



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

**TRANSFER OF TECHNOLOGY MODEL
(TOTEM)**

**WOVEN BAMBOO PRODUCTS MANUFACTURING
UNIT**

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 woven bamboo products** has been produced by Xiao JiangHua and Wu LiangRu at the Research Institute of Subtropical Forestry, Fuyang, China. It may be used alone, or in conjunction with the TOTEM on the bamboo splitting and slivering unit, which has been produced by the Indian Plywood Industries Research and Training Institute, Bangalore, India.

The report part of this TOTEM describes the technology for producing and establishing woven bamboo product-manufacturing 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

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 woven bamboo products in a small scale unit. **Appendix I** gives information on a case study 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 financial calculations are in Renminbi (RMB). At the time of writing RMB 8.25 = USD \$1.

WOVEN BAMBOO PRODUCTS AT-A-GLANCE

What are woven bamboo products?

Woven bamboo products are produced from thin strips of bamboo. There are a wide variety of such products and they have been closely associated with the development of civilisations in bamboo growing regions of the world for many millennia. The products may be primarily intended for agricultural use, such as baskets for vegetables or animals and winnowing trays for cereals, or they may be household products such as baskets, trays, jars, cases, lampshades, fans and mats.

How are they produced?

Bamboo culms are split longitudinally to produce pliable, thin sections of the culm. These are then used to weave the products. The techniques require considerable skill and experience on the part of the weavers and the designs require innovation on the part of the designers.

What is the market for woven bamboo products?

The market for bamboo handicrafts is large and ever-expanding. Handicrafts are very popular in many countries of the world where their natural appearance and their environmentally friendly production methods are major selling points. There is also a stable market for agricultural-use products in many countries.

What is the role of a woven bamboo products unit in rural development?

A woven bamboo products unit provides income generation and skills development to those that it employs. The work is gender sensitive and often favours women. Weaving can be done on site or at home in spare time. Increasing the use of local bamboo resources also encourages their sustainable management and benefits the bamboo cultivators.

How do I establish a woven bamboo products unit?

A woven bamboo products unit can be established very cheaply. If splitting is done by hand then the costs can be limited to land, raw materials and labour. The unit can be established at any scale, from a single person enterprise to a community cooperative. Proper links to markets and feedback on market demands are very important, and continued innovation and development of new product designs will help maintain sustainability of the enterprise.



PART ONE

INTRODUCTION

DEVELOPMENT ATTRIBUTES, TARGET GROUPS and BENEFITS of a WOVEN BAMBOO PRODUCTS MANUFACTURING UNIT

1. Woven bamboo products

The production of woven products is a traditional technology that has been practiced for more than a thousand years, and is widely distributed in southern China. Manufacturing woven products combines traditional weaving skills with modern technology. The majority of the remaining mills are grouped as cottage and small-scale enterprises.

In China, there are various bamboo woven products including baskets, trays, jars, boxes, cases, vases, folding screens, models of animals and figures, buildings, furniture, lamps and lanterns, bags, toys, fans and mats. Some are graceful pieces of art for decoration or enjoyment and some are indispensable commodities. The styles of the products often varies according to place of production. For example animal models are characteristic of Shengxian in Zhejiang province, the household utensils from Dongyang, Zhejiang province are famous, gaily decorated baskets are produced in Gutian, Fujian Province, bamboo pillows are speciality products of Ningde, Anhui province, woven surrounds for porcelain articles are from Chengdu, Sichuan Province, famous fans come from Zigong, Sichuan Province, and the mats from both Yiyang, Hunan Province and Shucheng, Anhui province are well known.

2. Development of woven bamboo products in China

China has long history of cultivation and utilization of bamboo resources. Bamboo has a distinctive status in Chinese culture and history and bamboo has deeply colored the lives of the Chinese people. The usefulness of bamboo in daily life especially in the rural areas, has been well eulogised in literature, both scientific and popular.

The history of bamboo weaving in China can be traced to the Neolithic Age. More than 200 bamboo woven articles have been unearthed in both the primeval Hemudu Ruin in Yuyao City and the Yanliangchu Ruin of Zhejiang Province, which show comparatively skilled weaving techniques. Baskets and other appliances for food storage were woven from bamboo, rattan, willow and straw, which were cut with stone knives and axes. During the Yin and Shang Dynasties the technology of bamboo weaving developed rapidly and various products were woven from bamboo culms. The colored bamboo mat and small suitcase found in the Chu Ruin from the Warring States Period (403~221 B.C.) in Hubei Province are highly ornamented and delicately woven. Various woven bamboo products such as mats, shades, suitcases, fans and baskets, were widely used in daily life or as decorations. The weaving methods differed considerably. For example, mats were woven by placing bamboo strips across one another either diagonally or longitudinally and baskets were loosely woven in three directions or in a circular pattern. These methods continue to be applied even now. The woven bamboo products from Shen County, Zhejiang Province enjoyed a high reputation early in the Eastern Jin Dynasty (317~420 A. D.), and were famous for their use of exceptionally thin bamboo strips. Woven bamboo products diversified during the Ming (1368 ~ 1644 A. D.) and Qing (1644 ~ 1911 A. D.) dynasties, the techniques improved and they became popular among ordinary people.

As the technology of weaving continued into modern times, it has been further developed in the southern provinces of China. Various products such as boxes, cases, trays, fans, lanterns, folding screens, jars, and baskets are produced, some of which are exported to countries in Europe and America. These various colored products are more widely used than before. Zhejiang, Fujian and Sichuan Provinces are the front runners in the bamboo weaving industry in China. As an example, in Shengxian county in Zhejiang Province over 5, 000 varieties of woven products have been produced and more than 200 new products are developed annually. Ninety-five percent of the total output is exported.

3. General development attributes

The main development attributes of the technology are as follows:

- It is labour intensive
- It is gender sensitive
- It increases the use of sustainable bamboo resources
- it is flexible in time and place
- It can build upon inherent weaving skills in the community

4. Suitable agro-ecological regions

The technology is suitable for all areas that grow bamboo that can supply the raw materials for the unit. This includes sustainably managed natural bamboo forests and plantations. Management of plantations and natural stands is highly desirable to guarantee a standard level of supply to the unit and to maximise the benefits of the plantation to the owner and cultivators. The woven bamboo products unit is especially suitable for areas where bamboo plantations are desirable for the restoration of degraded lands 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 are the rural poor. Weaving can be done as an additional activity during spare time or outside the cropping season and thus the farmers can maximise their productivity. Bamboo weaving is a traditional labour intensive industry. Although the weaving of handicrafts involves high levels of skills and creativity on the part of the weavers, in general, the technology for making commodities such as mat and baskets, is not so intricate such that unskilled workers and those with lower levels of education require only short periods of training before they are competent in it. Bamboo weaving can be done in a very decentralised manner and is easily done by homebound women and those that are unable to do manual labour. The unit may be established on a small scale as private household businesses or on a larger scale as a cooperative or government

enterprise. Therefore, bamboo weaving generates employment, especially for women and other disadvantaged groups, ensures better income distribution, and earns valuable foreign exchange through exports. The development of bamboo weaving-based industries will not only generate income for both men and women, but also will create more economic activities and benefit the growth of the rural economy in bamboo growing regions and countries. Woven products, particularly woven handicrafts, have high value addition and their production does not damage the climate or environment

In addition, manufacturing woven products consumes a large quantity of bamboo materials that lead to more income activities based on bamboo forestry, which promotes cultivation and management of bamboo stands and generates incomes for farmers. Additionally, bamboos can be intercropped with food crops and thus enhance the food security of the growers.

The bamboo weaving industry will play an important role in poverty alleviation in bamboo growing regions, which are in mountainous areas with poor transport, lack of energy, technology and finance. These all present some difficulties in developing other industries, yet there are rich bamboo resources and sources of labour available. Woven handicraft units would be ideal for this type of location.

6. Requirement for success

The essential requirements for a successful unit are:

- Regular supply of bamboo culms
- Unskilled and skilled labour
- Small amount of start-up capital
- Market access

The land requirement for setting up the unit is negligibly small and the investment required low. As a micro enterprise it can be established near the resource, and can form a significant part of both the monetary and non-monetary economies in bamboo growing regions. However, technical assistance for production, organizing seminars and training courses (management, production and maintenance), conducting relevant research and development are all required to ensure success, especially in the establishment phase.

Manufacturers rarely conduct market surveys to keep abreast of business trends and accepted products. In the export markets, the low prices offered for relatively high quality products deter them from entering these markets and so assistance is required to disseminate information on marketing.

Institutional and economic policy support is also required to guide new products into markets, to introduce preferential financial investment policies and to set up networks of technical and information services to train workers.

7. Potential improvements and research needs

In China the majority of the bamboo weaving industries are one-man businesses, family oriented or part-time and thrive on traditional manual work procedures. The procedures are relatively labour intensive and performed with on traditional devices that are of low technology and production capacities. Efficient mechanization is still limited and confined mainly to the export oriented manufacturers who boast of their products based on quality and prompt delivery. In addition, product designs fail to receive sufficient attention. The local designers have tried to meet local tastes but without impact. Most of the local manufacturers cannot afford to engage qualified designers and have to rely on existing ethnic designs or copying ideas from other sources for the development of new product designs.

Although bamboo has numerous uses, most of the woven commodities are traditional and low-value products, partly due to the wide utilization of plastic and metal products. The potential for high value addition has not been fully explored. In order to produce woven products from bamboo materials on a commercial scale, development of new technologies in this sector are not normally needed to start the project. Once the bamboo-weaving unit is in operation and requires further development, new products should be developed and value addition improved so as to enhance the competence and ease of access to international markets.

Additionally, in order to transform what used to be looked upon as a lowly material into attractive woven handicrafts that caters to the sophisticated tastes of urban consumers, the designs and creativity put into new products and certain technologies such as preservation and protection against decay and pests should be improved. Aside from obtaining information and designs from other sources that can be delivered to the interested local work-force, more diversified value-added products integrated from different cultures may also be expected. It is also necessary to continue research and development in response to dynamic changes in markets, and to address medium and long term objectives.

Concluding remarks

A woven bamboo products unit is an excellent option for rural development in bamboo growing regions. Weaving is gender sensitive and can be done by people in their own homes in spare time or at the unit itself. Because of the need for initial expert inputs in training weavers and seeking markets, it may be appropriate to establish the unit with the support of state agencies or NGOs.



PART TWO

THE WOVEN BAMBOO PRODUCTS UNIT

1. Introduction

The technical stages involved in manufacturing woven bamboo products are:

- Conception and design of handicrafts,
- Strip and split making
- Weaving skills
- Methods of colouring, preservation and protection against pests and relevant facilities.

Bamboo woven articles are made with various widths, thicknesses, lengths and sizes of bamboo splits made from bamboo culms, based on the design of the products. There are two kinds of bamboo splits used for weaving: bamboo threads and bamboo strips. As their names imply, the thickness and width of threads are approximately equal. Strips are much broader than they are thick.

2. Production of woven bamboo products

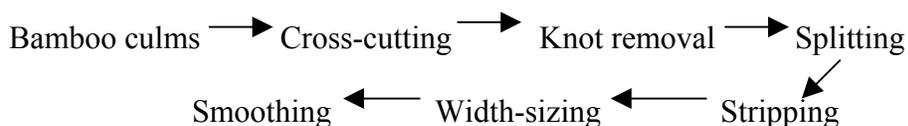
2.1 Raw materials

Bamboo culms are hard and flexible but can easily be split lengthwise into strips and threads for weaving. Many different bamboo species can be used, but the best are those with long internodes such as *B. textilis* and *B. chungii*.

2.2 Weaving process

2.2.1 Making strips and threads

Strips and threads are the basic materials for weaving various bamboo crafts. Proper treatment of raw materials is a very important procedure that affects the final quality of the goods. The processing techniques for making bamboo splits are briefly described below:



a. The narrow tip of the culm and the stout bamboo rhizome are removed before the culms are cross cut to length.

b. Remove the waxy epidermis and nodal flange: The waxy epidermis and nodal flange should be removed from culm surface preferably on the day of cutting to guarantee the brightness and smoothness of the culms. The nodal flange is removed first and then



the culms are fixed to a frame and the waxy epidermis removed by scraping gently and evenly with a sharp knife, without damaging the surface appearance.

c. There are two procedures for splitting bamboo culms. The first involves marking out lines 2~3cm apart, and then splitting into pieces with a knife. The other method is to split the culms in half longitudinally and then further split them into sections based on size of splits required. Attention should be paid to ensuring smooth passage of the knife through the nodes. This operation can be carried out manually or on a machine. Bamboo splits should be put on frames in the open air and dried under the sun with the green skin-side upward. The air-drying process continues until the bamboo skin turns light yellow or yellowish white. To retain their natural beauty the bamboo splits should not be exposed to rain.

d. Production of bamboo strips and threads: Split bamboo parts vertically along the radius of the cross section into bamboo strips. Bamboo strips can then be cut into bamboo threads according to the requirements for the final products. All the bamboo strips should be of same width and same thickness and each strip should be of equal width and thickness throughout its length.

e. Strips must be straight and smooth.

2.2.2 Weaving methods

Bamboo threads are mostly used for making articles such as baskets, boxes, bottles, jars and dolls. All these goods are woven from their base upwards. After the base is finished the weaving continues spirally upwards. Bamboo strips are used for making bamboo mats and curtains. These types of goods are usually woven from the middle outwards to the borders and corners.

3. Comprehensive input requirements

Bamboo is traditionally used in rural areas for weaving products or handicrafts. Manual crosscutting, splitting and slivering of bamboo culms is normally done by men with various tools like knives. Women, disabled or infirm people usually work as weavers.

It is possible for people to weave products such as mats and baskets after short-term training. Much more experience and higher levels of skill are required to weave superior quality handicrafts and these can only be learnt from master craftsmen and women, ideally under an apprenticeship scheme.

3.1 Raw materials

The main raw materials are bamboo culms. Auxiliary raw materials include dyes, bleaching agents and preservatives.

Bamboo culms are tough, flexible, straight, pressure-resistant, tension-resistant and corrosion-resistant. However, culms of different bamboo species, or of the same species of different ages, or under different site conditions, have different mechanical strengths. The material for certain bamboo woven products should be selected in accordance with the design requirements. For delicate products bamboos with flexible compact culms, and long internodes that split well should be selected. This is important due to the ease with which the thin bamboo strips breakdown at the node. Additionally, green-yellow bamboo culms growing exposed to the sun should be selected due to their pliability, greater flexibility and strong stretch resistance, while bamboo culms growing in the shade lose these properties, although they are usually larger.

Bamboo species commonly used for woven products in China mainly *Phyllostachys pubescens* (Moso), *P. sulphurea* cv. *viridis*, *Neosinocalamus affinis* (Rendle) Keng, *P. glauca* McClure, *P. heteroclada* Oliver, *Ph. bambusoides*, *Ph. glauca*, *Ph. angusta*, *Lingnania chungii*, *Bambusa textilis*. These species have very flat nodes, long internodes and fine, strong tissues.

Proper age for cutting: 2-4 years for *Phyllostachys pubescens*, 1-2 years for *Sinocalamus affinis*, *Phyllostachys congesta*, *Bambusa distiga*, *Phyllostachys henonis* and *Phyllostachys praecox*.

Culms should be straight, free of mechanical damage, insect damage and disease. They should be cut on cloudy days in summer. Harvesting on sunny days should be avoided if possible. The culm skin should not be damaged while harvesting and transporting.

Because there are various bamboo species with different processing characteristics distributed widely in the world, the selection of bamboo species with culms of suitable ages will depend on local bamboo resources and quality requirements for products.

The auxiliary raw materials in common use are as follows:

- The **dyes** are: direct dyes, electropositive and acid dyes;
- The **bleaching agents** are: hydrogen peroxide, sodium hydroxide, sodium silicate, oxalic acid, and sodium sulphite.
- The **preservatives** are: PCP, alum, boric acid, sodium borate, and sodium fluoride.

3.2 Tools and Machinery

The tools required for weaving bamboos are strip knives, saws, striking planks, sharp knives, shaving knives and hand drills. These tools can easily be purchased from any tool supplier or can be made by the weavers themselves.

Although cross-cutting, splitting of bamboo culms and making strips and threads can be done manually, machines are normally used to increase productivity, reduce wastage of



raw materials, increase the yield of bamboo strips and remove drudgery in the primary processing of the culms.

The main machines are crosscutting machine, sliver-making machine, splitting machine and width sizing machine. The types of machines, numbers required, suppliers and approximate prices are listed in **Appendix II**.

3.3 Institutional Support

Many farmers in some developing countries are illiterate and live in small villages under conditions of perpetual poverty. Some rural peoples who take up weaving in their spare time to supplement their income from seasonal agriculture are economically strong and have the capacity to organize themselves into cooperatives or aided institutions to benefit from schemes funded and aided by government agencies.

3.4 Variability in 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 for production. The input supplies should contain technological service fee, training fee and exploitation fee for new products, as well as investment costs.

3.5 Outputs

The main outputs of this project are bamboo-weaving products for both commodity and handicrafts such as mats and baskets, as well as processing waste which can be sold for papermaking materials, for energy production, or for making activated charcoal.

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

The average price of one Moso culm with 8 cm DBH was 7~8 RMB Yuan in 1998. The woven products made from one Moso culm with 8 cm DBH are valued at about 60~100 RMB Yuan in China, yet the benefits, value and costs of different bamboo weaving products varies widely.

Based on the costs of various woven products, which include raw materials (bamboo culms), other materials (chemicals for preservation, bleaching, staining etc.), energy, water, and the outputs mentioned above, the Net Present Value, Internal Rate of Return, Benefit-Cost Ratio, Breakeven Period will be 15.33%, 30.13% and 5.01 years respectively (For calculation of internal rate of return and net present value please refer to **Appendix III**).

APPENDICES

Appendix I

An interesting case study

Fuyang Bamboo Weaving Factory, Fuyang 311400, Zhejiang Province

Fuyang Bamboo Weaving Factory, located in Xinmin Township, not far from Fuyang town, is a private enterprise with 120 staff members, which includes 75 women and 6 managers and technicians. The main products are various woven baskets including small bowls, flower baskets and trays. This factory owns about 2,000 square metres of buildings that are rented from a village-level collective. The total working capital is 500,000 RMB Yuan and total annual output value reached approximately 2 million RMB in 1998. There is no other equipment except simple tools like various knives and saws, which are purchased in the local market or made by the artisans themselves. Almost all procedures are done manually. The important point is that the local farmers can weave the articles in their own houses when they have spare time. The average wage of the employees is about 500~600 RMB Yuan/person per month. based on a piece rate of 1.2 RMB per small bowl.

The raw materials (bamboo culms) come from both local communities and Fujian province where they are cheaper than in the local communities.

The economic benefits are listed as follows:

Table 1. The percentages of economic component in total output value (%)

Raw materials	Wages	Energy	Rent charge	Tax	Others	Profits
12	60	3	1.5	14	2.5	7

Note the main cost in this factory are wages, which occupy about 60% of the total output value.

Appendix II

Approximate costs and suppliers of the main machines

Machine	Number	Supplier	Contact	Price RMB/piece/unit
Crosscutting machine	1	Anji Machinery Factory	Anji Machinery Factory	1500
Splitting machine	1	Anji Machinery Factory	Anji Machinery Factory	11,000
Peeling machine (for skin side of culms)	1	Anji Machinery Factory	Anji Machinery Factory	9,000
Peeling machine (for interior side of culms)	1	Anji Machinery Factory	Anji Machinery Factory	9,500
Width sizing machine	1	Anji Machinery Factory	Anji Machinery Factory	2,000
Smoothing machine	1	Anji Machinery Factory	Anji Machinery Factory	4,000
Drying oven	1	Shanghai Machinery Factory	Shanghai Machinery Factory	7,500
Others		homemade		19,500
Total				64,000

Note the prices of machines usually fluctuate

The total cost of machine and tools is approximately 64, 000 RMB Yuan. This includes 19, 500 RMB Yuan for simple tools.

Appendix III

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 coefficient: 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

1. Zhou Junqi (ed). Nov. 1994. *Woven Techniques of Bamboo Products*, [in Chinese] Jindun Press, Beijing, China. 276 pp.
2. Ma Gaohua, Chu Huacheng, Qiu Xingyao. Feb.1987. *Woven Technology of Bamboo Products*, [in Chinese] Zhejiang Scientific and Technological Press, Hangzhou, Zhejiang, China. 210pp.
3. Bamboo Information Center-Chinese Academy of Forestry, Mar. 1994, *Substitute Bamboo for Timber in China*, A Final Report of Project PD 124/91 Rev. 1 (M), Beijing, China. 146pp.
4. Zhang Qisheng, Sheng Weishan, Jun.1997, *Chinese Bamboo Handicrafts*, China Forestry Publishing House, Beijing, China. 124pp.