ECONOMIC JUSTIFICATION
OF
INDUSTRIAL ROBOTS

MANAGEMENT OVERVIEW
I. INTRODUCTION

II. DISCUSSION OF KEY ISSUES IN ROBOT APPLICATIONS

III. ANALYSIS TOOLS

IV. SUMMARY
MAJOR DETERENTS TO ROBOT APPLICATION INVESTIGATIONS

- WHERE TO BEGIN
- IDENTIFYING GOOD APPLICATIONS
- ESTABLISHING RESPONSIBILITIES
- SECONDARY TO MEETING PRODUCTION
- MANPOWER
PURPOSE OF THE PRESENTATION

• ATTEMPT TO CLARIFY THE JUSTIFICATION PROCESS

• PROVIDE ANALYTICAL TOOLS TO ASSIST ENGINEERS

• MAKE THE INITIAL INVESTIGATION FASTER

• DEVELOP A METHODOLOGY FOR THE INVESTIGATION
GOALS

• MORE EFFICIENT USE OF ENGINEERS

• CONSTRUCT THE APPLICATION TO ACHIEVE THE LOWEST MANUFACTURING COST

• PROVIDE INITIAL DIRECTION (GO/NO-GO)

• IDENTIFY THE BEST APPLICATIONS
ROBOT APPLICATION?

EQUIPMENT CAPABILITIES
ROBOT CAPABILITIES
MACHINE TOOLS OR PROCESS
PART ORIENTATION DEVICES
SENSORS
MAINTENANCE
SPACE REQUIREMENTS

ECONOMICS
CAPITAL EXPENDITURES
SAVINGS
R.O.I.
RISK
PRODUCTIVITY
TECHNICAL FEASIBILITY/ECONOMIC FEASIBILITY RELATIONSHIP

Operations that are technically feasible

Operations that are economically feasible

Operations that are both technically and economically feasible
ROBOT CAPABILITIES

ROBOTS CAN DO PRACTICALLY ANYTHING YOU WANT THEM TO DO AND ARE WILLING TO PAY FOR
WHAT IS ECONOMIC JUSTIFICATION?

- CRITERIA FOR DECISIONS

- RELATIVE MEASURE
  - INDUSTRY TO INDUSTRY
  - COMPANY TO COMPANY
  - FACTORY TO FACTORY

- COMPARATIVE MEASURE
COSTS OF ROBOT SYSTEMS – Included Items

- ROBOT
- FIXTURING AND ORIENTING DEVICES
- INTERFACING SUPPLIES
- TRAINING
- SPARE PARTS
- TOOLING
- CONVEYORS AND RACKS
- MACHINE TOOL REVISIONS
- SAFETY EQUIPMENT
- INSTALLATION
- TAXES
- FREIGHT
- DESIGN
- LESS TAX CREDIT
SAVINGS AND EXPENSES IN NORMAL ROBOT APPLICATIONS

<table>
<thead>
<tr>
<th>SAVINGS</th>
<th>EXPENSES</th>
<th>EITHER WAY</th>
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<tbody>
<tr>
<td>Direct Labor</td>
<td>Maintenance Labor</td>
<td>* Indirect Labor</td>
</tr>
<tr>
<td>Farmout Reduction</td>
<td>* Part Redesigns</td>
<td>Energy</td>
</tr>
<tr>
<td>Direct Material</td>
<td>Training</td>
<td>Floor Space</td>
</tr>
<tr>
<td>* Indirect Material</td>
<td>* M.E. Support</td>
<td>* Downtime</td>
</tr>
<tr>
<td>* Quality</td>
<td></td>
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<tr>
<td>* WIP</td>
<td></td>
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<td>OSHA Compliance</td>
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<td>Scrap Reduction</td>
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<tr>
<td>Resale of Old Equip.</td>
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<td>Depreciation Costs</td>
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INTANGIBLES

* Safety
* Better Management Control
* Inflation
* Less Human Problems
* Step In The Right Direction For Future
* Capacity
* Maintaining State of the Art
* Meeting Product Demand

* ITEMS THAT ARE NOT NORMALLY INCLUDED ON AFE/DCF UNLESS SPECIFICALLY IDENTIFIABLE
ASSUMPTIONS IN ROBOT ANALYSIS

- An operator will be assigned to the operation

- It is preferable that the operation remain on incentive

- The operator should be given 130% incentive opportunity

- Safety devices will be sufficient to allow the operator and robot to work in the same cell
ROBOT WORK ELEMENT DISTRIBUTION

GRAPHIC DISPLAY

(SINGLE ROBOT SYSTEM)

ALL WORK PERFORMED BY THE OPERATOR

OPTIMAL WORK DISTRIBUTION

ACTUAL WORK ASSIGNMENT

MAXIMUM ROBOT WORK

LOST POTENTIAL

CYCLE TIME
Optimal Division of Total Standard Minutes (at 1.15 Avg. P&F Factor)

K-factor

K FACTOR = \frac{\text{Robot Time}}{\text{Operator Standard Time}}

Total Standard Minutes to Apportion Between the Operator and Robot
ROBOT ANALYSIS -- U.S. FACTORIES

TOTAL ANNUAL HOURS VS. JUSTIFIABLE CAPITAL EXPENDITURE
(@ % DIRECT LABOR REDUCTION AND % MACHINE UTILIZATION)

MORE THAN ONE ROBOT REQUIRED
(100% MACHINE UTILIZATION)

ONE ROBOT
25% ROI
$15/HR (D.L. + F.B.)
232 DAYS/yr
-130% INC. -PACE
8 YR DEPR.
48% TAX RATE

R. JERZ, D & CO.
28 APRIL 1980
ROBOT ANALYSIS -- U.S. FACTORIES

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MORE THAN ONE
ROBOT REQUIRED
(100% MACHINE UTILIZATION)

EXAMPLE: 65,600 HRS
50% REDUCTION
$150,000 JUSTIFIABLE CAPITAL

ONE ROBOT
25% ROI
$15/HR (D.L. + F.B.)
232 DAYS/YR
130% INC. FACE
8 YR DEPR.
48% TAX RATE

MACHINE LOADING

28 APRIL 1980

R. JERZ, D & CO.
Optimal Division of Total Standard Minutes (at 1.15 Avg. P&F Factor)

**K-Factor**

\[ K \text{-Factor} = \frac{\text{Robot Time}}{\text{Operator Standard Time}} \]

**Example:** 10 Std Mins

Robot Pace = Operator Pace \((K = 1.7)\)

Result: Assign 4.5 mins to Robot

5.5 mins to Operator
ROBOT ANALYSIS -- U.S. FACTORIES

TOTAL ANNUAL HOURS VS. JUSTIFIABLE CAPITAL EXPENDITURE (@ % DIRECT LABOR REDUCTION AND % MACHINE UTILIZATION)

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(100% MACHINE UTILIZATION)

EXAMPLE: 6,600 HRS
50% REDUCTION
$150,000 JUSTIFIABLE CAPITAL

R. JERZ, D & CO.
28 APRIL 1980
Optimal Division of Total Standard Minutes (at 1.15 Avg. P&F Factor)

Example: 10 Std. Mins
Robot Pace = Operator Pace (K=1.0)
Result: Assign 4.5 Mins to Robot
6.5 Mins to Operator

K-Factor = Robot Time / Operator Standard Time
EXAMPLE

HOT FORMING SCRAPER BLADES

CURRENT OPERATION

1 OPERATOR
4 PART NUMBERS
8104 YEARLY INCENTIVE HOURS
2.145 STANDARD MINUTES PER PART
Optimal Division of Total Standard Minutes (at 1.20 Avg. P&F Factor)

K-Factor

Standard Minutes to Allocate to Robot

Total Standard Minutes to Apportion Between the Operator and Robot

2.145
HOT FORMING OF SCRAPER BLADES

ROBOT APPLICATION

OPERATOR

ORIENTATION TABLE

PRESS

RACK

FURNACE

ROBOT
OPTIMAL WORK DISTRIBUTION
.95 MINS. TO ROBOT
1.20 MINS. TO OPERATOR

ACTUAL WORK DISTRIBUTION
1.27 MINS TO OPERATOR
40.8 % LABOR REDUCTION
ROBOT ANALYSIS -- U.S. FACTORIES

TOTAL ANNUAL HOURS VS. JUSTIFIABLE CAPITAL EXPENDITURE
(@ % DIRECT LABOR REDUCTION AND % MACHINE UTILIZATION)

MORE THAN ONE ROBOT REQUIRED
(100% MACHINE UTILIZATION)

MACH ND LOADING

ASSEMBLY

WELDING AND PAINTING

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RESULTS:

$150,000 JUSTIFIABLE CAPITAL

@ 25% ROI

67% MUF
LOW HOUR ANALYSIS OVERVIEW

OBJECTIVE: TO ANALYTICALLY DETERMINE THE YEARLY HOURS THAT AN OPERATION MUST RUN BEFORE IT BECOMES ECONOMICALLY FEASIBLE TO AUTOMATE IT.
LOW HOUR ANALYSIS

EXAMPLE - WELDING

NUMBER OF SET UPS PER YEAR - 6

SET UP TIME FOR OPERATION - 3/4 HR

SET UP TIME FOR ROBOT - 1/2 HR

INCREMENTAL TOOLING COST - $15 K

ROBOT COST - $100 K

DIRECT LABOR COST PLUS F.B. - $15/HR

PAYBACK FACTOR - 3.0

PERCENT LABOR REDUCTION - 45

PERCENT DELAYS - 20

\[ \text{YEARLY HOURS} = 1223 \]

\[ \# \text{ OF PARTS} = 10.5 \]
LOW HOUR ANALYSIS

EXAMPLE - MACHINE LOADING

NUMBER OF SET UPS PER YEAR - 12
SET UP TIME FOR OPERATION - $\frac{1}{2}$ HR
SET UP TIME FOR ROBOT - $\frac{1}{2}$ HR
INCREMENTAL TOOLING COST - $4$ K
ROBOT COST - $75$ K
DIRECT LABOR COST PLUS F.B. - $15/\text{HR}$
PAYBACK FACTOR - 3.0
PERCENT LABOR REDUCTION - 45
PERCENT DELAYS - 25

\[
\text{YEARLY HOURS} = 309.6
\]
\[
\# \text{ OF PARTS} = 37.51
\]
ONE ROBOT/ONE OPERATOR

ALL WORK CURRENTLY BEING PERFORMED

ROBOT CAPABLE WORK

75

OPTIMAL DISTRIBUTION 50/50

CYCLE TIME = 50

SAVINGS = 50

DUPLICATE SYSTEM (SUB-OPTIMIZATION)

SAVINGS = 100
SYSTEM OPTIMIZATION

TWO ROBOTS/ONE OPERATOR

Cycle Time = 200

OPTIMAL DISTRIBUTION 1/3, 1/3, 1/3

Cycle Time = 66

SAVINGS = 134
## EXAMPLE
### MULTIPLE ROBOT ANALYSIS

<table>
<thead>
<tr>
<th>NO. ROBOTS</th>
<th>% SAVINGS PER OPERATION</th>
<th>TOTAL ROBOT COST</th>
<th>SAVINGS PER SHIFT</th>
<th>ROI 1 SHIFT</th>
<th>ROI 2 SHIFTS</th>
<th>ROI 3 SHIFTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40.5</td>
<td>100</td>
<td>9,584</td>
<td>4.5</td>
<td>15.4</td>
<td>25.0</td>
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<tr>
<td>2</td>
<td>52.6</td>
<td>200</td>
<td>24,894</td>
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<tr>
<td>3</td>
<td>63.0</td>
<td>300</td>
<td>44,724</td>
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<td>4</td>
<td>69.6</td>
<td>400</td>
<td>65,880</td>
<td>12.5</td>
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<td>5</td>
<td>74.3</td>
<td>500</td>
<td>87,910</td>
<td>13.7</td>
<td>31.1</td>
<td>48.2</td>
</tr>
</tbody>
</table>

### ASSUMPTIONS

A. **ROBOT PERFORMS AT OPERATOR'S NORMAL PACE**
   - 1.15 AVG. P&F
   - 1.15 WAF TOTAL
   - 130% INCENTIVE OPPORTUNITY
   - 10% OF INC. STD. REMAINS AS "D" TIME

B. **$100,000 PER ROBOT SYSTEM**
   **$20,000 SALVAGE VALUE**

C. **SAVINGS = 8 HRS/SHIFT X 232 DAYS/YR X 85% UTILIZATION X $15/HR X % SAVINGS**

D. **BASED ON NUMBER OF SHIFTS OF CURRENT WORK LOAD**
EXAMPLE: FOUR OPERATIONS - OPERATOR WORK PERCENTAGES

\[
\begin{align*}
\% \text{ OPER}_1 &= .90 \\
\% \text{ OPER}_2 &= .25 \\
\% \text{ OPER}_3 &= .30 \\
\% \text{ OPER}_4 &= .70
\end{align*}
\]

WITHOUT BALANCING OF RANDOM WORKCELLS, THESE OPERATIONS WOULD BE EXCLUDED FROM ROBOTIC AUTOMATION DUE TO THE HIGH % OF MANUAL WORK ELEMENTS.

BY BALANCING, WE WOULD TRY TO RUN JOBS (1) AND (2) TOGETHER, AND (3) AND (4) TOGETHER.
BENEFITS OF SYSTEMS APPROACH

- GREATER SAVINGS \rightarrow \text{GREATER ROI'S}

- ABLE TO BALANCE LOW ROBOT PERCENT OPERATIONS WITH HIGH ROBOT PERCENT OPERATIONS

- MAY START EFFECTING OVERHEAD ACCOUNTS FOR EVEN GREATER SAVINGS
ADVANTAGES OF ANALYTICAL TOOLS

- TEST SENSITIVITY
- KNOW WHAT THE VARIABLES ARE
- CONCENTRATE ON IMPORTANT VARIABLES
### SUMMARY OF ANALYTICAL TOOLS

<table>
<thead>
<tr>
<th>TOOL</th>
<th>USE</th>
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</thead>
<tbody>
<tr>
<td>OPTIMAL DIVISION OF WORK ELEMENTS</td>
<td>BALANCE WORK ELEMENTS TO MAXIMIZE ROBOT AND OPERATOR UTILIZATION</td>
</tr>
<tr>
<td>ROBOT ANALYSIS</td>
<td>DETERMINES JUSTIFIABLE CAPITAL EXPENDITURE, TOTAL HOURS, OR % REDUCTION</td>
</tr>
<tr>
<td>LOW HOUR ANALYSIS</td>
<td>HELPS ANALYZE AUTOMATION OF LOW HOUR OPERATIONS</td>
</tr>
<tr>
<td>SYSTEMS ANALYSIS</td>
<td>FOR MULTIPLE ROBOT APPLICATIONS</td>
</tr>
<tr>
<td>EXPENDITURE CONVERSION CHART</td>
<td>CONVERTS JUSTIFIABLE CAPITAL AT VARYING ROI'S AND START-UP DELAYS</td>
</tr>
</tbody>
</table>
• ANALYTICAL TOOLS ARE AVAILABLE TO ASSIST ENGINEERS WITH ROBOT INVESTIGATIONS

• ROBOTS DO NOT HAVE TO PERFORM ALL TASKS CURRENTLY BEING PERFORMED BY OPERATORS

• MULTIPLE ROBOTIC SYSTEMS PROVIDE BENEFITS THAT MAY NOT BE OBTAINED IN SINGLE ROBOT SYSTEMS

• ROBOTS CAN WORK WITHIN THE DEERE INCENTIVE SYSTEM

• OPERATORS ARE AFFORDED GOOD INCENTIVE OPPORTUNITY