Dear Sir,

As you are aware, the Indian Tertiary Industries (service sector) are on the track of tremendous growth. There is a lot of competition due to the dynamically changing markets, which creates pressure for continuous improvement in the processes of the business and operations. To cope up with this demanding situation, organizations are adopting newer strategies and implementing improvement initiatives to enhance the performance of operation function.

We have taken up a project, as part of Doctoral studies at RK University, Rajkot, to find out about the challenges faced, areas of importance, strategic initiatives and practices adopted by service sector organizations, to compete in the market. It is also a matter of interest to know whether ‘Lean Principles’- the most popular philosophy in manufacturing and adopted by a few service organizations selectively- are having potential for enhancing competitiveness in the service organizations or not.

In this connection we are carrying out a pilot survey of selected service organizations in the Gujarat. Yours being one of the leading service organization, some of such improvement initiatives must being practices at your organization. We request you to kindly cooperate by sparing your valuable time to

1. Provide the response to the questionnaire attached here with and
2. Suggest and share valuable information that may be of use to carry out this project to its success.

We are quite aware that you have a busy schedule and your time is very much valuable to your organization. However, considering the importance of this project to our industries at large, we earnestly request you to respond to our request favourably. All critical data furnished by you shall be classified and kept confidential. We shall send you the result of this survey, if you so desire.
We are very much looking forward to having your response at the earliest please, preferably within one week of receiving this letter.

Thanking you with kindest regards.

Yours Sincerely,

Mrs. Maya D. Vadhvani

Dr. Mangal G. Bhatt

Enclosure: Questionnaire for survey
A Survey on Lean Principles in Service Sectors

Please give details in space provided/ tick on appropriate alternative(s)
Use blank sheet attached at the end for providing supplementary details

Section I: Organization profile

1. Name of the organization: ..............................................................

Address: ............................................................................................
............................................................................................
............................................................................................

Telephone no: (1) Landline: ..................... Fax no: ....................

(2) Mobile: .........................

Email address: ..............................................................
Website address: ..............................................................

2. The type and scope of organization

   a) Education industries
   b) Banking
   c) Health care
   d) Food industries
   e) Restaurants
   f) Service industries

3. Whether you are a member company of any corporate group?

   a) Yes
   b) No

   If yes, please give name of the group: ................................................

4. Year of inception: .............
5. Weather your organization offers
   a) Standardized services
   b) Customized services
   c) Both of (a) and (b)

Section II: Competitiveness Concerns and Enhancement Initiatives in Vogue

1. As per your experience in the globalization of economy and business environment do you feel that becoming more competitive is prime importance?
   a) Yes
   b) No

2. Please tick mark from following factors which you consider important to affect the current competitive business environment based on your experience.
   a) Increased customer awareness
   b) Increased customer expectations
   c) Increased buying power of customers
   d) Fast changing technology
   e) Large number of competitors
   f) Newer business models and practices like (ERP, CRM, SCM)
   g) Need for improved business infrastructure
   h) Frequently changing government policies
   i) Increasing cost of manpower
   j) Any other please specify
3. Please rank the most affected functions of your business due to competitive environment. (1-Most critical, 6-Least critical)

- a) Human Relation Management
- b) Sales and Marketing
- c) Research and Development
- d) Finance and Accounting
- e) Service Operation
- f) Any other please specify ………………………………………

4. Which of the following are adopted as strategy to compete in the market? Please tick.

- a) Discount on the cost
- b) Improved and innovative product or service quality
- c) Offering wide service variety
- d) Quick and short delivery practices
- e) Reduced waiting time/Quick service practices
- f) Flexibility in payment terms
- g) Provide Mistake proof service/product
- h) Any other please specify ……………………………………………

5. Kindly provide information regarding improvement practices/techniques in use to enhance competitiveness of following functions.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Functional Area of Improvement</th>
<th>Practice or Technique used</th>
<th>Improvement achieved in</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Human Relation Management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sales and Marketing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Research and Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Finance and Accounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Service Operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Any other please specify</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maya DilipKumar Vadhvani
6. Please tick among the following; which is offered by your organization for differentiation of services from those of competitors.

   a) Priority services with additional charges
   b) Priority to regular customers
   c) Faster services

7. Please tick mark in the suitable cell of below matrix where you find the usefulness of lean principles for the business functions.

<table>
<thead>
<tr>
<th>Functional area of business</th>
<th>Lean Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*SP</td>
</tr>
<tr>
<td>Human Relation Management</td>
<td></td>
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<tr>
<td>Sales and Marketing</td>
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<td>Research and Development</td>
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<tr>
<td>Service Operation</td>
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<tr>
<td>Any other please specify</td>
<td></td>
</tr>
</tbody>
</table>

SP: Simplification of Processes, CI: Continuous Improvement, WEP: Waste Elimination from Processes, CS: Customer Satisfaction, RK: Record Keeping, EUSR: Effective Utilization of Staff and Resources
For Supplementary Details
Dear Sir,

As you are aware, the Indian Manufacturing Industries are on the path of tremendous growth. There is a lot of competition due to the dynamically changing markets, which creates pressure for continuous improvement in the processes of the business and operations. To cope up with this demanding situation, manufacturing organizations like yours are adopting newer strategies and implementing improvement initiatives to enhance the performance of operation functions.

We have taken up a project, as part of Doctoral studies at RK University, Rajkot, to find out about the challenges faced, areas of importance, strategic initiatives to improve competitiveness and lean manufacturing practices adopted by manufacturing organizations.

In this connection we are carrying out a survey of Indian Manufacturing organizations. Yours being one of the leading organization, some of such improvement practices must have been a tradition. We request you to kindly cooperate by sparing your valuable time to

1. Provide the response to the questionnaire attached here with and
2. Suggest and share valuable information that may be of use to carry out this project to its success.

We are quite aware that you have a busy schedule and your time is very much valuable to your organization. However, considering the...
importance of this project to our industries at large, we earnestly request you to respond to our request favourably. **All critical data furnished by you shall be classified and kept confidential.** We shall send you the result of this survey, if you so desire.

We are very much looking forward to having your response at the earliest please, preferably within two weeks of receiving this letter.

Thanking you with kindest regards.

Yours Sincerely,

Maya D. Vadhvani

Dr. Mangal G. Bhatt

Enclosure: Questionnaire for survey
A survey on
Lean Manufacturing Practices in
Manufacturing Industries

Carried out by
Prof. Maya D. Vadhvani
Assistant Professor
Production Engineering Department
Shantilal Shah Engineering College, Bhavanagar

Ph. D. Research Scholar
Faculty of Technology-Mechanical Engineering
R. K. University, Rajkot
2016
A survey on Lean Manufacturing Practices in Manufacturing Industries

Please give details in space provided/tick in appropriate box.
You may use blank sheet attached at the end for giving additional details.

Section I
Organization Profile

1. Name of the organization: ____________________________________________

Address:
____________________________________________________________________
____________________________________________________________________

Telephone no: _____________________
Email address: ________________________________
Website address: ________________________________

2. Type of organization:
   a) Public sector [ ]
   b) Private Sector [ ]
   c) Multinational [ ]
   d) Any other, please specify: _______

3. Whether you are a member company of any corporate group?
   a) Yes [ ]
   b) No [ ]
   If yes, please give name of the group:
   ________________________________________
4. The organization is situated at
   a) Single location
   b) Multiple locations

5. Year of inception: ________________________

6. Approximate annual sales turnover of last three years:
   a) ________________________
   b) ________________________
   c) ________________________

7. Net fixed assets (last year): Rs. ________________

8. To which category the organization fall:
   a) Large scale
   b) Medium scale
   c) Small scale

9. Organization position in the market:
   a) Monopolist
   b) Leader in top 10%
   c) In top 25%
   d) Growing

10. Product and process:
    a) Organization manufactures
       1) Single products
       2) Multi products
    b) The manufacturing approach is:
       1) Make to order
       2) Make to stock
       3) Assemble to order
c) The organization has
   1) Mass manufacturing system
   2) Repeat batch manufacturing system
   3) Job order manufacturing system
   4) Continuous process system

d) The organization carries out
   1) Basic manufacturing only
   2) Assembly only
   3) Manufacturing as well as assembly

11. Organization structure, plant level - Please mention which is applicable

<table>
<thead>
<tr>
<th>Function</th>
<th>Designation of head</th>
<th>Designation of reporting</th>
</tr>
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<tbody>
<tr>
<td>Corporate planning</td>
<td></td>
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<tr>
<td>Marketing</td>
<td></td>
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<tr>
<td>Product/process engineering</td>
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<tr>
<td>Production</td>
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<tr>
<td>Materials / purchase</td>
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<tr>
<td>Finance</td>
<td></td>
<td></td>
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<tr>
<td>Quality control/quality assurance</td>
<td></td>
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<tr>
<td>HRD/Personnel</td>
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<tr>
<td>Maintenance</td>
<td></td>
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<tr>
<td>Distributions/logistic</td>
<td></td>
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<tr>
<td>Other (if any)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12. What are the main products of the company?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
13. The general demand pattern for the product(s) is/are:
   a) Uniform throughout the year  
   b) Seasonal (regular)  
   c) Seasonal (irregular)  
   d) Any other, please specify: ____________

14. Whether any conscious efforts are going on to address improvement in competitiveness of your company?
   a) Yes  
   b) No  
   
   If yes,
   1) Please furnish brief description:
      ______________________________________________________
      ______________________________________________________
      ______________________________________________________

   2) Please specify whether this system is practiced:  
      a) Widely  
      b) Selectively  
      c) On experimental basis  
      d) Just started  
   
   If no,
   1) Whether you are planning/intending to introduce in the near future?  
      a) Yes  
      b) No  

   Please give details:
      ______________________________________________________
      ______________________________________________________
      ______________________________________________________
Section II
Competitiveness Concerns and Enhancement Initiatives in Vogue

1. As per your experience in the globalization of economy and business environment, do you feel that becoming more competitive is prime importance?
   a) Yes  
   b) No

2. Which of the following factors affect the current competitive business environment relevant to your business? Please tick.
   a) Increased customer awareness and expectations
   b) Increased buying power of customers
   c) Fast changing technology and its quick implementation
   d) Ever increasing competition
   e) Newer business models and practices like (ERP, SCM, CRM)
   f) Improvement in national business infrastructure
   g) Changing government policies
   h) Any other, please specify: ____________________________

3. Please specify the most affected functions of your business due to competitive environment.
   a) Research and development
   b) Sourcing
   c) Distribution
   d) Marketing
   e) Manufacturing
   f) Quality
4. Please rank the following aspects according to their importance to competitiveness in the present business environment. (1-most important to 6-least important)

   a) Lower cost  
   b) Product quality conformance  
   c) High performance products  
   d) Dependable delivery  
   e) Service to customers  
   f) Speed to market  
   g) Flexibility of volume and variety  
   h) Innovative products and processes  
   i) Any other, please specify: _______________

5. Please rank following as means to enhance competitiveness of your organization (1-most important, 6-least important)

   a) Productivity  
   b) Quality  
   c) Technology  
   d) Cost/price  
   e) Distribution  
   f) Innovative manufacturing

6. Please list various improvement practices and its details that you are following in your company to enhance competitiveness.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Improvement Practice</th>
<th>Since When</th>
<th>How Introduced</th>
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<tbody>
<tr>
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</table>
7. Please specify which functional areas are covered by these improvement practices.

<table>
<thead>
<tr>
<th>Improvement practices</th>
<th>Functional areas covered</th>
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<tbody>
<tr>
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**Section III**

**General Awareness Regarding Lean Principles & Lean Manufacturing Practices**

Lean Principles (LPs) focus on reducing and eliminating of each type of wastes in terms of non value adding activities (NVAs) all the way through value chain of the product.

1. Is Lean Manufacturing Practices implemented in your organization, formally or informally? Please tick.
   a) Yes
   b) No

2. Which of the following factors have motivated you to implement the lean principles and improvement practices in your organization? Please tick.

   a) Organizational factors
      1) To increase sales turn over
      2) To become world class industry
      3) To increase customer satisfaction
   b) Support factors
      1) To improve the process continuously
      2) To increase the morale of employees
      3) To improve working conditions
c) Manufacturing factors
   1) To reduce changeover time
   2) To reduce cost of production
   3) To reduce number of defects
   4) To improve quality of product
   5) To meet delivery dates

3. Which of the following principles, you feel, are useful for improving manufacturing performance in your organization? Please tick.
   a) Achieving zero waiting time
   b) Achieving zero inventory
   c) Scheduling by pull system
   d) Reducing batch size
   e) Reducing manufacturing cycle time
   f) Cutting of actual processing time

4. Which of the following improvement practices are being followed at your organization? Please tick.
   a) Standardization of products and processes
   b) Employee training
   c) Employee welfare practices
   d) Use of standard operating procedure
   e) Continuous improvement
   f) Informal communication channel
   g) Problem solving in small groups
   h) Improvement based on customer’s feedback
   i) Documenting the knowledge base by past experience
5. Kindly give rank to the following competitiveness dimensions that are improved by practice of lean manufacturing as per your experience. (1-Highest, 6-Lowest)

   a) Quality    
   b) Cost       
   c) Flexibility
   d) Delivery   

6. Which of the following results are achieved as outcome of implementation of Lean Practices in your organization? Please tick.

   a) Increase in capacity utilization 
   b) Increase in inventory turnover ratio 
   c) Reduction in unit cost of product 
   d) Reduction in over production 
   e) Reduction in cycle time 
   f) Reduction in overall percentage defective 
   g) Reduction in setup time 
   h) Reduction in material handling time 

7. Based on your experience, which of the following factors you consider as barrier to smooth and easy implementation of Lean Practices, and how this was addressed?

   a) Resistance to change: Yes    No

   How addressed:

   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________
   ____________________________________________

   b) Lack of commitment: Yes       No

   How addressed:

   ____________________________________________
   ____________________________________________
c) Lack of communication: Yes ☐ No ☐

How addressed:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________


d) Lack of understanding of Lean Manufacturing concepts: Yes ☐ No ☐

How addressed:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________


e) Fear of increased work load and responsibility: Yes ☐ ☐ No ☐ ☐

How addressed:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________


f) Slow/Invisible results of implementation: Yes ☐ No ☐ ☐

How addressed:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________


8. Which areas of your organization are focused by practicing lean principles? Please tick mark on suitable options.

   a) Organizational processes
   b) Process Engineering
   c) Human resource
   d) Supplier relations management
   e) Shop floor
   f) Customer relations management
   g) Any other, please specify: ___________________________

9. In your organization, process of overall lean manufacturing implementation is reviewed at

   a) Shop level
   b) Section/Department level
   c) Plant level
   d) Corporate level

10. As part of lean implementation which of the following is being carried out in your organizations? Please tick the suitable options.

   a) Regular employee training
   b) Conducting awareness seminars
   c) Total employee involvement
   d) Training employees for multitasking
   e) Empowering employees for decision making
   f) Institutionalizing rewards schemes
   g) Any other, please specify: ___________________________
11. Which among the following lean Manufacturing Practices (LMPs) are being followed in your organization? Please tick.

a) Kanban
b) Single Minute Exchange of Dies (SMED)
c) Total Productive Maintenance (TPM)
d) 5S
e) Poka-yoke (Mistake Proofing)

Section IV

Part A - Kanban

It is an information system to control the production quantities in each process.

1. To what extent Kanban is practiced in your organization? Please tick.
   a) On pilot scale
   b) For selective work areas
   c) To considerable extent
   d) On large scale

2. With reference to Kanban practice being followed at your organization, kindly indicate the spread of Kanban /scope of its implementation out of following. Please tick.
   a) Material is moved using KANBAN cards within factory
   b) Material is moved using KANBAN cards amongst supplier factories
   c) The practice is in place among cooperative companies
   d) Any other, please specify: _______________________________

3. In your organization since how long the KANBAN is being used? Please tick.
   a) More than 6 months
   b) More than 2 years
   c) More than 8 years
   d) More than 15 years
   e) Any other, please specify: _______________________________
4. Please specify minimum and maximum % of reduction achieved in waiting time/idle time after implementation of Kanban practice, in different work areas.
   a) Minimum - _________ % ; Any additional information, please provide:_____________________________________
   b) Maximum - _________ %; Any additional information, please provide:_____________________________________

5. Please tick the manufacturing performance measures which have been improved due to implementation of Kanban. Kindly mention the % of improvement where ever possible.

<table>
<thead>
<tr>
<th>Manufacturing Performance Measure</th>
<th>Tick mark</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Increase in capacity utilization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Increase in inventory turnover ratio</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>e) Reduction in cycle time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) Reduction in material handling time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Kindly provide approximate percentage (%) improvement in following competitive dimensions, due to implementation of Kanban?
   a) Quality:___________
   b) Cost:_____________
   c) Flexibility:________
   d) Delivery:_________
7. Please tick of the following which you consider useful to implement Kanban according to your experience.
   a) Buzzer/light for material requirement
   b) Use of identification tag on material
   c) Use of instruction tag on the material
   d) Use of transfer tag on the material
   e) Practices of 5S
   f) Practice of SMED on machines
   g) Practice of Poka-Yoke
   h) Any other, please specify:___________________

8. Please tick; how frequently the improvement achieved by Kanban is being reviewed?
   a) Daily
   b) Weekly
   c) Quarterly
   d) Monthly
   e) Any other, please specify:________

9. Which of the following factors you consider responsible as constrains to smooth and easy implementation of Kanban as per your experience? Please tick.
   a) Resistance to change
   b) Lack of communication
   c) Lack of understanding of Kanban concepts
   d) Fear of increased work load and responsibility
   e) Slow/Invisible results of implementation
   f) Any other, please specify: ____________________________
10. According to your experience which out of following can be considered as motivating factors to initiate the practice of Kanban? Please tick.
   a) To produce according to takt time
   b) To accommodate fluctuating demand
   c) To make realization of Just In Time
   d) To stop defective items transportation further

**Part B – Single Minute Exchange of Dies (SMED)**

It is a practice which reduces the change over time by reducing the setup activities when product changes allows for frequent setups.

1. In your organization for how much % of the total change over operations SMED is employed? Please tick appropriate option.
   a) 0-25%
   b) 25-50%
   c) 50-75%
   d) More than 75%

2. To what extent SMED is practiced in the organization as a whole? Please tick.
   a) On experimental basis
   b) For selected operations
   c) Extensively
   d) On all the operations

3. In your organization since how long the SMED is being used? Please tick.
   a) More than 6 months
   b) More than 2 years
   c) More than 8 years
   d) More than 15 years
   e) Any other, please specify:______
4. Please provide the information regarding the highest and the lowest % reduction achieved in setup time on any of the operations in the organizations.
   a) Highest - __________% ; Any additional information, please provide:
      ________________________________________________________________
   b) Lowest- __________% ; Any additional information, please provide:
      ________________________________________________________________

5. Which of the following manufacturing performance measures have been improved due to implementation of SMED? Please tick. Kindly mention % of improvement wherever possible.

<table>
<thead>
<tr>
<th>Manufacturing Performance Measure</th>
<th>Tick mark</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Increase in capacity utilization</td>
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<tr>
<td>b) Increase in inventory turnover ratio</td>
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<td>e) Reduction in cycle time</td>
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<tr>
<td>f) Reduction in material handling time</td>
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</tbody>
</table>

6. Kindly provide approximate percentage (%) improvement in following competitive dimensions, due to implementation of SMED.
   a) Quality:________
   b) Cost:________
   c) Flexibility:________
   d) Delivery:________
7. Which of the following approaches were useful in implementing SMED? Please tick as per your experience.
   a) Employee commencement
   b) Help of process Engineering Officials
   c) Jointly by a & b
   d) With the help of consultant
   e) Any other, please specify: __________________

8. Which of following practice had helped you to implement SMED? Please tick.
   a) Practice of standard operating procedure
   b) Practice of checklist for ensuring the sequence to follow
   c) Practice of 5S
   d) Practice of Poka-Yoke
   e) Use of devices to reduce operator efforts
   f) Any other, please specify: ______________________

9. What is the frequency of reviewing improvement achieved by SMED? Please select appropriate box.
   a) Daily
   b) Weekly
   c) Quarterly
   d) Monthly
   e) Any other, please specify: ___________

10. Which of the following factors you consider responsible as constraints to smooth and easy implementation of SMED as per your experience? Please tick.
    a) Resistance to change
    b) Lack of communication
    c) Lack of understanding concept of SMED
    d) Fear of increased work load and responsibility
    e) Slow results of implementation
    f) Any other, please specify: _____________________
Part C – Total Productive Maintenance (TPM)

It is an innovative approach to maintenance that eliminates breakdowns and promotes autonomous maintenance by involving the total work force.

11. Which of the following had motivated you to implement SMED practice? Please tick.
   
   a) Need for reduction in change over time
   b) Need to improve flexibility
   c) Need to reduce inventory
   d) Need to improve productivity
   e) Need to increase output
   f) Need to meet delivery schedules

1. For how much % of the total equipments or machines; TPM is employed in your organization? Please tick appropriate option.
   
   a) 0-10%
   b) 10-25%
   c) 25-50%
   d) More than 50%

2. In your organization since how long the TPM is being used? Please tick.
   
   a) More than 6 months
   b) More than 2 years
   c) More than 8 years
   d) More than 15 years
   e) Any other, please specify: __________
3. Please provide the information regarding highest and lowest % of reduction achieved in average machine breakdown time.
   a) Highest - __________% ; Any additional information, please provide: ______________________________________
   b) Lowest- __________% ; Any additional information, please provide: ______________________________________

4. Please tick the manufacturing performance measures which have been improved due to implementation of TPM. Kindly mention the % of improvement where ever possible.

<table>
<thead>
<tr>
<th>Manufacturing Performance Measure</th>
<th>Tick mark</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Increase in capacity utilization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Increase in inventory turnover ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Reduction in unit cost of product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d) Reduction in over production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) Reduction in cycle time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) Reduction in material handling time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Kindly provide approximate percentage (%) improvement in following competitive dimensions, due to implementation of TPM.
   a) Quality:________
   b) Cost:________
   c) Flexibility:________
   d) Delivery:________

6. According to your experience please tick out of the following, which had helped to implement TPM.
   a) Development of initial equipment maintenance program [ ]
   b) Practice of 5S [ ]
   c) Small group activities [ ]
   d) Autonomous maintenance program [ ]
   e) Scheduled maintenance program [ ]
   f) Any other, please specify: __________________________
7. How frequently the improvement achieved by TPM is being reviewed? Please tick.
   a) Daily
   b) Weekly
   c) Quarterly
   d) Monthly
   e) Any other, please specify: _______

8. Which of the following factors you consider responsible as constrains to smooth and easy implementation of TPM as per your experience? Please tick.
   a) Resistance to change
   b) Lack of communication
   c) Lack of understanding of TPM concepts
   d) Fear of increased work load and responsibility
   e) Slow/Invisible results of implementation
   f) Any other, please specify: ______________________

9. Which of the following factors have motivated you to initiate the practice of TPM? Please tick.
   a) Need to reduce the occurrence of machine breakdown
   b) Need to increase the available time of machine
   c) Need to increase the quality production
   d) Need to increase the skill of employees
Part D – 5S

It is a determination to organize the workplace, to keep it neat and clean, to maintain standardize conditions and discipline that is needed to do a good job.

1. Which of the following is immediate outcome of implementation of 5S according to your experience? Please tick.
   - a) Motivated work force
   - b) Convenient Practices
   - c) Less fatigue
   - d) Improved organizational layout

2. Please specify, to what extent the 5S practices is implemented in your organization?
   - a) On pilot scale
   - b) For selective work areas
   - c) To considerable extent
   - d) On large scale

3. In your organization since how long the 5S is being used? Please tick.
   - a) More than 6 months
   - b) More than 2 years
   - c) More than 8 years
   - d) More than 15 years
   - e) Any other, please specify: ________

4. Please provide the information regarding the highest and the lowest % reduction achieved in search time of any part/ object after implementing the 5S.
   - a) Highest - ___________; Any additional information, please provide:

   __________________________________________________________________________

   b) Lowest- ___________; Any additional information, please provide:

   __________________________________________________________________________
5. Please tick the manufacturing performance measures which have been improved due to implementation of 5S. Kindly mention the % of improvement where ever possible.

<table>
<thead>
<tr>
<th>Manufacturing Performance Measure</th>
<th>Tick mark</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Increase in capacity utilization</td>
<td></td>
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<td></td>
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<tr>
<td>d) Reduction in over production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e) Reduction in cycle time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) Reduction in material handling time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Kindly provide approximate percentage (%) improvement in following competitive dimensions, due to implementation of 5S.
   a) Quality:________
   b) Cost:________
   c) Flexibility:________
   d) Delivery:________

7. Which among the following practices were found useful in execution of 5S at your organization? Please tick.
   a) Practice of cleanliness  
   b) Practice of standardization  
   c) Practice of record keeping  
   d) Practice of sorting  
   e) Any other, please specify:________

8. Which among the following are the important requirements to implement 5S as per your experience?
   a) Classification and coding of place and material  
   b) Constant efforts to sustain changes  
   c) Total employee involvement  
   d) Practice of putting everything at its proper place  
   e) Any other, please specify:______________________
9. How frequently the improvement achieved by 5S is being reviewed? Please tick.
   a) Daily
   b) Weekly
   c) Quarterly
   d) Monthly
   e) Any other, please specify:_________

10. Which of the following factors you consider responsible as constrains to smooth and easy implementation of 5S, as per your experience? Please tick.
    a) Resistance to change
    b) Lack of communication
    c) Lack of understanding of 5S concepts
    d) Fear of increased work load and responsibility
    e) Slow/Invisible results of implementation
    f) Any other, please specify:___________________

11. Which of the following you considered as motivational factors to implement 5S? Please tick.
    a) Improved work place
    b) Reduced time to locate material/tool
    c) Reduced wait time of work piece
    d) Reduced idle time of machines/equipments
    e) Any other, please specify:___________________
Part E – Poka-Yoke (Mistake Proofing)

It is a method of preventing occurrence of defects by providing immediate and accurate feedback at the source of defect to assure quality in the process and hence in product.

1. At your organization for how much % of the processes, Poka-Yoke is employed? Please tick.
   - a) 0-10%
   - b) 10-25%
   - c) 25-50%
   - d) More than 50%

2. Which of the following Poka-Yoke activities are routinely followed in your organization? Kindly tick.
   - a) Mistake proof devices are installed on the machines
   - b) Standard operating procedure is being provided to operators
   - c) Design of work place is revised frequently
   - d) Any other, please specify: ____________________________

3. In your organization, since how long the Poka-Yoke is being used? Please tick.
   - a) More than 6 months
   - b) More than 2 years
   - c) More than 8 years
   - d) More than 15 years
   - e) Any other, please specify: ___________
4. Please provide information regarding minimum and maximum reduction achieved in % of defects/ abnormalities/ errors/ mistakes after implementation of Poka-Yoke.
   a) Minimum - __________% ; Any additional information, please provide:
      ____________________________________________
   b) Maximum - __________% ; Any additional information, please provide:
      ____________________________________________

5. Please tick the manufacturing performance measures which have been improved due to implementation of Poka-Yoke. Kindly mention the % of improvement where ever possible.

<table>
<thead>
<tr>
<th>Manufacturing Performance Measure</th>
<th>Tick mark</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Increase in capacity utilization</td>
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<td></td>
</tr>
<tr>
<td>e) Reduction in cycle time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) Reduction in material handling time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Kindly provide approximate percentage (%) improvement in following competitive dimensions, due to implementation of Poka-Yoke?
   a) Quality:________
   b) Cost:________
   c) Flexibility:________
   d) Delivery:________
7. According to your experience, which of the following practices were found most effective in implementation Poka-Yoke? Please tick.

   a) Use of color codes on material, machines and devices
   b) Use of standard operating procedure
   c) Use of checklist
   d) Use of special devices
   e) Any other, please specify: __________________________

8. Please tick; how frequently the improvement achieved by Poka-Yoke is being reviewed?
   a) Daily
   b) Weekly
   c) Quarterly
   d) Monthly
   e) Any other, please specify:________

9. Which of the following factors you consider responsible as constrains to smooth and easy implementation of Poka-Yoke as per your experience? Please tick.
   a) Resistance to change
   b) Lack of communication
   c) Lack of understanding of Poka-Yoke concepts
   d) Fear of increased work load and responsibility
   e) Slow/Invisible results of implementation
   f) Any other, please specify: _________________________

10. Which of the following potential benefits you consider as motivation to initiate the practice of Poka-Yoke? Please tick.
    a) Reduction in % defect
    b) Reduction in maintenance cost
    c) Assurance of quality at each process
    d) Continuous improvement in the operations and processes
    e) Prevention of accidents/ hazards
    f) Relieving operators from repetitive actions
    g) Use human intelligence for creative and value adding work
Section V – Summary

This section summarises the questionnaire by your valuable responses related to supportive programs that have been useful for lean manufacturing.

1. Please tick (✔) in the cells below where you find usefulness of the following supportive programs for Lean Manufacturing.

   a) Total Quality Management (TQM)   b) Six Sigma

2. Which among the following manufacturing performance measures which have been improved due to implementation of TQM and Six Sigma? Please tick in appropriate cell.

<table>
<thead>
<tr>
<th>Manufacturing Performance Measure</th>
<th>TQM</th>
<th>Six Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Increase in capacity utilization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b) Increase in inventory turnover ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Reduction in unit cost of product</td>
<td></td>
<td></td>
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<tr>
<td>e) Reduction in cycle time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f) Reduction in material handling time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Please share your views how TQM and Six Sigma were helpful to implement lean manufacturing in your organization.
   TQM: ______________________________________________________

   Six Sigma: __________________________________________________

4. Would you like to know about the findings/results of this survey?
   a) Yes   b) No
5. Respondent’s signature: __________________
   Name & Designation: __________________
   Date: _____________
   Place: __________

We request you to please send the filled up questionnaire to: Prof. Maya D. Vadhvani, A-10, Krunal Apartment, Opposite Union Bank of India, Ghogha Circle, Bhavnagar- 364 002

Mobile No: (9909991656)
Email: mayavadhvani@gmail.com
Dear Sir,

As you are aware, the Indian Manufacturing Industries are on the path of tremendous growth. There is a lot of competition due to the dynamically changing markets, which creates pressure for continuous improvement in the processes of the business and operations. To cope up with this demanding situation, manufacturing organizations are adopting newer strategies and implementing improvement initiatives to enhance the performance of operation functions.

We have taken up a project, as part of Doctoral studies at RK University, Rajkot, to find out about the challenges faced, areas of importance, strategic initiatives to improve competitiveness and lean manufacturing practices adopted by manufacturing organizations. With this regard we request you to give your views and share your rich experience for the substance in attached sheets.

We are quite aware that you have a busy schedule and your time is very much valuable to your organization. However, considering the importance of this project, we earnestly request you to respond to our request favourably. All critical data furnished by you shall be classified and kept confidential. We shall send you the result of this survey, if you so desire.
We are very much looking forward to having your response at the earliest please, preferably within seven days of receiving this letter.

Thanking you with kindest regards.

Yours Sincerely,

Maya D. Vadhvani

Dr. Mangal G. Bhatt

Enclosure: Questionnaire for expert’s opinion
Survey of Expert’s Opinion for Lean Manufacturing Practices in Manufacturing Industries

Research Project by
Prof. Maya D. Vadhvani
Assistant Professor
Production Engineering Department
Shantilal Shah Engineering College, Bhavanagar

Ph. D. Research Scholar
Faculty of Technology-Mechanical Engineering
R. K. University, Rajkot
2016
Expert’s Opinion on Lean Manufacturing Practices in Manufacturing Industries

1. Since long you are closely associated with manufacturing as practicing or academic expert. Will you please express your views for prevailing competition scenario and importance of manufacturing function in our country?

2. Have you observed Lean Manufacturing Practices work well in our country towards achievement of competitiveness? Please indicate details.

3. According to your experiences which are the most popular Lean Manufacturing Practices amongst the following? Please tick.
   a) Kanban
   b) Single Minute Exchange of Dies (SMED)
   c) Total Productive Maintenance (TPM)
   d) 5S
   e) Poka-yoke (Mistake Proofing)
4. Which supportive program(s) amongst the following is useful to implement LMPs as per your experience? Please tick.

   a) Total Quality Management (TQM)  
   b) Six Sigma

5. According to your experience which supportive program is useful for smooth implementation of particular LMPs? Please tick in appropriate cell.

<table>
<thead>
<tr>
<th>LMPs</th>
<th>Supportive Program</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TQM</td>
</tr>
<tr>
<td></td>
<td>Six Sigma</td>
</tr>
<tr>
<td>Kanban</td>
<td></td>
</tr>
<tr>
<td>SMED</td>
<td></td>
</tr>
<tr>
<td>TPM</td>
<td></td>
</tr>
<tr>
<td>5S</td>
<td></td>
</tr>
<tr>
<td>Poka-yoke</td>
<td></td>
</tr>
</tbody>
</table>

6. As per your opinion which of the above program will find better appreciation and understanding in Indian manufacturing organizations? Please provide your valuable input.

7. Which LMPs have more potential to improve Competitive Dimensions (CDs) among the following as per your experience? Please tick in appropriate cell.

<table>
<thead>
<tr>
<th>LMPs</th>
<th>CDs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quality</td>
</tr>
<tr>
<td>Kanban</td>
<td></td>
</tr>
<tr>
<td>SMED</td>
<td></td>
</tr>
<tr>
<td>TPM</td>
<td></td>
</tr>
<tr>
<td>5S</td>
<td></td>
</tr>
<tr>
<td>Poka-yoke</td>
<td></td>
</tr>
</tbody>
</table>
8. Which LMPs have more potential to improve Manufacturing Performance Measures (MPMs) amongst the following as per your experience? Please tick in appropriate cell.

<table>
<thead>
<tr>
<th>LMPs</th>
<th>MPMs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increase in capacity utilization</td>
</tr>
<tr>
<td>Kanban</td>
<td></td>
</tr>
<tr>
<td>SMED</td>
<td></td>
</tr>
<tr>
<td>TPM</td>
<td></td>
</tr>
<tr>
<td>5S</td>
<td></td>
</tr>
<tr>
<td>Poka-yoke</td>
<td></td>
</tr>
</tbody>
</table>

Date: ___________
Place: ___________

We request you to please send the filled up questionnaire to: Prof. Maya D. Vadhvani, A-10, Krunal Apartment, Opposite Union Bank of India, Ghogha Circle, Bhavnagar- 364 002

Mobile No: (9909991656)
Email: mayavadhvani@gmail.com
## ANNEXURE 4.1

**Brief Summary of Products Manufactured Within Group**

<table>
<thead>
<tr>
<th>Group A</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Investment castings of automobile, industrial pumps, electrical and</td>
</tr>
<tr>
<td>instrumentation</td>
</tr>
<tr>
<td>- Aluminium Die cast parts, assemblies, textile processing machining</td>
</tr>
<tr>
<td>accessories such as textile flyers, hot air sterner</td>
</tr>
<tr>
<td>- Steel and alloyed steel closed die hot forgings, bearing housing</td>
</tr>
<tr>
<td>flange, boom pin, bush, cam shaft, clutch parts, hydraulic valve</td>
</tr>
<tr>
<td>chamber</td>
</tr>
<tr>
<td>- High speed steel cutting tools, carbide tip tool, cutting saw,</td>
</tr>
<tr>
<td>precision manufacturing instruments</td>
</tr>
<tr>
<td>- Tools and dies</td>
</tr>
<tr>
<td>- Special screens, Anilox Rollers for various coating application on</td>
</tr>
<tr>
<td>textiles, perforated nickel rotary screens for textile industries</td>
</tr>
<tr>
<td>- Filtration system, valve and allied products, 2 way diaphragm, zero</td>
</tr>
<tr>
<td>dead leg valve, tank bottom valve made of casting and forging</td>
</tr>
<tr>
<td>- Moulding Machine Parts, Fabrication of Machine Parts, Pneumatic</td>
</tr>
<tr>
<td>Conveying System, Screw Conveyor, Power Transformer System,</td>
</tr>
<tr>
<td>Heavy CNC Turning and Milling Components, Screw &amp; Barrels, Tie</td>
</tr>
<tr>
<td>Bars, Transformation Tank</td>
</tr>
<tr>
<td>- Oxy-fuel Straight &amp; Bevel Cutting, Plasma Cutting, Laser Cutting</td>
</tr>
<tr>
<td>- Steel Union, Alloy Pipes, Exotic Alloy Castings, Gate Valve, Globe</td>
</tr>
<tr>
<td>Valve, Check Valve, Ball Valve, Cryogenics, Forged Valves</td>
</tr>
<tr>
<td>- Steel Valve, Hydraulic Power Unit Cylinders, Manifold Blocks</td>
</tr>
<tr>
<td>- Composite Quartz, Kitchen Sink, Kitchen Chimney, Wash-Basin, Tiles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>- All types of tyre grade and food grade silica, Precipitated silica,</td>
</tr>
<tr>
<td>Aluminium silicates</td>
</tr>
<tr>
<td>- Power generation with gas based power plant, thermal, solar power</td>
</tr>
<tr>
<td>plant</td>
</tr>
<tr>
<td>- Soda Ash (Anhydrous Sodium Carbonate) &amp; Sodium Bicarbonate Chemicals,</td>
</tr>
<tr>
<td>Textiles &amp; Consumer products edible salt, industrial grade</td>
</tr>
</tbody>
</table>
salt, honey.

- Laundry detergents, contact adhesives, body lotion, hair care products, soaps, hair colour, humidity absorber
- Ink for commercial printing, offset printing, ultra violate ink and coating, flexible packaging, screen printing, wire enamels, aqueous coating, alkali blue pigment
- Steel, oil, processed steel, wood finished steel, abrasion resistance, silicon, modified polyester
- Glyphosate, Profenophos, Chloropyriphos, Quinalphos, Pesticides
- Petroleum Products, Polyester Products, Polyester Intermediates, Plastics, Polymer Intermediates, Chemicals, Synthetic Textiles, Fabrics

**Group C**

- Resistance temperature director, Industrial heaters, R & D furnaces, thermo-wells and accessories, calibration equipments, wires and cables, pyrometer
- Coal mining application- Side dump loader, Load haul dumper, Coal Hauler, Universal drill machine
- Metal mining application- Load Haul Dumper, Low Profile Dump Truck, Rock shovel loader
- Construction- Articulated wheel loader
- Chair Lift Man Riding System
- Systems used with hot air generators, dryers, boilers, thermal fluid heaters, oven, furnaces
- CNC turning centre, CNC turn mill centre, CNC horizontal machining centre, CNC universal line machine, High technology CNC-3 axis and CNC 5-axis machine centres
- Tube Axial Fans, Axial Flow Fans, Air pre heaters, Electric air heaters, poultry exhaust fans, ventilation exhaust fans, air pre heater baskets, Axial Fans, air finned heaters
- Engineered Equipment and Systems for Critical application in Chemical
and Pharmaceutical Industries - Reactor (customised), Conical Dryer, Blender, Dip-Pipe Sprayer, Glass lined Products based on customer requirements.

- Electrical Panel Control Boards, Power Control Panels, Motor Control Panels
- Plastic Processing Machines, Injection Moulding Machines, Pipe Extrusion Machine, Blown Film Machines
- Pressure Vessel, Chemical Process Plant and Expansion Bellows, Fabricated Capital Equipments, Heat Exchangers, Gas Cylinders
- Road Construction Equipments - Curb Laying Machines, Asphalt Batch Mix Plants, Wheeled Hydrostatic Sensor, Asphalt Drum Mix Plants
- Air Conditions, Refrigerators, Washing Machine

**Group D**

- Power steering pumps for Mercedes, Volvo Truck, Repair kit brake shoe, King pin kit for Mercedes, release shaft kit
- Submersible bore well pump set, submersible open well pump set, self priming mono block pumps, centrifugal mono block pump, pumping accessories
- Friction and antifriction bearings
- Mountings, Mountings and Dis-mountings, Monorail Guidance Systems, Deep Groove Ball Bearings, Mounting Managers, Propulsion and Controls
- Automated People Movers, Automated Monorails, Light Rail Vehicles, Locomotives, High Speed Trains, Urban Bogies, Metro Bogies, Power Bogies
- Automated Products and Vehicles
- Bearings
- Clutch Assemblies for car
ANNEXURE 4.2

Calculation Procedure with KW H Test

The data as per Table 4.8 is as below. The associated Hypothesis are listed thereafter.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Responses out of 35 Industries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
</tr>
<tr>
<td>Increased customer awareness and expectations</td>
<td>4</td>
</tr>
<tr>
<td>Increased buying power of customers</td>
<td>1</td>
</tr>
<tr>
<td>Fast changing technology and its quick implementation</td>
<td>3</td>
</tr>
<tr>
<td>Ever increasing competition</td>
<td>5</td>
</tr>
<tr>
<td>Newer business models and practices like (ERP, SCM, CRM)</td>
<td>2</td>
</tr>
<tr>
<td>Improvement in national business infrastructure</td>
<td>1</td>
</tr>
<tr>
<td>Changing government policies</td>
<td>1</td>
</tr>
<tr>
<td>Any other</td>
<td>-</td>
</tr>
</tbody>
</table>

H₀: Same factors affect the competitiveness business environment of each group of manufacturing industries.

H₁: Different factors affect the competitiveness business environment of each group of manufacturing industries.

Test Statistic $H_{stat} = \frac{12}{n(n+1)} \Sigma \frac{R_i^2}{n_i} - 3(n+1)$;

where $n=$ total number of observations, $n_i=$ number of observations in particular group and the condition is,
if $H_{\text{stat}} < \lambda^2_{\text{critical}}$, we cannot reject null hypotheses $H_0$

As per KW H Test, detail calculation is presented here in the following table for four groups.

<table>
<thead>
<tr>
<th></th>
<th>Rank for Observations</th>
<th>Rank for Observations</th>
<th>Rank for Observations</th>
<th>Rank for Observations</th>
<th></th>
<th>Rank for Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4</td>
<td>18</td>
<td>3</td>
<td>14</td>
<td>12</td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>14</td>
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<td></td>
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<td>5</td>
<td>21</td>
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<td>1</td>
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<td>4</td>
<td>3</td>
<td>14</td>
<td>16</td>
<td>24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sum of ranks= $R_i$</th>
<th>Sum of ranks= $R_i$</th>
<th>Sum of ranks= $R_i$</th>
<th>Sum of ranks= $R_i$</th>
<th></th>
<th>Sum of ranks= $R_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R_1$=74</td>
<td>$R_2$=75</td>
<td>$R_3$=161</td>
<td>$R_4$=96</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Now, $(R_1)^2 = 5476$ $(R_2)^2 = 5625$ $(R_3)^2 = 25921$ $(R_4)^2 = 9216$

So, $(R_1)^2 / n_i = 782.2857$ $(R_2)^2 / n_i = 803.5714$ $(R_3)^2 / n_i = 3703$ $(R_4)^2 / n_i = 1316.571$

Therefore, $\sum R_i^2 / n_i = 6605.429$

Now, $12/n(n+1) = 12/28*29 = 0.014778$

Therefore, $12/n(n+1) * \sum R_i^2 / n_i = 97.61717$

So, $H_{\text{stat}} = [12/n(n+1) * \sum R_i^2 / n_i] - 3(n+1) = 16.61717$

$\lambda^2_{\text{critical}} = \text{Critical Value for degree of freedom 3 at 95% from table of } \lambda^2 \text{ is 7.815}$

In this case $H_{\text{stat}} > \lambda^2_{\text{critical}}$ so we shall accept alternate hypothesis
ANNEXURE 4.3

Calculation Procedure with MW U Test

The data as per Table 4.117 is as below. The associated Hypothesis are listed thereafter.

<table>
<thead>
<tr>
<th>MPMs Improved due to TQM (Responses out of 27 Industries)</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Capacity Utilization</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Increase in Inventory Turnover Ratio</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Reduction in Unit Cost of Product</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Reduction in Over Production</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Reduction in Cycle Time</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Reduction in Material Handling Time</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MPMs Improved due to Six Sigma (Responses out of 27 Industries)</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>Group D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase in Capacity Utilization</td>
<td>1</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Increase in Inventory Turnover Ratio</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>Reduction in Unit Cost of Product</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Reduction in Over Production</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>Reduction in Cycle Time</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Reduction in Material Handling Time</td>
<td>-</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>
H₀: There is equal improvement in MPMs due to implementation of TQM and Six Sigma in manufacturing industries.

H₁: There is not equal improvement in MPMs due to implementation of TQM and Six Sigma in manufacturing industries.

\[ U_{stat} = \text{Rank Sum} - n \frac{(n+1)}{2}; \]

where \( n \) is the number of observations in the group, and the condition is,

If \( U_{stat} < \text{or} = U_{critical} \), we should reject null hypotheses \( H₀ \)

As per MW U Test, detail calculation is presented here in the following table for two groups.

<table>
<thead>
<tr>
<th>For TQM</th>
<th>Rank for Observations</th>
<th>For Six-Sigma</th>
<th>Rank for Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>12</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>7</td>
<td>2.5</td>
</tr>
<tr>
<td>14</td>
<td>10.5</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>7</td>
<td>2.5</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>10.5</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

\[ \text{Sum of ranks} = R_1 = 57 \]

\[ \text{Sum of ranks} = R_2 = 21 \]

\[ U_{stat} = \text{Rank Sum} - n \frac{(n+1)}{2} \]

\[ U_{stat} = 57 - 6 \frac{(6+1)}{2} = 36 \]

\[ U_{critical} \text{ at 95% confidence interval and degree of freedom } n₁=6 \text{ and } n₂=6 \text{ is 8} \]

\[ U_{stat} < U_{critical} \text{ so we shall accept the alternate hypothesis} \]