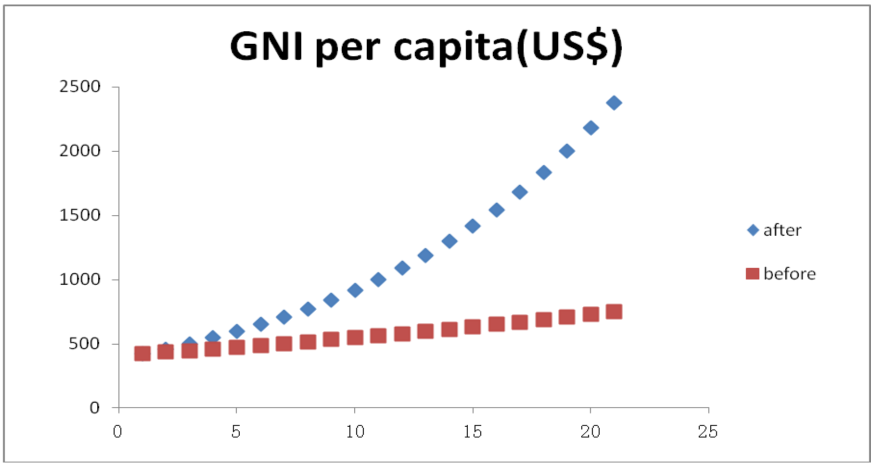

Chart 2 comparison of GIN per capity(with/without the plan)

Results:

GP reach 2311.099$ in twenty years , increasing five fold(around 3 times the level of that without the plan) . This result suggests Part A is practical.

6.3.2 Part B

Part B aims at improving B and we propose part B on its performance .

We obtaina fitting curve which is consonant with the observation data and use the curve to make a prediction before we implement part B.

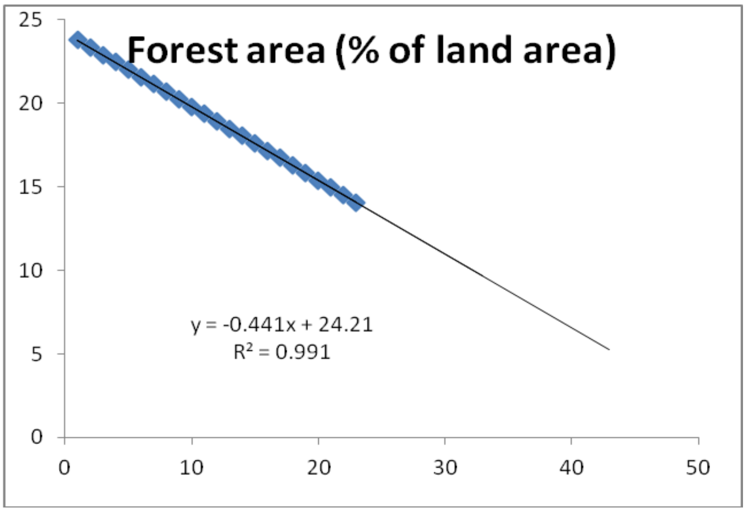

Chart 3 Forest area percentage prediction

The formula of this fitting curve and correlation coefficent

$$C13 = -0.441m + 24.21 \qquad R^2 = 0.991$$

There is a steady decline in the proportion of forest land area in Uganda , dropping from around 24% to less than 5% . part b we propose can reverse this trend .

Having draw lessons from other countries' effort to increase the covering of forestry in Uganda , we have

$$C13 = 0.26m' + 12.0473$$

This formula is used to describe the improved C13 after we put our plan into practice.

For the current year , $m' = 0$ 。

According to our calculation, According to our calculation , forest coverage rate will rise by 0.7011% (forest coverage will increase by 1693.1565sq.km) . This can meet the need of the annual wood consumption of Uganda and keep percentage of forest cover increasing at the same time .

Table 8

the growth of forest coverage rate in Uganda before and after Part B（%）

year m'	the growth of forest coverage rate at end of a year	year m'	the growth of forest coverage rate at end of a year
1	13.0084	11	15.6084
2	13.2684	12	15.8684
3	13.5284	13	16.1284
4	13.7884	14	16.3884
5	14.0484	15	16.6484
6	14.3084	16	16.9084

7	14.5684	17	17.1684
8	14.8284	18	17.4284
9	15.0884	19	17.6884
10	15.3484	20	17.9484

The trend of forest area(%of land area)

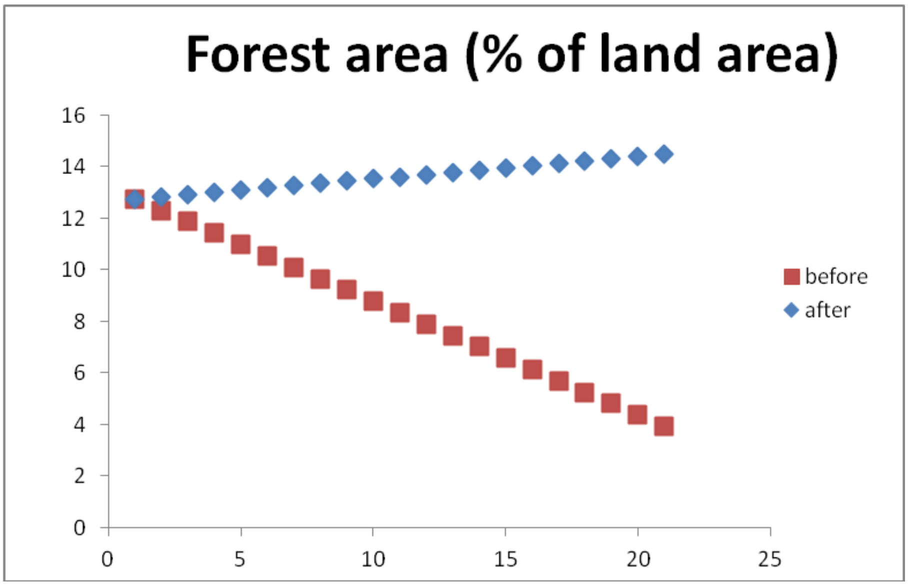

Chart 4 Comparision of forest area percentage(with/without the plan)

This result suggests our part b is effective.

6.3.3 Part C

The main purpose of Part C is to improve problem C. How much aids is to be provided depends on the development condition of Uganda.

We collect figure of Urban population of Uganda since 1960, and obtain a fitting curve. With the equation, we deduced that in the next 40 years, Uganda's Urban population growth tendency may fit the following graph:

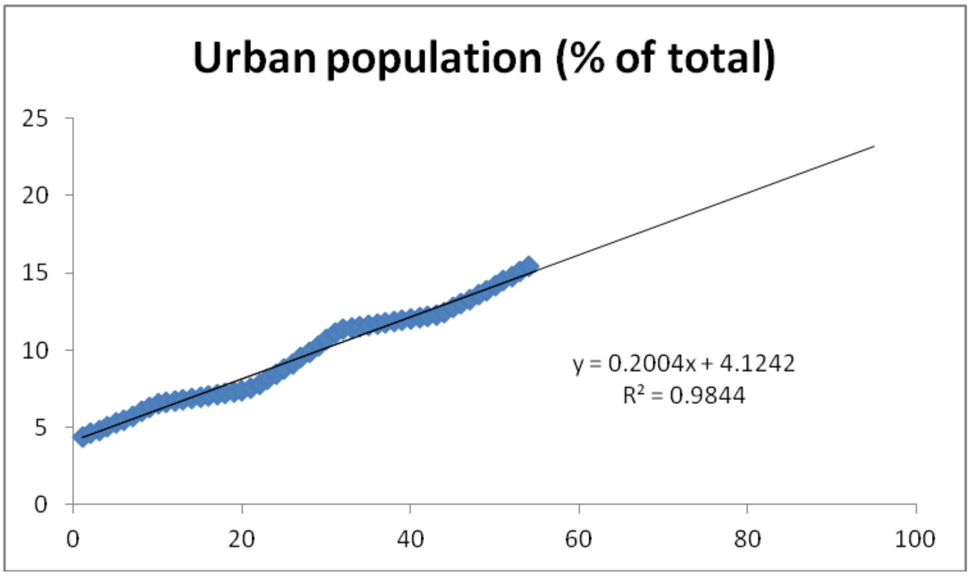

Chart 5 Urban population percentage prediction

We get a fitting curve and correlation coefficient:

$$C35 = 0.200m + 4.124 \qquad R^2 = 0.984$$

An R ²value of 0.984 means a fairly good fit.

The figure shows that the urban population has a very low percentage in Uganda's whole population. To promote development, it needs a rapid growth in urban population and a speed-up on urbanization progress. Considering the regular pattern of urbanization and the coordination of urban construction and resource consumption, we abandoned exponential function $C35 = ae^{bm'}$, which has too large a slope for actual progress, and take on a linear function:

$$C35 = 0.601m' + 15.5482$$

Under the assumption that ICM provides aids for Uganda, making its urban population raising by 0.4008% each year, we obtain the urban population percentage listed as follow:

Table 9

Urban population(% of total) in the next 20 years

Year(m')	C35 cumulative value at end of year	Years to reach same condition without partC	Year(m')	C35 cumulative value at end of year	Years to reach same condition without partC
1	16.1482	3	11	22.561	3
2	16.9498	3	12	23.1622	3
3	17.7514	3	13	23.7634	3
4	18.3526	3	14	24.3646	3
5	18.9538	3	15	24.9658	3
6	19.555	3	16	25.567	3
7	20.1562	3	17	26.1682	3
8	20.7574	3	18	26.569	3
9	21.3586	3	19	26.9698	3
10	21.9598	3	20	27.3706	3

Comparison:

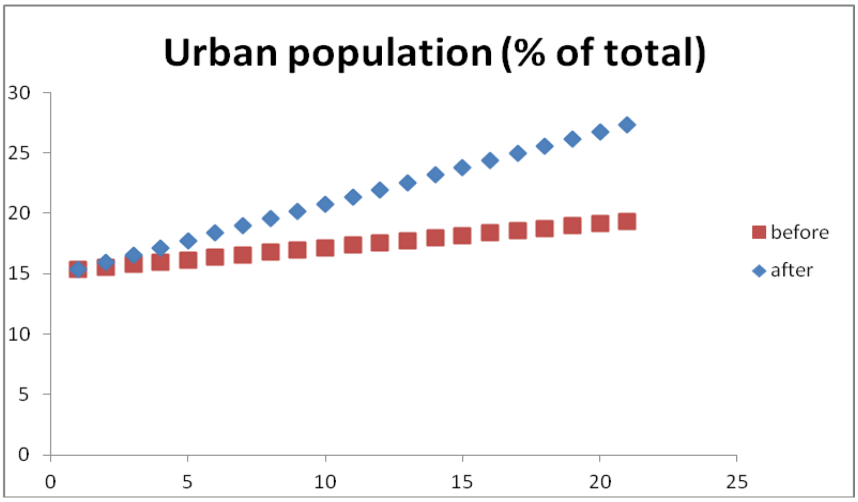

Chart 6 Comparison of Urban population perscentage(with/without the plan)

7 Comprehensive Effects

7.1 Methods to evaluate effects

A certain plan is provided in order to act on a certain criteria, but the effects of the plan may involve other criteria as well. We take Part A for an example, and explain how our assessment for our plan works.

Part A is aimed at GNI(C43), but carrying out Part A also affects other basic criteria, such as poverty headcount ratio at national poverty lines, which will decline. As such, we also analyze the correlations between GNI and other criteria to quantify the change they make while carrying out Part A. In this way we assess the effect Part A in a comprehensive way.

7.2 Prediction of effects

There are several additional factors to be taken into account in predicting the future of Uganda: drought, tropical disease and political issue. Uganda has a stable government, and no riots occur in the past few years. Drought and, consequently, famine is the primary issue of Uganda. We take this into account in measure P(C42 Malnutrition prevalence). Tropical disease also often rages on Uganda. We take this into account in measure P(C41 Life expectancy at birth and C44 Health expenditure per capita). Under these circumstances, we presume our measure P includes crucial issue of Uganda.

In the 20 years of our plan, each part gives an effect on the criteria aimed at(in absolute figure), other related criteria(in relative figure), assessment measure P and sustainable level. In Table 10, we present a clear analysis of dynamic change Uganda has in the 20-year-plan.

7.2.1Development of Uganda with our plan:

Table 10

Dynamic change of Uganda in 20 year

Year	Part A		Part B		Part C		P	Ra-nk	sustain-able?
	factor C43($)	all factors	factor C13	all factors	factor C35	all factors			
1	460.668	0.00153	13.01	0.00403	16.1482	0.00298	0.37165	IV	U
2	502.240	0.00806	13.28	0.00597	16.9498	0.00056	0.38114	IV	U
3	547.563	0.01209	13.53	0.00896	17.7514	0.00081	0.39061	IV	U
4	596.977	0.01612	13.79	0.01195	18.3526	0.00104	0.40008	IV	U
5	650.849	0.02015	14.05	0.01494	18.9538	0.00126	0.40957	IV	U
6	709.583	0.02418	14.37	0.01793	19.555	0.00147	0.41909	IV	U
7	773.618	0.02821	14.57	0.02091	20.1562	0.00166	0.42868	IV	U
8	843.431	0.03224	14.83	0.02390	20.7574	0.00185	0.43834	IV	U
9	919.544	0.0362	15.09	0.02689	21.3586	0.00203	0.44809	IV	U
10	1002.52	0.01161	15.35	0.04031	21.9598	0.02988	0.45796	IV	U
11	1092.99	0.04434	15.61	0.03287	22.561	0.00236	0.46796	IV	U
12	1191.63	0.04837	15.87	0.03586	23.1622	0.00252	0.47812	IV	U
13	1299.16	0.05240	16.13	0.03884	23.7634	0.00267	0.48845	IV	U

14	1416.40	0.05643	16.39	0.04183	24.3646	0.00281	0.49898	IV	U
15	1544.22	0.06046	16.65	0.04482	24.9658	0.00295	0.50973	III	S
16	1683.58	0.06449	16.91	0.04781	25.567	0.00308	0.52073	III	S
17	1835.51	0.06852	17.17	0.05080	26.1682	0.00321	0.53201	III	S
18	2001.15	0.07256	17.43	0.05379	26.569	0.00334	0.54358	III	S
19	2181.74	0.07659	17.69	0.05678	26.9698	0.00346	0.55550	III	S
20	2378.62	0.08062	17.95	0.05976	27.3706	0.00358	0.56778	III	S

Note: figures of ‘all factor’ are weighted normalized numbers, indicating effect each part has on P.

7.2.2Comparison:

In order to demonstrate the effect our plan has on the sustainable development of Uganda clearly, we studied figures of previous few years, and predicted the tendency of assessing measure P without the effects of our plan. We compare its curve fitting with our plan’s.

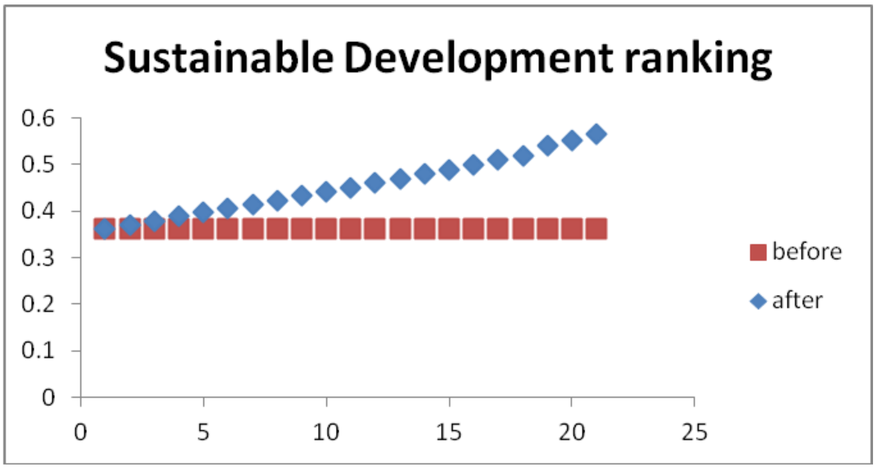

Chart 7 Comparison of Sustainable development ranking

7.2.3 Analysis:

We can conclude from the above chart and table 10 that in the next 20 years, the development score P will approximately stay as a constant. That is to say, if Uganda continue to develop at present pace, short of aids from community and society, it’s almost impossible to meet the request to become sustainable. On the other hand, if our plan is carried out, in the next 20 years, assessing measure P has a significant increase, from 0.37165 to 0.56778, and level of sustainable development goes up from class-4 to class-3, making Uganda sustainable in development.

In mere 20 years, Uganda can become a sustainable country. This requires not only strong support from ICM and other community, but also the effort from people and government of Uganda, aiming at making their country more sustainable. Additionally, the small territory and sparse population of Uganda may also contributes to this conclusion.

8 The Most Bang for the Buck

To get the most bang for the buck, programs can be measured by a measure R, R is defined as the ratio of input (I) to output (O).

$$R = \frac{O}{I}$$

Because we are measuring the effects every part has on sustainability measure P, output is how much the P changed caused by implementing the part over the next 20 years. Input is how much money will be invested to the part.

We take R_A as an example to explain how to calculate the measure R.

According to the definition of output and figures of Table 10, the output of Part A is

$$O_A = 0.06449 - 0.00153 = 0.06296$$

Because Part A is closely related to C43 (GNI per capita), over the next 20 years, the growth of GNI per capita multiplied by the population equals I_A.

In order to get the population over the next 20 years, we should predict the statistics needed. The process of fitting is shown in Chart 8.

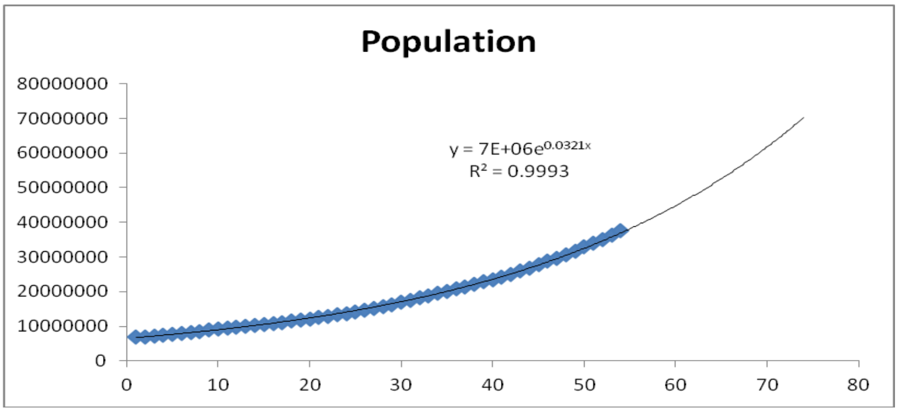

Chart 8 Population prediction

The fitting curve is $Pop = 7\times10^6 e^{0.032m}$ and correlation coefficient is $R^2 = 0.999$. So the result is acceptable.

Therefore, we get

$$I_A = 1.21236\times10^{11}\$$$

$$R_A = \frac{O_A}{I_A} = 5.1932\times10^{-13}$$

In the similar way, we can get the Table 11.

Table 11

R of every part

Part	Part A	Part B	Part C
Output	0.06296	0.04378	0.00010
Input (10^{10}\$)	12.1236	18.3587	0.5669
R (10^{-13})	5.1932	2.3847	0.1764

From the table above, we can draw the conclusion that $R_A > R_B > R_C$. That is to say, the programs and policies of Part A is “the most bang for the buck”.

The details of Part A are stated in “Part A：Programs and policies to improve GNI per capita”.

9 Strengths and weaknesses

9.1 Strengths

- The measure system is intensive. 26 criteria of 5 categories is used without combination. Because of the large number of criteria, the sustainability measure is comprehensive.
- The models are practical and operational. Data processing algorithm is easy to use and the sustainability measure is not sophisticated to calculate. In the process of figuring out to what extent the plan will be carried out, we can get the detailed figures based on past figures. And the effects have been verified.
- The models have strong universality. They have easy application and can be extend to any countries, because we never aim at any certain country in the process of modeling.

9.2 Weaknesses

- Lack of variance and adjustment in assessing the level of different countries. Our plan makes a generalization on how to assess countries in terms of sustainable development and may fails to determine whether a specific country in real world is sustainable or not. This is because we lack relevant experience on environmental engineering and cannot get up-to-date information .
- The model about sustainability measure may fail to be independently objective. we base our matrix mainly on personal judgment rather than accurate analysis, so the weights we decide on may not be the best-fit. In the future , we can invite some expertise and skilled workers in relevant areas to help us improve the model or even put it in to practice.
- Models rely on the accuracy of data. If the significant figures aren’t accurate enough, it is likely that the result changes apparently. In order to get correct criteria and results, reliable official figures are needed.
- The plan takes one year as a unit to calculate and predict. Chances are that the results and figures is rough to some extent. Fortunately, it can be solved by dividing time with the same methods explained in this report.

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http://data.worldbank.org/indicator/SI.POV.NAGP

Appendix 1

The matrix used in AHP:

$$A=\begin{pmatrix} 1 & 3 & 1/2 & 1 & 4 \\ 1/3 & 1 & 1/2 & 1/2 & 2 \\ 2 & 2 & 1 & 2 & 4 \\ 1 & 2 & 1/2 & 1 & 3 \\ 1/4 & 1/2 & 1/4 & 1/3 & 1 \end{pmatrix} \qquad B1=\begin{pmatrix} 1 & 5 & 3 & 2 & 2 \\ 1/5 & 1 & 1/3 & 1/2 & 1/3 \\ 1/3 & 3 & 1 & 1/4 & 1 \\ 1/2 & 2 & 4 & 1 & 3 \\ 1/2 & 3 & 1 & 1/3 & 1 \end{pmatrix}$$

$$B2=\begin{pmatrix} 1 & 1/2 & 1/5 & 1/4 & 1/4 & 1/3 \\ 2 & 1 & 1/3 & 1/2 & 1/2 & 1 \\ 5 & 3 & 1 & 1 & 2 & 2 \\ 4 & 2 & 1 & 1 & 2 & 2 \\ 4 & 2 & 1/2 & 1/2 & 1 & 1 \\ 3 & 1 & 1/2 & 1/2 & 1 & 1 \end{pmatrix} \qquad B3=\begin{pmatrix} 1 & 1/3 & 4/5 & 1/5 & 1 \\ 3 & 1 & 1/2 & 1/3 & 1/3 \\ 4 & 2 & 1 & 1/2 & 1/2 \\ 5 & 3 & 2 & 1 & 1 \\ 5 & 3 & 2 & 1 & 1 \\ 1/2 & 1/4 & 1/5 & 1/6 & 1 \end{pmatrix}$$

$$B4=\begin{pmatrix} 1 & 1/5 & 4 & 5 & 2 & 1/3 \\ 5 & 1 & 6 & 6 & 3 & 2 \\ 1/4 & 1/6 & 1 & 1 & 1/4 & 1/3 \\ 1/5 & 1/6 & 1 & 1 & 1/3 & 1/4 \\ 1/2 & 1/3 & 4 & 3 & 1 & 1/2 \\ 3 & 1/2 & 3 & 4 & 2 & 1 \end{pmatrix} \qquad B5=\begin{pmatrix} 1 & 5 & 4 \\ 1/5 & 1 & 1/2 \\ 1/4 & 2 & 1 \end{pmatrix}$$

Appendix 2

$$W_{B1}=(0.3687\ \ 0.0711\ \ 0.1269\ \ 0.2905\ \ 0.1429)^T$$

$$CR_{B1}=CI_{B1}/RI_5=0.0775<0.1$$

$$W_{B2}=(0.0515\ \ 0.1074\ \ 0.2834\ \ 0.2573\ \ 0.1633\ \ 0.1371)^T$$

$$CR_{B2}=CI_{B2}/RI_6=0.0117<0.1$$

$$W_{B3}=(0.0701\ \ 0.1195\ \ 0.1845\ \ 0.2945\ \ 0.2945\ \ 0.0369)^T$$

$$CR_{B3}=CI_{B3}/RI_6=0.0664<0.1$$

$$W_{B4}=(0.1531\ \ 0.4016\ \ 0.0481\ \ 0.0455\ \ 0.1220\ \ 0.2296)^T$$

$$CR_{B4} = CI_{B4} / RI_6 = 0.0580 < 0.1$$

$$W_{B5} = (0.6833\ \ 0.1168\ \ 0.1998)^T$$

$$CR_{B5} = CI_{B5} / RI_3 = 0.0212 < 0.1$$