# ECONOMIC JUSTIFICATION

# OF

# INDUSTRIAL ROBOTS

# MANAGEMENT OVERVIEW

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RICK JERZ
MANUFACTURING RESEARCH & DEVELOPMENT
DEERE & COMPANY

This information was developed during investigations for robot applications for expanded or new factories. Two of the early problems encountered were:

1. No criteria had been established for selecting good robot applications.

2. Very little robot information had been compiled to assist engineers with some of the major issues in robot applications.

It was decided to develop criteria and a methodology for robot investigations to make the investigations go faster and to present management with the criteria used in selecting the best applications so that they might feel more comfortable with their robot application decisions.

It should be pointed out that this is <u>one</u> approach to robot investigations and should not be treated as the only approach or the approach that <u>must</u> be used. The purpose of this information is to help an engineer get started and not to eliminate ingenuity - one important element in applying new technology. What is important is maintaining, building, and passing down information to the next engineer who gets started in robot investigations.

We will start with an introduction to the presentation, followed by a discussion of key issues in robot applications, then look at some analytical tools that have been developed to assist engineers, and last, a summary.

I. INTRODUCTION

II. DISCUSSION OF KEY ISSUES IN ROBOT APPLICATIONS

III. ANALYSIS TOOLS

IV. SUMMARY

MAJOR DETERENTS TO
ROBOT APPLICATION INVESTIGATIONS

What are some of the major deterents in robot applications? One deterent is getting started and knowing where to begin. After starting the investigation, one must start identifying the good applications and separating these from the bad applications.

- WHERE TO BEGIN
- IDENTIFYING GOOD APPLICATIONS
- ESTABLISHING RESPONSIBILITIES
- SECONDARY TO MEETING PRODUCTION
- MANPOWER

Responsibilities must also be established to know who is going to investigate applications. There is no specific rule. Sometimes the responsibility falls into Process and Tool, Research and Development, Plant Layout, or Welding Engineering.

Another deterent is that robot investigations, usually being cost improvement, are secondary to meeting production. Many times an engineer is assigned to robot investigations part of his time and to production activities the other part. Depending on the amount of production activities, an engineer may spend very little time on the robotic activities.

Manpower is the last deterent. Robot investigations are not easy and do require manpower. Many times the number of robot applications at a factory will depend directly upon the manpower assigned to the applications. Again, robotic activities usually compete with production activities and other cost improvement activities.

The purpose of this presentation is to clarify the justification process, provide analytical tools to assist engineers in determining the better applications, make the initial investigation faster, and develop a methodology for the investigation.

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

There are several goals of this presentation. One is to use engineers more efficiently. If we are limited with manpower, it is important to use the manpower assigned to robot investigations as efficiently as possible.

Another goal is to construct the application to achieve the lowest manufacturing cost. There are good and bad ways of developing a robot application.

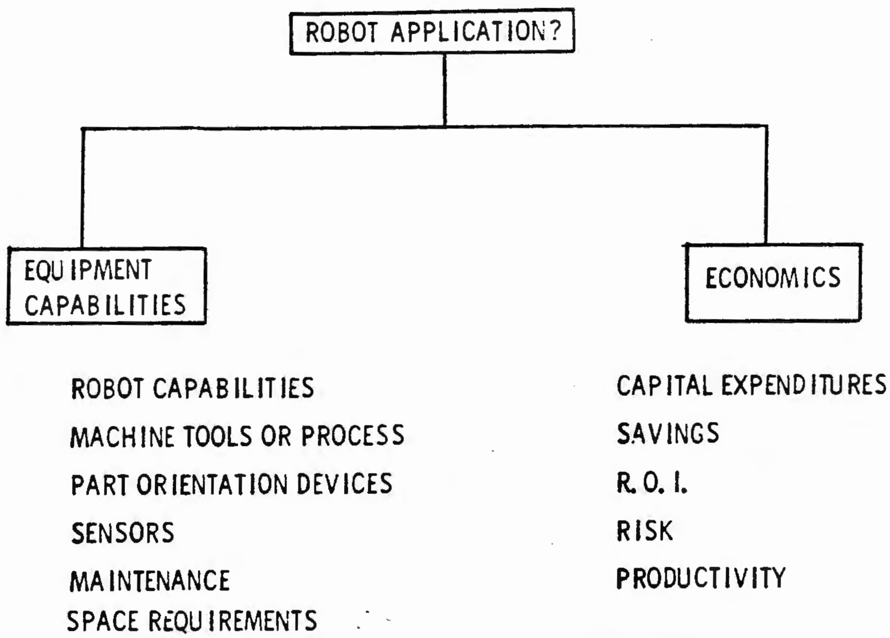
GOALS

- MORE EFFICIENT USE OF ENGINEERS
- CONSTRUCT THE APPLICATION TO ACHIEVE THE LOWEST MANUFACTURING COST
- PROVIDE INITIAL DIRECTION (GO/NO-GO)
- IDENTIFY THE BEST APPLICATIONS

Providing initial direction on whether or not to pursue an application is another goal.

Last is the goal of identifying the best application.

How does an engineer determine if there is a good robot application?

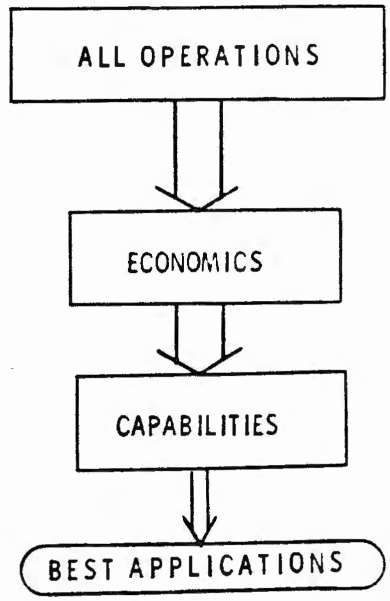



Two things must be looked at - equipment capabilities and economics. The above flow chart illustrates some of the items included under each. Both sides of the flow chart are very important. An engineer must always ask "Is this project technically feasible?" and "Is this project economically feasible?".

The equipment capabilities side can usually be addressed through vendor's knowledge of what his equipment can do, factory past experience, or experience of other companies. However, the economics must be evaluated by your own company. This is due to the internal methods of calculating the economics (Return on Investment) and the relative current operating efficiency. Therefore, it is recommended that you do not rely upon a vendor to tell you if a particular robot application is a sound business proposition for your company.

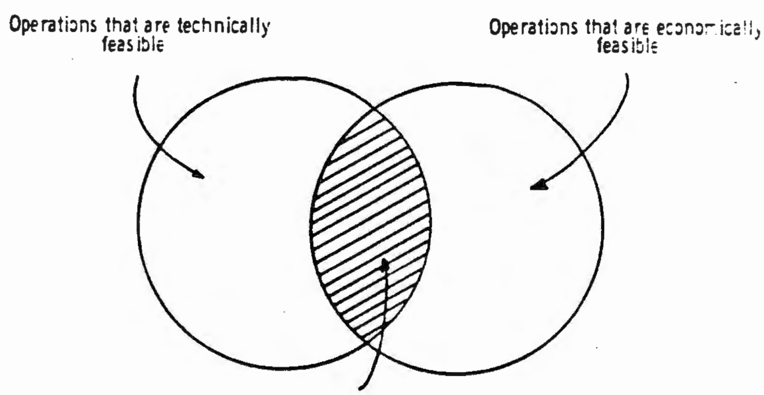
Since there is information and help available on how to select technically feasible applications, this presentation will not address technical feasibility. However, very little information is available on selecting economically feasible applications; and therefore, we will concentrate on economic feasibility.

This chart represents what one could ideally want to do. Two filters, economic and technical, could be set up to sort all applications. The filters could be based on criteria established by the engineer. For example, one economic criteria could be "we desire a 30% ROI", and one capabilities criteria could be "it must be a proven application (currently performed by some company)". Based on this criteria, we could sort all applications. If too many applications come out the bottom, we would tighten the filter; for example, change the 30% ROI to 50% ROI. If too few applications come out the bottom, we may want to loosen our criteria.




Another representation of the relationship between economic and technical feasibility is shown below.

TECHNICAL FEASIBILITY/ECONOMIC FEASIBILITY RELATIONSHIP




Operations that are both technically and economically feasible

There are some applications which are economically feasible and some applications that are technically feasible. We would like to work on applications that are both economically and technically feasible.

One thing to realize about robot capabilities is that robots can do practically anything you want them to do and are willing to pay for.

ROBOT CAPABILITIES

ROBOTS CAN DO PRACTICALLY ANYTHING YOU WANT THEM TO DO

ROBOTS CAN DO PRACTICALLY ANYTHING YOU WANT THEM TO DO AND ARE WILLING TO PAY FOR

What is economic justification and why should we be concerned about return on investment?

WHAT IS ECONOMIC JUSTIFICATION?

- CRITERIA FOR DECISIONS
- RELATIVE MEASURE
  - INDUSTRY TO INDUSTRY
  - COMPANY TO COMPANY
  - FACTORY TO FACTORY
- COMPARATIVE MEASURE

A business needs to establish some criteria to make decisions. Hopefully this criteria should be related to improving the profitability of the company, and should be a criteria which allows us to compare one project against others (for example, comparing buying a mini-computer). We have found that the ROI methods satisfies the above concerns.

It is important to realize that the economic evaluation is a relative measure and depends upon the evaluation techniques, relative current efficiency, and governmental regulations. The economic results can vary from industry to industry, company to company, and even factory to factory. For example, our Welland Works will show a better ROI on an application than any U.S. factory for an identical application because their government has more favorable tax laws. Another example is that our incentive system produces a higher level of manual operating efficiency than many other companies which makes it harder for us to justify cost improvement equipment.

The point is that we must evaluate every application on its own merits instead of pursuing an application because another company is "doing it" or another factory is "doing it".

In making economic evaluations, we have to be concerned about costs and savings.

It should be realized that the cost should include not only the robot, but everything that it takes to make it work. This list is an example of some of the things that should be included.

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 can occur in many areas. The important thing in the economic evaluation is to identify and quantify the areas of savings. If one is unable to quantify the savings but feels that something is important (such as safety, for example), this should be listed as an intangible on the AFE.

SAVINGS AND EXPENSES IN NORMAL ROBOT APPLICATIONS

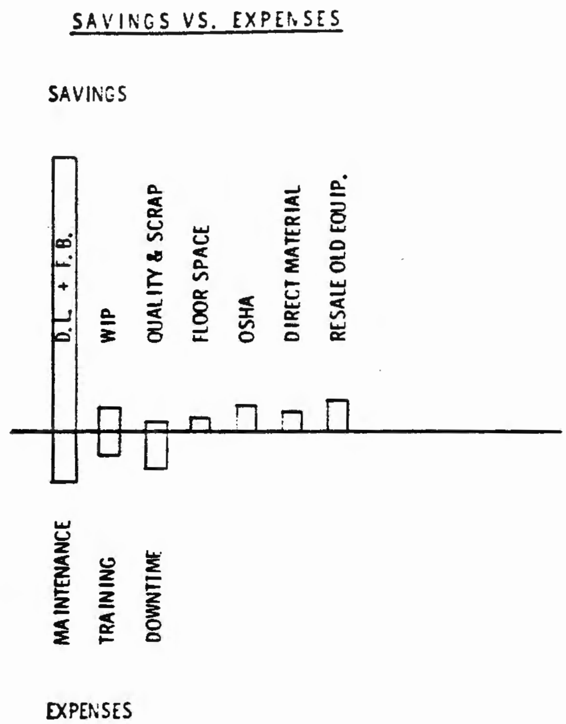
| SAVINGS | EXPENSES | EITHER WAY |
|---|---|---|
| Direct Labor | Maintenance Labor | • Indirect Labor |
| Farmout Reduction | • Part Redesigns | Energy |
| Direct Material | Training | Floor Space |
| • Indirect Material | • M.E. Support | • Downtime |
| • Quality | | |
| • WIP | | |
| OSHA Compliance | | |
| Scrap Reduction | | |
| Resale of Old Equip. | | |
| Depreciation Costs | | |

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

In most normal robot applications, the major savings will be in direct labor plus fringe benefits. It may be that you do have savings in other areas and expenses in several areas, but 80% of the total net savings will be direct labor plus fringe (80/20 rule may apply).



# ANALYTICAL TOOLS

Several assumptions are needed to develop the analytical tools. These assumptions pertain to John Deere's operations.

The first assumption is that an operator will be assigned to the robot operation. In John Deere operations, we do not run any equipment completely automatic and unattended.

Once we assign an operator to an operation, it is preferable that the operation remain on incentive instead of hourly.

If an operator is on incentive, it is preferred that he be given 130% incentive opportunity. This figure is the accepted Industrial Engineering incentive opportunity.

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

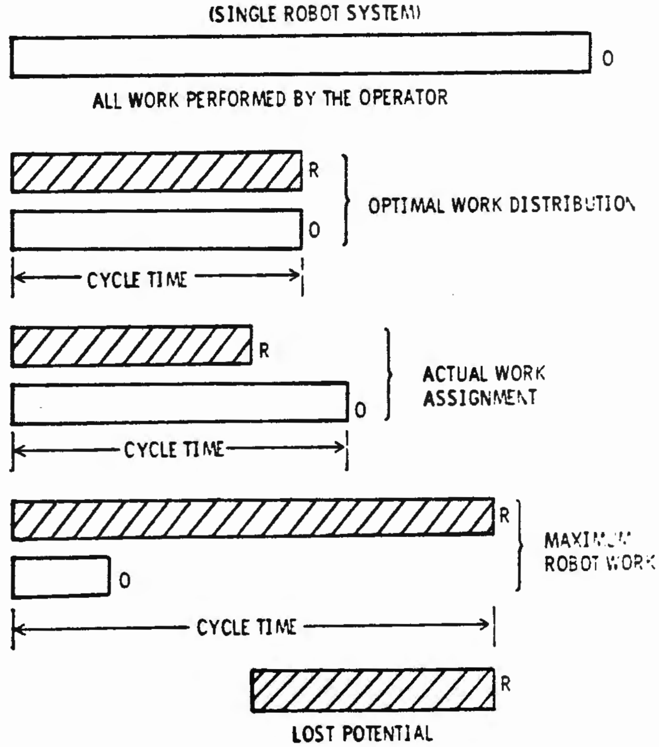
Lastly, safety devices will be put into the operation so that the operator and robot can work in the same cell.

We can visually see how these assumptions apply to the operation.

The first bar represents all the work currently being performed by the operator. If we now add a robot, we essentially have two operators (one mechanical and one human) to split the work between. Let's assume the optimal distribution is 50-50. The resulting cycle time will be one-half the current cycle time and the labor savings will be 50%.

Once we have calculated the optimal work distribution, we should look at all the current work elements to see if we can split the work optimally. What we will most often discover is that we cannot optimally distribute the work and will have to assign slightly more work to either the robot or operator, sacrificing some cycle time and labor savings.

ROBOT WORK ELEMENT DISTRIBUTION
GRAPHIC DISPLAY
(SINGLE ROBOT SYSTEM)

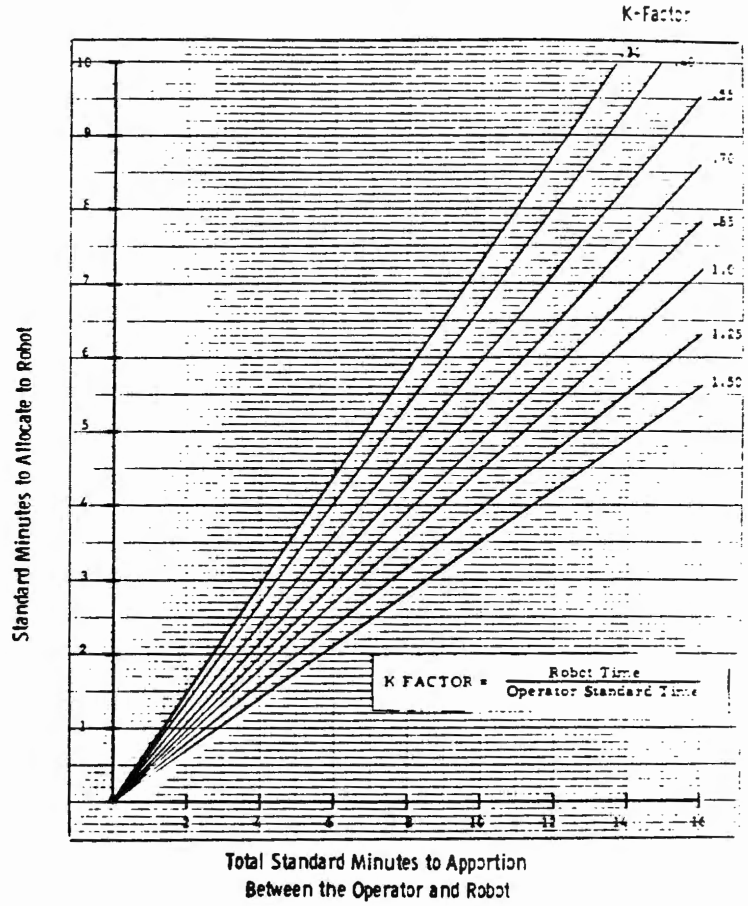



One can see that if we were to try to assign all the work that the robot could perform to the robot, cycle time could increase and labor savings could decrease (unless we could find other useful work for the operator). Ideally, we would like neither the robot nor operator standing around idle.

The question now is "how does one determine this optimal distribution?" It is not always 50-50!

A strict mathematical analysis was performed and is available to determine the optimal distribution. An example of the analysis is shown graphically. The major variables are: the current total standard minutes (from the time study) that we want to apportion between the operator and robot; the speed of the robot compared to the operator speed (K-factor); and the environment that the operator is currently working in, represented by the average personal and fatigue (P&F) factor. As the speed of the robot or P&F factor increases, we will always want to assign more work to the robot.

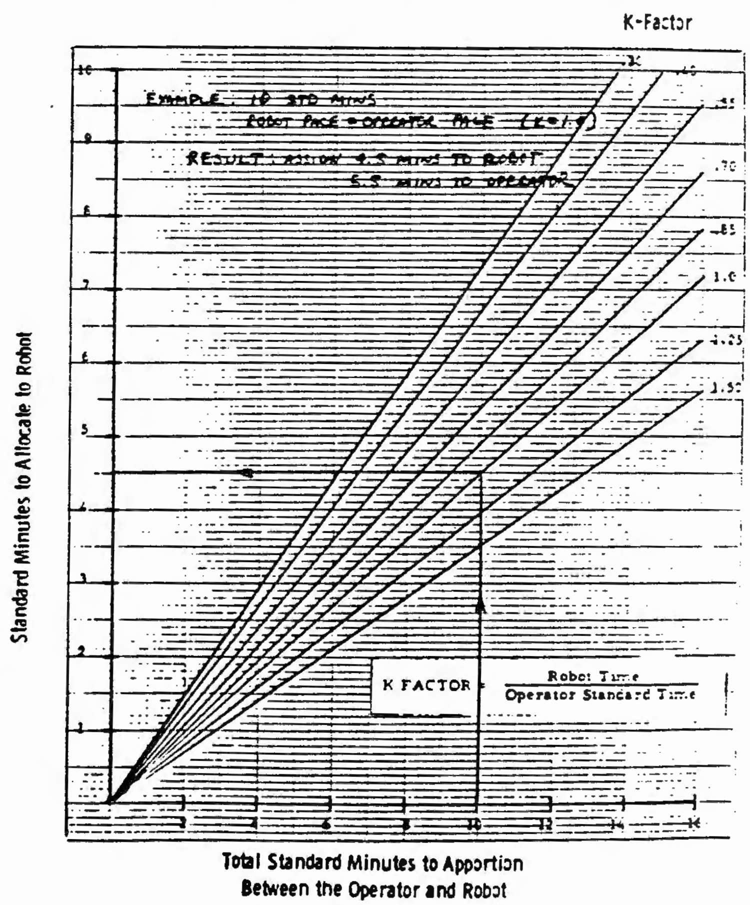
Optimal Division of Total Standard Minutes (at 1.15 Avg. P&F Factor)




Let's see an example of how to use this chart.

If we have 10 standard minutes to divide between the operator and robot, an average P&F of 1.15, and robot speed equal to the operator speed (K=1), we would optimally try to give the robot 4.5 standard minutes of work and the operator 5.5 standard minutes of work (10 -4.5 = 5.5). We would go back to the initial time study to see how close we can come to this optimal distribution.

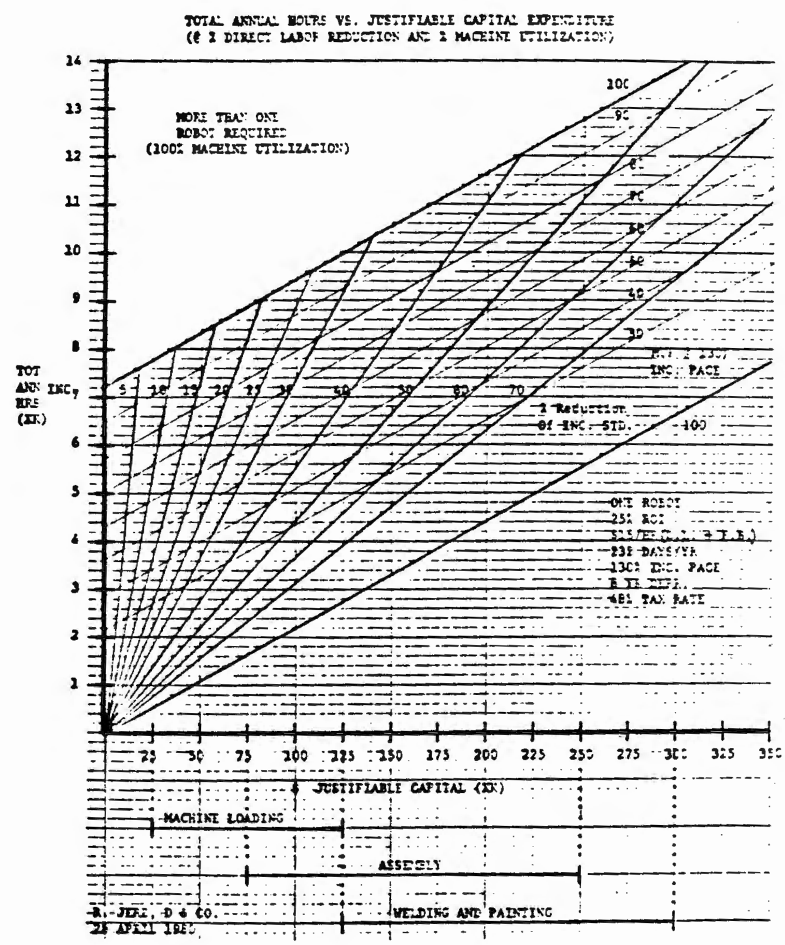
Optimal Division of Total Standard Minutes (at 1.15 Avg. P&F Factor)



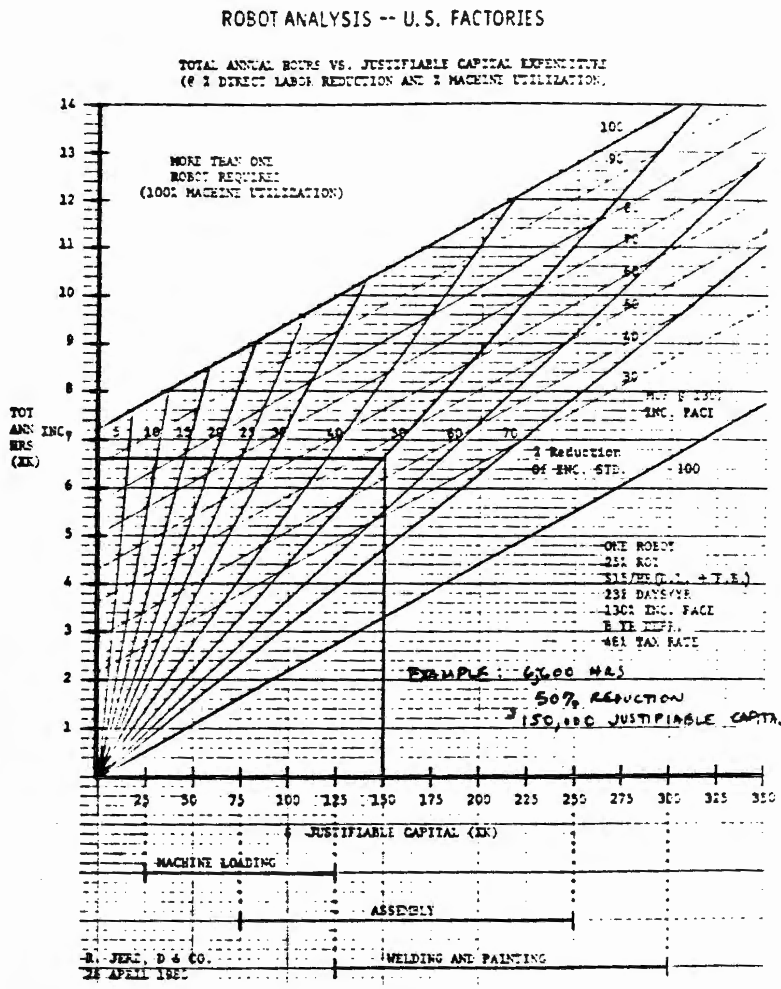
After we have determined the distribution of work, an industrial engineer should calculate the new incentive standard. After we have the new incentive standard, we should calculate the percent reduction from the current standard to our new proposed robot operation standard.

Once we have the percent reduction we are able to use a Robot Analysis chart, shown below, to help us evaluate economic feasibility.

ROBOT ANALYSIS -- U.S. FACTORIES



This chart uses four variables. Justifiable capital is represented on the x-axis, yearly total annual incentive hours is on the y-axis, percent reduction in incentive hours are the lines originating from the origin, and machine utilization is shown on the parallel lines. Let's look at an example of how the chart can be used using all the variables except machine utilization.




Lets assume that we've analyzed an application and determined that we can obtain a 50% reduction in labor and that we have 6,600 yearly incentive hours on the operation. The chart would tell us that we can afford to spend $150,000 on the application and obtain a 25% return on our investment. If we estimate that the application will cost more than $150,000, we will obtain less than a 25% return. If the equipment costs less than $150,000, we will have better than a 25% return. Please note that these results are based on a specific set of assumptions; one robot, 25% ROI, $15 per hour direct labor plus fringe, 8 year depreciation, and 48% tax rate.

This chart is a three way chart. One example was given above. Another example is if we are obtaining a 50% labor reduction and know that the cost of equipment will be $150,000, the chart would tell us that we used at least 6,600 incentive hours in order to obtain a 25% ROI.

The third example is when we know how many hours we have and the approximate cost of equipment. The chart will then tell us the minimum labor reduction necessary to obtain a 25% ROI.

Recall that this chart is based upon one set of conditions. To give the engineer a chance to vary some of the conditions, a total investment conversion chart was developed. For example, if a 35% ROI was desired, and the breakdown of total investment was 10% for expense items and 90% for capital items, the salvage percent was 10%, and the project start-up time was 12 months, the conversion factor would be .60. In the previous example, if we were able to justify $150,000, we could now only justify .60 x $150,000 = $90,000.

The mathematical equations are available for any set of conditions.

Total Investment Conversion Chart

| ROI | % Expense | % Salvage Value | Months Delay | Total Investment ROI 15 | 25 | 35 |
|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 1.70 | 1.14 | .85 |
| | | | 6 | 1.55 | 1.01 | .72 |
| | | | 12 | 1.40 | .87 | .59 |
| | | | 18 | 1.27 | .76 | .50 |
| | | 10 | 0 | 1.74 | 1.15 | .85 |
| | | | 6 | 1.58 | 1.01 | .72 |
| | | | 12 | 1.43 | .87 | .59 |
| | | | 18 | 1.29 | .77 | .50 |
| | | 20 | 0 | 1.77 | 1.16 | .85 |
| | | | 6 | 1.62 | 1.02 | .72 |
| | | | 12 | 1.46 | .88 | .59 |
| | | | 18 | 1.32 | .77 | .50 |
| | 5 | 0 | 0 | 1.71 | 1.15 | .86 |
| | | | 6 | 1.56 | 1.01 | .73 |
| | | | 12 | 1.40 | .88 | .60 |
| | | | 18 | 1.27 | .77 | .50 |
| | | 10 | 0 | 1.74 | 1.16 | .86 |
| | | | 6 | 1.59 | 1.02 | .73 |
| | | | 12 | 1.43 | .88 | .60 |
| | | | 18 | 1.30 | .77 | .51 |
| | | 20 | 0 | 1.78 | 1.17 | .86 |
| | | | 6 | 1.62 | 1.03 | .73 |
| | | | 12 | 1.46 | .89 | .60 |
| | | | 18 | 1.32 | .78 | .51 |
| | 10 | 0 | 0 | 1.72 | 1.16 | .87 |
| | | | 6 | 1.56 | 1.02 | .73 |
| | | | 12 | 1.41 | .88 | .60 |
| | | | 18 | 1.28 | .77 | .51 |
| | | 10 | 0 | 1.75 | 1.17 | .87 |
| | | | 6 | 1.59 | 1.03 | .74 |
| | | | 12 | 1.43 | .88 | .60 |
| | | | 18 | 1.30 | .78 | .51 |
| | | 20 | 0 | 1.76 | 1.18 | .87 |
| | | | 6 | 1.62 | 1.04 | .74 |
| | | | 12 | 1.46 | .89 | .60 |
| | | | 18 | 1.33 | .78 | .51 |

Here is an example of how to use these charts.

The application investigated was hot forming scraper blades at the Plow & Planter Works, which involved heating parts in a gas furnace and then forming them on a two station punch press. One operator performs these operations, four different part numbers are manufactured, 8104 yearly incentive hours are the production requirements, and the current standard minutes per part is 2.145.

EXAMPLE

## HOT FORMING SCRAPER BLADES

CURRENT OPERATION

1 OPERATOR

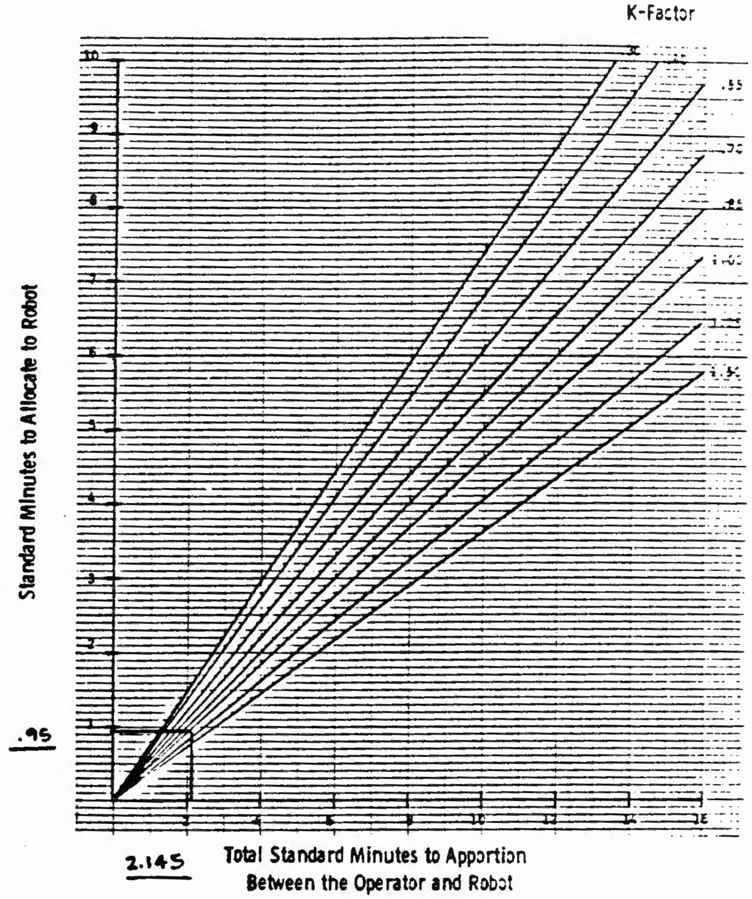
4 PART NUMBERS

8104 YEARLY INCENTIVE HOURS

2.145 STANDARD MINUTES PER PART

It was assumed that the robot could work as fast as the operator in this operation (K=1). Using the distribution of work chart for an average P&F of 1.20 and total standard minutes of 2.145, the result was that optimally the robot should be given .95 standard minutes of work. We next looked at the operation to determine how to distribute the work elements.

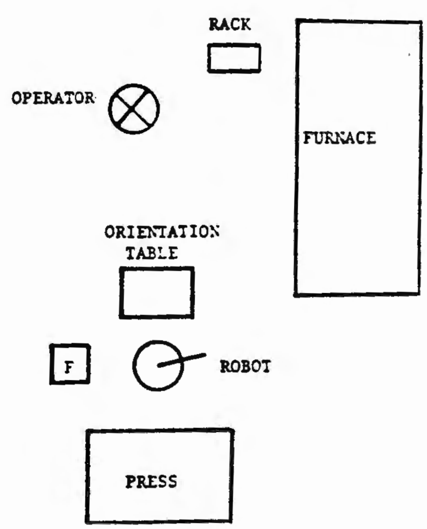
Optimal Division of Total Standard Minutes (at 1.20 Avg. P&F Factor)




It was decided that the best arrangement of the work cell would be to have the operator place scraper blades on a part positioning rack, load the racks into the furnace, and remove the racks when the parts were hot enough and place them on an orientating table. The rack orients the scraper blades and the orientation table orients the rack so part orientation is established for the robot. The robot would take parts from the orientation table, carry them through the two stations, and place them in a finished part pallet. By establishing this distribution of work, we could avoid the expense of modifying an old gas furnace.

HOT FORMING OF SCRAPER BLADES

ROBOT APPLICATION



Recall that the optimal distribution was to give the robot .95 minutes of work and the operator 1.20 minutes of work. Under the proposed operation we ended up giving the operator 1.27 minutes of work (close to optimal) resulting in a 40.8% labor reduction.

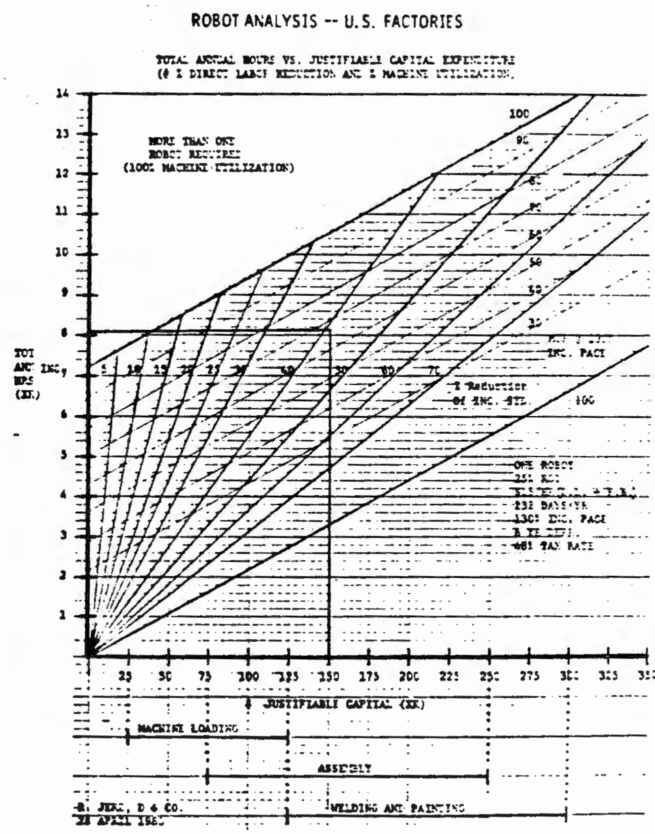
OPTIMAL WORK DISTRIBUTION

.95 MINS. TO ROBOT
1.20 MINS. TO OPERATOR

ACTUAL WORK DISTRIBUTION

1.27 MINS TO OPERATOR
40.8 % LABOR REDUCTION

Using the robot analysis chart with a 40.8% labor reduction and 8104 yearly total incentive hours, we can afford to spend $150,000 and obtain a 25% ROI. The chart also indicates a machine utilization of 67% - basically 2 shifts of full utilization.




Now we must ask ourselves if we can robotize this operation for less than $150,000. In most machine loading applications using a Unimate type of robot, our experience has been that projects generally cost approximately $100,000. This should be true for our application. Knowing that we can afford to spend $150,000 and should only have to spend $100,000, this project can be classified as a good project.

RESULTS:

$150,000 JUSTIFIABLE CAPITAL
@ 25% ROI

67% MUF

Another problem that is faced in robot applications, especially in lower volumn operations, is to decide how many yearly hours must be on an application to make it economically feasible to automate. For example, some people have chosen 1000 yearly hours as a cut-off point. Any operation without 1000 yearly hours would not be considered. Other people have chosen 500 hours or 1500 hours.

Instead of arbitrarily chosing a number, a mathematical analysis called "Low Hour Analysis" was developed to determine analytically the yearly hours that an operation must run before it becomes ecomonically feasible to automate it. An engineer must supply best estimates for a set of variables, and the analysis will calculate the minimum yearly hours per part number and the number of parts.

LOW HOUR ANALYSIS OVERVIEW

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

Below are two examples of this analysis:

## 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 |

YEARLY HOURS = 1223

# OF PARTS = 10.5

## LOW HOUR ANALYSIS

EXAMPLE - MACHINE LOADING

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

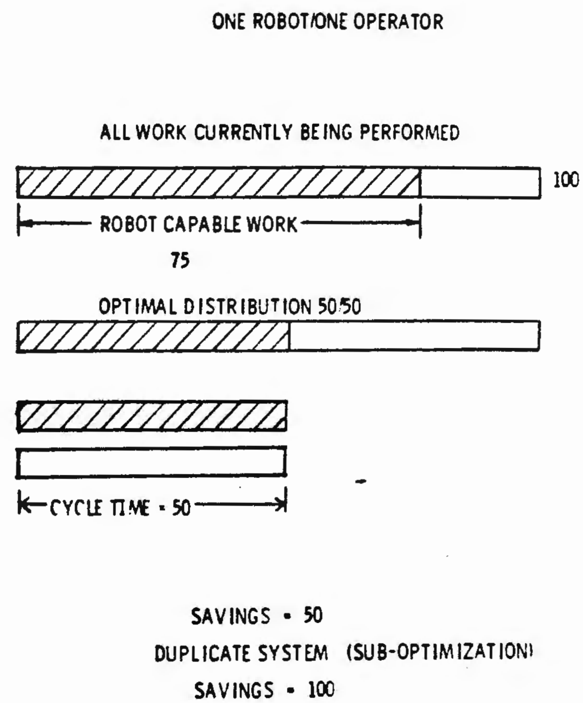
YEARLY HOURS = 309.6

# OF PARTS = 37.51

One can see the estimated variables and the results. Please note that these results are only for a very specific set of conditions and can vary from application to application. In the machine loading example, parts with less than 309.6 hours should not be looked at; and in the welding example, parts with less than 1223 hours should not be looked at.

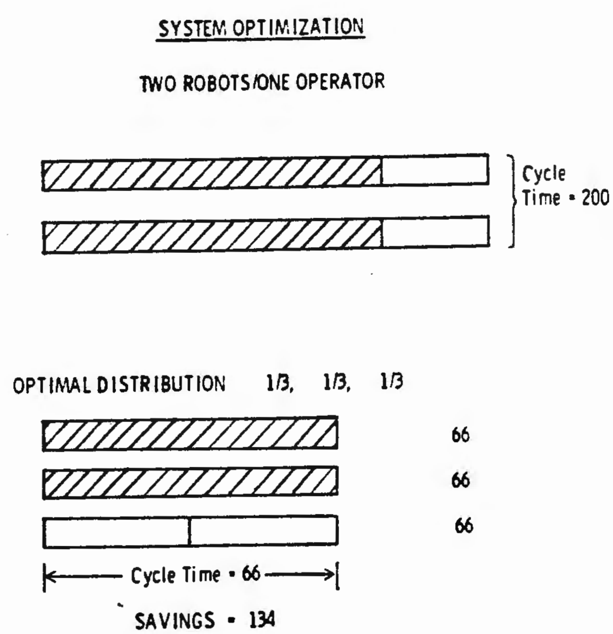
Do multiple robot systems provide better economics than single robot systems? In some situations they can!

Recall our previous example using one robot and one operator. In this example we used a 50-50 distribution as optimal. The savings would be 50 units. If we were to duplicate this system identically, the total savings would be 100 units.




A systems approach using two robots and one operator instead of two robots and two operators could provide better savings. Recall that we currently have 200 total units of work to split between three operators (2 mechanical and 1 human). The optimal is illustrated as 1/3 to each producing a savings of 134 units compared to 100 units without system optimization.

An example to illustrate this concept was developed based on certain assumptions.



EXAMPLE
MULTIPLE ROBOT ANALYSIS

| NO. ROBOTS | A<br>% SAVINGS PER OPERATION | B<br>TOTAL ROBOT COST | C<br>SAVINGS PER SHIFT | 1 SHIFT | D<br>ROI<br>2 SHIFTS | 3 SHIFTS |
|---|---|---|---|---|---|---|
| 1 | 40.5 | 100 | 9,584 | 4.5 | 15.4 | 25.0 |
| 2 | 52.6 | 200 | 24,894 | 8.0 | 21.2 | 33.2 |
| 3 | 63.0 | 300 | 44,724 | 10.8 | 26.0 | 40.3 |
| 4 | 69.6 | 400 | 65,880 | 12.5 | 29.0 | 44.9 |
| 5 | 74.3 | 500 | 87,910 | 13.7 | 31.1 | 48.2 |

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

This example illustrates that as one operator operates more and more robots, the ROI's will increase!

Another potential benefit of using multiple robot cells is in balancing operations. Without balancing, operations where robots cannot perform many work elements would be eliminated as not economically feasible.

With balancing, low robot work operations may be combined with high robot work operations to provide full work for both the robots and operator.

EXAMPLE: FOUR OPERATIONS - OPERATOR WORK PERCENTAGES

% $OPER_1$ = .90
% $OPER_2$ = .25
% $OPER_3$ = .30
% $OPER_4$ = .70

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.

Another benefit of the system's approach is that we may be able to start effecting overhead accounts, especially operator related overhead, for even greater savings.

BENEFITS OF SYSTEMS APPROACH

- GREATER SAVINGS ⟶ GREATER ROI'S
- ABLE TO BALANCE LOW ROBOT PERCENT OPERATIONS WITH HIGH ROBOT PERCENT OPERATIONS
- MAY START EFFECTING OVERHEAD ACCOUNTS FOR EVEN GREATER SAVINGS

These economic tools provide several advantages. One advantage is that they allow us to test the sensitivity of the results by changing the variables. We could answer the question "What would have to change to make an uneconomical project economical?" By testing sensitivity, we may be able to identify the most sensitive variables and then concentrate on improving these most important variables. Last, these analyses help engineers know what the variables are.

ADVANTAGES OF ANALYTICAL TOOLS

- TEST SENSITIVITY
- KNOW WHAT THE VARIABLES ARE
- CONCENTRATE ON IMPORTANT VARIABLES

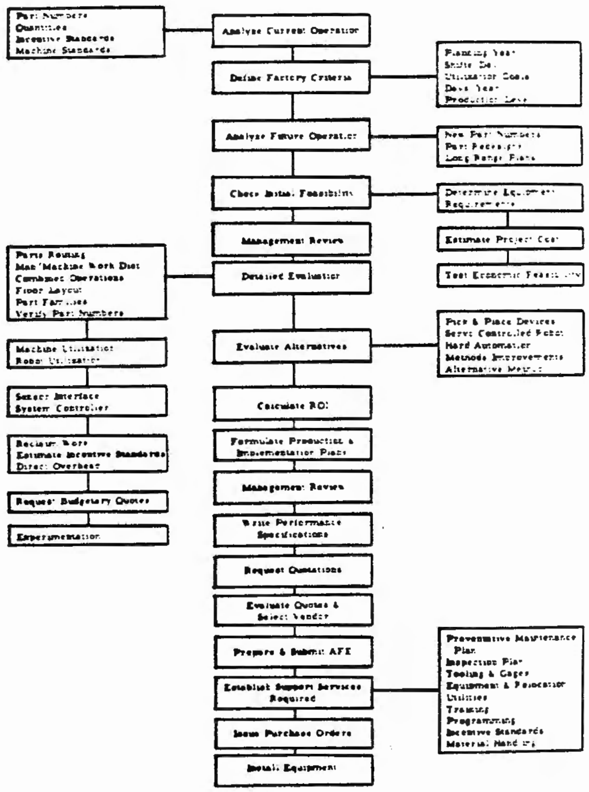
Below is a summary of the analytical tools.

SUMMARY OF ANALYTICAL TOOLS

| TOOL | USE |
| --- | --- |
| OPTIMAL DIVISION OF WORK ELEMENTS | BALANCE WORK ELEMENTS TO MAXIMIZE ROBOT AND OPERATOR UTILIZATION |
| ROBOT ANALYSIS | DETERMINES JUSTIFIABLE CAPITAL EXPENDITURE, TOTAL HOURS, OR % REDUCTION |
| LOW HOUR ANALYSIS | HELPS ANALYZE AUTOMATION OF LOW HOUR OPERATIONS |
| SYSTEMS ANALYSIS | FOR MULTIPLE ROBOT APPLICATIONS |
| EXPENDITURE CONVERSION CHART | CONVERTS JUSTIFIABLE CAPITAL AT VARYING ROI'S AND START-UP DELAYS |

In addition to these tools, a "Robot Application Logic Chart" was developed to assist engineers in robot investigations.

ROBOT APPLICATION LOGIC CHART




Below is a summary of the major points in this presentation.

## SUMMARY

- 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