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Investment Appraisal of Robotic Systems taking into consideration the quantitative, qualitative and strategic benefits

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Investment Appraisal of Robotic Systems taking into consideration the quantitative, qualitative and strategic benefits

A thesis submitted to the

Graduate School

of the University of Cincinnati

in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

in the Department of Mechanical Engineering

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by

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Abstract

Investment Appraisal of Robotic projects is still done using traditional methods which take into consideration only the quantitative benefits of the project. The thesis describes an approach where the quantitative, qualitative and strategic benefits are taken into consideration for the Investment Appraisal of Robotic projects. The qualitative and strategic benefits are quantified in monetary terms and thus the appraisal is done for the projects. The significance of this work is that it will give an insight into the real benefits of a project and will avoid companies from disregarding viable projects. Survey was undertaken to get views of prominent people from the Robotics industry and from customers of the Robotics industry. The results are shown in an Economic model, which can be used by managers to calculate the actual costs and the actual benefits of a Robotics project.

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Chapter 1

Introduction

Robotic Projects are capital equipment projects and require huge investments from the companies employing them. Hence, proper investment appraisal of these projects is vital for the company. The managers have to understand all the benefits associated with a project before making any decision.

There have been many advances in the Investment Appraisal methods of Capital Equipment purchase; however in many industries managers still use methods like Return on Investment and Net Present Value due to the ease of its use. These methods might give a good rough estimate of the investment appraisal, but many times viable projects get cancelled because of inaccurate estimates.

These days with intense competition between firms, strategic benefits have to be taken into consideration. Companies can gain tremendous competitive advantage by using robotic systems, and hence it is important to quantify strategic benefits accurately.

Also for a proper estimate, qualitative benefits have to be accounted for. Qualitative benefits like less scrap, less rework, manufacturing of higher quality goods have to be taken in to consideration.

Taking into consideration all these things, robotic projects can make a huge difference to a company if employed correctly. Also avoiding these projects, when needed, due to inaccurate estimate of their costs and benefits, can be a huge loss for the company. Hence, careful and detailed appraisal should be done of investments in such projects.

Chapter 2

Literature review

Different justification techniques that have been proposed:

Economic:

1. Payback period
2. Return on Investment
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4. Internal Rate of Return
5. Net Present Value
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Analytic:

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2.1 Economic:

2.1.1 Payback Period:

In Payback period method, the total number of years required for recovering the entire investment is calculated. If the number of years meets the requirement of the company then the investment is justified. [28]

$$Payback\ period = \frac{I}{L + PI - E}$$

Where,

I - Initial Investment

L- Annual Savings in labor

PI- Annual Production increase

E- Annual expenses of maintaining the robot

Example. I= $1,20,000, L= 20,000, PI= $35,000 and E= $5,000,
Then,

Cash Flow Table:

YR 0	YR 1	YR 2	YR 3
I = 120000	S_1 = L + PI – E = 50000	S_2 = L + PI – E = 50000	S_3 = L + PI – E = 50000

$$Payback\ period = \frac{120000}{20000 + 35000 - 5000}$$

= 2.4 yrs

2.1.2 Return on Investment:

In this approach, the Benefit of the Investment is divided by the Cost of the Investment. An investment is justified if it has a positive Return on Investment or in case there is more than one alternative, the alternative with the highest Return on Investment is chosen. It is generally expressed as a percentage. [28]

$$ROI = \frac{L + PI - I}{I} * 100$$

Where,

I - Initial Investment

L- Annual Savings in labor

PI- Annual Production increase

Example. I= $1,20,000, L= 20,000, PI= $35,000 and E= $5,000, then ROI for a period of 3 years will be,

Cash Flow Table:

YR 0	YR 1	YR 2	YR 3
I = 120000	S_1 = L + PI – E = 50000	S_2 = L + PI – E = 50000	S_3 = L + PI – E = 50000

$$Return\ on\ Investment = \frac{120000 + 105000 - 15000}{120000} * 100$$

= 125%

ROI is positive. Hence the investment is justified.

2.1.3 Benefit to Cost Ratio:

In this approach the Benefits are divided by the Costs of the investment. However, in this approach all the costs are adjusted for time value of money. [28]

$$BCR = \frac{L + PI - I}{I}$$

Example. I= $1,20,000, L= 20,000, PI= $35,000 and E= $5,000, then for a period of 3 years,

Cash Flow Table:

YR 0	YR 1	YR 2	YR 3
I = 120000	S_1 = L + PI – E = 50000	S_2 = L + PI – E = 50000	S_3 = L + PI – E = 50000

$$BCR = \frac{120000 + 105000 - 15000}{120000}$$

$$= 1.25$$

2.1.4 Internal Rate of Return:

IRR is the annualized compounded return rate that that can be earned on the investment.

The investment is justified if the IRR is greater than the cost of capital. [28]

$$I(1+r)^N = \sum_{j=1}^{N} S_j (1+r)^{N-j}$$

I - Initial Investment

r- Internal Rate of Return

S- Annual Savings

N- Number of years

In the equation, the value of r that satisfies the equation is the Internal Rate of Return.

Example. I= $60,000, L= 20,000, PI= $35,000 and E= $5,000, then for a period of 3 years,

Cash Flow Table:

YR 0	YR 1	YR 2	YR 3
I = 60000	I(1+r) = 85800	$I(1 + r)^2$ = 122694	$I(1 + r)^3$ = 175452
	S1 = 50000	$S1(1 + r)$ = 71500	$S1(1 + r)^2$ = 102245
		S2 = 50000	$S2(1 + r)$ = 71500
			S3 = 50000

Capital Investment		**$60,000.00**		
	year 0	year 1	year 2	year 3
Capital investment	-$60,000.00			
Set-up expenses	$0.00			
Tax savings(34%)		$0.00		
Equipment Depreciation		$20,000.00	$20,000.00	$20,000.00
Tax savings (34%)		$6,800.00	$6,800.00	$6,800.00
Wages of shifted worker		$20,000.00	$21,000.00	$22,050.00
Tax cost (34%)		-$6,800.00	-$7,140.00	-$7,497.00
Productivity increase		$35,000.00	$36,750.00	$38,587.50
Tax cost (34%)		-$11,900.00	-$12,495.00	-$13,119.75
Maintenance expense		-$5,000.00	-$5,250.00	-$5,512.50
Tax savings(34%)		$1,700.00	$1,785.00	$1,874.25
Energy expense		-$3,000.00	-$3,150.00	-$3,307.50
Tax savings(34%)		$1,020.00	$1,071.00	$1,124.55
Annual cash savings	-$60,000.00	$37,820.00	$39,371.00	$40,999.55

Tax Cost:	34%	
Inflation:	5%	
Total Savings:	$118,190.55	
Average yearly saving	$39,396.85	
Initial Investment:	$60,000.00	
Rate of Return:	**43%**	
Payback period	**2.35**	

2.1.5 Net Present Value:

Net Present value is calculated as the total present value of a series of cash flows. An investment is justified if the Net Present Value is positive. In case of different alternatives, the alternative with the highest Net Present Value is chosen. [29, 30]

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t} - C_0$$

Where,

NPV- Net Present Value

C_t - The net cash flow for time t

r- the discount rate

t- the time of the cash flow

C_0 - Initial Investment

Example. C_0= $1,20,000, L= 20,000, PI= $35,000, r=0.1, E= $5,000, then for a period of 3 years, Cash Flow Table:

YR 0	YR 1	YR 2	YR 3
I = 120000	$\frac{C_1}{(1+r)^1}$ = 45454	$\frac{C_2}{(1+r)^2}$ = 42322	$\frac{C_3}{(1+r)^3}$ = 37565

C_0 = 120000

For 1st year,

$$\frac{C_1}{(1+r)^1} =$$

$$\frac{35000 + 20000 - 5000}{(1 + 0.1)^1} = 45454$$

For 2nd year,

$$\frac{C_2}{(1+r)^2} =$$

$$\frac{35000 + 20000 - 5000}{(1 + 0.1)^2} = 42322$$

For 3rd year,

$$\frac{C_3}{(1+r)^3} =$$

$$\frac{35000 + 20000 - 5000}{(1 + 0.1)^3} = 37565$$

Hence, NPV = 45454 + 42322 + 37565 – 120000 = 4341

NPV is positive. Hence investment is justified.

2.1.6 Accounting Rate of Return:

Accounting Rate of Return or ARR is calculated as the ratio of average profit to the average investment. The average is calculated as the arithmetic mean. [31]

$$ARR = \frac{Average\ Profit}{Average\ Investment} * 100$$

Example. I= $1,20,000, L= 20,000, PI= $35,000 and E= $5,000, then for a period of 3 years,

Cash Flow Table:

YR 0	YR 1	YR 2	YR 3
I = 120000	S_1 = L + PI – E = 50000	S_2 = L + PI – E = 50000	S_3 = L + PI – E = 50000

Average Profit: 20000 + 35000 – 5000-40000 = 10000

Average Investment: 120000/3 = 40000

$$ARR = \frac{10000}{40000} * 100$$

= 25%

2.1.7 Break-Even Analysis:

In this approach, the Break-even point is determined, which is the point when the total revenue from the investment is equal to the total costs associated with the investment. If the Break-even point is agreeable then the project is selected. [24, 8]

2.1.8 The Theory of Games and Rational Decision making theory:

For making decision regarding investments, this approach gives a mathematical model of the situation and then provides solutions to the problem with the help of some principles like Minimax, Maximax etc. The problem is formulated in a Matrix and 2 forms of games are formulated: Game against an intelligent opponent and game against Nature. In the game against an intelligent opponent, the opponent will try to move rationally and we try to formulate our strategy as per the moves of the opponent to minimize loss or maximize profit. In a game against nature, there can be no prediction about any rational behavior. Investment decision problems fall in the category of Game against Nature.

The project is further divided according to the risks involved as uncertain, risky and certain. All criteria are taken into consideration. For projects which are highly uncertain, different weightage is given to alternate criteria but the approach does not tell which approach will be realized practically. For projects which are risky, the approach gives different alternatives and all alternatives have a degree of risk associated with them. For projects with high certainty, the approach will give an absolutely correct evaluation.

A large number of criteria are used for this approach and the common approaches for this method are the Minimax theory, Maximax theory, Laplace's criteria etc. [24]

2.1.9 Sensitivity Analysis:

This method of project evaluation is often used in projects with a high degree of uncertainty. In this approach, the fundamental principle is that the input data might change as the project proceeds and hence the final output will be different than what is anticipated. This approach takes into consideration these variations while selecting a project and thus, is a good approach for selecting projects with a high degree of uncertainty. [24]

2.1.10 Scenario Method:

This method is also used for projects with a high degree of uncertainty. The method takes a heuristic approach. To develop the heuristic, an actual case is studied and the main steps of the heuristic are determined. The main function of the heuristic is to link the relevant trends and uncertainties to the actual project in consideration and to blend it together. This approach is more useful in projects with a high level of uncertainty. [24, 25]

2.1.11 Activity Based Costing:

In this method, all the activities included in a project, like the usually accountable activities like manufacturing, transportation are included along with activities like waiting time, idle time etc. Due to this, this approach considers all the activities that are not normally accounted for and gives a better evaluation of the project. [26]

2.2 Analytic:

2.2.1 Value Analysis:

In this approach, the appraisal is carried out in 2 steps. In the first or the pilot stage, the project is considered as a research and development project, as a small scale project and the value of the project is roughly estimated and only the direct benefits that can be easily estimated are taken into account. The cost of the investment is compared to see if the project is acceptable. If the project is accepted in the pilot stage, then in the build stage the development of the full system is considered. All the benefits are evaluated very carefully and if expected benefits are more than the expected costs, then the project is approved. [2]

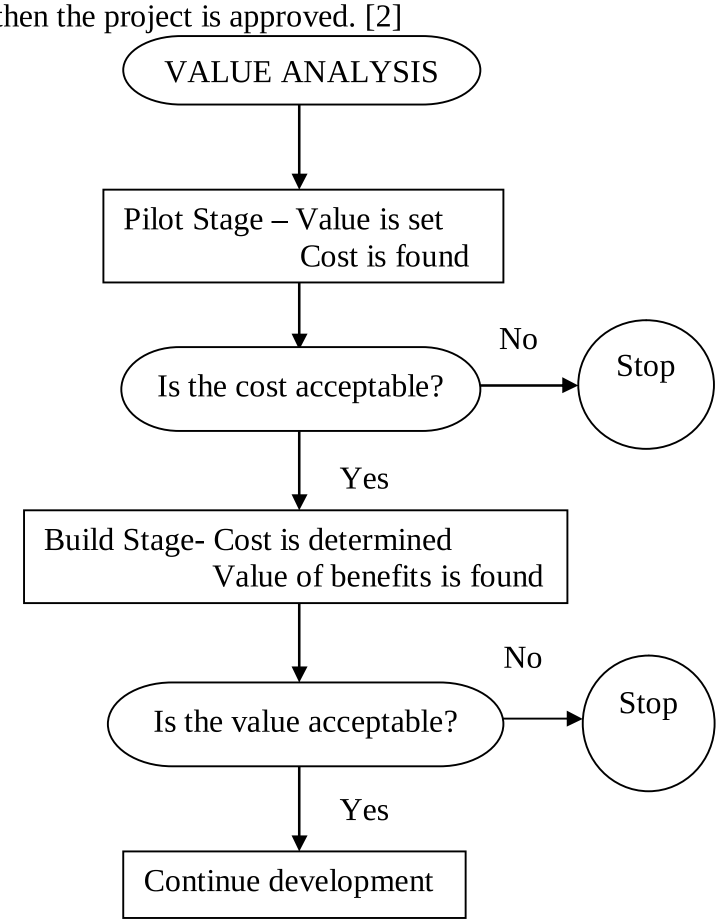


Fig. 1 Value Analysis Approach

2.2.2 Portfolio Analysis (Non-Numeric models):

In this approach, the costs and the benefits are not directly taken into account as the name suggests. Such an approach is usually followed when a project is proposed by a very influential or senior person in the company. In this approach, the project is carried out and is executed as long as the person who proposed it does not feel like it is a bad idea. It happens in organizations where a lot of authority rests in the hands of a few influential people. New technologies like robotic systems often are decided by this method in small and medium enterprises. [2]

2.2.3 Analytical Hierarchy Process:

In this process, the problem is first decomposed into a hierarchy of smaller independent problems/ criteria which can be analyzed individually. Once this hierarchy is developed, the pairs of criteria are compared. Then preference values are given to each of the criteria comparing them to each other. Once the criteria are assigned values, different alternatives are compared as per those criteria and the best alternative is chosen which gets the highest total value. [1, 2]

2.2.4 Unweighted 0-1 factor model:

In this approach, a number of relevant factors are collected, and many supervisors rate the factors as either 0 or 1. If 0 then the factor is removed. If 1 then the factor is considered important and adds to the score of the project. Likewise all the factors are assigned 0 or 1 and the project with maximum ones is selected. In this approach, no consideration is given to the weightage of each factor or its importance to the project. [2]

Example:

Factor	**Project 1**	**Project 2**
Factor 1	0	1
Factor 2	1	0
Factor 3	1	0
Total Score	**2**	**1**

Fig.2 The 0-1 Unweighted factor model

Thus, the project 1 will be selected as the total score for it is 2 and for project 2 it is 1.

2.2.5 Unweighted factor model:

This approach is similar to the Unweighted 0-1 factor model, with the exception that each factor considered important is weighed by the supervisors on a linear scale of 1-5 and the project having the highest total is selected. In this method, however, the factors themselves are not given weightage as per their importance. [2]

Example:

Factor	**Project 1**	**Project 2**
Factor 1	2	3
Factor 2	4	5
Factor 3	4	1
Total Score	**10**	**9**

Fig.3 The Unweighted factor model

Thus, the project 1 will be selected as the total score for it is 10 and for project 2 it is 9.

2.2.6 Weighted factor model:

As the name suggests, in this approach, in addition to the Unweighted factor model, weights are assigned to each of the factors considered. Then the project getting the highest value is considered. It is a pretty common approach used in industries as it is easy to use and more effective than the other portfolio analysis methods. [2]

Total = $w_1 s_1 + w_2 s_2$

Where,

w_i - Weight for factor i

s_i - Score of factor i

Example:

Factor	**Project 1**	**Project 2**
Factor 1 (weightage-3)	2	3
Factor 2 (weightage-4)	4	5
Factor 3 (weightage-4)	4	1
Total Score	**38**	**33**

Fig.3 The Weighted factor model

Total for project 1: 3*2+4*4+4*4= 38

Total for project 2: 3*3+4*5+4*1= 33

Thus, the project 1 will be selected as the total score for it is 38 and for project 2 it is 33.

2.2.7 Portfolio Analysis (Programming models):

With the help of the methods mentioned above, various programmed models can be established by building equations from the approaches above and assigning constraints based on budgets or performance. [2]

2.2.8 Risk Analysis:

In this approach, the various projects under consideration are simulated taking into consideration different factors that are important. Then the simulation results are analyzed and the project with minimum risks is accepted. [2]

2.3 Strategic:

2.3.1 Technical Importance: In this approach, the technical importance of the project is taken into consideration. The project is undertaken if it is of technical importance to the industry. Such projects are either accepted or rejected based just on their requirement and an in-depth cost-benefit analysis is not carried out many a times. If projects are found to be important and essential for their technical value and further work cannot be carried out without these projects, then the projects are accepted even if they do not provide a positive Return on Investment. [2]

2.3.2 Business Objective:

In this approach, projects are appraised depending on their usefulness to the business objectives of the firm. If a project is in alignment with its business objective, then such projects are accepted. For such projects, the cost benefit analysis is not carried out and the acceptance of such projects depends to a large extent on the thinking of the management of the company. [2]

2.3.3 Competitive Advantage:

In some cases, some projects are required for gaining a considerable competitive advantage for the firm. The project might not be directly giving a positive Return on Investment to the firm, but it is required to give a considerable competitive advantage to the firm and can prove to be a Unique Selling Proposition for the firm. In such cases such projects are likely to be accepted. [2]

2.3.4 Research and Development:

All successful companies invest a large amount of their funds in research and development. There are very few inventions which will eventually pay off, but the ones which do, payoff for the research costs of all other projects as well. A good research project idea is often appraised on the grounds of its usefulness to the strategic objectives of the company and to the future of the company. Many a times, such projects are appraised by the top management taking into consideration either the possible benefits of the project for increasing sales or improving manufacturing process efficiencies. [2]

Chapter 3

Proposed Investment Appraisal Technique

3.1 The factors initially considered:

In the proposed technique for investment appraisal, quantitative, qualitative and strategic benefits are taken into consideration to quantify the benefits of a Robotics project.

Some of the benefits commonly associated with robotics project that were initially considered for building the model are as follows:

3.1.1 Quantitative benefits:

- Increase in production
- Savings in labor cost
- Savings due to reduced wastage
- Savings due to saved floor space
- Tax savings due to depreciation
- Compensation to workers for accidents

3.1.2 Qualitative benefits:

- Higher process efficiency (less breakdowns, less maintenance)
- Higher quality (less rework)
- Less variation in per shift output
- Increase in operator's comfort/ morale

- Lower management attention

3.1.3 Strategic benefits:

- Competitive advantage
- Technological advantage
- Meeting delivery schedules
- No labor union issues
- Flexibility to scale up production
- Trained workers to new shops
- Opportunity costs of a new business unit
- Technology to attract customers

3.2 Initial Survey of the factors:

3.2.1 Purpose of the initial survey:

An initial survey was conducted to get views from the Robotics industry experts on this justification model. The survey was undertaken by professionals in the Robotics and Manufacturing industry.

The survey was undertaken for the following three purposes:

- To check if there are any unnecessary factors in the model
- To check if any other important factors are necessary and to be included
- To rank the factors according to their importance

3.2.2 A Sample survey:

A sample copy of the survey is as follows:

	Factors accounted for Investment Appraisal of Robotic systems		
	Please fill all the yellow boxes in Column 1 and Column 2		
	Column 1: Do you think the factor mentioned is required- Y/N		
	Column 2: Rank the quantitative, qualitative and strategic factors independently		
		Col 1	*Col 2*
	Quantitative factors	**(Y/N)**	**Rank (1-6)**
Sr. No.	**Factor**		
1	Production Increase		
2	Savings in labor		
3	Savings due to reduced waste and scrap		
4	Savings due to reduced floor space		
5	Tax savings due to depreciation		
6	Compensation to workers for accidents		
	Qualitative factors	**(Y/N)**	**Rank (1-5)**
Sr. No.	**Factor**		
1	Higher process efficiency (lesser breakdowns, lesser maintenance costs)		
2	Higher quality (lesser rework)		
3	Lower variation in per shift production output		
4	Higher operator comfort/ morale		
5	Lower managerial attention to per shift outputs		

	Strategic factors	**(Y/N)**	**Rank (1-8)**
Sr. No.	**Factor**		
1	Competitive advantage		
2	Technology advantage		
3	Regularly meeting delivery schedules		
4	Lesser labor union issues		
5	Flexibility to scale up or scale down production in lesser time		
6	Flexibility to get trained workers to new production shops		
7	Opportunity cost of a new business unit		
8	Use of technology to attract customers		
	Additional factors /Comments		

3.2.3 Details of the Survey:

The survey was undertaken by 9 people who were selected from amongst the prominent professionals in the robotics industry, the automobile industry and the automobile parts manufacturers. The Survey was undertaken by professionals in India and United States. This gave an overview from professionals of 2 countries with varying manufacturing needs and varying robotics demands.

3.2.4 Results of the Survey:

The results of the Survey are given below. The number of professionals out of the total 9 that agreed to the necessity of the factors is given in the table below. The factors which were accepted by the majority (more than 50% of participants) were included in the model and the factors were ranked according to the degree of acceptance they received from the survey.

Number of people taking Survey: 9

	Quantitative factors		**Acceptance**
Sr. No.	**Factor**		
1	Production Increase		7/9
2	Savings in labor		9/9
3	Savings due to reduced waste and scrap		7/9
4	Savings due to reduced floor space		5/9
5	Tax savings due to depreciation		4/9
6	Compensation to workers for accidents		4/9
	Qualitative factors		**Acceptance**
Sr. No.	**Factor**		
1	Higher process efficiency (lesser breakdowns, lesser maintenance costs)		9/9
2	Higher quality (lesser rework)		9/9
3	Lower variation in per shift production output		8/9
4	Higher operator comfort/ morale		5/9

5	Lower managerial attention to per shift outputs		4/9
	Strategic factors		**Acceptance**
Sr. No.	**Factor**		
1	Competitive advantage		8/9
2	Technology advantage		8/9
3	Regularly meeting delivery schedules		9/9
4	Lesser labor union issues		6/9
5	Flexibility to scale up or scale down production in lesser time		7/9
6	Flexibility to get trained workers to new production shops		6/9
7	Use of technology to attract customers		5/9
8	Opportunity cost of a new business unit		4/9

As per the results of the survey, the factors were finalized and ranked as per their importance.

The revised factors arranged according to their ranks are as follows:

	Quantitative factors
Rank	**Factor**
1	Savings in labor
2	Production Increase
2	Savings due to reduced waste and scrap
3	Savings due to reduced floor space
	Qualitative factors
Rank	**Factor**
1	Higher process efficiency (lesser breakdowns, lesser maintenance costs)
1	Higher quality (lesser rework)
2	Lower variation in per shift production output
3	Higher operator comfort/ morale
	Strategic factors
Rank	**Factor**
1	Regularly meeting delivery schedules
2	Technology advantage
2	Competitive advantage
3	Flexibility to scale up or scale down production in lesser time
4	Lesser labor union issues

4	Flexibility to get trained workers to new production shops
5	Use of technology to attract customers

3.3 The second survey:

3.3.1 Purpose of the second survey:

After the initial survey, the factors thought of as unnecessary by the experts were removed from the model. Also the factors were arranged according to the ranks they received in the initial survey. A second survey was then conducted with more number of participants.

This survey was conducted for 2 purposes. The first was to evaluate the final economic model by professionals from different industries and different departments of the industries and to arrange the factors according to their importance. It was expected that this survey would give a general view of managers in companies who actually deal with such equipments and evaluate them on a day-to-day basis.

The second purpose was to compare the factor acceptance received in USA and in India.

The Hypothesis for the survey was stated as follows:

“Are all the factors included in the model necessary and are they necessary in both USA and India?”

3.3.2 A Sample second survey:

For the second survey, the factors thought as unnecessary by the experts were discarded and the factors were arranged according to the importance they received in the initial survey.

A sample copy of the survey is as follows:

	Quantitative factors	*Col 1*	*Col 2*
Sr. No	**Factor**	**(Y/N)**	**Rank (1-4)**
1	Savings in labor		
2	Production Increase		
3	Savings due to reduced waste and scrap		
4	Savings due to reduced floor space		
	Qualitative factors	**(Y/N)**	**Rank (1-4)**
Sr. No.	**Factor**		
1	Higher process efficiency (lesser breakdowns, lesser maintenance costs)		
2	Higher quality (lesser rework)		
3	Lower variation in per shift production output		
4	Higher operator comfort/ morale		
	Strategic factors	**(Y/N)**	**Rank (1-7)**
Sr. No.	**Factor**		
1	Regularly meeting delivery schedules		
2	Technology advantage		

3	Competitive advantage		
4	Flexibility to scale up or scale down production in lesser time		
5	Lesser labor union issues		
6	Flexibility to get trained workers to new production shops		
7	Use of technology to attract customers		
	Additional factors /Comments		

3.3.3 Details of the second Survey:

The survey was undertaken by 31 participants from different industries and different departments of work. Participants were from USA and India.

3.3.4 Results of the second Survey:

The results of the survey are shown in the table below. The number of participants that agreed to the factors out of the total 31participants is given against each factor.

Total number of participants: 31

	Quantitative factors	**Acceptance**
Sr. No.	**Factor**	
1	Production Increase	28/31
2	Savings in labor	30/31
3	Savings due to reduced waste and scrap	27/31
4	Savings due to reduced floor space	17/31
	Qualitative factors	**Acceptance**
Sr. No.	**Factor**	
1	Higher process efficiency (lesser breakdowns, lesser maintenance costs)	29/31
2	Higher quality (lesser rework)	30/31
3	Lower variation in per shift production output	29/31
4	Higher operator comfort/ morale	17/31
	Strategic factors	**Acceptance**
Sr. No.	**Factor**	
1	Competitive advantage	29/31
2	Technology advantage	29/31
3	Regularly meeting delivery schedules	30/31
4	Lesser labor union issues	21/31

5	Flexibility to scale up or scale down production in lesser time	25/31
6	Flexibility to get trained workers to new production shops	23/31
7	Use of technology to attract customers	26/31

3.4 Analysis of the Survey results

Analysis of the data collected was done using SPSS data analysis software.

The data was analyzed for the following two main purposes:

a. Comparison of different factors overall and arrangement as per their importance

b. Comparison of factor acceptance in USA and India

3.4.1 Comparison of different factors and arrangement as per their importance

Factors Ratio: Arranging factors from the most important to the least important

	Quantitative factors	
Savings in Labor/ Production Increase	**Savings in Labor/ Waste Savings**	**Savings in Labor/ Floor space savings**
1.07	1.11	1.76
	Qualitative factors	
Higher Quality/ Higher Process Efficiency	**Higher Quality/ Lower variation in shift output**	**Higher Quality/ Higher operator morale**
1.03	1.03	1.76
	Strategic factors	
Meeting delivery schedules/ Competitive advantage	**Meeting delivery schedules/ Technology advantage**	**Meeting delivery schedules/ Use of technology to attract customers**
1.03	1.03	1.15
Meeting delivery schedules/ Flexibility to scale production	**Meeting delivery schedules/ Flexibility to get trained workers**	**Meeting delivery schedules/ Less labor union issues**
1.20	1.30	1.43

From the results of the factor's ratio chart, the final list of factors to be included in the model was finalized as also the order in which the factors are to be included in the model.

The final list is as follows:

	Quantitative factors
Rank	**Factor**
1	Savings in labor
2	Production Increase
3	Savings due to reduced waste and scrap
4	Savings due to reduced floor space
	Qualitative factors
Rank	**Factor**
1	Higher quality (lesser rework)
2	Higher process efficiency (lesser breakdowns, lesser maintenance costs)
3	Lower variation in per shift production output
4	Higher operator comfort/ morale
	Strategic factors
Rank	**Factor**
1	Regularly meeting delivery schedules
2	Competitive advantage
3	Technology advantage
4	Use of technology to attract customers
5	Flexibility to scale up or scale down production in lesser time

6	Flexibility to get trained workers to new production shops
7	Lesser labor union issues

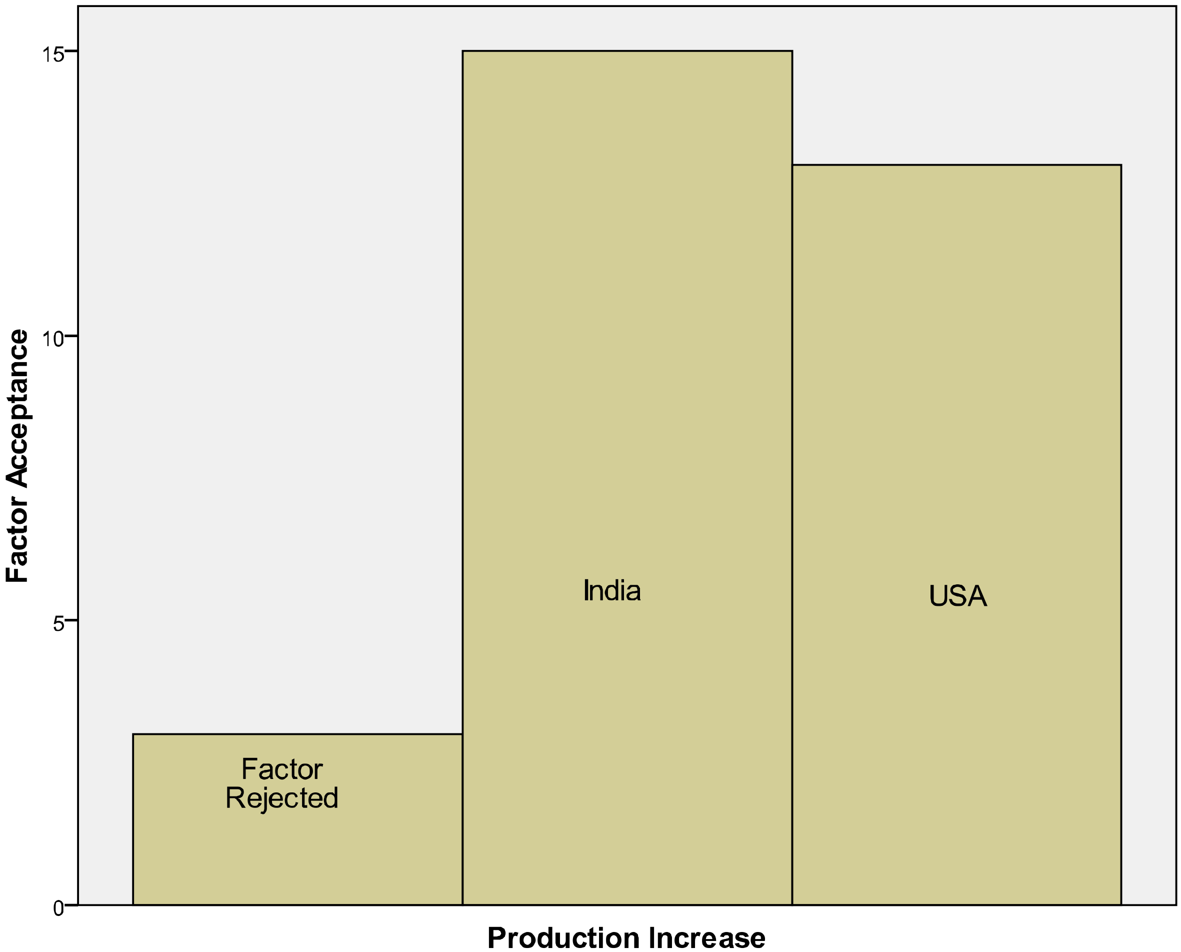
3.4.2 Comparison of factor acceptance in USA and India

Comparison of factor acceptance in USA and India was done using Frequency Charts and Regression Analysis

Comparison of factor acceptance in USA and India using Frequency Charts:

Production Increase

	Frequency	Percent
Rejected	3	9.7
India	15	48.4
USA	13	41.9
Total	31	100.0

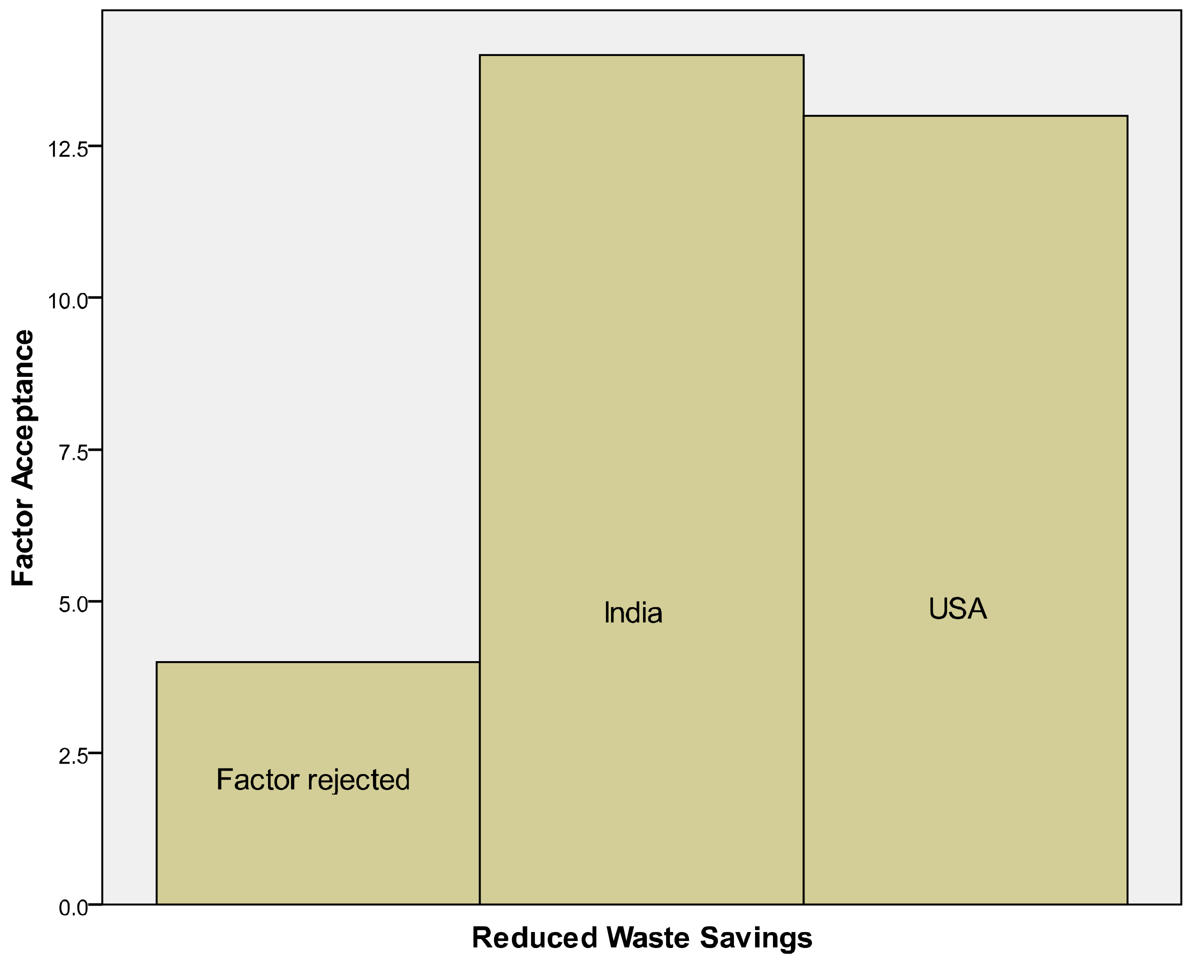


Labor savings

	Frequency	Percent
Rejected	1	3.2
India	17	54.8
USA	13	41.9
Total	31	100.0

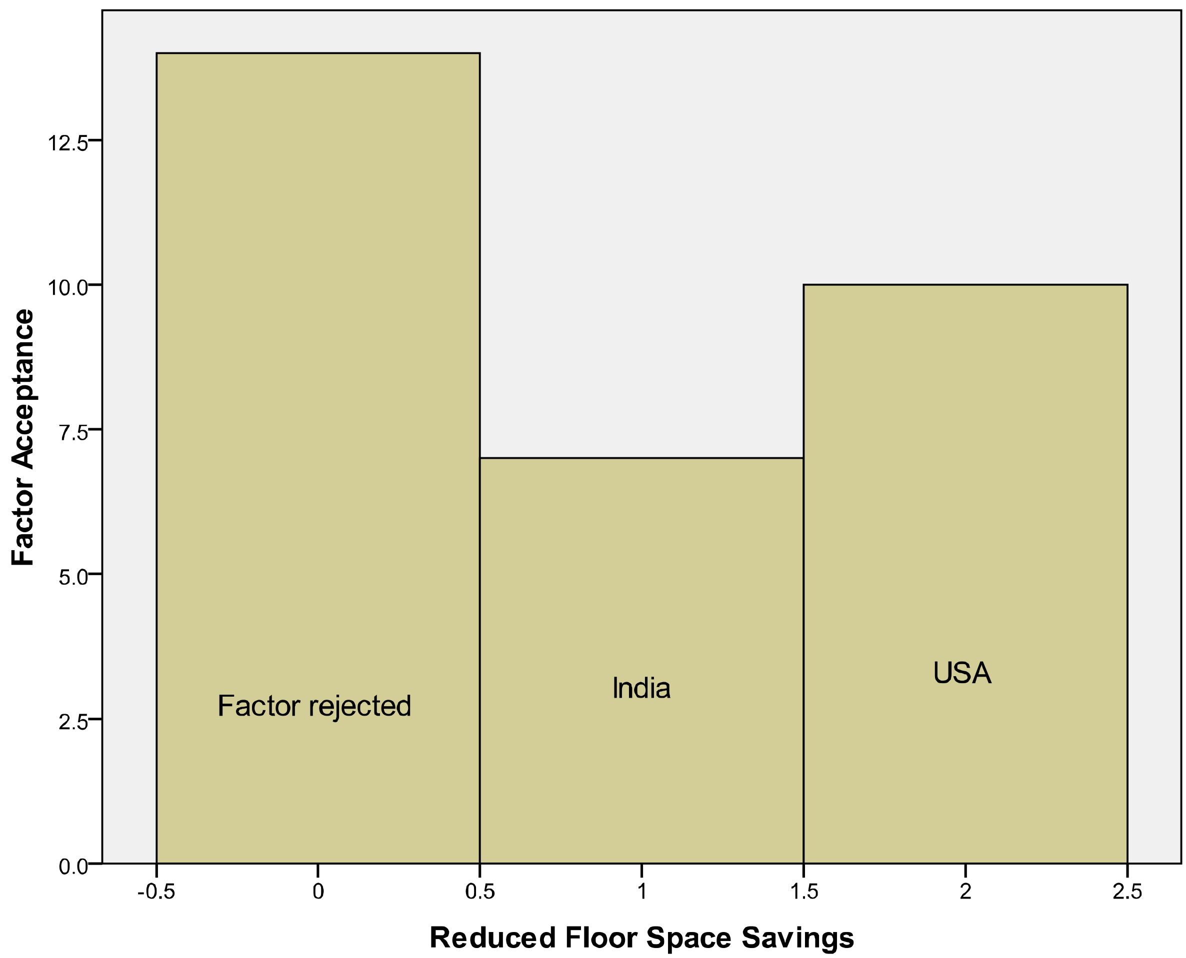
Reduced waste savings

	Frequency	Percent
Rejected	4	12.9
India	14	45.2
USA	13	41.9
Total	31	100.0



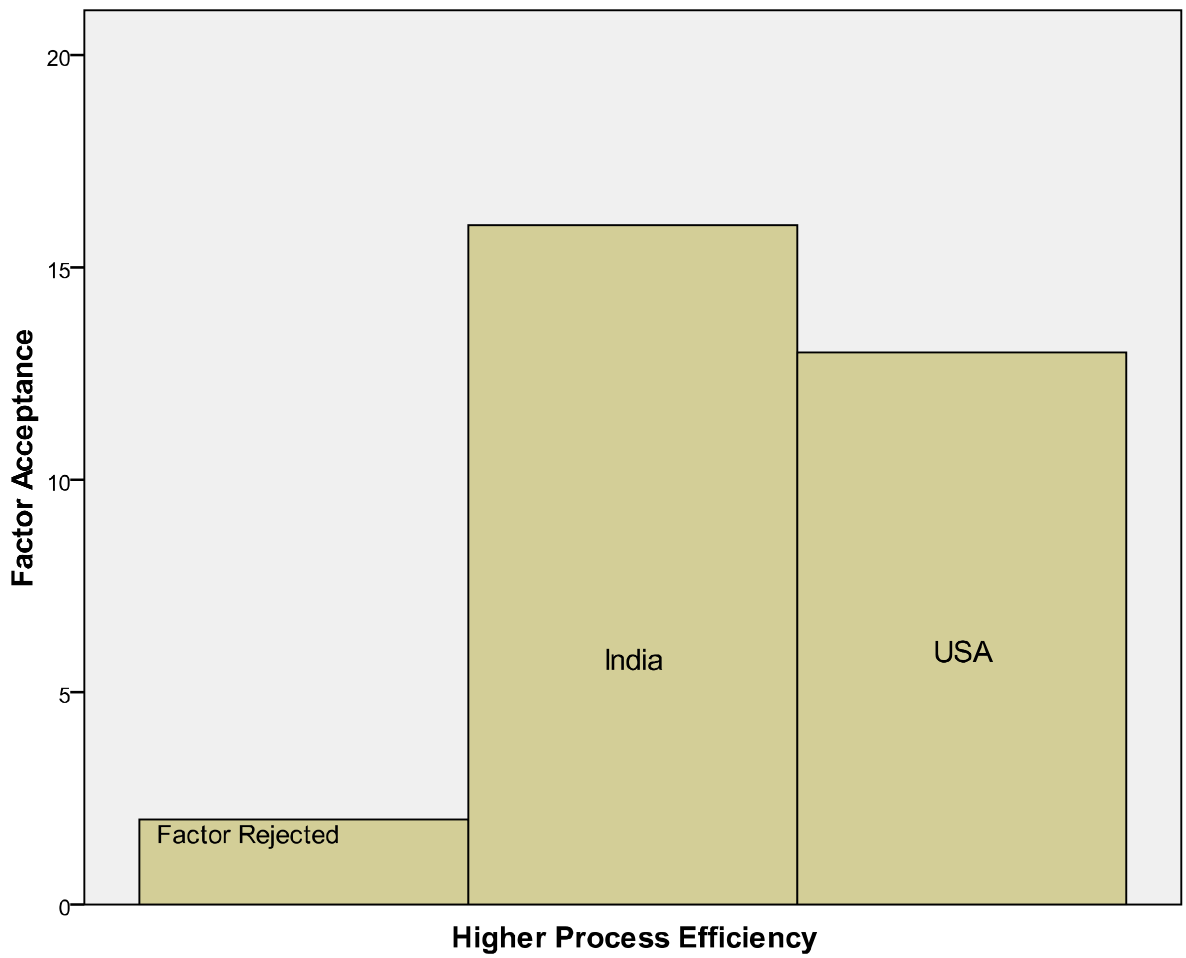
Reduced floor space savings

	Frequency	Percent
Rejected	14	45.2
India	7	22.6
USA	10	32.3
Total	31	100.0



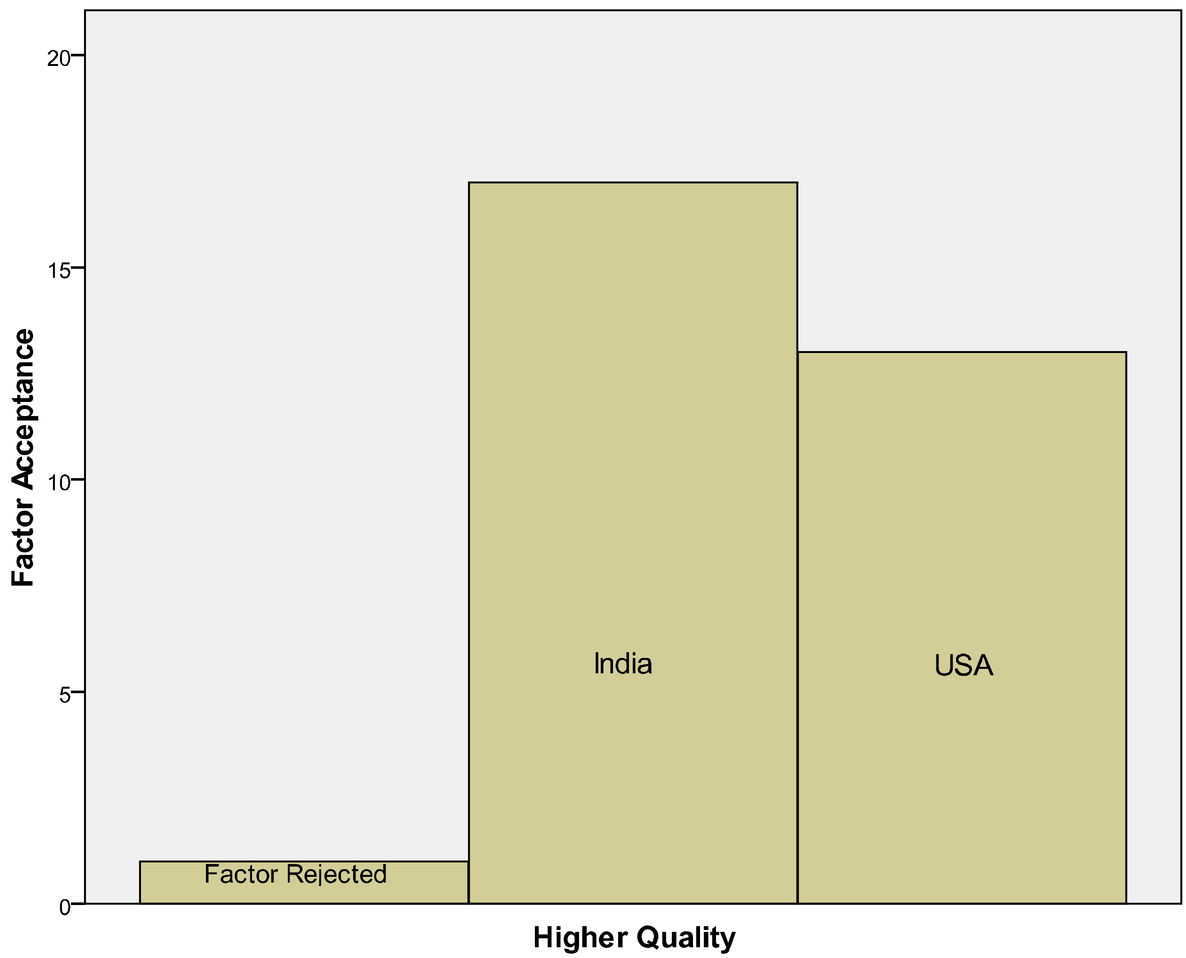
Higher process efficiency

	Frequency	Percent
Rejected	2	6.5
India	16	51.6
USA	13	41.9
Total	31	100.0



Higher quality

	Frequency	Percent
Rejected	1	3.2
India	17	54.8
USA	13	41.9
Total	31	100.0

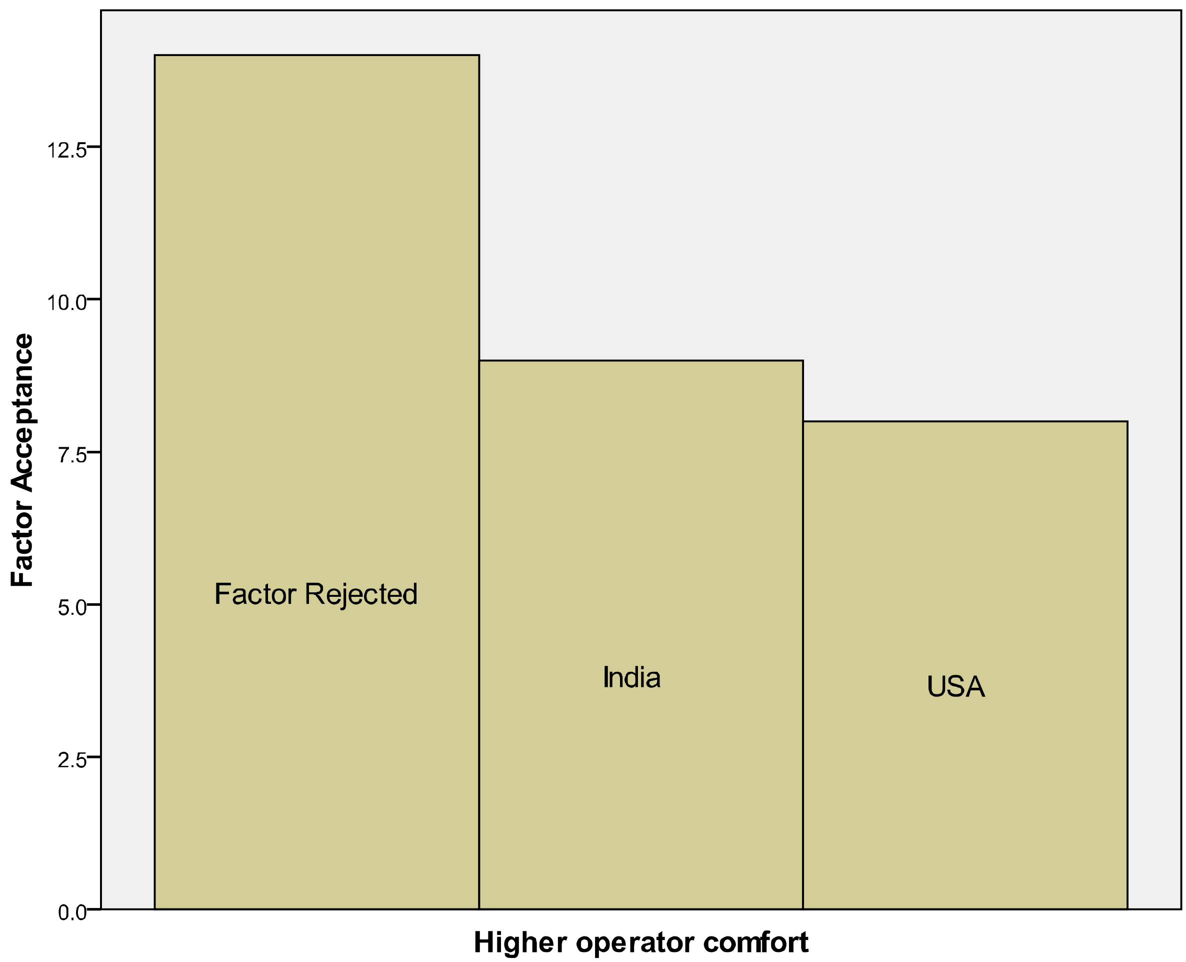


Lower variation in per shift production

	Frequency	Percent
Rejected	1	3.2
India	16	51.6
USA	14	45.2
Total	31	100.0

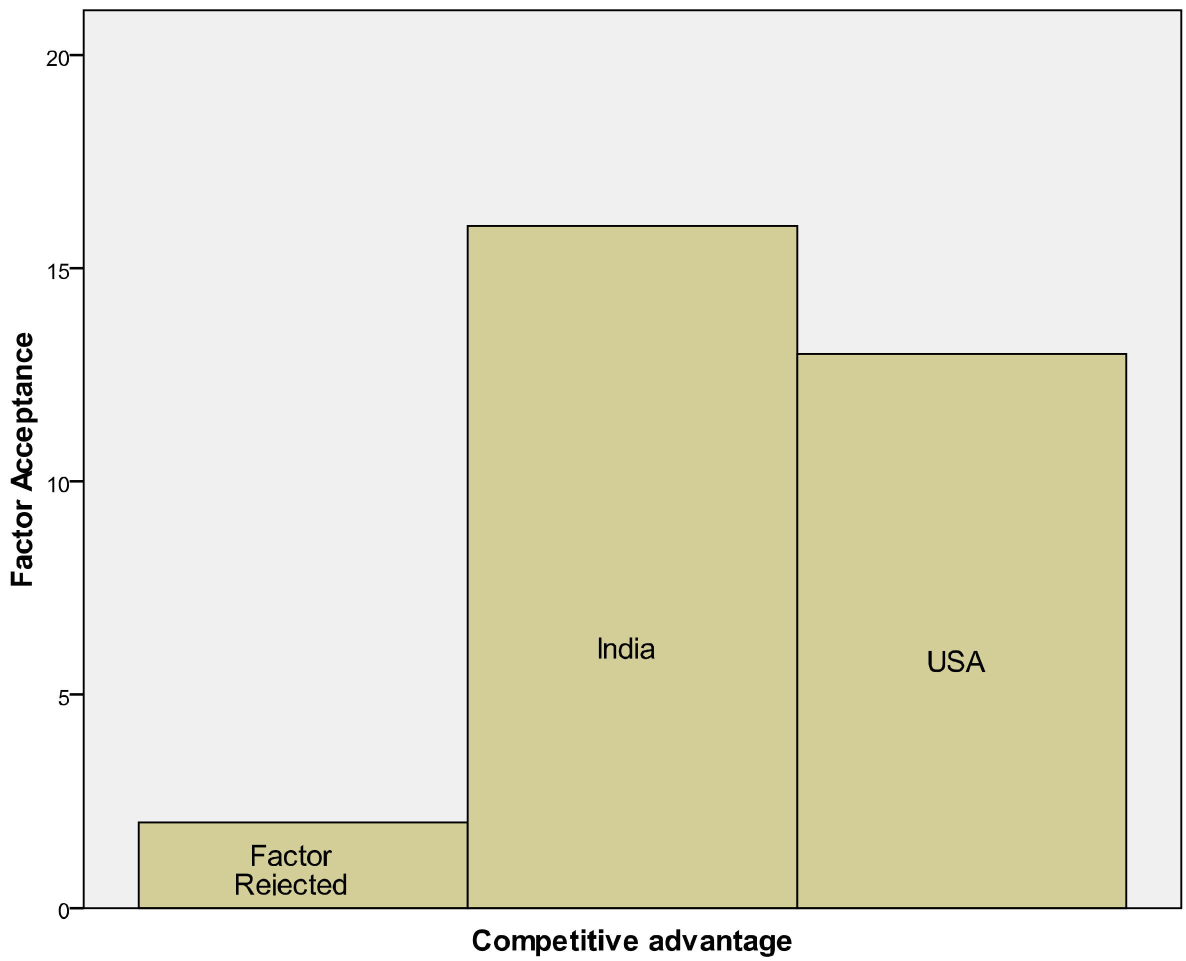
Higher operator comfort

	Frequency	Percent
Rejected	14	45.2
India	9	29.0
USA	8	25.8
Total	31	100.0



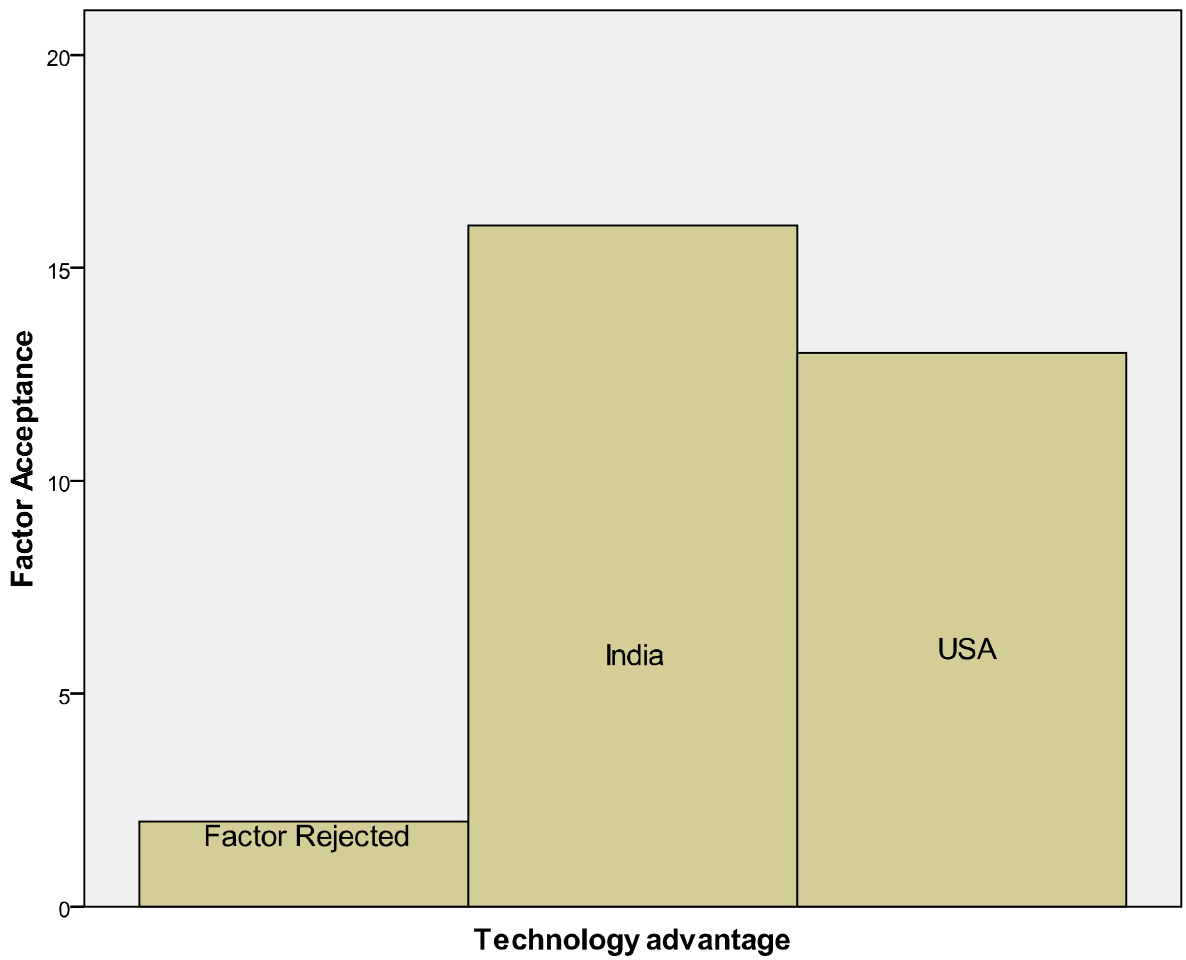
Competitive advantage

	Frequency	Percent
Rejected	2	6.5
India	16	51.6
USA	13	41.9
Total	31	100.0



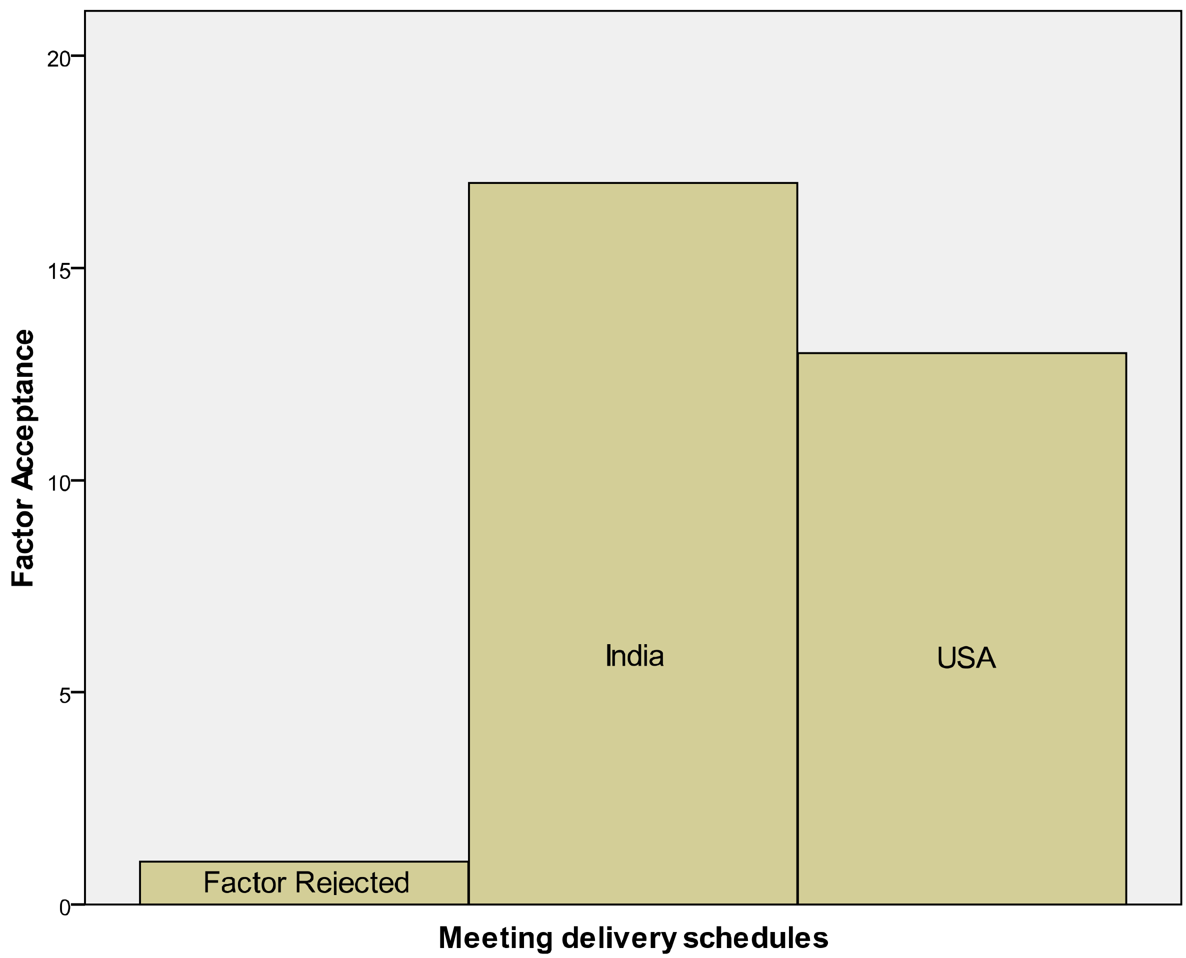
Technology advantage

	Frequency	Percent
Rejected	2	6.5
India	16	51.6
USA	13	41.9
Total	31	100.0



Meeting delivery schedules

	Frequency	Percent
Rejected	1	3.2
India	17	54.8
USA	13	41.9
Total	31	100.0

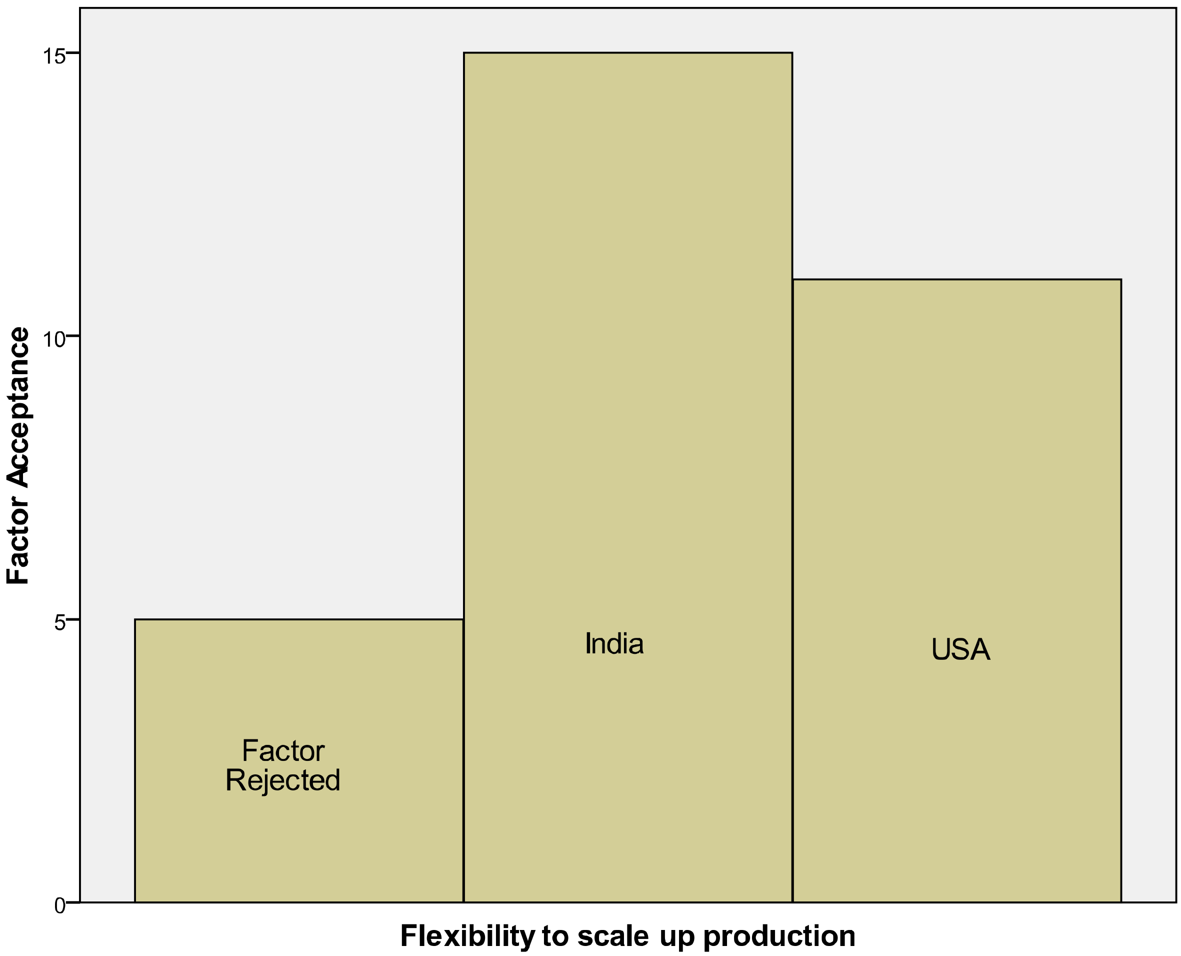


Less Labor union issues

	Frequency	Percent
Rejected	10	32.3
India	12	38.7
USA	9	29.0
Total	31	100.0

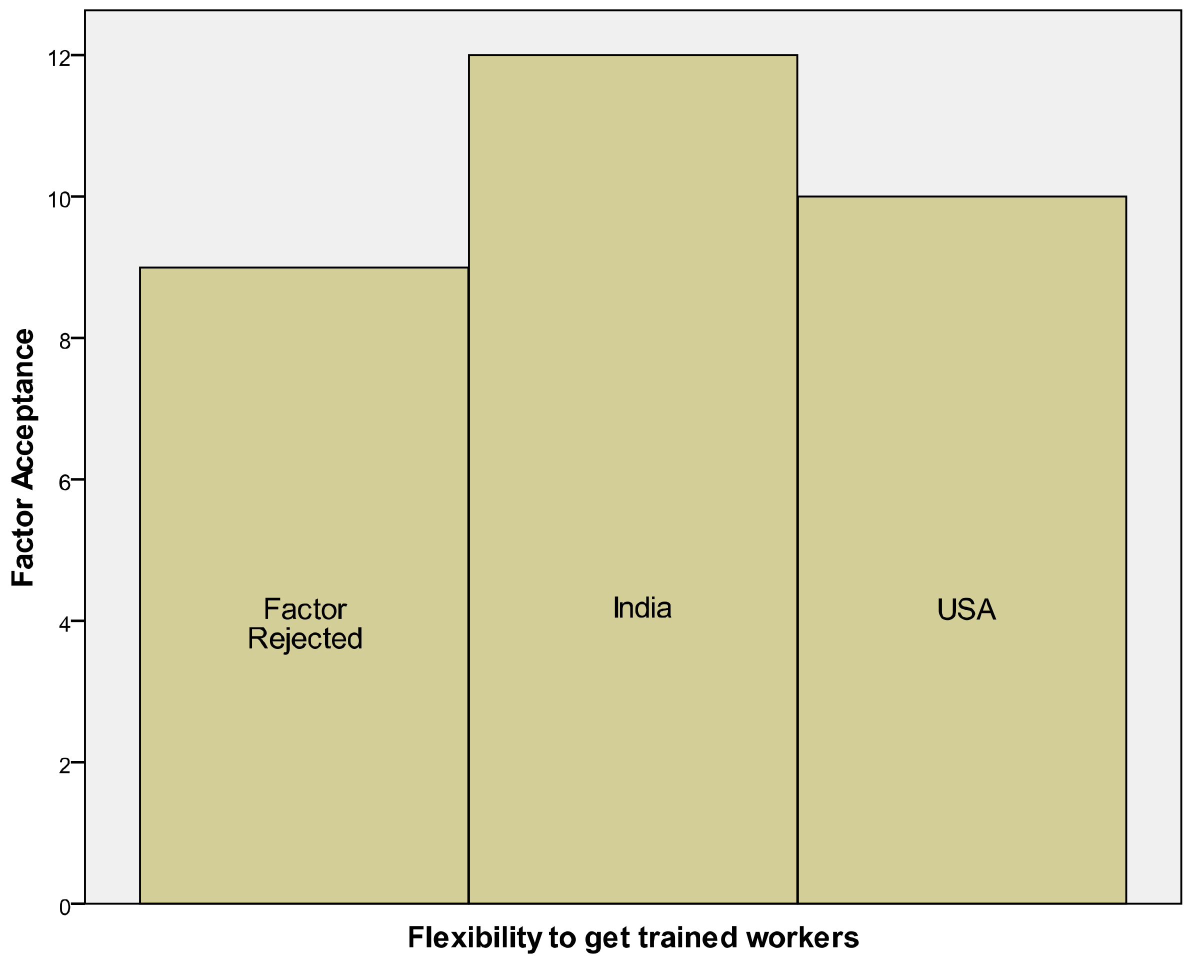
Flexibility to scale up production

	Frequency	Percent
Rejected	5	16.1
India	15	48.4
USA	11	35.5
Total	31	100.0



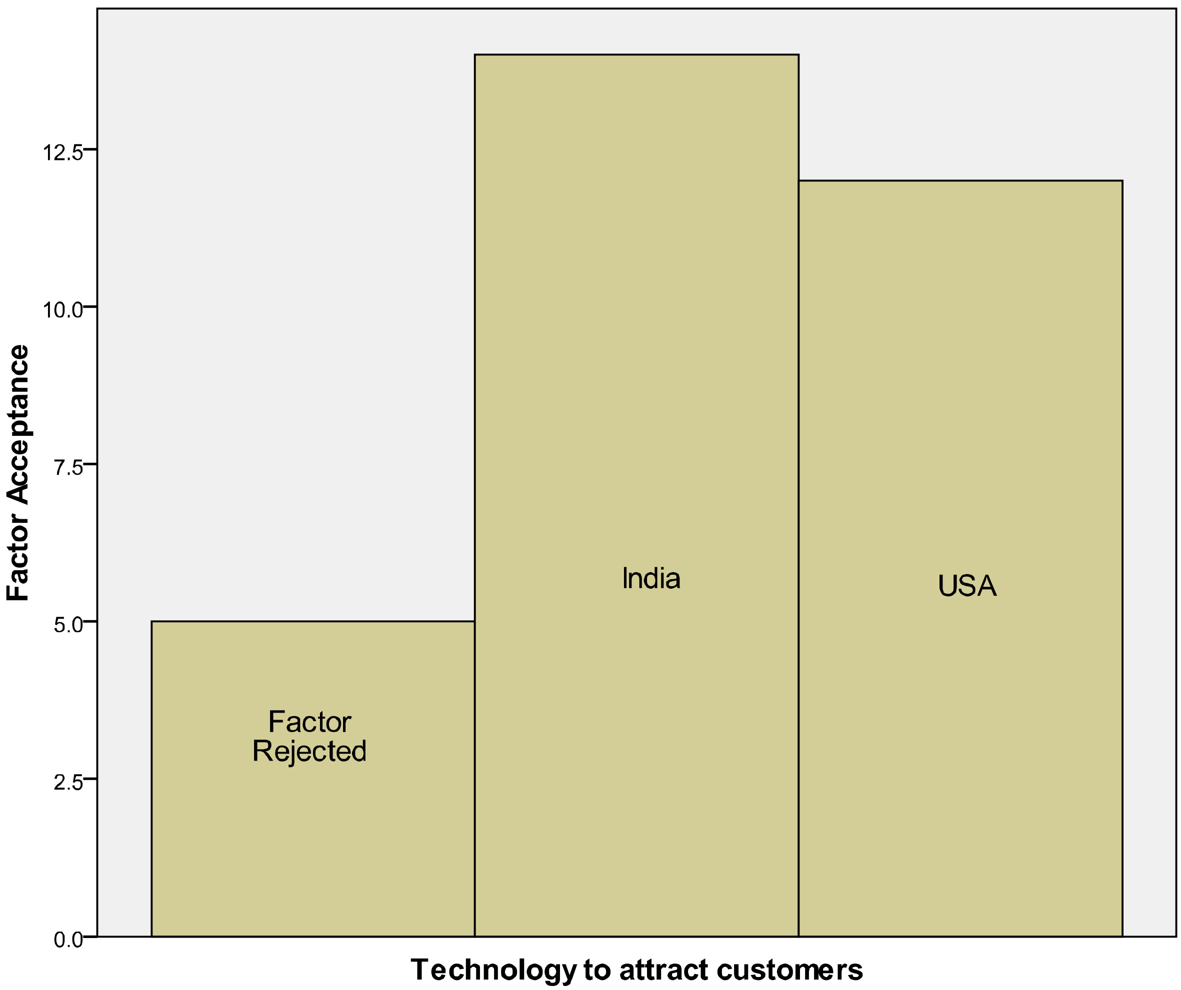
Flexibility to get trained workers

	Frequency	Percent
Rejected	9	29.0
India	12	38.7
USA	10	32.3
Total	31	100.0



Technology to attract customers

	Frequency	Percent
Rejected	5	16.1
India	14	45.2
USA	12	38.7
Total	31	100.0



Comparison of factor acceptance in India and USA using Regression Analysis:

The factor acceptance in India is compared with that in USA and the deviations are given by regression analysis. The factor acceptance in India is considered as an independent variable and the factor acceptance in USA is predicted. Then the actual results are compared with the predicted values to check the deviation.

Table 1: Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	India[a]		Enter

a. All requested variables entered.

b. Dependent Variable: USA

Table 2: Coefficients

The following table shows the coefficients of the regression line. It states that the expected values of factor acceptance for USA is (0.502*Corresponding value of factor acceptance for India + 4.744).

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.744	1.335		3.555	.004
	india	.502	.092	.834	5.447	.000

a. Dependent Variable: USA

Table 3: The Model Summary

The model summary table reports the strength of the relationship between the model and the dependent variable.

R, the multiple correlation coefficient, is the linear correlation between the observed and model-predicted values of the dependent variable. Its large value indicates a strong relationship.

R Square, the coefficient of determination, is the squared value of the multiple correlation coefficient.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.834[a]	.695	.672	1.03526

a. Predictors: (Constant), India

b. Dependent Variable: USA

Table 4: Residuals Statistics:

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	8.2553	13.2711	11.8667	1.50713	15
Std. Predicted Value	-2.396	.932	.000	1.000	15
Standard Error of - Predicted Value	.268	.715	.360	.120	15

a. Dependent Variable: USA

3.4.3 Conclusion of the Analysis:

With the Standard deviation of the standard error of predicted value being as low as 0.120, the values of factor acceptance of USA and India are comparable with very less deviation. This shows that similar factors have received similar acceptance in USA and in India and thus, even for such different manufacturing setups, the same factors can be included in the economic model.

3.5 The Proposed Technique for quantifying qualitative and strategic benefits:

To quantify qualitative benefits, following questions are answered by the user:

- How much discount would the user need to justify 5% lower process efficiency by using conventional techniques?
- How much discount would the user need to justify 5% lower quality by using conventional techniques?
- How much discount would the user need to justify 10% variation in per shift output?
- How much discount would the user need to justify lower operator comfort/ morale?

To quantify strategic benefits, following questions are answered by the user:

- How much premium will the user pay for gaining competitive advantage by using the robotics system?
- How much premium will the user pay for the technological advantage?
- How much premium will the user pay for meeting delivery schedules?
- How much premium will the user pay for no labor union issues?
- How much premium will the user pay for flexibility to scale up production?
- How much premium will the user pay to get trained workers to new shops?
- How much premium will the user pay to attract new customers?

The approach for the investment appraisal is as follows:

1. Compare the investment with only the quantitative benefits. If it is justified then there is no need to consider the qualitative and strategic benefits.
2. If the investment is not justified against the quantitative benefits alone, then consider the qualitative and strategic benefits and check if the project can be justified.

3.6 Formulation of the sheet:

3.6.1 Inputs required:

For the formulation of the sheet, the following values are required as inputs:

1. Total Investment
2. Cost of Investment/ year (Time value of money)
3. Running cost/ year
4. Number of years (n)
5. Tax Rate in %
6. % increase in production expected by automation
7. Present Production per year (Number of components)
8. Profit per Unit Production
9. Number of workers saved
10. Compensation per worker per year
11. Expected wastage and rejection in % of total production after automation
12. Earlier Wastage and rejection in % of total production

13. Price per unit production

14. Total floor space saved in sq feet

15. Cost per sq feet per year

16. Discount for lower process efficiency in %

17. Discount for lower quality in %

18. Discount for +/- 10% variation in per shift output in %

19. Discount for operator comfort/ morale

20. Premium for competitive advantage in %

21. Premium for technological advantage in %

22. Premium for meeting delivery schedules

23. Premium for no labor union issues

24. Premium for flexibility to scale up production

25. Premium to get trained workers to new shops

26. Premium to use the technology to attract customers

3.6.2 Calculation of quantitative benefits:

Benefits of production increase:

[(% increase in production expected by automation)/100 * Present Production per year (Number of components) * Profit per Unit Production] * [1-Tax Rate in % /100]

Benefits of workers saved:

(Number of workers saved * Compensation per worker per year) * (1-Tax Rate in % /100)

Savings due to reduced wastage:

(Earlier Wastage and rejection in % of total production - Expected wastage and rejection in % of total production after automation) /100 * Present Production per year (Number of components) * Price per unit production

Savings due to saved floor space:

Total floor space saved in sq feet * Cost per sq feet per year

Total quantitative benefits:

Benefits of production increase + Benefits of workers saved + Savings due to reduced wastage + Savings due to saved floor space

3.6.3 Calculation of qualitative benefits

Qualitative benefits discount factor Qd:

((100-Discount for lower process efficiency in %) /100) * ((100- Discount for lower quality in %) /100) * ((100- Discount for +/- 10% variation in per shift output in %) /100) * ((100- Discount for operator comfort/ morale) /100)

3.6.4 Calculation of strategic benefits

Strategic Benefits discount factor Sd

((100-Premium for competitive advantage in %) /100) * ((100-Premium for technological advantage in %) /100) * ((100-Premium for meeting delivery schedules in %) /100) * ((100-Premium for no labor union issues in %) /100) * ((100-Premium for flexibility to scale up production in %) /100) * ((100-Premium to get trained workers to new shops in %) /100) * ((100-Premium to use the technology to attract customers in %) /100)

3.6.5 Total Costs:

Total Investment + [Cost of Investment/ year (Time value of money) + Running cost/ year] * Number of years (n)

Then the effective cost is calculated multiplying the total costs by the strategic and qualitative discount factors so as to discount the actual cost by the strategic and qualitative benefits.

3.6.6 Effective costs:

Total Costs * Qualitative benefits discount factor **Qd** * Strategic Benefits discount factor **Sd**

3.6.7 Benefit to Cost Ratio:

Quantitative benefits / Effective Costs

3.6.8 A Sample Sheet:

A sample economic model created by the study is given below. The user needs to enter in values required in the yellow boxes and the model calculates the total costs, the quantitative benefits, the qualitative discount factor, the strategic discount factor, the effective costs and the BCR. With this calculation, the manager can make his decision depending on the number of years (n) in which he is looking to recover all the costs associated with the project.

Investment Appraisal of robotic systems	
Currency:	
Company:	
Project Manager:	
Quotation reference:	
Calculation	
Total Investment	
Cost of Investment/ year (Time value of money)	
Running cost/ year	
Number of years (n)	
Tax Rate in %	

Number of workers saved	
Compensation per worker per year	
Benefits of workers saved	
% increase in production expected by automation	
Present Production per year (Number of components)	
Profit per Unit Production	
Benefits of production increase	
Expected wastage and rejection in % of total production after automation	
Earlier Wastage and rejection in % of total production	
Savings due to reduced wastage	
Price per unit production	
Total floor space saved in sq feet	
Cost per sq feet per year	
Savings due to saved floor space	
Total quantitative benefits	
QUALITATIVE BENEFITS	
Discount for lower quality in %	
Discount for lower process effciency in %	
Discount for +/- 10% variation in per shift output in %	
Discount for operator comfort/ morale	
STRATEGIC BENEFITS	
Premium for meeting delivery schedules	
Premium for competitive advantage in %	

Premium for technological advantage in %	
Premium to use the technology to attract customers	
Premium for flexibility to scale up production	
Premium to get trained workers to new shops	
Premium for no labour union issues	
Total Costs	
Quantitative benefits	
Qualitative benefits discount factor Qd	
Strategic Benefits discount factor Sd	
Effective Costs	
BCR for n years	

Chapter 4

Conclusions and future work:

Advanced Manufacturing Technologies like Robotics are essential nowadays, especially in a very competitive environment for manufacturing companies. Ignorance of these techniques when necessary can have an adverse effect on the growth of the firms in a competitive environment. Evaluating by the traditional techniques like ROI and IRR, many a times, results in projects being rejected which otherwise should have been implemented.

The Economic model proposed takes into account all the quantitative, qualitative and strategic benefits of Robotics systems and thus evaluates it effectively. This not only results in a better evaluation of the systems, but also reduces the chances of rejecting the projects which are necessary. The model was finalized after taking a survey from experts in the Robotics industry, Automobile industry, Defense industry, Automobile Part manufacturers and economists working in this research area from two different countries: USA and India. Thus, this survey helped to get feedback from different manufacturing environments and a model is developed whose use is not just restricted to one country but can be generalized for different manufacturing setups in varying environments.

Along with the model, an easy-to-use Microsoft Excel spreadsheet has been developed which can be easily used by professionals in the industry to evaluate the projects.

Also this model, unlike other traditional models that weigh the degree of importance of different factors to the project evaluation, asks the end user to define the importance of the factor to their industry’s environment. Hence this model can be used more effectively by different managers with varying needs, customizing the model to suite their own needs.

In this area of work, further work can be carried out to build different models, taking this model as a reference, which will be more customized to specific industries. There will be additions/ subtractions to the factors considered depending on the specific industry. Also awareness about this new ideology of Economic Justification of Robotics systems has to be created in industries, so that a project necessary for a manufacturing setup will not be rejected due to improper evaluation of the project.

Chapter 5

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