Economic Analysis of Public Policy

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Final Report

Three Gorges Dam in Hubei, China:

A Cost and Benefit Analysis

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Executive Summary

Situated on a canyon known as the Three Gorges in Hubei, China, Yangtze River's Three Gorges Dam is the world's largest power station in terms of installed capacity (22,500 MW). The project was initiated by the Chinese government in 1994, with the support of different international cooperation agencies, for three main reasons. First of all, it would generate hydroelectricity to meet China's rapidly increasing demand. Second, the Three Gorges Dam would protect millions of people living along the river from potential floods. And finally, it would transform a 600-kilometre stretch of the fast-flowing river into a smooth navigable waterway for vessels and provide business opportunities to western landlocked provinces.

The Chinese government regards this project as a historic engineering, social and economic success, with the design of sophisticated large turbines, and a move toward limiting greenhouse gas emissions. However, the dam has been a controversial topic, the reason why a cost and benefit analysis was developed to understand all possible variables related to this gigantic project and its complicated development process. For the evaluation of major benefit components, special care was taken to understand flood control (and dam's capacity to control 100 years events); electricity generation (and the reduction of CO_2 emissions); and the enhanced shipping capacity (allowing the transit of large quantities of cargos). For the evaluation of major costs components, special care was taken to understand the costs related to dam's construction (and its maintenance); people's resettlement and displacement (from rural to urban areas); environmental degradation (mainly water pollution, sedimentation and ecosystem disruption); loss in archeological sites (and cultural heritage); and the potential risk caused by earthquakes.

On one hand, the advantage to study the Three Gorges Dam was the large amount of data and sources available, being possible to evaluate the project according to financial and economic appraisals and according to four-sensitivity analysis scenarios, two with 5% and two with 10% discount ratio. On the other hand, some components were difficult to calculate due to unclear or diverse methodologies, or even subjectivities like social capital losses, production relationships, culture and kinship networks, and also due to uncertain predictions, like the probability of the occurrence of an earthquake. As final results, considering maximum benefits and minimum costs, cost-benefit ratio was 1.79 (10%) and 3.22 (5%), and considering minimum benefits and maximum costs, ratio was 0.31 (10%) and 0.49 (5%). In case of the financial appraisal, the cost-benefit ratio was 1.13, which was in the midst of cost-benefit ratio in the both cases.

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1. Introduction

Three Gorges Dam, located on a canyon known as the Three Gorges along the Yangtze River in the province of Hubei, China, is the world's largest hydroelectric power plant in terms of installed capacity (see Appendix I for the map and the location of the dam). The construction is divided into three stages, as below.

Phase	Year	Construction stage	Water level (m)
Preparatory Phase	1993		66
Phase I (1994-1997)	1994	Earthmoving starts; inauguration ceremony.	66
	1995	Concrete longitudinal cofferdam building starts; resettlement program is launched.	66
	1996	Xiling bridge, four-line highway from Yichang, and Yichang airport are into service. Transverse cofferdams building starts.	66
	1997	Closure and diversion of the river; about 100,000 people have been resettled.	66
Phase II (1998-2003)	1998	Temporary ship-lock is put into operation.	66
	1999	Excavation of the double-lane ship-lock is finished; about 230,000 people have been resettled.	66
	2000	About 295,000 people have been resettled.	66
	2001	About 325,000 people have been resettled.	66
	2002	The diversion channel is closed; left bank concrete pouring completed, about 640,000 people resettled.	66
	2003	The reservoir is filled up to 135 m pool level; first trials with the double lane ship-lock; the four first generators are connected to the grid.	135
Phase III (2004-2009)	2004	The double-lane ship-lock is put into operation; ten turbines are already connected to the grid.	139
	2005	Left bank powerhouse completed (14 turbines in operation).	139

	2006	Concrete pouring on the right bank is finished; the reservoir is filled up to 156 m.	156
	2007	Fill the reservoir up to 156 m; ship-lift construction started.	156
	2008	The reservoir was filled up to 175 m pool level.	175
	2009	26 turbines fully operational; target for completion of the whole project.	175
O&M	2012	The underground power plant connected to the grid.	175
	2014	Ship-lift will put into operation (expected).	175

Table 1. Construction phases of the Three Gorges Dam

Source: Ponseti and López-Pujol (2006, p. 158), reproduced and updated by the authors

Chinese government with the support of international credit agencies for three main reasons initiated this project. First of all, the Three Gorges Dam would protect millions of people and their livelihood along the river from potential floods. Second, it would generate about 20 terawatts of hydroelectricity to meet China's rapidly increasing demand for electricity. Finally, it would transform a 600-kilometre stretch of the fast-flowing river into a smooth navigable waterway for large vessels and provide business opportunities to landlocked provinces in the western China. The project is considered as a symbol of modern engineering combined with mega scale construction.

Nevertheless, the dam has remained as a controversial topic both within China and outside the country for several reasons. The project is criticized to incur excruciatingly high investment so that it can never be covered by current level of tariff, which is unrealistically controlled by the government. It is also targeted by human rights activists for displacing around 1.2 million people without proper consideration of economic and social costs that they have to bear. Many environmental activists claim a huge change in nearby ecosystems would create a huge external cost. Also, the reservoir that flooded 12 cities, 140 towns, and 1,500 villages, also flooded invaluable archaeological and cultural sites that can never be recovered. Finally, it has many risks involved, including landslides and earthquakes.

Therefore, this study seeks to find out the overall cost and benefit of the Three Gorges Dam by dissecting the project into major benefit components and cost components. Also, it will take into account factors that may influence the performance of the dam such as risks and externalities. Each benefit and cost component will include brief explanation, problems in measurement, methodology for monetization, and maximum and minimum value. Furthermore, pros and cons of the project for each component will be analyzed based on existing literature. Benefit components will end by presenting the hypothetical ‘without’ case in comparison to the actual ‘with’ case. Then, after using the appropriate social discount rate within the context, the net present value of each component will be calculated. Based on this calculation, the financial and economic evaluation of the project will be conducted to find out the feasibility of the project.

2. Major benefit components

2.1. Flood Control

Flood control is the first purpose of the original plan because Yangtze River has caused some of China's worst natural flood disasters. In 1954, Yangtze floods killed 30,000 people (Fung 1999). The heavy rains and flooding along the Yangtze River damaged 100,000 houses, toppled 34,000 houses, inundated 1.13 million hectares of farmland (causing a grain output loss of 880,000 tons), forced more than 2,000 companies to limit production, killed 5,200 livestock, and induced economic losses of more than 4.6 Billion Yuan in less than one month [1]. Moreover, the change of river flows is one of factors of droughts and floods, which in turn affect the stability of agricultural production and water supply [2]. Therefore, Three Gorges Dam is expected to control the river’s flooding capacity “from the present 10-year frequency to 100-year frequency” [3], and the result would be reduction in the area flooded and the prevention of any consequent loss of life, social disruption, health impacts and economic losses [4].

Methodology: for the benefit calculation, the general mean annual benefit from flood control was the key variable. The following is the function of the flood control [5]: $\mathrm{FI} = \mathrm{FB}\ (\text{Billion Yuan/Year})$ (FI indicates the benefit from flood control, and FB shows the mean annual benefits from flood control). Luk and Whitney (1993) estimated the minimum value of

[1] See http://www.irn.org/programs/threeg/991029.central.html
[2] Allin (2004), p.16
[3] Morimoto and Hope (2003), p.3
[4] World Commission on Dams (2000)
[5] Morimoto and Hope (2003) p.20

mean annual benefits from flood control as $0.76 billion Yuan per year. So, the minimum net present value (NPV) of flood control amounts to $3.48 billion Yuan (with 10% discount ratio) or 8.96 billion Yuan (with 5% discount ratio) [6]. The maximum benefit of flood control is assumed as "if an exceptionally huge flood similar to that of 1870 should occur, the project would reduce losses caused by inundation by $35 billion Yuan, and also prevent a great number of casualties caused by burst dikes" (Rulan et al 1997) [7]. But, according to the statement of Rulan et al (1997), the maximum value is assumed similar to the 1870 flood. It implies that the flood, which may occurs once in 100 years, would happen every year and the average benefit of flood control would be too large. The Net Present Value of flood control amounts to about 160 billion Yuan with the discount rate of 10% and 412 billion Yuan with the discount rate of 5%.

Limitations: critics states that the Three Gorges Dam is located at the end of the upper reaches, controlling only 55% of the Yangtze River; while the Sanmenxia Dam, which is also designed to control floods in the Yellow River, can control over 92 % of its watershed (Dai, 1994). It means that the Three Gorges Dam would not be able to protect from big floods like those in 1954 and 1998 (Dai, 1994; McCormack, 2001) [8]. Therefore, some authors remain skeptical if the location of the TGD covers the river major areas that cause flooding. Additionally, the people in the reservoir area face an increased risk of flooding without any compensation. But, if compensation were provided, the project's cost would increase by 20 percent [9].

As without TGD case, we can imagine a riverbank through Yangtze River with several small and middle size dams. These dams might be flexible because even if one of these dams broke by 10-year frequency flooding, the others can help to manage the flood. So it is expected to restrict the realm of the area that receives flooding. This scenario with multiple dams can disperse the risk of flood disaster. However, it is doubtful if the small and medium sized dam can control the 100-year frequency big flooding like the one in 1870 (so this type of dam doesn't necessarily clear out the risk of flooding).

2.2. Electricity generation

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[6] Morimoto and Hope (2003), p.20
[7] Morimoto and Hope (2003), p.27
[8] Ponseti and Lopez-Pujol (2006), p.163
[9] Barber and Grainne (1998), p.42

Power generation is officially the second purpose mentioned by the original plan. Skyrocketing demand for electricity caused by rapid industrialization of the national economy put much pressure on the construction of thermal power plants which can be built and supply the electricity in a shorter period. However, due to the limited coal resources of China and the high pollution associated with coal-burning power plants, there was an increasing importance of developing alternative sources of energy. The hydropower, viewed as a cleaner source of energy compared to coal, began to get attention as a middle and long-term solution [10].

The Three Gorges Dam is equipped with 26 sets of hydro turbine generators with a capacity of 700MW each on the left and right banks. Additionally, it has 6 underground turbines[11]. Each turbine is the world's largest turbine and also all together, the dam is the world's largest dam in terms of installed capacity and the actual generation [12]. On the first feasibility study of 1989, the dam was expected to serve about 10% of the total national power consumption. However, due to the long construction span, the electricity consumption rose exponentially in China and the power generation from the Three Gorges Dam can only contribute about 1.7% of the total national consumption in 2011 [13].

Methodology: For benefit calculation, the annual electricity generation up to 2012 is collected from the official website of Chinese government [14]. The minimum is assumed to be the 2012 level for the rest of the 50 years. The installed capacity of 22.5GW, though it is unrealistic that a dam can have a capacity factor of 1 producing at its full capacity, is set as the maximum level [15]. Then, the estimated production is multiplied by the onto-grid electricity price of $0.25 Yuan per kWh to be expressed as money value [16]. In this subchapter, the direct benefit from the electricity is calculated for simplicity. The related issues such as social benefit caused by reduced

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[10] Ponseti and Lopez-Pujol (2006), p. 165
[11] Wang (2002) p.374
[12] Chang, Liu and Wei (2010), p.4405
[13] Annual production of the Three Gorges Dam in 2011 (Zhangjin 2012) is 78.29 Bln KWh.
CRI English Retrived from <http://english.cri.cn/6909/2012/01/07/ 1461s675113.htm>. Annual consumption of China (2012) "能源局: 2011年全社会用量累达46928千瓦". Retrived from <http://www.gov.cn/gzdt/2012-01/14/content_2044324.htm>
[14] <http://www.gov.cn/>
[15] The efficiency of hydroelectricity plant can be expressed as capacity factor that is the ratio of its actual output over a period of time divided by the full capacity over the same period.
[16] Chang, Liu and Wei (2010), p.4405

CO_2 and potential damage by sedimentation are dealt in the separate subchapter in the latter part of this research.

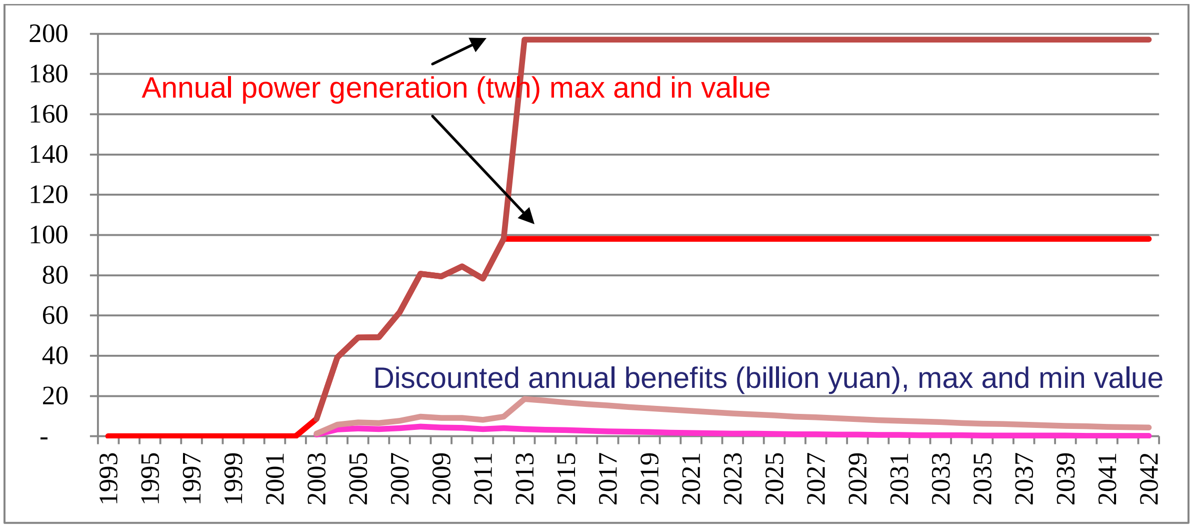

Figure 1. Estimation of power generation and net present revenue

Note: Calculated by the authors, 2003-2012 data is actual and 2013-2044 data is estimation.

This world's largest dam supplies clean energy to east provinces and cities such as Shanghai, Hubei, Guangdong and other provinces and cities. However, it will especially relieve pressure in Central China, which includes Henan, Jiangxi, Hubei, and Hunan with over 250 million people as they have relatively less coal resources in the region [17].

Limitations: criticism of the dam strongly argue that the Three Gorges Dam was certainly not the most cost-effective means of producing electricity. Due to its long construction period, the investment could not be utilized quickly enough while demand for power rose rapidly. In such situation, building a series of smaller power stations is much quicker and cheaper option for power shortages [18]. To illustrate, the average investment for hydropower stations has been about $1,000 Yuan per kilowatt until the late 1990s while for small and mid-sized hydropower, average is $843 Yuan per kilowatt. For large stations which are normally far from load centers and in rugged, isolated terrain and is the case for the Three Gorges Dam, the cost goes up to $1,324 Yuan per kilowatt because of difficulty in construction [19]. In addition, critics of the project point

[17] Battelle Memorial Institute (1998), p.22
[18] Ponseti and Lopez-Pujol (2006), p. 166
[19] Battelle Memorial Institute (1998), p. 55

out that so much energy is currently wasted in China so that the immediate solution should be improving energy services, rather than building new generate plants. In fact, the estimated amount of electricity saved by increasing efficiency of the system and adjusting the tariff level mounts up to 270 terawatt-hours. That is nearly four times the output at Three Gorges [20].

As without case, if only electricity generation aspect was considered, which means using other cheaper means such as coal or smaller dams, to generate power, it could have been much more cost-effective. Yet, it is unfair to relate the cost of large plants such as the Three Gorges Dam with the costs for electricity since features like flood control and shipping improvements were added to the total cost and the allocation of capital investment costs, therefore, it is difficult to do precise calculation for the electricity part only.

2.3. Reduction in CO_2 emissions

China's thirsty for energy has never been satiated since the economic boom in 1990s. To meet the increasing demand for energy, there are several alternative ways. Let's differentiate into two cases. One case is for energy produced by hydroelectric station, hereafter we call it with case; the other is for energy produced by other means other than hydroelectric station, hereafter we call it without case.

As without case, now coal accounts for more than 80% of the energy consumption in China. The burning of coal to generate electricity produces CO_2. According to the current technological level in China, to generate 1 KWH unit of electricity by burning coal in a thermoelectric power station, 0.86 kg CO_2 is produced and emitted to the atmosphere [21].

As with case, CO_2 coming from the electricity generation by hydroelectric station could be neglected. The operation of TDG will decrease the use of coal to generate electricity, thus decreasing CO_2 emission. The electricity generation by TDG could be divided into 3 periods. First period is from 2003 to 2006 with average of 50 billion KWH electricity generated per year when TDG started to generate electricity after the impoundment of the Yangtze River in 2003. Second period is from 2007 to 2009 with average of 80 billion KWH electricity generated per year when TDG construction was completed in 2008. Third period is from 2010 to 2044 with

[20] Paranjpye (1992)
[21] <http://zhidao.baidu.com/question/248505532.html>

average of 100 billion KWH electricity generated per year when all the turbines installed in TDG would be put into operation.

Methodology: To calculate the benefit from reduction in CO_2 emission, we assume the burning of coal would otherwise have generated all the electricity generated by TDG. Then, we need to know the price of carbon emission (since China is a developing country under Kyoto Protocol, it shoulders no responsibility to reduce carbon emission; as result, there is no market and price for carbon emission transactions). Internationally, price in European Union Emissions Trading Scheme has been fluctuating fiercely in the past several years with the highest as $32 euros per ton in 2006 and lowest $1 euro per ton in 2012. Taking into consideration the development level in China, we set the shadow price for carbon emission as between $10 Yuan and $30 Yuan [22]. Thus, under the 10% discount rate, the NPV for reduction in carbon emission is between minimum $5,902,930,032 Yuan and maximum $9,499, 632,086 Yuan.

Limitations: Since there is no market and price for carbon emission in China, we had to use price in European Union Emissions Trading Scheme as our reference price. This is debatable because in reality the energy generated by TGD is consumed in China rather than transmitted to Europe. However, as China is trying to build up its carbon emission market [23], the price of carbon emission will become more accurate in the future.

2.4. Enhanced shipping capacity

Western part of China is landlocked and rugged and has underdeveloped transportation infrastructure compared to that of coastal regions in eastern China. Thus, transporting goods through the Yangtze River, the longest river in China that stretches from the Qinghai-Tibet Plateau to the Eastern China Sea plays a vital role in the region's economy. To illustrate, 90 percent of goods transported to Chongqing, the major city in Sichuan province is through water transportation [24]. Although it was the only reasonable and cost effective means of transporting freight, still there are two factors that made water transportation along the upper Yangtze River

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[22] <http://finance.stockstar.com/JC2013061800002591.shtml>

[23] The first trial carbon emission market was staged in Shenzhen in June 18, 2013 and the price for carbon emission was set at 30 Yuan per ton.

[24] Gleick (2009), p.144

challenging and costly. First, the Three Gorges are filled with rapids. Second, during the dry season the water level is too low for large vessels.

With the construction of large Three Gorges dam, the navigation capacity increases for two reasons. First, the reservoir that is larger than the city of Singapore dramatically increases the depth of water and allows 10,000 tons vessels to go up the river until Chongqing, located more than 600 kilometers upstream of the dam (previously, only 3000 ton vessel were allowed). It is even more valuable during the dry season. Secondly, the project included one of the largest two-way systems of ship locks in the world and a ship-lift, permitting large quantities of cargo to move either ways. In fact, 50 million tons of cargo passed through the new lock system up to Chongqing, up from 18 million tons before the dam in the first year that the ship lock started its operation in 2006 [25].

Methodology: Along with the demand expansion, the official feasibility study asserts the overall shipping cost to reduce by 30% due to slower river flow. The speed of river decreases to about one-tenth. Yet, the study acknowledges the variance of shipping capacity depending on water level. Also, there is a controversy over how much the cost will decrease. Hence, for the minimum, the lowest estimation of cargo passing times reduction of 25% in costs is assumed. For maximum, the maximum shipping capacity expected by the official feasibility study is a 37% of reduction claimed by the company, as for the price fall is applied [26]. For both, the shipping cost of $122.85 Yuan per ton is used for monetization [27]. We assumed no change in value during the construction period of 1994-2003, as the company guarantees the smooth navigation at the construction site by opening temporary ship locks.

Limitations: Peng et al. (2010) argue that benefits are larger because shipping capacity increases greatly due to shoals and rapids being submerged, higher water level during dry season, even for the branch rivers [28]. Opponents, however, regard the benefits are much smaller due to forthcoming bottleneck effect with fast growing container traffic (Veenstra et al., 2008) [29]. In this case, it is difficult to give accurate estimative because the threshold point where bottleneck

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[25] Gleick (2009), p.144
[26] Wang (2002), p.369
[27] The most likely is the forecasted transport costs of goods from Central to East on Yangtze in 2005 are 15 USD per ton. It is converted to Chinese Yuan by adopting the exchange rate of 8.19, which is annual average middle exchange rate in 2005. Morimoto and Hope (2004), p.216
[28] Peng, Shuai and Xin (2010)
[29] Veenstra, Zhang and Ludema (2008)

happens is unknown. Therefore, for the calculation, we assumed that there would be no bottleneck. Also, the possibility of accidents and unexpected delays at the ship lock are ignored, although it may significantly reduce the benefits.

Without the construction of such navigational facilities, the only alternatives would be truck cargo which is much more expensive, both in terms of actual cost and social/environmental costs. Also, the project would stimulate the regional economy by allowing more goods and services to flow into the region. For example, reduction in freight cost can enhance competitiveness of producers in the region while for consumers, the retail prices fall and the consumer surplus may enlarge.

3. Major cost components

3.1. Dam construction and maintenance

Gleick (2009) states that it is no longer possible to estimate the total cost of the Three Gorges Dam with definitive numbers because of the complexity of the intertwined nature of the expenditures and expenditures made unofficially [30]. China Daily sees that although the total cost exceeds the original plan of 1989, it is due to the expansion of projects and inflation. The dam is within the adjusted budget [31].

Methodology: Therefore, for the calculation for minimum, we assume that it is what the company admits as the cost, which is 55.6% of $204 billion Yuan – i.e. $113 billion Yuan [32]. For maximum, Morimoto and Hope (2005), takes 1.4 as multiplier. This is based on the fact that large hydropower projects commissioned between 1915 and 1986 financed by the World Bank show average cost overruns 40% [33]. Since the power generation, there must be operation and maintenance cost incurred. From the tariff rate of $0.25 Yuan/kwh, $0.20 Yuan is said to be cost of operation, depreciation, financing and taxation [34]. $0.2 Yuan per kWh multiplied by the electricity generated could have been used for the O&M. This method was disregarded since it is

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[30] Gleick (2009), p.141
[31] Three Gorges Project spending within budget (2009, September 14). *China Daily.* Retrieved from <http://www.chinadaily.com.cn/china/2009-09/14/content_8687672.htm>
[32] Wang (2002), p.370
[33] Morimoto and Hope (2005), p.215
[34] Chang, Liu and Wei (2010), p. 4405

commonly thought that the tariff is suppressed unrealistically low by the government so that it does not reflect the true market cost. Instead, estimation by the Battelle's report in 1998 is used as the minimum. The report approximates US$20 as O&M cost per kw per year to be O&M cost. Again, 40% more expenditure per kw/year is assumed to be the maximum.

Limitations: The Three Gorges Dam claims minimal O&M cost with fewer employees by adopting e-Project Management Information System. Yet, new city has been built to house TGD maintenance workers. Heavy monitoring of the dam's operation is required for safety and efficiency. Furthermore, construction funds were embezzled by selecting cheap, inferior equipment and materials so that some suspects higher O&M cost than the usual [35]. Hence, the maximum of 40% is reasonable.

3.2. People resettlement

The Three Gorges Dam produced the world's largest dam-displaced population: 600 km^2 of land inundated, 12 cities in 2 prefectures, 140 towns, 326 townships and 1,500 villages [36] – in total around 1.2 million affected people, which 640,000 to be resettled (946,000 original amount) and 560,000 people displaced. In this sense, resettled people are related to rural social movement, or the change of residence, aiming the maintenance of previous agricultural activities or income generation [37] by the Government through a compensation policy. And displaced people are related to "nonpersons", or not officially registered as resident in agricultural or urban areas.

Methodology: According to the Chinese government, for registered inhabitants, a public policy was formulated to compensate people forced to move due to the construction of the dam, called "lump sum" that grants people the total net worth of their home and land, according to a criteria pre-established, criticized as being not a equal nor effective for resettlement. The financial cost of resettling 640,000 people, according to the Chinese government was around $6.4 billion Yuan, which was the minimum planned figure [38] and based on the actual number of resettled people according to the WCD Cross-Check Survey [39] (640,000 people multiplied by $10,000 Yuan, the average amount spent with land and assets). The minimum economic

[35] Allin (2004)
[36] Ponseti and Lopez-Pujol (2006)
[37] Ponseti and Lopez-Pujol (2006)
[38] <http: www.china-embassy.org /issues/ gorges.htm>
[39] World Commission on Dams (2000)

appraisal estimated was 47 billion Yuan, based on a value 47% higher on the actual number of resettled people, according to WCD Survey and among the projects financed by the World Bank (therefore, 1.47 increase due to the total affected population, plus 5 times the necessary value to compensate productivity before the dam construction – to replace 400,000mu (1ha=15mu) of fertile land it would necessary to replace it for 2,000,000mu in low upslope area (640,000 x 10,000 x 1.47 x 5= 47 billion Yuan)). The maximum economic appraisal estimated was 93 billion Yuan [40] estimated as the minimum estimative but with a value 94% higher on the actual number of resettled people. The NPV of the social cost of resettled people is between minimum $33,999,004,011 Yuan and maximum $45,188,664,238 Yuan with a discount rate of 10%.

Limitations: There are many studies on how to estimate resettlements and most diverge on concept and meaning. China's record of resettlement is not good, and government admitted that past resettlements have been plagued with "mistakes such as uncoordinated management, duplicate development, wasteful use of volunteer labor, and limited funds" [41]. The government argued that "resettlement construction and development would spur growth in the area bordering the reservoir" encouraging development of the region with resettlement funds. But, fundamentally, the problem was that the best fertile lands were located in the valleys, flooded by the reservoir, and the government promoted the resettlements in the remaining land, further uphill, too steep to cultivate properly, and relatively infertile. Also, a factor that contributed to some of the early challenges with TGD resettlement was local government corruption, which led to significant resettlement funds ending up in the pockets of government officials, rather than passing to the resettlers [42].

3.3. People displacement

A displaced person, who has been forced to leave his native place, presents a permanent loss of social connections and must face several cultural, social and economic challenges. Including these costs in a CBA is not easy, and requires estimative using market and non-market valuation studies. In the particular case of Three Gorges Dam, Chinese government apparently had no intention of providing resettlement benefits to "nonpersons", who are not officially registered as

[40] Morimoto and Hope (2003), p.11
[41] Barber and Grainne (1998)
[42] Ponseti and Lopez-Pujol (2006)

resident in agricultural or urban areas, considered illegal migrants not include in the official survey. According to the WCD Cross-Check Survey 254,000 people is the total floating and illegal population (174,000 and 80,000 respectively) affected by the dam construction. Mainly inhabitants target of orderly involuntary migration: population from upstream to downstream due to urban flooded or lack of rural land; and, also, 306,000 people target of the resettlement program that did not receive proper compensation, reaching a total of 560,000 people displaced.

Methodology: for economic appraisal on displaced people it was considered all the population target of involuntary and government-oriented migration: people non-officially registered (non-registered and illegal immigrants), and people resettled in urban downstream to engage in secondary and tertiary activities due to the lack of proper compensation or available fertile land. In this sense, the difference between resettle and displaced social costs calculation is the notion of "replacement value". The difference between "compensation" and "replacement value" is that the latter equals to market value of total assets and includes intangible assets such as social capital losses, production relationships, culture and kinship networks [43], which are difficult to measure or to evaluate without proper survey or additional data. In this sense, for this research we will consider the set of variables and values for displaced people according to intangible assets and other analytical social costs provided by other authors as a fixed cost [44]. Therefore, the fixed economic appraisal for the displacement of 560,000 people was estimated in 53.7 billion Yuan, (560,000 x 96,000 fixed cost per capita [45]= $53 billion Yuan). The NPV of the social cost of replaced people is $37,616,848,051 Yuan with a discount rate of 10%.

Limitations: There are innumerous difficulties to evaluate social costs in displacement scenarios. Pervasive and systematic failure to assess the range of potential negative impacts and implement adequate mitigation have led to the impoverishment and suffering of thousands, giving rise to growing opposition to dams by affected communities worldwide. Especially in case of migration, farmers and fishermen lack skills and techniques to work in industries or other jobs; and also, government do not implemented complementary policies and infrastructure such as land provision, household registration, schools and hospitals. Worthy to mention that the

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[43] Yan, Hugo and Potter (2005)
[44] Morimoto and Hope (2003)
[45] The given fixed cost per capita includes an approximation of several components, including compensation, replacement land, jobs, housing, health and, especially, training for industries and other city related jobs.

worst risk in measure displacement is related to the uncertainties in estimate target population and the variations in numbers of people who deserve compensation, replacement land, jobs, housing, and so on. Finally, a gender differentiation should be considered as women bear most of the social costs as they are unable to achieve occupational mobility in the process of resettlement: fewer employment opportunities, a gender-segregated labor market, low level of human capital and social prejudice are principal causes [46].

3.4. Environmental degradation

3.4.1 Water pollution: Since the impoundment in 2003, the water quality behind the TGD has been deteriorating. On one hand, the dam has detained approximately millions of tons of wastes that would have otherwise flowed out to sea. In addition, TDG flooded thousands of abandoned factories, mines, hospitals, and potential toxic waste sites after reaching its designed normal storage water level of 175 meters. On the other hand, due to the reduced water flow, the self-purifying function of the river also declined, which contributed to the deterioration of water quality. Water quality monitoring results demonstrate that after impoundment the pollution concentration reaches 49.4 mg/L from 11.14 mg/L while pollution zone extends 4 to10 km [47].

The Yangtze River and its tributaries is the main drinking water source of people living in the Yangtze River basin and Chongqing and Hubei Province are the most directly affected by the TGD. If the water in Yangtze River became too polluted to drink, a huge amount of money has to be invested to control the water pollution and improve the water quality, which constitutes social cost of the TGD.

Methodology: to calculate the social cost of the water pollution by TGD, we use the same social cost borne by household in China's Taihu Lake in 2007. Due to the severe proliferation of blue-green algae in Taihu, households surrounding Taihu Lake had to pay average of $100 Yuan per year to buy the bottled water for drinking. Survey showed that household would pay $50-100 Yuan per year to eradicate the water pollution. In the TGD case, the households affected in Chongqing Hubei province are estimated at $20 million. The NPV of the social cost of water

[46] Yan, Hugo and Potter (2005)
[47] Xiong Zhongfu (2007). "The Effect of Impoundment of TGD on the Water Quality." (In Chinese)

pollution is between minimum $4,579,888,289 Yuan and maximum $9,159,776,579 Yuan with a discount rate of 10%.

Limitations: due to the time constraint, we can't conduct a real survey in Chongqing and Hubei province to find out how much households in these two provinces are willing to pay per year to combat water pollution caused by the TGD. Hence, the value of WTP we used here may not be accurate. This could be improved in the future study by field survey.

3.4.2. Sedimentation: Siltation is always a concern for any dam construction and this is especially true in China because most of China's rivers are full of muddy water. Because of reduced water speed behind the dam, the sediments carried by water will settle down and cause siltation behind the dam. Siltation could eventually cause upstream of Yangtze River unnavigable, hinder the power generating capacity of the hydroelectric dam, and reduce the ability of the dam to control the flood during rain season.

The cost incurred by siltation comes from 2 reasons. The first is the reduced capacity of power generation, shipping, and flood controlling due to the siltation. The second is the cost of dredging siltation. In 2013, first dredging of the shipping lane was conducted by the China Three Gorges Corporation (CTGC) after TGD has generated electricity for 10 years.

Methodology: CTGC siltation budget showed that 144, 133, and 177 meters of siltation were trapped in TGR in 2003, 2004, and 2005, respectively. With normal storage water level of 175m, the total capacity of TDG is 39.3 billion cubic meters. Hence, siltation decreased the capacity of TDG at an annual rate of between 0.3% (based on 2004 data) and 0.4% (based on 2005 data). The NPV of cost caused by siltation is between minimum $4,637,024,169 Yuan and maximum $6,706,692,764 Yuan with a discount rate of 10%.

Limitations: the annual decline rate of capacity caused by siltation was based on a single year observation, thus it may prove to be inaccurate in the long run. In addition, the dredging cost is not publicized yet, therefore, in our calculation is neglected. With more data on siltation and dredging available in the future, the calculation will be more accurate.

3.4.3. Ecosystem disruption: The giant hydroelectric dam serves as a physical barrier that disrupts the river ecosystem and affects biodiversity in the area due to the fragmentation of the habitats. Some endangered species, such as Baiji dolphin and Chinese Sturgeon, which are only found in Yangtze River, are driven into the brink of extinction because the dam blocks their way back to the upstream to lag eggs. The downstream of Yangtze River has also been affected. Decrease in freshwater flow has meant that more saltwater is creeping up the Yangtze, endangering fish populations already threatened by water pollution and overfishing. There has also been a loss in sediment and nutrients downstream, a common issue with most dams, which will cause erosion to river systems, wetlands, and seacoast ecosystems.

Here we choose two representative losses as the cost of dam incurred ecosystem disruption. First is the cost of extinction of endangered unique species. The second is the loss of commercial fishery in Yangtze River due to the ecosystem disruption.

Methodology: for the cost of extinction of endangered unique species, we use shadow prices suggested by BGVW, and make adjustment according to the income level, history and people's WTP in China. In 1980s, to save the endangered Giant Panda, government called on everyone to donate money and the donation per person ranged from $1 to several hundred Yuan. In this case, $1-10 Yuan per person is appropriate and the total population in China is 1.35 billion. For the cost incurred by loss in commercial fishery, we use Morimoto and Hope (2003) data to estimate the loss, between $0.04 and $2.7 billion Yuan per year. The NPV of cost caused by ecosystem is between minimum $6,366,044,722 Yuan and maximum $74,194,190,287 Yuan with a discount rate of 10%.

Limitations: to determine the true cost of environmental degradation, long-term data is needed, so that the effect of TGD can be distinguished from effects caused by other factors, such as the general climate change, human activities, etc. In addition, the cost of erosion to river systems, wetlands, and seacoast ecosystems is not included in the analysis due to complexity.

3.5. Loss in archaeological sites

Large dams construction have significant adverse effects on cultural heritage through the loss of archaeological sites (temples, shrines, and sacred elements, such as landscape, artifacts and buildings) and the submergence and degradation of archaeological resources (plant and animal remains, burial sites and architectural elements). The Three Gorges area is a rich archaeological and cultural heritage, documented as settlement since prehistoric times for several ancestral cultures, such as the Daxi (ca. 5000-3200 B.C.), the Chujialing (ca. 3200-2300 B.C.), the Shijiahe (ca. 2300-1800 B.C.) and the distinctive Ba culture (ca. 2000-220 B.C.) [48].

In this particular case, the dam's construction have a significant negative effect on the Yangtze Basin cultural heritage as it became virtually impossible to collect and document all the archaeological sites threatened by the reservoir after its filling. In 1992, when the Chinese Congress approved the construction of the Three Gorges Dam, among the panel of 412 experts involved in the dam approval, no sociologist, cultural anthropologist or archaeologist were consulted. Before the beginning of the Dam construction (1994), some archaeological campaigns within the dam construction zone were carried out, mainly focused on aboveground cultural sites (ancient buildings, stone sculptures, bridges, and cliff paths) and underground sites (habitation settlements and historical cemetery complexes). In 2000, it was estimated that the area to be inundated contained at least 1,282 cultural heritage places [49], but some recent researches argues that the number of unexplored sites can reach 8,000. The Dam construction will imply not only a material loss, but also an important change in the landscape, and all the information not collected before the completion of the dam in 2009 will never be recovered.

Methodology: According to international standards, the preservation budget for historical sites and cultural antiquities should be 3% to 5% of the total project budget. Using these recommended percentages, the budget for relics preservation had to reach an amount of at least $1.7 billion Yuan when the Three Gorges Dam project was approved in 1992 (the initial budget for the whole project was estimated in $57 billion Yuan), and about $4 to 5 billion Yuan at the middle of 1990s, when the total budget of the project raised to $120 billion Yuan [50]. These suggested amounts were never allocated to the involved research institutions and agencies, and the archaeologists were forced to agree to work with an unrealistic budget, of only about $500 million Yuan, which was clearly insufficient [51]. Therefore, using the proposed methodology, as the minimum project total costs was estimated in $204 billion Yuan, minimum appraisal for loss in archaeological sites is $6 billion Yuan (5% of 204 billion Yuan) and the maximum appraisal for loss in archaeological sites is $33 billion Yuan (considering maximum project total costs

[48] Ponseti and Lopez-Pujol (2006), pp.173
[49] Ponseti and Lopez-Pujol (2006), pp.174
[50] Childs-Johnson (2000), p.53
[51] Ponseti and Lopez-Pujol (2006), pp.177

evaluate in $660 billion Yuan). The NPV of the social cost of loss in archaeological sites is between minimum $1,223,234,170 Yuan and maximum $6,643,357,629 Yuan with a discount rate of 10%.

Limitations: The Three Gorges Project illustrates the potential damage to archaeological sites through the neglect of proper actions. The combined problems of time constraints, under-budgeting, and a shortage of qualified personnel were seriously hampering the salvation and preservation of the impressive archaeological and cultural sites in the affected areas [52]. There are many studies on how to place values on archaeological sites, but there's no simple conclusion for this argument [53] and use a percentage value of the total project budget to evaluate relics preservation, specially when more 8,000 sites remained unexplored, it is quite controversial.

3.6. Externalities and risks

3.6.1. Potential damage earthquakes: Special events such as technical failures, terrorism, and earthquake are very rare cases so that each estimated accident costs will be multiplied by probability of occurrence of these events. On average, we see around 110 dam collapses per year and the official deaths toll shows 9937 deaths due to dam failures [54]. Therefore, to consider the accident cost by earthquake, it was used the probability of occurrence of an earthquake and the cost of the earthquake based on the number of deaths, injuries, and economic impact.

Methodology: is the following [55], cost of earthquake = DDt + IDt + IDt [56], where DDt and IDt are the number of deaths and injuries based on the amount of power generation capacity. The maximum value of DDt and IDt are estimated value for past projects [57]. Inhaber stated that injuries per unit energy was 0.0011 – 0.0128 injuries/Mw, and the calculation for death was also led in the similar way. The minimum values of DDt and IDt are a half of Inhaber's estimate. So we need to add the power generation capacity and to convert the number of deaths and injuries

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[52] World Commission on Dams (2000), pp.117-118
[53] See Carman et al (1999); Carver (1996); Darvil, Saunders, and Startin (1987); Schaafsma (1989).
[54] See Fu. S (1998) "A profile of dams in China" In: Qing (1998)
[55] DDt (or IDt) = (GC*DCR" (or MCR'')*VD (or VM))*(P") (for t>Tc, Million Yuan / Year), IDt = (GC*MCR''*VM)*(P") (for t>Tc, Million Yuan / Year): DDt (or IDt) indicates the accident costs in terms of the deaths (or injuries), DMt = ECL*(P") (for t > Tc, Billion Yuan / Year): DMt indicates the accident costs in terms of economic loss (Morimoto and Hope, 2003)
[56] Morimoto and Hope (2003), pp.20-21
[57] Inhaber, H. (1982) "Energy Risk Assessment" Gordon & Breach Science Publishers

into the amount of money by multiplying the value of the deaths and injuries. The maximum value of power generation capacity is the current planned installed capacity [58] and the minimum value of power generation capacity is the energy output of Victoria Dam in Sri Lanka (about 31% lower than the planned figure [59]). As for the value estimate for deaths, the maximum value is $550 million Yuan [60] and the minimum value is the referred to the compensation for the person who was killed by a construction, $418 million Yuan [61]. In terms of the value estimate for injuries, the minimum value is obtained from regression analysis using data from India and is $0.03 million Yuan/injury [62], and the maximum value in the developed countries in the past studies is $3.3 million Yuan/injury [63]. The NPV of cost caused by earthquake is between minimum of $129,500,495 Yuan and maximum $564,575,195 Yuan with a discount rate of 10%, and between minimum value of $333,449,648 Yuan and maximum value of $1,453,719,535 Yuan with the discount rate of 5%.

Limitations: Many scientists state that the pressure from the reservoir and the dam on fragile geographical structures might lead to earthquakes [64]. It means that the exact calculation of cost of earthquake is difficult because the cost entails the cost of earthquakes led by the TGD and the cost of earthquake originally occurred.

4. Financial and economic evaluation

4.1. Financial evaluation

After considering all the possible variables, the financial evaluation was carried including as major benefits, electricity and shipping and as major costs, construction and resettlement. The results of the financial evaluation can be seen in the following summary of financial appraisal considering 50 years of project duration and discount rate of 10%.

[58] CEB (1994) "Environmental Impact assessment for the UKHP."
[59] World Commission on Dams (2000)
[60] Viscusi (1993)
[61] China News Service 13, October 2000
[62] Shanmugam (2000)
[63] Shanmugam (2000)
[64] New Scientist, 2 Nov 1991, p.13

Project Duration	50 years
Discount Rate	10%
Total Net Benefits	141,561,793,752 Yuan
Total Net Costs	124,817,825,558 Yuan
Benefit-Cost Ratio	1.13

Table 2. Summary of Financial Appraisal

4.2. Economic evaluation

The economic evaluation was carried including as major benefits, flood control and reduced CO_2 and as major costs, earthquake, environmental, displacement, and archeological loss. The results of the economic evaluation can be seen in the following summary of economic appraisal considering 50 years of project duration and discount rate of 10%.

Project Duration	50 years
Discount Rate	10%
Total Net Benefits	311,357,515,963 Yuan
Total Net Costs	173,510,107,116 Yuan
Benefit-Cost Ratio	1.79

Table 3. Summary of Economic Appraisal

4.3. Horizon value

Here we simply assume the value of TGD after 50 years is 0, so the horizon value is zero. However, dams usually still work after the projected lifetime. If we take this into consideration, the benefit-cost ratio should be a little bit higher.

4.4. Sensitivity analysis

We considered four different scenarios: the combination of maximum benefit and the minimum cost, the combination of minimum benefit and maximum cost, under social discount rate of 10% and 5%, respectively, as follow:

(Benefit maximum – Cost minimum) 5% & 10%

(Benefit minimum – Cost maximum) 5% & 10%

Scenarios	Benefit-Cost Ratio	
	Discount Rate 10%	Discount Rate 5%
Maximum Benefits & Minimum Costs	1.79	3.22
Minimum Benefits & Maximum Costs	0.31	0.49

Table 3. Summary of Sensitivity Analysis – Benefit-Cost Ratio

5. Conclusions

By reviewing the chapters, we can conclude the following aspects about the advantages and disadvantages, minimum value and maximum value, and the comparison between the with-case and without-case in this research:

The advantage to study the Three Gorges Dam is the large amount of data sources, as it can be seen in all subchapters. Second, TGD attains the goal of the Chinese Government; especially flood control and electricity generation. The TGD has the capacity to control a 100-year frequency flood, and TGD can produce a large amount of clean energy.

The critics against the TGD project argue that the TDG cost benefit analysis was made in the short run. Some variables of the cost and benefit considered a limited amount of data. The environmental degradation, the externalities and, especially, the risks require a large amount of variables and scenarios, some of which are unexpected. Some samples are uncertain predictions, such as water pollution, the cost of erosion to river systems, wetlands, seacoast ecosystems, displacement and the probability of occurrence of an earthquake. They are so difficult to calculate that the value depends on the change of technology, political policy, environment, and demands for TGD in the long run. And one of the reasons for the unclear or omitted evaluation is that the Chinese Governmental might undervalue the economics losses in the official numbers such as losses of livestock in people resettlement. For example, “costing of civil and mechanical works, project management costs, commissioning costs/rates, wage rates, labor costs, and cost of fuel, etc., has been deleted from the government study. Aggregated values do not mean much if the rates per unit, wage rates of different categories, etc., are not known" [65].

In terms of the minimum value and maximum value, we saw the maximum case and minimum case of the cost and benefits in each chapter, but some maximum values of the factors are sometimes over-evaluated because the variables used in the worst or best cases are extreme. We saw the economic analysis on the basis of discount rate, using minimum or maximum benefit and cost (minbenefit-maxcost (5 or 10%) and maxbenefit-mincost (5 or 10%)). From the cost and benefit analysis, it was clear that in the case of minimum benefit and maximum cost the benefit-cost ratio is 0.31 (10%) and 0.49 (5%). And, in the case of maximum benefit and minimum cost the benefit-cost ratio is 1.79 (10%) and 3.22 (5%). So the former case of benefit-cost ratio amounts to above 1, and the latter one is below 1. Finally, we divide the economic analysis and financial analysis, and find that the benefit-cost ratio in the financial analysis is 1.13, which is higher than the case of minimum benefit and maximum cost but lower than the case of maximum benefit and minimum cost.

Considering other economic analysis, the Chinese government applied the standard discount rate used by the Ministry of Water Resources and Electric Power, 10%, which also the CYJV (Canadian Yangtze Joint Venture) applied to the expected costs and benefits over a 62-year period. Considering other similar studies, the World Bank, one of the financiers for this project, applied a 12% rate of discount in its economic appraisals as it did for the Narmada dams in India. Applying a 12% discount rate causes a 15% decline in costs and almost 30% decline in benefits. The net project benefits decline by 59% [66]. Also, the CYJV uses the administered rate of exchange, $3.7 Yuan per U.S. dollar in its economic analysis of the TGD Project, and included shortage of funds, bottlenecks in management and phases of construction, multiplicity of decision-making organizations, and technical issues in the CBA of the project. In some cases, the schedule is delayed due to the factors mentioned above and the cost of the delay can be as much as 100% or more. CYJV also recognizes that a drastic drop in the exchange rate to about $6 Yuan per U.S. dollar would increase discounted construction costs by 30% [67]. Recent changes

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[65] Barber and Grainne (1998), p.166

[66] Three Gorges Project Proposal, U.S. Three Gorges Working Group, July 1985.

[67] Haines, P. (1986) "Canadian Competitiveness and After Sales Service", an address delivered at the Canadian Export Association's Annual Consultations with the Canadian International Development Agency, Ottawa, 10-11.

in China's economic policy, especially since the 7th Five Year Plan (1986 – 1990), imply that such a devaluation of the Yuan is going on rapidly.

In addition, we need to consider the inflation change in accordance with the time, but the following sentence show the difficulty in estimating inflation: "In the case of the Three Gorges Project, the CYJV analysis is conducted with reference to mid-1987 prices. Of course, all analysts are aware of the fact that some prices escalate faster than others, causing relative price differentials. In China, as in many other countries, project construction costs tend to rise faster than the price of benefits such as the price of power per unit, or the price of agricultural products. This has a tendency to reduce net benefits thereby lowering the ratio of benefits to costs" [68]. We need to calculate the change of the value to too many variables, and these factors make a biased influence on the cost and benefit analysis.

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[68] Barber and Grainnes (1998), p.170

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Appendix I – Maps of the Three Gorges Dam

Image 1. Localization of Three Gorges Dam and Inundated Area Comparison 1987-2006

Source: http://www.cq.xinhuanet.com/sanxia/yimin/english.htm

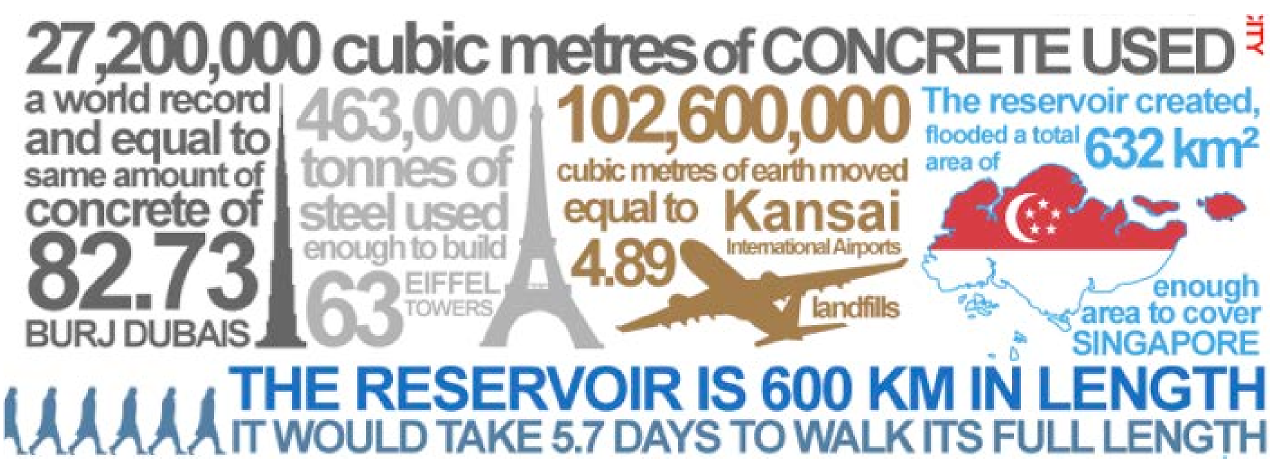

Image 2. Comparing Three Gorges Dam with international references

Source: http://www.cq.xinhuanet.com/sanxia/yimin/english.htm

Appendix II – Summary Table on Benefits/Costs Methodology Pros/Cons

<table>
<tr><th rowspan="2">Variable (Benefits)</th><th colspan="2">Methodology</th><th rowspan="2">Pros</th><th rowspan="2">Cons</th></tr>
<tr><th>Minimum</th><th>Maximum</th></tr>
<tr><td>Flood prevention</td><td>Mean annual benefits from flood control (min) = 0.76 billion Yuan per year (Luk & Whitney 1993)</td><td>Maximum value of mean annual benefits, which assumed that the exceptionally huge flood similar to that of 1870 should occur</td><td>- Flood control protects the agricultural production and water supply against droughts and floods (Allin 2004)
- Flood Control capacity from the present 10 to 100-year frequency (Morimoto and Hope 2003)
- Reductions in the area flooded and prevention of any consequent loss of life, social disruption, health impacts and property and economic losses (World Commission on Dams 2000)</td><td>- Small power of flood control due to the location at the end of the upper reaches (Poseti and Lopez-Pujol 2006)
- Increased risk of flooding without any compensation or heavy burden of compensation (Barber and Grainne 1998)
- We can consider the other measures such as building the small and medium sized dams</td></tr>
<tr><td rowspan="2">Electricity generation</td><td colspan="2">Until 2012, actual production * 0.25 was used</td><td rowspan="2">- Energy conservation and emission reduction (Cao et al. 2007)
- Solve power shortage problem in Central China (Battelle Memorial Institute 1998)</td><td rowspan="2">- Long construction period, while demand rose rapidly building a series of smaller power stations is much quicker and cheaper option for power shortages (Dai, 1994; Challman, 2000a)
- Raising efficiency of transmission and managing demand is better policy (International River, 2008)</td></tr>
<tr><td>Assume actual production in 2012 continue for the future * tariff of 0.25 Yuan per kwh</td><td>Assume full production at the installed capacity per hour * 24 * 365 * tariff of 0.25 Yuan kwh</td></tr>
<tr><td>Reduction in CO_2 emissions</td><td>Assume shadow price 10 Yuan per ton * average reduction in CO2 emissions</td><td>Assume shadow price 30 Yuan per ton * average reduction in CO2 emissions</td><td>- Energy conservation and emission reduction (Cao et al. 2007)
- Reduction in CO2 emission as a result of the TGP (Morimoto and Hope 2003)</td><td>- Use price in European Union Emissions Trading Scheme as shadow price is debatable because in reality the energy generated by TGD is consumed in China rather than transmitted to Europe</td></tr>
</table>

Enhanced shipping capacity	Minimum shipping capacity by the official feasibility study * reduction of cost of 25% * shipping cost of 122.85 Yuan per ton	Maximum shipping capacity by the official feasibility study * reduction of cost of 37% claimed by the company *122.85 Yuan per ton	- Increased shipping capacity due to shoals and rapids being submerged, higher water level during dry season, even for the branch rivers. Larger vessels can pass through. (Peng, Shuai and Xin 2010)	- Bottleneck effect with the current growth of container traffic (Veenstra, Zhang and Ludema, 2008)

Variable (Costs)	Methodology		Pros	Cons
	Minimum	Maximum		
Dam construction	Official number announced by the company (Wang 2002)	Official * 1.4 average cost for large dams overruns at 40% (Morimoto and Hope 2005)	- Although the total cost exceeds the original plan, it is due to the expansion of projects and inflation. - The dam is within budget (China Daily 2009)	- The dam will far exceed the official cost estimate because there are many unknown costs missing from the budget (Li 1989)
Operation and maintenance for electricity production	Electricity produced * O&M cost for large hydro dams=166yuan/kW/year (Battelle	Electricity produced * O&M cost * 1.4 (40% overrun cost assumed by Morimoto and Hope 2005)	- Minimal O&M cost with fewer employees by adopting e-Project Management Information System (www.ifsworld.com)	- New city has been built to house TGD maintenance workers. - Heavy monitoring of the dam's operation required construction funds - embezzled by selecting cheap, inferior equipment and materials; higher O&M

	1998, Table 5.11)			(Allin 2004; www.powertechnology)
People resettlement	The minimum estimative was 640,000 people multiplied by $10,000 Yuan plus 1.47 on the actual number of resettled people, plus 5 times the necessary value to compensate productivity	The maximum estimative was 640,000 people multiplied by $10,000 Yuan plus 1.94 on the actual number of resettled people, plus 5 times the necessary value to compensate productivity	- The government argued that "resettlement construction and development would spur growth in the area bordering the reservoir" encouraging development of the region with resettlement funds. (Barber and Grainne 1998)	- China's record of resettlement is not good, and government admitted that past resettlements have been plagued with "mistakes such as uncoordinated management, duplicate development, wasteful labor use, and limited funds" (Barber and Grainne 1998) - The problem was that the best fertile lands were located in the valleys, flooded by the reservoir, and the government promoted the resettlements in the remaining land, uphill, relatively infertile (Barber and Grainne 1998)
People displacement	Fixed value based on secondary source due to the difficulty in evaluate total assets and includes intangible assets such as social capital losses, production relationships, culture, etc.	Fixed value based on secondary source due to the difficulty in evaluate total assets and includes intangible assets such as social capital losses, production relationships, culture, etc.	- The calculation included the notion of "replacement value". The difference between "compensation costs" and "replacement value" is that the latter equals to market value of total assets and includes intangible assets such as social capital losses, production relationships, culture and kinship networks, etc. (Morimoto and Hope 2003)	- Worst risk in measure displacement is related to the uncertainties in estimate target population and the variations in numbers of people who deserve compensation, replacement land, jobs, housing, and so on. (Morimoto and Hope 2003) - Gender differentiation was not considered as women bear most of the social costs as they are unable to achieve occupational mobility in the process of resettlement (Yan, Hugo and Potter 2005)
Environmental degradation	The cost break up into 3 categories, with each category having	The cost break up into 3 categories, with each category having the largest value	- Report by the China Three Gorges Corporation (CTGC) shows that environment degradation is within the initial estimation (www.ctg.com.cn/)	- To determine the true cost of environmental degradation, long-term data is needed, so that the effect of TGD can be distinguished from effects caused by other factors

	the least value			
Loss in archaeological sites	The preservation budget for historical sites and cultural antiquities should be 3% to 5% of the minimum total project budget	The preservation budget for historical sites and cultural antiquities should be 3% to 5% of the maximum total project budget	- There are many studies on how to place values on archaeological sites, but no simple conclusion for this argument has been reached. See Carman et al (1999), Carver (1996), Darvil, Saunders, and Startin (1987), Schaafsma (1989)	- These suggested amounts were never allocated to the involved research institutions and agencies, (Childs-Johnson 2000), and using a percentage value of the total project budget to evaluate relics preservation, specially when more 8,000 sites remained unexplored, it is quite controversial
Potential damage: earthquakes	The number of deaths and injuries due to special circumstances * value estimate for deaths or injuries* Generation Capacity * Probability of occurrence of earthquake		- Earthquake is important factor of accident costs because we can see the 110 dam collapses per year and the official deaths toll show 9937 deaths due to dam failures (Fu 1998)	- More exact calculation of the cost of earthquake is difficult because the earthquake derives not only from the natural factor but also from the pressure from the reservoir and the dam (New Scientist, 2 Nov 1991, p.13)
	The number of deaths and injuries is a half of Inhaber's estimate below (Inhaber 1982)	The maximum value is the estimated value for past projects (Inhaber 1982)		