# SYNTHESIS REPORT
# FOR PUBLICATION

**CONTRACT NUMBER: Bi?E2.CT92.0217**

**PROJECT NUMBER: 5455**

## OPERATOR-DRIVEN TECHNOLOGICAL INFORMATION SYSTEM FOR THE CONTINUOUS IMPROVEMENT OF PROCESS PLANNING

# PLANMAN

**PERIOD FROM 1/4/93 TO 31/3/96**


**PARTNERS:**
**CIMTEL (COORDINATOR)**
**TEKNIKER**
**IFW**
**ZAYER**
**MWH**
**ADWEST**

**AUTHOR: C. Pudig, M. Harstorff**



**REPORT NO: I -005**

**VERSION NO: 2**

**DATE: 20th June 1996**


---


PROJECT FUNDED BY THE EUROPEAN

COMMUNITY UNDER THE BRITE/EURAM

PROGRAMME

# 1 EXECUTIVE SUMMARY

The estimation of accurate and consistent times for manufacturing operations is an important activity within most manufacturing companies. This process of generating operation times is yet all too often a theoretical exercise which does not reflect the actual situation on the shop floor. Investigations have shown that at least 20% of the times/values generated by the process planner are changed during the manufacturing process. The changes within manufacturing are normally not known by the process planning department. Without feeding back information to the process planning department, detected mistakes and/or faults will not be corrected there and possible improvements will not be made.

PLANMAN **was set up as a project to investigate and produce a** means of helping to overcome these difficulties.

The investigations and research carried out defined the techniques to be used and the requirements of a flexible software solution to assist in the use of these techniques. The software solution is designed as an interfacing element of mainly the shop floor and the process planning departments of a company. The software solution contains different modules. The developed modules meet the direct needs of transmitting information from the shop floor to a database for access by the planning engineers. The feedback can be from both manually and automatically collected (direct machine monitoring) data. The process planner is supported by different models to predict tool life, to estimate costs and to calculate times based on actual performance data.

The evaluation of mathematical models has also identified the models that can be used to meet the needs of the engineers in carrying out the improvement of turning, milling and grinding operations. The applied techniques including regression analysis have been suggested together with the relevance of each model/technique.

The developed systems and modules are based on the widely used "standard" personal computer and **windows architecture in either a stand-alone or network environment.** A completely user definable database is provided **using a conventional** file structure or relational database as chosen by the end-user. Standard software tools such as common spread sheet programs have been interfaced with the

Technical Informationssystem so that engineers do not need to learn a new piece of software to carry out these mathematical functions.

Summarizing the Technological Information system produced by PLANMAN has built a mechanism to bridge the gap between the planning office and the shop floor encouraging:

- A team work environment between the engineer and the operator,
- The involvement of the operator in the planning process.
- The commitment of the operator to achieving process standards.
- The engineer specifying processes that reflect shop floor capability.

## 2 OBJECTIVES of the PROJECT

Many enterprises are facing the situation of increasing exchange of complex information. The result is a large variety of (undocumented) interfaces which are needed to transfer information between different systems. In particular Small and Medium Enterprises (SME) do not have the resources to build and manage several interfaces. This is particularly true in the technical area of data exchange between the shop floor and the engineer concerning the validity or effectivity of manufacturing processes in machining.

Today's machines and tools are continually changing capability. Changes are made in manufacturing to improve a process because the process planning department does not know machining conditions as well as the operator on the shop flour. The changes should be known to the process planning department. Due to the lack of effective systems this information is not communicated. This leads to inaccurate or even invalid process plans being specified by the engineer with the obvious effects of poor productivity, bad quality, and inaccurate cost estimating. An inaccurate cost quotation can mean either a lost job or producing a product at a loss.

To solve these problems of detection, correction and data exchange an integrated Technological Information system (TI) was to be developed. The technical aims of the PLANMAN project are:

- To develop a self-adjusting model initially for the milling process that would have generic applicability and be capable of extension to other machining processes, thus enabling improvement of process parameters.
- To build a shop floor monitoring system capable of making the technological process data available to the engineering systems and people, thus ensuring the use of the correct nominal process parameters and the ability to diagnose process deviations.
- To integrate the machine tool control system with the TI, thus providing a complete monitoring and control package for the machine to a machine tool manufacturer.
- To provide an "operator driven" system applicable in a number of different environments.

# 3 SCIENTIFIC and TECHNICAL APPROACH

During the analysis of end-user's requirements and following specification of the system different modules were defined, figure 1. Within the *Process Data Definition Module* the process planner specifies the critical process or operation to be investigated. Within the *Process Tracking Module* the actual results of the specified process will be collected. This includes on-line collection of process data via machine control and operator's input of corrections, changes within the examined **process, remarks,** etc.. The collected data are stored within a relational database or **a** conventional file. This database takes information from all modules and provides them with the required information. The *Process Analysis Module* can be used at process planning or shop floor level. It enables **the user to select and** to visualise all information stored within the database. Several routines for these analysis/visualisations are provided. Beside the actual values from the shop floor, the nominal ones could be put in manually or could be transferred from existing Process Planning Systems by using the *Information Manager*.

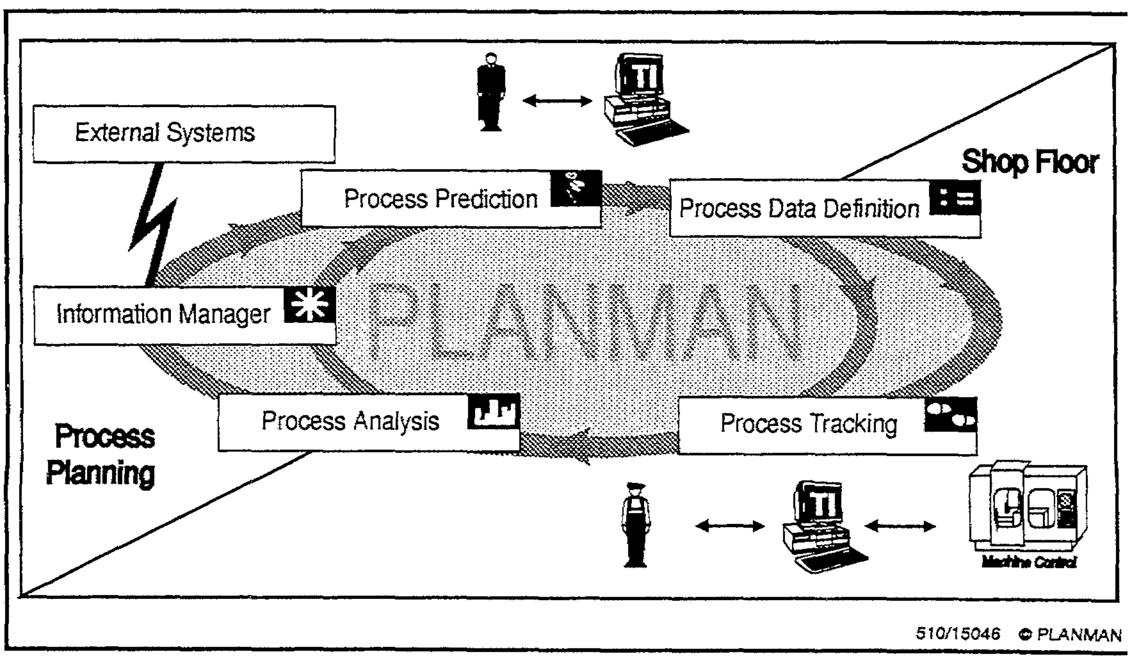



**Figure 1: Module Overview**

The routines of the *Process Prediction Module* predict the outcome of different process conditions. This includes models for cost estimation as well as technological recommendations or limits of process values. By using regression techniques and collecting actual performance data the predicted values will become more reliable and close the often found gap between nominal and actual process data.

Furthermore the modularity is useful to fit different requirements. E.g. the *Information Manager* is necessary *only,* if the system works in a network environment. The *Process Tracking Module* is unnecessary, if the machine to be investigated is not numerical controlled. To add process specific models only the Process *Prediction Module* is implemented,

### 3.1 Process Data Definition

The experience of the process planner allows the identification of 'bottlenecks' - processes considered critical for the overall productivity of the shop floor. Although the system is capable of monitoring all processes, this would not increase the efficiency of process planning activities. Additionally, it leads to **a** huge amount of data to be managed.

Following the philosophy of the system, PLANMAN considers mainly the most important manufacturing processes. The influencing parameters of these processes can be defined within the Process Data Definition module (PDD).

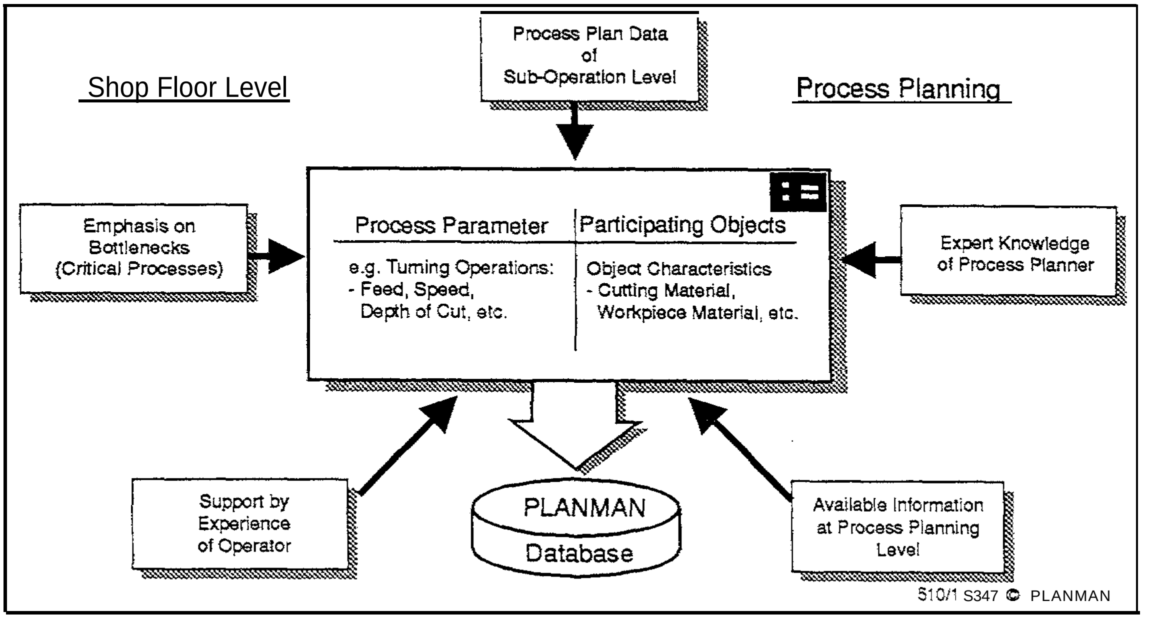



**Figure 2: Process Data Definition Module**

Typical influencing parameters are shown in fig. 2. Furthermore, the PDD includes the definition of the objects participating in the manufacturing process. The final aim of this step is the linkage of a process operation with all related information on pre-production level:

- sub-operations of the specified process
- nominal values of process parameters
- quality requirements
- resources **such as tools,** workpiece **and cutting materials,** gauges, fixtures, etc..

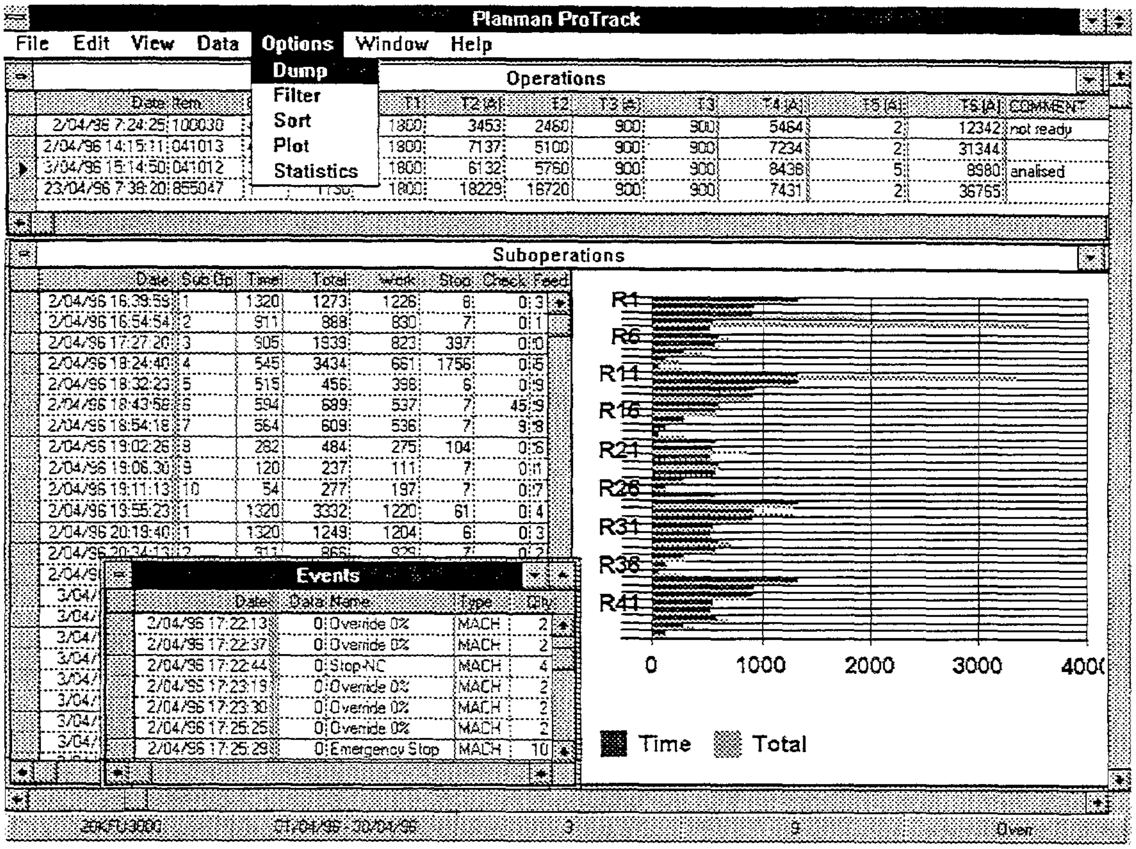
Knowing the critical process the Process Data Definition Module allows the definition of all data required by this specific process. The user is able to name the data sets (sub-operation of the process plan of the target process) to meet his specific requirements. The data definition can be set up manually or automatically. Automatic set up means loading process parameters of a critical process defined previously.

### 3.2 Process **Tracking**

The Process Tracking Module collects the actual data **for each required process** parameter specified by the Process Data Definition. The values of these parameters can be accessed directly from the machine control or entered manually. This data is filtered and transferred to the database by this module. The transfer of the selected data is possible in on-line or in batch mode. This module does not require the interaction or communication with other systems.

The on-line data collection and the filter mechanism applied to the module can be used to analyse the process execution at shop floor level. This means, process times, events and registered parameters can be used to investigate observed process results and disturbances.

The figure shown below is an example of the data analysis capabilities available to the production engineer from the Tracking Module with an On-Line connection to a machine tool.




An application element for machine control collects the actual data for each required parameter of the specified process using direct access to the machine controller. For the physical connection between the numerical control and computer the standard RS232 has been used. The system architecture for the Process Tracking consists mainly of two different components: Machine control software components and PC side software components

The machine control software components are Programmable Logic Controller (PLC) software and an NC-manual data collection module. PLC software is the program running in the machine and monitoring the NC program execution. The objective of the PLC software is to catch the working conditions during the machining process as parameters. These are feed, spindle speed etc..

The NC-manual data collection consists of screens in the NC to introduce manually required data, e.g. machine stoppage justification, work finishing notification. In order to pick up these messages simply, different NC screens pop up automatically e.g. whenever there is a machine stoppage taking more time than specified.

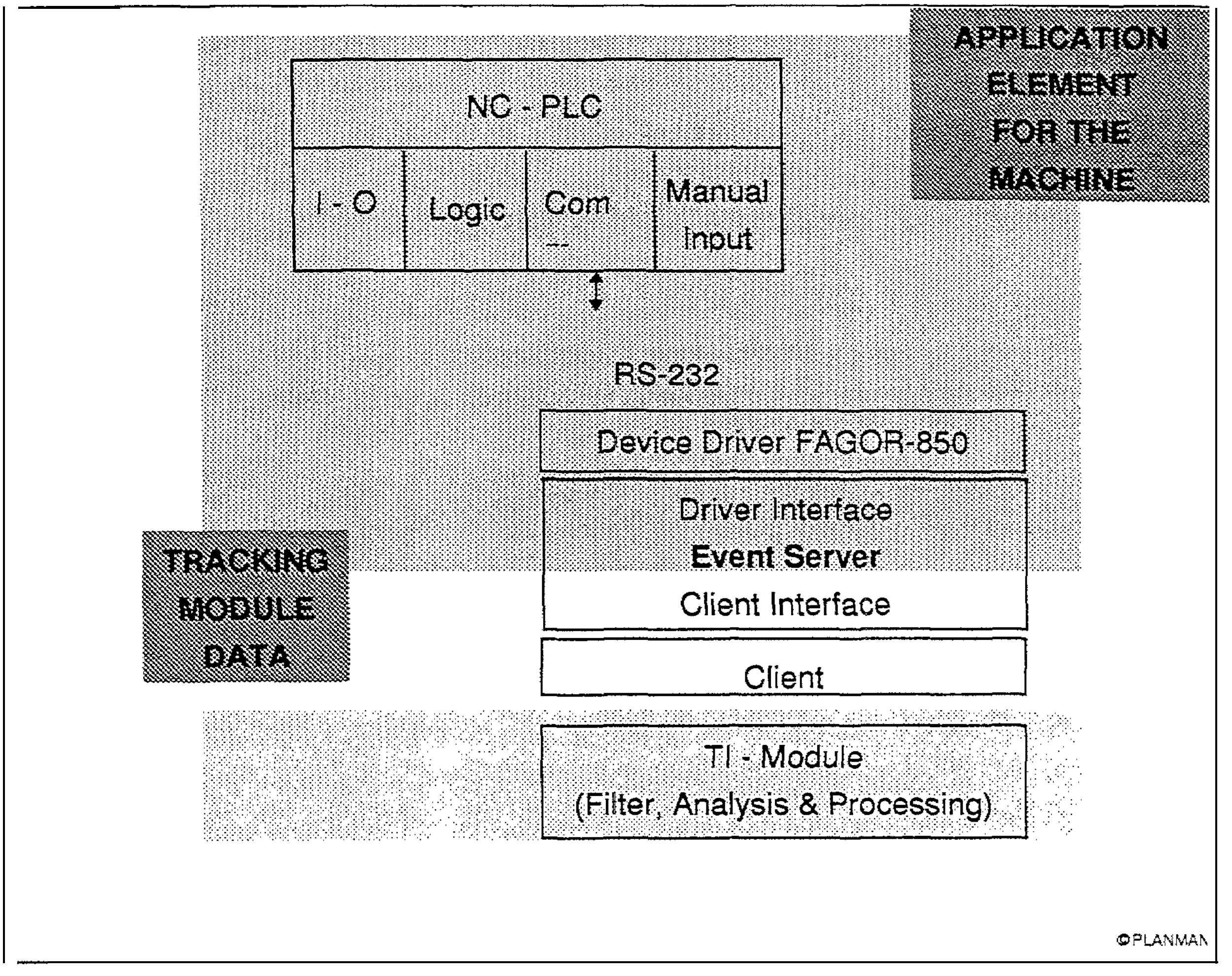



Figure **3: Process Tracking** Module

The central element of the on-line data collection system in the PC is the Event Server, fig. 3. This Event Server is connected with the two parts to be integrated: the machine and the TI using a client interface and a driver interface. The Event Server works independently and can be connected with different clients: the TI, the NC Program Manager, etc.. Client applications interact with the Event Server using a library of functions. The client interface library includes functions to connect to servers, services and variables and to set-up the variable notification mechanism.

The device driver interface is a set of functions, structures and conventions to realise the interface between Event Server and NC machines, PLC and so on. A particular driver developed according to the device driver interface specification and used in PLANMAN is the one for connection with the NC FAGOR-850.

### 3.3 Process Analysis

Besides the pre-analysis within the Tracking Module, several possibilities of inquiries, visualizations, reports etc. are provided in the Process Analysis module, fig. 4. The minimum, maximum and the average values of a specified process will be regarded. These inquiries can be visualized as scatter plots, pie charts, etc. and can be summarised in printed reports. The main purpose of this module is the detection of deviations between nominal and actual process values. Thereby, the user is able to assess the need for process improvements.

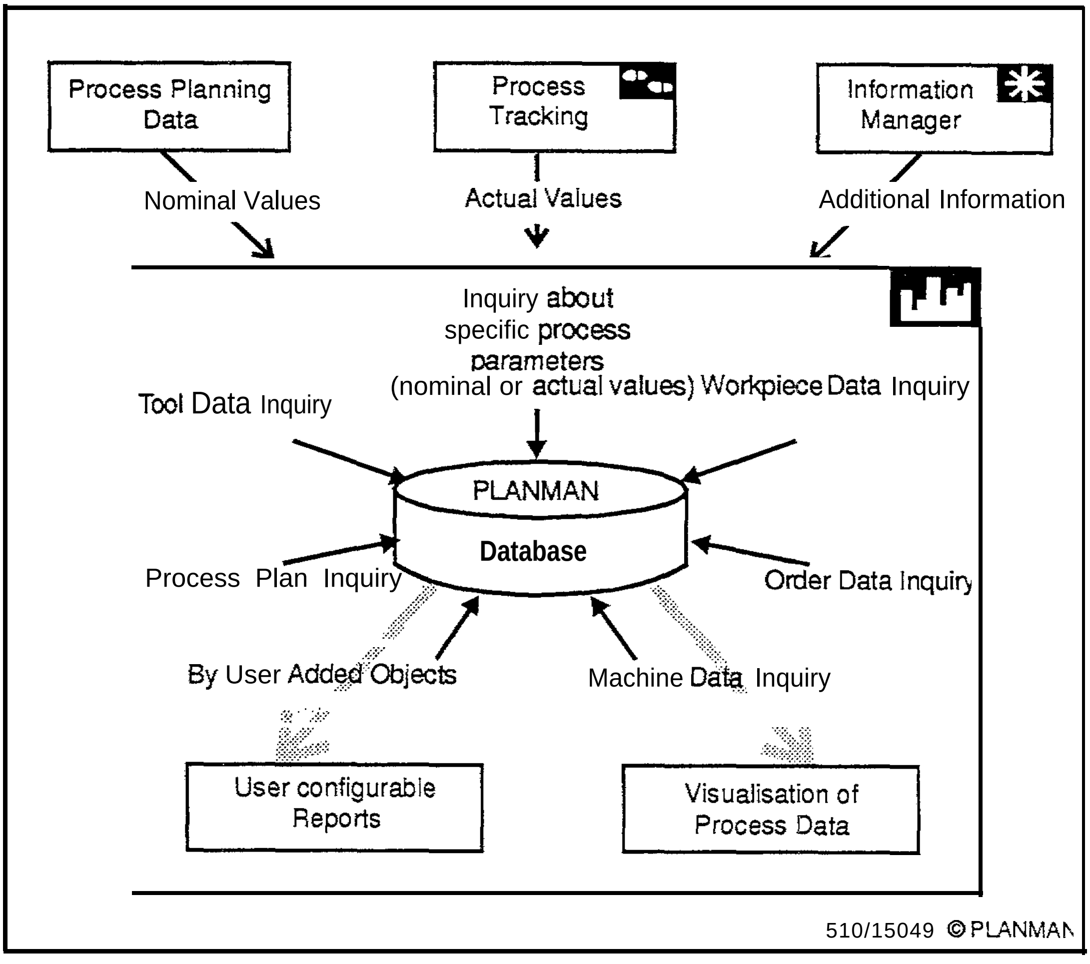



**Figure 4: Process Analysis Module**

The analysis includes the examination of similar machining conditions. An example of an inquiry is the selection of all available cutting conditions like feed, speed, depth of cut, etc. (maximum, minimum and average of actual as well as nominal values) for:

- one machine

- one tool or a list of tools
- a specific workpiece or cutting material
- a sub-operation
- an order identification
- or any characteristic of the objects n. a.

In general, this module presents the user with the results and predictions coming from the technological and economic models designed in the **Process Prediction** module.

### 3.4 Process Prediction

The collected actual process results and nominal values drive economic and technical calculations within the Process Prediction module, fig. 5. The calculations predict the likely outcomes of different process conditions for common machining operations. Within this module different technological and economic base models are implemented in a library, and can be activated by a user interface.

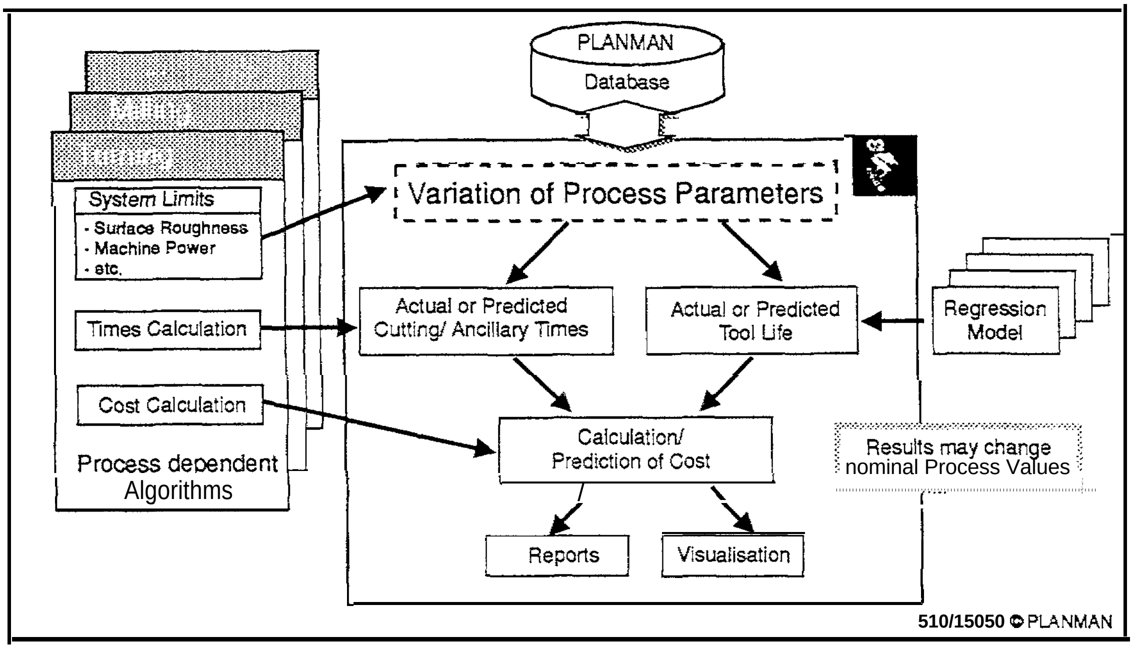



**Figure 5. Process Prediction Module**

For example different base models are realised for estimating tool life. The coefficients of these models are calculated by data sets selected from the database using regression techniques. The quality of the models can be determined by calculating statistical values for the model e.g. standard deviation. By using this customised models, the user could either calculate the costs of the specific machining operation using actual results or predict the effects of a variation of process parameters.

Thereby, the user is able to estimate the results of changes in process parameters. The prediction of results is limited by the differences of calculations for different machining operations and the validity of the models.

During the Project at MWH a particular grinding process "Set-Shaftend-Down" was investigated using these techniques. The model produced for calculating machining time gave a deviation from actual times of +/- 0.2 % in comparison with - 10%/+7.8% for the model that was in use within the company.

As shown in fig. 6 the models improve the accuracy with the increase of data extracted from the database. This ensures a self learning ability in terms of adjustment between nominal and actual values.

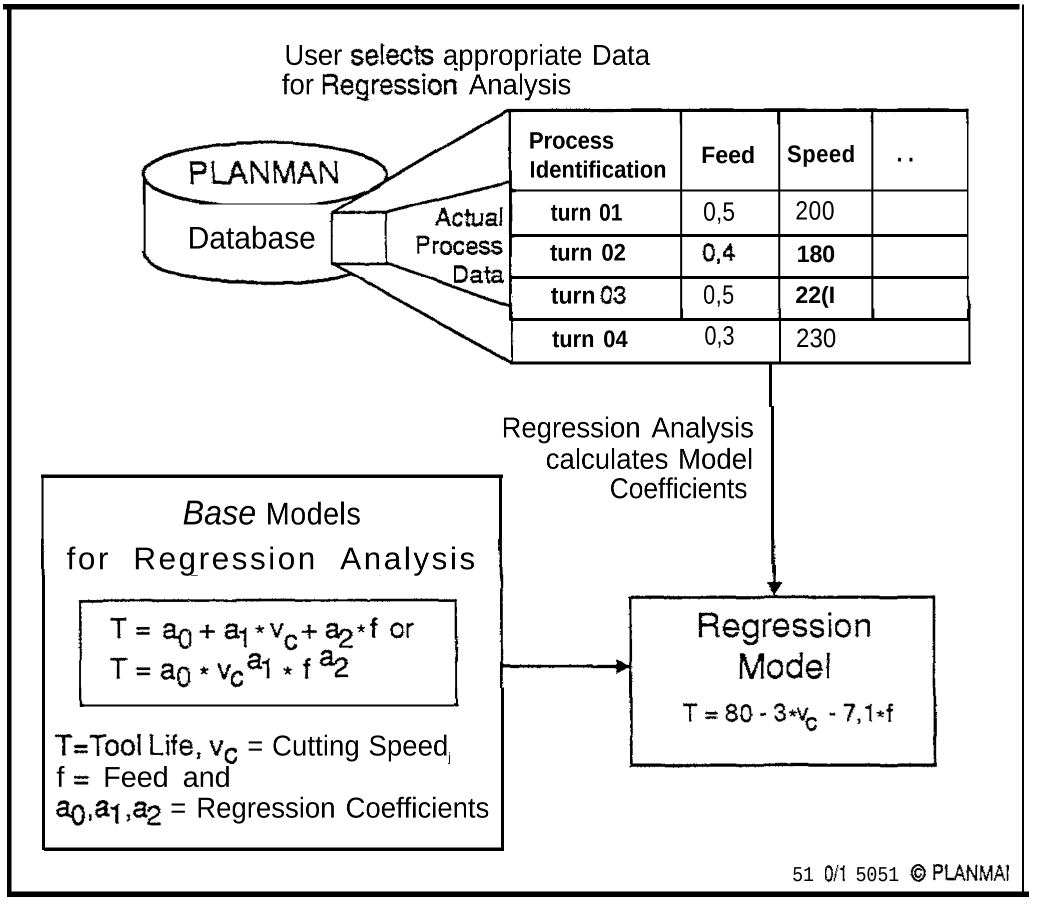



**Figure 6: Building of Technological Models**

The more actual values are collected the more exact the predicted values can be calculated by the models. Furthermore, by the extraction of data the user has to ensure the applicability of the data selected. This means that the sets of data have to fit the chosen machining operation. E. g. a set of data could be extracted for rough turning operations, another set has to be chosen for face milling operations.

## 3.5 **Database**

**A** general database stores different types of information (e.g. cutting data, workpiece and batch information, etc.) and serves as a source for different departments within the company. Therefore, a feature-based approach was used to define the characteristics of an item to be stored in the TI such as operation, sub operation, tool, material, order etc.. This approach uses object oriented methods of managing data, e.g. inheritance of characteristics. The outline of this approach is given below.

A family group is the first bound to classify the items. For example, the production engineer may divide parts into machined parts, castings, and pressings. Each of these can be put to a family group, and may have a “Feature Profile” of standard features or feature classes common to all members of this group. An option will be available to go to the feature profile maintenance.

Each family group may be subdivided into family classes. For example, the machined parts may be divided into regular boxes, irregular boxes (housings), regular blocks and irregular blocks. These all inherit the Feature Profile of additional features each member of the class owns.

Each family class may be subdivided into **a** family too. These behave in a similar way to family classes, and provide the finest means of classifying items.

## 3.6 **Information Manager**

This module provides the means of communication between other systems and PLANMAN for the creation of data specified for the definition of the process. Process Planning, Tool Management, Quality Management Systems, etc. are the natural providers of process information.

The main objective of this integration tool is to help in the phase of definition of the data for a sub-operation coming to PLANMAN from external systems. It can be used during the tracking and analysis process to add other required information.

# 4 MAIN RESULTS, COMPARED to the INITIAL OBJECTIVES of the PROJECT

In the initial Work Programme the major technical investigations concerning:

- the contents of the database,
- Model of Process,
- Time Estimating Models

were to be concentrated on the milling process. However, as a result of the investigations into the requirements of the industrial partners it was found to be necessary to include more effort into the turning and grinding processes,

The investigation into user requirements identified, particularly in Spain, the need for shop floor analysis of data collected from the Machine Monitoring of the machining process. This resulted in some extra system design and programming effort in one of the modules, Process Tracking, which was undertaken by Tekniker in co-operation with Zayer. This work did not effect the production of the machine control interface software.

It was initially expected to adapt the Programmable Logic Controllers of machines at every end user of the project. This work was only undertaken at one end user. This end user was able to adapt the simulation of machine interface to one of their machines, because this machine is equipped with an “open” Numerical Control. The work saved was used in the investigation of the models of process for turning and grinding. This did not adversely affect the project as it was still possible to show that automatic data capture of data was practicable where the machine/machine control were of a suitable type.

Adoption of the machine control has also shown that it is difficult, in this mode of automatic data capture, to identify the results coming from a series of similar machining cuts. The capture of data between tool changes is suitable. This may mean that a detailed technical evaluation can be identified as being required by automatic data collection but that manual intervention will be necessary to conduct the evaluation. The long term storage and analysis of the data collected and passed to the TI is similarly influenced but is still valid as a means of achieving the project aim of closely linking the planning engineer with the shop floor processes.

As a result of the findings concerning automatic data collection and user requirements, the facility to manually record data directly into the TI has been provided. This also means that PLANMAN can be used in an experimental mode when introducing a new machining operation, and thus does not depend on the availability of machine interfaces.

The original intention to use a relational database for the prototype was not undertaken. A relational model of the data structures has been used with an indexed file management system. The commercially available modules from Cimtel will have a relational database available as an option, this work is already underway as part of a general technical option for all Cimtel products and is thus not dependent upon the project funding. The more traditional file management system option will provide a less costly solution that achieves exactly the same user functionality.

ADWEST used the system during the evaluation phase to help investigate the balancing of production of a component on two machines. The result of the suggested changes were a theoretical improvement of 31 components per hour from 23 per hour (34.8%). In actual operation on the shop floor a production rate of 30 components (30.4%) was achieved.

# 5 CONCLUSIONS

The series of tests at the end users have shown that the general approach of PLANMAN works. Once all available objectdata are stored within the file system/ database, it is easy to feed back, select and analyse relevant data with the developed modules of the system,

The expected benefits cart be summarised in:

- Improve the quality of process planning and the process itself
- Comparability of resources: best resources for further use
- Pre-process cost estimate capabilities (more precise)
- On-tine, real time and accurate information means better process and production diagnostics and a better knowledge of process behaviour
- Integration with other systems working with the maximum amount of actual data reduces errors derived from the lack of process information

The main objective of the TI is to improve the quality of process planning. By the feedback of actual process data from the shop floor level to the process planning, the process planner is informed about the accuracy of his previous planning activities. This will lead to improved efficiency of the existing production environment because critical points of a production line can be monitored and (if necessary) optimised.

The monitoring of selected machines or operations by feeding back actual production data will also enhance the comparability of resources. The main influences on the execution of production processes such as different tools, workpiece materials, etc. can be evaluated. The comparison of these different resources is supported with visualisations of actual technological relationships by the TI. The process planner (or other responsible person) is able to analyse which resources have better behaviour. By choosing only the best resources for further use, their number will probably decrease, The visualisation of technological relationships (with the aid of process models) supports process monitoring and off-line control. Based on the results and experience gained by the process analyser, processes with enhanced performance can be designed. Therefore, the Technological Information System supports the continuous improvement of shop floor operations by transferring relevant information within a company from the execution levels (= shop floor) to the planning levels (= process planning).

Although predicting the exact percentage of cost saving is not possible now, it can be expected that economy measures on processes will be encouraged by the TI. Direct savings on processes can be made e.g. reducing the machining time per workpiece or the number of tools needed for many workplaces. Probably, the number of cutting tool materials on the shop floor can be decreased as well; this simplifies materials supply. Also, the cost calculation for the operations which are monitored by the TI will become more transparent and accurate.

Algorithms for cost calculation will be implemented within the TI and can be used for pre-process cost estimation and/or post-process cost calculation. Post-process calculations based on actual values (and not on nominal or estimated values) are more precise.

In addition to these primary benefits from the use of the TI, there are some benefits which more concerned with the quality of the company's organisation structure, By employing the TI, the communication between the shop floor and the process planning department is improved. If the process planner is informed, by the TI, that changes to the process plan have been made on the shop floor, he will communicate with the shop floor to find the reasons for the changes, This communication link helps to integrate the knowledge of the process planning department with the operational knowledge and manufacturing skills of the shop floor operators. This active integration of the worker and his knowledge will probably enhance **his job satisfaction. The TI will also help to improve the acceptance of new manufacturing technologies** in all relevant departments of a company. The economical and technological benefits of a new technology can be calculated, visualized and analysed within the TI and thereby accelerate their acceptance within the company, Additional benefits for the company are given by the conservation of process knowledge as tables in a database. There is only one main database as a source of information, the data is consistent and available for a variety of different departments. General benefits of the use of PLANMAN cart be expected in the fields of quality control and the improvement of process planning for selected shop floor operations.

## 6 ACKNOWLEDGEMENTS

The PLANMAN Project (Project No. 5455) was supported by the European Community under the BRITE/EURAM Programme.

The assistance of Mr. P. Trousson (EU - Project Officer) throughout the project was appreciated.

This Report was produced with the support of :-

- J. Newbury (Adwest)
- P. Purslow, D.C. Cordle (Cimtel)
- O. Berth old (1 FW)
- Dr. I-i. Fellman (MWH)
- A. Alzaga (Tekniker)
- A. Muji ka (Zayer)

The assistance and co-operation of all of the staff of the Project Members concerned during the life of the project, in addition to those mentioned, above was given enthusiastically and helped to achieve the satisfactory conclusion of the Project.

## 7 PUBLICATIONS; CONFERENCE PRESENTATIONS

- ZWF-CIM89 1996- Paper Published
- VALUE VACRO Day, Castellon, May 1994- Paper Presented
- Industrial Technologies Conference Brussels December 1994 - Poster Exhibited
- FAIM Conference Stuttgart May 1995 - Paper Presented
- Thematic Group Meeting Athens 1995- Paper Presented
- Process Planning Seminar Hannover 1995- Paper Presented
- Advanced Summer Institute Toulouse June 1996 - Paper to be Presented (Planned)
- 19 BIEMH - Bienal Espanola de Maquina Herramienta, March 1996- Poster& Paper Presented