Testing a technology audit methodology : a rapid assessment of 11 enterprises in Costa Rica

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Testing a

Technology Audit Methodology

a rapid assessment of 11 enterprises in Costa Rica

J.J. Busink & S. Wilson July 1997

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Executive summary

Summary

This research deals with the Technology Audit Methodology (TAM) developed by the department of Technology and Development Sciences of the Eindhoven University of Technology. TAM is developed to identify most promising enterprises in a sector on the basis of a product comparison. In general TAM consist of three parts.
The product part is the core of TAM and consists of comparing the product of the enterprise under consideration with the product of the market leader. The second step of TAM is the production process analysis which consists of a general description of the production process. The goal of this analysis is to find the main (technical) sources of the product shortcomings. The third step of TAM consists of a non technical analysis. The most important elements of interest are product price, management, availability of information, skills and knowledge of employees and direct enterprise environment.

The goal of the research is to test the second draft of TAM, find its shortcomings and, as a result of this, improve the methodology.
The problem definition of the research is: *can TAM effectively and efficiently be used to identify important national manufacturing sectors in developing countries and to preselect small and medium scale enterprises in these sectors for a detailed investment analysis?*

To identify shortcomings in TAM, the following research questions are used:

1 *Can the (technical) shortcomings of a product of a specific enterprise be identified by means of comparing this product with the product of a national and/or international market leader?*
(Is step 1 of TAM viable?)
2 *Can the technical shortcomings of a product of a specific enterprise be related to specific characteristics of the production process of the enterprise concerned?*
(Is step 2 of TAM viable?)
3 *Can product shortcomings and production process shortcomings of a specific product in a specific enterprise be related to knowledge and skills of employees, management structure (including financial management), information level and supply and the direct enterprise environment?*
(Is step 3 of TAM viable?)
4 *How can the theoretical methodology be adjusted best to obtain a workable instrument?*

The methodologies used to answer the research questions are observation and the interviewing of experts working at the enterprise concerned. During the data collection, the second draft of TAM was used as a checklist.

The field work consisted of visiting 11 enterprises in the Costa Rican metal industry. The metal industry in Costa Rica consists of 961 enterprises which is about 15% of the country's industry. In general, the whole metal industry sector is very inward oriented. About 70% of the production is for the local market, the rest is exported mainly to other Central American countries.
Most of the sector (64%) consists of small-scale (<30 employees) enterprises. Medium-scale

(30-70 employees) enterprises represent 31% of the sector. The remaining 5% consists of large-scale enterprises.

The 11 enterprises were selected by Asometal, the Costa Rican organization for the metal industry where the research was executed. The products of the enterprises consisted of, among others, ovens, oil filters, clips and sink units.

During the field execution, the product part of TAM was tested by describing the products of the enterprises. The product characteristics were determined by questioning an expert working at the enterprise. In The Netherlands, products of market leaders were described by observation, reading product documentation or by visiting enterprises and questioning an expert working at the enterprise. A product comparison was made by comparing the product characteristics.
The production process part of TAM was tested by describing the production processes of the Costa Rican enterprises in detail. In The Netherlands, after the product comparison, the production process features responsible for the identified product shortcomings were determined.
While visiting the enterprises, problems regarding step 3 were identified through observation and questioning of the general manager.
All problems encountered during the testing of TAM were described. After this, solutions were sought and used to adjust and improve TAM.

Conclusions

The problems encountered during the testing of TAM can be divided in three groups, problems with respect to the product part, problems with respect to the production process part and general problems. Below, these problems are described.

1. problems with respect to product part of TAM

Most problems regarding the product part of TAM can be found in the definition of product characteristics. The following list shows the problems with respect to these definitions:
- the definition of the product characteristic reliability is too complicated
- the definition of the product characteristic maintainability does not include frequency of maintenance
- there is a large similarity between the product characteristics versatility and compatibility
- there is a large similarity between the product characteristics ergonomics and operational complexity
- the product characteristics storage capabilities and use of rare materials give the answers 'none' or 'not applicable' for every product
- the definition of the product characteristic performance is too broad for a practical application

Another problem with respect to the product part of TAM arises when the product of the market leader cannot be obtained easily (due to size or price). In this case, it is difficult to obtain product information of the market leader due to fear of competition.

Also, TAM uses the ISIC/SITC codes for identifying market competitors. During the testing of TAM it appeared that this classification is not detailed enough for the purpose.

Finally, TAM does not contain a methodology to determine the weighing factors needed to indicate the importance of the product characteristics.

2. problems with respect to production process part of TAM

Most problems regarding the production process consist of the machine features degree of mechanisation, capacity and tolerances. Another problem concerns the description of raw materials and ready bought parts.

The degree of mechanisation classification should give a first indication of the predictability of quality (tolerance), capacity and flexibility of machines. In practice, however, category 2 of the classification (self acting machines) covers a wide variety of machines with different features.

The problem with respect to tolerances is that it appeared that tolerances are rarely specified on technical drawings in Costa Rica.

The capacity determination and analysis described in the second draft of TAM is very time consuming.

The problem regarding the description of raw materials and ready bought parts is that a complete list becomes too long for complex products.

Finally, TAM does not give an indication of the condition of the machines. This is an important factor for determining the costs of new investments.

3. general problems of TAM

TAM has shortcomings related to enterprises which manufacture a large variety of products or made to order products with one production line. The reason for this is that comparing more than one product takes too much time. Also, when the production process is adjusted to improve a product, it can influence the quality of other products produced in the same production line.

Another problem of TAM is that it only focuses on shortcomings of step 2 and 3 of TAM that cause product shortcomings. However, an enterprise can have problems regarding these steps of TAM which are not directly related to product shortcomings.

TAM is a methodology to select the most promising enterprises in a sector. However, TAM in its present form does not contain a methodology to select these most promising enterprises from the results of the audits. Also, it does not give a clear, practical guideline for the data collection.

Finally, a sector can be too large to execute TAM for all companies in the sector.

Feedback to research questions

When comparing the research questions with the conclusions, it appears that the methodology has to be adapted with respect to the above mentioned aspects to obtain a workable instrument.
Step 1 and 2 of TAM are viable. Step 1 can be used to identify product shortcomings and

step 2 is suitable for relating the product shortcomings to shortcomings in the production process. Adjustments are necessary to make the execution of TAM more efficient.
Step 3 of TAM is not yet suitable for relating enterprise characteristics to product and production process shortcomings. This part of TAM has to be worked out in more detail.

Recommendations

1. recommendations with respect to product part

The product characteristics performance and maintainability must be redefined and the characteristics versatility/compatibility and ergonomics/operational complexity must be combined. The characteristics use of rare materials and storage capabilities can be removed from TAM. For the product characteristic reliability, the MIR-approach can be incorporated in TAM. With this approach, the reliability of a product is determined according to the type of reliability information that is available within an enterprise. This approach is described in more detail in paragraph 8.1.1. A complete list of new definitions of the product characteristics is presented in paragraph 8.1.2.

In the case of large or expensive products, the product information of the market leader should be obtained through specialists such as wholesale businesses and dealers. The market leader can be determined by interviewing the producer of the initial product. This information must be verified by the local chamber of commerce in the case of a local market leader. Information about international market competitors must be obtained before the actual execution of TAM.

Finally, a method for weighing the product characteristics must be included in TAM. A good weighing method is the pairwise comparison procedure. With this method, every characteristic is compared with each other characteristic, one at a time, by determining which characteristic is more important for the success of the product. The weighing method is elaborated upon in paragraph 5.3.1.

2. recommendations with respect to production process part

Category 2, self acting machines, of the machine feature degree of mechanisation is subdivided in two categories. The sub-categories differ in flexibility and predictability of quality. Category 2A contains machines with a relatively low flexibility and medium predictability of quality. Category 2B contains machines with a relatively high flexibility and high predictability of quality.

Tolerance figures must only be collected if one or more important product shortcomings can be related to tolerances.

For a general picture of the production process, only the maximum and actual production capacity of the complete production process are determined. Detailed capacity figures of a particular machine must only be collected when there is an indication that they influence the quality of the product.

The list of raw materials and ready bought parts must be limited to the parts of the product with shortcomings. Especially for large and complicated products, this can be considerably time saving.

In order to get an overview of the condition of the machines, each machine is classified in one of the following categories: relatively new (depreciation within ten years), used (depreciation within five years) or obsolete (already depreciated).

3. general recommendations

A sector can be too large to execute TAM for all enterprises in the sector. Also, not all enterprises are suitable for TAM. Therefore, a methodology is needed to make a selection of enterprises suitable for TAM. The first part of this methodology excludes companies from TAM on the basis of the criteria company size, number of different products, type of product and demands or wishes of the client. When the remaining group of companies is still too large for TAM, a sample is taken to obtain the desired number of companies. This methodology is explained in paragraph 8.3.1.

Problems within the enterprise, which not directly influence product quality, but which hamper efficient operation, must be indicated. While executing TAM, all the identified shortcomings regarding step 2 and 3 must be listed. All the characteristics of the production process part and the enterprise part are listed separately in two columns. After this, shortcomings directly and indirectly influencing product quality are distinguished. In chapter 6, this procedure is used for the identification of the shortcomings in the production process and the enterprise environment.

For the execution of TAM a clear, practical guideline is necessary. The solution for this is a manual with forms, on which all the information to be collected during the execution of TAM can be filled in.

A methodology for selecting the most promising enterprises from the results of audits must be added to TAM. The general outline of such a methodology is based on a list of the technical remedies needed to lift product shortcomings, the market prospects of the product and a ranking of the technical remedies on the basis of costs and technology. This methodology is elaborated upon in paragraph 8.3.5.

Further research

TAM is a very comprehensive subject of research. It was not possible to study all aspects of the methodology in detail. Further research is necessary on the following aspects of TAM:

The possibility of incorporating the product life-cycle in TAM
It seems useless to execute TAM when the product has entered the phase of decline. Is has to be examined if it is possible to quickly determine the phase of the product life-cycle in which a product is situated.

The development of a methodology to determine market competitors
Important sources of information must be listed, especially with respect to the determination of international market competitors. Also, the method for determining the market leader must be examined.

The development of a methodology for selecting the most promising enterprises
The methodology for selecting the most promising enterprises from the results of TAM must be worked out in more detail. Elements of step 3 of TAM must also be incorporated in this methodology.

The elements of step 3
Step 3 of TAM has not been worked out in detail. It has to be determined how the elements of step 3 should be included in TAM and which financial characteristics of an enterprise must be included. Also, the incorporation of the product price in TAM has to be studied. It has to be determined if, for example, the introduction of life cycle costs is useful.

The design of a checklist or data form
TAM should be executed following a practical guideline which consists of a checklist or data form that contains all the elements of TAM.

Preface

After nine months of work, this M.Sc. thesis concludes our period as a student in Eindhoven. The field research for this thesis was carried out at Asometal, the Costa Rican branch organisation for the metal industry. The completion of the thesis would not have been possible without the help of the following people.

In Costa Rica, we would like to thank the personnel of the enterprises we visited for being extremely helpful in answering all our questions.
We would also like to thank Luis Gómez for driving us through the San José rush hour every week and for introducing us at the enterprises.
Also thanks to all the other people at Asometal, especially to doña Elisa for helping us with our Spanish and arranging the enterprise visits.
We would like to offer our special thanks to our field supervisor ing. José Alberto Salazar. First of all for being patient, especially during the first weeks when it appeared that our Spanish wasn't as good as he had expected. Also for contacting the enterprises, preparing our visits and for his stimulating remarks like "no vamos a complicar la vida" when we encountered problems during the field work. Despite his busy schedule, he always made time for us.
Finally, we would like to thank Douglas and his family for their hospitality and for making us feel at home in Costa Rica, Jeroen Ygosse for getting us settled and Jeroen Thielemans for his lively discussions and just for being a good room mate.

In the Netherlands, we would like to thank ir. G. Janssen of Gemco for his expertise on ovens. In addition, we want to thank mr. Ligtenberg of Reginox for his information on steel sink units and for an (unexpected) guided tour through the plant.
We want to thank ir. Emilia van Egmond and ir. Adrieke de Kraker for establishing the contact with Asometal and for arranging the necessary details.
Also thanks to Rob and Gertrude for being good colleagues.
And last but not least, we want to thank our supervisors at the university, prof. dr. A. Szirmai, ir. H. Toersen and especially dr. ir. Paul Lapperre for his critical remarks and the many hours he spent on reading our reports.

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1 Introduction

The Technology Audit Methodology (TAM) was developed by the Department of Technology and Development studies of the Eindhoven University of Technology after a request from the Polish government and a Dutch consultancy firm. The methodology was required to select the most promising enterprises in an industrial sector.

After the development of the second draft of TAM in the summer of 1996, the methodology had to be tested in practice. Testing TAM formed the basis of a graduate research assignment. This report is the result of that research assignment.
The goal of the research is *to indicate shortcomings of TAM and, as a result of this, improve the methodology.* During the field research period (October 1996 to March 1997), TAM was tested in 11 enterprises. The enterprises were selected by Asometal, the branch organisation for the Costa Rican metal industry, where the research was executed. Although the research is primarily aimed at improving TAM, indirectly, the enterprises benefitted from the research as well. Each enterprise received a report with a description of their product and production process. The products of four enterprises were compared with the products of the market leaders and recommendations were made to improve the quality of the products.

The report starts with a general part that describes the theoretical framework and research setting. After this, the report describes the second draft of TAM. Next, the products of the 11 enterprises are described as well as the products of four market leaders. Then, a product comparison is carried out and the product shortcomings are described. The report continues with a description of the production processes of the 11 enterprises. After this, the product shortcomings are related to the production process to find the causes of these shortcomings and recommendations are made for product improvement. Based on the practical experiences of the field work, the next part of this report gives an overview of the problems of TAM. Finally, these problems are solved in order to improve TAM.

2 Theoretical framework

This chapter describes the theoretical framework of the research. First, a profile of Costa Rica is presented together with a description of the area of interest: the small and medium scale industry in Costa Rica. After this, TAM is very briefly described because it forms the basis of the research. Finally, the problem setting, research questions, objectives and methodologies are presented.

2.1 Problem setting

2.1.1 Brief country profile

Geography

Costa Rica is a republic in southern Central America, bordered in the north by Nicaragua, in the east by the Caribbean Sea, in the southeast by Panama and in the southwest and west by the Pacific Ocean. Costa Rica ('the rich coast') was dubbed so by Christopher Columbus in 1502. The total area of Costa Rica is 51,060 sq km. Costa Rica is divided into seven provinces and each of these has a governor appointed by the president. The country's capital is San José. Most of Costa Rica consists of rugged highlands, about 915 to 1830 meters above sea level. Several mountain ranges extend nearly the entire length of the country. A central plateau, the Meseta Central, is located between the ranges and accommodates the bulk of the population. Wide lowlands extend along the Caribbean coast. The lowlands along the Pacific are narrower. Here the coast is broken by a number of bays. Figure 1 shows a map of Costa Rica[1] with its main cities.

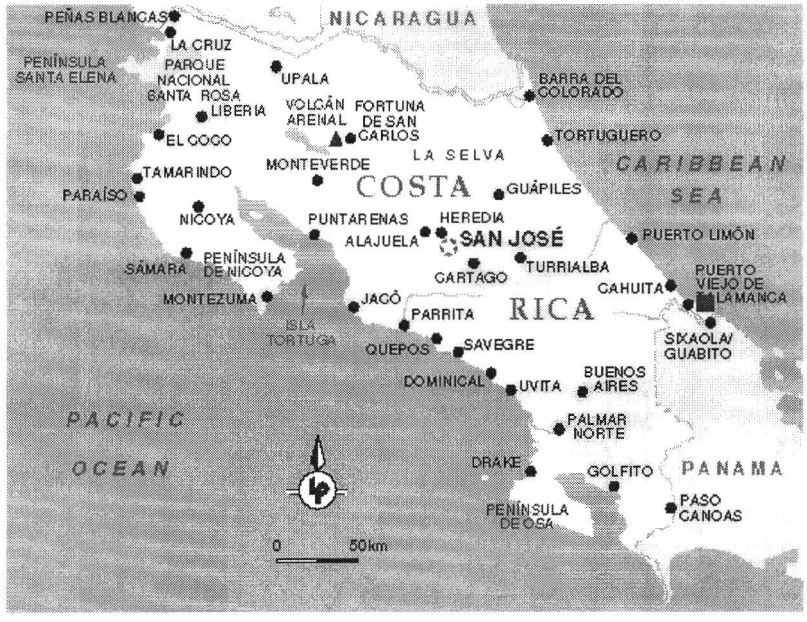

Figure 1: Map of Costa Rica

[1] http://www.lonelyplanet.com/

Population

A majority of the people of Costa Rica is of European (largely Spanish) descent. About 50 percent of the population is defined as rural. Spanish is the official language, but English is also spoken by educated people and some of the formerly Jamaican population. The population of Costa Rica is 3,419,114 (July 1995) giving the country an estimated overall population density of about 67 people per sq km.

Politics

Costa Rica is a republic governed under the constitution of 1949. Executive power is vested in a president and two vice-presidents, each of whom is elected by direct popular vote for four-year terms. The president and the vice presidents may not succeed themselves. Each candidate must receive more than 40 percent of the total vote. Voting is compulsory for all citizens over 18 years of age. The president is assisted by a cabinet of 20 ministers. In February 1994 José María Figueres Olsen of the PLN was elected president.

Legislative power in Costa Rica is vested in a single-chamber Legislative Assembly, with 57 deputies, elected for 4-year terms. The leading political groups in Costa Rica are the National Liberation Party (Partido de Liberación Nacional, or PLN), a reformist organisation, and the Social Christian Unity Party (PUSC). The PLN started reorienting the country's economic and social policies in 1948. They used the power of state to diversify the country's economy and to create more opportunities for the entrepreneurs. Since then, the PLN has been a supporter of the industrial development of Costa Rica. The policies of the PUSC, in general, focus more on the growth of the traditional exports like bananas and coffee.

Judicial power in Costa Rica is vested in a supreme court, appellate courts, a court of cassation (highest appeals' court) and subordinate provincial courts. Capital punishment has been abolished.

Economy

In table 1, the main indicators of the Costa Rican economy are presented.

The economy of Costa Rica remains basically agricultural, although manufacturing industries have been expanding since the early 1960's. Good agricultural soils in Costa Rica are concentrated in the Meseta Central and in the river valleys. About one-third of the total land area is covered by forests, much of which are commercially productive. Mineral resources, including bauxite, are believed to be extensive but remain largely undeveloped. Fishing for tuna, sharks, and turtles is carried out along the coast.

Overall living conditions are high by Latin American standards. About 10% of Costa Rica's land is under cultivation. Apart from banana plantations, most of the agricultural holdings are small. Coffee, one of the most valuable crops, is cultivated mainly in the central plateaus. Bananas are raised in the tropical coastal regions. A United States firm, the United Fruit Company, opened the largest banana plantation in the world on the Pacific coast of Costa Rica and constructed the ports of Quepos and Golfito as banana-shipping points. Cacao, sugarcane and pineapples are also raised primarily for exports. Except for the gold and silver deposits, most of Costa Rica's natural resources remain largely unworked.

The unit of currency is the Colón. The Banco Central, established in 1950, is the bank of issue and administers foreign reserves.

Table 1: Economic data of Costa Rica[2]

GDP per capita (1994)[3]	US$ 2400
Distribution of GDP	agriculture: 18% industry: 28% services: 54%
GDP per capita (growth)	6.1%
Contribution to GDP growth	agriculture: 0.4% industry: 1.7% services: 4.0%
Export (value)	US$ 1823.9 mln
Most important export products	Coffee, bananas
Natural resources	Gold, silver, nickel, manganese, sulphur, mercury and oil
Import (value)	US$ 2785.8 mln
Inflation (1994)[2]	17%
Exchange rate Colón-US$ (Feb.1997)[4]	223 Colones
HDI rank (1991)	40
Population	3.27 mln
Labourforce	1.01 mln
Employment	agriculture: 28% industry: 17% services: 39% other: 16%

2.1.2 Small and medium scale enterprises

Approximately 75% of the Costa Rican industry consists of small and medium-scale enterprises. The medium and small scale industry has a large variety of different enterprises, ranging from coffee-drying plants to woodworking and all kinds of metal working factories. The medium and small scale industry plays a fundamental role in the economic, social and political development of Costa Rica. The development of this industry increases the industrial production and creates employment. Another advantage of the small-scale industry is that it can react very quickly to market-changes[5]. The PLN has always had a lot of support from the entrepreneurs and thus benefits from the growth of the medium and small scale industry. Even so, the medium and small scale enterprises are very vulnerable to changes in the international economic environment which sometimes leads to the complete disappearance of a sub-sector. However, this process of economical changes also provides growth potentials for the sector which must be identified and stimulated.

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2 World Bank tables, all data 1993 unless otherwise indicated

3 Baker, C.P., *Costa Rica Handbook* (Moon Publications, 2nd ed., USA, 1996)

4 Banco Central de Costa Rica

5 *Centroamerica: Agenda para la modernización industrial* (Costa Rica, p. 60)

The main problems of small and medium-scale enterprises are:

- no access to credits
- lack of humanware: not enough knowledge/educated people
- lack of quality for international competition
- especially small-scale enterprises have problems with management
- lack of cooperation with the large-scale enterprises, no subcontracting systems exists
- problems to get access to the international markets, problems with marketing their products.

The small and medium scale industry is stimulated by several measures such as special loan arrangements with lower interest rates and income taxes, facilitating access to financial resources. Also technical assistance is provided. Exporting industries of non-traditional products are being stimulated by the exemption of income tax. In order to further stimulate the development of small and medium scale enterprises it is important to identify those enterprises which are likely to benefit most of government and/or private assistance. For this identification a rapid assessment method is required.

2.1.3 The Technology Audit Methodology

This paragraph provides a short description of the Technology Audit Methodology (TAM). A more detailed description can be found in chapter 4.
TAM can be used to select the most promising enterprises in a sector suitable for further analyses (complete investment and feasibility studies). Before starting the actual audit, the sectors and enterprises to be audited must be identified. This can be done by looking at, for example, the sector contribution to GDP, the import-export situation and the prime mover role of the sector imposed as a policy focus. Of course, the sector and even the enterprises to be audited can also be selected by the client for whom the audit will be executed.
TAM consists of three parts, the product, the production process and the enterprise part. The product and process part are executed sequentially, the enterprise part is executed simultaneously during the complete duration of TAM.
The sequence of TAM is presented in figure 2.

The product part is the core of TAM and consists of comparing the product of the enterprise under consideration with the product of the market leader. The comparison of products is structured by the following categorisation of product characteristics: functional, inherent/intrinsic and aesthetic product characteristics.

The second step of TAM is the production process analysis which consists of a general description of the production process by making, among others, a flow chart and lay out of machines. Also the following features of the process will be analysed: degree of mechanisation, tolerance, capacity and flexibility. The goal of this analysis is to find the main (technical) sources of the product shortcomings. Therefore, the focus in the production process analysis is guided by the product shortcomings found in the product characteristics comparison.

The third step of TAM consists of a non-technical analysis. The most important elements of interest are product price, management, availability of information, skills and knowledge of employees and direct enterprise environment.

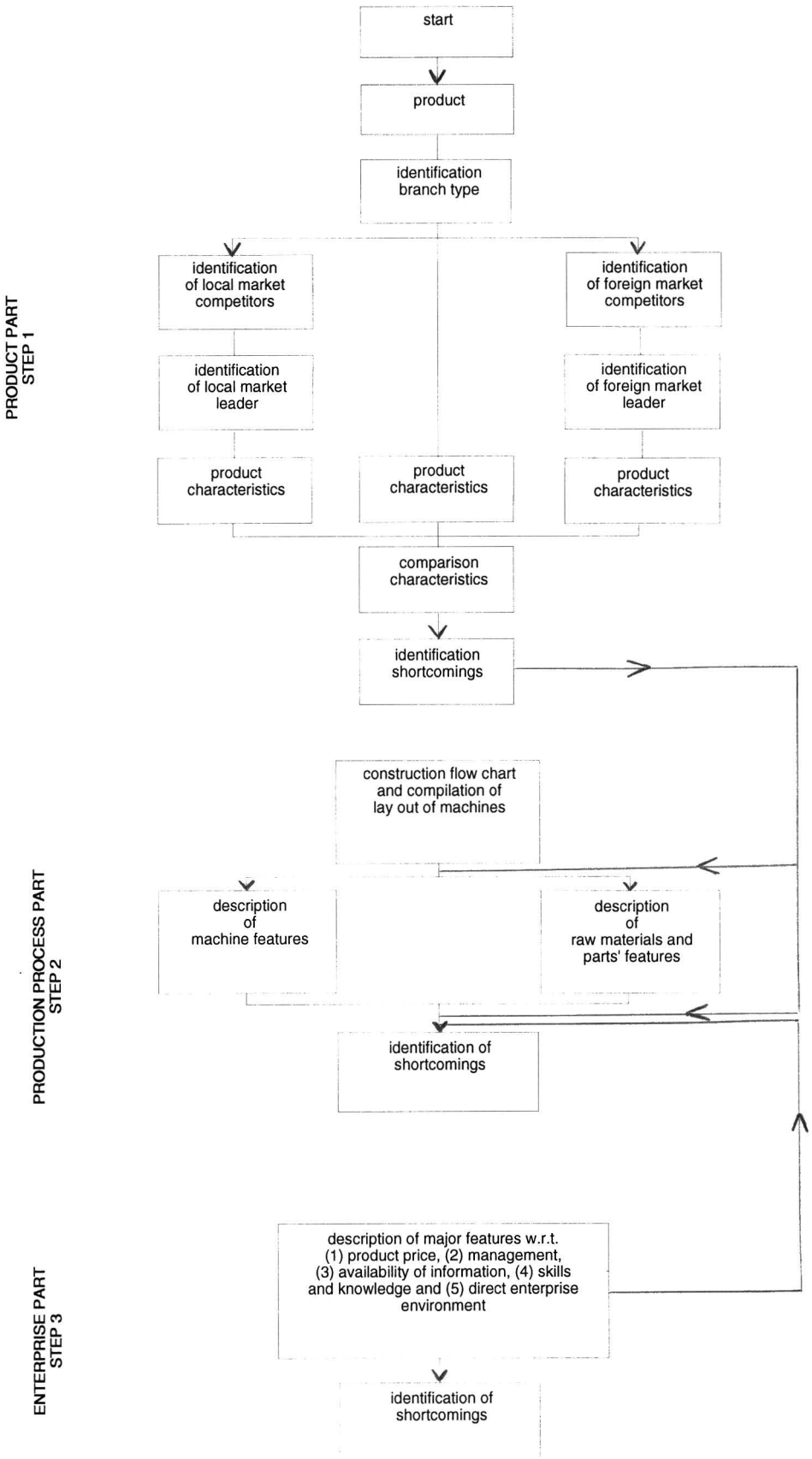

Figure 2: Sequence of the technology audit methodology

2.2 Problem definition

Can the technology audit methodology developed by the TDS-department of the Eindhoven University of Technology effectively and efficiently be used to identify important national manufacturing sectors in developing countries and to select small and medium scale enterprises in these sectors for a further investment analysis?

2.3 Concrete research goal

The concrete research goal is to indicate shortcomings of TAM by testing the methodology in practice and, as a result of this, to improve the methodology.

2.4 Research questions

1 *Can the (technical) shortcomings of a product of a specific enterprise be identified by means of comparing this product with the product of a national and/or international market leader?*
(Is step 1 of the proposed methodology viable?)

- What kind of product is being examined?
- What is the main application of the product?
- What are the alternative applications?
- What is the national/international market leader?
- What are the product characteristics important for product comparison?
- What kind of weighing factors can be applied to these product characteristics?

2 *Can the (technical) shortcomings of a product of a specific enterprise be related to specific characteristics of the production process of the enterprise concerned?*
(Is step 2 of the proposed methodology viable?)

- What is the lay-out of the production process?
- What are the machine features?
- What kind of raw materials and ready bought parts are used as inputs?

3 *Can product shortcomings and production process shortcomings of a specific product in a specific enterprise be related to the elements of step 3 while testing step 1 and 2 of the methodology?*
(Is step 3 of the proposed methodology viable?)

- What kind of product shortcomings can be related to these elements?
- What kind of production process shortcomings can be related to these elements?

4 *How can the methodology be adjusted best to obtain a workable instrument?*

- Are the points for improvement (paragraph 4.3) still viable
- Can the identified problems be translated into improvements of the theoretical model?

2.5 Methodology

The field work in Costa Rica consisted of visiting 11 companies in the small and medium scale metal industry. During these visits TAM was tested. The companies were selected by Asometal, the Costa Rican organisation for the metal industry where the research was executed. After conferring with Asometal, the list of companies was adjusted to obtain a larger variety (in size and level of technology) of companies.
Below, the used methodology per research question is described.

1 *Can the (technical) shortcomings of a product of a specific enterprise be identified by means of comparing this product with the product of a national and/or international market leader?*
(Is step 1 of the proposed methodology viable?)

In Costa Rica, the products were described while visiting the enterprises. The product characteristics were determined by questioning an expert working at the enterprise (usually the plant manager). In The Netherlands, the products of the market-leaders were described by reading product documentation or by visiting enterprises and questioning an expert working at the enterprise.
A product comparison was made by comparing the most important characteristics of the products. After the comparison the product shortcomings were determined.
During the data collection, the second draft of TAM was used as a checklist.

2 *Can the technical shortcomings of a product of a specific enterprise be related to specific characteristics of the production process of the enterprise concerned?*
(Is step 2 of the proposed methodology viable?)

In Costa Rica, the production process was described in detail through observation (lay-out, flow chart, degree of mechanisation and inputs). In The Netherlands, after the product comparison, the production process features responsible for the identified product shortcomings were determined.

3 *Can product shortcomings and production process shortcomings of a specific product in a specific enterprise be related to the elements of step 3 while testing step 1 and 2 of the methodology?*
(Is step 3 of the proposes methodology viable?)

While visiting the enterprises problems regarding step 3 were identified through observation and questioning of the general manager.

4 *How can the theoretical method be adjusted best to obtain a workable instrument?*

The problems encountered during the testing of TAM were described. After this, solutions were sought and used to adjust and improve TAM.

2.6 Review of chapter contents

This paragraph contains a short review of the contents of the following chapters.

Chapter 3 discusses the metal industry in Costa Rica and the 11 companies that were visited for this research.

In chapter 4, the second draft of TAM, on which the research is based, is explained in more detail.

The product comparison is discussed in chapter 5.

Chapter 6 contains the determination of the causes of the product shortcomings which are found in chapter 5. The product shortcomings are related to the production process and the elements of step 3.

The problems encountered during the testing of TAM are discussed in chapter 7. Also, solutions to these problems are presented.

Finally, chapter 8 contains a revised version of TAM in which the solutions to the problems encountered during the testing are incorporated.

2.7 Division of activities

The research was carried out by two M.Sc. students: Jurgen Busink and Sander Wilson
The responsibility for the contents and results of this thesis will be borne by the both of us.

3 The metal industry of Costa Rica

The research was executed at Asometal, the branch organisation for the Costa Rican metal industry. This chapter first describes the history and present situation of the Costa Rican metal sector. Next, a short description of Asometal and its activities is given. A large part of the research consisted of visiting 11 member enterprises of Asometal. The final part of this chapter presents an overview of these enterprises and their products.

3.1 Short history

Before 1950, Costa Rican industry mainly consisted of small-scale enterprises, producing agricultural products. Most of the financing sector was not very interested in financing non-agricultural projects.
In the 1950s, awareness started for the importance of industrial development. Several incentives were provided to develop industry. Funds were raised by a number of organisations to stimulate the industrial development of Costa Rica and Central-America in general.
In the 1960s, the industrial activity increased by approximately 8.4% a year. In the 1970s, the Costa Rican Corporation of Development was established to help small and medium-scale enterprises with technical and financial assistance. After the 1970s, Costa Rica became aware of the importance of exporting its products, several laws were passed to stimulate the export industry. Until now the Costa Rican metal industry has major problems of getting access to the export market[6].

3.2 The present situation

The metal industry in Costa Rica consists of 961 enterprises which is about 15% of the country's industry. In general, the whole metal industry sector is very inward oriented. About 70% of the production is for the local market, the rest is exported mainly to other Central American countries.
Figure 3 gives an indication of the position of the metal industry in Costa Rica.

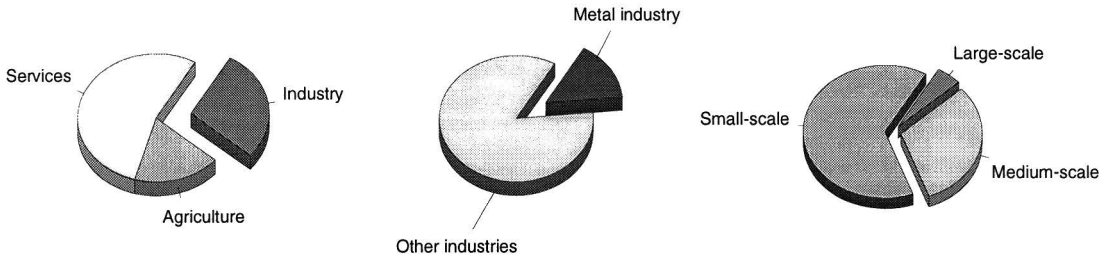

Figure 3: Position of the Costa Rican metal industry

[6] *Centroamerica: Agenda para la modernización industrial* (Costa Rica, pp. 16-21)

Three types of enterprises are distinguished by Asometal:

- small scale enterprises (0-30 employees): production or services mainly for the local market
- medium scale enterprises (30-70 employees): mainly substitution of imports for the local and regional market
- large scale enterprises (> 70 employees): production mainly oriented towards the export market.

Most of the sector (64%) consists of small-scale enterprises of which most have less than six employees. Medium-scale enterprises represent 31% of the sector. The remaining 5% consists of large-scale enterprises.

In 1996, Asometal made a diagnosis of 52 enterprises of which 26 small, 13 medium and 12 large scale ones[7]. Approximately 50% of the enterprises was purely production oriented. The rest also had commercial activities and services. Only one of the small scale enterprises was a subsidiary of a transnational enterprise, the rest was nationally owned. In the case of the medium scale enterprises, three had external capital. Four of the large scale enterprises had external capital, of which two had a mix of internal and external capital.
Some other results of the study were:

* The small scale enterprises have little or no company development and obsolete or overdimensioned production processes. They have serious problems in the areas of administrative financing and the marketing of their products. Some other problems are a shortage of educated employees, poor product and process quality and a lack of cooperation with the medium and large scale enterprises.

* The medium scale enterprises, of which most can be found in a modernisation process, have a limited development of commercial and export activities.
  Their main problems are a lack of credit and a shortage of educated employees. It is also very difficult for these enterprises to compete on the international market because of a poor product quality and efficiency to compete with respect to prices.

* The large scale enterprises have a very internationally oriented production and have a lot of international competition. They use more modern technologies and have a higher production efficiency than the small and medium scale enterprises.
  The large scale enterprises have almost no relations with the rest of the sector. There is no sub-contraction system.

Asometal mentions that the metal industry of Costa Rica has a lot of relations with other sectors like the electronics industry, the food industry, the plastic industry and the automobile-parts industry. It is, therefore, very important that these sectors develop at the same time.

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[7] MEIC/ASOMETAL, *Plan de modernización del subsector metalmecanica* (San José, Costa Rica, 1996, pp.5-9)

3.3 Asometal

Asometal is a private organisation which unites enterprises in the Costa Rican metal industry. It was founded in 1967 and its main objective is to provide information and to develop projects for the development of the sector. The policies are set by a management of eight directors.

Asometal currently joins about 60 enterprises and has several projects running or under development of which some are presented below:

- *Diagnosis of the metal sector*
  This diagnosis was developed to identify the viability of the sector. For this diagnosis, data on production processes, installed capacity, machinery and equipment, personnel training, quality control, waste management and information systems was collected by interviewing a number of enterprises. The diagnosis contains some elements of TAM but only provides a very general overview of the enterprises in the sector. No product specific information was collected.
- *Multi-sectoral industrial park*
  This project was set up to promote the integration of various industries. It facilitates the use of common services (security, transport, etc.) and the integration of production processes.
- *Institute of tools and machines*
  This project is oriented towards the technical training of operators.
- *Recycling of waste metal*
  This project tries to develop recycling and commercialisation of metal waste products.
- *Normalisation and quality control*
  By introducing normalisation and quality control processes in the metal industries, this project tries to raise the quality level and to improve the competitiveness.
- *Technical and management training programs*
  This project tries to identify the training needs for the sector and to improve the current technical and management training.

3.4 The enterprises audited

For testing the technology audit methodology, 11 enterprises in the metal industry of Costa Rica were visited. These enterprises were selected by Asometal. In table 2, the basic information of each company and its main product is presented.
The list contains four small, five medium and two large enterprises. A striking aspect is that only three of the 11 enterprises produce one product or a series of products. All the other enterprises produce several products sometimes ranging from steel sink units to curtain rails.
The level of technology of the enterprises was indicated by Asometal. Two of the enterprises produce high-tech products or use high-tech production machines. These two enterprises were among the most modern enterprises in Costa Rica, of which there are very few. The other companies use more straightforward technologies.
The market competitors listed in table 2, were indicated by the enterprises as the most important ones. When no competitors are listed, this means that the product is very common and thus the number of competitors is large.
As we will elaborate upon later, TAM has shortcomings related to enterprises which manufacture a great number of different products and enterprises which focus on very small numbers of custom made products. From table 2 it apparent, that diversity of products is not linked with technology level and production volume.

Although at this stage it is too early to make a selection of enterprises suitable for TAM, it is possible to make a pre-selection on the basis of the company information in table 2. Companies that manufacture more than five different products and have a small production volume of the product to be audited are not suitable for TAM in its present form. The reason for this is that comparing more than one product takes too much time. Also, when the production process is adjusted to improve a product, it can influence the quality of other products produced in the same production line. On the basis of the above mentioned criteria, Bendig, Fundición Saborio, R&R Precisión and Termomecánica are excluded from the sample of TAM.

Table 2: Company information

Company name	Level of technology acc. to Asometal	Nr. of employees	Nr. of different products	Name of main product	Product price (US$)	Application mode	Usual operating conditions	SITC ISIC code	Market competitors	Production volume
Xeltron	1	75	1	optical sorting machine	12.500	sorting coffee beans	indoors, in coffee factories	712 382	Sortex (UK) Elexo (Ger)	200/year
Bendig	2	65	>5	oven	25.640	supplying hot air	indoors, on coffee farms	711 382	Pinalense (Bra) Joca (CR)	30/year
DICTE	2	25	1	oven	15.120	baking bread	bakeries	718 382	Polin (Ita) Winkler (Ger)	4-5/month
DIMMSA	2	25	>5	telephone	230	making calls	open air, remote areas	724 383	CEECO (USA)	500/week (case)
FILCA	2	96	2-5	oil filter	3-5	filtering oil through paper	high tempera-tures and vibrations	698 381	Fram (USA) Purolator (USA)	150000/month
Bananera	2	35	2-5	trolley	13-15	transporting bananas	banana planta-tion, hot and humid	698 381	Thomas cable way (USA) Sueje (CR)	48000/year
Corusa	3	50	1	clips and wire	85 per 1000	part of cloth hanger	stores and wardrobes	698 381	-	500000/month
Fundición Saborio	2	15	>5	cast products	depends on product type	depends on product type	depends on product type	679 371	-	no information available
R & R Precisión	1	35	>5	precision parts	depends on product type	machine part	depends on machine type	695 381	-	no information available
INASA	2	60	2-5	steel sink unit	27-80	installation in a kitchen	kitchen	812 381	Teca (Spa)	3000/month
Termomecánica	3	15	>5	oven	25.000	drying painted products	factory	718 382	Isotex (CR)	3-5/year

4 Technology Audit Methodology

This chapter describes the Technology Audit Methodology (TAM) in more detail. After an introduction, the three main steps of the methodology (product part, process part and enterprise part) are described. Finally, a list of critical remarks on the second draft of the methodology, made before testing the methodology in Costa Rica, is presented. In a later stage, these remarks will be compared with the actual results of the testing of the methodology.

4.1 Introduction

TAM was initially developed following a request from the Polish government to a Dutch consultancy firm. A methodology to select the most promising enterprises for a further detailed investment analysis was required. The methodology would have to be suitable to screen a large number of enterprises in a relatively short time (approximately three days for each enterprise). The consultancy firm contacted the Department of Technology and Development Studies of the Eindhoven University of Technology and a first draft was developed by a group of students of this department. The methodology was described in more detail by Lapperre and v.d. Ploeg in a second draft[8].

TAM focuses on medium and small scale manufacturing enterprises in developing and middle and eastern European countries. These enterprises play an important role in national development. In addition to contributing significantly to the GDP and to national employment, these enterprises appear to react in a rather flexible manner to changes from a centralised economic policy to a more liberal one. However, medium and small scale enterprises often find it difficult to compete on the home market with the high quality and relatively low priced products from highly industrialised countries. Access to foreign markets is usually completely denied to them. The reasons for this phenomenon are complex, but the unfavourable price/quality ratio of the products - compared to foreign ones - is an important factor.

Before governments and agencies decide to invest in structural support for the medium and small scale manufacturing sector, they usually insist on the identification of the most promising manufacturing sectors and - within these - the most promising enterprises. TAM can be used as an instrument to select these enterprises. In a later stage, these enterprises can be subjected to a full scale feasibility (investment) study. In this manner, a significant survey cost reduction can be achieved.

For time and cost reasons, it will usually not be possible to include all sectors, sub sectors and enterprises in a technology audit. Therefore, before the actual execution of the technology audit, the most promising sectors and enterprises are identified using macro economical data and information provided by ministries, branch organisations or other relevant organisations. Even when the sector has already been indicated by the client, it will still be useful to collect these data because they provide a better understanding of the sector concerned.

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[8] Lapperre, P.E., (ed.), *Technology Audit Methodology* (Eindhoven, The Netherlands,1996)

4.2 Description of TAM (second draft)

The description in this paragraph is entirely based on the original document of the second draft of TAM[9] and, as yet, no modifications are suggested or made. This will be done in chapter 8.

TAM consists of three parts. The core and step 1 of the methodology is a comparison between the technical characteristics of the product of the enterprise under consideration with the technical characteristics of the product of the market leader (either local or foreign). Step 2 is the production process part, which consists of a description of the main features of the production process. Step 3 is the enterprise part, in which important non-technical aspects are taken into account.
Figure 4 gives a schematic presentation of TAM.

4.2.1 Step 1: product part

As shown in figure 4, the product part consists of several steps. Each of these steps will be explained below.

Product description

The product description consists of:
- name of the product
- drawings/pictures of the product
- proposed functioning of the product (viewpoint of manufacturer)
- usual application mode(s) (viewpoint of customer)
- usual operating conditions of the product
- classification of product type (according to SITC code, appendix 1).

Identification of branch type

The branch or sector is classified by the ISIC code (appendix 2). By assigning an ISIC code, the sector and thus other manufacturers of the same product can be identified.

Identification of market competitors

The identification of market competitors provides an overview of all producers of the product under consideration. On basis of this overview, the market share of each producer can be determined and consequently, the market leader can be identified. To obtain data on the market share of competitors, among others, the following information sources can be consulted:
- chamber of commerce
- branch organisations
- ministries
- bureau of statistics.

[9]Lapperre, P.E. (ed.), *Technology Audit Methodology* (Eindhoven, The Netherlands, 1996)

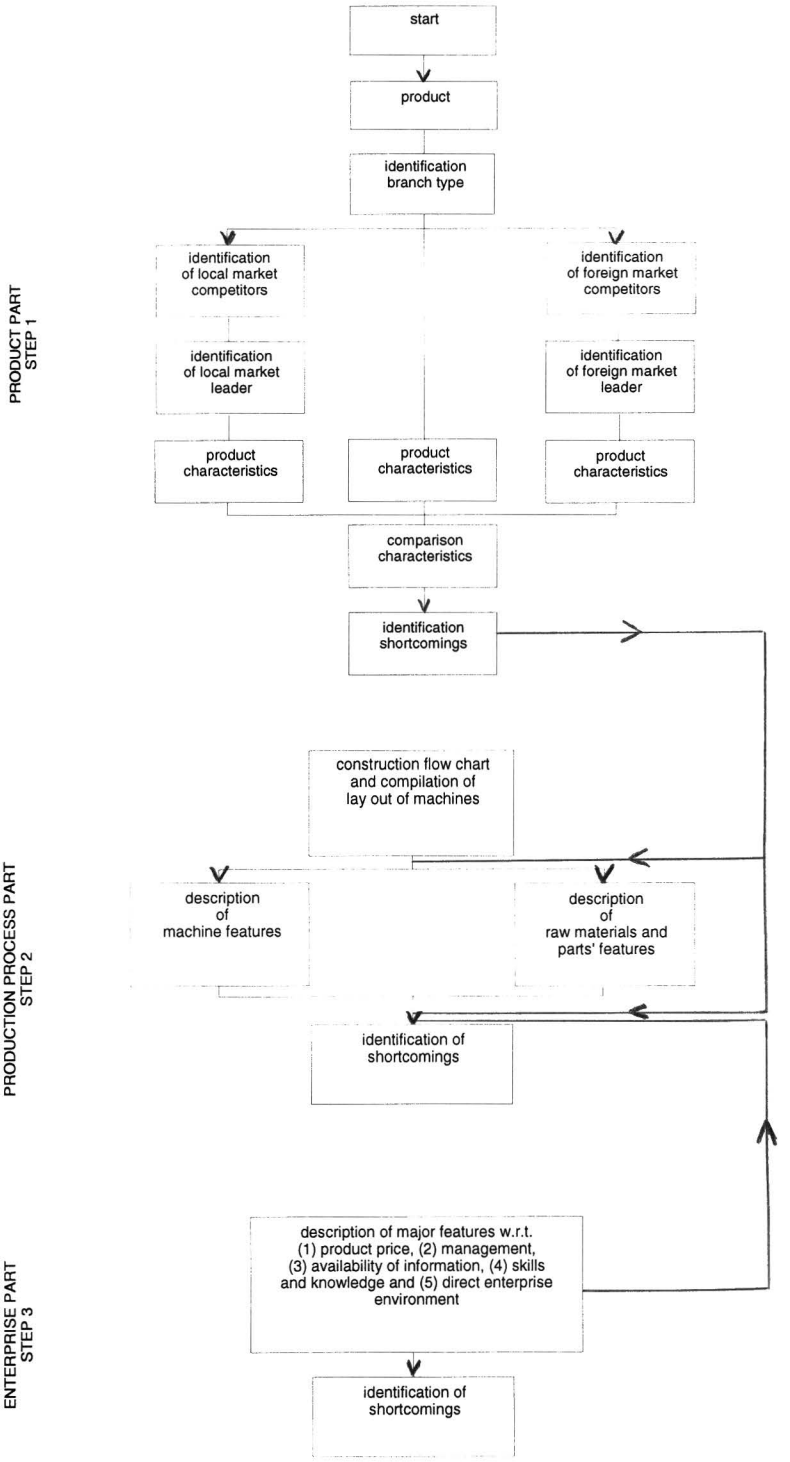

Figure 4: Sequence of TAM

Identification of market leaders

The market share is a measure which allows the identification of the most successful product in its sector. Increases in market share are closely associated with increases in profitability, improved chances of survival and minimising risks of loss. The market leader is identified by ranking the quantities sold on the market (foreign or local) of the product under consideration. A prerequisite is that the market leader and the enterprise concerned manufacture exactly the same product and that they operate in the same market niche.

Product characteristics

The product characteristics are divided into three categories:
- functional characteristics
- inherent/intrinsic characteristics
- aesthetic characteristics.

The characteristics are described in tables 3, 4 and 5.

Table 3: Functional product characteristics

Characteristics	Description
1. durability	time, number of cycles the product performs adequately
2. reliability	chance that functioning since new without failure will last for at least a certain period of time
3. safety	measurements taken to prevent injuries of users
4. maintainability	ability to replace, correct an conserve the product
5. sensitivity w.r.t. environment	weather conditions, shocks, vibrations, dust, temperatures, etc.
6. versatility	different way of application
7. performance	the ability of the product to execute the intended application
8. operational complexity	number of actions required to obtain the intended use, number and dependency of additional input requirements
9. compatibility	ability of product to adapt to different applications and environments
10. ergonomics	ease of handling the product
11. storage capabilities	possibility to keep the product on the shelf without losing the performance of the product

Table 4: Inherent/intrinsic product characteristics

Characteristics	Description
12. construction complexity	number of parts, shape of parts, functioning principle
13. ecological impacts of materials	production, usage and wasting of the product involves an unsustainable burden on environment and users
14. use of rare materials	applying materials which can easily be replaced by more suitable materials

Table 5: Aesthetic product characteristics

Characteristics	Description
15. look	appearance, attractiveness of the product
16. smell	n.a.
17. noise	n.a.
18. feel	physical feeling

Each characteristic of the product has to be translated into product specific characteristics. These product specific characteristics are evaluated for the product of the manufacturer under consideration and the product of the market leader. The result of the comparison states the position of the product in relation to the position of the product of the market leader.

4.2.2 Step 2: production process part

First, this step is executed to identify production process features, which may cause the product shortcomings as identified in step 1. Secondly, step 2 serves to recommend technical remedies in the production process for the shortcomings of the product. The production process is described on basis of the following characteristics:

- flow chart and lay-out of machines
- description of machine features (degree of mechanisation, tolerance, capacity, flexibility)
- description of raw materials and ready bought parts.

Below, these characteristics are explained in more detail.

Constructing a flow chart and lay-out of machines

This first step is executed to provide an overview of the total production process. For the flow chart, the conventional method of input-process-output is applied. Figure 4 shows the symbols that are used for the construction of the flow chart.

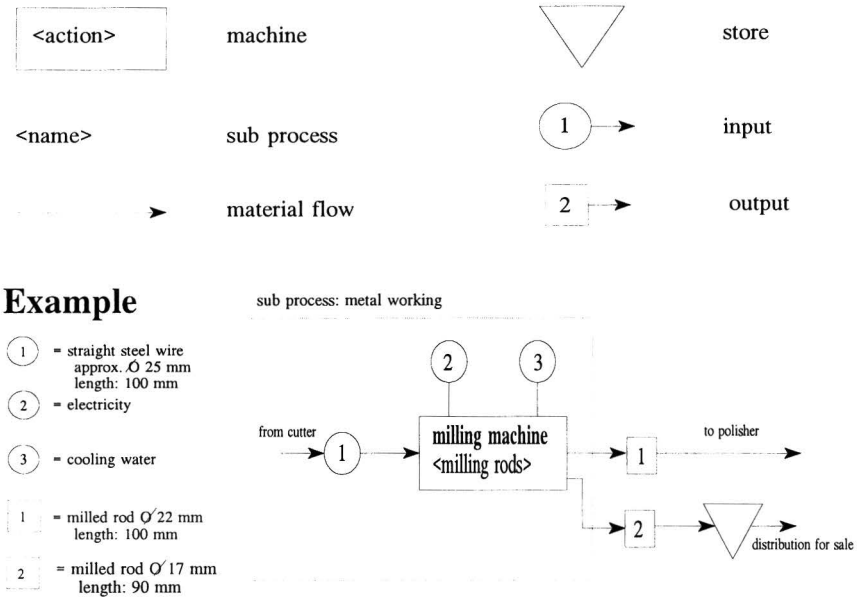

Figure 4: Flow chart symbols

The lay out of the machines indicates their position. This position affects the product and the other production process characteristics. The lay out will prove its value in a later stage of the audit. If investments in new machinery are needed to remedy product shortcomings, information necessary for the accommodation of new machines is already available.

Description of machine features

In this step, the actual application for each machine in the production line is described. The functioning of the machines is expressed in the machine features degree of mechanisation, capacity, tolerance and flexibility.

- *Degree of mechanisation*
  The degree of mechanisation gives a first indication of the flexibility, predictability of quality and capacity of a machine. Table 6 shows the different categories for the degree of mechanisation.

Table 6: Degree of mechanisation

Degree of mechanisation	Description	Predictability of quality	Machine capacity	Machine flexibility
1. Tool or handicraft	Tools or handicrafts are an extension of the human hand. They enable the function not performable with bare hands.	low	low	high
2. Self-acting machine	Machines only able to repeat recorded mechanical movements.	medium	high	low
3. Self-checking machine	Machines able to identify production deviations by means of a sensor. Switching off by detection out of tolerance production.	medium/high	high	low

4. Self adjusting machine	Machines for mass production of products with a long life cycle. Sensor information is used to correct an observed deviation.	high	high	medium
5. Flexible machine	Autonomously working machines, controlled by an external (computer) program.	high	medium	high

- *Tolerance*
  Tolerance figures are used to explain deviations in product and product-parts quality. In this part, the design tolerances, as specified in drawings, are compared to the machine tolerances and the actual production tolerances. First, the product specified and machine specified tolerances are compared. The product specified tolerances should normally not exceed the machine specified tolerances. If the product specified tolerances lie within the machine specified tolerances, the product specified and performed tolerance figures are compared. The qualitative exercise here is to determine the reasons for out of tolerance of products.

- *Capacity*
  The capacity determination can be divided into three steps:
  1. machine supplier capacity
  2. prescribed production process capacity
  3. actual production capacity.

  Capacity figures are important when intermediate storage affects the technical quality of products. Also, capacity figures clearly picture the material stream through the production process. Wrong input products (parts) to cover up under-capacity of a previous machine are easily detected this way.

- *Flexibility*
  The flexibility of a machine is defined as the ability to change the action of the machine with minor adjustments. The flexibility of a machine is expressed in:
  1. variety of products/parts produced by a particular machine
  2. time required to transform that machine from one product output to another
  3. accuracy of flexibility.

  While examining the flexibility of machines, two types of flexibility can be distinguished: internal and external flexibility. Machines with internal flexibility are able to produce parts or products that are present in the product under comparison. The machine has the flexibility to perform changes necessary to adjust the product to the specifications of the product of the market leader. The external flexibility goes beyond the application function of parts in the product under comparison. This external flexibility is of lesser importance. It only provides a better insight in the technological capabilities of a machine.

Description of raw materials and ready bought parts

An overview must be made of all raw materials and ready bought parts. The place of entrance in the production process must be indicated in the flow chart and the product or production function must be described. A comparison of specified and actual quality of raw materials and ready bought parts results in a list of shortcomings regarding inputs of the production process.

Identification of production process features causing product shortcomings

The production process part analysis results in a list of shortcomings compiled from the analysis of the production process and the analysis of raw materials and ready bought products. Now, the product shortcomings found in step 1 are related to shortcomings in the process production part.

Identification of technical remedies lifting product shortcomings

A consideration of types of technical remedies is needed. The final result of this last step of TAM must be: lifting of the product shortcomings of the product under consideration. The product shortcomings can originate from different sources:
1. design of the product is not optimal or wrong
2. production process is not optimal or wrong.

This will lead to two major flows of remedies: *product improvement or redesign* and *production improvement.*

4.2.3 Step 3: enterprise part

The third and last step of TAM is aimed at finding shortcomings with respect to:
- product price
- management
- availability of information
- skills and knowledge of employees
- direct enterprise environment.

This step has not been worked out yet. However, at this stage it is already possible to collect information such as product price, influence of direct enterprise environment and skills and knowledge of employees while executing step 1 and 2 of TAM.

4.3 Critical remarks before testing the second draft of TAM

Before testing TAM in practice, a list of possible shortcomings was formulated based on a critical evaluation of the methodology. In chapter 7, these remarks will be compared with the actual results of testing TAM to verify if they are still valid. Below, the list of critical remarks is presented.

- We doubt if it is really possible to execute TAM in three days. In our opinion more time is needed.

- The three steps of TAM procedure must not be seen as sequential steps, but as parallel.

- The second draft focuses on the government, TAM will be executed on behalf of the government. In our opinion, it is wiser to broaden the application area. TAM can be very useful for a branch-organisation or a investment-company, to determine the most promising sectors and companies in this sector and to improve their competitiveness.

- Maybe it is wise to couple TAM to the phase of the product-lifecycle (introduction, growth, maturity and decline). It is a bit useless to execute TAM, when the product

under consideration has entered the last phase of the product-lifecyle: decline. In this phase sales and profits decrease fairly, so the marketshare drops and is not expected to rise, unless a better, less expensive product takes its place. A product in the introduction phase is sold at a loss, because the introduction costs are high (marketing costs etc.). It appears that this product has no prospects, but after the introduction phase the growth phase will be entered where the market-share will grow rapidly.

- It is possible that a lot of companies can be found in the most promising sector of a country. It will not be possible to execute TAM for all companies found in this sector, so a clear sample and/or a pre-survey methodology is needed to select companies.

- The price of a product is very important. Maybe the product-price is that high that the product will never compete with the local or foreign market leader. Therefore the price should be taken into account from the start of the audit, not only in the third step.

- The classification of producttypes is a bit vague[10]. A new and clearer classification is needed.

- Where possible, parameters (=units) should be added to the product characteristics.

- It is very likely that weighing-factors are needed for a comparison of product characteristics. The determination of the weighing-factors is very subjective, it depends on the person that formulates them.

- How many products should be compared to get a reliable comparison? A reliable sample from the production is needed, not only from the company under consideration but also from the market leader.

[10] Lapperre, P.E. (ed.), Technology Audit Methodology (Eindhoven, The Netherlands, 1996, p. 5)

5 Product comparison

5.1 Product characteristics of initial product

It is emphasised, that the description of the main product of each of the 11 enterprises is based on the original description guidelines presented in the second draft of TAM[11] (see also tables 3,4 and 5). If an enterprise manufactured more than one product, the product to be described was indicated by the enterprise itself or selected according to production volume. Tables 7 and 8 present an overview of the product characteristics of the main product of the 11 companies. With the help of these tables, it can already be shown at this stage, that a number of products has certain shortcomings. While describing the products, problems arose with some of the definitions of the product characteristics. These problems are dealt with at the end of this paragraph. A list of new definitions of product characteristics is presented in chapter 8.

As can be seen in tables 7 and 8, Corusa has shortcomings regarding performance and look of their clips and wire for cloth-hangers. The material the wire is made of is not flexible enough. Also, the spring inside the clip is too strong and, therefore, opening the clip requires too much force.
INASA's only problem is the finish of the product. INASA manufactures the sink unit in two parts, which results in a welding seam. After polishing and cleaning the sink unit, this welding seam can still be seen.
Bendig has shortcomings regarding safety and ergonomics. The hatch of the combustion chamber jams and the handles cannot be touched with bare hands.
Other product shortcomings can only be determined after the product comparison which is elaborated upon in paragraph 5.3.

Tables 7 and 8 also show that the list of product characteristics has some clear shortcomings. The first product characteristic under discussion is the *reliability*. Reliability is defined as 'the chance that functioning since new without failure will last for at least a certain period of usage time'[12]. This definition of reliability is too comprehensive in the context of TAM. The reliability can only be determined by extensively testing the product and its components. A different approach towards reliability is necessary.
The product characteristic *maintainability* is defined as 'the ability to replace, correct and conserve the product'[12]. It does not include the frequency of necessary maintenance. This characteristic must be replaced by the characteristic maintenance that includes both frequency of maintenance and the ability to maintain the product.
Furthermore, the two characteristics *versatility* and *compatibility*, defined as 'the different ways of application' and 'the ability of the product to adapt to different applications and environments'[12] respectively, are strongly related. All information mentioned in the versatility description can also be found in the compatibility description. Therefore, these two characteristics must be combined in the characteristic compatibility.
The characteristics *operational complexity* and *ergonomics*, defined as 'the number of actions required to obtain the intended use' and 'the ease of handling the product'[12] respectively, have a lot in common. These two characteristics can also be combined into one characteristic

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[11] Lapperre, P.E. (ed.), *Technology Audit Methodology* (Eindhoven, The Netherlands, 1996)

[12] Lapperre, P.E (ed.), *Technology Audit Methodology* (Eindhoven, The Netherlands, 1996, p. 7)

called ease of use.
There are two characteristics that can be removed from the list of product characteristics. Both *storage capabilities* and *use of rare materials* give the answers 'not applicable' and/or 'none' for each of the 11 products.

5.2 Description of product market leader

Initially, the market leaders were indicated by the enterprises visited in Costa Rica. Almost all enterprises were able to give a list of their main competitors. However, it was difficult to make a product comparison with these competitors because of two reasons. First, Asometal wanted a comparison with the international market leaders and secondly, most of the selected enterprises already were market leaders in Costa Rica. Due to the nature of the products and time and cost reasons, it was not possible to make a product comparison with the international market leader in Costa Rica. Therefore, it was decided to make a comparison with Dutch products after the data collection in Costa Rica. Because of the relatively high standard of Dutch industrial products, they are suitable for a product comparison. Due to the limited time available and the fact that some enterprises were not suitable for TAM (see paragraph 3.4), only four products are compared.

In The Netherlands, the product information was obtained out of product documentation and by questioning experts from the enterprises. However, it was a major problem to obtain information because most enterprises were very reluctant in providing detailed product information. Dutch enterprises appear to be very afraid that competitors will use the information that they provide. This fear for competition could be one of the major problems of executing TAM.

Tables 9 and 10 give an overview of the product characteristics of the product of the market leader.

Table 7: Functional product characteristics of initial product

Company name	Product name	Durability	Reliability	Safety	Maintainability	Sensitivity w.r.t. environment	Versatility	Performance	Operational complexity	Compatibility	Ergonomics	Storage capabilities
Xeltron	optical sorting machine	10 years	95%	ground connection, moving parts covered	easy access and replacement	vibrations, dust, electrical interference, voltage peaks	sorting different grain types	90% rejection 200-250 kg/h	easy (despite many parameters)	110V/220V easy to adjust to different grain types	clear control panel	n/a
Bendig	oven	15 years	>95%	little or no protection	easy access	not sensitive	supplying different drying machines	$1.3 \cdot 10^6$ BTU/h η=0.60, 12000 m^3/h (60°C) per channel	easy	different types of fuel	hatch jams hot handles	n/a
DICTE	oven	10 years	>95%	moving parts covered	most parts easily accessible	dirt and dust	baking all kinds of food	2.46 l diesel/h η=0.7, heat flow not spread evenly	easy	diesel/electric, easy to adjust to other food	clear control panel	n/a
DIMMSA	telephone	>10 years	>95%	less sensitive to fraud	easy replacement of parts	not sensitive	not versatile	max. dist. from exch.: 12km	complex	diff. sizes, programs, radio or cellular networks	clear buttons	n/a
FILCA	oil filter	450 operating hours	-	n/a	easy replacement of product	not sensitive	not versatile	depends on paper used	easy	rubber seal for colder climates	easy to handle	n/a
Bananera	trolley	10 years	-	n/a	access to bearings rather difficult	corrosion	transporting all kinds of agricultural products	low resistance bearings, load >>25kg	easy	easy to adjust to other agricultural products	easy to handle and install	n/a
Corusa	clips and wire	-	-	n/a	easy replacement	rough handling	different sizes of clothes	wire not very flexible, clip spring too strong	easy	easy to adjust to other sizes of clothes	good grip but difficult to open	n/a
Fundición Saborio	cast products	-	-	-	depends on product	depends on metal used	depends on product	depends on product	depends on product	depends on product	depends on product	n/a
R & R Precisión	precision parts	-	-	-	depends on product	depends on metal used	not versatile	very low tolerances	depends on product	not compatible	n/a	n/a
INASA	steel sink unit	20-25 years	-	sharp edges removed	easy to clean	not sensitive	not versatile	long lifetime	easy	no adaption necessary	large sink	n/a
Termo-mecánica	oven	15 years	-	no contact with hot parts necessary	easy access and replacement	not sensitive	drying all kinds of non-food products	20 min.- 200°C η=0.75 3-5 gln gas/h (500000 BTU)	easy	no adaption necessary	clear control panel	n/a

Table 8: Inherent and aesthetic product characteristics of initial product

Company name	Product name	Construction complexity	Ecological impacts of materials	Use of rare materials	Look	Smell	Noise	Feel
Xeltron	optical sorting machine	many high tech parts	chromatised rollers	none	reliable, modern	n/a	noisy, especially rejection valve	n/a
Bendig	oven	many parts, straightforward assembly	exhaust gases, wood as fuel	none	big and ugly	depends on fuel used	not excessive	n/a
DICTE	oven	many parts, straightforward assembly	exhaust gases	none	reliable, modern	n/a	not noisy	n/a
DIMMSA	telephone case	not complex	none	none	simple but robust	n/a	n/a	n/a
FILCA	oil filter	not complex	only paper cannot be recycled	none	reliable	n/a	n/a	n/a
Bananera	trolley	not complex	galvanising process	none	reliable and strong	n/a	n/a	n/a
Corusa	clips and wire	4 parts, not complex	easily wasted, but recycling possible	none	unreliable	n/a	n/a	ribbed surface
Fundición Saborio	cast products	not complex (1 part), shape depends on product type	easy to recycle	none	depends on product	n/a	n/a	depends on product
R & R Precisión	precision parts	not complex (1 part), shape depends on product type	low	none	very good	n/a	n/a	n/a
INASA	steel sink unit	not complex (2 parts)	low	none	good, except welding seam	n/a	n/a	smooth surface
Termo-mecánica	oven	many parts, straightforward assembly	exhaust gases	none	big and ugly	n/a	-	n/a

Table 9: Functional product characteristics of product market leader

Company name	Product name	Durability	Reliability	Safety	Maintainability	Sensitivity w.r.t. environment	Versatility	Performance	Operational complexity	Compatibility	Ergonomics	Storage capabilities
Gemco[13]	oven for bakeries	25-30 years	-	-	-	-	baking all kinds of food	η=0.7 heat flow spread evenly	very easy, automatic functions	easy to adjust to other food	clear control panel	n/a
CEECO	telephone	-	-	less sensitive to fraud	easy replacement of parts	not sensitive	not versatile	-	complex	different sizes, programs, radio or cellular networks	clear buttons	n/a
Coronet	clips and wire	-	-	n/a	easy replacement	not sensitive	different sizes of clothes	strong wire, strong clip spring	easy	easy to adjust to other sizes of clothes	very good grip	n/a
Reginox	steel sink unit	20-25 years	98.5%[14]	sharp edges removed	easy to clean	not sensitive	not versatile	long lifetime	easy	no adaption necessary	large sink	n/a

Table 10: Inherent and aesthetic product characteristics of product market leader

Company name	Product name	Construction complexity	Ecological impacts of materials	Use of rare materials	Look	Smell	Noise	Feel
Gemco	oven for bakeries	-	exhaust gases	none	-	n/a	n/a	n/a
CEECO	telephone	not complex	none	none	simple but robust	n/a	n/a	n/a
Coronet	clips and wire	4 parts, not complex	easily wasted, but recycling possible	none	reliable	n/a	n/a	dented surface
Reginox	steel sink unit	not complex (1 part)	low	none	very good, no welding seam	n/a	n/a	very smooth surface

[13] Although Gemco does not produce ovens for bakeries, they were able to provide a list of characteristics of an oven for bakeries produced in The Netherlands.

[14] Based on the yearly fall-out during production.

5.3 Product comparison

After describing the initial product and the product of the market leader, the products can be compared. This results in a list of shortcomings for the initial product. To determine the importance of each shortcoming, the product characteristics related to the shortcomings have to be weighed. Paragraph 5.3.1 describes the determination of the weighing factors. Paragraph 5.3.2 describes the actual comparison of product characteristics. Finally, paragraph 5.3.3 contains an overview of the product shortcomings and their importance.

5.3.1 Determination of weighing factors

Ullman[15] gives a possible method for weighing product characteristics in the description of the Quality Function Deployment (QFD) technique.
The QFD method consists of six steps. One of the steps involves the weighing of the different customer requirements. The method used in this step can also be used to weigh the different product characteristics of TAM. A pairwise comparison technique is used to determine the relative importance of each characteristic. Every characteristic is compared with each other characteristic by determining which characteristic is more important for the success of the product. The most important characteristic of the two is given a score of 1 and the other a score of 0. Finally, for each characteristic, the scores are added up and after dividing the scores by the total number of comparisons, the relative importance of each characteristic is known. A structured way to execute this comparison is by filling out a chart, of which an example is shown in table 11.

Table 11: Pairwise comparison procedure[16]

	1. Durability	2. Reliability	3. Safety	4. Maintainability
1. Durability	-	0	0	0
2. Reliability	1	-	0	0
3. Safety	1	1	-	1
4. Maintainability	1	1	0	-
Total	3	2	0	1
%	50%	33%	0%	17%

In appendix 3, the weighing factors of all product characteristics of the 11 products are determined, following the above mentioned methodology. These tables show that the most important characteristics, as indicated by the weighing factor, correspond with the characteristics that one would intuitively indicate as the most important.

5.3.2 Comparison of product characteristics

Now that the weighing factors have been determined, the actual product comparison can be

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[15] Ullman, D.G., *The mechanical design process* (McGraw-Hill, Singapore, 1992, pg. 112-125)

[16] From weighing procedure for oil filter, appendix 4E.

made using the data from tables 7-10. For each of the products listed in tables 9 and 10, the characteristics are compared with the characteristics of the product of the market leader. Each characteristic is given a '+' when it is better, a '0' when it is equal and a '-' when it is worse than the one of the market leader. When no comparison was possible due to a lack of information, it is indicated by a 'x'. The result of the comparison is shown in table 13 and 14. When comparing products, the price is an important factor as well. Table 12 gives a comparison between the prices of the market leader and the local company.

Table 12: Comparison of product price

Product	Price initial product (US$)	Price product market leader (US$)
oven for bakeries	15.120	19.600 [17]
telephone	230	365
clips and wire	85 per 1000	-
steel sink unit	80	150

When analysing tables 12 and 13, it appears that most of the time, a lack of information concerns durability and reliability. The reason for this is that product information from the market leader can often only be obtained through observation and from product documentation. Durability and reliability figures can often only be obtained through interviewing an expert of the enterprise.
Another striking aspect, which is shown more clearly in table 15, is that the characteristics with shortcomings often have high weighing factors. This is related to the fact that a lack of competitiveness with respect to product quality is mainly caused by shortcomings in the most important product characteristics.
From table 12 it appears that the Costa Rican enterprises concerned are competitive regarding the price of their products.

[17] Average price of ovens of competitors of DICTE (see also appendix 4C).

Table 13: Product comparison of functional product characteristics

Product name	Local company / Market leader	Durability	Reliability	Safety	Maintainability	Sensitivity w.r.t. environment	Versatility	Performance	Operational complexity	Compatibility	Ergonomics	Storage capabilities
oven for bakeries	DICTE	-	x	x	x	x	0	-	0	0	0	n/a
	Gemco	6%	11%	10%	12%	6%	2%	13%	9%	4%	8%	0%
telephone	DIMMSA	x	x	0	0	0	0	x	0	0	0	n/a
	CEECO	9%	14%	5%	12%	13%	2%	7%	10%	4%	11%	0%
clips and wire	Corusa	x	x	n/a	0	-	0	-	0	0	-	n/a
	Coronet	7%	11%	7%	2%	3%	9%	13%	3%	10%	9%	0%
steel sink unit	INASA	0	x	0	0	0	0	0	0	0	0	n/a
	Reginox	8%	8%	7%	5%	10%	1%	10%	1%	1%	7%	0%

Table 14: Product comparison of inherent and aesthetic product characteristics

Product name	Local company / Market leader	construction complexity	Ecological impacts of materials	Use of rare materials	Look	Smell	Noise	Feel
oven for bakeries	DICTE	x	0	0	x	n/a	n/a	n/a
	Gemco	3%	2%	0%	10%	0%	5%	0%
telephone	DIMMSA	0	0	0	0	n/a	n/a	n/a
	CEECO	3%	1%	1%	7%	0%	0%	0%
clips and wire	Corusa	0	0	0	-	n/a	n/a	-
	Coronet	4%	3%	1%	10%	0%	0%	10%
steel sink unit	INASA	-	0	0	-	n/a	n/a	-
	Reginox	11%	3%	4%	13%	0%	0%	12%

5.3.3 Product shortcomings

Table 15 provides an overview of the product shortcomings that can be derived from paragraph 5.3.2 The importance of each shortcoming is indicated by the weighing factor.

Table 15: Overview of product shortcomings

Product	Shortcomings	Weighing factor
oven for bakeries	- performance - durability	13% 6%
telephone	no shortcomings found	-
clips and wire	- performance - look - feel - ergonomics - sensitivity w.r.t. environment	13% 10% 10% 9% 3%
steel sink unit	- look - feel - construction complexity	13% 12% 11%

In the following chapter, these shortcomings are linked to the production process and the causes of the shortcomings are determined. Also, possible solutions to lift the product shortcomings are indicated.

6 Causes of product shortcomings

This chapter focuses on the determination of the causes of the product shortcomings that can be related to the production process features. First, the production processes of all enterprises are described to determine possible shortcomings in TAM. Next, the four production process descriptions of the products included in the comparison (paragraph 5.3) are analysed to find the causes of the product shortcomings.

6.1 Description of production processes

Table 16 summarises the production process features of each enterprise. A detailed description of all production processes, including flow charts and factory lay outs, can be found in appendix 4. The description of the production processes is based on the original guidelines presented in the second draft of TAM (see also 3.2.2). Table 16 is used to determine the causes of the product shortcomings. Also, a number of shortcomings of the methodology is derived from this table.

The source of most problems, which arose while describing the production process, is the description of the degree of mechanisation. Table 16 shows that almost all machines are classified as self-acting machines (category 2). This classification should give a first indication of the predictability of quality (tolerance), capacity and flexibility of the machines. In practice, however, category 2 covers a wide variety of machines with different features. This problem, and a solution, is elaborated upon in more detail in chapter 7 and 8.

Table 16: Production process characteristics

Product name	Company name	Machines used	Degree of mecha-nisation	Tolerance	Capacity	Flexibility	Most important raw materials and ready bought parts	Product or production function
optical sorting machine	Xeltron	- lathe - NC milling machine - milling machine - grinding machine - bending machine - plastic moulding machine - cutting machine - balancing machine - column drill - stamping machine - soldering machine - chromatising equipment - polishing machine	2 5 2 2 2 5 2 1 2 2 2 2 2	parts requiring low tolerances produced by NC machine	200 machines per year	low flexibility, except for production optical system	- lenses - halogen lamps - optical fibres - electric motor - steel pipes	- focusing light beams - providing light for fibres - transporting light - driving rollers - base material rollers
oven	Bendig	- cutting machine - plasma cutter - bending machine	2 2 2	no tolerances on technical drawings, in practice ±1mm	30 ovens per year	low flexibility, except for manual assembly	- sheet metal, type 310S - heat-resistant concrete - pipes	- wall of combustion chamber - inside combustion chamber - heat exchangers
oven	DICTE	- cutting machine - bending machine - milling machine	2 2 2	no tolerances on technical drawings, problems in precision de-partment	4-5 ovens per month	low flexibility, except for manual assembly	- burner - stainless sheet metal - steel - electric motor	- providing heat - walls of oven - other oven parts - driving ventilator
telephone case	DIMMSA	- cutting machine - NC stamping machine - bending machine - welding machine - polishing machine	2 5 2 1 1	no tolerances on technical drawings, low tolerances possible	500 cases per week	high flexibility	- stainless steel laminate - keyboard - electronic board	- case of telephone - dialling numbers - operation of telephone

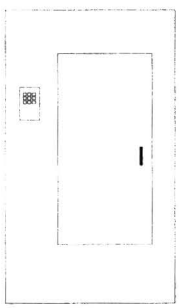
Product name	Company name	Machines used	Degree of mecha-nisation	Tolerance	Capacity	Flexibility	Most important raw materials and ready bought parts	Product or production function
oil filter	FILCA	- cutting machine - deep-drawing machine - painting machine - stamping machine - column drill - welding machine - folding machine - scissors - oven - press - testing equipment - mould	2 2 2 2 2 2 2 1 2 2 2 2	no tolerances on technical drawings, toler-ances depend on dies of stamping machines	150000 filters per month, of which 60% oil filters	low flexibility, however flexi-ble w.r.t. sizes and types of filters	- rubber ring seal - rubber valve - spring - filter paper - cold roll steel, long extension	- preventing oil from leaking - preventing oil flowing back - part of valve - filtering oil - base material for cans
trolley	Bananera	- stamping machine - column drill - polishing machine - lathe - stamping machine - welding machine - bending machine - scissors - NC lathe - oven - galvanising equipment	2 2 2 2 2 2 2 1 5 2 2	problems with bearings after galvanising process	48000 trolleys per year	low flexibility, except for NC machine	- rubber seal - chain DIN 766 - plastic cage - steel, Thomas - steel rod AISI 1018 - hexagonal rod AISI 12L14	- protection bearing - fastening load - balls of bearing - plates - hook - axis
clips and wire	Corusa	- spring winder/cutter - wire cutter - stamping machine - end/clip assembly machine - clip assembly machine - spring press	2 2 2 2 2 2	parts with important toler-ances regularly checked, no exact tolerance figures known	max. 500.000 products per month	low flexibility, many special machines	- galvanised wire - spring wire - T-5 temper steel - plastic strip	- wire for attaching the clips - spring for clips - body of the clips - ends for gripping clothes

Product name	Company name	Machines used	Degree of mecha-nisation	Tolerance	Capacity	Flexibility	Most important raw materials and ready bought parts	Product or production function
cast products	Fundición Saborio	- circular saw - planning machine - lathe - grinding machine - sawing machine - column drill - melting pot - moulding press - cleaning mill - polishing machine - sandblast - hand craft tools	2 2 2 2 2 2 2 2 2 2 2 1	not important, products can be milled to size if necessary	no exact information due to variety of products	high flexibility, models are hand-made	- scrap metal - black sand - wood (cedar, mahogany)	- base metal for products - material for mould - material for models
precision parts	R & R Precisión	- wire-EDM - grinding machine - lathe - EDM - milling machine - NC milling machine - sawing machine	5 2 2 5 2 5 2	very important, up to 0.00254 mm	no exact information due to variety of products	high flexibility, final production with NC machines	- certified steel, aluminium, carbide	- base metal for products
steel sink unit	INASA	- cutting machine - deep-drawing machine - stamping machine - bending machine - welding gun - welding machine - grinding machine - polishing machine - polishing machine	2 2 2 2 1 2 1 1 2	no tolerances on technical drawings, accuracy depends on dies of machines	max. capacity 3000 units per month	low flexibility, indicate by degree of mechanisation	- AISI 430 steel (0.7 mm) - AISI 304 steel	- material for worktop - material for sink
oven	Termo-mecánica	- cutting machine - bending machine - welding machine - column drill - grinding machine	2 2 2 2 2	no tolerances on technical drawings	3-5 ovens per year, max. 10 ovens per year	high flexibility, large variety of products	- motors - pneumatic equipment - burner (Maxon) - steel 0.25 inch - galvanised steel - ceramic material	- driving fans - opening door - heat production - outside oven - tubes, inside oven - insolation

6.2 Determination causes product shortcomings

In this paragraph the product shortcomings are related to the production process and the enterprise environment (step 2 and 3 of TAM). Also, problems within the enterprise, which do not directly influence product quality, but which hamper efficient operation, are indicated. The shortcomings directly related to the product quality are marked dark-grey. The shortcomings not directly influencing product quality are marked light-grey.

Oven for bakeries (DICTE)



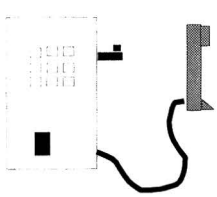
Product shortcomings:
- performance
- durability

Shortcomings production process:
- machines used
- degree of mechanisation
- tolerances
- capacity
- flexibility
- raw materials & ready bought parts

Shortcomings enterprise environment:
- product price
- management
- availability of information
- skills & knowledge
- direct enterprise environment

The *durability* shortcoming is probably caused by the use of the wrong type of material for the inside walls of the oven. However, a comparison of durability figures is very complex, because the durability depends for a large part on the frequency of use.
The shortcoming in *performance* is the heat distribution in the oven. DICTE has solved this by rotating the cart with the trays on which the products are baked. This shortcoming is caused by lack of skills and knowledge of the design department.
A shortcoming not directly related to product quality is capacity. DICTE does not have the possibility to increase production due to the size of the assembly department.

Telephone (DIMMSA)



Product shortcomings:
no shortcomings found

Shortcomings production process:

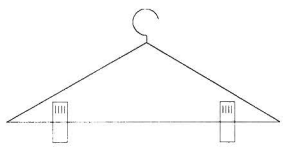
- machines used
- degree of mechanisation
- tolerances
- capacity
- flexibility
- raw materials & ready bought parts

Shortcomings enterprise environment:

- product price
- management
- availability of information
- skills & knowledge
- direct enterprise environment

No product shortcomings were found for the telephone of DIMMSA. The reason for this is that most ready bought parts for the telephone (like the keypad, wire, hook and receiver) are bought from CEECO. CEECO is also their competitor and the product comparison has been made with a CEECO telephone. Another reason for the lack of shortcomings is that it was not possible to compare the electronic system, which is an important part for the functioning of a telephone.
In general, the DIMMSA telephone is a good product using appropriate technology. There is a potentially very large market for this telephone in developing countries.
DIMMSA has one shortcoming with respect to the direct enterprise environment. DIMMSA consists of two separate plants in different parts of the city. This involves transportation through the centre of San José which is very time consuming.

Clips and wire (Corusa)



Product shortcomings:

- performance
- look
- feel
- ergonomics
- sensitivity w.r.t. environment

Shortcomings production process:

- machines used
- degree of mechanisation
- tolerances
- capacity
- flexibility
- raw materials & ready bought parts

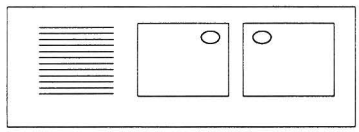
Shortcomings enterprise environment:

- product price
- management
- availability of information
- skills & knowledge
- direct enterprise environment

The main problems that cause the product shortcomings *performance* and *sensitivity w.r.t. environment* are the raw materials and the skills and knowledge. The raw materials cause problems with respect to the flexibility of the wire. When the wire is bent (necessary for installing the wire in a cloth hanger), it deforms plastically.
The *look*, *feel* and *ergonomics* shortcomings are related to a design problem and thus to a lack of skills and knowledge. The profile and grip of the clips are not very good and it is therefore difficult to open the clips.

Corusa has several problems with respect to machines used, capacity and flexibility. The problems with respect to machines used and capacity are caused by the plastic end to clip assembly machine which is not functioning properly. Furthermore, the assembly machines are designed specifically for the production of the clips in their present form.

Steel sink unit (INASA)



Product shortcomings:
- look
- feel
- construction complexity

Causes related to production process part:
- machines used
- degree of mechanisation
- tolerances
- capacity
- flexibility
- raw materials & ready bought parts

Causes related to enterprise part:
- product price
- management
- availability of information
- skills & knowledge
- direct enterprise environment

The three product shortcomings *look*, *feel* and *construction complexity* can all be related to the welding seam between the sink and the worktop. This seam is caused by the fact that the product is made out of two parts. The reason for this is the lack of the right die for the deep drawing machine. Also, the design department lacks skills and knowledge concerning deep drawing technology. Another aspect is the difficulty for INASA to obtain the right type of stainless steel necessary for the deep drawing process.
Finally, the degree of mechanisation is too low with respect to the polishing of the sink unit. This is done by hand which does not give a constant quality.

6.3 Solutions to lift product shortcomings

Below, possible solutions are presented for lifting the product shortcomings found in the preceding paragraphs. The solutions are not very detailed but provide a starting point from which they can be worked out.

Oven for bakeries (DICTE)

The main shortcoming of the oven is the heat distribution inside the oven. DICTE has solved this by rotating the cart with trays. This system requires extra costs and maintenance for the customers. A better way to solve the uneven heat distribution is to redesign the oven and create a better airflow through the oven. Currently, the airflow enters the baking chamber from the top-left side and exits from the bottom-left side. The redesign involves relocating the point of entry of the air at the ceiling of the baking chamber and making an extra exit for the air in the bottom-right side of the oven. Figure 5 shows the heat distribution in the old design and in the new design.

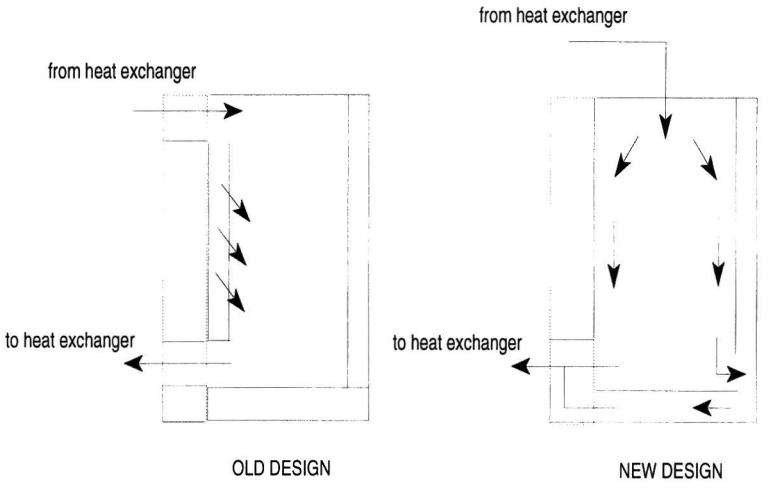


Figure 5: Heat distribution of the oven

Clips and wire

The shortcomings of the clips and wire are the flexibility of the wire and the look, feel and ergonomics of the clips. The first shortcoming can be lifted by changing the raw material for the wire. When bent, the wire should deform elastically instead of plastically.
To lift the shortcomings look, feel and ergonomics, the clips must be redesigned to improve the grip and general appearance of the clips. Currently, the surface of the clip is only ribbed, but the surface should also centre the push force to open the clips. If the force is not centred, the clips will easily buckle. A possible redesign is presented in figure 6. To manufacture this new design, a new die for the stamping machine is required.

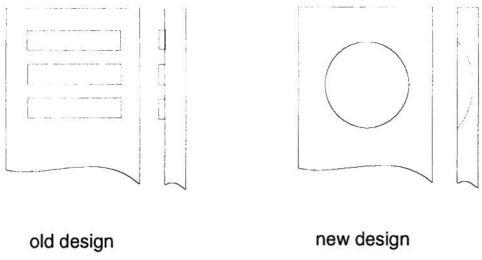


Figure 6: Design of the clip surface

A major problem in the production process is caused by the machine that assembles the plastic end to the clip. The machine cuts plastic strips to size and places them in the clips. After this, the ends of the clip are bent to secure the plastic strip. The main problems of the machine are:

- the strips are not positioned well
- the strips are not cut to the right size
- clip halves get stuck on the transport chain

A solution to solve this problem is to replace the plastic strip by a plastic end. The clips are dipped in liquid plastic which solidifies. This solution also requires a new design of the clips and a new die for the stamping to manufacture the new design. Figure 7 shows the clip with the new plastic end. The hole at the end of the clip is to make sure the plastic end does not detach from the clip.

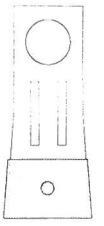


Figure 7: New design of clip end

Steel sink unit (INASA)

As already mentioned in paragraph 6.2, all the product shortcomings of the sink unit can be related to the welding seam between the sink and the worktop. There are two possible solutions to lift the shortcomings.

Solution 1
This solution consists of redesigning the sink and producing it in one part. This eliminates the existence of the welding seam. Labour costs for polishing the sink are reduced and the production capacity will increase. A disadvantage are the high costs of this solution, because it involves buying a new die for the deep drawing machine. This process also requires a better knowledge of the deep drawing process which is currently not available.

Solution 2
This solution consists of getting a better finish of the welding seam. The sink unit continues to be produced in two parts, but in order to get a better finish of the welding seam, the manual grinding and polishing of the seam is replaced by an automatic grinding machine. This will result in a more constant quality of the finish of the seam. A possible solution for a design of an automatic grinding machine is given in figure 8.

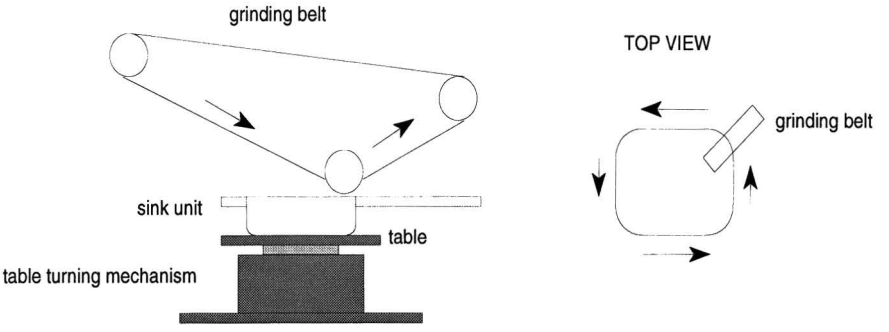


Figure 8: Outline of automatic grinding machine

The sink unit is placed on the rotating table of the machine. While rotating the sink unit, a grinding belt is grinding the welding seam. The movement of the sink unit is controlled by a track along a die with the same shape as the sink.

7 Problems encountered during the testing of TAM

This chapter discusses the problems encountered during the testing of TAM in the Costa Rican metal industry. Most of the problems have already been mentioned briefly in previous chapters. First, the problems are summarised in paragraph 7.1 together with possible remedies and ways in which these remedies can be incorporated in TAM. After this, the critical remarks before the testing of TAM are compared to the practical experiences of the testing of TAM to verify if they are still valid and whether they should be incorporated in TAM.

7.1 Problems encountered and possible remedies

The problems have been divided in three categories, problems with respect to the product part, problems with respect to the production process part and general problems. The problem descriptions, possible remedies and their incorporation in TAM can be found in tables 17, 18 and 19 respectively. The third column (incorporation in TAM) of each table is worked out in more detail in chapter 8. The number of the paragraph in which this is done is listed in the last column.

Table 17: Problems encountered during the testing of TAM: product part

	Description of problem	Remedy	Incorporation in TAM	ref.
1.	The reliability definition is too complicated for TAM	Redefine reliability according to the MIR level definition of Brombacher[18]. The information about the reliability of the product is indicated by the MIR level of the enterprise (see paragraph 8.1.1)	Redefinition of product characteristic reliability	7.1.1 and 7.1.2
2.	Maintainability does not include frequency of maintenance	Define a new characteristic that includes both ability to maintain and frequency of maintenance	Define new product characteristic named maintenance	7.1.2
3.	Large similarity between characteristics versatility and compatibility	Combine the two characteristics into one characteristic named co mpatibility, including different ways of application and the ability of the product to adapt to these applications	Remove the product characteristic versatility and change the definition of compatibility	7.1.2
4.	Large similarity between characteristics ergonomics and operational complexity	Combine the two characteristics into one characteristic named ease of use including number and ease of actions required for use of product	Replace the product characteristics ergonomics and operational complexity with the characteristic ease of use	7.1.2
5.	The product characteristics storage capabilities and use of rare materials give the answers 'none' or 'not applicable' for every product	Exclusion of both characteristics	Remove the product characteristics storage capabilities and use of rare materials. When rare materials are used, this will result from the list of raw materials and ready bought parts	7.1.2

[18] Brombacher, A.C., *Predicting reliability of high volume consumer products* (Lecture notes, Eindhoven University of Technology, Eindhoven, 1996)

6.	The definition of the product characteristic performance is too broad for a practical application	Redefine performance based on the product specifications as indicated by the manufacturer	Redefinition of product characteristic performance	7.1.2
7.	If the product of the market leader cannot be obtained easily (size or price), it is very difficult to obtain product information of the market leader due to fear of competition	Obtain information through specialists selling the product (wholesale business, dealers, etc.)	Add instructions in case the product cannot be obtained easily	7.1.3
8.	ISIC/SITC code not suitable for identifying market competitors. Classification is not detailed enough	Design of a methodology to determine market competitors. Interviewing the producer of the initial product should be included	Add a new methodology to TAM for determining market competitors, especially on the international market	7.1.3

Table 18: Problems encountered during the testing of TAM: Production process part

Description of problem		Remedy	Incorporation in TAM	ref.
9.	Category 2 (self acting machine) of the machine feature 'degree of mechanisation' is too broad to give an indication of the flexibility, predictability of quality and capacity of the machines	Sub-division of category 2 to be able to make a better assessment of the degree of mechanisation	Add sub-categories to category 2 of the degree of mechanisation	7.2.1
10.	Especially in developing countries, tolerances are rarely specified on drawings	Tolerances should only be collected when they lead to clear product shortcomings and production fall-out	Exclude the determination of tolerance figures when not leading to clear shortcomings or fall-out	7.2.2
11.	Capacity determination is too detailed	Only determine current and maximum capacity	Change capacity determination methodology	7.2.2
12.	A complete list of raw materials and ready bought parts becomes too long for complex products	The list of raw materials and ready bought parts should be based on parts of the product with shortcomings	Add instruction for making list of raw materials and ready bought parts	7.2.2

Table 19: Problems encountered during the testing of TAM: general problems

Description of problem		Remedy	Incorporation in TAM	ref.
13.	No assessment of appropriateness[19] of technology when TAM is applied in developing countries	Assessment of the appropriateness of the technology of the product and/or production process	Add a new item to the enterprise part of TAM named 'use of appropriate technology'	-
14.	The size of the enterprise is not included in TAM	Determine company size according to the number of employees	Add a new item to the enterprise part of TAM named 'company size'	-

[19] The telephone of DIMMSA (appendix 4D) gives an excellent example of appropriate technology which can be an incentive for investors. Therefore, it may be useful to incorporate this aspect in TAM.

15.	Making a product comparison for enterprises that produce a large variety of products with one production line or made-to-order products is very difficult	Exclude these enterprises from TAM	Add a pre-selection methodology to TAM in which these kind of enterprises are excluded	7.3.1
16.	An enterprise can have shortcomings regarding step 2 and 3 of TAM which are not related to product shortcomings	List these shortcomings while executing TAM	Distinguish two types of production process and enterprise environment shortcomings, shortcomings directly related to product quality and shortcomings not directly influencing product quality	7.3.2
17.	The second draft does not give a clear, practical guideline for executing TAM	Make a checklist or data form based on the various elements of TAM	Add a checklist or data form to TAM	7.3.4
18.	TAM does not contain a clear methodology to select the most promising enterprises from the results of the audits	Develop a methodology to indicate the most promising enterprises on the basis of the data collected with TAM	Add a methodology to TAM	7.3.5

7.2 Critical remarks and the practical experiences of TAM

This paragraph describes the critical remarks that were made before the testing of TAM. They are described in detail in paragraph 4.3. The remarks are related to the practical experiences of testing TAM in Costa Rica. Tables 20 and 21 list the remarks, following the same procedure as in paragraph 7.1. No critical remarks were made with respect to production process part before the testing of TAM.

Table 20: List of critical remarks made before the testing of TAM: product part

Description of remark		Remedy (when necessary)	Incorporation in TAM	ref.
1.	The classification of product types is not clear[20]	The classification is not used during execution of TAM and is thus redundant	Exclude classification from TAM	-
2.	Parameters (units) should be added to the product characteristics	Due to the variety of products, it is not possible to add parameters or units to the product characteristics	-	-
3.	Weighing factors are needed for comparison of product characteristics	A weighing methodology has already been worked out in paragraph 5.3.1	Add the weighing methodology of paragraph 5.3.1 to the product part of TAM	4.3.1

[20] Lapperre, P.E. (ed.) *Technology Audit Methodology* (Eindhoven, 1996, p. 5)

Table 21: List of critical remarks made before the testing of TAM: general problems

Description of remark	Remedy (when necessary)	Incorporation in TAM	ref.
4. A sample of products is needed to get a reliable comparison	Using a sample of products is only possible for simple and cheap products, because of time and cost reasons	-	-
5. More than three days are necessary for execution of TAM	3-5 days is enough for executing TAM	-	7.3.3
6. The three steps of TAM must be executed parallel, not sequentially	Steps 1 and 2 can be executed sequentially, step 3 parallel with step 1 and 2	-	-
7. A sector can be too large to execute TAM for all companies in the sector	A methodology is needed to select companies to be included in TAM	Add a methodology to select companies within a sector suitable for TAM	7.3.1
8. The product price should be taken into account from the start of the audit	See remedy of remark 2	-	-
9. Broaden the application area of TAM to investment companies and branch organisations	Leave out development criteria when selecting enterprises for TAM	-	-
10. Couple TAM to the phase of the product life-cycle	For products with a short life-cycle an assessment of the product life-cycle is necessary	Add a new product characteristic named 'phase of the product life-cycle', further research is necessary	-

8 Revised version of TAM

In this chapter, the remedies to the problems mentioned in chapter 7 are incorporated in TAM. The paragraphs in this chapter correspond with the classification of the tables with problems and remarks in chapter 7. Paragraph 8.1 describes the changes to step 1 (product part) of TAM. Paragraph 8.2 describes the changes made to step 2 (production process part) of TAM. Finally, paragraph 8.3 discusses the solutions for the general problems and the changes made to step 3 (enterprise part) of TAM.

8.1 Changes in step 1 of TAM

8.1.1 A new approach towards reliability

Currently, reliability is included in TAM as one of the product characteristics. However, when visiting an enterprise, it is almost impossible to determine the reliability of a product. The classical reliability calculations are based on (constant) component failure rates and are too time consuming to incorporate in TAM. They are also not always accurate. However, reliability is a very important product characteristics for almost every product and it is, therefore, important that the reliability of a product is incorporated in TAM.
Brombacher[21] describes a new method for predicting the reliability of a product. With this method, an enterprise is classified according to the Maturity Index on Reliability (MIR). This index consists of five levels. The higher the level, the more information is available within the enterprise with respect to reliability. The five MIR levels are:

- *MIR level 0:* 'Not available'
  No information available on failed products.
- *MIR level 1*: 'How much'
  Only quantitative information available on a per product basis, such as the number of failed products in the field or during production.
- *MIR level 2*: 'Where'
  Quantitative information is available on the primary and secondary locations of failures. Primary location refers to the causes of failures in terms of the primary causes design, material, production process and customer use. The secondary location refers to the location within the primary cause such as the part number for material or the event description for customer use.
- *MIR level 3*: 'Why'
  Detailed information is available for all dominant failures on root-cause level.
- *MIR level 4*: 'What to do'
  Techniques and tools are in place in the organisation to anticipate risks for new products and processes and to eliminate these risks where necessary.

Appendix 5 gives a scheme of the relations between these levels.

To incorporate this approach in TAM, the amount of information with respect to reliability available within the enterprise has to be determined to classify the enterprise in a MIR level.
An enterprise which has no information available on failed products is classified in MIR level 0. The

[21] Brombacher, A.C., *Predicting reliability of high volume consumer products*, (Lecture notes, Eindhoven University of Technology, The Netherlands, 1996)

products have a relatively low reliability. An enterprise which has detailed information available and which has the capacity to anticipate and eliminate risks for new products and processes is classified in MIR level 4. The products have a relatively high reliability. In the same way, the relative reliability of products can be indicated for enterprises classified in the MIR levels 1, 2 and 3. The higher the MIR level, the higher the reliability.

8.1.2 Definitions of product characteristics

Tables 22, 23 and 24 give new lists of definitions of product characteristics based on the problems one to six mentioned in table 17.

Table 22: Revised list of functional product characteristics

Functional characteristics	Description
1. durability*	time, number of cycles the product performs adequately
2. reliability	MIR-level of enterprise
3. safety*	measurements taken to prevent injuries of users
4. maintenance	frequency and ability for replacing, correcting and conserving the product or product parts
5. sensitivity w.r.t. environment*	weather conditions, shocks, vibrations, dust, temperatures, etc.
6. performance	product specifications as indicated by manufacturer
7. ease of use	number and ease of actions required to obtain the intended use
8. compatibility	different ways of application and the ability of the product to adapt to these different applications and to different environments

Table 23: Revised list of inherent/intrinsic product characteristics

Inherent/intrinsic characteristics	Description
9. construction complexity*	number of parts, shape of parts, functioning principle
10. ecological impacts of materials	production, usage and wasting of the product or production process that involve an unsustainable burden on environment and users

Table 24: Revised list of aesthetic product characteristics

Aesthetic characteristics	Description
11. look*	appearance, attractiveness of the product
12. smell*	
13. noise*	
14. feel*	physical feeling

*description has not been changed

8.1.3 Information about the product of the market leader

Before obtaining information about the product of the market leader, the market leader has to be determined. TAM in its present form determines the market competitors using the ISIC code and, subsequently, the market leader is identified according to its market share. However, the ISIC classification (appendix 2) is too broad to determine manufacturers of the same product. Therefore, a different approach is necessary. A first indication of the market leader can be obtained from the producer of the initial product. This information can be verified by consulting the local chamber of commerce. In case of an international market leader, it is better to obtain the information of international market competitors before the actual execution of TAM because this information is difficult to obtain in developing countries.

The product of the market leader is described with the list of product characteristics, in the same way as the initial product. To be able to make a description, a product has to be bought in a local shop. However, when the product of the market leader cannot be obtained easily because of financial or practical reasons, it is difficult to obtain the required product information. While collecting product information of the market leaders in The Netherlands, most enterprises did not want to release detailed product information, due to fear of competition.

A way to solve this problem is to collect the information through specialists like wholesale businesses and dealers. These specialists know exactly the most important quality characteristics of the product and the customer requirements. Because they usually sell different brands of the same product, there is no fear for competition. However, this has not yet been tested in practice.

8.2 Changes in step 2 of TAM

8.2.1 Degree of mechanisation

Category 2 of the degree of mechanisation classification (paragraph 4.2.2) is too broad. The classification should give a first indication of the predictability of quality (tolerance), capacity and flexibility of machines. However, category 2 covers a wide variety of machines with different features. To illustrate this, one can compare a sawing machine with a lathe which are both classified in category 2. The two machines have very different tolerance, capacity and flexibility figures. A lathe is, for instance, much more accurate and flexible than a sawing machine.
To solve this problem, category 2 is sub-divided in two categories. The sub-categories differ in flexibility and predictability of quality. Category 2A contains machines like bending machines, sawing machines and cutting machines with a relatively low flexibility and medium predictability of quality. Category 2B contains machines like lathes and milling machines with a relatively high flexibility and high predictability of quality.
Of course, these two categories are not completely exclusive. A polishing machine, for example, can be used for producing products with very low tolerances. In these kind of exceptional cases, a machine is not classified in one of the sub-categories, but simply in category 2. The new degree of mechanisation classification is presented in table 25.

Table 25: Degree of mechanisation

Degree of mechanisation	Description		Predictability of quality	Machine capacity	Machine flexibility
1. Tool or handicraft	Tools or handicrafts are an extension of the human hand. They enable the function not performable with bare hands.		low	low	high
2. Self-acting machine	Machines only able to repeat recorded mechanical movements.	A	medium	medium	low
		B	high	medium	medium
3. Self-checking machine	Machines able to identify production deviations by means of a sensor. Switching off by detection out of tolerance production.		medium-/high	high	low
4. Self adjusting machine	Machines for mass production of products with a long life cycle. Sensor information is used to correct an observed deviation.		high	high	medium
5. Flexible machine	Autonomously working machines, controlled by an external (computer) program.		high	medium	high

Table 26 presents a part of table 16 in which the machines are described using the new classification of the degree of mechanisation.

Table 26: Illustration of the new classification of the degree of mechanisation

Product name	Company name	Machines used	Degree of mechanisation
Optical sorting machine	Xeltron	- lathe	2B
		- NC milling machine	5
		- milling machine	2B
		- grinding machine	2A
		- bending machine	2A
		- plastic moulding machine	5
		- cutting machine	2A
		- balancing machine	1
		- column drill	2A
		- stamping machine	2A
		- soldering machine	2A
		- chromatising equipment	2
		- polishing machine	2

8.2.2 Other adjustments to production process part

This paragraph describes small adjustments to step 2 of TAM. These adjustments are based on problems ten to twelve of table 18.

Tolerances

Tolerance figures are used to explain deviations in product and product parts quality. It is already indicated in the second draft of TAM, that collecting all data concerning tolerances is a very time consuming process. Collecting, for example, performed tolerance figures of one machine is an exercise which is too extensive to execute during a technology audit. Also, in developing countries, tolerance data are almost impossible to obtain, simply because they are not available. If drawings of the product and product parts are available, tolerances are usually not specified.
Tolerance figures should be collected, if one or more important product shortcomings can be related to tolerances. If a machine causes a large production fall-out, tolerance data should also be collected, although production fall-out can have several other causes.

In all other cases, the collection of tolerance data is excluded from the execution of TAM.

Capacity

Similar to the tolerance data collection, the capacity determination of all machines is a very time consuming process. Because capacity figures only influence the technical characteristics in extreme cases[22], this exercise should be as limited as possible. For a general picture of the production process, the maximum and actual production capacity is determined for the complete production process. This results in the capacity utilisation, which is an important aspect in the price of a product. Detailed capacity figures of a particular machine are only collected, when there is a clear indication that they influence the quality of the product.

Description of raw materials and ready bought parts

Listing all raw materials and ready bought parts of a product can be a superfluous exercise when the product shortcomings are only related to a specific part of the product. The list of raw materials and ready bought parts must be based on the parts of the product with shortcomings. Especially for large and complicated products, this can be very time saving. However, when the price of the product is a problem, a complete list of the main raw materials and ready bought parts has to be made in order to determine possible cost saving opportunities.

Condition of machines

In order to get an overview of the condition of the machines, each machine is classified in one of the following categories: relatively new (depreciation within ten years), used (depreciation within five years) or obsolete (already depreciated). With this information, among others, the grading of the remedies in paragraph 8.3.5 is easier. If a remedy for a product shortcoming involves the replacement of machines, this will involve higher investment costs for an enterprise with obsolete machines than for an enterprise with new or used machines. New and used machines can be sold for a relatively high price.

8.3 General changes of TAM

8.3.1 Enterprise selection procedure

This procedure is based on problem 15 from table 19 and remark 7 from table 21.

Enterprises which manufacture a great number of different products and enterprises which focus on very small numbers of made-to-order products are not suitable for TAM in its present form. The reason for this is that comparing more than one product takes too much time. Also, when the production process is adjusted to improve a product, it can influence the quality of other products produced in the same production line.
An exception is the case in which an enterprise produces different products with different, separated, production lines. In this case, TAM should focus on one of the products.

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[22] Capacity is of influence when wrong inputs are used to cover up under-capacity or when storage affects the technical quality of parts. This is the case with overcapacity of a previous machine. Lapperre, P.E. (ed.), *Technology Audit Methodology*, (Eindhoven, 1996, p. 12)

Another problem of TAM is the possibility that a lot of companies can be found in the sector of the enterprises to be audited. Because of time and cost reasons, it will not be possible to execute TAM for all companies found in this sector.

To solve the above mentioned problems, a methodology is needed to select companies for TAM. The first part of this methodology excludes companies from TAM on the basis of the following criteria:

- company size: TAM aims at small and medium scale enterprises. Companies with more than 100 employees are excluded from TAM
- number of different products: enterprises that manufacture more than five different products are excluded from TAM
- type of products: enterprises that produce made-to-order products are excluded from TAM
- demands/wishes client: on the basis of criteria determined by the client for whom TAM is executed enterprises are excluded from TAM. Examples of such criteria are: employment creation, influence on natural environment, use of natural resources and export figures

When the remaining group of companies is still too large for TAM, a sample is taken to obtain the desired number of companies.

8.3.2 Enterprise shortcomings not related to product quality

TAM in its present form only indicates shortcomings in the production process part and enterprise part that are causing clear product shortcomings. However, shortcomings in step 2 and 3 of TAM are not always directly related to product shortcomings. The test case of Corusa (appendix 4G) gives a good example of this: most of the production process shortcomings can not be related to the quality of the clips, but have a major influence on the efficiency of operation.

Therefore, problems within the enterprise, which do not directly influence product quality, but which hamper efficient operation, must be indicated. While executing TAM, all the identified shortcomings regarding step 2 and 3 must be listed. A practical way to incorporate the identification of these shortcomings in TAM is already worked out in paragraph 6.2. All the characteristics of the production process part and the enterprise part are listed separately in two columns. After this, shortcomings directly related to the product quality are marked dark-grey. The shortcomings which do not directly influence product quality are marked light-grey.

8.3.3 Time aspect of TAM

Although the results of the testing of TAM indicate that 3-5 days is sufficient for auditing one enterprise, time remains an important aspect of TAM. Table 27 gives a rough indication of the time needed for the execution of every part of TAM. Some parts of TAM, such as the determination of market competitors, were not part of this research and, thus, no time estimate is given for these parts.

Table 27: Time estimates for the execution of TAM

Part of TAM		field execution [hours]	administration [hours]
1.	Description of initial product	4	2
2.	Description product of market leader and product comparison	4	4
3.	Making lay-out and flow chart of production process	4	8
4.	Making list of raw materials and ready bought parts	3	1
5.	Gathering information with respect to step 3 of TAM	4	1

Table 27 shows that for most parts of the execution of TAM, the field work takes more time than the administration of the data collection, except for the construction of a flow chart and a plant lay-out. This is caused by the fact that making flow charts on a computer is a very time consuming job. To limit the time used for administrative activities, the production process should be described in a more efficient way. This can be done by either using specialist software or using a different method for constructing flow charts. A more compact method[23] is the use of a standardised form in which the various steps of the production process must be filled in. Appendix 6 shows an example of such a standardised form.

8.3.4 Practical execution of TAM

For the execution of TAM, a clear, practical guideline is necessary. The solution for this is a manual with forms in which all the information to be collected during the execution of TAM can be filled in. The manual consists of a short description and a table in which the information can be filled in. The general design of the manual is described below:

Step 1: product part
- table with general product information like name of product, operating conditions, etc.
- table with information of market competitors and determination of market leader
- table with a list of product characteristics
- matrix for determination of weighing factors (see paragraph 5.3.1, table 11)
- table for product comparison (see paragraph 5.3.2, table 13)

Step 2: production process part
- table on which the flow chart and lay out information can be filled in
- table with the machines used and the degree of mechanisation (see table 26)
- table with tolerance, capacity and flexibility figures
- table with list of important raw materials and ready bought parts
- table with determination of the causes of product shortcomings and general shortcomings (see paragraph 6.2)

Step 3: enterprise part
- table with enterprise characteristics

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[23] Vereniging Logistiek Management, *Logistiek, integrale goederenstroom besturing*, (Educatieboek, De Bilt, 1990, p. 295) and Bedaux, *Werkboek behorende bij het project:'Analyse van kernprocessen in het kader van de ontwikkeling van de logistiek'*, (Nunspeet, 1995)

8.3.5 Selecting most promising enterprises

TAM was developed as a tool to identify the most promising enterprises within a sector. By using TAM, a relatively large number of enterprises can be audited in a relatively short time (3-5 days). The most promising enterprises resulting from the audit can be subjected to a feasibility or investment study. However, TAM in its present form does not contain a methodology to select the most promising enterprises from the results of the audits. In other words, the actual goal of TAM is not yet incorporated in the second draft. This paragraph gives a possible structure for such a methodology.

First, for each enterprise, a list of the technical remedies needed to lift the product shortcomings has to be made. This list is gives a first indication of the most promising enterprises. An enterprise with a short list of remedies will in most cases be more promising, than an enterprise with a long list of necessary remedies.

Next, the market prospects of the audited products have to be determined. Technologically speaking, an enterprise can be very promising, but if the product has no favourable market prospects, new investments would be rather useless. After a small market study, the enterprises without favourable market prospects are excluded.

Subsequently, for the remaining enterprises, the technical remedies are studied in detail. Each remedy is rated on a scale between one and ten. The higher the score, the more complex the technology and the higher the cost of the remedy. Redesigning the product in such a way that only a slight adjustment to the production process is necessary scores lower than, for example, a redesign involving a new machine and hiring qualified personnel[24].

Finally, all the scores are added up. The enterprises with the lowest score are the most promising enterprises.

The results of step 3 of TAM have not yet been included in this selection process. Especially in more developed countries, the causes of a low market share are usually not related to product quality but to marketing, product price and other items of step 3 of TAM. Further research is necessary to develop a workable selection procedure to determine the most promising enterprises based on the results of the audits.

8.3.6 Production costs

As already mentioned in the previous paragraph, the product price is an important aspect in the selection process of promising enterprises. Enterprises with a low profit margin are not suitable for investments in new machines with high costs. The investments will raise the cost price of the product, but it is usually not possible for the enterprise to raise the retail price.
To be able to make an estimate of the profit margin of an enterprise, it is necessary to collect information about the production costs in order to determine the cost price.

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[24] When grading the remedies, the information about the production process collected in step 2 of TAM, such as the degree of mechanisation, is indispensable.

For the determination of the cost price, among others, the following information has to be collected:

- amount and costs of raw materials and ready bought parts
- number of employees, directly and indirectly involved with the production process and the average yearly wages
- price and depreciation of machines
- energy costs
- overhead costs
- retail price of product

With this information, it is possible to make an estimate of the cost price. Together with the retail price, it gives an indication of the profit margin.

9 Literature

[1] Baker, C.P., *Costa Rica Handbook, second edition*, Moon Publications, USA, 1996

[2] Brombacher, A.C., *Predicting reliability of high volume consumer products* (Lecture notes, Eindhoven University of Technology, Eindhoven, 1996)

[3] *Centroamerica: Agenda para la modernización industrial*

[4] Lapperre, P.E., Ploeg, J van der, *Technology Audit Methodology for medium and small scale enterprises*, Eindhoven, 1996

[5] MEIC/ASOMETAL, *Plan de modernizacíon del subsector metalmecánica*, San José, Costa Rica, 1996

[6] Ministerio de economía industria y comercio (MEIC)/ministerio de ciencia y tecnología, *Política de modernización industrial, un pueblo en marcha*, San José, Costa Rica, 1996

[7] Ullman, D.G., *The mechanical design process* (McGraw-Hill, Singapore, 1992, pg. 112-125)

[8] Vereniging Logistiek Management, *Logistiek, integrale goederenstroom besturing*, (Educatie-boek, De Bilt, 1990, p. 295) and Bedaux, *Werkboek behorende bij het project:'Analyse van kernprocessen in het kader van de ontwikkeling van de logistiek'*, (Nunspeet, 1995)

[9] World Bank, *World Bank tables*, 1993

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