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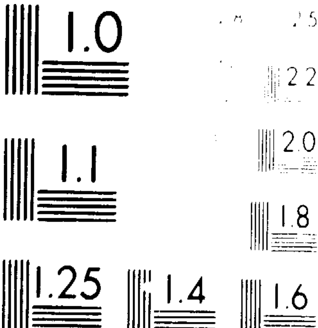
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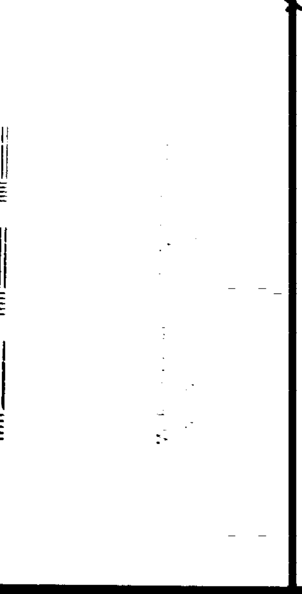

11416
(1 of 2)

Restricted

Project:

Yugoslavia.

EXAMINATION OF CONDITION FOR
ESTABLISHING FLEXIBLE
PRODUCTION SYSTEMS
(optimization possibilities)

FINAL REPORT
PROJECT FINDINGS AND RECOMMENDATIONS

(basic approach)

Report prepared for the UNDP and the Government
of Yugoslavia by

Prof. Dr Dragutin Zelenović
National Project Director

United Nation Industrial Development Organization

Acting as Executive Agency
for
United Nations Development Programme

Novi Sad, 1979.

Project:

EXAMINATION OF CONDITION FOR ESTABLISHING FLEXIBLE PRODUCTION SYSTEMS
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C o n t e n t s

1. INTRODUCTION

The Project "EXAMINATION OF CONDITIONS FOR ESTABLISHING FLEXIBLE PRODUCTION SYSTEMS" investigations are financed by:

a) UNDP programme
b) Self-Management Community for Education of Vojvodina
c) Self-Management Community for Scientifical Work of Vojvodina
d) Faculty of Technical Sciences itself.

In the Project the theoretical (basic) and applied (practical) investigations in the area of establishing flexible production systems are included.

The main practically tested theoretical results are given in the appendices of the basic report

The main aim of the Project is to help the development of industry in Vojvodina in the way of productivity increasing by introducing the flexible production systems - lines. In connection with that the Laboratory for industrial systems, partially financed by UNDP, is established. The aim is to enable the testing of some theoretical assumptions and models fixed on the basic theoretical investigations and to give the solutions applicable in industry. On the other side, the aim also is to make the base for seminars and training courses such as:

1. labour procedures in mechanical engineering
2. material flows
3. lay-out design
4. effectiveness and maintenance
5. production systems control

for specialists from industry.

2. FINDINGS

2.1 Long range objectives

The long range objectives of the Project are:

(i) To increase the quantity and improve the quality of Project Participants and Professional Managers and controllers of Production Systems. These personnel are needed for schools and universities, economic planning and development programmes and the industrial sector; and

(ii) To improve industrial productivity by the development and introduction of optimal production systems for various situations, mostly as job, batch and line production.

(i) This aim is realized during the work on the Project by the working team which at the begining of the work included the following experts from the Institute:

1. Prof.E.Čupić, Organization of Production
2. Prof.Dr D.Zelenović, Production Systems, Production Control, Reliability-Project Manager
3. Asist.prof.S.Radlovački, Organization of Production, Decision Making
4. D.Stanivuković, Reliability and Maintenance
5. I.Ćosić, Production Systems, Assembly Lines
6. B.Džigurski, Work and Time Study
7. S.Rankov, Operations Research, Engineering Economy
8. D.Malbaški, Computer Sciences, Computer Programming
9. T.[illegible]ković, Chief of Laboratory

During the work the following specialists were included:

1. M.[illegible]ić, Production Control
2. M.Pavlović, Material Handling
3. N.R[illegible]ković, Production Systems
4. B.Marić, Decision Making, Engineering Economy
5. R.Maksimović, Production Systems, Work and Time Study

6. B.Kamberović, Quality Control
7. Z.Šišarica, Information Systems, Computer Sciences
8. M.Simić, Production Systems
9. Ž.Čadjenović, Production Systems
10. Dj.Milić, Laborant

The members of the working team from other firms were:

1. Prof.Dr L.Kun, Operations Research
2. Prof.Dr B.Popović, Quality Control
3. Asist.prof.D.Ristić, Organization of Production
4. Prof.Dr Š.Šereš, Industrial Dynamics
5. Prof.A.Mora, Decision Making

(ii) In connection with the work at the Project the following Laboratories are established:

1. Laboratory for method and time study
2. Production Systems Laboratory
3. Laboratory for production control

The aim of the investigations in the laboratories is to test the theoretical models and their use in the training of the specialists from industry, students and postgraduate students, and for MSci and PhD investigations.

1. Laboratory for method and time study

is established with the aim to be done the knowledge transfer of time and work study by the application of MTM-1, MTM-2, MTM-3, WORK FACTOR, MTU and other methods.

In the Laboratory the time norms by the methods of determined beforehand times are being done. The aim of the investigations is to be done the rationalization of processes especially in the case of high degree personal work presence , such as in assembling processes.

Up to now some investigations are done in industry of Vojvodina cf. INOMAG-OOUR "Okov" in Bačka Topola.

The programme of the courses from the area is as follows:

- theoretical basis of rationalization of work process with the application of time and work study methods
- practical application of various methods of beforehand determined times
- influence of that actions to the production and economical work increasing.

It is expected that the real basis for technology transfer into the industry would be made by training of a number of specialists from industry

2. Production systems laboratory

In the Laboratory the possibilities of flexible production systems establishment are investigated with the aim to establishe general assumptions and dependences which could be applied in industry of Vojvodina and Yugoslavia.

The investigations in such a Project are initiated by the heterogenous production programmes in industry of Vojvodina. The Project results showed that the investigations of the problem were justified by the direct apply in the production processes. The fixed dependences in production line constructions are applied in the factory projecting such as:

1. Factory of valves and guides for SUS motors in Sremska Mitrovica
2. Factory of spherial bearings in Temerin
3. Factory of agricultural machines in Bačka Palanka
4. Factory of agricultural machines in Stara Pazova
5. Machine,tool and gallantry industry "INOMAG" - - stores and assembling
6. Factory of devices for painting in Čurug
7. Factory of wire and steel armature in Bač

Flexible flow line established in the Laboratory for production systems gives the possibility to invest the work methods in different conditions. The processing systems in the line enable the parallel action doing in the operation as such as the parallel way of work object moving from one operation to another. It considerably enable the reducing of treatment and production series of the work objects. The transport system which is established on the line and at the same time enable the application of another transport systems is of the great importance in the flow forming. So the line enables besides the direct production of machine parts for metal industry in Vojvodina, the engineers from the industry to invorm themselves about the new work methods, about the new possibilities of the treatment and production series restriction, as such as the possibilities of various transport systems application.

Besides that, during the production on the line in the Laboratory the specialists form industry and others can study the problem of reliability of the line, more exactly production system. The informations about reliability, failures (time, duration, reasons, repair costs, etc.) are automatically separated by Kienzle's devices. For those investigations the preliminary courses about the application of the methods and reliability techniques in analysis are organized. The coruses about machine care treatment on the basis of reliability are also organized. The advantage of the courses is rapid and effective transfer of methods and knowledge into the production systems in industry of Vojvodina.

The necessary determination buffer stocks results are used directly in projecting of automatical lines for various production programmes.

3. Laboratory for production control

The investigations in production control depend on the application of different techniques - mechanized and automatized (computer) data processing for planning and production control. In connection with the mentioned the production control projects are done on the basis of the plan of mechanized system for production control such as DISPO in:

1. "INOMAG" Factory in Bačka Topola
2. Factory for agricultural machines "Majevica" in Bačka Palanka
3. Factory of valves and guides for SUS motors in Sremska Mitrovica

The part of the Laboratory which would be used for automatized production control is being developed. In that purpose the computer system CDC Cyber 18-05 equipment is bought such as:

- desplay-terminal
- card reader
- card puncher
- modem
- printer.

In the future this part of the Laboratory will be connected to the Laboratory for production systems.

The production control (planning, launching , material and tool providing, flow control etc. in the production process at the processing line is done in the Laboratory in the Institute for industrial systems.

Production control training courses are intensively organized especially for problems which could be seen in the factories in Vojvodina, such as:

- planning and termining control
- work sheet control
- stock control
- computer application in production control

The DISPO system work is practically demonstrated. After those demonstrations several factories were interested in application of the production system control.

2.2 Immediate objectives

The immediate objectives of the Project are:

(i) To change the orientation of the research activities of the Institute from its present emphases on theoretical problems towards a more practically oriented programme.

(ii) To improve the Institutes teaching capacity in modern methods of the management of systems.

(iii) To explain the capacity of the Institute to provide training programmes for manager in industry.

(iv) To develop parameters and mathematical models which will be relevant for the solution of investment problems generally and particularly for the metal working industry in Vojvodina.

(v) To develop and test with appropriate experiments, parameters and mathematical models in the field of management of production systems.

(vi) To make the Institute better equipped to provide consultant services in the field of management of systems, survays, studies, etc., for industry and other sectors;

(vii) To facilitate the introduction of numerically controlled machines and computer controlled scheduled production systems into factories by developing appropriate systems and parameters. Industrial management personnel do not at present have experience with these equipment and systems, nor do they have the time to become knowledgable because of the day-to-day operating demands.

In connection with the immediate objectives in the Project the following is done:

(i) At the begining, before the establishment of mentioned Laboratories the following theoretical investigations were done:

- productional systems (development of flow material models, informations, criterions type and production flow choice

- small batch production, batch production and mass production
- production control
- work and time study
- reliability and maintenance, etc.

The Laboratory enabled some theoretical models and assumptions to be cheecked in practice and to be applied in the real production systems - see the projects mentioned in 2.1.

(ii) Personnel numbered in 2.1 from which 17 are permanently engaged at the Institute (3 professors, 10 teaching assistents, 4 engineers-collaborators) and 5 outside collaborators represent teaching capacity in modern methods in the numbered areas.

The teaching programme at the Institute includes:

a) THE OLD ONE

No.	Subjects	Semesters		
		VII	VIII	IX
1.	Computer programming	2+2		
2.	Logical systems and components	2+2		
3.	Labour procedures in mechanical engineering	2+2	2+2	
4.	Tool machines	2+2	2+2	
5.	Automatical machine tool control			2+2
6.	Production systems	2+2	2+2	
7.	Production systems control		3+3	
8.	Quality control			2+2
9.	The theory of effectiveness of systems and maintenance			2+2
10.	Industrial dynamics		2+2	
11.	Operations research			3+3
	Number of lessons in the section:	10+10	11+11	9+9

Note: 2+2 means: lecturing (2) + training (2) weakly.

b) THE NEW ONES

.1 Department for INDUSTRIAL SYSTEMS ENGINEERING

No	Subject	Semesters IV	V	VI	VII	VIII	IX
1.	Mathematical modelling of industrial processes			2+2			
2.	Production measuring	2+2					
3.	Labour procedures in mechanical engineering				4+4		
4.	Tool machines exploitation				4+4		
5.	Automatization of the design processes					2+2	
6.	Production Systems					4+4	
7.	Material handling					2+2	
8.	Operations research					2+2	
9.	Industrial dynamics					2+2	
10.	Automatical machine tool control						4+4
11.	Production systems control						2+2
12.	Quality control						2+2
13.	Incustrial systems organization						2+2
14.	Industrial equipment maintenance						2+2
	Number of lessons in the section:	2+2 4		2+2 4	8+8 16	12+12 24	12+12 24

.2 Department for INFORMATIONS SYSTEMS AND INFORMATICS

No	Subject	Semesters IV	V	VI	VII	VIII	IX
1.	Theory of information			2+2			
2.	Data collection and data	2+2					
3.	Data processing				4+4		
4.	Computer systems				4+4		
5.	Automatization of the design processes					2+2	
6.	Production systems					4+4	
7.	Data transfer					2+2	
8.	Operations research					2+2	
9.	Information systems designing					2+2	
10.	Operating systems						4+2
11.	Production system control						2+2
12.	Quality control						2+2
13.	Industrial systems organization						2+2
14.	Programming languages and compiles					2+2	
15.	Develop. and applic. of progr.systems					2+2	
	Number of lessons in the section:	2+2 4		2+2 4	12+12 24	12+12 24	10+8 18

(iii) By development of capacity of the Institute - laboratories and personnel - there started troining programmes for managers and experts in industry in Vojvodina. Courses are partly theoretical and more care is given to the case studies.

The following courses are organized:

COURSE 1: LABOUR PROCEDURES IN MECHANICAL ENGINEERING

Part 1.' - labour procedures and control
- the basis for procedures development
- the widening of the labour area and the selection of alternatives
- labour duration and time cycles
- ergonomy and work conditions
- case study

Part 1.2 - labour and time measurements
- the techniques for measuring time
- case study

Part 1.3 - interrelationships in the work process
- the motivation
- the satisfaction in the work
- case study.

COURSE 2: INTEGRATED MATERIAL FLOWS AND THE LAYOUT OF THE SYSTEM COMPONENTS

Part 2.1 - the basic principles of the establishment of production systems
- the general model of material flows - group technology
- the methods and techniques for the layout of system components
- case study

Part 2.2 - material handling
- stocks and warehouses
- the transport equipment and storing
- case study

Part 2.3 - simulation technique as a means for the development of alternatives in the area of modelling of production systems
- the computerized layout of work places
- case study

COURSE 3: PRODUCTION SYSTEMS CONTROL

Part 3.1 - the control function for the production processes
- forecasting
- planning
- determining deadlines
- control of flows in system
- case study

Part 3.2 - the use of computers in production control
- programming the planning procedures, control of the production etc.
- case study

Part 3.3 - the use of the production control system
- the case study

COURSE 4: EFFECTIVENESS OF SYSTEMS AND MAINTENANCE

Part 4.1 - effectiveness of automatical lines (availability, reliability)
- the effectiveness criteria for production systems
- operational readiness
- time picture of states
- maintainability
- case study

Part 4.2 - maintainance and repairs - need and perspectives
- maintainance procedures
- the use of the maintainance policy
- case study
- problems of maintenance ([illegible])
- service costs etc.

COURSE 5: PRODUCTION PROCESSES ORGANIZATION

Part 5.1 - rule of work organization in industrial systems
- system approach in work processes organization
- decision making processes
- case study

Part 5.2 - information systems in production
- communication processes in organization
- motivation
- organization and environment conditions changing
- case study

Part 5.3 - resources allocation principles
- resources allocation programmes
- resources allocation methods
- case study

COURSE 6: SIMULATION METHOD

Part 6.1 - the philosophy of simulation
- simulation procedures
- interactive programming
-rrandom number generators and sampling techniques
- simulation languages
- case study

Part 6.2 - planning of simulation experiments
- the necessity to simulate
- case study.

(iv) Results in connection with this objective in details are given in the Apendices 1 and 2 of this Report (FINAL RE-PORT and FLEXIBILITY OF PRODUCTION SYSTEMS).

(v) The testing of appropriate experiments, parameters and mathematical models is still being performed in several real production systems in metal working industry in Voj-vodina.

(vi) For the development of the Laboratory for industrial sys-tems in the framework of the Project the following finan-cial means are invested:

a) Laboratory for productional systems
   a.1 building - workshop 20x12=240 m^2,
       value: cca 3.240.000 DN (cca 162.000 US$).

   a.2 equipment

No	Title of equipment	Value of equipment [illegible]	Provided by
1.	Hydraulic copying lathe "Dubied" 517S (Producer: Dubied & Cie.S.A. Switzerland)	88,208	UNDP
2.	detto	88,208	Yugosla[illegible]n-ment
3.	Circular saw machine "[illegible]" (Producer Fortemat, W. Germany)	45,310	"
4.	End working machine "Duap SS 30K (Producer: Duap A.G., Switzerland)	60,310	"
5.	Kienzle data-logger Kienzle MS A71+CM11 (Producer: Kienzle Apparate G[illegible]M.,Villingen, W.Germany)	8,000	"

b) Laboratory for production control

No	Title of equipment	Value of equipment US$	Provided by
1.	DISPO-control system (Producer: DISPO)	18,500	Yugoslav Government
2.	Computer display-terminal CDC-Cyber 18-05 with printer, modern and card reader	50,000	RO Naftagas-Informatika, Novi Sad

c) Laboratory for method and time study

No	Title of equipment	Value of equipment US$	Provided by
1.	Motion Camera H 16 RX-5 (Roxki)	4,100	Yugoslav Government
2.	Projector BOLEX 521 (Sonal)	2,700	
3.	Automatical camera objective (Kern Vario Switar 100 POE)	550	
4.	Additions		
	Total: a+b+c	528,016 US$	

(vii) Laboratory for total machines with teaching personal

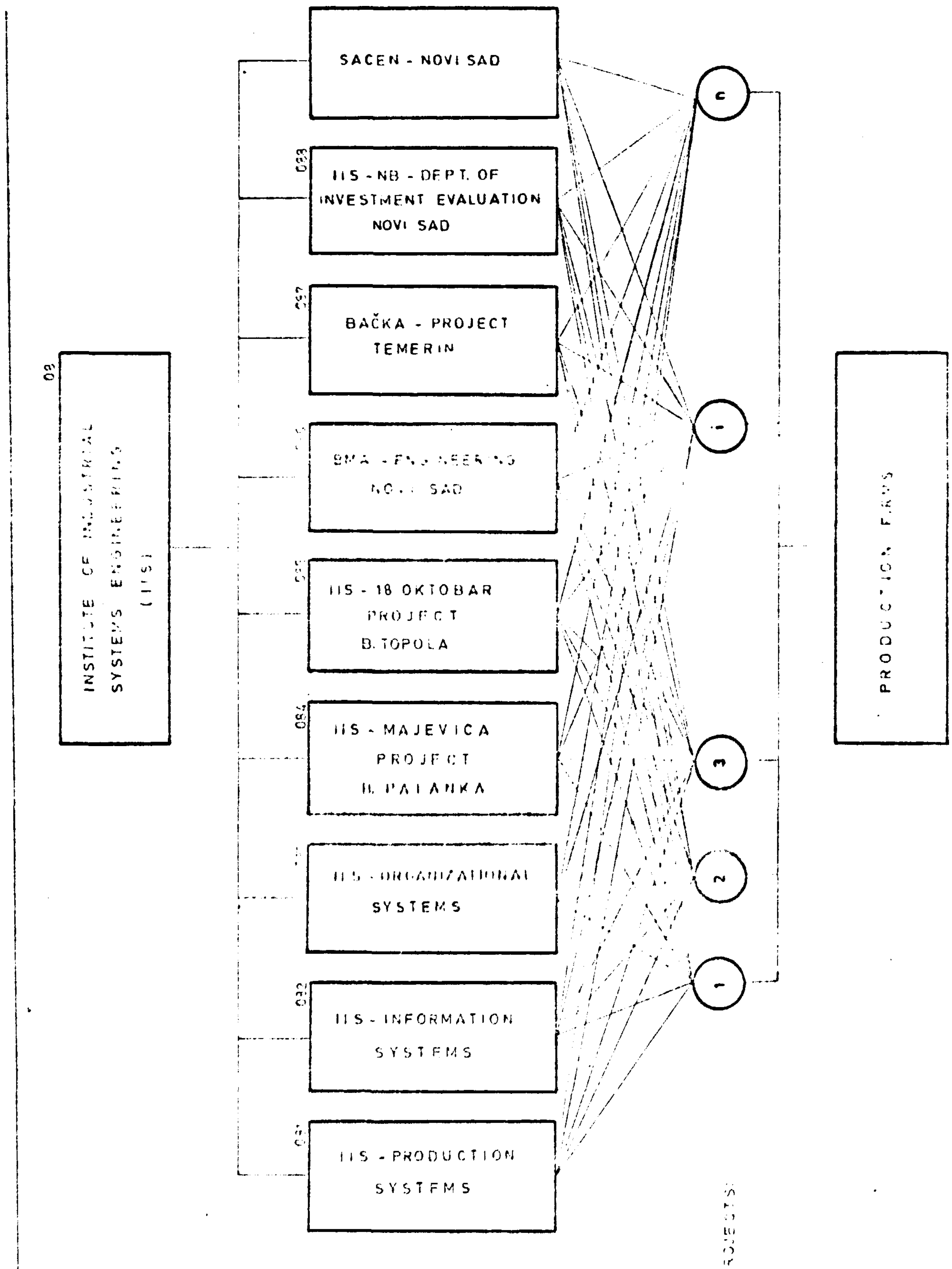
1. Prof.Dr J.Rekeczky, Tool Machines
2. Prof.Dr R.Gatalo, Automatical Designing
3. J.Hodolič, Tool Machines Exploitation
4. Lj. Borojev, " " "
5. M.Zeljković, Tool Machines Designing

load the courses of NC and CNC tehnology in the factory of electromotors "Sever" in Subotica. The courses include the use of NC and CNC machines, the technology projecting, programming, etc.

2.3 Benefits

Benefits of the Project are complex:

1. the material basis for practical trainings with students and the investigations in MSci and PhD thesis is made
2. there are possibilities for practical demostraations for students
3. various training courses for specialists from industry are organized
4. the mission of the experts from abroad whose help in investigations in the Project was especially important for the working team on one side, and for the postgraduate students on the other side, for during the mission the students have learnt many new methods and techniques from the area of the mentioned investigations.
5. The mission of the working team in factories and scientific institutions in Europe, helped a lot in their personal advanced training and transfer of technology and new scientific knowledge of projecting and of production system analysis in the developed countries such as: Switzerland, West Germany, Great Britain and other.
6. The Institute continuously work together with J. L. Burbidge, expert who hives lectures to the postgraduate students (April-May 1980) and further investigations.
7. The Institute is capable of accentance the experts from other countires for training in 43 objects of the Project.
8. The Institute is ready to give the technical help to the developing countries in:
   - educational training
   - the industrial objects projecting
   - consulting.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PRODUCTION FIRMS
PROJECTS

9. The Institute established the direct business co-operation on the basis of the settlement with other related firms in the way given at the following sheme which shows the possibilities for more complex action to be carried out on area of industrial production rationalization.

3. RECOMMENDATIONS

The investigations carried out during the work on the Project have resulted in the following recommendations and suggestions to the UNIDO Agency and Yugoslav Government:

1) Recommendations for continuing the investigations

We think that the following investigations have to be continued and expanded (the suggestions are the result of trainning programmes and expert missions):

- in the investigation of production systems' structures in a sense of automatization of machining and assemblying structures of production systems in order to decrease the cycle time in machining and assembly as well as work and time study investigations
- in the area of determinations of the variants of operation performance related ot the loading, capacity and the latest terms for finishing; the choice of the optimal termination variant for the production
- the use of minicomputer as a support for organizational tools in the area of production control
- mathematical and simulation modelling (computer oriented) of production systems, particularly of automatic lines and using the group technology
- introducing computer performance evaluation techniques into computer centers in industry in order to minimize costs of equipment supply
- the transport problems between work places

- the investigation of the use of Computer Aided Design (CAD/CAM technology) in metal working industry
- the flexibility of production systems structures
- the possibilities of introducing buffers into the existing equipment in the line installed at the Laboratory for Industrial Systems
- maintainability as a function of the complexity of technological systems
- design adequacy and operational readyness of technical systems
- transfer of knowledge into the industry.

2) Recommendations for further training ans spetialization

The further training of the project team members is necessary in some of the scientific or industrial firms in USA or Europe. The extend list is given in the FINAL REPORT.

3) Recommendations for thepurchase of new equipment

- in the area of the automatization in production systems

a) semiautomatic and automatic assembly lines
b) assembly machines
c) the equipment for the work places that are ergonomically formed on the principles of rational execution of operations
d) the time measuring equipment
e) the robot for performing certain operations

- in the area of production systems control

a) minicomputer to be used together with DISPO system in the process of production planning and processing of feedback information
b) Kienzle card reader for circular diagrams and the equipment for data processing about downtimes

- in the area of CAD/CAM technology

a) the equipment for computer aided design made by
    - Tectronix
    - Calcomp
    - CDC (Control Data Corporation)

b) the equipment for transport and storage made by Demag, BRD.

The money which we might get form UNDP we need for the purchase of numbered new equipment is cca 180.000 US$.

For the neccessery space spreading out the Institute will ask for the help from the Yugoslav Government in amount of cca 6.000.000 DN (cca 300.000 US$).

4. CONCLUSIONS

Long range objectives are realized completely according to the project programme. Immediate objectives are also completely realized, except for the objectives (v) and (vii) for they are still in progress.

During the realization of the project for the necessery buildings, equipment, for the training team members and experts mission the following financial resources are invested provided by:

- UNDP	cca 130,000 US$
- Yugoslav Government and Institute	cca 408,808 US$
Total:	569,808 US$

The experts from UNIDO had given a significant help
4 x 1 expert/month

UNIDO had supplied the training programme for the project team members to receive advanced training in scientific and industrial firms in Wales, Great Britain, Poland, West Germany and Switzerland in amount of

5 x 3	man/month
1 x 2	man /month
Total:	17 man/month

which has significantly contributed to the strengthening of the teaching capacity as well as to the increase of the level of the skilled expirience which the team member have gained in these firms.

We consider that the further cooperation and the help from the UNDP Institute is of particular interest.

5. ACKNOWLEDGEMENT

We take the advantage of this opportunity to thank you once again for the help from UNIDO and UNDP and their stuffs. Special thanks to Mr.J.Renart, the President Representative in UNDP in Belgrade and to Mrs.D.Elez who gave the significant contribution in order to overcome certain difficulties during the adaptation of the project which had appeared as a result of unsufficient development of the Institute.

To the experts of UNIDO:

1. Mr G.G.Hitchings-u, Ph.D.,Professor of University of Wales, Wales
2. Mr L.I.Volchkevitchu, Ph.D.,Professor of University "Bauman" of Moscow,URSS
3. Mr J.L.Burbidge-u, Prof.of Production Management, Cambridge, England

we thank for their special help in the development of the Institute capacity (laboratories and teaching capacity).

We also thank to Regional Office for Scientific and Technical Cooperation, specially to its secretary Mr. E. Ljubibratić and to Mrs. M. Marković.

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C O N T E N T S

1. INTRODUCTION

The project "Examination of Conditions for Establishing Flexible Production Systems" has been proposed on May 5th,1972 and has been proposed on 5th May 1972 and has been signed on 7th December 1973 by the Yugoslav Government and on 8th January 1974 by the UNDP as the Executive Agency.

The anticipated duration of the Project was three years while the anticipated expences for its realization amounted to 2.730.000 din. as the Contribution of the Yugoslav Government and 100.000 $ as the Contribution of UNDP.

The basic Objectives of the Project are:

A. Long range objectives

The long range objectives of the Project are:

(i) To increase the quantity and improve the quality of Project Participants and Professional Managers and controllers of Production Systems. These personnel are needed for schools and universities, economic planning and development programmes and the industrial sector: and

(ii) To improve industrial productivity by the development and introduction of optimal production systems for various situations, mostly as job, batch and line production.

B. Immediate objectives

The Immediate objectives of the Project are:

(i) To change the orientation of the research activities of the Institute from its present emphases on theoretical problems towards a more practically oriented programme.

(ii) To improve the Institutes teaching capacity in modern methods of the management of systems;"

(iii) To expand tha capacity of the Institute to provide training programmes for manager in industry;

(iv) To develop parameters and mathematical models which will be relevant for the solution of investment problems generally and particularly for the metal working industry in Vojvodina;

(v) To develop and test with appropriate experiments, parameters and mathematical models in the field of management of production systems;

(iv) To make the Institute better equipped to provide consultant services in the field of management of systems, survays, studies, ets., for industry and other sectors; and

(vii) To facilitate the introduction of numerically controlled machines and computer controlled and scheduled production systems into factories by developing appropriate systems and parameters. Industrial management personnel do not at present have experience with these equipment and systems, nor do they have the time to become knowledgable because of the day-to-day operating demands.

During the period of realization of this project the research potential of the Institute of Industrial Systems Engineering has been increased in the sense of total number of research workers from 5 employees in 1974 to 14 employees in 1979. Total number of employees at the Faculty of Technical sciences in Novi Sad (8 Institutes) has been increased during a given time from 115 in 1974 to 310 in 1979. Besides that the number of external collaborators of Institute of Industrial Systems Engineering increased during the given time from 12 to 65. It enables the institute to be one of the greatest research places in the field of Industrial Systems Engineering among Yugoslav Universities. At the same time the total income of the Faculty of Technical Sciences and of the Institute of Industrial systems Engineering has been increased more than 10 times (see Fig.1).

THE INCOME OF THE FACULTY OF TECHNICAL SCIENCES

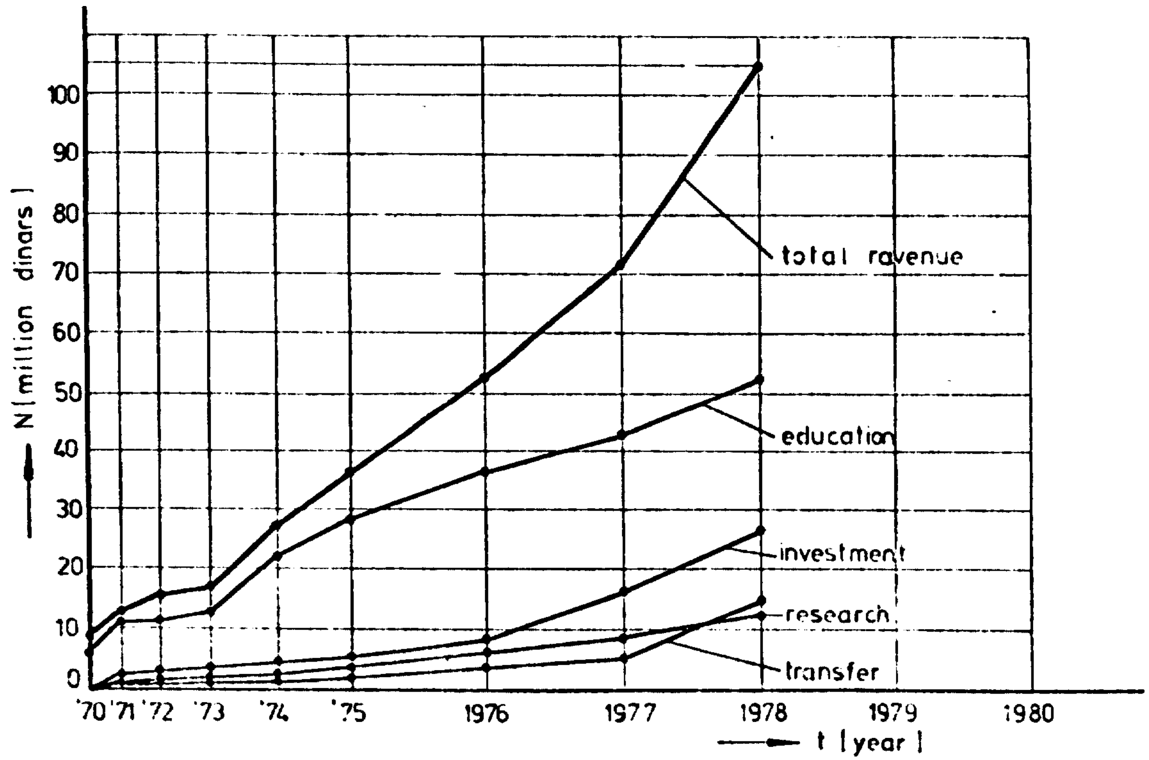


Fig. 1.

The increase of the Institute's research recources has been proved:

(i) by meeting long range an immediate range objectives,

(ii) by improving a process of colaboration with metal working industry in this part of the country and

(iii) by a great number of research projects, batchelor, master of science and doctor of Philosophy theses.

Besides the above mentioned results the laboratory of Production Systems, laboratory of Production Flow Control System and Laboratory for Method and Time study has been established. It should be expecially pointed out, as it is shown in the enclosed anexes, that the majority of items for all of Laboratories has been successfully realized.

Three of UNDP Experts in total time duration of four months have been controlled the flow of project activities and helped that the basic objectives of proposed project have been realized as how it can be seen from the following informations.

2. FINDINGS

The activities of the Institute of Industrial Systems Engineering in connection with project YUG 73/005/A/01/37 entitled "Examination of Condition for Establishing Flexible Production System", were oriented towards fields defined in the long term and immediate objectives of the Project. These included:

- To establish and equip the laboratories of the Institute of Industrial Systems Engineering, in order to be able to carry out research, to perform exercises for students according to the education plan, and to provide consultancy services and training programmes in the field of management of production systems, technology, method and time study etc., for industry and other sectors.
- To develop a methodology for the investigation of the parameters of production systems, mathematical models, flow analyses, investment criteria, system structure and the reliability of systems, in order to get objective data about the behaviour of production systems. To improve the teaching capacity of the Institute in modern methods of organization and management, and to improve the productivity of industrial system's by the development and introduction of optimization criteria in the different fields of production.
- To work out the General model of material flow in Production systems, in order to produce an objective tool for the selection of the appropriate type of organisation and plant layout for different industrial situations.

This report presents a brief description of work which has been done and of results obtained in the above mentioned fields. The References and lists of results of studies are given in the Appendices.

2.1 The layout and equipping of the laboratories of the Institute of Industrial Systems Engineering

The Laboratories of the Institute of Industrial Systems Engineering were developed in order to meet demands in education, research and industrial consultancy, especially in the fields of method and time study, plant layout, management science, reliability of production systems and a study of system elements and their organization.

During the period covered by this project three laboratories have been developed as described below:

.1 The Laboratory for method and time study

This Laboratory is designed to meet needs for the education of students and for short-time seminars for participants from industry.

The following equipment has been selected and installed:

1. Motion Camera	H16 RX-5	(REXKI)
2. Automatical camera objective	Kern Vario-Switar 100 POE	(VASEC)
3. Protective shell of camera		(BLIMO)
4. Teleobjectiv		(PRERI)
5. Sticking equipment		(COLSE)
6. Projector	BOLEX 521	(SONAL)
7. Mycrophone		(MICSA)
8. Additions		(TELEC) (ECOUT) (SCOOP) (SCOSU) (OSLAP) (BOBOT) (BOBSI)

.2 The Production Systems Laboratory

This Laboratory is purpose-built for teaching and research. It contains:

- A Four-Station transfer line for machining turned components
- Materials Handling Equipment
- A Set of different kinds of tools, jigs and fixtures
- A Data logger - Kienzle MSA71+CM11.

The layout of the Laboratory is shown in Fig.

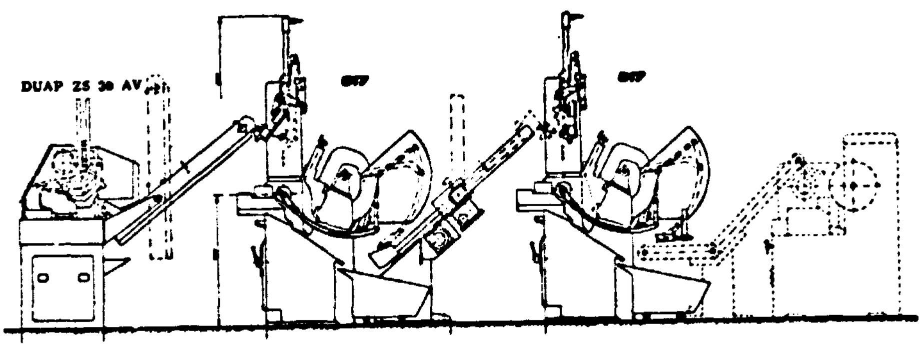


Fig.

The Four-Station transfer line is designed for research in the field of the flexibility and reliability of production systems. The layout of the line consists of:

The first station - a circular cold Sawing Machine type Forte FKA 45, cuts a preloaded bar to the determined lenght shown on the operation sheet.

The second station consists of a facing and centering Machine (type DUAP ZS 30 K). It faces the bar and centrebores both ends according to the instructions in the operation sheet.

The third station consists of a copying lathe (type DUBIED 517 S) use to both rough and finish turn the bars on one end.

The fourth Station consists of another copying lathe (type DUBIED 517 S) which roughs and finish turns the other end of the parts.

Form turning at stations three and four is based on profile templates which are followed [illegible]. After turning on the fourth station the components are ready for subsequent heat treatment operations carried out elsewhere.

In order to get data about flexibility and the influence of different types of material handling equipment, the different types will be provided.

Equipment is provided for getting data about UP TIME and DOWN TIME of the transfer line as illustrated in Fig. 3.

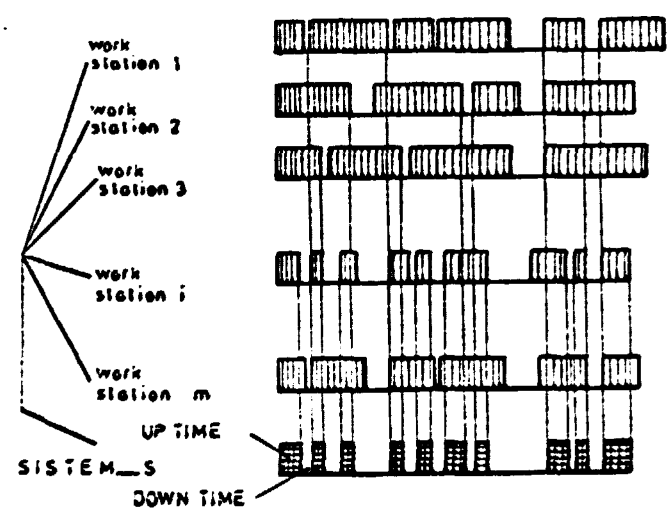


Fig. 3

Besides the basic data about UP and DOWN TIME the same equipment can record up to ten different causes of DOWN TIME. The data obtained can be used therefore for research in the field of the reliability of production systems.

.3 The Laboratory for the PRODUCTION CONTROL

This laboratory, that is in a state of finalisation, is supplied with the following equipment:

1. "Dispo" system for the production control
2. Terminal 18-5 connected to the computer "CYBER 171"
3. The equipment for data collection and processing.

Dispo system consists of the following:

- terminal center
- planning tables
- tables for the final work distribution at the working place
- optico-acustical system for signalisation
- card file (materials, tools, workers, machines, work orders, matrices of the technological procedure etc.).

The equipment for the data collection and processing consists of:

- the equipment for data collection KIENZLE MSA 71/CM 11
- the equipment for data processing KIENZLE-EDA.

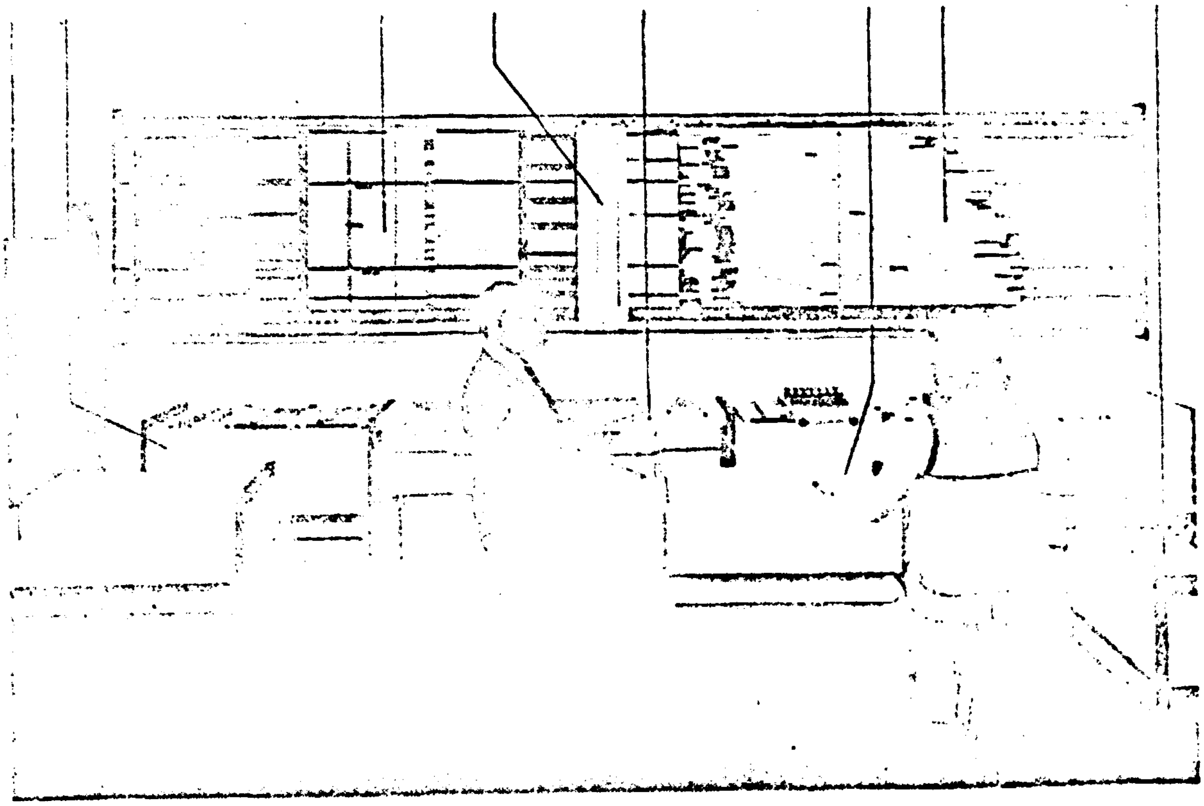


Fig.4 Terminal center

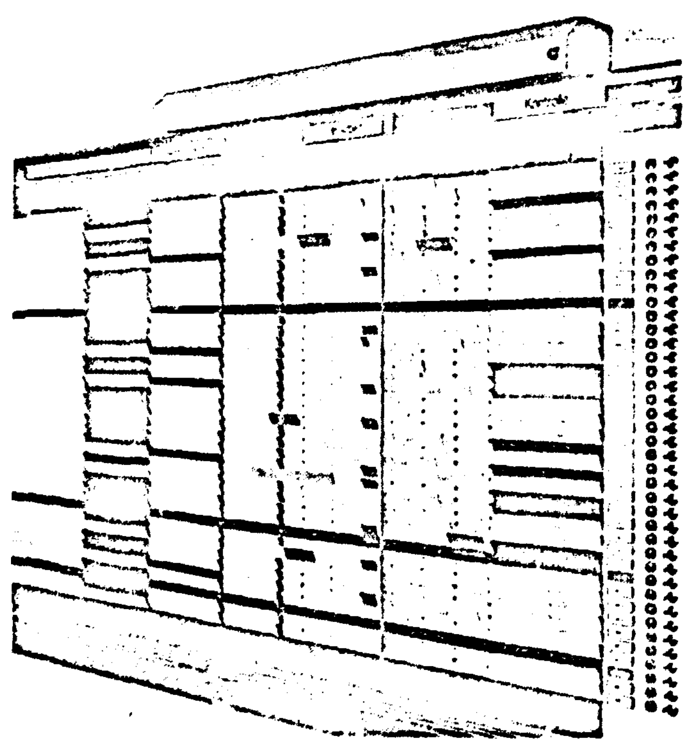


Fig.5 Tables for planning and control

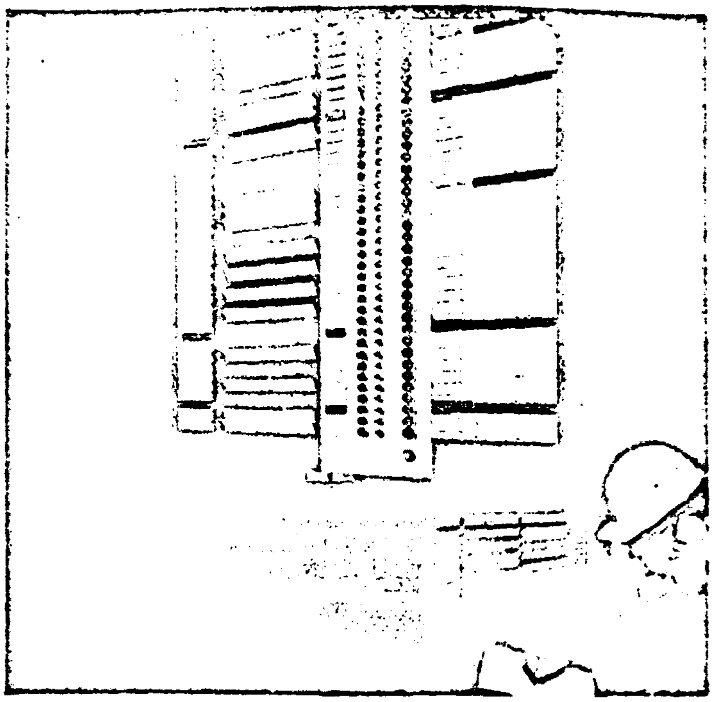


Fig.6 Optico-acustical system for signalisation

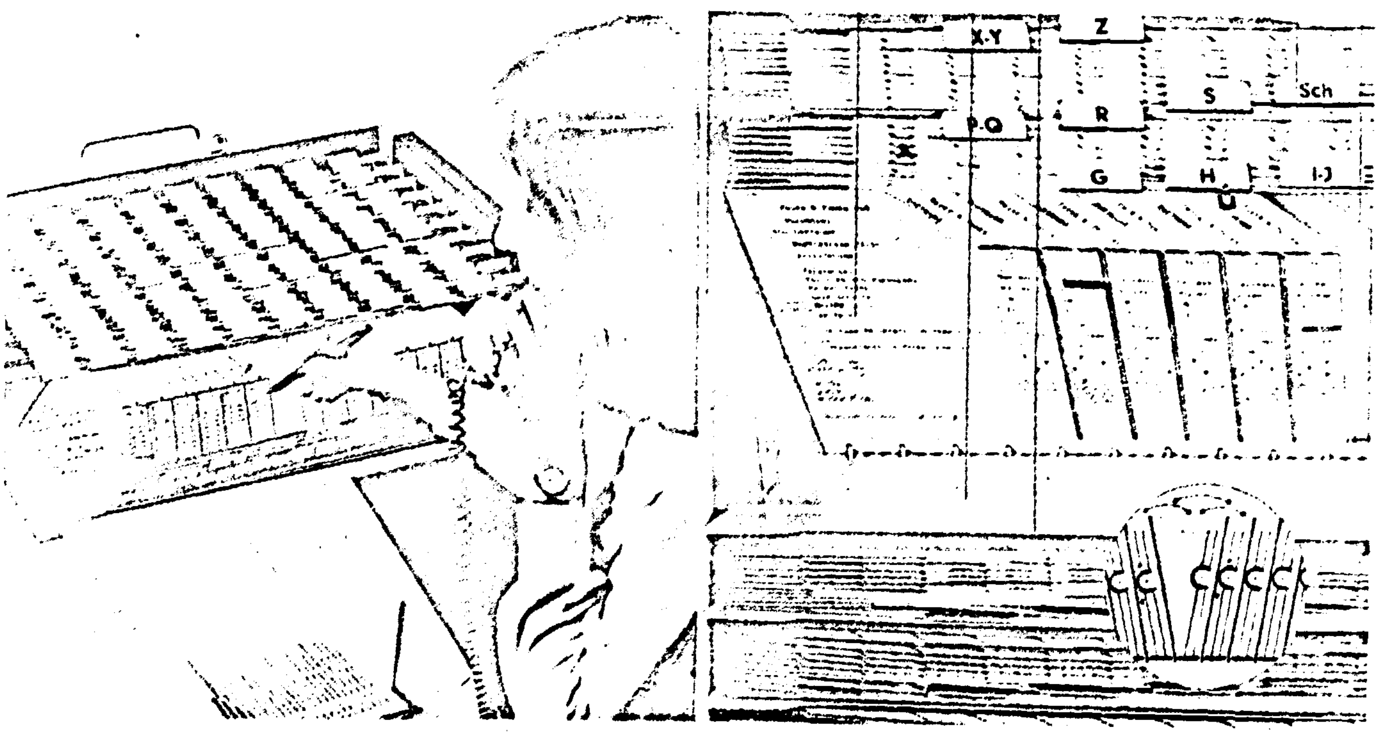


Fig.7 File system

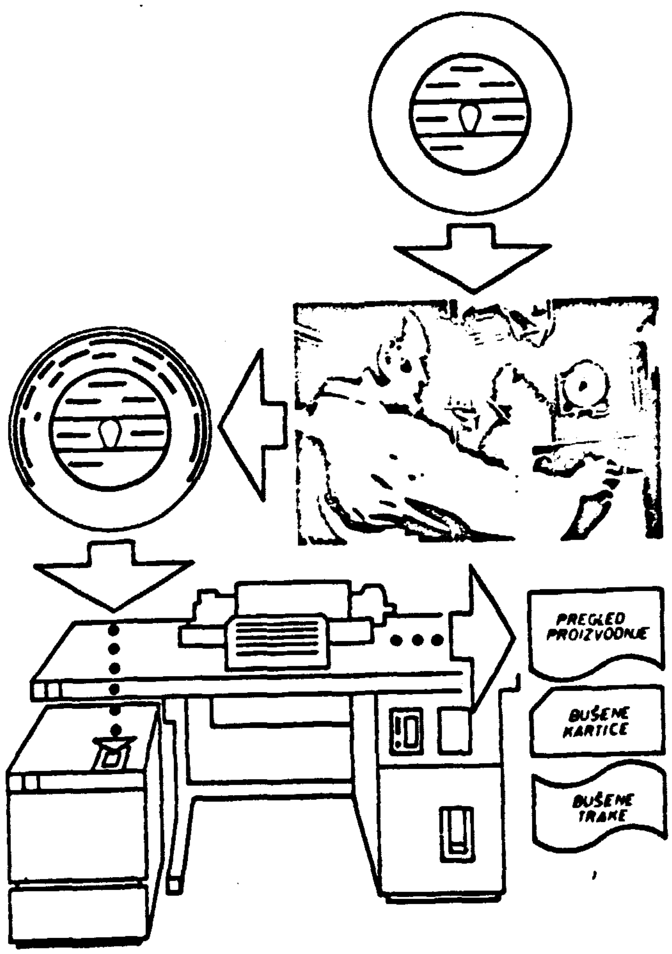


Fig.8 Data collection and processing

According to the needs of the project as well as in order to further develop the scientific work and lecturing process at the Institute for industrial systems the terminal subsystem was purchased to be connected to the computer system CDC-Cyber that is located at the "Naftagas" company, Novi Sad, The terminal subsystem consists of the following components:

- console with video display
- card reader
- printer
- modem.

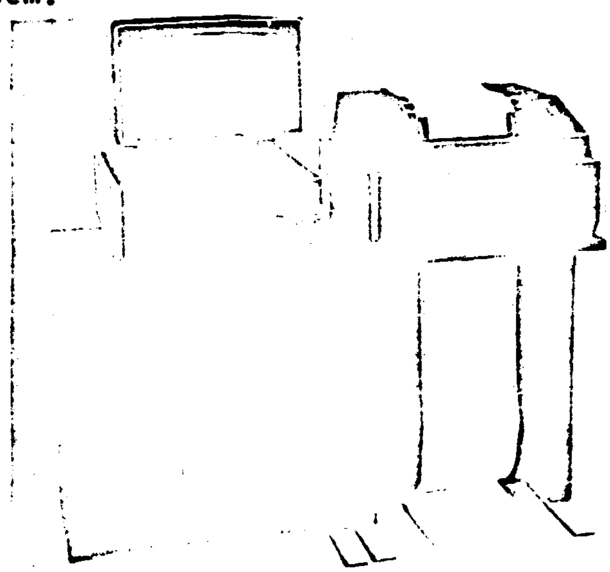


Fig.9 Console and printer

2.2 Investigating production systems structures

2.2.1 The structure of the investigation

On the basis of the basic conditions for the investigation of system structures there is possible to investigate on the installed system the following relationships:

.1 Duration of operations against mode of the tool action composition (machining structures).

.2 Duration of the production cycle against
- variant of the transport system

- mode of work piece transitions from operation to operation
(TECHNOLOGICAL STRUCTURES).

.1 The Relationship Between the Duration of the Operation and the Mode of the Tool Action Composition

.1.1 Introductory remarks

The structure of the majority of machining operations could be made of:

- with one or more tools
- in one or more positions
- in one or more flows
- in the discrete or continuous procedure etc.

For these reasons the question of the choice of the machining operations structure is a complex one and is closely related to:

- the quality of the product
- the quality of the process (U,E,R).

The difference between the usual approach and the recently developed one is that in the former the structure was investigated on the basis of machine clasification, not the process clasification, while in the later uses the data on graspes and the flows of the machining operation considered. This is, at present, the basic direction in the search for solutions for the improvement of production effectiveness from the aspect of its quality. From that fact follows that the construction of the machine must be a consequence of the machining operations structure adopted.

When the load/capacity degree is low the processing technology is based on the basic (simple) machining operation structure regardless of the procedures (methods) of machining. The basic structure (Fig.1) is defined as a procedure of the machining of the work piece on the single-positional machine, with one flow and one tool and with the serial mode of grasp. The designed accuracy of the work piece measures is attained by the use of the method of occasional checking measurements.

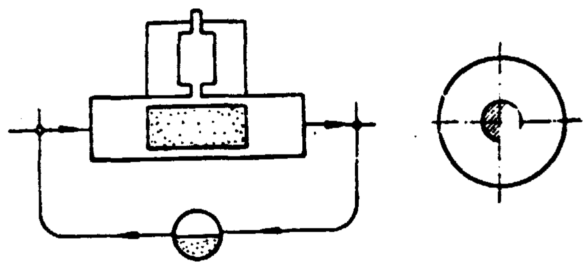


Fig.10 The basic structure of the machining centre (single position work with one tool)

The increasing requirements for productivity improvement led to more complex machining operation structures in a sense of tools work composition and the use of machining procedures with the parallel work of several tools (Fig.11) in a single position (this leads to the need for constructing of single position-multiple tool machine) as well as the use of machining operation with one or more tools and multiple positions (Fig.11) leading to the need for constructing multiple position machines

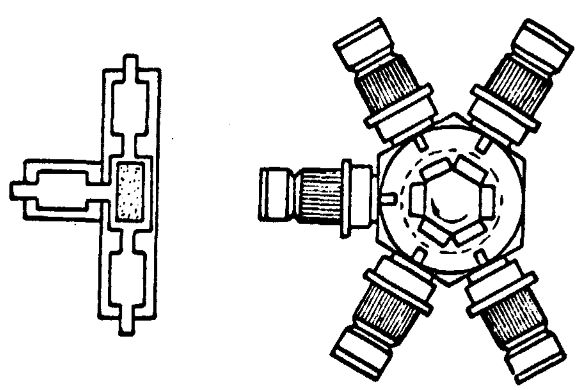


Fig. 11

with the transition of the work piece during the machining process.

Moreover, in some processes, instead of discrete mode of work piece movement, there is introduced continuous mode.

However, the requirements for further increase of the productivity led to the need of replacing single flow structures with multiple positions by multiple flow structures with single or multiple position in the flow, as given on figure 12.

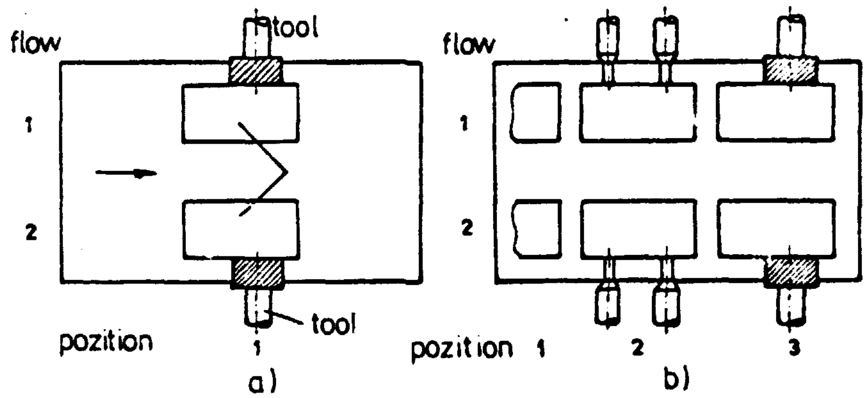


Fig.12 The machining system structure with the higher degree of complexity

a) machining in two flows in a single position
b) machining in several flows and multiple positions with one or more tools

The machining of particular work piece in one or more positions must be considered from the aspect of one flow the reason being that other flows are identical to the one in question.

It is clear that the development of machining operations structures has a considerable impact on the productivity increase. The impact could be expressed as a decrease of preparing time. It is known that for the particular kind of product, and for single flow mode of work, the machining time, t_i, is:

$$t_i = t_{io} + t_{ip} + t_{id} \text{ [units of time]}$$

giving the oportunity to determine the productivity of the machining system. The machining time is:

$$t_{op} = t_{io} + t_{ip} \text{ [units of time]}$$

For single flow systems

$$t_{op} + t_{ps} = T_{cr_1}$$

e.g. it is equal to the duration of the working ycle.
For multiple flow systems:

$$t_{op} + t_{ps} = \frac{T_{cr_1}}{p_o}$$

where

p_o - number of flows

Preparing time is

$$t_{ip} = t_{rp} + t_{po} + t_{ph} \text{ [units of time]}$$

where

t_{pr} - the time for mannual placement of the jigs and fixtures and adjustment

t_{po} - total time for removering and placing the work piece

t_{ph} - idle time.

Thus, for the multiple flow machining we can write

$$t_{op} = t_{io} + t_{ip} = \frac{T_{cr_1}}{p_o} = \frac{t_{io} + t_{pr} + t_{po} + t_{ph}}{p_o} \text{ [units of time]}$$

where the time for tool placement is neglected (because of the early preparation). If the choice of the machining operation structure leads to the overlap of preparing time elements with the basic time the above expression converts to

$$t_{op} = \frac{t_{io}}{p_o} \text{ [units of time]}$$

and for p_o=1 (single flow machining) there will be

$$t_{op} = t_{io} \ [\text{units of time}]$$

From the above it follows that the basic parameter that makes the distinction between various machining operation structures is the machining time or, more precise, its structure.

The fast development of machining operations structures colud be explained by the slow development of procedures (methods) for machining in the conditions of rapidly growing productivity.

.1.2 The Composition of Tool Actions - Grasps The Machining Time and Working Cycle

There are three basic procedures of the compositions of tool actions (grasps):

1. serial
2. parallel
3. series-parallel

and those give different machining times. The composition of actions show:

.1 Serial procedure

In this kind of procedure the machining is executed by one or more tools in series where the next grasp starts immeditely or after some time without any overlap as seen on the Fig.13.

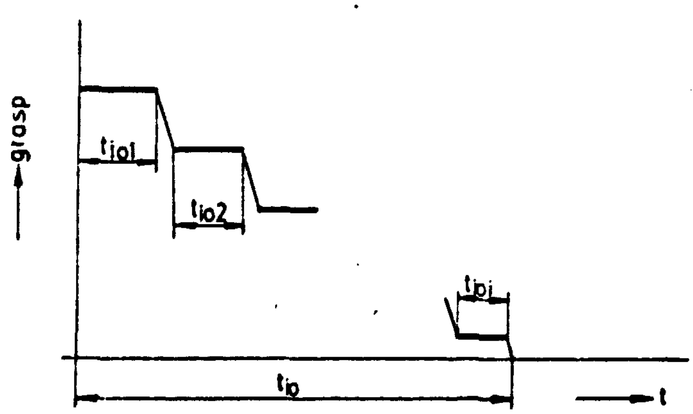


Fig.13 Serial procedure for the composition of tool grasps in the machining structure

It is clear that, in all such cases, the basic machining time t_{io} is:

$$t_o = t_{o_1} + t_{o_2} + \dots + t_{ok} = \sum_{i=1}^{k} t_{ioi} \text{ [units of time]}$$

.2 The Parellel Procedure

is characterised by the simultaneous grasps (Fig.11), provided that it is not necessary that the begining and the end of every grasp fall in the same moment.

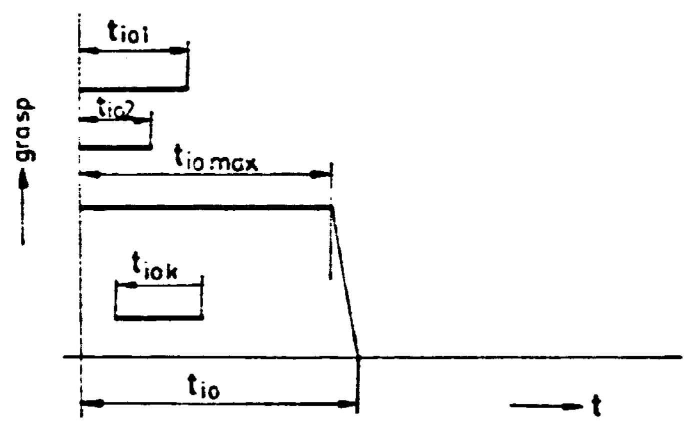


Fig.14 The parallel procedure of the tool grasp composition in the machining structure

Thus, the parallel work is defined as a simultaneous action of all tools from the begining to the end of the particular grasp in a single flow. Consequently, we can distinguish the following possibilities:

1. In every position in one flow there is executed one grasp by one tool.
2. When using multipositional machines in every blocks of tools simultaneously.
3. In the continuous one-flow process (line), in every work place the machining is performed by the use of different tools simultaneously.

The basic machining time for the parallel case is equal.

to the machining time for the grasp with the maximal duration of machining that is given by the relation:

$$t_{io} = (t_{io})_{max} \quad [\text{units of time}]$$

.3 Series-Parallel Procedure

for the composition of machining grasps (tool actions) is characterised by the situation where two or more isolated tools or several tools in blocks act sumultaneously (in parallel), and the replacement of tools or blocks is serial.

It is clear, as before, that the duration of the grasp is equal to the maximal working time of the individual tool or the block of tools, as given on the Fig.15.

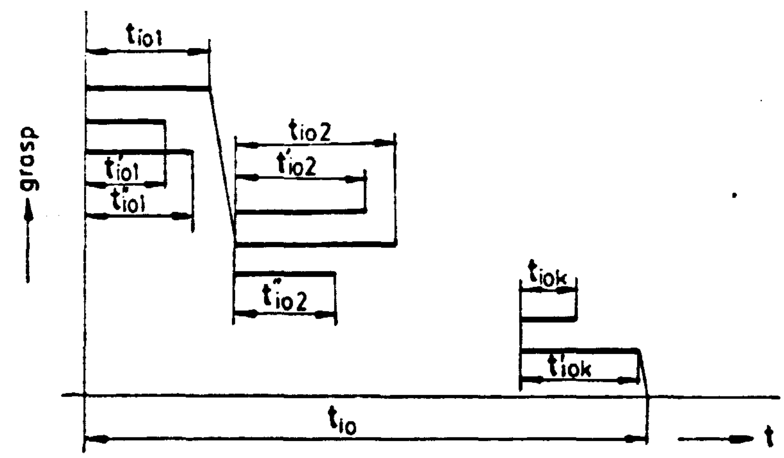


Fig.15 Series-parallel procedure for the composition of tool grasps in the operational structure

Thus, the basic machining time for one operation is:

$$t_{io} = (t_{io_1})_{max} + (t_{io_2})_{max} + \ldots + (t_{io_i})_{max} + \ldots +$$

$$+ (t_{io_k})_{max} = \sum_{i=1}^{k} (t_{io_i})_{max} \quad [\text{units of time}]$$

The duration of the work cycle for single product is (single position, one flow):

$$T_{cr_1} = t_{io} + t_{ip} \text{ [units of time]}$$

where

t_{ip} - preparing time spent on the placement and replacement of work pieces, preparation, measurements and idle time

.1.3 Determination of the Duration of the Operational Cycle

Based on the chosen working conditions there can be determined the basic machining time for every grasp using:

- analitical methods
- nomograms.

The basic operational time is determined on the basis of preliminary analysis and is related to the mode of the composition of the tool actions:

The preparing time as the elements of time standards are determined by the methods of data collection or pre-determined times MTM that is executed by the MTM-ANALYSIS charts.

The procedure shedule with drawings, the working conditions as well as the elements of the duration of the operation (the basic time and preparing time) can be found in the OPERATION SHEET.

On the basis of the data available on the basic time and preparing time the work cycle for one product is calculated using the formule:

$$T_{cr} = t_{io} + t_{ip} \text{ [units of time]}$$

OPERATION SHEET	product					material				operation group	job group	Institute of INDUSTRIAL SYSTEMS
	part	code of part	dimens	pieces	drawing Nº	dimension	weight					
							designed	techn.	planed			

operation			quality	work station	tools, jigs and fixtures	cooling fluid	cutting conditions				time standards				
							i	v	s	a	t_{pz}		t_i		
Nº	sheme	title					d	n	s_z	i	t_{pzo}	t_{pzd}	t_{io}	t_{ip}	t_{id}
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

SRF-MTM
MTM-ANALYSIS

Drawing № ______ № Of sheets ______
Study № _________ Sheet № ______

Institute of INDUSTRIAL SYSTEMS

№ of detail	Operation	Executed by	Date

Description of left hand operation	times	symbol	TMU	symbol	times	Description of the right hand operation

.2 The relationship between the production cycle duration and the variant of the transport system and the mode of the transition mode from operation to operation

.2.1 Variants of the Transport System and the Duration of the Transportation Cycle

In the material flows of the given production system (Fig.7) it is possible to divide the transport procedure into three phases:

PREPARATION

transportation of the material from the stock to the first machining centre (saws, T).

TECHNOLOGICAL PHASE

transportation of the material from the first until the last processing system (Saw-T; end working machine MPZ, copying lathes SK1 and SK2).

FINAL PHASE

transportation of the material from the last processing center to the stock of final products.

All the operations within the production process are given in the PROCESS FLOW CHART (page) and the symbols in the CHART have the CHART have the following interpretations:

SYMBOLS	D E F I N I T I O N	
OPERATION ○	The operation is defined as a change of physical or chemical characteristics of the material by: machining,	Contained in the produc-tion process
TRANSPORT ⇨	The transport is defired as a translation fo the material, semi-products or final products except when keing the part of the operation excuted by one worker during the operation or the control.	Transport or movement
INSPECTION □	The control is defined as an in-spection of dimensions or the quality of material, semi-pro-ducts or final products with the aim of determining the quantity, quality etc.	Inspection, examination
DELAY D	The delay arises when the pro-duction conditions do not requi-re execution of the next opera-tion in the technological process cess. The exception are the de-lays caused by the replacement of physical or mechanical charac-teristics of the material,semi--product and parts enter the stock not to be extracted with-out permission.	Removing
STORAGE ▽	The stocking is done in the case when the material, semi-product and parts enter the stock not to be extracted without permission.	Keeping
COMBINED WORK ⧇	This is used in the case when it is recessorry to show the execu-tion of the operation and the technical control with one or more workers and one work place.	

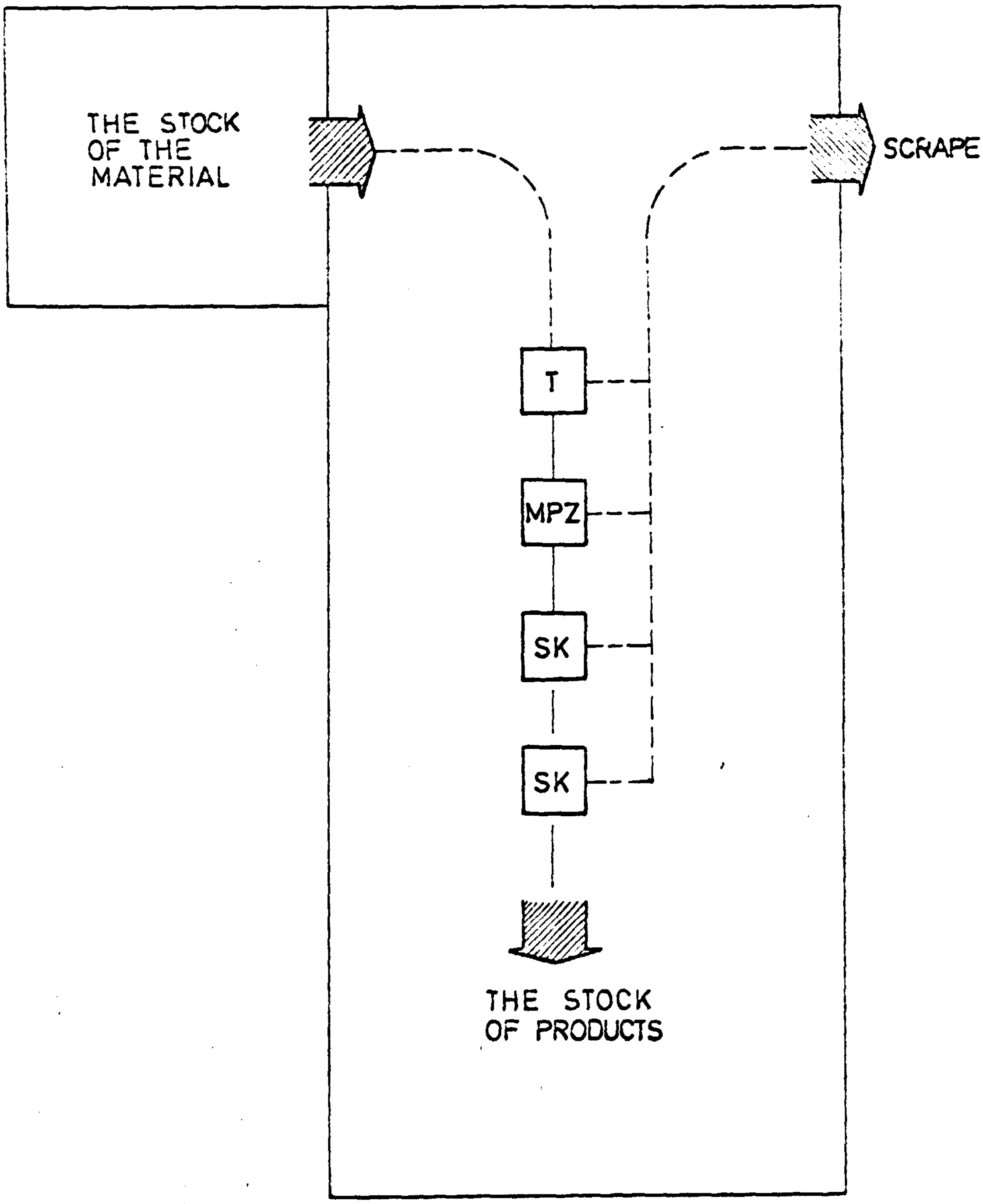


Fig.16 Material flows

FLOW PROCESS CHART

[ ] work piece
[ ] machine______ [ ] state______
[ ] labour______ [ ] preposition______

product /part/				
code	quantity	dimens	weight	drawing

Institute of INDUSTRIAL SYSTEMS

operation		work station	machining	inspection	transport	delay	storage	distance	quantity	weight	position	№ of workers	time standards				
													t_{pz}		t_i		
№	title												t_{pzo}	t_{pzd}	t_{io}	t_{ip}	t_{id}
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.	Bars unloading		○	□	⇨	D	△										
2.	Input inspection		○	□	⇨	D	△										
3.	Storage		○	□	⇨	D	△										
4.	Transportation to T		○	□	⇨	D	△										
5.	Cutting		○	□	⇨	D	△										
6.	Transportation to EWM		○	□	⇨	D	△										
7.	End machining		○	□	⇨	D	△										
8.	Transportation to CL1		○	□	⇨	D	△										
9	Copying		○	□	⇨	D	△										
10.	Transportation to CL		○	□	⇨	D	△										
11.	Copying		○	□	⇨	D	△										
12.	Transportation to storage		○	□	⇨	D	△										
13.	Storage		○	□	⇨	D	△										
			○	□	⇨	D	△										
			○	□	⇨	D	△										
			○	□	⇨	D	△										
start point ______		sume															
		state															
ending point ______		diferen.															

date:
designer:

date
collaborator:

THE VARIANTS OF TRANSPORT IN THE PREPARATION

On the basis of concrete conditions:

a) Transported material

- the same kind
- the bar ø<100 m and l<4000 mm
- large quantity, medium weight

b) Transport paths:

- length < 20 m
- the movement plane - horizontal
- width 2 m
- throughput: small

there si possible to use 3 variants of the transport e.g.:

1. VARIANT

the transport system with the manual taking, transporting, and stocking the material without the use of mechanical equipment and transport mechanisms.

2. VARIANT

containing the transport system with the mannual bringing and taking away of the work pieces with tee use of transporting equipment without the feeding engine, for instance the cylindrical transporters eith the scater etc. If this means are fixed on the angle the movement of the material is supported by the self weight and gravitation. We will consider the cylindrical transporter.

3. VARIANT

is the transport system for the lift-transportation works that uses different kinds of crans and transports.

The transportation time for the VARIANT No.1 is:

$$t_t = t_p + t_{pr} + t_o \quad [\text{units of time}]$$

where

t_p - lifting time
t_{pr} - transport time
t_o - down time.

The duration of the transport cycle is:

$$T_c = t_t\ (1+k)\quad [\text{units of time}]$$

where

k = 0,1-0,2 - coefficient that contains delays for rest and slowdown.

The transport time for the second variant is

$$t_t = t_p + t_{pr} + t_o\quad [\text{units of time}]$$

where

t_p - loading time
t_{pr} - transport time
t_o - down time.

The transportation cycle time is:

$$T_c = t_t\ (1+k)\quad [\text{units of time}]$$

where

k = 0,1-0,2 - coefficient that takes into account the time delays caused by delays and rests.

The third variant is usable for the rest two phases (e.g. technological and final phase) and is executed on the overground tracks according to the Fig.17.

The transportation time for the third variant is

$$t_t = t_p + t_d + t_{pr} + t_s + t_o$$

where

t_p - loading time
t_d - lifting time
t_{pr} - transport time
t_s - dropping time
t_o - down time.

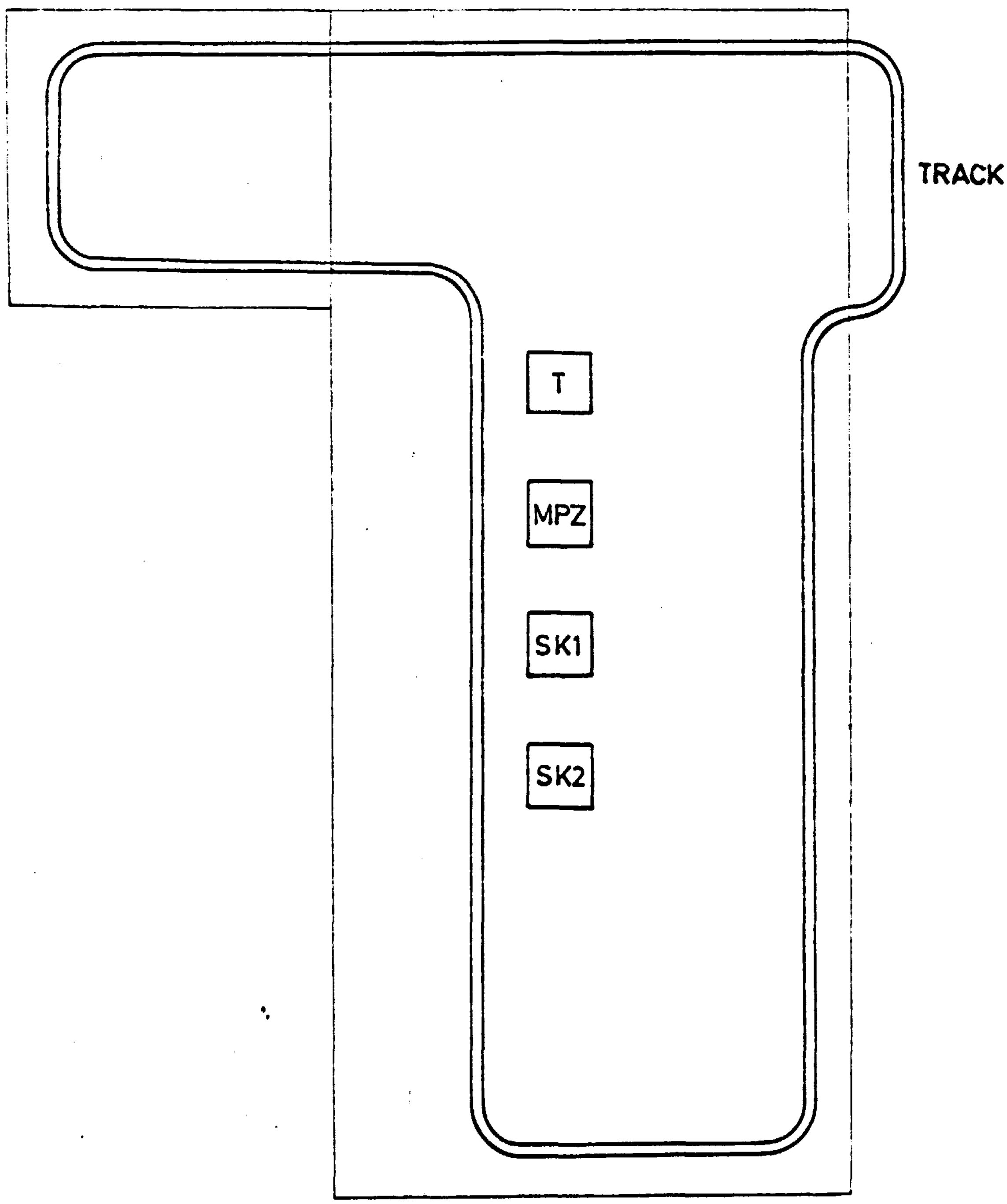


Fig.17 The transport scheme for the third variant

The duration of the transport cycle is

$$T_c = (1,1 - 1,2) \sum_{i=1}^{n} t_i$$

where

(1,1-1,2) - coefficient that takes into account the time lost for transition between switches or the pass through the switch when starting or stopping.

TRANSPORTATION VARIANTS IN THE TECHNOLOGICAL PHASE

Starting from the conditions defined for the choice of the transport variant given by:

a) Transportation material

- the piece material is transported (always)
- ø<100 mm and 200<l<450 mm
- large quantities
- piece weights until 10 kp.

b) Transport parhs

- length: less than 5 m
- movement plane: horizontal
- throughput: high
- width: optional

c) Production conditions

- normal.

d) Material flows

- continuous with the linear layout of work places giving the following variants:

1. VARIANT
transport system with the manual taking, transport and leaving without the use of automatized equipment and transport outfit.

2. VARIANT

   transport system for the manual feeding and leaving the work pieces using the equipment without engine.

3. VARIANT

   transport system that uses various kinds of systems with wheels.

4. VARIANT

   is a transport system of the conveyer type.

THE CHARACTERISTICS OF THE VARIANTS

1. VARIANT

The transportation is performed on the following way: after the processing of the work piece on the production unit the worker puts it into the box (Fig.18) that is put on the table beside the machining unit. The transportation could be performed in two ways:

- production workers
- transport workers.

In the first method every production worker takes the box from the previous machining unit and transports it to his unit, and in the second method the special, transport, workers who do the transportation.

The decision of which of the methods will be used is a function of the number of workers needed. If the transportation time is long than the second method is used, and if it is not the first method is used.

As seen below, special technological charts for transport must be designed because the number of pieces transported in one transport unit depends on the characteristics of pieces.

Transportation time

$$t_t = t_p + t_{pr} + t_o \quad [\text{units of time}]$$

where the times are taken from the technological chart for transport and have the following interpretations:

t_p - loading time

t_{pr} - transportation time

t_o - down time.

The duration of the cycle is

$$T_c = t_t (1+k) \quad [\text{units of time}]$$

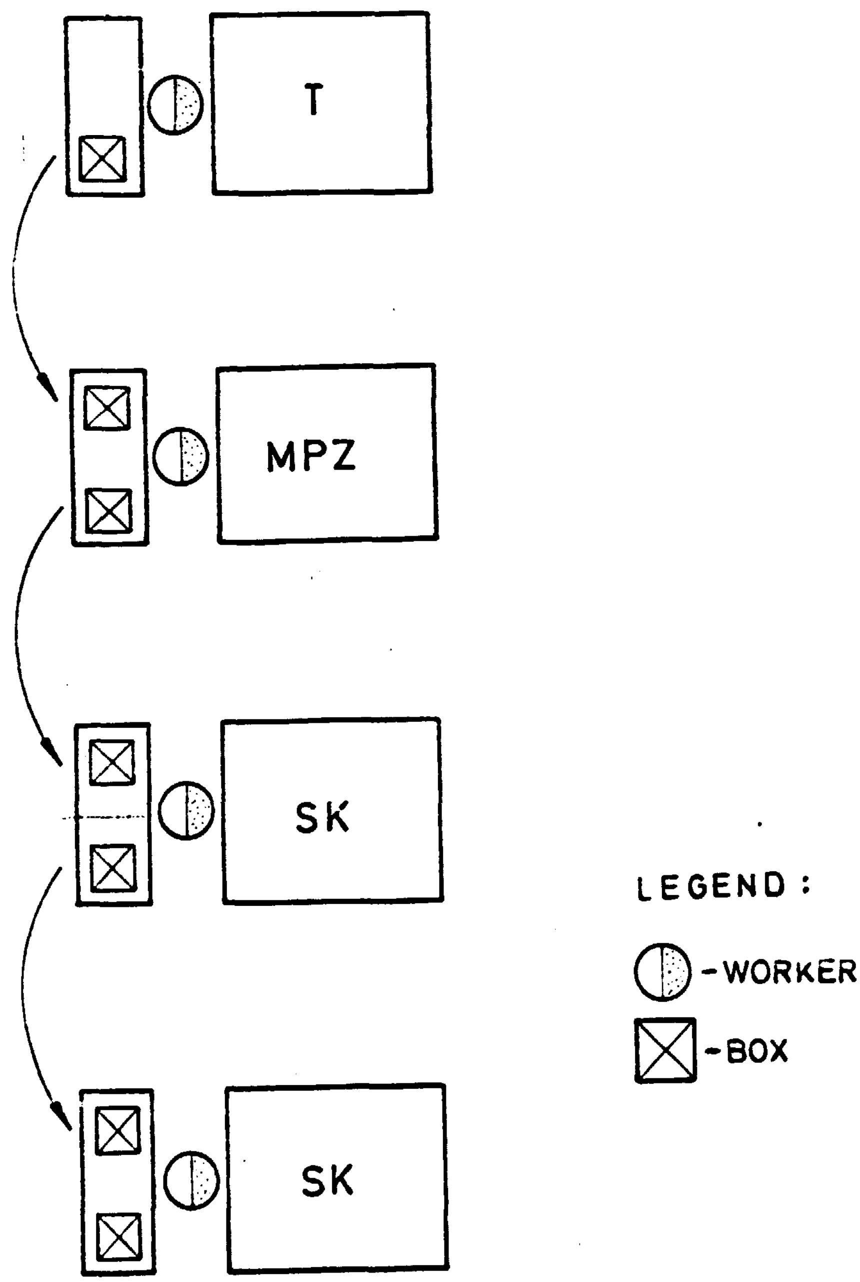


Fig.18 The transporting scheme for the variant 1

ROUTE CHART	product: P1-U 301				
	part	part code	dimens of part	№ of pieces	drawing №

OPERATION		GRASP
№	title	title
1	2	3
1.	transportation from the saw machine (T) to the end working machine (MPZ)	unloading transportation Loading
2.	transportation from MPZ to the copying lathe SK1	-〃-
3.	transportation from MPZ to the copying lathe SK 2	-〃-

Material: dimension	weight designed	technolog	planed	operation group	job groupe	Institute of INDUSTRIAL SYSTEMS
ϕ 12,75 × 200	0,139					

handling	jigs	coord.	№ of parts in transp.	working conditions		time standards			
				l	v	t_{pz}	t_{io}	t_{ip}	t_{id}
4	5	6	7	8	9	10	11	12	13
manual	box		100						
-//-	-//-		-//-						
-//-	-//-		-//-						

2. VARIANT

For the transportation of work pieces from one work place to another there is used the equipment without the engine - here the transporter is of the rolling type.

The transportation is performed in such way that the worker fills the box fixed on the cylindrical transporter and the transportation is done by the transporter. The transportation can be done in two ways:

- production workers
- transport workers.

When using the first method the worker having spent all work pieces takes the box and by the use of cylindrical transporter transports it to his work place. Which of the methods will be used depends on the calculation of the number of workers needed. If the calculation gives a result that it is economically profitable to employ a special worker for the transportation the second method will be used and if not, the second.

The transportation is performed as shown on the scheme (Fig. 19).

As seen on the figure that the cylindrical transporter is put beside the work place and is used for the transportation of work pieces. Feeding and laydown are performed manually.

The transporting operation is divided into grasps as shown on the TECHNOLOGICAL CHART FOR TRANSPORT:

- loading
- transportation
- down.

Transportation time

$$t_t = t_p + t_{pr} + t_o \ [\text{units of time}]$$

where

t_p - loading time

t_{pr} - transportation time

t_o - down time.

The duration of the transportation cycle is:

$$T_c = t_t\ (1+k) \quad [\text{units of time}]$$

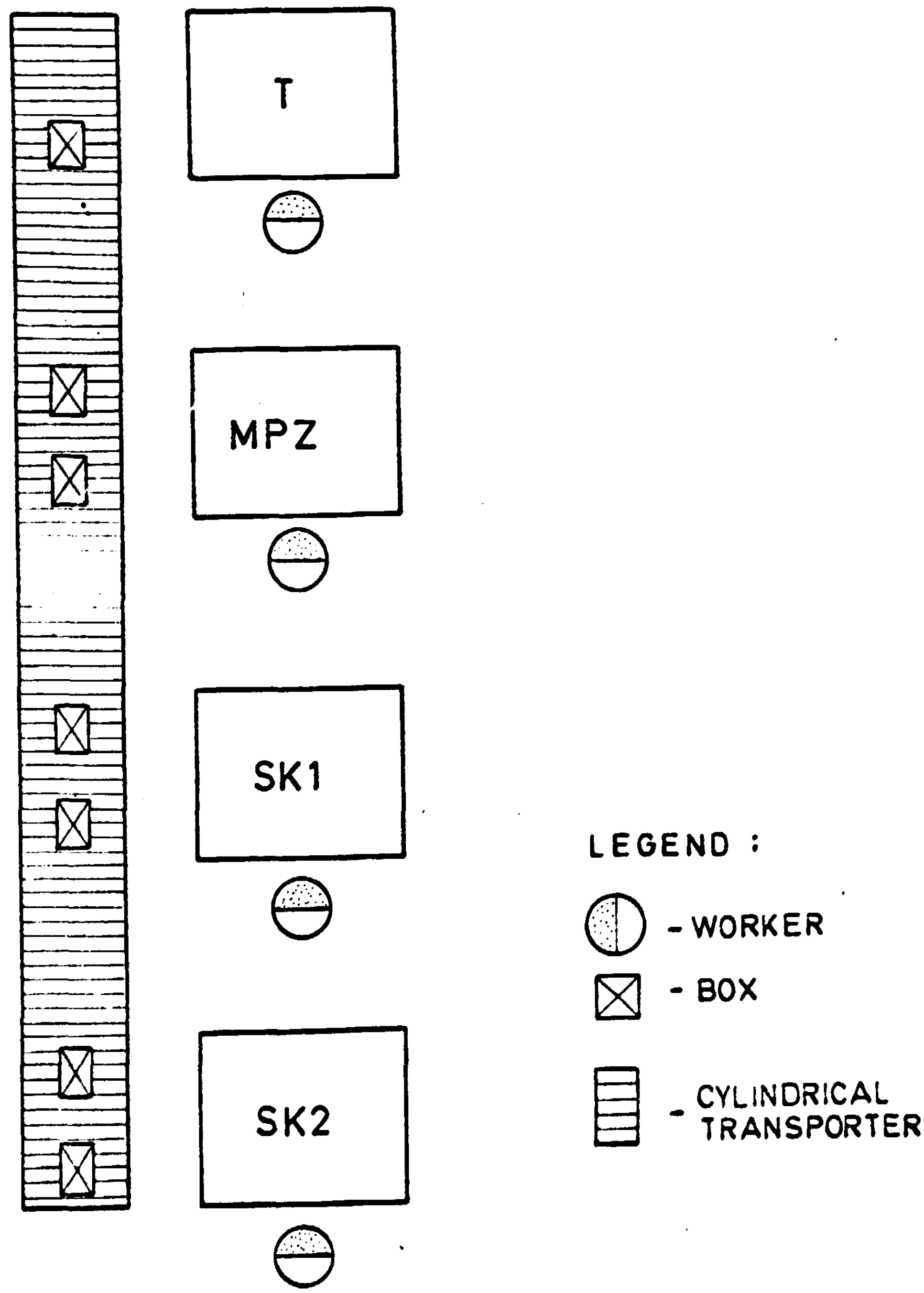


Fig.19 The scheme of transport for the second variant

3. VARIANT

For transportation of work places between work places is used the equipment with wheels. In our case will be used forklift as a means for transportation of work pieces.

The transportation is performed in the following way: beside every work place on the flor or 80 cm above the flor are situated box palette where the parts to be transported are put into. Forklift takes the palette when it is filled and transports it to the next work place. Immeditely after putting away the palette in question forklift takes another one ready for transportation. Such sequence of forklift operations goes this way to the end of the production process-the last machine as shown on fig.20, and, even, to the stock.

From technological charts follows that the transport operation is divided into:

- loading
- lifting
- transportation
- lowering down
- unloading.

Transportation time is:

$$t_t = t_p + t_{po} + t_{pr} + t_s + t_o$$

where

t_p - loading time
t_{po} - lifting time
t_{pr} - transportation time
t_s - lowering time
t_o - unloading.

Here is not used the method of dividing transport operations into usual grasps for practical reasons because t_{po} and t_s are easily measured and the transportation time can be calculated from

$$t_{pr} = L/v_t + t_g \quad s$$

where

L m - transportation distance

v_t m/s - speed of loaded forklift

t_g s - delays when starting or stopping.

Duration of the transportation cycle is:

$$T_c = t_t(1+k) \quad \text{units of time}$$

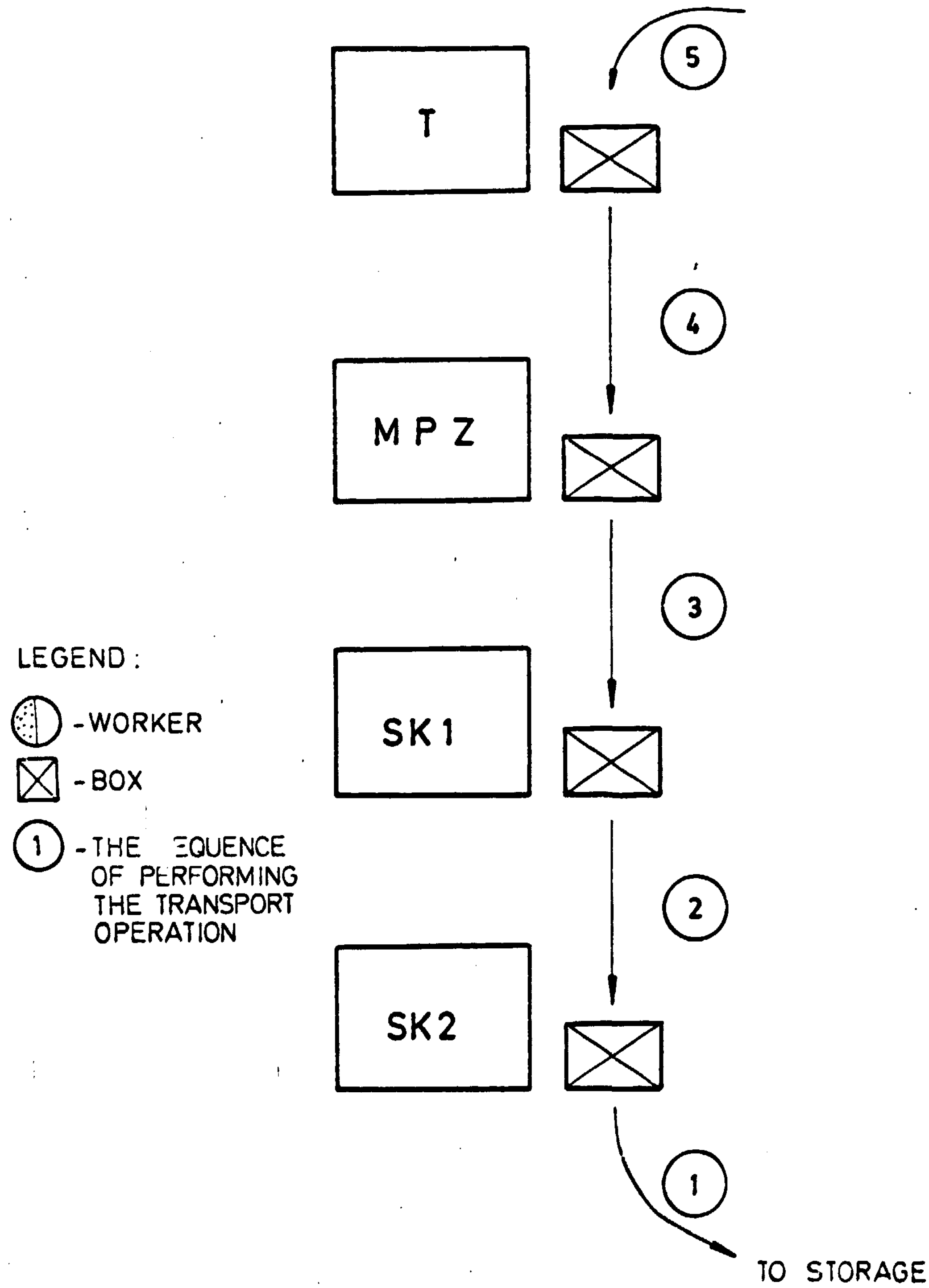


Fig.20 Transport scheme to the third variant

ROUTE CHART	product: P1 - U301					Material:				operation group	job groupe	Institute of INDUSTRIAL SYSTEMS
	part	part code	dimens. of part	Nº of pieces	drawing Nº	dimension	weight: designed	technolog	planed			
						ϕ 12,75 × 200	0,139					

OPERATION		GRASP	handling	jigs	coord.	Nº of parts in transp.	working conditions		time standards			
Nº	title	title					l	v	t_{pz}	t_{io}	t_{ip}	t_{id}
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	transportation from saw machine to the end working machine MPZ	loading lifting transportation lovering unloading	manual forklift -11- -11- manual	box palete		2000 2000 2000						
2.	transportation from MPZ to the copying lathe SK1	-11-	-11-	-11-		-11-						

ROUTE CHART	product: P1 – U301					Material:				operation group	job groupe	Institute of INDUSTRIAL SYSTEMS
	part	part code	dimens of part	Nº of pieces	drawing Nº	dimension	weight designed	technolog	planed			
						ϕ 12,75 × 200	0,139					

OPERATION		GRASP	handling	jigs	coord.	Nº of parts in transp.	working conditions		time standards			
Nº	title	title					l	v	t_{pz}	t_{i}	t_{ip}	t_{s}
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	transportation from SK1 to the copying lathe SK2	loading lifting transportation lowering unloading	manual forklift –11– –11– manual	box palete		2000 2000 2000						

4. VARIANT

For the transportation of work pieces on the line there is used the transport system of conveyer type (INTEGRATED TRANSPORT).

The transport is performed according to the scheme that is shown on the Fig.21, in the following way:

After cutting the part on the saw it is lifted by the mechanical hand (1) and transported to the slipping equipment (2). The parts can be arranged on the slipping equipment in such way that it has a role of buffer stock. Work pieces are then transported to the MPZ using horizontal transporter (3) (which goes through the machine) and after processing they fall to forks (4). Forks rotate in the vertical plane and they put the work pieces on the vertical transporter (5) which lifts them to the feeding mechanism (6). After copying one side on SK1 the work pieces are turned over using the turning station (7) and are transported to the feeding mechanism (8) attached to the copying lathe SK2.

The transport equipment is adapted to machining conditions so that it is not easy to divide the transport operation into grasps. We think that it is simpler and more efficient to measure the total transportation time instead of measuring grasp durations for:

- loading
- transportation
- unloading,

because they are often overlapped. The TECHNOLOGICAL CHART FOR TRANSPORT is made using this principle.

Transportation time

The durations of machining operations are mainly syncrhonised whereby the transport equipment moves in tacts "t" that are determined by the duration of the longest operation. Such kind of flow line is a production track of discrete character, with the compulsory rhytm with the work transporter - - TRANSFER LINE.

Duration of the transport cycle: $T_c = t_t\ (1+k)$ units of time

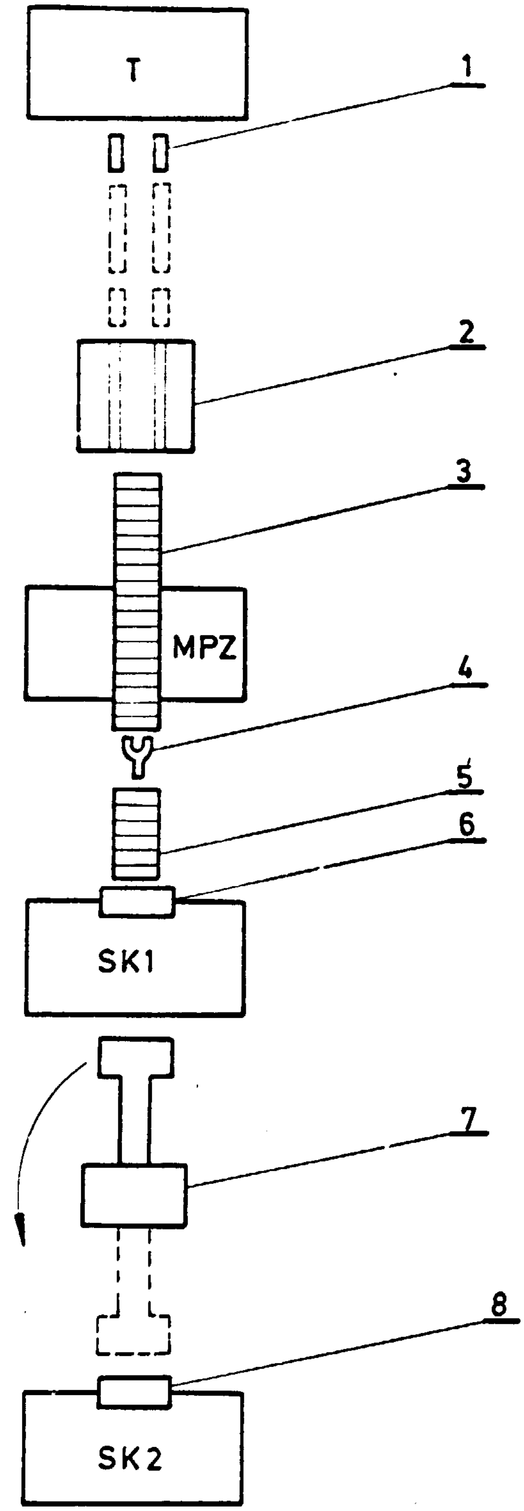


Fig.21 The transport scheme for the forth variant
1-mechanical hand,2-slipping equipment,3-horizontal transporter,4-fork,5-vertical transporter,6-feeding equipment,7-turning station,8-feeding equipment

ROUTE CHART	product: P1 - U301					Material:				operation group	job groupe	Institute of INDUSTRIAL SYSTEMS
	part	part code	dimens of part	Nº of pieces	drawing Nº	dimension	weight designed	technolog	planed			
						ϕ 12.75 × 200	0,139					

Nº	OPERATION title	GRASP title	handling	jigs	coord.	Nº of parts in transp.	working conditions l	working conditions v	time standards t_{pz}	t_{m}	t_{ip}	t_{id}
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	transportation from T to MPZ	unloading transportation loading	manual rolling manual	box		200						
2.	transportation from MPZ to SK1	–"–	–"–	–"–		–"–						
3.	transportation from SK1 to SK2	–"–	–"–	–"–		–"–						

THE VARIANTS OF THE TRANSPORT IN THE FINAL PHASE

The final phase is driving off, storing and dispatching of final product, after the finish of the process, to the final product warehouse and further to the means for exterior transport. Because in our line the last machining unit is a copying lathe SK2, this phase is related to the transport:

- from SK2 to the warehouse
- from the warehouse to the means for exterior transport.

Bearing in mind the facts that stand for the preparation phase and the machining phase we can conclude that there are applicable two transport variants e.g.:

1. VARIANT

The transport system with the mannual taking, transfer and leaving of the work pieces without the use of mechanical equipment and other means for transportation.

2. VARIANT

The transport system that uses various kinds of transport equipment with wheels, in our case forklift.

Since both variants are already explained in the transportation for technological phase, it will be ommited.

Thus, only TECHNOLOGICAL CHARTS FOR TRANSPORT are constincted, because they differ from previous ones and they are made for both variants together.

In order to store the final parts at the end of the technological phase there is used a warehouse where the parts are to be put and taken from by the use of the forklift.

ROUTE CHART	product: P1 – U301					Material:				operation group	job groupe	Institute of INDUSTRIAL SYSTEMS
	part	part code	dimens. of part	№ of pieces	drawing №	dimension	weight designed	weight technolog.	weight planed			
						ϕ 12.75 × 200	0.139					

OPERATION №	OPERATION title	GRASP title	handling	jigs	coord.	№ of parts in transp.	working conditions l	working conditions v	time standards t_{pz}	time standards t_{is}	time standards t_{ip}	time standards t_{id}
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	transportation from T to MPZ		horizontal transporter	– slipping equipment – mechanical hand		1						
2.	transportation from MPZ to SK1		vertical transporter	fork		1						
3.	transportation from SK1 to SK2		turning station	dispatching lever								

ROUTE CHART	product: P1- U301					Material:				operation group	job groupe	Institute of INDUSTRIAL SYSTEMS
	part	part code	dimens of part	№ of pieces	drawing №	dimension	weight designed	technolog	planed			
						Φ 12.75 × 200	0.139					

OPERATION		GRASP	handling	jigs	coord.	№ of parts in transp.	working conditions		time standards			
№	title	title					I	V	t_{pz}	t_{io}	t_{ip}	t_{id}
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	transportation from SK2 to storage	lifting transportation unloading	manual -11- -11-	box		100						
2.	transportation from SK2 to storage	-11-	forklift	box palete								

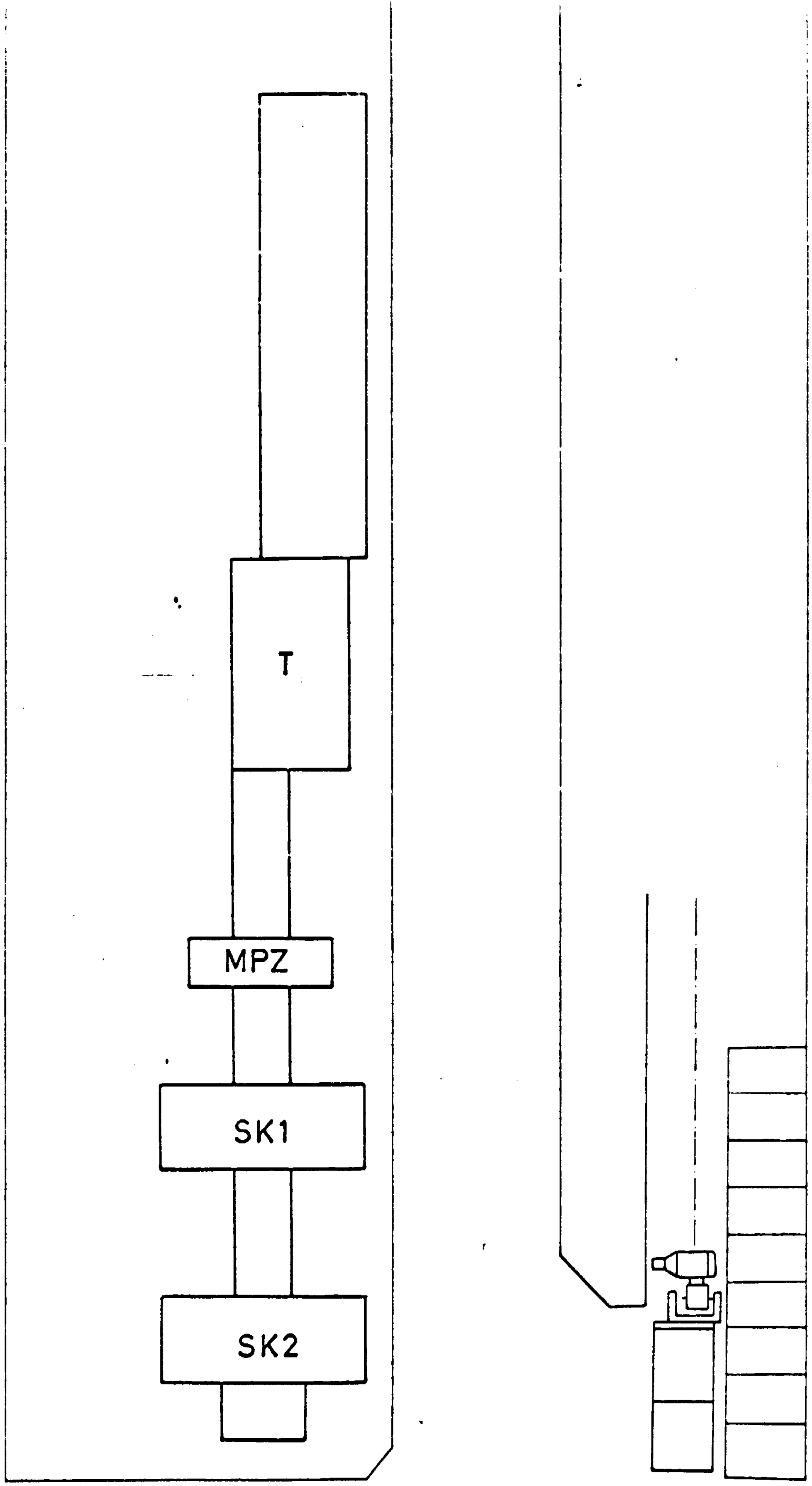


Fig.22 The scheme of the production system with the warehous

.2.3 The methodology for the investigation of relationships

For every variant described, the components of the total transportation time such as

- lifting time t_{po}
- loading time t_p
- raising time t_d
- unloading time t_o
- transportation time t_{pr}
- lowering time t_s

can be determined using the method of predetermined times, analytically or by measuring using chronometer. Thus, for every transport operation these times can be written into the TECHNOLOGICAL CHARTS FOR TRANSPORT described before.

The total transportation time is a intermediate operational time(t_{mpi}) and it is a component of the duration of the production cycle (T_{cp}) that is influenced, apart from t_{moi}, as well by the mode of transfer of work pieces from one operation to another. Thus,

1. For the parallel mode of transfer

$$T_{cp}=T_{ct}+\Sigma t_{moi}=\Sigma t_{ii}+(n-1)t_{i_{max}}+\Sigma t_{moi}$$

where

T_{ct} - technological cycle (the sum of machinig times)

.2 For the series-parallel mode of transfer

$$T_{cp}=T_{ct}+\Sigma t_{moi}=\Sigma t_{ii}+(n-1)t_{i_{max}}+\Sigma\tau_i+\Sigma t_{moi}$$

where

$\Sigma\tau_i$ - delay at the machine that is determined analytically

.3 For the serial mode of transfer

$$T_{cp} = T_{ct} + \Sigma t_{moi} = n \cdot \Sigma t_{ii} + \Sigma t_{moi}$$

where

t_{ii} - the duration of the operation as explained in chapter 1, and the data can be found in TECHNOLOGICAL CHARTS FOR MACHINING.

.2.4 The Courses for the Specialists from Industry

As a part of the work in the Laboratory for the Time and Labour Measurement the following courses will be organized:

COURSE 1: LABOUR PROCEDURES IN MECHANICAL ENGINEERING

Part 1.1 - labour procedures and control
- the basis for procedures development
- the widening of the labour area and the selection of alternatives
- labour duration and time cycles
- ergonomy and work conditions
- case study

Part 1.2 - labour and time measurements
- the techniques for measuring time
- case study

Part 1.3 - interrelationships in the work process
- the motivation
- the satisfaction in the work
- case study.

In the area of production systems there will be organized the following courses.

COURSE 2::INTEGRATED MATERIAL FLOWS AND THE LAYOUT OF THE SYSTEM COMPONENTS

Part 2.1 - the basic principles of the establishment of production systems

- the general model of material flows - group technology
- the methods and techniques for the layout of system components
- case study

Part 2.2 - material handling
- stocks and warehouses
- the transport equipment and storing
- case study

Part 2.3 - simulation technique as a means for the development of alternatives in the area of modelling of production systems,
- the computerised layout of work places
- case study.

Since the duration of the production cycle T_{cp} is equal:

$$T_{cp} = T_{ct} + \Sigma t_{moi}$$

where

T_{ct} - technological cycle (the time spent in the machining process) that depends on the mode of transfer from one operation to another as well as on the flow type

$\Sigma t_{moi} = \Sigma t_t$ - transportation time in the preparation, technological and final phases that depends on the variant of the transport system.

The influence of the variant of the transport can be determined on the duration of the production cycle using the relevant information for the variant of the transport system, the mode of transfer and the batch size.

The relevant information is collected from the particular TECHNOLOGICAL CHARTS FOR MACHINING AND TRANSPORT as well as from sheets with analytical calculatioss and the information is wirtten into the PROCESS FLOW CHARTS as a basic document and the container for these informations.

2.3 THE INVESTIGATION OF THE TRANSFER-LINE EFFECTIVENESS

On the transfer-line with the outfit described in the chapter 2.1.2 and The Production Systems Laboratory there are performed:

- fundamental research
- education for undergraduate and graduate students
- courses for specialists from the industry (transfer).

.1 Fundamental Research

When designing an automatical processing line in the mechanical engineering it is necessary to make several decisions of various factors and limits. In this work will be considered some of the technico-technological and economical aspects of design of lines (AOL) such as:

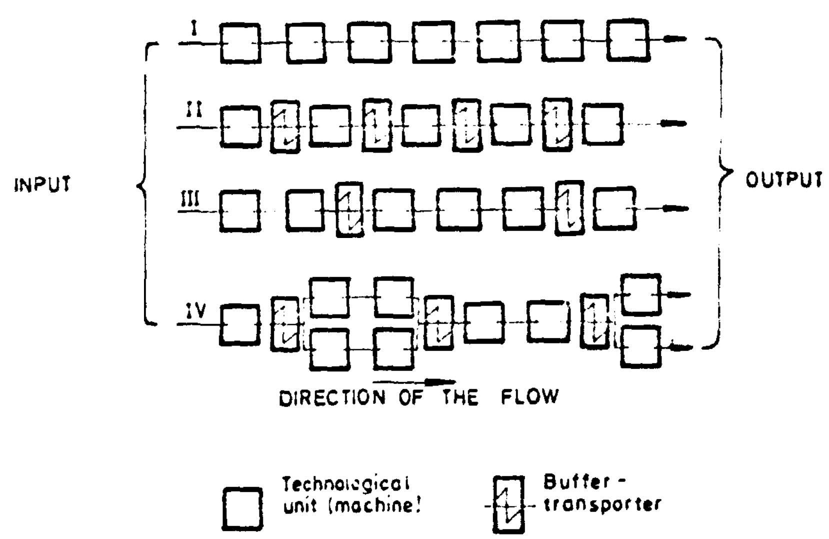
- number of sections (machines) in the line (necessary) that provides the maximal effectiveness
- the installation sequence - dividing into sections and layout
- the stock capacity needed between sections
- the stock capacity allocation between sections (buffers)
- the influence for buffers on the line effectiveness
- if the buffer will be filled after emptying during the downtime etc.

Each of these decisions can be analysed from the aspect of tis limits and completely depends on the technical possiblities of the line such as the unit time of machining and the characteristics of the line in FAILURE (location and duration of the failure).

The technical limits hava a great impact on the decision making in question. With regards to these decisions it is possible to minimize the own costs and the costs of the line operation (with constant costs of the workers' labour - operators and maintenance) or to maximize the limit profit provided by the operation of the line (with variable operator's labour costs).

Automatical machining (production) line AOL or the transfer line in the mechanical engineering is defined as a sequence of the automatical (mechanically controlled) production stations which are mutually connected. The aim of AOL is production (machining) of a certain product or group of products that are similar geometrically and tehcnologically.

The line is IN WORK when there is an output on the last station. Otherwise the line is IN FAILURE. On the Fig.23 there are given various types of lines. Every machine (section) in the line is a potential source of failures that are randon. The causes of failures can be various. The consequences are always the same - decrease of the effectiveness of the line.



I strongly connected - block line
II machines and buffers alternatively
III erroneus allocation of buffers
IV partial parallelnes of the line

Fig.23

Apart from the basic states (IN WORK, IN FAILURE) the line cnn be in a state FORCED SLOWDOWN (waiting).

The possibility of making stocks between two sections is called BUFFER. The maximal number of units of products that can be put into the buffer and is called capacity. The buffer has a role to neutralise the states IN FAILURE, e.g. increasing the reliability, that has an impact on the effectiveness increase. Buffers are not loaded before the start of the production.

The limit types of lines: block-line (without the buffer, w.g. with the stock capacity 0) and the line with the unlimited (infinite) stock capacity are in the first case rear and in the second imaginary (impossible).

The machining time (production time) for the product unit on every particular station in AOLE is considered to be constant principally it si the normal distribution but the coefficient of variation is very small so that the above approximation is valid).

The transportation time for the production unit (semi--final product) between stations is neglogible or can be added to the machining time. The effectiveness of lines can be expressed in several ways, such as:

1. technical effectiveness

$$E_t(t) = R(t) \cdot P(t) \cdot F_p$$

or as a product of availability, reliability and functional capability that will be described in chapter 3.0.

2. productivity or the output of products from the line

3. availability

$$k_g = \frac{\bar{\theta}}{\bar{\theta} + \bar{\nu}}$$

that is, also, described in chapter 3.0.

4. the ratio of times IN WORK and IN FAILURE

$$E = \frac{P_o(0) - P_o}{P_o(0) - P_o(\infty)}$$

where

P_o - time percentage IN FAILURES for the line

$P_o(0)$ - time percentage IN FAILURE for the line without the buffer

$P_o(\infty)$ - time percentage IN FAILURE for the line with unlimited (infinite) fuffers

5. economical effectiveness

as a difference between the total income (brutto) and total costs

$$DOH = BUP - \sum_{i=1}^{n} T_i$$

6. the product of technical and economical effectiveness or some other combination or measure of the effectiveness of the work of the line.

In investigations the following questions are of interest:

1) Whether to use process stocks-buffers

Effectiveness of the buffer e_B depends on the buffer capacity and the way of dividing the line into sections, and does not depend on the undivided (block) line, so that when the effectiveness of the line is high, the increment of the effectiveness by using the buffer is small. For instance, the same buffer capacity qill increase the effectiveness of the line from 0,70 to 0,85 or from 0,90 to 0,95. Thus, if the effectiveness of the line is high the buffers are useless.

The buffer capacity calculation is necessary only when slowdowns of the line are a result of failures in stations without buffers only, and not a result of tool shortage, resources shortage or energy shortage e.g. external factors. In the opposite the buffers will not have any considerable impact on the line effectiveness.

When considering the line effectiveness it is necessary primarily to analize the causes and consequences of failures and theirs duration, distribution etc. Consequently there must be tested the criteria shown in previous chapters in order to determine the maximum gained by the use of buffers.

2) On how many sections the line should be divided?

Generally, providing processing stocks(using the buffers) incorporates important fixed (investment) costs that do not depend on the buffer capacity. This is caused by the necessity to maintain the flow of work pieces - e.g. special equipment for the transfer (transport) of work pieces from one buffer to another. From the fig.7 it can be seen that the advantage of using every additional section decreases and can be even negative (e.g. loss) if the buffer capacity is too small.

From the above it can be concluded that the number of sections must decrease the costs of both stocks and that the number of dividions (to sections) must be small.

It is difficult to prove that building the lines with more than 5 sections can be justified.

3) Between which sections must the buffer be put?

On Fig.2 and 5 is shown the optimization of the division of the line into sections. From these figures it can be gathered that the effectiveness is not sensible to the changes in number of sections in the line. It is better to keep the failure rates of the first and the last sections higher than those on the middle ones because otherwise [illegible] line is divided primary on the basis of technico-technological considerations.

4) How to divide the total buffer capacity, e.g. what is the necessary buffer capacity?

The necessary buffer capacity must be such that at [illegible] satisfies the mean time in failure for the previous section. Because the size of the buffer capacity necessary for the improvement of the line work is sensible according the change of the repair time distribution (this always has to be proven) it is recommendable that the buffer capacity sholud not exceed five times the mean repair time. This can'not be justified by the fact that the marginal costs of the extra-capacity could be negligible. It is necessary to analyze some other parameters such as the space (area-volume necessary), transporters etc.

a) OPTIMIZING AOL

.1 Theoretical considerations

Consider a line with n stations without buffers, the so called block-line e.g. AOL with strong commections between machines.

Let P_{oi} be a percentage of time in failure for the i-th station when the machines are independent (e.g. the failure of i-th macnine do not cause the failure of the j-th machine).

The percentage of time IN FAILURE for the station that works in the buffered line with limited stock decreases because the station will periodically enter the state FORCED SLOWDOWN (failure, for instance waiting for job). Here is assumed that the station can not be in failure if forces to slowdown.

Without buffers the forces slowdown lasts until any of machines fails.

Divided to observation period T of the line without buffers into n intervals that represent moments of the failure for every station (when one station is in failure and others in forced slowdown) and one interval where all stations are IN WORK. The intervals IN FAILURE will be labeled by t_{oi} and interval IN WORK by $\theta = \Sigma t_{ri}$, as shown on Fig.24.

The times t_{oi} are put into a sequence just because of simplicity and do not have any implications on the sequence of failures.

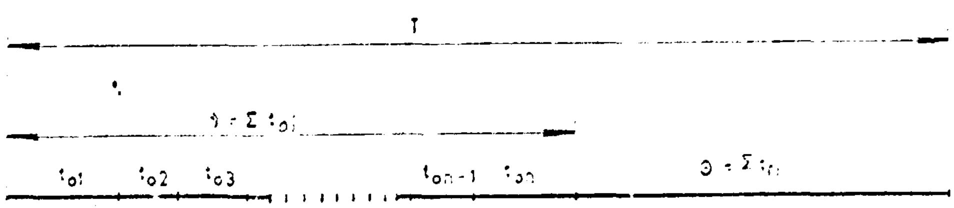


Fig. 24

Clearly,

$$P'_{oi} = \frac{t_{oi}}{\theta + t_{oi}} \quad |\%| \qquad \text{A}$$

and

$$\Sigma t_{oi} + \theta = \nu + \theta = T \qquad \text{B}$$

If t_{oi} is a percentage of time IN FAILURE for the i-th machine in the line then

$$P_{oi} = \frac{t_{oi}}{T} = \frac{t_{oi}}{\theta+\nu} = \frac{t_{oi}}{\theta + \sum_{j=1}^{n} t_{oj}} \qquad \text{C}$$

From the expressions A and C

$$P_{oi} = \frac{\frac{P'_{oi}}{(1-P'_{oi})}}{1 + \sum_{j=1}^{n} \frac{P'_{oj}}{(1-P'_{oj})}} \qquad \text{D}$$

orć

$$P_{oi} = \frac{P'_{oi}}{1 + (1-P'_{oi}) \sum_{j \neq 1} \frac{P'_{oj}}{(1-P'_{oj})}} \qquad \text{E}$$

The time percentage IN FAILURE for the entire line without buffers is a sum of percentages IN FAILURE for machines, e.g.

$$P_L(0) = \Sigma \frac{P'_{oi}}{1 + (1-P'_{oi}) \sum_{j=1} \frac{P'_{oj}}{(1-P'_{oj})}} \qquad \text{F}$$

If we consider the AOL with n machines connected with buffers with infinite capacity then the above considerations of the time percentage for the line that do not product are the same as for the station with maximal percentage of time IN FAILURE e.g.

$$P_L(\infty) = \max_i (P'_{oi})$$

If the experssions F and G are calculated for a particular line then the difference $P_L(\infty)$, and $P_L(0)$ is a maximal percentage of the productivity (output) increment of the line:

$$\Delta Q = P_L(\ ) - P_L(0) \qquad H$$

FINICH 30 gives two expressions for the effectiveness of the line with two stations - for the "balanced" line ($U_1=U_2$) and "unbalanced) line ($U_1 \neq U_2$), whereby $U_1=\lambda_1/\mu_1$ and $U_2=\lambda_2/\mu_2$.

The number of parts in the buffer for the "balanced" line with two stations is (formula from 30)

$$N = \frac{2(h/\mu)}{\frac{(1+u)}{\Delta} - (1+u)} \qquad I$$

where

$U = U_1 = U_2$

ΔE - increment of the effectiveness

The expression for N is a linear function of the ratio h/μ and can be presented as on the Fig.25.

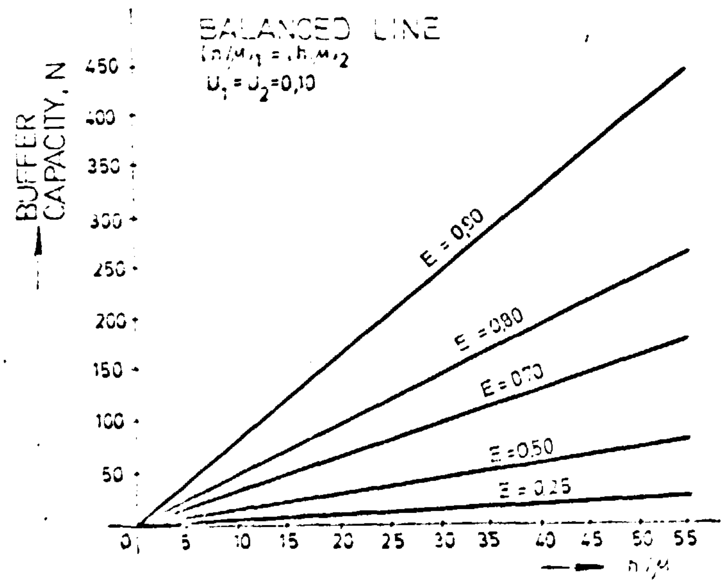


Fig. 25

These results should not be surprising. It must be expected that the buffer capacity increases with the increase of the mean time IN FAILURE because it means that the system must fill the buffer almost all the time. The same stands for the decrease of the production time for the unit of product. It seems reasonable that the expected buffer capacity for the product that is processed for say $t_{cp}=2$ sec is twice as small as for the product with $t_{cp}=1$ sec, naturally under the same line effectiveness.

For large values of E, which is of special interest as well as small values of u that present the degree of line utilization the necessarc buffer capacity is relatively unsensible to the exact values of u. For instance, for E=0,8 the change of u cross the factor 5 from 0,10 to 0,02 the divisor in the expression I changes with the factor of only 1,4.

.2 The line with three sections

For lines with more than two sections there will not be given the general solution for the ratio of stocks and production and the persepctives of solving are not clear so that the special attention must be devoted to the limitations because the problem becomes too complex.

Because every section can be found in one of the following states

- IN WORK
- IN FAILURE
- IN FORCED SLOWDOWN (waiting)

The line with n sections can be found in one of 3^n states.

Naturally, this number of states contains also a certain number of impossible states such as, for instance, "all stations in the FORCED SLOWDOWN" but these form just a little fraction of 3^n states.

The line considered here is composed of 4 sections so that the total number of sections (including impossible ones) is 81.

It is possible to obtain the quantitative results for the line with three sections by the use of digital simulator developed by FREEMAN 40 in the programming language ALGOL (This simulator will not be considered here).

The investigations of the necessary buffer capacity for the balanced line were performed when the times IN WORK and IN FAILURE are the same for all three stations.

The next step is how to allocate the total buffer capacity between sections if they are not balanced?

The simulator has slown that, as in the case of 2-sectional line, the necessary buffer capacity between sections of 3-sectional line (capable of producing the given effectiveness increase E), is a linear function of the ratio h/μ as shown on Fig.26.

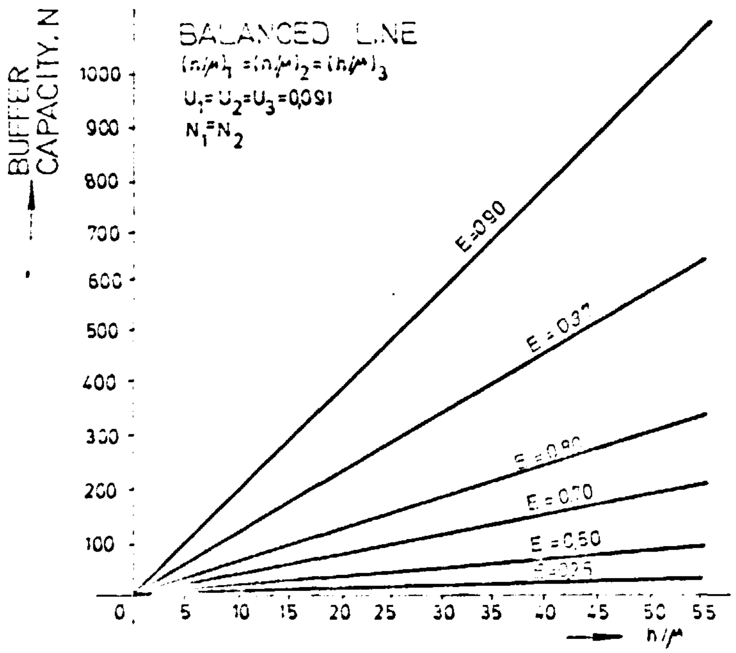


Fig.26 The influence of the effectiveness of the 3-sectional line on the buffer capacity

Basically the same curves are obtained for values 1/λ ranged from 1 to 10, 1/μ ranged from 10 to 100 and U from 0,05 to 0,20. On the Fig.26 the value of U is 0,10. The values of N would increase by 10% if U=0 and decrease by 10% if U=0,02 with the proportional tunning.

The same argument concerning linear relationships, considered with 2-sectional hold also for the 3-sectional line. Although it can not be proven it seems reasonable to expect that such (linear) ralationships should be held for the line with n secitons.

On the Fig.27 there is given a comparison for the 2- and 3-sectional lines.

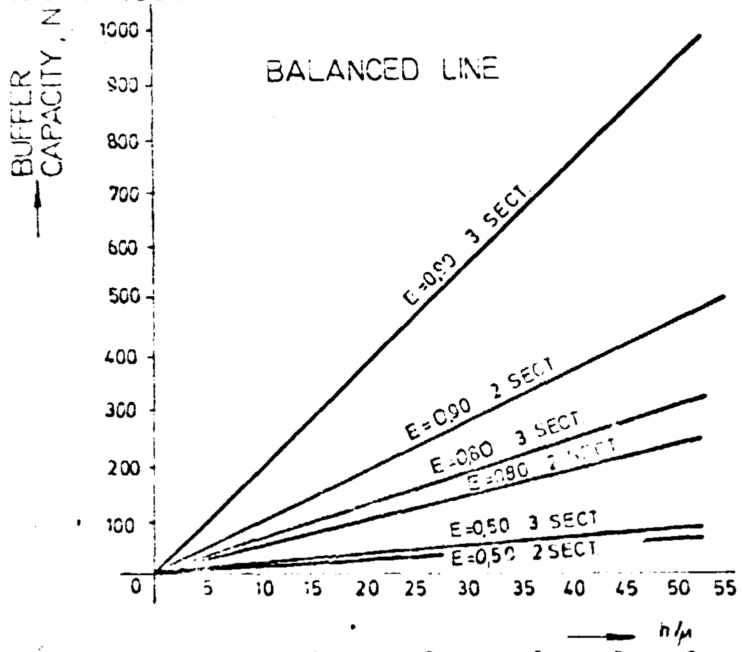


Fig.27 The comparison of results for 2- and 3-sectional lines

For the low values of E the differences in the necessary value of N are small, but for the values such as E=0,90 the difference is of the order 2 times. Unfortunately, it seems that when the number of sections increases there arises the need for buffers with the infinite capacity for high values of E.

The simulation shows that the value of U has smaller impact on the necessary value hor N_i for the 3-sectional then for 2-sectional line.

For the multisectional lines without analytical formulation the linear property of the necessary buffer capacity has an extremely important practical significance. Therefore, the informations about the system can be obtained for every ratio h/μ from the graph of the effectiveness increment related to the buffer capacity, Fig.28.

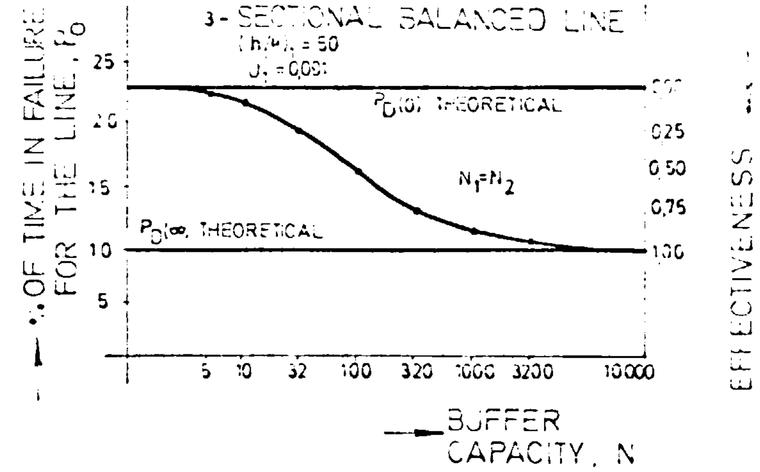


Fig.28 The effects of buffer capacity because of decrease caused by line failure

It should be noted that Fig. 26 and Fig.28 are usable together (for Fig.28 $h/\mu=50$).

For instance, let h/μ be known for the line and that it is necessary to determine the effectiveness increase derived from the buffer capacity N_i. On the Fig.26 the point $(h/\mu_i, N_i)$ is fixed, then the line is drown from the eeggining of the coordinate system through that point until the intersection with the line $h/\mu=50$. The value of N in that point is used on Fig.28. From the Fig.28 the effectiveness increase can be read directly.

Alternatively, the buffer capacity can be determined that provides the effectiveness increase E for a system with known h/μ. In that case E is put on the FIG.28 and the buffer capacity is determined for $h/\mu=50$.

The value of N is found on the intersection of the line $h/\mu=50$ on Fig.28 and the line drawn through the beggining of coordinate system.

If AOL is not balanced, the problems arise for decision making which of the buffer capacities is to be used, how do determine the effect of variable sections and the mode of the buffer allocation between sections. The approximate effectiveness obtained for the given total buffer capacity when optimally alocated can be determined by dividing the capacity by the number of the average h/μ of the line as the parameters of the theoretically balanced line. The method described in the previous part is appropriate for this goal.

The simulation of results shows that for every reasonable distribution of the buffer capacity is better when the production technology allowes to exist a good section (which is rearly IN FAILURE) and a bad section that are situated immediately one after the other in a 3-sectional line than to allow them to be separated by the middle section. The maximum possible increment for the given total capacity of the buffer is always higher for the former system.

One must always insist that, if possible, the BAD section in the line must be surrounded by GOOD sections. For the fixed buffer capacity if (before and after) the bad section this decreases the FORCED SLOWDOWN time as much as possible. The forced slowdown of the bad section is already a limitting factor in AOL because of its own FAILURE states.

The results of the simulation show clearly that the correct allocation of the total buffer capacity is important for consideration. This is particularly time for the large buffer capacities. The erroneus allocation of large buffers can totally eliminate their potential ability to increase effectiveness, Fig.29.

It is possible to generalize some considerations on the basis of simulation.

1. to avoid extremal allocations such as that between certain sections there do not exist buffers and the rest of capacity to be spread between other sections,
2. it is worse from the bad section (compared to the good one) if the bigger part of the capacity is allocated to the bad section (behind it),
3. the main part of the capacity should be allocated between the bad and the average (or between two bad) sections rather than between the good and bad ones.

It is worse if there are two bad sections and a main buffer capacity (Fig.29).

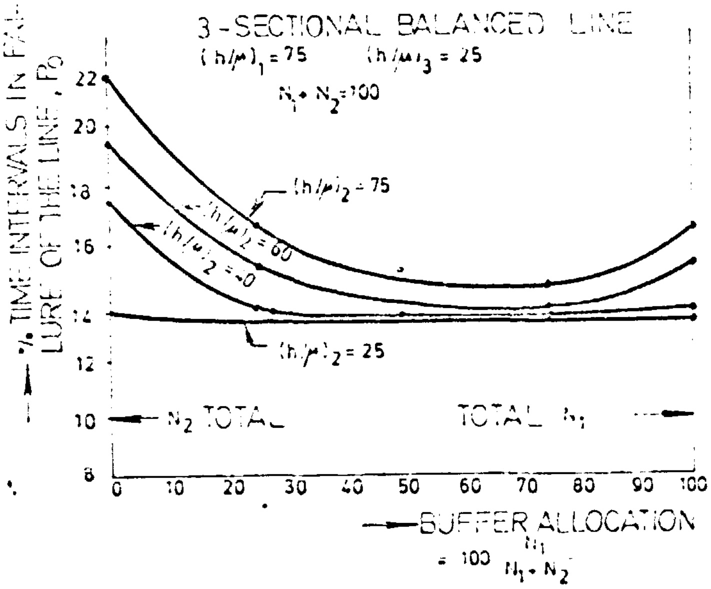


Fig.29 Buffer capacity allocation between bad sections

4. the optimum of the relative allocation is basically invariant with the variation of the total buffer capacity,

5. the end of the line is more critical then the legging. If the bad section (machine) is towards the end of the line the total capacity will be bigger.

.3 Lines with more than 3 sections

If the line consists of more than 3 sections it is necessary to have larger capacity between sections to maintain the same effectiveness increase. On Fig.27 is seen that if changing from 2-sectional towards 3-sectional line the difference in the buffer capacity required N_i is significant only for very high values for the given effectiveness E. It is reasonable to expect the similar behaviour of the line with more than 3 sections. Thus, there can be expected proportionally bigger increase of the capacity required from 2-sectional towards 3-sectional line than, for example, from 3-sectional towards 4-sectional because the buffer line represents proportionaly samller increase over the number of sections.

here is noticed the reaction of the effect of increasing the independency of sections when they become independent with more and more medium sections and buffers. In every case it is necessary to evaluate the necessary buffer capacity with more than 3 sections on the basis of 3-sectional line.

.4 Further considerations of the optimizing problem for AOL

If the line contains one bad section on all the others basically equivalent, there will be smaller number of units of production in the increase that is provided by the buffer capacity. The reason for this is when a bad section becomes relatively worse $P_o(0)$ and $P_o(\infty)$ and $P_o(\infty)$ tend to each other. This depends on the real value of the mean time IN FAILURE. The formulation of this effect is derived from the difference between $P_o(0)$ and $P_o(\infty)$. The results are ahown in Fig.30.

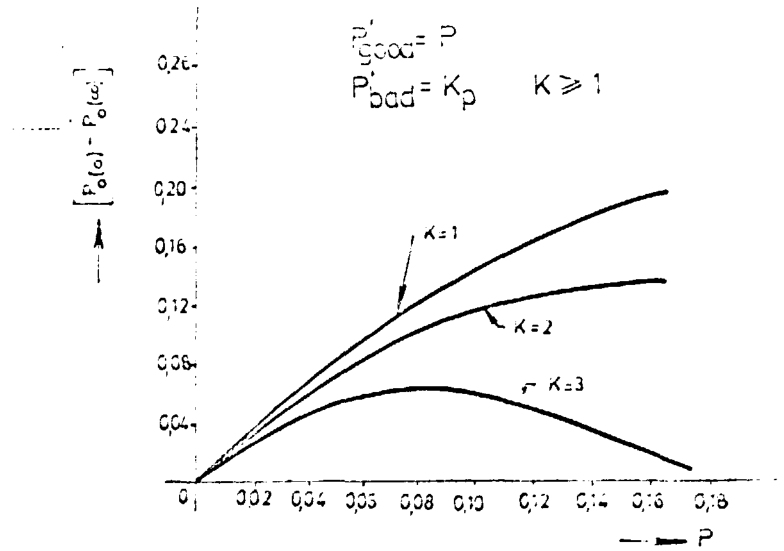


Fig.30 The influence of the bad section on the possible increase of the effectiveness of the line

It is of interest to evaluate the total effects of this deviation.

The machining times can not be constant from the product to the product on all sections.

In that case the buffers must absorb not only the fluctuation of the quantity of product caused by FAILURES but also those quantities caused by the randomness of the machining times for product units (from the production programme). This increase in influence of RANDOMNESS in the system is dangerous (harmful) related to the working time of the line because it decreases the total production capacity.

If the times IN WORK and IN FAILURE have distributions less random from the exponential it is useful to the system in a sense of decreasing the total buffer capacity. The necessary buffer capacity is certainly a monotonically increasing function with the change of distributions of time IN FAILURE.

Using the results of quening theory we feel that when changing the distributions from exponential to constant the buffer capacity decreases at a rate of two.

The main importance of this assumption is a conclusion that the necessary size of the buffer is relatively senseless to the change in a distribution of the time IN FAILURE.

Practically, it is unconvinient to take into consideration the distributions that are much less random then the exponential.

.5 Economical aspects of optimization

The final composing and installing the line is highly dependent on the unit increment in the production, e.g. economy of the production. It seems that this conclusion holds with the sufficient accuracy. The value of the extra unit of production can be composed of several different elements of price.

In the majority of applications it can be expected that the price or value is considerable if it is taken together with the following effect of the well-designed line:

a) decreasing the overtime work

b) decreasing the batch preparation time

c) decreasing the inter-phase (process) stock

d) decreasing the final products stock

e) better utilisation of the seivers work (operators and maintenance)

f) increasing the equipment capacity.

It is clear that those elements must be quantified.

The designed value of the production capacity increase together with the methods and considerations performed before and, naturally, certain, unavoidable, technical limits can be used as a help during the AOLE design.

In further cinsiderations there will be covered the problems of the economy during the design and exploitation of the AOLE.

.6 Effectiveness of AOL

.1 Block line (without buffers)

The line with n stations has the mean REPAIR time for the i-th station equal to $\bar{T}_0$. Suppose that the working time of this station follows geometrical distribution with the mean $1/\lambda_i$. The value of λ is a probability of the failure in the previous cycle e.g. the failure rate.

Let T be the time period in which the station is in WORK for θ units of time.

During the period T the line will have the total number of FAILURE states

$$n = n_1 + n_2 + \ldots + n_n$$

where n_i is a number of failures for the i-th station during T. The total time IN FAILURE is

$$\nu = \sum_{i=1}^{n} n_i \cdot \bar{T}_{oi}$$

The expected value of n_i is

$$n_i = \lambda_i \cdot \theta$$

So

$$T = \theta + \sum_{i=1}^{n} \lambda_i \cdot \bar{T}_{oi} \cdot \theta$$

where

$\Sigma a_i T_{oi} \theta$ is a total time IN FAILURE.

The effectiveness of the line is

$$E_o = \frac{\theta}{T} = \frac{\theta}{\theta + \sum_{i=1}^{n} {}_i\bar{T}_{oi}\theta} = \frac{1}{1 + \sum_{i=1}^{n} {}_i\bar{T}_{oi}}$$

If the repair times for every line are equal T_0=const. then

$$E_o = \frac{1}{1+\lambda\bar{T}_o} .$$

.2 *The Lines with Infinite Buffers*

This structure coresponds to the line whose stations are completely independent.

The effectiveness of the line $E\infty$ is equal to the minimal *effectiveness of the station e.g.*

$$E\infty = \min_i |E_i| \text{ or ing. } |\varepsilon_i| \text{ - inferior}$$

where

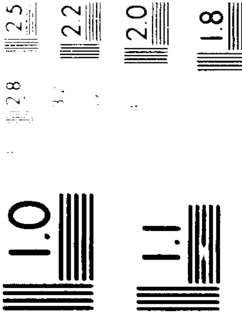
$$E_i = \frac{1}{1+a_i\bar{T}_{oi}}$$

whereby $\bar{T}_{oi}$ is a mean repair time for the station (it is supposed that it is equal for all stations in the line), and $1/\lambda_i$ is a mean time in work for the i-th station.

Clearly, the necessary effectiveness of the line belongs to

$$E_o < E_L < E\infty$$

and has a corresponding buffer capacities.



1.0
1.1
1.8
2.0
2.2
2.5
2.8


1.25
1.4
1.6

.3 The Line with 2 sections

If both sections have the same effectiveness the effectiveness of the line can be expressed as

$$E_L = E_o + P_1 h(z) \text{ or}$$

$$E_L = E_o + P_2 h'(z)$$

where P_1 and P_2 are the portions of T when the first and second sections are under repair, respectivelly, h(z)-portion of the time in T when the first section is under repair, but the line is IN WORK and h'(z) is a portion of the time T when the second station is under repair and the first section is IN WORK.

It can be written

$$h'(z) = \frac{P_1}{P_2} h(z) = \frac{\lambda_1 \bar{T}_{o1}}{\lambda_2 \bar{T}_{o2}} h(z)$$

Two cases are possible:

a) the repair time distribution is GEOMETRICAL

1) $\bar{T}_{o1} = \bar{T}_{o2} = \bar{T}_o$

2) $\bar{T}_{o1} \neq \bar{T}_{o2}$

b) the repair time distribution is CONSTANT

$$\bar{T}_{o1} = \bar{T}_{o2} = \bar{T}_o$$

The approximation $\lambda_1 \cdot \bar{T}_{o2} << 1$ e.g. $\lambda_2 \bar{T}_{o2} << 1$ is acceptable. On the Fig.31 h(z) is shown as a function of $r = \lambda_1 / \lambda_2$ when the stations have identical a) geometrical and b) constant distributions, $\bar{T}_{o1} = \bar{T}_{o2} = 20$ and z=40 (buffer capacity).

If $\lambda_i \cdot \bar{T}_{oi}$ is not small the bufferless line has the effectiveness smaller than 50%.

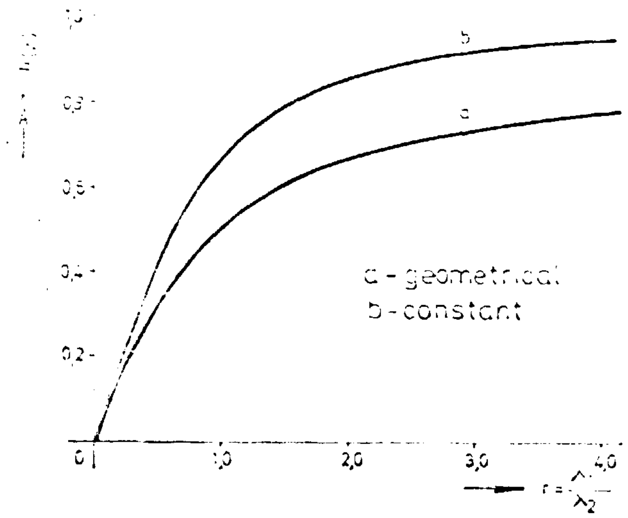


Fig.31 Relationship between h(z) and $r=\lambda_1/\lambda_2$ for $z=40$, $\bar{T}_{01}=\bar{T}_{02}=20$

When $\lambda_i \bar{T}_{0i}$ is not small the effectiveness of the line is:

1) for the case of identical constant distributions of the repair time ($\bar{T}_{01}=\bar{T}_{02}=\bar{T}_0$) and identical failure rates for sections ($\lambda_1=\lambda_2=x$).

When $\lambda<<1$ and $z=L\cdot\bar{T}_0$ then the effectiveness of the line is

$$E_L = \frac{L+1+L\cdot\lambda\cdot\bar{T}_0}{L+1+2(L+1)\cdot\lambda\cdot\bar{T}_0+L\cdot\lambda^2\cdot\bar{T}_0^2}$$

When $\lambda\bar{T}_0<<0,5$ then E_L is considerably smaller than the effectiveness in the expression given in paragraph b), e.g.

$$E_L = \frac{L+1+L\cdot\lambda\cdot\bar{T}_0}{(L+1)\cdot(1+2\lambda\bar{T}_0}$$

2) For the case of identical geometrical distributions of the repair time and identical failure rates for sections ($\bar{T}_{01}=\bar{T}_{02}=\bar{T}_0$, $\lambda_1=\lambda_2=\lambda$).

The effectiveness of the line is

$$E_L = \frac{2+z/\bar{T}_o+z\cdot\lambda}{2+z/\bar{T}_o+2\cdot\lambda\cdot\bar{T}_o(2+z/\bar{T}_o)+\lambda^2\bar{T}_o^2\cdot z/\bar{T}_o}$$

Inversely, when $\lambda\bar{T}_o<<0$ or so, E_L is significantly smaller then the effectiveness given above, e.g.

$$E_L = \frac{2+z/\bar{T}_o+z\cdot\lambda}{(2+z/\bar{T}_o)(1+2\cdot\lambda\cdot\bar{T}_o)}$$

Finally it is necessary to determine the value of $h_{ij}(z)$ e.g. the portion of the time when section i is under repair and j IN WORK.

The formula for h(z) can be obtained from the analysis of Markov chains adopted for the line behaviour:

1) h(z)+a for 2-sectional line
   a) for the geometrical distribution of the repair time

I Identical mean repair times ($T_{01}=T_{02}=T_o$) of sections

Let us define the parameter

$$c = \frac{1 + r - \frac{1}{T_o}}{1 + r - \frac{r}{T_o}}$$

Then

$$h(z) = \frac{r(1-c^z)}{1-rc^z}, \qquad r \neq 1$$

or

$$h(z) = \frac{z/\bar{T}_o}{2 + (z - 1)/\bar{T}_o}$$

For $T_o>>1$ there can be used the exponential approximation for c^z so

$$h(z) = \frac{1 - \exp(-\frac{z}{T}\frac{r-1}{r+1})}{1 - r\exp(-\frac{z}{T}\frac{r-1}{r+1})} \qquad r \neq 1$$

or

$$h(z) = \frac{z/T_0}{2 + z/T_0} \qquad r = 1$$

II Unidentical mean repair times for sections

The parameter c is

$$c = \frac{1 + r - 1/T_{o2}}{1 + r - r/T_{o1}}$$

Then

$$h(z) = \frac{r \cdot T_{o2}}{T_{o1}} \left(\frac{1 - c^z}{1 - \frac{rT_{o2}}{T_{o1}} c^z}\right) \qquad \frac{r \cdot T_{o2}}{T_{o1}} \neq 1$$

or

$$h(z) = \frac{z/T_{o1} \cdot T_{o2}}{1/T_{o1} + 1/T_{o2} + (z-1)/T_{o1} \cdot T_{o2}} \qquad \frac{r \cdot T_{o2}}{T_{o1}} = 1$$

When $T_{o1} >> 1$ and $T_{o2} >> 1$ then the exponential approximation for c^z can be used so

$$r' = \frac{r \cdot T_{o2}}{T_{o1}}$$

and

$$\frac{1}{T'} = \frac{1}{T_{o1} T_{o2}} \left(\frac{T_{o1} + r \cdot T_{o2}}{1 + r}\right)$$

$$h(z) = r' \frac{1 - \exp(-\frac{z}{T_0}(\frac{r'-1}{r'+1}))}{1 - r'\exp(\frac{z}{T'_0}(\frac{r'-1}{r'+1}))} \qquad r' \neq 1$$

or

$$h(z) = \frac{z/T'_0}{2 + z/T'_0} \qquad r' = 1$$

When $r'=1$ then $T' = \frac{T_{01}+T_{02}}{2}$

b) Constant distribution of the repair time

Identical mean repair times $T_{01}=T_{02}=T_0$ suppose

$$z = LT_0 + v \qquad 0 < v < T_0$$

and L is the integer value of z/T_0.

Then

$$h(z) = r\frac{1-r^L}{1-r^{L+1}} + \frac{v}{T_0}\frac{r^{L+1}(1-r)^2}{(1-r^{L+1})(1-r^{L+2})} \qquad r \neq 1$$

or

$$h(z) = \frac{L}{L+1} + \frac{v}{T}\frac{1}{(L+1)(L+2)} \qquad r=1$$

The measure of the effectiveness of the buffer is

$$e_B = \frac{P_1(h(z))}{P_1+P_2} = \frac{h(z)}{1+r\cdot T_{02}/T_{01}}$$

On the Fig.31 si shown the relationship between e_B and r when $T_{01}=T_{02}=20$ and $z=40$ for distributions of the mean repair time a) geometrical, b) constant

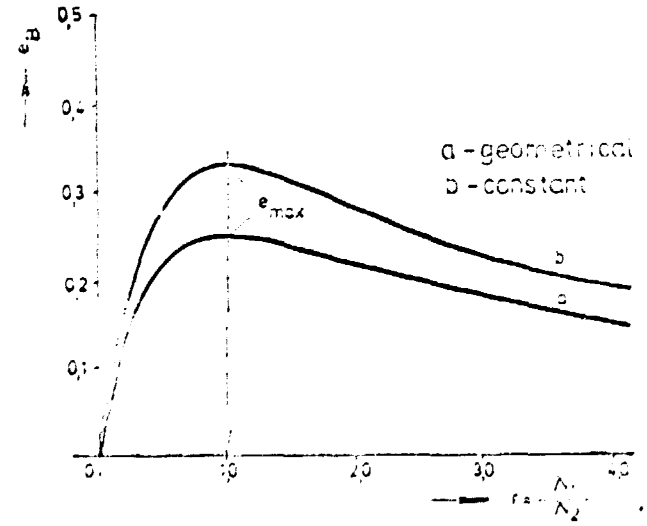


Fig.32 Relationship between e_B and $r=\lambda_1/\lambda_2$, $z=40$, $T_{01}=20$

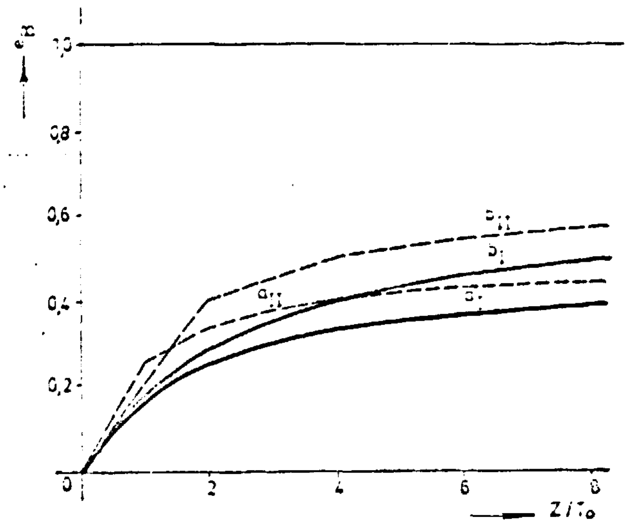
Clearly, e_3 takes its maximum for $r=1$, e.g. when λ_1 and λ_2 are equal regardless of the mean repair time distribution.

When those distributions are not identical geometric, e_3 has a maximum for $\lambda_1 \cdot T_{01} = \lambda_2 T_{02}$.

On the fig.33 there is given a relationship $e_B(z/t_0)$ for theeline divided optimally, when the distributions of the repair time are identical: a) geometrical b) constant.

On the Fig.34 there is given a ratio of the mean time IN WORK for the line and the mean machining time on the station as a function of z/T_0 ehen $\lambda_1=\lambda_2=\lambda$ and $T_{01}=T_{02}=T_0$ and the distributions of the repair time are: a) geometrical b) constant.

Sometimes it is important to emphasize the question of the mean time IN WORK for the line if the stock in the buffer is on a given level z_x.



a-two- b-three-sectional line
I - geometrical II constant
distribution of T_{0i}

Fig.3 The relationship between e_B and z/T_0 for two-and three-sectional line

On the Fig.35 is shown the ratio of the mean time to the slowdown and the mean machining time as a function of 2x for $z=40$, $T_{01}=T_{02}=20$, $\lambda_1=\lambda_2=\lambda$, $T_0=0,1$ and identical distributions

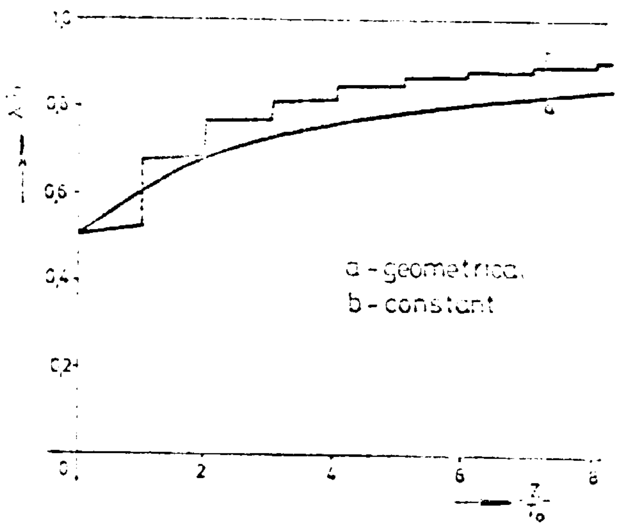


Fig.34 The relationship $\lambda\bar{\delta}/(1/\lambda)$ as a function of 2/T

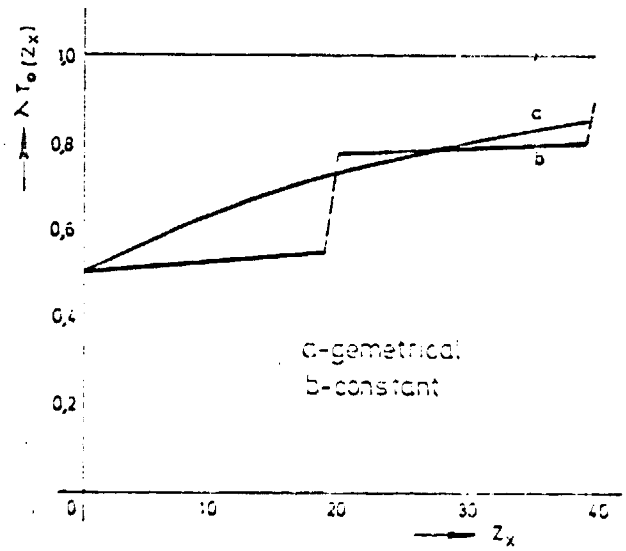


Fig.35 The relationship $T_o(2x)$ for $T_o=T_{o1}=T_{o2}$, $\lambda_1=\lambda_2$, $T_o=0,1$, z=40

of the repair time. The possible values of 2x are 0,20, 40.

It can be shown that the time IN WORK has approximately geometrical distribution if the distribution of the repair time is geometrical. The time IN WORK has also geometrical distribution if the repair time has a constant distribution and large z/T_o (larger than 10), because the coefficient of variation of the distribution of the time IN WORK is less than 1 when z/T_o is small.

The effectiveness of the line with three sections can be written in one of the following three ways (if every section has the same effectiveness):

$$E_L = E_o + P_1 h_{13}(z_1 z_2) + P_2 h_{23}(z_1,z_2)$$
$$E_L = E_o + P_1 h_{12}(z_1,z_2) + P_3 h_{32}(z_1,z_2)$$
$$E_L = E_o + P_2 h_{21}(z_1,z_2) + P_3 h_{31}(z_1,z_2)$$

where

E_o - effectiveness of the block-line

P_1, P_2, P_3 - portions of the section repair time

$h_{ij}(z_1,z_2)$ - portion of the time when the section i is under repair and j IN WORK

z_1, z_2 - buffer capacities

The values $h_{ij}(z_1,z_2)$ can not be determined quickly except when the distributions of the repair times are identical and constant. In that case if $z_1/T_{o1}=M$ and $z_2/T_{o2}=N$ where M,N are integers $h_{ij}(z_1,z_2)$ can be calculated by solving (M+1)(N+1) equations.

.4 Three-Sectional Line as a Two-Sectional

Effectiveness of the 3-sectional line can be obtained from the result for 2-sectional if 2-sectional line has a repair time distribution different from the geomatrical and if the distributions are identical for sections.

Three-sectional line can be considered as a 2-sectional in two ways:

1. Line divided into two sections at the first stock--buffer

2. Line divided at the second buffer.

If the main times IN WORK for stations are $1/\lambda_1, 1/\lambda_2, 1/\lambda_3$ and if the line is divided at the first buffer, the first section has a failure rate λ_1, and the second $\{\lambda_2+\lambda_3|1-h_{32}(z_2)|\}$ where $h_{32}(z_2)$ is a portion of the repair time for the third station when the second station works (it is supposed that it depends only on z_2). Then

$$h_{12}(z_1) = h(z_1,r_1) \text{ where}$$

$$r_1 = \frac{\lambda_2+\lambda_3|1-h_{32}(z_2)|}{\lambda_1}$$

and $h(z_1,r_1)$ is $h(z)$ for 2-sectional line.

It is similar when the line is divided into two sections at the second buffer - the failure rate for the first section is $\{\lambda_2+\lambda_1|1-h_{12}(z_1)|\}$ and the second λ_3, so

$$h_{32}(z_2) = h(z_2,r_2) \text{ where}$$

$$r_2 = \frac{\lambda_2+\lambda_1|1-h_{12}(z_1)|}{\lambda_3}$$

Thus, we have two equations that can be solved by the iteretive procedure. We suppose the initial value of h_{12} and place it into r_2 in order to solve for h_{32} etc. The convergence is rapid.

For the solutions obtained the effectiveness of the line can be expressed as

$$E_L = E_o + P_1h_{12}(z_1)+P_3h_{32}(z_2)$$

$$E_L = E_o + P_1h_{12}(z_1)+\{P_1|1-h_{12}(z_1)|+P_2\}h_{23}(z_2)$$

$$E_L = E_o + \{P_2+P_3[1-h_{32}(z_2)]\}h_{21}(z_1)+P_3h_{32}(z_2)$$

where

$$h_{21}(z_1) = \frac{h_{12}(z_1)}{r_1} \qquad r_1 = \frac{\lambda_2+\lambda_3[1-h_{32}(z_2)]}{\lambda_1}$$

$$h_{23}(z_2) = \frac{h_{23}(z_2)}{r_2} \qquad r_2 = \frac{\lambda_2+\lambda_1[1-h_{12}(z_1)]}{\lambda_3}$$

The effectiveness of the buffer is:

$$e_B = \frac{\lambda_1 h_{12}(z_1) + \lambda_3 h_{32}(z_2)}{\lambda_1+\lambda_2+\lambda_3}$$

On the Fig.36 is shown the relationship between e_B and λ_3/λ_2 and λ_1/λ_2 for $z_1=z_2=40$ and $T_{U1}=T_{o2}=T_o=20$.

It can be seen that e_B is not sensible to the variations of λ_3/λ_2 and λ_1/λ_2 near optimal values of these ratios.

By the use of approximate methods it can be proved that for the maximal effectiveness of the buffer the total capacity of the buffer z must be divided into two buffers $z_1=z_2=z/2$, and the line must be divided into sections such that $\lambda_1=\lambda_3$ and $\lambda_2=\lambda_1 \cdot h$ whereby $h=h(z/2)$ for the two-station line when $r=1$.

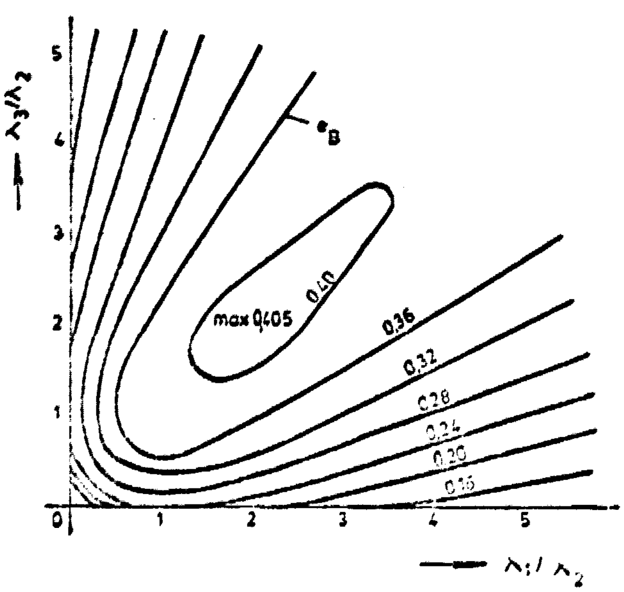


Fig.36 Relationship between e_B and λ_1/λ_2 and λ_3/λ_2 for the 3-station line with $z_1=z_2=40$ and $T_{o1}=T_{o2}=T_o=20$

When the line is divided in such way the ratios r_1 and r_2 are equal.

It is possible to increase the value by the use of approximate procedures, that must be smaller of a_1 and λ_3 for the macimal effectiveness. The line divided in such way is close to the maximal effectiveness because, when close to the optimum, the effectiveness is senseless to the changes in dividing.

When the line is optimally divided into sections

$$e_B = \frac{2h}{h+2} .$$

On the Fig.33 there is shown the value of e_B as a function of z/T_0 for the optimally divided line, and when the distributions of the repair time are a) geomebrical and b) constant.

.5 The Line with more than 3 stations

The effectiveness of the line can be determined by generalizing the approximate procedure from d). The line with n stations can be divided into two sections on (N-1) ways according to the division at every buffer. It is assumed that all stations in the line have the identical distributions of the repair time.

We will use the following notation:

λ_k - failure rate of k-th station

λ_k' - failure rate of k-th station caused by its own failures or failures caused by 1,2,...,(k-1)-th station

λ_k'' - failure rate of the k-th station caused by failures of k, (k+1)...n-th station

$h_{k,k+1}$ - portion of the downtime of the k-th station caused by the own failure or the failure of 1,2, ...,(k-1)-th station, the (k+1)-th station being IN WORK

$h_{k+1,k}$ - portion of the downtime of the (k+1)-th station caused by its own failure or the failure of (k+2),(k+3)... n-th station the k-th station being IN WORK

z_k - capacity of the k-th buffer between k-th and (k+1)-th station.

Let us consider the line divided into 2 sections at the k-th buffer. The values of h are:

$$h_{k,k+1} = h(z_k, r_k) \qquad 1 < k < N-1$$
$$h_{k+1,k} = h(z_k, r_k^{*}) \qquad 1 < k < N-1$$

and

$$r_k = \frac{\lambda'_{k+1}}{\lambda'_k}$$

$$r_k^{*} = \frac{\lambda'_k}{\lambda''_{k+1}} = \frac{1}{r_k}$$

where

$$\lambda'_k = \lambda_k + \lambda'_{k-1}(1-h_{k-1,k}) \quad 1 < k < N-1$$

$$\lambda''_k = \lambda_k + \lambda''_{k+1}(1-h_{k+1,k}) \quad 1 < k < N-1$$

$$\lambda'_1 = \lambda_1 \qquad \lambda''_N = \lambda_N$$

We have here 2(N-1) equations that have to be solved for 2(N-1) values of $h_{k,k+1}$ and $h_{k+1,k}$.

The effectiveness of the line is now

$$E_L = E_o + P'_{n-1}h_{n-1,n} = E_o + P_1 h_{12} + |P_1(1-h_{12}) + P_2| h_{23} +$$
$$+ |P_1 + (1-h_{12})(1-h_{23}) + P_2(1-h_{23}) + P_3| h_{34} + \ldots$$

If we replace $d_{k,k+1} = (1-h_{k,k+1})$ then

$$E = E_o + \sum_{i=1} P_i - P_1 d_{12} d_{23} \ldots d_{N-1,N} - P_2 d_{23} d_{34} \ldots d_{N-1,N} \ldots$$
$$- P_{N-1} d_{N-1,N} - P_N$$

THE OPTIMAL DIVISION OF THE LINE INTO SECTION

It can be shown that for the maximal effectiveness of the buffer the total capacity given can be spread across (N-1) buffers so that every buffer has the capacity z/(N-1) and that the line is divided into sections thus that $\lambda_1=\lambda_N$, $\lambda_2=\lambda_3,\dots,=\lambda_{N-1}=\lambda_1 h$ where

$$h = h(z(N-1)) \text{ for } \quad r = \lambda_1/\lambda_2$$

When the line is divided the effectiveness of the buffer is

$$e_B = \frac{(N-1)h}{(N-2)h+2}$$

that, when the sections have identical constant distributions of the repair time and $z/(n-1)t_o=L$ and $z/t_o=M$ as integers, equal to

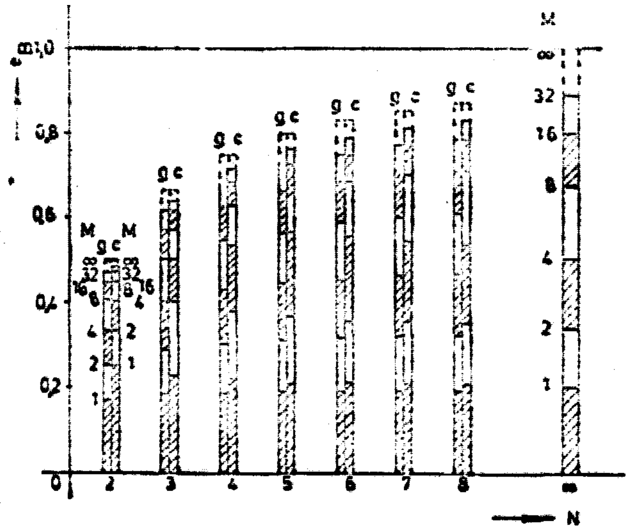
$$e_B = \frac{M}{\frac{MN}{N-1} + 2}$$

When the sections have identical geometrical distributions of the repair time and $z/T_o=M$ than

$$e_B = \frac{M}{\frac{MN}{N-1} + 4}$$

On the Fig.37 is given a relationship between e_B and N for various values of M in two cases.

Note, that for identical constant distribution of the repair time the maximum of e_B (as a function of M) is reached when M=N-1, e.g. when every buffer has the capacity at least equal to the mean repair time of sections.



g - geometrical   c - constant

Fig.37 Relationship between $e_B(N)$ and $e_B(M=z/T_0)$ for geometrical and constant repair time

b) Methodology of the investigations of the effectiveness

The investigations are performed under the methodology described in this section.

Phase I: DATA COLLECTION

Data-logger KIENZLE MSA71+CM 11 is used for the data collection about DOWN TIM[illegible] data collection is automatised using cards-circular diagrams as shown on Fig.38.

The Kienzle equipment is 9-channel and it can registre nine different kinds of down times.

The records on cards are, by the use of a card reader, converted to a digital values giving the basis for TIME PICTURES. Naturally, before the begining of down times registration is is necessary (based on the past data) to make a list of possible failures.

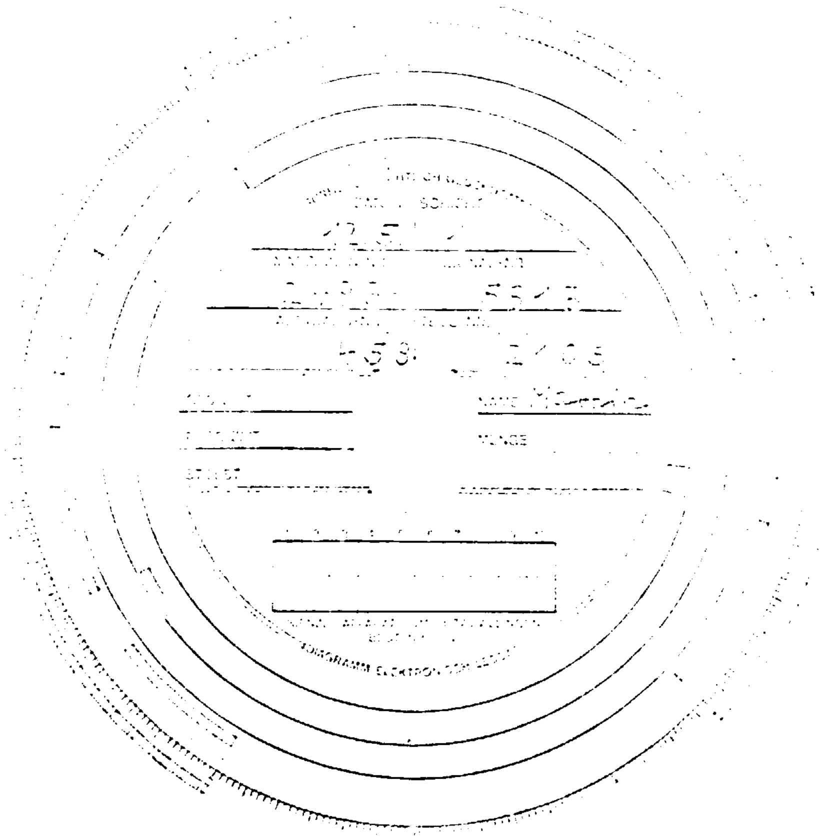


Fig.38 Circular diagram

Phase II: DATA PROCESSING

Digital data about the appearance, sources and duration of failures as well as repair costs are INPUT DATA for the computer of the type KIENZLE.

The computer determins the number and width of the intervals during the observation interval and calcultes the following parameters of effectiveness:

- $\lambda(t)$ - failure rate
- $f(t)$ - failure density
- [illegible] - mean up time
- $u(t)$ - mean down time
- [illegible] - mean time between failures
- [illegible] - availability
- $R(t)$ - reliability

The hypotheses about the distributions $\lambda(t)$, $f(t)$, $A(t)$ and $R(t)$ are tested and determined giving the base for the analysis of the line behaviour e.g. its effectiveness.

Phase III: ANALYSIS AND OPTIMIZATION

The effectiveness of the transfer-line can be determined according to the given expression giving, also, the basis and directions for further development.

Apart from the data mentioned above there are registered the data about working conditions and the environment such as

- cutting speed (r_{pm})
- displacement
- cutting depth
- materila
- pressure, humidity and temperature of the environment
- voltage variations
- pressure variations in the installation with the comprimed air etc.

In the document SYSTEM BEHAVIOUR CHART are given all the relevant input data about the functioning ` system during the period given.

.2 Lectures for undergraduate and graduate students

In the Laboratory for production systems for the students of mechanical engineering are partially performed the experiments describen in part .1 Fundamental research as a part of the subject Effectiveness of technical systems.

The undergraduate level students during the course are obliged to execute projects and are involved during their final projects in the fundamental investigations under the lead of the members of Institute.

The graduated students, as well, through the course Effectiveness of technical systems are obliged to submit a seminarial work about investigating the line as well as MS theses that is of special interest to the candidate and Institute.

For the needs of lecturing process the Institute is supplied with two films about the functioning of the line:

- without buffers (as installed in the Laboratory)
- with buffers, as we want to installe in the future based on the bases of the results of the investigation in the chapter 1.

Also, presently one of the collaborators in the Institute is working on his Ph.D. Thesis using the Laboratory equipment.

.3 Coruses for specialists from the industry

During the period of establishing the Laboratory on the Institute where designed the courses for specialists from the industry and for areas:

COURSE 4. EFFECTIVENESS OF SYSTEMS AND MAINTENANCE

Part 4.1 - effectiveness of automatical lines (availability, reliability)
- the effectiveness criteria for production systems
- operational readiness
- time picture of states
- maintainability
- case study

Part 4.2 - maintainance and repairs - need and perspectives
- maintainance procedures
- the use of the maintainance policy
- case study
- problems of maintenance (maintainability)
- service costs etc.

The courses are to be held periodically and will last 2-3 days with the aim to train the specialists for the analysis and solving the problems of reliability and/or maintainance as well as forecasting problems.

The programme of courses is variable influenced by the particular problems and need.

Apart from these courses the Institute will organize every third year the Symposium "Effectiveness of Technical Systems - EFTES" in Novi Sad, On the next, III symposium (1981) that will be a part of the INTERNATIONAL CONFERENCE ON PRODUCTION there will be presented some results of these investigations.

2.4 Investigating production control

The basic aim of using Dispo system is:

1. Training of students
2. Scheduling and control of the line
3. Training of specialists from the industry.

The title 1. contains a set of practical excercises for the students on IX semester, and according to the programme of the course "Production systems control". Scheduling and control of the line is performed in the following way:

Using the tables for planning all the production activities are scheduled using the information from card files. The activity scheduling is transfered from the terminal centre to the table for final scheduling through the optico-acustical system. Based on this information the production activities are performed. Through the same connection the feedback information is transfered back to the terminal centre giving the background for the knowledge about the systems' state at every moment.

In the scope of the activity No.3 is performed the training for the people from industry, and through special courses. This is particularly devoted to the people from firms that will or already have introduced the system for the production control.

The purpose of introducing the terminal sybsystem to the laboratory is

- training of students

- joint use with the Dispo system
- scientific research in the field of the software development for production control.

Several excercises from the topic "Production systems control" are performed in this laboratory with the aim to present the possibilities of the computer use in production control.

The terminal also can be used together with the Dispo system in order to execute all the calculations connected to the planning. This activity is strongly connected to the activity "Scientific research in the field of the software development" because it is a part of the development of the general model of the production control whose use is possible under the following conditions:

- mannual information processing
- information processing using the organizational equipment (Dispo, Georga, Optiplan, IMAX etc.)
- use of the computer.

The equipment for data collection will be used for the following:

- on the diagramatic plate situated on the equipment KIENZLE MSA 71/CM11 that is directly connected to the machine the following data are collected:
  - number of parts producted
  - duration of the production
  - the kind, duration and frequency of failure
  - start and trermination of the work.

Through the analysis of this data using KIENZLE EDA equipment the following can be obtained

- straightforward infromation
- basis for the enalysis of technical and organizational buttlenecks
- the data about the necessary activities for the for the decrease of time in failure
- information necessary for the flow control

- the data for comparison of planned and real values
- utilization coefficients for machines
- exploitation costs
- bases for various calculations
- data for various statistical calculations.

For the specialists from industry the following courses are organized:

COURSE 3: PRODUCTION SYSTEMS CONTROL

Part 3.1 - the control function for the production processes
- forecasting
- planning
- determining deadlines
- control of flows in system
- case study

Part 3.2 - the use of computers in production control
- programming the planning procedures, control of the production etc.
- case study

Part 3.3 - the use of the production control system
- the case study

The terminal subsistem is installed at the Institute for industrial systems and is connected to the main system through telephone line.

The terminal is used for the following:

1. Scientific research
2. Lecturing e.g. training of students and specialists from the industry
3. Transfer of knowledge

1. Scientific research for the people of the Institute

The Institute for industrial systems is involved in a very rich scientific work that is executed through a number of papers presented in Yugoslavia and abroad as well as a number of scientific projects.

Such kind of activities lead, in present phase, to the necessity of the use of computer basically for two reasons:

- shortening the time necessary fro routine work
- improving the approach to the scientific research.

In the first phase the terminal subsystem will be used for writting and execution of application programmes that will, partly or totally, automatize the methodology developed so far in order to its practical use.

Particularly, there will be developed special software for the control of the automatic line that is installed at the Institute. The applications to be developed will contain:

- the programmes for the line control together with the Dispo system
- investigation of the work of the line from the aspect of effectiveness and, particularly, reliability and making appropriate statistics
- development of simulation models of the line reliability.

2. Lecturing

The terminal subsystem will be used in the lecturing process at the Faculty of Technical Sciences in the following way:

- training of students to use the terminal
- learning high programming languages (FORTRAN and COBOL)
- introduction to some programming packages (PERT).

Apart from this the courses will be organized for specialists from the industry and for the collaborators at the Institute on the same topics.

3. Transfer of knowledge

One among the main aims of collaboration with the firm "Naftagas" which is the owner of the main computer system in the joint work on the development of software for the use at both organizations. In that sense the specialists from the Institute and "Naftagas" will develop software packages for the production control in "Naftagas" as well as on adapting the existing applications for the use at both organizations.

Finally, the programmes developed as a part of the activity No.3 will be used for the direct transfer of knowledge between the Institute and "Naftagas" and other organizations interested.

Apart from this there will be organized the following course.

COURSE 6: SIMULATION METHOD

Part 6.1 - the philosophy of simulation
- simulation procedures
- interactive programming
- random number generators and sampling techniques
- simulation languages
- case study

Part 6.2 - planning of simulation experiments
- the necessity to simulate
- case study.

3.0 RECOMMENDATIONS AND SUGGESTIONS

The investigations carried out during the work on the Project have resulted in the following recommendations and suggestions to the U.N.I.D.O. Agency and Yugoslav Government:

1) Recommendations for continuing the investigations

We think that the following investigations have to be continued and expanded (the suggestions are the result of trainning programmes and expert missions):

- in the investigation of production systems' structures in a sense of automatization of machining and assembling structures of production systems in order to decrease the cycle time in machining and assembly as well as work and time study investigations
- in the area of determinations of the variants of operation performance related to the loading, capacity and the latest terms for finishing. The choice of the optimal termination variant for the production
- the use of minicomputer as a support for organizational tools in the area of production control
- mathematical and simulation modelling (computer oriented) of production systems, particularly of automatic lines and using the group technology
- introducing computer performance evaluation techniques into computer centers in industry in order to minimize costs of equipment supply
- the transport problems between work places
- the investigation of the use of Computer Aided Design (CAD/CAM technology) in metal working industry
- the flexibility of production systems structures
- the possibilities of introducing buffers into the existing equipment in the line installed at the Laboratory for Industrial Systems
- maintainability as a function of the complexity of technological systems
- design adequacy and operational readyness of technical systems
- transfer of knowledge into the industry.

2) Recommendations for further training and specialization

The further training of the project team members is necessary in:

- the following scientific-research institutes and factories in a field of the automatization of production processes:
  a) IPA (Institute für Produktion und Automatisierung den Produktionssystemen) - Stutgart - BDR
  b) TU (Technische Universität in Dresden) - DDR
  c) BWI (Betriebswissenschaftliches Institut der ETH) in Zürich, Schweiz
  d) BOSCH FA. in Stutgart, BRD
  e) OKU-Automatik, Winterbach, BRD
  f) Georg Fischer A.G., Schaffhausen, Schweiz
  g) Mikron-Hesler, Boudry, Schweiz
  n) Lanco-Economic, Belach, Schweiz

- in the field of production control in institutes and idustry such as:
  a) MIT (Massachusets Institute of Technology) in USA
  b) IMB - International Bussines Machine CO.
  c) Institut Bauman in Moscow, USSR
  d) Dispo-Organisation - Factory for production control equipment
  e) Ormig - Factory for computer equipment - BRD

- in the field of operating systems in following firms:
  a) ICL Ltd., UK
  b) IBM, GB or USA
  c) Kingston Coledge, UK

- in the field of information systems:
  - IBM - International Bussines Machine Co.
  - WML, TH - AACHEN, BDR

- Gildemaister maschinenfabrik GMBH Biklefeld, FR Germany

- in the field of CAD
  - WML,TH - AACHEN, BDR
  - Tektronix, USA
  - CDC - Control Data Corporation

- in the field of performance evaluation

  a) in ICL or IBM firms inUK and/or USA

  - the use of processes computers in the production control
  - UNIVAC, USA
  - CDC - Control Data Corporation, USA
  - the training in the field of reliability theory as a tool for productivity improvement of production systems in the metal working industry
  - the training in the area of transport and storage equipment in Fa. Demag, BRD

3) Recommendations for the purchase of new equipment

   - in the area of the automatization in production systems

     a) semiatuomatic and automatic assembly lines
     b) assembly machines
     c) the equipment for the work places that are ergonomically formed on the principles of rational execution of operations
     d) the time measuring equipment
     e) the robot for performing certain operations

   - in the area of production systems control

     a) minicomputer to be used together with DISPO system in the process of production planning and processing of feedback information

b) Kienzle card reader for circular diagrams and the equipment for data processing about down-times

- in the area of CAD

a) the equipment for computer aided design made by

  - Tectronix
  - Calcomp
  - CDC (Control Data Corporation)

b) the equipment for transprot and storage made by Demag, BRD.

4.0 APPENDICES

4.1 List of granted fellowships

LIST OF GRANTED FELLOWSHIPS

1. Zelenović Dragutin, project manager:

    CARDIFF - University of Wales - Institute for Sciences and Technology, from june 18th through September 10th 1978

    Title of fellowship: Study in grouping technology, lay-out of equipment and production control

    Aim: Finalization of manuscript of project findings and recomendations.

2. Ćosić Ilija, research engineer:

    - OKU-Automatik, Winterbach, Germany from September 1st through 15th 1978
    - Micron Hessler, Boundry, Switherland from September 15th through 30th 1978
    - Betriebswissenschaftinstitut der ETH, Zürich, Schwitzerland, from October 1st through November 31st 1978

    Title of fellowship: Assembly Processes in Production Systems

    Aim: Education in System Theory and Application in Production Systems

3. Džigurski Branko, research engineer:

    CARDIFF - University of Wales - Institute for Sciences and Technology, from January 15th through April 15th 1977

    Title of fellowship: Method and work study and use of equipment for work study

    Aim: Education of the candidate in this area.

4. Ustić Milorad, research engineer:

   - Fabriki samochdowi osobovich, Warszaw, Poland from Januray 2^{nd} through February 5^{th} 1979, and from February 19^{th} through 25^{th}
   - Przemyslowy Instytut Maszin Budowlanych-Bumar, Warszaw, Poland, from February 5^{th} through 19^{th} 1979

   Title of fellowship: Computer Aided Design

   Aim: Educationof the Candidate in Production Control and Computer Aided Design

5. Malbaški Dušan, research engineer:

   - ICL, London, U.K. from June 4^{th} through September 2^{nd} 1979

   Title of fellowship: Computer Systems

   Aim: Studies in Computer Systems and Application in Production Control

6. Stanivuković Dragutin, research engineer:

   - Betriebswissenschaftliches Institut der ETH, Zürich, Switherland, from June 25^{th} through August 25^{th}, 1979
   - DUAP Ag., Herzogebuschsee, Switherland, from August 27^{th} through September 1^{st}, 1979
   - DUBIED E.+Cie.S.A, Neuchatel, Switzerland, from September 3^{rd} through 8^{th}, 1979
   - TAREX S.A., Geneve, Seitzerland, from September 10^{th} through 22^{nd}, 1979
   - GEORG FISCHER, A.G., Schaffhausen, Switzerland
   - BROWN-BOVERY COMPANY, Baden, Switzerland

   Title of fellowship: Reliability of Technical Systems

   Aim: Education of the Candidate in the Reliability of Technical Systems and Applications on the Tool Machines (that are produced in DUAP and DOUBIED)

4.2 List of major equipment provided by UNDP

LIST OF MAJOR EQUIPMENT PROVIDED BY UNDP

Order No	TITLE OF EQUIPMENT	Equipment value $	Received on
1.	Hidraulic Copying Lathe Dubied 517 S (Producer: DUBIED & Cie. S.A. Switherland	88,208 (money of UNDP)	may 1975

4.3 Abstracts of reports of experts mission

4.3.1

Graham G. Hitchings, PhD
Expert - Production systems

DRAFT INTERMEDIATE REPORT - 1975.

- S u m m a r y -

Although successful in areas involving theoretical work both in teaching and research, the Institute of the School of Mechanical Engineering of the University of Novi Sad desires to change its direction toward a more practically oriented programme serving the best interest of both industry and the University. Ways are suggested as to the most effective way of achieving this goal. At root, funcamental changes may be necessary in restructuring existing diploma courses such that an element of co-operative education is involved from the early part of the course. Existing links with industry must be strengthened and real problems examined and research using the latest management aids. Consultancy in industry resulting in the setting up of specialist training courses for managers brings about much Case Study material beneficial to both industry and the University. Purpose built-laboratories already planned can enhance the contribution of the Institute to some of industries real problems. New equipment for the efficient collection and collation of industrial data will prove of vital use in practical research. Surveys can indicate to the Institute useful directions for applying their research and teaching effort. Development of readily available computer programmes involving heuristic and simulation procedures can immediately contribute to solving specific industrial problems. Such re-orientation will both in the short and long terms prove of mutual benefit to both parties.

4.3.2

Leonid Ivanovich Volchkevich, PhD
Expert - System reliability

DRAFT MISSION REPORT

- S u m m a r y -

During the stay at the Faculty of technical sciences, University of Novi Sad (dean of the Fakulty, professor D. Zelenović) I have a number of lectures and accomplished scientific consultations concerning a set of questions concerning the theory and the practice of the reliability of the technological machines and their systems, as well the applications in the area of exploitation and the design.

The new problems are opened and among them is one of the most important the provision of the high reliability of the machine, especially the automate and the automatic lines. The low values of the reliability decrease the production and increase the quantity of the labour spent on the service.

Therefore, the modern machines must be designed in such a manner that the calculation includs not only the motion and strength of the elements, but also the high reliability. The important task of the modern machine science are the development of the methodology of calculation and production according to the reliability and productivity criteria and the economical effectiveness. Therefore in many countries the basic development of the investigation of the machine and systems reliability found its place in the lectures for students and graduated students, on a number of conferences and simposiums as well as the scientific literature.

It is necessary to develop the international relationships, including UN, concerning the questions mentioned above, that is the interchange of ideas and extending the progressive scientific methodology.

4.3.3

Graham G. Hitchings, PhD
Expert - Production systems

INTERMEDIATE SECOND REPORT - 1977.

- S u m m a r y -

The long range objectives of the Department of Industrial Systems, Institute of the School of Mechanical Engineering, University of Novi Sad, Yugoslavia are to increase the quantity and improve the quality of project participants, professional managers and controlles of production system. Linked with this prime objecitve is the need to improve productivity in industrial and other sectors of the country's economy by using modern systems of industrial optimization with specific consideration to the more extensive use of batch and line methods of production. These long range aims are being met in gradations by achieving stated immediate objective. This report covers the period 1975-1977 and records the progress which has been made in achieving these immediate objectives and the extent to which it is possible to realize the long range objectives. Comparisons are drawn with a report which covered the period 1973-1975. Indications are that satisfactory progress has been made in achieving the immediate objecitves and that the Institute is directly on course to achieve the long range objectives. Delays have stilted progress somewhat in one of the main areas, namely the purpose-built teaching laboratory, but it is hoped that lost time can be made up in the future by concentrating efforts in this direction. Firm recommendations for the upcoming time period are included.

4.3.4

John L. Burbidge, PhD
Production management - expert

DRAFT MISSION REPORT

- S u m m a r y -

This project is now nearing completion and the final report has already been drafted.

There were long delays in the supply of machines for the automated transfer line, - included in the project -, but the line is now installed in the Institute's laboratory. Arrangements have been made for the supply of materials by industry. Research using the line will start as soon as the fellows being trained to use the machines, return from Switherland.

The Institute has developed a very close practical cooperation with Industry, covering Research, Training and Consultancy. Over 40% of the Institute's income now comes directly from Industry.

The Institute has already done useful research into parts grouping on a technological basis. It now needs to broader it's approach and to study the organisational approach to groups, - developed in the UK and USA -, and the group production methods developed by behavioral scientists, - Socio-Technological Systems.

The technique of "Production Flow Analysis" should be added to the curriculum and be used in future research and consultancy.

The Institute should buy one or more micro computers, for research and also to help accelerate the rate of computer introduction into Industry.

4.4 Abstract of the report of the training programme of the national project director

Dragutin Zelenović, PhD
National project director

FINAL REPORT
The training programme
- S u m m a r y -

The objectives of my personal Fellowship Programme, in the Frame of Project Objectives, are stated as follows:

1) To study the methods which are employed at the University of Wales I.S.T. in maintaining university links with industry with particular emphasis on training courses and in-house training provided for industrial participants.
2) To assess the content of training courses for industrial participants which have to be held in future in Department of Industrial Systems Engineering.
3) To prepare a document of research which has been carried out on flexible production systems production systems based on the approach of group technology in the Department of Industrial Systems Engineering - - Novi Sad.

The Engineering production is concerned with the planning, manufacturing, organizing and control of production process. The field of interest ranges from the basic characteristics of manufacturing processes to the investigation of complex industrial systems. The growing rate of changes in environmental conditions and the need for obtaining higher and higher output figures from industrial systems are directed toward design and layout of flexible production systems and to more close relationships between Research Institutions and Industry.

4.5 Abstracts of reports of fellowship participants

4.5.1

Branko Džigurski, M Sci
Work and time study

FINAL REPORT ON THE USE OF THE FELLOWSHIP

- S u m m a r y -

At the Faculty of Technical Sciences, in Novi Sad, there will begin a new subject: Work Study. My taks is to prepare all conditions for that subject. By the lectures, as a important point there are and the exercises in the laboratory. That laboratory will be completed in the present and the next year. My task, also, is to make the project and to manage the arrangement of that laboratory.

In relation with above I visited the Department of Mechanical Engineering and Engineering Production, at the University of Wales, Institute of Science and Technology in Cardiff, United Kingdom. I was a guest of Dr G.G. Hitchings, who is a lecturer in the group for Industrial Engineering. Dr. G.G. Hitchings is the expert of UNIDO, and he is the participant in our UNDP Project. His group, in Cardiff, has a developed subject of Work Study with the high level of quality.

The goal, of my training programme, was to collect necessary informations. Together with the tuition for students, the new laboratory of Work Study will be used and for the contribution with the industry and for the scientific work.

The training programme was very efficient in the sense of improving of my knowledge and make it immediately applicable, in a short time. Also, I improved my English language which is very important in this field.

Ilija Ćosić, M Sci
Production systems

4.5.2

FINAL REPORT ON THE USE OF THE FELLOWSHIP

- S u m m a r y -

A. PROGRAM IN FR OF GERMANY from 01.09. to 15.09.1978.

The programme was made by Carl Dusberg-Gesselschaft in OKU-Automatik firm in Winterbach and it consisted of the following:

- acquaintance with the work at the Construction and Technology Department with special construction study of one installation automation
- attending manufacturing of the vibration device for transport
- assembling automata assembly with special respect to mechanic and electrical installation
- documentation and operation with EDV.

The programme was very rich and useful. I have had a special interest in that kind of work because it refers to the production programme for manufacturing machines for automated assembly (that is for assembly without use of human workers), the production field in which Yugoslavia is highly interested.

B. PROGRAMME IN SWITHERLAND FROM 15.09.78 to 30.11.1978.

Programme was provided by Politique Department in Bern and Mr. Stutz.

B.1 Programme in MIKRON HAESLER-BOUNDRY from 15.09. to 30.09.1978. consisted of the following:

- acquaintance with the firm and the production programme
- general problems in transfer machines production and technology
- application of standard elements in constructionand application of Bau-Kasten system
- work on concrete examples with preliminary project of transfer machines

- film projecting about production
- general problems in assembly automata production
- assembly of transfer machines and assembly automata.

Most of the time I spent dealing with the transfer-machines production where I managed to master the use of Bau-Kasten system (the system for standard element composition). These. transfer machines provide possibilities ofr manufacturing certain products of:

- watch industry
- water and heath armature
- other complicated parts.

B.2 Programme on BWI der ETH ZURICH from 01.10. to 30.11.1978.

Within the programme at Betribswissenschaftliches Institut der ETH in Zürich I attended the following courses organized for the specialists engaged in production in Switherland:

1. Measuring and evaluation of workers work
2. Application of network technique in projects
3. Investments - statistic and dynamic calculations
4. Courses for constructors
5. [illegible]ing systems
6. Organization of industrial systems.

4.5.3

Milorad Ustić, B.S.
Production control

FINAL REPORT ON THE USE OF THE FELLOWSHIP

- S u m m a r y -

In the period mentioned above I was for 32 working days in the FABRYKA SAMOCHODOW OSOBOWYCH, AL. STALINGRADZKA 50, 03b--215 WARSZAWA, POLAND, 12 working days in "BUMAR" INDUSTRIAL INSTITUTE PIMAB OF CONSTRUCTION MACHINERY, ul.KOLEJOWA 57 01--210 WARSZAWA, POLAND and two working days in the Ministery of Informations, Warszawa, Poland.

During the period spent in the INDUSTRIAL INSTITUTE OF CONSTRUCTION MACHINERY "BUMAR" my mentor was MACIEJ ZGORZELSKI, Phd Mech, ing, chief of the COMPUTER AIDED DESIGN AND MANUFACTRUING DEPT. to whom I also owe the gratitude for the care for my professional education. The visit to the Ministery of Informations was for the purpose of leing informed, only.

On the basis of the training programme I have taken the following courses:

1. FABRYKA SAMOCHODOW OSOBOWYCH

Introduction to the organization of the factory, its history and the future development, visiting the factory, visiting and introduction to the work of ZETO (Computer centre), studying the use of the computer in the designing process, studying the technological documentation, studying the use of the "Small Informatics" e.g. the use of mini computers, design and organization of the data bases, organization of introducing the data, the organization of mass memory systems, etc.

1. INDUSTRIAL INSTITUTE PIMAB OF CONSTRUCTION MACHINERY "BUMAR"

The organization and work of the Institute, the organization and work of the Institute, the configuration and organization of their computers, the microfilming of the designing infromations and the use of computers, the system for designing calculations using the method of finite elements (ASKA method), the system "BICEPS" for the automatic design of the control informations for NC machines, the comparative analysis of programming languages for NC machines, the systems for graphic verification, etc.

4.5.4

Dušan Malbaški, BS
Computer sciences

FINAL REPORT ON THE USE OF THE FELLOWSHIP

- Summary -

1. PRACTICAL SIZING COURSE, MODULE 1 (PS-1)

The main aim of the course was, generally, "to equip the course member to discover how far existing application systems use the potential throughput of his configuration and to optimise the performance of individual applications."

The main topics of the course were: introduction to Sizing eg. the need for and the basic concepts of sizing, gross Sizing eg. the first step in the approach to sizing of every system, including gross sizing of processor, discs and magnetic tapes, description of main hardware components from the aspect of sizing feauturing processors, magnetic tapes and exchangable disc subsystems.

2. PRACTICAL SIZING COURSE, MODULE 2 (PS-2)

The aim of the course was "to equip the course mem with more advanced sizing skills in particular in the areas of communications based systems the influence of operating systems and multiprogramming", thus enabling the member of "assisting in the practical sizing of multiprogramming instalations performing mixed workloads".

The course conssisted of the following:

- introduction and gross sizing (same as for PS-1)
- gross sizing of TP systems. The aim of this tonic was to introduce gross sizing to the TP systems that were excluded from the PS-1 course. There were presented the specific problems of gross sizing when dealing with TP systems including the gross sizing of processors, terminals, lines and peripherals

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- queuing theory featuring various theoretical queuing models and their application to the specific problems.

3. TRAINING AT G. WIMPEY AND CO. LTD

The main aim of this part of the Training Programme was:

- to get acquainted with the work and problems in running a large computer centre
- to master the knowledge gathered at the courses PS-1 and PS-2 attended before.

4.5.5

Dragutin D. Stanivuković, M Sci
System reliability and maintenance

FINAL REPORT ABOUT THE USE OF THE FELLOWSHIP

- Summary -

The benefits from the training programme can be divided into two groups:

- the benefits for the UNDP project
- the benefits for personal improvement.

1. The Benefits for the Project

a) The Stay in ETH Zürich

The talks with specialists for reliability and machine tools during the stay in ETH in Zürich provided us with a lot of useful suggestions related to the investigations on the transfer line in the Laboratory for INDUSTRIAL SYSTEMS. The ideas and suggestions of Prof.E.Mattias, Dean of the Department of Mechanical Engineering in ETH, related to the investigations of the impact of the environment (electrical distrurbances etc.) on the work of the line.

During the stay at ETH I have used more than 80 publications - naturally in a limited scope.

The extremely large number of journals from all over the world helped me to realize certain problems related to the choice of machines, establishment of the line, organizing the investigations and courses for students and specialists from the industry.

b) The Visit to the DUAP Company in Herzogenbuhsden

The benefits derived from the visit to DUAP are considerable the reason being that by studying the technology and assembly processes I have gathered useful informations about the sources of possible failures on machines that are manufactured in DUAP (and that make a part of our line). In the factory I was given the film about the work of the line that is similar to our and that will be of great importance for our work with students and specialists from the industry.

c) The Stay at the DUBIED Company in Neuchatel

Our line contains two machines made by DUBIOE and we are naturally interested in their behaviour in exploitation from the aspect of reliability, e.g. maintenability, planning of spare parts, inspection, repair etc.

From the discussion with the chief of construction, ing. Schaffer, I derived important data about possible failures of these machines that were gathered from the observations made during exploitation.

Particularly important is the joint report about the problems in transport of the work pieces between the machines in the line that will be presented at the IV Yugoslav Conference about Transport Processes in Industry to be held in Belgrade 1980. The report will be presented by four of us: Ing.Schaffer, Ing.Schmid, Dr. Zelenović and myself.*/ This will be the first report of this kind in Yugoslavia and it will be very interesting for the specialists from the industry and scientists as well.

d) The Visit to the TAREX Company in Geneve

The analysis fo the production process for machine tools in TAREX is not directly related to the behaviour and work of the machines from our transfer line, but is very important from the aspect of the use of existing theory and know methods and techniques.

e) The Visits to Companies in Baden, Georg Fischer in Schaffhousen and CERN in Geneve (not included in UNDP programme)

Unfortunately the duration of these visits was not enough to provide the complete knowledge about the work in areas that are of interest for the UNDP project and me, but, however, the

*/ The abstract of this paper is enclosed.

partial knowledge gathered there will be of great help for the further development of the Laboratory, and, particularly, the investigations in the area of reliability.

The infromation from BBC (Dr.Ari) and CERN (Dr.Schorr) about systematic investigation in this area will give opportunity for further progress in the use of the line.

The benefits derived from the visit to the firm GF will be manysided because GF is a manufacturer of equipment that is similar to ours (from the aspect of functioning) so that the problems and solutions of buffers and transporters are of great importance for the further development of establishing lives in Yugoslavia.

2. The Benefits for Personal Investigations

According to the fact that my PhD dissertation is in a sense a part of the project YUG/73/005 the visits to the companies mentioned before are of interest for the work on the dissertation. The study of the literature at ETH helped me, particularly some references (the papers of Weibull, Plait and others) that I did not have an opportunity to see in Yugoslavia. I have also had the chance to study some important works about the establishment of production lines (the works of Koenigsberg, Freeman, Ropohl, Finch, Elmagraby etc.) as well as some PhD dissertations from the area of reliability and lines establishment.

The contacts with some 20 specialsits from fields related to the reliability and metal working industry have also had a considerable impact on the improvement of my knowledge, particularly the contacts with Dr.Stravs, Prof.Matthias and Dr. Birolini. The visits to factories have completed the knowledge with pracitcal information.

The contacts with specialists, their suggestions and iniciatives are important for my further work on PhD dissertation as well as for personal development.

IV SYMPOSIUM ÜBER TRANSPORTPROZESSE IN INDUSTRIE
Beograd, 17 - 19. April 1980.

*E. Schmid, H.-R. Schaffer**)
*D. Zelenović, D. Stanivuković***)

DIE TRANSPORT - UND LAGERPROBLEMEN BEI KOPIERDREHE-STRASSENBAU
(Arbeitstitel)

Zusammenfassung

In der Artikel werden die Transport - und Lager-problemen bei Kopierdrehestrassenbau in der Metalverarbeitungsindustrie analisieren. In der Teil: TEORETISCHE GRUNDLAGE sind die Grundlage von Produktionstrassenbau, die Pufferkapazitierung, die Produktionstrasseverteilung und die Kapazitätalokation gegeben.

In zweiter Teil ist ein neues Model für Produktionstrasseoptimierung gegeben. Die Grund der Optimierung ist die Einsteig der Efektivität der Produktionstrasse durch die Einführung den Puffern.

Also, die praktische Lösungen diesen Problemen in Werkzeugmaschinenfabrik "DUBIED E. + Cie. S.A." in Neuchätel in Schweiz werden verstellen. Die Beispiele sind sehr illustrative und schon, bei Dubied, hergestellt.

In Diskusionzeit wird ein Film über diesen Problemen demonstriert.

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4.6 Abstract of the book FLEXIBILITY OF PRODUCTION SYSTEMS

Dragutin Zelenovi, PhD
National project director

THE FLEXIBILITY OF PRODUCTION SYSTEMS*)

Abstract,

This paper is concerned with the flexibility of production systems. An examination is made of conditions for the establishment of flexible production systems and of the possibilities for optimisation. The Advantages and Disadvantages of such systems are discussed across the broad spectrum from job to line production. A quantitative model is porposed for the selcction of production processes. Consideration is given to the flexibility of material flow with Group Technology. Different aspects of planning, monitoring and control are discussed both at micro and macro levels. Finally, a Methodology id presented for investigating such complex dynamic systems.

In this paper an attempt has been made to introduce the idea of the flexibility of production systems based on the princićle of group technology.

Dynamic changes in environmental conditions require a constant effort to develop production systems with higher degree fo flexibility in order to meet the demand for an constant increase in output values such as productivity, quality and profitability.

The introduction of Group Technology could be a good base for increasing of flexibility and output values of production systems. It brings many advantages and more effective approach based on analyses of component processing needs and then de-

*) The book is an annex to this FINAL REPORT.

signing of material flow structure, woek centers, tooling for group production and finally it looks forward to higher degre of automation of batch production. On the basis of carried studies it is cleat that the effective planning of technological development is impossible without knowing the characteristics of components of production programme. Ideally technological development schould also follow nationalization of products and parts to avoid making tools which are not needed after rationalization on the way shown in Fig. 14.

In a shown way Group Technology is an usefull new philosophy based on the simplification of material flow which can increase the flexibility of production systems.

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