# THE TECHNOLOGY MAPPING METHODOLOGY FOR BENCHMARKING THE CONSTRUCTION PERFORMANCE

EMILIA.L.C. VAN EGMOND – DE WILDE DE LIGNY, MSC PHD

*Department of Technology Management, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands*

PROF.DR. ROGER A.F. SMOOK, MSc PhD,

*Section Design & Construction Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology Delft, The Netherlands*

---

## ABSTRACT

Globalization and increased international competitiveness point at the need for on-going improvement of the effectiveness of the industries in terms of the achievement of the quality and quantity of the required production output and the efficiency of the production processes. The Technology Status and Technological Capabilities are indicated to play an important role in the production performance of industries in literature of the last decade.

Adequate management and policy plans that should be formulated to enhance an improved production performance in industries require insight in the actual status of technologies and technological capabilities in the production sector. This insight forms the basis for the development of new products and production systems. Benchmarking the performance -including the state of art of technologies and technological capabilities- enables the management of firms and the policy makers in industries to compare their performance with industry norms and market expectations and improve the major factors that have an impact on this.

A proper methodology to benchmark the construction performance and to map the essential elements that have an impact on this is not readily available. This paper describes the principles of the so-called *Technology Mapping Methodology* that was developed and the results of its application in the construction industry. The key-elements in the theoretic framework that forms the basis for this methodology includes the market requirements and expectations, the status of technological capabilities, the technology status and the production performance and the socio-economic development status of the country. The last element is useful for international comparisons of the production performance which enhances the value of the benchmarking in the perspective of the increasing international competitiveness.

The studies rendered a considerable amount of valuable data that could serve to support Construction Management and Policy Making with the objective to improve the Construction Performance. It also discusses the need for further research to establish a technology database similar to the existing socio-economic databases in the countries.

## KEYWORDS:

Benchmarking Construction Performance, Competitiveness, Technology and Technological Capabilities, Management, Technology Mapping Methodology

## INTRODUCTION

The recent pattern of globalization has urged enterprises to improve productivity and deliver a constant higher quality on on-going basis to be able to compete on the international market. Studies on the performance of industries and improvement efforts thereafter were based on benchmarking models. Several benchmarking tools and methodologies have been developed for the analysis of the production performance in manufacturing and service sectors. The management in the construction industry can benefit from the experience that has been gained in other industries on the improvement of their production performance and competitiveness. At present benchmarking is also gaining in popularity within the construction industry although acceptance has been slow in construction.

The *general purpose of benchmarking* is the improvement of production performance. A key issue in point refers to what is going to be benchmarked and to what specific purpose. The improvement of the production performance in any industry implies an improvement of the production output in terms of quality and quantity. Single benchmarking the output of the production process as such makes no sense in case one does not know the factors causing the particular performance that need improvement. An improvement of the output of the production performance may require improvements of the execution of the various phases of the production process or an improvement of the inputs of these processes. *Benchmarking the production performance* should enable the management of firms and the policy makers in industries to compare their performance with industry norms and market expectations and improve the major factors that have an impact on this. Once performance gaps have been identified as a result of benchmarking, and the reasons for these differences examined and understood, it is assumed that organisations will implement changes based on the study's findings. Change can be made either by incremental steps, or it can involve major restructuring. Once a basic strategy has been agreed, related functional goals should be set, and an action plan and a method of monitoring should be developed in order to measure progress and report on planned goals. Thus benchmarking should be seen as a process of establishing critical areas for improvement within the enterprises in an industry.

*An appropriate benchmarking tool* should offer a generic, comprehensive, structured and systematic approach for the achievement of an improved quality and quantity of the production output and the efficiency of the production processes in industries. The benchmarking tools that were found in literature all have a defined theory or process for benchmarking, which are slightly different from each other, but have common features. Many of these were based on mono-disciplinary theories addressing single aspects of the production performance in industries, resulting in fragmented isolated improvement efforts and benefits cannot be integrated or repeated.. Further literature studies indicated the non-existence of a methodology that is comprehensive enough to determine the production performance of industries and the major factors that are considered to have an impact on this. (Van Egmond 1999) A generic benchmarking methodology was needed specifically for the construction industry. Such a methodology has been developed in our research project and applied in a number of case studies. It is a performance based approach, which determines the need for product and process innovations in building construction, taking into the level construction performance expected in the market and defined in the building regulations. The developed benchmark framework involves these aspects the state of technology and technological capabilities, expectations of society and the market dynamics.

*The target groups* for whom the methodology should be useful are a) the management of enterprises; b) policy makers at industry and national level.

## METHODOLOGY

### The construction industry

The construction industry is essential to us all. The construction industry provides shelter for all kinds of activities. It contributes to the achievement of socioeconomic development objectives in a country. At the same time it forms an inducement to other sectors of the economy through its backward linkages.

*Building construction* can be seen as the translation of a client's needs and intentions: first into documents and other information and later into a physical item. A construction process can be compared with the production processes in the manufacturing industry. The processes take place by means of an integrated *complex of people, tools, information and procedures*.

There are a number of differences though. A most remarkable difference is that nearly every end-product of a construction process has its own characteristics -based on individual terms of reference (specifications)- and nearly none of the end-products is composed out of exactly the same components.

Another particular characteristic of construction processes is that every finished product requires *adaptations to the specific location and terms of reference* set by the potential owner, client or architects and construction engineers. Moreover complete buildings rarely are moved and thus are bound to location the where the production process has taken place. In contrast to processes in the manufacturing industry the construction process takes place in and is organized around projects. Project executing organizations deal with the fact that there is not necessarily a continuous follow-up of one project after the other. Every project consists of a process of interrelated activities and interactions that take place in sequence between the involved parties with beforehand planned and specified goals, scope, costs, time span, performance criteria, which on their turn are intimately related. The process can be organized in several ways and the sequence of activities can also differ from one project to another.

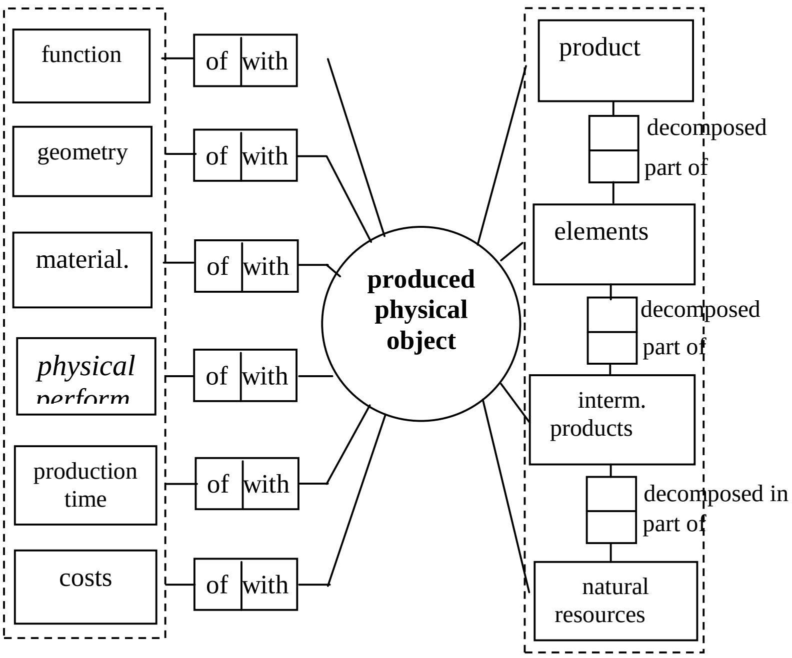
The construction process is a *multi stage process,* that forms the *production chain* in the construction industry. This chain includes a number of subsequent activities and sub-processes in various stages of the construction project.

The realization of the construction project generally takes place *on site* and is mostly unique due to the ever needed adaptations to the particular functional requirements and the physical circumstances. The activities take place in, around and in connection with a facility from the time of its initial conception to the time of its destruction. Activities that take place during the early phases of a construction project set the framework for the production process on site. This means that also the site production performance is affected by the outcome of the foregoing activities. (Smook, RAF, et all, 1997, van Egmond 1999).

**Technologies**

The construction industry uses and produces technologies alike any other industry production process. Alike in any other production process the construction industry uses *construction process technologies* to transform the material inputs into the desired *output.*

**Figure 1** Product technology components Source: ISO-TR 1994




Technology is a complex concept. In a practical definition -that is considered useful for the understanding of its role in production processes - a distinction is made between (a). product technology and (b) process technology. (Stewart 1974/ 1977; Van Egmond 1999)

***Product technology*** refers to the complex of product technological attributes *embodied in the output* of the production process required by the society in which it is used and which is using it.

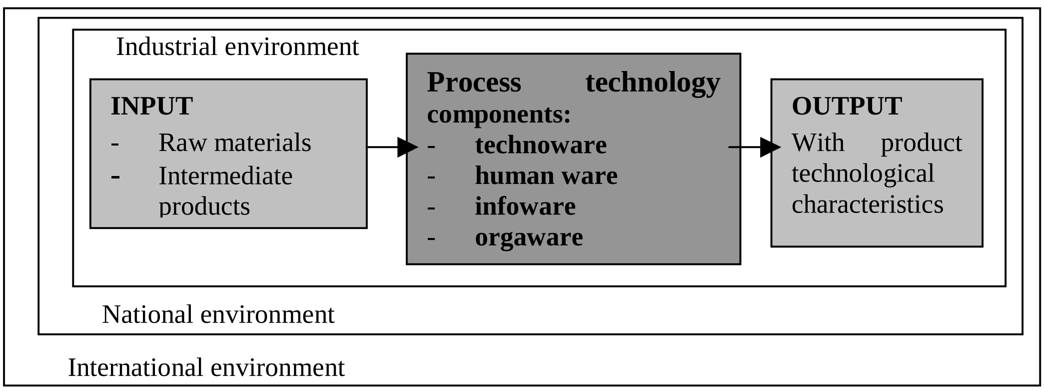
***Process technology*** refers to the *"transformer"* applied for the production of goods and services, in the context of transformation of inputs in production processes.

*Products* can be seen as the output of processes of attuning the specification of the market demand with technologically feasible solutions. The product technological attributes of a product refer to the coherent complex of the attributes of the products that determine its *costs*. This combination of attributes generally is laid down as basic product specifications in documents such as (standard) product specifications and drawings of basic details of the product. This specification of the product describes the product's characteristics regarding it's function, geometry and appearance, materialization, physique-technical performance, production complexity and costs. (ISO-TR/1994) Each product is composed of parts that can be seen as products of foregoing production phases. (See figure 1 right column).The *specifications or terms of reference for the products* are generally a combination of requirements for the desired product. These requirements are set by the customers in the market, by the designers in the preparatory phase of a product development trajectory, by the engineers and the consultants for particular aspects of the products and by the managers in the decision making processes in a production unit (enterprise).

The final *production output of a construction process* is the total building (the product with specific product technological characteristics). The building is composed of a construction system. This construction system can be de-composed in the components: (1) construction products (building materials), (2)work sections (building components), (3) elements (ISO/TR 14177:1994) The *product technological characteristics in the construction industry* are the properties and features of the built objects and their components, including construction products, work sections, elements and whole facilities. The attributes of the components determine the attributes or *product technological features* of the final product.

C*onstruction process technologies* are regarded as the complex of the four inextricably interrelated process technology components: Object embodied technology (Facilities or techno ware), person-embodied (Abilities or Human ware), document embodied (documented facts or infoware), organization embodied (frameworks or orgaware) applied to the construction process on- site. Any transformation process only can take place when a minimum is present of all four components of technology. All four components can be marketed separately. (UN-ESCAP 1989) In each of the stages of the construction process on site a different complex of process technology components can be applied.

**Figure 2** Technologies in the Production system and the respective environments
Sources: ESCAP 1989, Van Egmond 1999

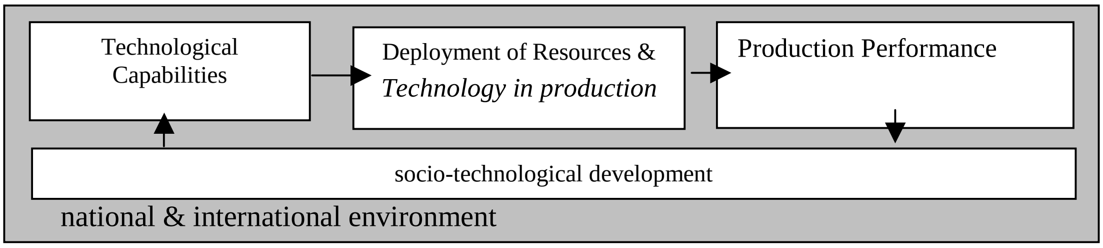



## Technology, production performance and socio-economic development

It is undeniable that the dependence on technology[i] of present societies is high. Since far back in history man made use of technologies to be able to stay alive. First technologies were needed and developed to enforce human energy, in order to have more power to transform the natural environment into the products that were needed by man. At present in this era of on-going automation and computerization, machines even take over parts of human brains or form a supplement to these. Man has increasingly been able to utilize the available natural resources more efficiently and effectively by means of or supplemented with means that were produced by man himself. New products and services were and still are being developed with an increasing complexity. Products and services that

increasingly better meet the market demand for a higher quality. At the same time this demand changes at an increasing higher pace. The present global developments lead towards an increasing international competitiveness and at the same time an increasing international inter-dependence. This dependence refers particularly to the scarce resources that are needed for production in order to meet the increasing and faster changing market demand for products and services. On-going proper selection, acquisition, application, adaptation, improvement, and generation of technologies is needed for efficient and effective production that keeps pace with the changes in the global market.
Theoretic viewpoints -that emerged only since the last two decades -point at the importance of technological capabilities[ii] for efficient and effective production leading to competitiveness of industries and nations. Technological capabilities and the state of art of technology were also assumed to have a direct relationship with the socioeconomic development status in a country. The conclusion is that it is worthwhile to investigate the state of art of Technological Capabilities and of Technologies when these elements are key-factors for efficient and effective production performance.

**Figure 3** Theoretic model




**Production performance in the construction industry**

The present *construction performance* in many countries requires a higher qualitative and quantitative value of output to meet the needs in the construction market which to a great extent can be attributed to the current (poor) quality arising from the existing structures and working practices in the construction industry.

An improvement of the construction performance implies a more effective production output with an increased quality, sustainability and a more efficient use of the material inputs and process technologies at lower costs, and higher speed contributing to socioeconomic development goals in a country. Such improvements contribute to a supply of a higher quality of the buildings, a better affordability (lower cost) of the buildings for the end-users and to an increased profit margin for the involved contractor. Moreover if the contractor is able to realize the construction process on site more efficiently this may contribute to strengthening his position on the construction market.

The idea that *production performance* in building construction depends on the technology status in the construction projects induced that technology developments and improved technology utilization were launched to improve the project production performance. Empirical evidence showed that widespread performance improvement at the project level result in growth on sector and national level. It also appeared that cost effects seem to depend on the scales of operation. The production performance thus depends on the quantitative, qualitative and cost attributes of the construction output versus the utilized means and procedures applied in the construction processes for the transformation of inputs into the desired output.

The quality and price of a building is determined by the totality of attributes of the finished building (the product technologies) including the way on which individual attributes are related, balanced and integrated in the whole building and its environment for an acceptable period of time and which enables it to perform a stated task or to satisfy a clients given needs. (Atkinson1995; van Egmond 1999). The duration of the construction process in man-hours may serve as an indicator for the *quantitative features* of the construction performance.

To achieve a satisfactory construction performance for the market it is at least necessary to (a) identify the quantitative and qualitative needs of the target group and their characteristics; (b) clearly identify and specify the roles and responsibilities of the teams involved in the building construction process;

(c) recognize the need for quality in the total system of building construction to achieve a satisfactory end-product, including building materials production, design and engineering and construction on site, which requires for total quality management. The first aspect refers to the terms of reference of the production output (*technological features of the product).* The last two aspects refer to the status of the utilization of the *process technology*. Thus alike in any other sector the effectivity of the production output and the efficiency of the use of process technologies determines the technological production performance.

Improvement of the production performance in the construction industry thus relies on

- The development and application of technologies in the production chain of the construction industry
- Technological Capabilities for the development and application of technologies in the production chain of the construction industry.
- Construction management for the sustainable development and application of technologies in the production chain of the construction industry.

**Construction management**, which involves attuning of the various tasks and responsibilities of the various parties in the construction process becomes rather important for the ultimate efficiency and effectivity of the construction process. Due to the involvement of various parties during the physical realization of a building the problem may rise *who* is going to balance out the pros and con´s of the alternative technical solutions. The major limiting factors on meeting the actual terms of reference (that represent the preferences of the end-users) are of financial nature. The end-user or potential owner of the building will not always be the final decision maker, neither is the contractor. Moreover the contractor and end-user do not always communicate during the construction process. In many cases a property owner who invests in the construction of buildings will be the one who makes the final decisions on the technical as well as the financial aspects, whereby the preferences of the future end-user of the building are not always taken into account. Often investors in dwelling construction projects like for example national governments, which have the objective to build as many houses as possible in a short time, at best tend to take investment decisions based on short term analyses of the preferences of the future end-users, without taking into account the possible changes in these preferences at longer term.

***Construction management*** can benefit from the experience that has been gained in other industries on the sustained improvement of their production performance and competitiveness. However, the industry does not have a generally accepted and recognized methodology or framework on which to base a process improvement initiative. The absence of guide-lines to systematically and comprehensively assess construction processes has meant that any improvements are isolated, prioritization of process improvements is difficult and benefits cannot be integrated or repeated.

**A generic methdology for benchmarking studies on the production performance of industries**

A first *requirement for proper production management* is the availability of a full set of information on the current status of technological capabilities and the technologies in production to be able to determine the opportunities problems and constraints for improvement. The above presented views form the basis of a specific methodology that is assumed to be useful for the purpose of benchmarking the status of Technological capabilities and of technologies in production sectors to support production management.(Van Egmond 1999).

It may be concluded that an **integral method for benchmarking the production performance in industries** in their respective environments at different levels of aggregation (micro, -meso-, macro- and supra-macro level) is necessary to achieve an appropriate formulation and implementation of production management, policies and strategies in a country. By means of the so called Technology Mapping Methodology the status of technological capabilities and technologies in industries has to be investigated in a *number of sub-studies* at different levels of aggregation, including a study on the state of a) technologies in production processes; b) Technological capabilities; c) sectoral socioeconomic performance and the national environment.. These baseline-studies are necessarily of different disciplinary nature and mutually supportive to yield complementary data. This is to ensure a meaningful integration of the various socioeconomic and technological components that play their role in the actual situation regarding the production performance of the enterprises and socioeconomic development in the country. Such a *comprehensive study* results in a relatively extensive data set. The technology mapping studies are of *comparative descriptive nature* and can be seen as ad-hoc sample surveys during which the major characteristics of the particular production sector are investigated and described.

The data on the state of art of Technological Capabilities and of Technologies in production sectors should facilitate the determination of the problems and constraints in production sectors, the identification of the technology needs and the prioritization of these for the formulation of adequate technology management and policy plans focused on the improvement of the production performance. The data also should facilitate the determination of design solutions and selection of a proper technology that should be locally developed or acquired from elsewhere through technology transfers. The data should facilitate the determination of the saleability, viability and feasibility of the solutions that meet the need for technologies for production. This production ultimately should lead towards socioeconomic development in terms of economic growth, income generation, employment, increased skills and knowledge. Herewith the potential socioeconomic value of research on Technological Capabilities and Technologies to contribute to socio-economic development and sustainable development of the production is indicated.

## CASE STUDIES

### Objectives and research set up

Case studies were carried out on the production performance and technology utilization in the lower income dwelling construction industry in Tanzania and Costa Rica The *major objective* for the execution of the case studies was to determine the usefulness of the developed benchmarking method by its application in field studies. Next to this the results of technology benchmarking studies are expected to offer insights in the possibilities for management and policy interventions directed to bring about the improvements in the weak elements of the technological capabilities and technologies in the construction industry in order to achieve the development targets for the successful performance of the sub-sector in question.

*Research instruments* were developed and adapted to the particularities of the sub-sector of dwelling construction to collect the necessary data. Many data were collected from secondary sources. Most attention was given to the collection of *primary data* on the status of technologies in the dwelling construction projects and the resulting construction project performance. The basic *research unit* in the benchmarking studies of the technology status was the dwelling construction project for the lower income households. The *data collection* during the field studies was carried out in collaboration with various institutes, organizations, enterprises and government agencies in Tanzania and Costa Rica, which made the collection of the extensive data set possible.

### Results of the case studies

Tanzania and Costa Rica have to face a tremendous *housing problem***.** This housing problem can to a large extent be attributed to the diminishing volume of resources that are necessary for the construction of adequate shelter for all sections of society.

**Table 1** A comparison of the Technology Mapping results in Tanzania and Costa Rica

| | **TPP** | **STP** | | **TCAP** | | | | | **HDI** |
|---|---|---|---|---|---|---|---|---|---|
| | | Teffect | Tefficy | **Total TCAP** | Tstock | HR | NR | Tinfra | |
| **Tanzania** | **1,27** | 0,12 | 10,6 | **2,2** | **2,1** | **2.9** | **1,8** | **2,1** | 26,8 |
| **Costa Rica** | **4** | 0,14 | 28,6 | **6,6** | **5,75** | **6,6** | **8,3** | **6,1** | 84,2 |

In both countries the *technological production performance (TPP)* is not sufficient to meet the actual need for housing in particular for the lower income households. This TPP results from the *status of technologies (STP)* that are used in the construction projects. The present *technological production performance* at construction project level can be attributed to the *status of technological capabilities (TCAP)* in the sector**.** The status of technological capabilities (TCAP) is equated with *the stock of national resources* that can be committed to the dwelling construction industry in the countries appears to show a number of weaknesses. The situation as described is noticeable in the general *socio-economic performance of the construction industry* in the countries. The dwelling construction industries in both countries take a relatively large percentage of all construction activities. But their socio-economic performance requires improvement. The national technology setting in both countries is not favorable for an optimal performance for the construction industry particularly in economic sense. The socio-economic development status in Tanzania is remarkably lower than in Costa Rica given the HDI figures. From the studies can be concluded that the technological capabilities that are held responsible for the Technological Production Performance in the sector is not optimal. (see table 1, whereby 0<TCAP<10). This status of the technological capabilities is reflected in the limited scores for the Technological Production Performance in the sector. (see table 1 ,whereby 0<TPP<10)

**Box 1** Recommendations to construction management and policy makers in Costa Rica

**RECOMMENDATIONS FOR THE DWELLING CONSTRUCTION PROJECT MANAGEMENT**

***Recommendation 1*** Continue and increase the execution of dwelling construction in mass construction projects to take advantage of economies of scale.

***Recommendation 2*** Take the particular locational and climatological characteristics like earthquakes, hurricanes, and landslides during heavy rains into account while preparing the project design and engineering details.

***Recommendation 3*** Continue to involve the house owners and their relatives in the construction process

***Recommendation 4*** Take care of the availability of professional instructions during the project execution

***Recommendation 5*** Continue to use low capital tools and equipment in the mass construction projects for low cost houses.

***Recommendation 6*** Take the advantages of using information and documentation systems

***Recommendation 7*** Enhance and stimulate the improvement of the knowledge and skills among the labor force.

***Recommendation 8*** Closely collaborate with professionals (architects, engineers and consultants) and suppliers of materials and equipment

**RECOMMENDATIONS FOR THE DWELLING CONSTRUCTION INDUSTRY**

***Recommendation 1*** Continue to carry out the dwelling construction plans as stated in the National Housing Program coordinated by the Ministry of Housing and Urban Settlements (MIVAH)

***Recommendation 2*** Increase the linkages between the actors in the technology infrastructure.

***Recommendation 3*** Extend the stock of construction technologies for dwelling construction.

***Recommendation 4*** Up-grade and mobilize the stock of human resources.

***Recommendation 5*** Exploit on sustainable basis the limited stock of natural resources

**RECOMMENDATIONS FOR NATIONAL POLICY MAKERS**

***Recommendation 1*** Stimulate economic development

***Recommendation 2*** Improve the existing policy structure, regulative and legislative system to become less bureaucratic, adaptable to changing circumstances and more supportive for the production sectors including the construction industry.

***Recommendation 3.*** Stimulate the improvement of the training and education system tailor made for the construction industry.

***Recommendation 4****:* Improve the physical infrastructure.

***Recommendation 5*** MIVAH should continue its tasks as a dwelling construction coordination unit.

***Recommendation 6*** Establish specialized private sector employment agencies to register and control the availability and quality of the labor force in the construction industry.

***Recommendation 7*** Train the labor force and further develop low cost prefab construction systems that are durable, sustainable, easy to transport and handle and have a low import content should get a primary attention.

Adequate government policies, regulations and legislation, stimulating the promising sectors in Costa Rica and adequate technology management could be based on full information regarding the actual status of technology and technology capabilities to exploit and expand the available national resources to the benefit of the technological and economic production performance. On the other hand the same aspects are - whenever they are achieved in reality- also the result of an improved performance of the construction industry.

A ***remarkable finding*** is that the ratio of the socioeconomic development status in the two countries expressed in the Human Development Index (HDI) corresponds with the ratio of the status of Technological Capabilities and the ratio of the Technological Production Performance. This is an endorsement of the theoretical views adhered to in our research project.

**Implications for construction management**

The results of the benchmarking studies on the dwelling construction performance made it possible to formulate recommendations to the management of the construction firms and policy makers *to* their performance -and the major factors that have an impact on this- in line with the industry norms and market expectations. Changes can be made either by incremental steps, or it can involve major restructuring. Once a basic strategy has been agreed, related functional goals should be set, and an action plan and a method of monitoring should be developed in order to measure progress and report on planned goals.

In our study it has been clear that both countries have to face serious problems in providing adequate shelter. Given the limited status of technological capabilities a most obvious route to improvement of the performance of the dwelling construction sector should be sought in technological capability building. Therefor it was recommended *to increase the quantity and quality of the total complex of technological capabilities that can be committed to the construction sector.*

*The Tanzanian situation* points at an opportunity for Technology Management to emphasize on the development of a more efficient and effective utilization of the available stock of Natural Resources available in abundance.

*In Costa Rica* the availability of a stock of Human Resources with a relatively high education level gives an opportunity for Technology Management to emphasize on a more efficient and effective utilization of these Human Resources for a further development of the Technology Stock.
The national setting of the countries is not very favorable. The setting is largely determined by factors not directly manageable at sector level. National policy makers in Costa Rica for example are recommended to improve the existing policy structure, regulative and legislative system to become less bureaucratic, adaptable to changing circumstances and more supportive for the production sectors including the construction industry. The present economic and politic-regulatory setting forms a constraint for the implementation of the Technological Capability Building efforts, which has to be taken into account.

The technology mapping studies however give a clear direction of priorities to be set to effectuate an improved living condition for the population.

## CONCLUSIONS

*The theoretical framework* developed and used in this research had to meet a number of requirements.

It was meant to be *comprehensive*. It includes the major determinants that were supposed to have an impact on the level of technological production performance in a sector, in terms of its contribution to socio-economic development. The data found in this research project by means of the application of the developed research methodology made a detailed and comprehensive description of the industrial technological production performance possible.

The theoretical framework was also supposed to be *generally applicable* for a systematic analysis of technologies and technology capabilities in production systems irrespective of sector, region, nation or time. It constitutes a blueprint for the collection, measurement and analyses of the data on the technological capabilities, the status of technologies and the technological production performance in any production sector. Included in the framework are the factors of the *production environments* that are supposed to have an impact on the technological production performance.

The conditional particularities that were assumed to have an impact on the scores of the variables have been taken into account. This refers for example to the geographic conditions in the different countries in which the investigations took place. Herewith the multiple applicability of the theoretic framework irrespective of time place and sector might have been shown.

It is possible to translate the variables included into the framework into measurable units. The major concepts of the theoretic framework are for all sectors the same. The particularities of the production processes in each production sector differ however. The complex of indicators, that determines the features of the core concepts, therefor needs to be adapted to the sector in which the field application of the theoretical framework takes place.

The multi-disciplinary character of the theoretic framework highlights the relevance and need of collaboration between researchers with different disciplinary backgrounds. The framework was developed by synthesizing the relevant elements of a number of analytical frameworks that were utilized in various disciplines to carry out research on technology. (reference is made to part I-1)

The operational definitions of the core concepts point at the need to make use of the analytical tools of disciplines like sociology, economics, engineering sciences. The methods of the engineering sciences are needed for the techno metric analysis and valuation of the utilized technologies. Not all data need to be collected by one researcher however.

The concepts in the framework -like technology and technology capabilities- are complex and multi-dimensional. The consequence is that more than one indicator was necessary for their analysis.

Nominal and ordinal measurement scales are applied in the technology benchmarking studies. The scales that were applied to measure qualitative aspects in this research have been developed on ad hoc basis. This means that the researcher has gathered as much as possible the generally accepted and possibly formalized opinions on the topic area thereby relying on her own experience. The results were cross-checked with experienced professionals in the topic area of the study. The technique is applied with being conscious of its limitations. One of these is the particular frame of reference that the researcher may have in devising a certain score for the observation or object. The rates were discussed with experts in Tanzania and Costa Rica. This was done to be able to omit any bias to a certain extent and in order to increase the reliability of the scores, that were based on her evaluation. Pretests with the questionnaires were carried out and reverse translation of these in English, Swahili and Spanish to avoid as much as possible any additional forms of bias. Other possibilities of a bias could also be traced by investigation of additional literature and comparison of the data in these publications with the findings in this research.

A merit of the way of data collection and subsequent scaling that was applied is that the underlying information for the scores can always be traced back and thus add more information and meaning to the research results.

Technology mapping studies to benchmark the production performance are found to be indispensable for technology management and technology policy planning and should be put on the research agenda in the country.

With regard to the *practical usability* can be said that –thanks to the relative comprehensiveness of the theoretical framework- the methodology provides a reasonable coverage of the topic under study. The developed *measuring instruments* supplied the *information* that was needed.

On the other hand -regarding aspects like time spending, costs and convenience- can be noticed that the research methodology requires a rather extensive data set that is not always readily available. In particular the technological data require in-depth surveys to get reasonable data sets. The non-existence of technological data banks -in contrast to most economic data banks- may make a research project like this expensive and time consuming.

Given the evidence that Technological Capabilities and the status of technologies indeed can be seen as the key factors for the production performance in industries, it is considered worthwhile, to set-up and to maintain a databank for technological data for every sector in a country. Technology mapping studies offer a good opportunity to realize this. The experience is that the measuring method is reasonably easy to administer in particular by using software for spreadsheet programs.

A professional organization like CIB in collaboration with international organizations such as the OECD or the UN agencies could form a stimulating forum to promote the studies for the establishment of a technology databank for the construction industry.

## REFERENCES

Atkinson, G. (1995), *Construction quality and quality standards: the European perspective.* London: E & FN Spon.

Bell, M., B., Ross-Larsen and L.Westphal (1984), Assessing the Performance of Infant Industries. *Journal of Development Economics, 16*, 101-128.

Egmond, E.L.C. van, Technology Mapping for technology Management, 1999, TU Delft

ESCAP (1989a), *A framework for technology based development. : an overview of the framework for technology-bases development* Bangalore: United Nations.

ESCAP (1989b), *A framework for technology based development: technology status assessment*. Bangalore: United Nations.

Fransman, M. (1984), Technological Capability in the Third World: an overview and introduction to some of the issues raised in this book In: Fransman and K. King (Eds.), *Technological Capability in the Third World*. London: Macmillan press Ltd.

International Organization for Standardization, *ISO-TR/1994* : international standard. - Geneve :International Standards Organization

Lall, S (1987), *Learning to Industrialize: the acquisition of technological capability by India*. London: Macmillan.

Lall. S. (1990) *Building industrial competitiveness in developing countries* - Paris : OECD

Miles, D. and R. Neale (1991), *Building for tomorrow: international experience in construction industry development*. Geneva: International Labour Office.

Moavenzadeh, F. (1987), The construction industry In: L. Rodwin, Dept. of urban studies and planning, MIT (ed), *Shelter, Settlement and Development*. Boston: Allen & Unwin.

Smook, RAF, et all, (1995) *Organisatie van het bouwen*, Ctbd 211, , TU Delft -CT

Stewart, F. (1977), *Technology and underdevelopment*. London: MacMillan Press.

Stewart, F. (1978), Technological self reliance of the developing countries: towards operational strategies In: *UNIDO, Development and transfer of technology series*. New York: UNIDO.

## FOOTNOTES

[i] *Technology* refers to *products*, with particular technological characteristics like its (1) functionality, (2) appearance or geometry, (3) materialization, (4) physique-technical characteristics, (5) production complexity, (6) costs.

But technology also refers to the *production process components* by means of which the products are being produced. A process technology is composed of four process technological components:

(1) *technoware* (equipment and tools), (2) *humanware* (labor force), (3) infoware (documents, instructions, guidelines), (4) orgaware (organizational framework)

Production processes only properly can take place incase the four process technological components all are available.

[ii] The concept *Technological Capabilities* refers to the **total stock of national resources** that can be committed to the production sector, in order to produce efficiently and effectively anticipating the on-going market developments. This total stock of national resources is formed by the complex of (1) technology systems, (2) human resources stock, (3) natural resources stock, (4) technological infrastructure (the network of more or less related organizations and institutes in which technologies in various embodiments are available). Empirical evidence in a number of sectors reported in literature indicate that the strength of the Technological Capabilities becomes evident in the efficiency and efficacy of (a) **production** by application and maintenance of technologies, (b) **technology improvement and development** for production, (c) **selection and transfer of technology** for production purposes. (Bell, Lall, Fransman)