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**INTERNATIONAL NETWORK FOR BAMBOO AND RATTAN  
(INBAR)**

**TRANSFER OF TECHNOLOGY MODEL  
(TOTEM)**

**MANUFACTURING HANDMADE PAPER  
FROM  
SYMPODIAL BAMBOOS**

by

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## TRANSFER OF TECHNOLOGY MODELS (TOTEMS)

Transfer of Technology Models (TOTEMS) are focussed educational tools providing relevant information and distance training on one specific area of bamboo/rattan management, processing or utilization. They are a means of technology transfer between similar regions throughout the world, with the emphasis on South-South transfer for livelihood development. They enable those involved in the management and use of bamboo and rattan resources to more efficiently and effectively develop and use skills relating to these resources.

TOTEMS are primarily intended as practical information resources and teaching aids for those at the local extension level in their communities, who can utilize them to assist local community development. Each TOTEM consists of a detailed written report of the technology, a PowerPoint presentation, a film, and, where relevant, a set of technical photographs. They also include information on target users, financial analyses of sample set-ups from the partner country preparing the report and information on where to source particular technologies (such as equipment). The TOTEM thus provides all the information required for establishing similar technologies within interested countries and regions.

- The **report** contains all the technical details of the particular processes involved, as well as other relevant information for establishing the technology such as costs of business establishment, running costs and cash flows.
- The **PowerPoint** presentation contains details of the relevant technologies and their applications, and is intended to provide an overview of the potential of the technology for development.
- The **film** provides a visual guide to the processes involved and helps to bring them alive in the minds of the learners.

The different parts of the TOTEM are targeted at slightly different audiences, via the local extension workers. The report and film are intended to be the main means of extension to the individuals and communities who will implement the technology and who will directly benefit from it. The PowerPoint presentation is primarily intended as a tool for the extension worker to sell the technology and its role in development to those who provide the infrastructural, policy and financial support for its implementation, such as government departments, donors and NGOs. There is considerable flexibility, however. Local extension workers will be able to incorporate the TOTEMS in their own work as they wish and adapt and develop them to suit their particular requirements and conditions.

This TOTEM on **manufacturing handmade bamboo paper** has been produced by Xiao JiangHua and Yang XiaoSheng at the Research Institute of Subtropical Forestry, Fuyang, China. The report part of this TOTEM describes the technology for producing and establishing handmade papermaking facilities for rural development in regions where bamboo is available as a raw material. It is intended to be used in conjunction with the illustrative film included in this TOTEM package



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The first part of the report introduces the technology, discusses its history, its development attributes, its benefits and its applicability. The second part of the report provides detailed information on the technical aspects of producing bamboo paper by hand. **Appendix I** gives information on two case studies in China. **Appendix II** lists source companies and prices of the main pieces of equipment. **Appendix III** explains assumptions made in the financial analyses. **Appendix IV** is a short bibliography.

This TOTEM is one of the first to be produced by INBAR/ RISF and your feedback is most welcome - kindly contact INBAR or RISF with your comments or suggestions.

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**Note 1:** This TOTEM has been edited at INBAR and differs slightly from the form in which it was received from the authors.

**Note 2:** All calculations are in Renminbi (RMB) At the time of writing RMB 8.25 = USD \$1.



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## **PART ONE**

### **INTRODUCTION**

**DEVELOPMENT ATTRIBUTES, TARGET GROUPS and  
BENEFITS of a**

**HANDMADE BAMBOO PAPER UNIT**

## 1. Handmade bamboo paper

The production of hand-made paper is a traditional technology that has been practiced for hundreds of years. The procedures are well known and it is widely practiced in southern China. The products of hand-made paper include joss paper, writing paper, toilet paper and packing paper. Most of the mills are cottage and small-scale enterprises.

## 2. Development of handmade bamboo paper in China

Bamboo paper has been produced in China for at least one and a half thousand years. The book *Tongtian Qinglu Ji* (Record of Valuables in Caves) stated: "Most of the hand writing by the two Wangs referred to the famous calligraphers Wang Xizhi the father, and Wang Xianzhi the son during Jin Dynasty. In recent years, evidence indicates that the original inventor of bamboo paper was a native to Kuaiji, named Zhang Mao in the Eastern Jin Dynasty (317 - 420AD). According to research conducted by Japanese Scholar Dr. Sawasinobi in the Liang Dynasty (502-55AD) the paper on which Buddhist scriptures were written contained bamboo fibres". This illustrates that bamboo paper has a long history in China. The Tang Dynasty was the peak period of feudalism, noted for political stability, cultural progress and economic prosperity. In frequent contacts with foreign countries, paper requirements increased rapidly. The raw bamboo materials were collected locally. In the "Manual of Paper", written by Su Yijian, it was said that the natives in Sichuan, Fujian, Shanzhou and Zhejiang used jute, fresh bamboo, liana and wheat or rice straw to make paper. After the Tang Dynasty, the variety of papers available multiplied and papers such as Yuban paper, Gongchuan paper, Shujian paper, Jingxiao paper, Biaoguang paper and Guangdu paper were produced. All these papers were made of plant fibres, with bamboo as the main source. Rags and waste jute were rarely used.

In the Song Dynasty, Bi Sheng invented the art of printing with wooden types and the development of the printing industry sped up the development of papermaking. In provinces such as Zhejiang and Fujian in South China great quantities of bamboo paper were being produced and paper quality improved. The bamboo paper made in Yuezhou in Zhejiang province became a popular product. Statesmen and men of letter such as Wang Anshi and Su Dongpo all preferred using bamboo paper to write on. They thought bamboo paper absorbed ink well and could show clearly the vigorous strokes. At the time many scholars followed their example. The famous calligrapher and artist Mi Fei wrote in the "History of Calligraphy": "With a hammer I often beat the Yuezhou bamboo paper which appears like a metal plate.....". In the southern Song Dynasty the rapidly developing printing industry required large quantities of paper. The bamboo paper became increasingly refined, and enjoyed great popularity.

In the Ming Dynasty the production technology of bamboo paper was perfected. Song Yingxing gave details of the technology in his book "Tiangong Kaiwu" (Development of Agricultural and Industrial Production): Removal of Green Skin" with illustrations of equipment and operation. The key points were sorting and soaking raw materials, full

boiling, pounding (beating) and bleaching, picking up with a bamboo screen, web pressing, sunning and drying. This was the earliest work recording in detail the production techniques of bamboo paper in China.

In China in 1949, the annual production of hand made paper was only 120, 000 tonnes. Since 1953, output has remained at about 200, 000 tonnes with highest output of 300,000 tonnes in 1954. After 1979 the reform and opening up policies reached the rural and mountain areas. As a result the production of handmade paper increased again. Up to 1985, the annual production stabilised at 260,000 tonnes. In Sichuan 364 paper mills and workshops were registered at the Industrial and Commercial Control Office with a production of 28, 400 tonnes. There was no statistical data available concerning the proportion of bamboo paper of the handmade paper but a rough estimate indicates that it was over 50%. In 1986, a Hand Made Paper Museum was built and opened in Jiayang county. The museum has much historical data and systematically displays the technology of paper making with the bamboo paper as the main example.

### **3. General development attributes and advantages**

The main development attributes of the technology are as follows:

- It is labour intensive
- Provides income generation for men and women
- Increases the use of sustainable bamboo resources
- Reduces dependency on timber wood for paper
- The work is gender sensitive

The main advantages of the technology are:

- Low input requirements for day-to-day management
- Low capital start-up costs
- Flexibility in production of different papers
- Higher price obtainable for handmade paper

### **4. Suitable agro-ecological regions**

Handmade paper manufacturing is suitable for bamboo growing regions that can supply the raw material for its production. Regions of natural bamboo forest are suitable, but handmade paper could also be produced in areas where bamboo is grown on plantations or in homesteads. Management of plantations and natural stands is highly desirable, both to guarantee a standard level of supply to the unit and to maximise the benefits of the plantation to the owner and cultivators. The technology is especially suitable for areas where bamboo plantations are desirable for the restoration of degraded forests or

wastelands such as abandoned shifting cultivation areas, or where bamboos can be grown to reduce soil erosion, particularly on steep slopes in high rainfall areas

## 5. Target groups and benefits

The main target group is those who will be employed in the unit. Manufacturing handmade paper is a traditional, labour-intensive, manual industry. Although some procedures require high levels of skill generally the technology is relatively simple such that that non-skilled farmers, even those with lower levels of education, can become competent in it after a short period of training. Manufacturing handmade paper generates employment for both men and women, ensures better income distribution and earns valuable foreign exchange through exports. The paper making units can be established particularly for poor households or communities in bamboo growing regions/countries. Additional beneficiaries will be the local cultivators and harvesters of bamboo who will benefit from increased demand for culms. Once the bamboo paper making industry has developed, the demands for bamboo raw materials will increase and this will attract more farmers to take up bamboo cultivation.

A handmade paper industry will bring financial income and foreign exchange for local economies and supply more, cheaper papers for local communities and possibly for other countries and regions. Additionally, the bamboo paper making industry will play an important role in poverty alleviation in bamboo growing regions, which are usually mountainous with poor transport access and a lack of energy, technology and finance. Bamboo-based industries are often one of only a handful of development options available for these regions.

According to statistical data from 1992 in China, the profit and tax-cost ratio, average profit and tax of one worker in the handmade paper manufacturing sector are shown in table 1.

Table 1 Benefits of handmade paper manufacturing in China in 1992

Profit and tax-cost ratio %	Profit and tax by one worker Yuan	Profit by one worker Yuan
8.02	1118.8	384.6

## 6. Requirements for success

A regular supply of bamboo culms, a stable workforce and a limited amount of start-up capital are required. Additionally technical assistance may be required in production, to organize seminars and training courses (management, production and maintenance) and to conduct relevant research and development programmes. In addition to providing extra income for the participants, the programmes intend to meet the requirements for skilled



and trained workers in the industry, particularly for making high quality papers. Finance for purchasing/selling raw materials and semi-finished- or finished product is also required

Assistance will be needed to disseminate information on marketing. Institutional/economic policy supports are also required for the success of this sector to guide access to markets, introduce financial investment with preferential treatment on taxes and loans, and to establish technological systems and information service networks to train skilled workers.

## **7. Potential improvements and research needs**

Research on further improvement and value addition of the products, and development of new technologies are not normally required to start a papermaking unit. But once the unit is established further development will be required to exploit new products, innovate processing technologies and improve value addition, so as to enhance the competitiveness and ease of access to international markets.

## **Concluding remarks**

Establishing a handmade paper unit is an excellent means of bringing jobs and empowerment to local rural communities whilst ensuring and increasing the sustainable management of bamboo resources. The initial investment required is low and the unit is very labour intensive. The markets for handmade paper are growing and there may be opportunities to export the product. It is also an excellent means of promoting the sustainable management of bamboo stands and plantations.



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## **PART TWO**

### **THE HANDMADE BAMBOO PAPER UNIT**

## 1. Introduction

Bamboo paper is produced by the following basic steps

- Cross cutting culms and removing the epidermis layer
- Soaking, boiling and washing the culm sections
- Bleaching
- Pounding
- Preparing the stock
- Picking up
- Pressing
- Baking
- Packing

The description of the stages of papermaking that follows is based on field visits to the two paper making units listed in **Appendix I** and has been compiled with their assistance.

## 2. Production of handmade bamboo paper

### 2.1 Raw materials

There are many available bamboo species for pulping, which are divided into four classes based on quality for papermaking. These are as follows:

#### First class:

*B. rigida* Keng et Keng f., *P. heterocycla* var. *pubescens* (Mazel) Ohwi (also known as “Moso”), *B. sinospinosa* McClure, *N. affinis* (Rendle) Keng f., *S. hainanense* Merrill ex McClure, *B. lapidea* McClure, *P. sulphurea* cv. *Viridis*, *D. strictus* (Roxb.) Nees, *D. oldhamii* (Munro) Keng f., *S. funghomii* McClure, *P. sulphurea* (Carr.) A. et C. Riv., *B. chungii* McClure.

#### Second class:

*D. minor* (McClure) Chia et H. L. Fung, *B. pervariabilis* McClure, *B. pervariabilis* McClure, *P. heteroclada* Oliver, *P. robustiramea* S. Y. Chen et C. Y. Yao, *B. cerosissima* McClure, *C. quadrangularis* (Fenzi) Makino, *B. duriuscula* W.T.Lin, *P. glauca* McClure.

#### Third class:

*D. latiflorus* Munro, *C. marmorea* (Mitford) Makino, *B. textilis* McClure and species of *Fargesia* Franch. emend. Yi.

Fourth class:

*B. multiplex* (Lour.) Raeuschel ex Schult., *B. rutila* McClure, *P. amarus* (Keng) Keng f., *P. amabilis* (McClure) Keng f., *B. distegia* (Keng et Keng f.) Chia et H. L. Fung, *P. japonica* (Sieb. et Zucc.) Makino.

## 2.2 Papermaking

A brief description of the key points of manufacturing process is given as follows:

1. Selection of raw materials
2. Cross-cutting and peeling
3. Soaking
4. Boiling
5. Washing
6. Bleaching (sunning)
7. Pounding (beating)
8. Preparing the stock
9. Picking up
10. Pressing
11. Baking
12. Packing.

**1) Selection of raw materials:** Ideally the first or second class species are chosen. The culms chosen should be mature but not too old. For Moso bamboo culms 6 or 8 years old are selected and for most of the bamboos in these grades culms 3 or 4 years old are used. The culms should have no insect or fungal infection.

**2) Crosscutting and peeling:** Fresh bamboo culms are cut into 2 m-long segments.

**3) Soaking:** The culm segments are placed into ponds to soak for 1-3 months according to local particular conditions. The time required for soaking can be reduced by adding lime. Then a wooden hammer is used to remove the green skin by repeated pounding. Bamboo joints and internal diaphragms are also removed.

**4) Boiling:** Cauldrons with a capacity of 5,000 kg are used for boiling. In the past boiling was done in two stages: firstly boiling with lime and then boiling with soda ash. Materials were boiled for about 5-10 days under normal air pressure to remove the lignin. With the lignin removed, the fibers were dispersed into stock. Sometimes after boiling in soda ash (“caustification”), the boiled materials were put into a fresh clear solution of the same, covered and water sealed. In recent years, the procedure has been improved. Bamboos are now cut into short segments and are first put in the lime water or soda ash solution. Only one day is needed for boiling and the raw materials are not boiled with soda ash.

**5) Washing:** Black liquor is drained from the boiled materials, which are washed with warm water two or three times. Then they are placed in ponds to soak until they are



macerated. In the past the alternative was to pour bean juice or rice water on them so they fermented for 5-7 days. Then they were soaked and washed.

**6) Bleaching (sunning):** In ancient times, the stock was spread on the southern slopes of hills to be sunned and weathered for 3-4 months. During this period it was turned twice or thrice. This was natural oxide bleaching. Since the time of Republic of China, most of the handmade paper in Sichuan province has been bleached with bleaching powder.

**7) Pounding (beating):** Coarse matter and trash are removed before washing and pounding. In most localities in Sichuan, water-powered stone hammers or treadled stone hammers were used for pounding. Fibers are fibrillated and dispersed into stock at high concentrations. As the fibers were well interwoven, the paper has better strength.

**8) Preparing the stock:** Stock is put in a tank containing clean water and a dispersing agent and the fibers are suspended evenly in the water, facilitating picking up of the web (the crude paper sheet). The area of the tank should be larger than the bamboo screen that is used for picking up.

**9) Picking up:** The paper is picked up from stock with the bamboo screen and produces a wet web in which fibers are evenly distributed and well interwoven on the screen. Then they are shifted to a wooden press. This is the critical link in papermaking. The picking up is often done by the technical superintendent.

**10) Pressing:** When over one thousand webs have been produced a flat board is placed on top of them and some of the water is pressed out. A soft brush is then used to paste them on the drying walls.

**11) Baking:** The metal walls of the bakery have a smooth surface. There are cold baking and hot baking methods. In hot baking the inner layer of the drying wall is heated. In cold baking drying is by natural ventilation.

**12) Packing:** The oven-dried or air-dried sheets are sorted and counted. In the past, one hundred sheets were referred to as a “Dao” and packaged as such ready for sale. They were bound with bamboo strips.

The production process may be simple or complex, depending on the quality and variety of paper, but most of the work is done manually. It is characterized by high labour intensity, simple equipment and long cycle of production. Long ago, efforts had been spent on improving the equipment, tools and methods of operation. Presently in some mills bamboo is pulped using chemicals, but picking up is still done manually. In workshops using traditional production technologies and manual operation, the stock is kept in churned tanks. The traditional technology of hand made paper has its own strong points, which the modern mechanized papermaking should learn from. For example, its advantages are the choice of bamboo materials, joint and diaphragm removal, green skin removal, oxide bleaching and pulp beating at high concentrations. Some of these have been applied in the modern paper industry and have been mechanized.

## 2.3 Tools and machinery

The tools for bamboo pulping and papermaking are strip knives, saws, bamboo screens, and flat boards. There are various sizes of bamboo screens, which are selected according to product requirements. These tools can be purchased in major cities and some also can be made by the craftsmen and women themselves.

Although crosscutting, splitting and peeling of bamboo culms can be done manually, machines are normally used for this because they can increase productivity and the yield of bamboo splits and remove drudgery in processing the culms. The main machines used are crosscutting machines and splitting machines. The name of machines, number required, supplier, contacts and prices are listed in **Appendix II**

## 3. Input requirements

### 3.1. Labour

Bamboo is traditionally used in rural areas for papermaking. Manual crosscutting, splitting and peeling of bamboo culms are often done by men due to the intensity of the work, but can equally be done by women. Women often work in the less physically demanding jobs such as paper drying, quality control and packaging of the final-products.

### 3.2. Variability of input supplies and costs

The cost of investment for this project includes fixed capital and flow capital that is essential to ensure project implementation and management activities. The input supplies should contain technological service fee, training fee and exploitation fee for new products, as well as investment costs.

### 3.3. Outputs

The outputs are mainly joss paper, toilet paper and packing paper.

### 3.4. Financial attributes (Net Present Value, Internal Rate of Return, Benefit-Cost Ratio, Breakeven Period)

The Net Present Value in different years is listed in table 12. This has been calculated based on the costs of papermaking, including raw materials (bamboo culms, chemicals for preservation, bleaching agents etc.), energy and water, and the output noted above. The Internal Rate of Return, Benefit-Cost Ratio and Breakeven Period are 17.75%, 31.77% and 4.78 years respectively (For assumptions in the calculation of internal rate of return and net present value please refer to **Appendix III**).

## **APPENDICES**

## Appendix I

### CASE STUDIES

#### A: Case one

**Survey site:** Handmade paper manufacturing in Muchuan County, Sichuan province

This is a case study of the hand made paper industry in Muchuan County, Sichuan province, China. Muchuan county is located on the southwestern rim of the Sichuan basin and belongs to the Min and Jingshaji river systems of the upper reaches of the Yangtze River. It is a mountainous forestry county with 1405.26 square kilometers of land and a population of 250, 000, of which there are 220, 000 farmers. The forest area was 955 thousand mu (63, 600 hectares) in 1998, of which bamboos covered 320 thousand mu (21, 333 hectares) with 1.0 million tons of standing culms. The dominant bamboo species is *N. affinis* (Rendle) Keng f., and has been cultivated in the county for centuries. The industry and agriculture output is 545 million RMB, including 279.5 million RMB of agricultural output, and the average annual net income of farmers was 1703 RMB (USD\$ 206) in 1998.

In the past decade, the bamboo sector in Muchuan has developed greatly thanks to institutional/policy supports from various local governments, incentive systems and scientific and technological improvements. There are more than 2500 handmade paper family mills in Muchuan, producing over 13 million RMB Yuan-worth of paper and employing about 20 thousand labourers. Consumption of bamboo raw materials has reached 20, 000 tons and the dominant hand made paper is joss paper.

The majority of the bamboo handmade paper industries are either one-man businesses, family oriented or part-time of businesses. The nine surveyed hand paper mills had 29 staff (13 females and 16 males), the majority of whom had graduated from primary school and were owners or their family members. Only one person was employed by an owner. The wages are calculated based on a piecework rate of: one Yuan per kilogram of paper. The total annual output was less than 14 tons of paper and average output is less than 0.5 ton paper per person. The raw materials for paper making mainly came from their own bamboo forests. The financial investment, costs and benefits are listed in tables 2, 3 and 4. Additional income can be obtained by selling surplus culms from their bamboo forests.

Table 2 Total investment of nine mills (RMB Yuan)

Fixed capital	Flowing capital	Loan from bank	Total
30,000	19,000	500	49,000

Table 3 Total Cost of paper making of nine mills (RMB Yuan)

Total output (ton)	Raw materials	Auxiliary materials	Energy	equipment	Wages for employee
13.6	17,600	2080	2185	2300	480



Table 4 Benefits of hand paper making industry of nine mills (RMB Yuan)

Total output value	Total cost	Benefit	Benefit-cost ratio
34,720	21,865	12,855	0.58

## B: Case two

**Survey factory/site:** Fuchunjiang Painting and Calligraphy Paper Factory, Fuyang, Zhejiang

The factory is the largest professional producer of painting and calligraphy paper in Hangzhou. It is known by many customers both domestic and overseas. It is located in Shuangxi village, Dayuan Town, Fuyang, in the suburbs of Hangzhou, an area known as the “kingdom villages of paper manufacturing”.

The factory was founded in 1978 by the original village-level collective. Now it is a private enterprise covering 6000 square meters and the building covers 4000 square meters. There are two methods of papermaking: machine-made and handmade. There are many handmade paper products, such as traditional painting paper, calligraphy paper and mounting paper. The hand-made paper was awarded the silver medal in the National Forest Industry Famous, Special, and Excellent Novelty Fair ‘94. The hand-made paper produced by this factory is widely sold in Japan, Korea and many Southeast Asian Countries, and is well known abroad.

There are normally 35 staff employed by the owner for handmade paper manufacturing, which includes 16 females, 3 managers and technicians and 14 from other counties/provinces. The raw bamboo materials come from local community forests. The total working capital for handmade paper is 400, 000 RMB Yuan and the total annual output value of handmade paper was about 1.5 millions RMB Yuan in 1998. The main equipment is a caldron for boiling, ponds for fermentation, a pond for bleaching, a stone hammer for pounding, a tank for picking up paper and a paper cutting machine. The cost of all equipment was 200,000 RMB Yuan. The average wages of the employees are calculated based on a piece rate of 140 RMB Yuan per Jian (one Jian is equal to 2000 pieces of paper), and is about 1200 RMB Yuan/person per month.

About 85% of the hand made paper is sold in international markets, mainly in Japan, by the Artware Import and Export Co. The economic benefits are listed in table 5:

Table 5. Annual cost of economic component and profits of handmade paper manufacturing (thousands RMB Yuan)

Raw materials	Wages	Energy-water	Tax and fee	Others	Profits	Selling income
320	450	240	150	240	100	1,500

Of the total income derived from sales, wages occupied about 30% (see table 5), which is the highest of all the costs.

## Appendix II

Suppliers and prices of the main equipment (RMB Yuan)

Equipment	Number	Supplier	Contact	Price Yuan/piece/unit
Crosscutting machine	1	Anji Machinery Factory	Anji Machinery Factory	1500
Whole sheet high speed paper cutter (Model (1300) Q2-103)	1	Shanghai Xinjian Paper Cutter Factory	Shanghai Xinjian Paper Cutter Factory	30,000
Cauldron	1	Homemade	RISF-CAF	5,000
Bleaching Pond	1	Homemade	RISF-CAF	2,000
Stone hammer	1	Homemade	RISF-CAF	10,000
Tanks	10	Homemade	RISF-CAF	15,000
Wall oven	1	Homemade	RISF-CAF	30,000
Electromotor	3	Hangzhou electromechanical factory	Hangzhou electromechanical factory	2,500
Other tools		Homemade	RISF-CAF	12,500
Total				108,500

The total cost of tools and machinery for this factory is about 110, 000 RMB Yuan (USD\$ 13, 300).

## Appendix III

### Explanation of any assumptions used in calculating financial aspects

a. Flow capital is calculated based on requirements of reserve, working capital, Bankroll for finished products, Balance of bankroll and Bankroll in currency.

b. Reserve is calculated based on following equation:

$$\text{reseve} = \frac{\text{anual quantity of raw materials} \times \text{price}}{360} \times \text{days for reserve}$$

days for reserve: 100

c. working capital is calculated based on following equation:

Cost coefficent: 50%

working capital = daily working capital × days for production circle × cost coefficient

d. Bankroll for finished products is calculated based on following equation:

bankroll for finished products = quantity of daily selling products × unit cost × days  
days for bankroll for finished products: 30

e. Calculating Balance of bankroll and bankroll in currency are similar with bankroll for finished products.

f. Cost of products = cost of raw materials + wages + management fee + selling fee + depreciation charge + other cost

g. Output value is calculated based on total selling income

h. Net present value is calculated based on following equation:

$$\text{FNPV} = \sum_{t=1}^n (\text{CI} - \text{CO})_t (1 + i_c)^{-t}$$

FNPV: Net Present value

CI: Amount of cash influx

CO: Amount of cash outflow

$(\text{CI} - \text{CO})_t$ : Net cash value in t year

n: Evaluation period (years)

$i_c$ : Fiducial rate of return (8%)

i. Internal Rate of Return is calculated based on following equation:

$$FNPV = \sum_{t=1}^n (CI - CO)_t (1 + FIRR)^{-t} = 0$$

FIRR: Internal rate of return

CI: Amount of cash influx

CO: Amount of cash outflow

$(CI - CO)_t$ : Net cash value in t year

n: Evaluation period (years)

j. Benefit-Cost Ratio is calculated based on following equation:

$$BCR = \frac{\text{average annual benefit}}{\text{total cost}} \times 100\%$$

BCR: Benefit-cost ratio

k. Breakeven Period is calculated based on following equation and data in following table:

$$\sum_{t=1}^{P'_t} (CI - CO)_t (1 + i_c)^{-t} = 0$$

$P'_t$ : Breakeven period

CI: Amount of cash influx

CO: Amount of cash outflow

$(CI - CO)_t$ : Net cash value in t year

$i_c$ : Fiducial rate of return

$$p'_t = \text{years of positive value of accumulation of net present value} - 1 + \frac{\text{absolute accumulation of net present value in past year}}{\text{net present value this year}}$$

## Appendix IV

### Main bibliographic references

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