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ENGLISH

COMPUTER AIDED DESIGN AND COMPUTER AIDED MANUFACTURING CENTRE

DP/SRL/85/011

SRI LANKA

Technical report: Establishment of a CAD/CAM Design and Service Centre

* Prepared for the Government of Sri Lanka,
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Maciej Bossak,
expert in CAD/CAM

Backstopping Officer: J. Turkus, Engineering Industries Branch

United Nations Industrial Development Organization
Vienna

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ABSTRACT

The mission has been undertaken under preparatory assistance to the project " Computer Aided Design and Computer Aided Manufacturin Centre ", (SRL/86/014/A).

The immediate objective of the mission was to asses the possibility of and requirments for setting up a CAD & CAM Centre as well as elaborate with assistance of UNIDO's backstopping officer, a draft project document.

ACKNOWLEDGEMENTS

The author would like to express his thanks and appreciation to the Head of Department of Mechanical Engineering Professor P.A. de Silva and the Staff, for their assistance, interest and support in efforts to fulfill the mission.

It is hoped that much use can be made of the outcome of the assignment and many achievements be reached in implementing computer aided design and computer aided manufacturing techniques to the benefit of Sri Lanka's industry.

Thanks are addressed to Mr. J. FUrkus from UNIDO for collaboration in preparing a draft project document.

TABLE OF CONTENTS

FINDINGS AND RECOMMENDATIONS

A. Findings

1. In order to upgrade local industrial capabilities the Government accords high priority to the improvements and expansion of modern methods in manufacturing processes, particularly in medium and small scale industry.
2. The local industry is vitally interested in implementing and utilising available computer aided design and computer aided manufacturing techniques.
3. It has been decided that a Computer Aided Design and Computer Aided Manufacturing Centre be erected at the Mechanical Engineering Department of the University of Moratuwa.
4. The Mechanical Engineering Department has already started some activity in computer aided design but their current facilities as well as personnel skills have to be increased.

B. Recommendations

1. Permanent education and training possibilities in CAD and CAM for students and industrial engineers should be established.
2. The cooperation with foreign institutions with the possibilities of obtaining M.Sc. degrees in CAD & CAM should be established.
3. It is necessary to enhance current hardware, software and machine tools capabilities (Annex V).
4. It is necessary to buy additional books and to subscribe supplementary periodicals on CAD & CAM. (Annex II)
5. It would be advisable to enter into connections with foreign institutions with established reputation in CAD & CAM activity. (Annex IV)

I. OBJECTIVE OF THE ACTIVITY AND DUTIES

A. Objective

The objective of the mission was to asses the possibility of and requirements for setting up a CAD & CAM Centre as well as elaborate, with assistance of UNIDO's backstopping officer, a draft project document.

B. Duties

According to the terms of reference the author was supposed:

1. To review the present facilities of the Computer Centre at the University of Moratuwa and to assess the possibility of and requirements for setting up a CAD & CAM Centre and its potential to help the country's industry.
2. To study potential application of CAD & CAM for Sri Lanka's industry and assess the demand for CAD & CAM services according to local needs.
3. To elaborate a programme for the establishemnt of CAD & CAM Centre and implementation of NC methods within identified areas of industry including the need of training - both locally and abroad - with estimated timing as well as equipment.
4. To prepare a technical report setting out findings and recommendations and elaborate, assisted by UNIDO's backstopping officer, an appropriate draft project document for technical assistance.

II DESCRIPTION OF THE ACTIVITY

A. Visits and Discussions at the Department of Mechanical Engineering.

Initial discussion was held with the Vice Chancellor of the University, the Dean of the Faculty of Engineering and the Head of the Department of Mechanical Engineering.

A series of visits were made to a number of the university laboratories including the Design Office, Mechanics Laboratory, Metrology Laboratory, Production Engineering Laboratory, Refrigeration and Air-conditioning Laboratory, Thermodynamics Laboratory and the Training Workshop.

A separate visit to the Computer Centre and Electronics Workshop was also made.

Authorities of the University have decided that a Computer Aided Design and Computer Aided Manufacturing Centre will be erected at the Department of Mechanical Engineering. The Department has already started some activity in computer aided design but their current facilities as well as personnel skills have to be increased in specifically application of CAD & CAM techniques.

In this context a long series of meetings were held with the members of the staff of te Department. Documentation on the student curriculum, student workloads and laboratory experiments were discussed.

To some courses inclusions, relevant to CAD & CAM techniques were suggested. (See Annex I).

A new course on CAD & CAM and its curriculum were proposed. (See Annex I)

A development programme for the centre as well as specifications of necessary equipment (See Annex III) were elaborated.

B. Industry Visits

Some visits to local industry were arranged. In order to see manufacturing facilities and to discuss possibilities of collaboration the following four companies were visited.

- Brown & Co. Ltd. (Engineering Division),
- Colombo Commercial Company (Engineers) Ltd.
- Colombo Dockyards Co. Ltd. and
- Jinasena Co. Ltd.

The proposed CAD & CAM Centre was outlined to them with facilities for education, training and subcontract work. When asked if they would consider collaborration with the University in the field of CAD & CAM, each firm agreed. The Centre could prove to ba an essential vehicle for industry to learn the new technology and to develop a critical awareness of when and how to innovate.

C. Lectures

During the mission lectures were given on " Introduction of CAD/CAM at the University " for the University staff and on " Finite Element Applications to Design Analysis" at the Institution of Engineers Sri Lanka.

D. Development Programme

It is possible to distinguish two groups of CAD & CAM users:

- design offices and factories
- research and development institutions

First users are interested only in applications, the second users in applications, implementation, research and development as well as education and training. The relations and aims of all these kinds of activities are as follows:

Research & Development	Problem -> Theory -> Method
Implementations	Model -> Method -> Software
Applications	Data->Software->Results
Education and training	PERSONNEL -> KNOWLEDGE + EXPERIENCE

The Department of Mechanical Engineering should be involved in all kinds of CAD & CAM activities.
According to the performed work it is possible to distinguish three levels of CAD & CAM activities.

1. Fundamental,
2. Advanced, and
3. Developed.

1. Fundamental level

Tasks

Simple design analyses, performed using application software. NC part programming . Development of computer programmes

Personnel skills.

Ability to define problem, to model analysed design, to use application software to perform NC part programming and to write computer programmes using higher level language.

Means

a. Hardware configuration
IBM PC/XT compatible CPU with 512 kB RAM
Monochrome or colour monitor of medium resolution
2 floppy disk drives (2 x 360 kB)
Line printer (200 cps)
Plotter, format A3 (using speed 1 cm/s, resolution 200 lines/cm).

b. Necessary software
MS DOS operating system, Basic interpreter, scientific subrutine library, application programmes mainly product oriented, properly chosen to the needs (analysis of gears, shafts, etc.)

2. Advanced level

Tasks.

Complex design analysis, performed using engineering applications systems (finte element analyses, simulatations, optimisations etc.). NC past processor writing. Intractive pre and post processing of data and results. To adopt and to write engineering application software. To train up CAD & CAM users.

Personnel skills.

Ability to use graphical pre and postprocessors, to model anlysed designs, to utilise engineering application systems and to write complex computer programmes (systems) using higher level languages.

Means.

a. Hardware configuration
IBM - PC/AT compatible CPU with 640kB RAM
2 floppy disk drives (1 x 360kB + 1 x 1.2 MB)
Harddisk 20MB,
Numeric coprocessor 80287
Monochrome or colour monitor medium resolution
Line printer (200 cps)
Plotter, format A1 (writing speed 5 cm/s, resoluion 200 lines/cm)
Digitizer (tablet), format A3 (resolution 200 lines/cm)

b. Necessary software
MS DOS operating system, BASIC and FORTRAN translators graphical system, scientific subroutine library, finite element system with graphical pre and postprocessors.

3. Developed level

Tasks.

Three dimensional geometry modelling using interactive graphics. Complex designs performed using CAD/CAM systems. Automated drafting. Research and development activity. Development of engineering application software.

Personnel skills.

Ability to use CAD/CAM systems for geometry modelling, preparing data to engineering application systems, automated drafting, NC port programming. To utilise engineering application systems, and to develop software. Possession of necessary knowledge and experience to perform research and develpoment.

Means

a) Hardware configuration (workstation)
32-bit CPU (like VAX or PRIME) with 4MB R & M
Disk drive min 140 MB,
Tape backup unit,
12" or 14" monochrome/ color alphanumeric monitor,
17" monochrome/color graphic display terminal of high resolution,
Digitizer (tablet), format A3 (resolution 200 lines/cm)
Hard copy unit,
Line printer (250 cps),

Plotter format A0 (writing speed 5cm/s, resolution 200 lines/cm)

(b) Necessary software
UNIX like operating system, BASIC, FORTRAN 77 and C translators, data base management system (relational type), CAD/CAM System (like EUCLID, MEDUSA), FEM System (like ADINA, MARC) with pre and pastprocessors.

The above classification describes only some general tendencies and do not pretend to be strict.

CAD and CAM are very rapidly developing and changing disciplines and permanent education training constitute the basis for effective activity in these fields.

Main forms of professional education

There are the following main forms of professional education in CAD and CAM.

1. Self teaching

   Having basic knowledge, engineers utilise existing capabilities for performing more and more complex tasks.

2. Courses

   Attendants obtain new knowledge (information about methods, developments, achievements, etc.).

3. Trainings

   During trainings (workshops) engineers do some exercises and actively take part in solving problems.

4. Consultations

   Usually this is a very effective form of education because the consultant can act flexibly according to the needs and can collaborate with many engineers.

Activities, necessary skills and forms of education for development programme

Taking into account existing possibilities it is assumed that CAD and CAM activities at the Department of Mechanical Engineering will be developed in two phases.

During the first phase, up to 1990, an advanced level will be achieved. Necessary equipment is specified in Annex III.

During the second phase, after 1990, a developed level will be put into operation. Necessary equipment is specified in Annex III.

Activities

1988 - 1990

- Simple and more complex design analysis of machine or structure parts. (shafts, gears, beams, etc)
- Complex design analysis (linear static and dynamic) of machine and structures.
- Interactive preprocessing of data and postprocessing of results.
- Development of computer programmes accordingly to the needs.
- Utilisation of existing CNC machine-tools.
- Lectures and training for students and industrial engineers.
- Consultation for industry.

1990 onwards

- Complex design analysis (nonlinear static and dynamic, thermal) of machines and structures.
- Geometry modelling.
- Automated drafting.
- NC part programming.
- Development of computer application systems.
- Start research and development activity in the CAD & CAM fields.

Necessary skills

1988 - 1990

- Ability to define and to model such problems as well as to solve them using computer techniques.
- Fundamental knowledge of using microcomputers with DOS operating system and engineering application programmes.
- Ability to define and to model linear static and dynamic problems as well as to solve them using computer systems (mainly finite element).
- Fundamental knowledge of computer graphics, ability to utilise the graphical pre and postprocessors.
- Knowledge of BASIC & FORTRAN languages and fundamentals of software engineering.
- Knowledge of NC part programming and of using dedicated programming workstation.
- Ability to formulate and to solve problems encounted in engineering practice.

1990 onwards

- Ability to define and to model nonlinear static, dynamic and thermal problems as well as to solve them using FEM systems.
- Ability to use CAD/CAM and DBMS systems.
- Knowledge of UNIX like operating system and software engineering.
- Ability to formulate and to solve research problems.

Form of education

1988 - 1990

- Course with exercises and training on computer graphics and software developments delivered by consultant (1 month).
- Course with exercises and training on mathematical modelling delivered by consultant (1 month).
- Training at design offices, research and development and CAD/CAM centres (8 persons x 6 months).
- BASIC language course with exercises (40 hours).
- FORTRAN language course with exercises (30 hours).
- Course with exercises and training on NC part programming and using dedicated programming workstation delivered by consultant (1 month).

1990 onwards

- FEM users course (30 hours).
  Training at design office (2 persons x 3 months) self teaching.
- Course on UNIX like O/S (20 hours), self teaching.
- Send abroad some staff members for M.Sc and Ph.D studies.

E. Draft Project Proposal

With the assistance of UNIDO's backstopping officer Mr.J.Fuerkus, a Draft Project Proposal was elaborated covering the period 1988 - 1990. It is included in a separate document.

ANNEX I

PROPOSED CHANGES IN THE CURRICULUM

FIRST YEAR

A. ENGINEERING DRAWING (ME 11)

Elements of Computer Graphics (Application of Matrix Notation to Geometry)

1. Matrix description of point coordinates in the two- and three- dimensional frame of references
2. Elementary transformations used in computer graphics
   - Translations in 2-D and 3-D
   - Scaling in 2-D and 3-D
   - Rotations
     - 2-D about Z-axis
     - 3-D about X,Y,Z, axes
3. Concatenations (Sequence of Transformations)
4. Definition of more complicated elements than points
   - Lines (two points)
   - Arcs and circles (Centre + point on the circle <=> centre + radius, three points)
   - Conics (specify five points on the elements)
5. Transformations of the more complicated elements than points
6. Examples and exercises

B. MATHEMATICS

Elements of discretization, quantification and interpolation

PART I

DESIGN OF MACHINE ELEMENTS (ME24)

Introduce elements of design analysis

1. Utilize existing engineering applied programs for calcualtions connected with designing machine parts: gears, shafts, cams etc.
2. Collect appropriate programs (developed by students attending CAD/CAM course).

PART II

PRODUCTION ENGINEERING (ME33)

Enhance point 1.5 on control of machine tool

1. Conventional NC
   Basic components of an NC system
2. NC coordinate systems
3. NC motion control systems
   Point-to-point
   Straight cut
   Contouring
4. Applications of NC
5. NC Part programming
   Manual
   computer assisted
6. Computer controls in NC
   CNC
   DNC
   Adaptive control

DESIGN OF MACHINE ELEMENTS (ME34)

Introduce elements of design analysis
1. Utilize existing engineering applied programs for calculation connected with designing machine parts, sub-assembly and specific machine
2. Collect appropriate programs (developed by students attending CAD/CAM cources

PART III

CAD/CAM COURSE

A. INTRODUCTION

1. Product cycle and CAD/CAM
   - Engineering Design
   - Manufacturing planning
   - Factory Automation
   - Manufacturing control

2. Computer Technology

   Hardware
   - Central processing unit
   - Memory
   - Peripherals
   - Main-frame computers, mini computers, microcomputers, workstations, programmable controllers

   Software
   - Programming Languages
   - System software (operating systems, translators, assemblers)
   - Tool software (data base, scientific subroutines, graphic systems
   - Application software:
     - problem oriented,
     - product oriented

3. Interactive computer graphics
   - Function of graphic packages
   - Computer geometry
   - Wire-frame and solid modelling
   - Automated drafting

4. Databases
   - Structures
   - Contents

5. CAD in mechanical engineering
   - Differences between conventioal design and CAD
   - Product characteristiics and design criteria
   - Shaping and dimensionig, design analysis
   - Objects, problem areas and disciplines
   - Mathematical modelling in engineering (see below)
   - Integration of analysis methods
   - Economical aspects of CAD

6. CAM

   Fields of CAM
   - Factory automation, manufacturing planning
   - Manufacturing control
   - Computer controls in NC
   - NC procedure, NC motion control systems

   NC part programming
   - APT languages

   Industrial robots
   - Robots physical configurations, basic robot motions, programming the robot, robot programming languages, robot sensors, robot applications

   Flexible manufacturing systems

MATHEMATICAL MODELLING IN ENGINEERING

Real problems and their simplifications
Physical model
Initial mathematical model
Approximations (mathematical models)
Final mathematical model
Variational formulations
Sources of errors
Computer simulation
Verification of the model

COMPUTATIONAL MECHANICS

FINITE ELEMENT METHOD

LINEAR STATIC ANALYSIS
The idea of the method
Definition of a finite element
shape, modes, nodal values, approximation function (shape functions)
Shape functions
Nodal values (known) equivalent to distributed values
Relations between known and unknown nodal values for the element (stiffness matrix)
Coordinate systems
global, local, boundary, material
Translations of values from one to another coordinate. system
Relation (in global coordinates) between known and unknown nodal values for the whole system (global stiffness matrix)
Boundary conditions
System equations and its properties
Solution of the system of equattions
Calcualtion of other derived values
Finite element systems
pre and post processors
Examples of Applications

ANNEX I

LINEAR DYNAMIC ANALYSIS
- Frame of references
- Types of forces used in dynamic analysis:
  - loads, mass forces, elastic forces, damping forces
- Equations of motion
- Eigenvalue problems
- Initial value problems
  - direct integration, mode superposition method
- Accuracy analysis

NONLINEAR ANALYSIS
- Classification of nonlinear analyses
- Equations of equillibrium
- Solution of nonlinear equations

FUNDAMENTAL INFORMATION ON BOUNDARY ELEMENT METHOD

FUNDAMENTAL INFORMATION ON BOND GRAPH METHOD

ANNEX II

RECOMMENDED LITERATURE

A. BOOKS

1. Encarnacao, Schilechtendahl
"Computer aided design"
Springer-verlag

2. Shigley, Mischke
"Standard handbook of Machine Design"
McGraw Hill

3. Groover
"Automation, production systems, and CAM"
Prentice-Hall

4. Rogers, Adams
"Mathematical Elements for Computer Graphics"
McGraw Hill

5. Foley, Van Dam
"Fundamentals of Interactive Computer Graphics"
Addison-Wesley

6. Robinson
"Understanding the Finite Elements"
Bobinson and Associates

7. Wellstead
"Introduction to physical system modelling"
Ellis Horwood Limited

8. Reddy
"Applied Functioral Analysis and Variational Methods in Engineering"
McGraw Hill

9. Huebner
"The Finite Element for Engineers"
J. Wiley

10. Zienkiewicz
"The Finite Element Method"
McGraw Hill

11. Bathe
"Finite Element Procedures in Engineering Analysis"
Prentice-Hall

12. "Guidelines to Finite Element Practice"
NAFEHS-NEL, Glasgow

13. Brebbia
"The Boundary Element Method for Enngineers"
Pentech

14. Banerjee, Butterfield
"Boundary Element Methods in Engineering Science"
McGraw Hill

15. Blundell
"Bond Graphs for Modelling Engineering Systems"
Ellis Horwood

B. PERIODICALS

1. "Mechanical Engineering"
   ASME/Order dept., Box 2300, 22 Law Drive,
   Fairfield, ND 07007-2300, USA

2. "Computers in Industry"
   North-Holland, POB 1991, 1000 BZ Amsterdam, The Netherlands

3. "CAD"
   Butterworth Scientific Ltd., 88 Kingsway, London WC2 6AB
   England

4. "Computer Aided Geometric Design"
   North-Holland, POB 1991, 1000 BZ Amsterdam, The Netherlands

5. "Computer Methods in Applied Mechanics and Engineering"
   North-Holland, POB 1991, 1000 BZ Amsterdam, The Netherlands

6. "Numerical Methods in Engineering"
   J. Wiley, Bsffins Lane, Chichester, Sussex, England

7. "Computers and Structures"
   Pergamon Press, Fairview Park, Elmsford, NY 10523, USA.

8. "Finite Elements in Analysis and Design"
   North-Holland, POB 1991, 1000 BZ Amsterdam, The Netherlands

EQUIPMENT EXTENSION
(for years 1990 and after)

a) Hardware
32-bit CPU (like VAX or PRIME)
RAM - min 4MB
Disk Memory : min 0.5GB
Tape Drive Unit : 1690 bpi
Terminals and utilities for Local Area Network (LAN)
.....Estimated Cost $100,000

b) Software
UNIX like operating system
FORTRAN 77, PASCAL, C, translators
Assembler
DBMS (relational type like ORACLE)
CAD/CAM system (like EUCLID, MEDUSA)
FEM system (with nonlinear and thermal analysis capabilities like ADINA, NASTRAN) with pre and post processors
.....Estimated Cost $150,000

c) CNC Machine tools
NC 5 Axes Machining Centre
.....Estimated Cost $500,000

ANNEX IV

RECOMMENDED INSTITUTIONS

1. Computational Mechanics Centre
   Ashust Lodge, Ashurst, Southampton SOU 2AA, England

2. Computer Aided Design Centre
   Madingley Road, Cambridge CB3 OHB, England

3. IKO Software Service, GmbH
   Albstadtweg 10, D-7000 Stuttgart 80, West Germany

4. Industrial Institute of Construction Machinery-PIMB
   Computer Aided Engineering Centre
   Kolejowa 57, 01-911 Warszawa, Poland

5. National Engineering Laboratory
   East Rilbride, Glasgow G75 OQU, England

6. Structural Dynamic Research Corporation
   300 Techne Center Drive, Milford, Ohio 45150, USA

CURRENT CAD/CAM CAPABILITIES AT DEPARTMENT OF MECHANICAL ENGINEERING UNIVERSITY OF MORATUWA

HARDWARE

IBM-PC
- RAM - 512 MB
- Floppy disks 2x360kB
- Colour Monitor with EGA

Tablet Format A4 (WACOM WT-4000)
Plotter format A3 (Roland DXY-880)
Printer (EPSON EX-800)

SINCLAIR SPECTRUM (Two with 16kB RAM and two with 48kB RAM)

SINCLAIR QL (Two with 112kB RAM each)

Monitors

Printer (BROTHER HR-15XL)

SOFTWARE

PC DOS 3.1
BASIC Interpreters
dBASE III
LOTUS
Some locally developed programs for engineering applications

EQUIPMENT

Locally converted milling machine tool into NC 2 axes milling machine with locally developed control programs

Items
that the Department has already ordered

1. TERCO CNC U500 milling machine with automatic tool changer, recirculating ball units on all 3 axes
   Spindle speed 0-6000 rpm
   Feed motor torque 150 Ncm
   Maximum size of workpiece 290x160 mm

2. ATLAS II robot system

3. Terco CAD/CAM station CNC 4510 with 512kB RAM, Monitor, Keyboard, mouse, floppy disks 2x400kB (SS/DD)

4. Printer

5. Plotter

ANNEX V

Facilities of the Computer Centre at the Department of Computer Science*

1. TRS 80/16kB
   - RAM - 512kB
   - Hard disk - 12 MB
   - Terminals - 3
   - Printer
   - XENIX operating system
   - BASIC, FORTRAN 77, C, PASCAL translators, Multiplan, Word processor

2. SORD M685
   - 32-bit CPU with 1MB RAM
   - Hard Disk - 20MB
   - Terminals - 4
   - Software
     - UNOS operating system, BASIC,PASCAL,C,FORTRAN translators,
     - Word processor

3. Commodore PC-20
   - RAM 640kB
   - Hard Disk-10MB
   - Floppy Disk 360kB
   - Terminal
   - Printer (EPSON -800)
   - Software
     - MS DOS 2.1
     - BASIC, FORTRAN, PASCAL,LISP translators

4. NEC - 9801
   RAM-640kB
   Flopy disk 2x1.2MB
   Terminal
   Printer (EPSON VP 80)
   Software
      MS DOS 3.1
      BASIC,FORTRAN, PASCAL,LISP, translators
      some Finite Element Programs

The computer centre has already ordered two installations of MICROVAX computers.

*The staff and the students of the Department of Mechanical Engineering can also utilize facilities at the computer centre of the Department of Computer Science.