Expected maintenance waste reduction benefits after implementation of Just in Time (JIT) philosophy in maintenance (a statistical analysis)

Received 28 March 2017
Revised 2 August 2017
Accepted 13 July 2018

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Abstract

Purpose – The maintenance department of today, like many other departments, is under sustained pressure to slash costs, show outcome and support the assignment of the organization, as it is a commonsensical prospect from the business perspective. The purpose of this paper is to examine expected maintenance waste reduction benefits in the maintenance of organizations after the implementation of just-in-time (JIT) managerial philosophy. For this, a structured questionnaire was designed and sent to the 421 industries in India.

Design/methodology/approach – The designed questionnaire was divided into two sections A and B to assist data interpretation. The aim of the section A was to build general information of participants, type of organization, number of employees, annual turnover of the organization, etc. Section B was also a structured questionnaire developed based on a five-point Likert scale. The identified critical elements of the JIT were included in the questionnaire to identify the maintenance waste reduction benefits in the maintenance of organizations.

Findings – On the basis of the 133 responses, hypothesis testing was done with the help of *Z*-test, and it was found out that in maintenance, we can reduce a large inventory of spare parts and also shorten the excessive maintenance activities due to the implementation of JIT philosophy. All the four wastes: waste of processing; waste of rejects/rework/scrap in case of poor maintenance; waste of the transport of spares, and waste of motion, have approximately equal weightage in their reduction. Waste of waiting for spares got the last rank, which showed that there are little bit chances in the reduction of waiting for spares after the implementation of JIT philosophy in maintenance.

Practical implications – The implication of the research findings for maintenance of organizations is that if maintenance practitioners implement elements of JIT philosophy in maintenance then there will be a great reduction in the maintenance wastes.

Originality/value – This paper will be abundantly useful for the maintenance professionals, researchers and others concerned with maintenance to understand the significance of JIT philosophy implementation to get the expected reduction benefits in maintenance wastes of organizations which will be helpful in the great saving of maintenance cost and time side by side great increment in the availability of machines.

Keywords Maintenance, JIT in maintenance, Wastes, Wastes in maintenance, Just in Time (JIT)

Paper type Research paper

1. Introduction

Manufacturing companies face augmented demands in terms of extreme flexibility and speed in operations in order to stay competitive in today's fast-changing market (Cholasuke *et al.*, 2004). To manage this challenge, companies are searching for new ways to advance their manufacturing practices (Kutucuoglu *et al.*, 2001). During the past decades, adopting just-in-time (JIT) production principles has been widely popularized in order to allow for increased profitability and productivity (Stuchly and Jasiulewicz-Kaczmarek, 2014).

Journal of Quality in Maintenance Engineering
Vol. 25 No. 1, 2019
pp. 25-40

1355-2511
DOI 10.1108/JQME-03-2017-0020

A result of motivation for more modernized processes is that the penalty of failures is growing (Ericsson, 1997), and JIT philosophy, such as waste reduction and antagonistic inventory reduction, makes the production flow sensitive to instability and apparatus failures (Faria and Nunes, 2012). Therefore, an evolution toward a JIT production organization also requires elementary changes in the maintenance operations (Baluch *et al.*, 2012). However, maximum companies are exclusively focusing on industrialized efficiency through the use of JIT invention tools, but a precondition for the accomplishment of a JIT manufacturer is the concurrent adoption of JIT in maintenance (Baluch *et al.*, 2012). Furthermore, the maintenance purpose often has low status and is underdeveloped, and there is an enormous improvement prospective for more successful maintenance in the average manufacturing firms (Jonsson, 1999).

The maintenance department of today, like many other departments, is under sustained pressure to slash costs, show outcome and support the assignment of the organization, as it is a commonsensical prospect from the business perspective (Lahiri *et al.*, 2008). The embryonic maintenance procedure has been distorted with sustaining the broader hard work of world-class maintenance like Six Sigma, JIT manufacturing and other major quality initiatives (Ahuja and Khamba, 2008).

Wireman (1990) in his book titled *World Class Maintenance Management* referred to maintenance planning as the last frontier for organizations. A large number of organizations are realizing a significant need for valuable maintenance of manufacturing facilities and operating systems. Wireman (1991) emphasized that it is fundamental for maintenance administration to be incorporated with corporate stratagem to ensure apparatus availability, superiority products, on-time deliveries and competitive pricing. The changing necessities of contemporary organizations require a reconsideration of the responsibility that maintenance administration plays in gaining key cost and service advantages, leading them to become a world-class manufacturer (Al-Turki, 2011).

Ahmad *et al.* (2003) tinted a unique maintenance strategy that combines singular maintenance techniques and concepts that can be used based on certain situations, objectives and unambiguous needs of organizations. In additional words, it is apprehensive to develop and design an appropriate maintenance strategy in the form of a maintenance decision support model. Preceding studies on the enlargement of structured maintenance decision support for definite cases and viewpoint were available from a small number of researchers. For example, Ahmad and Kamaruddin (2012) developed a controlled maintenance policy to methodically identify and make associated maintenance decisions based on an optimization approach. Utne *et al.* (2012) presented a decision prop up model for condition monitoring methods collection. Elhdad *et al.* (2013) projected a framework for course of action monitoring and maintenance to make certain that decision makers have adequate information to make the right decision at the right time. Faccio *et al.* (2014) introduced a fresh quantitative structure to develop most favorable maintenance policies by means of several cost models. Barbera *et al.* (2013) introduced a consistent support technique for maintenance management decision making, namely graphical analysis for maintenance management. Detailed applications of this method based on two case studies of slurry pumps in a mining plant located in Chile are presented in Barbera *et al.* (2014).

Risk assessment during the design of production systems and planning of maintenance activities is furthermore of vital importance in order to make sure the safety and health of maintenance workers (Cholasuke *et al.*, 2004). Even though the central part of JIT principles is an assurance to customer satisfaction and continuous improvements by striving toward the elimination of waste and perfection, it is most excellent known for its elements such as Kaizen, 5S, standardized work, value stream mapping and Poka-Yoke (Baluch *et al.*, 2012). These are not only applied in the production environment toward targets in order to obtain reduced lead time or cost, but they can also be applied for maintenance operations (Monden, 1998).

To improve production and reduce costs, many large process and manufacturing companies that have embraced the JIT Enterprise perception have, in use, an approach of building all of the systems and infrastructure throughout the organization (Jonsson, 1999). The consequence of this long-established approach has been the unpredictable implementation of hard work that frequently stalls out, or is completed, before the reimbursement is granted. Industries can pick up the pace of their improvement to a great extent with low risk throughout the eradication of the defects with the intention to impede production efficiency and create work (Labib, 2004). Optimizing the upholding function first will both raise maintenance time accessible to do supplementary improvements and will trim down the defects that ground production downtime. Thus, improved production and cost reduction are instantaneous results obtained by implementing JIT in maintenance operations as the first step in the overall JIT enterprise transformation (Baluch *et al.*, 2012). Mendes and Ribeiro (2014) projected a quantitative method for sustaining the review or preparation of an equipment maintenance strategy in a JIT production scenario.

Much have been printed about the elements that are essential for achieving success in the context of JIT enterprise and JIT manufacturing, so that almost all readers are familiar with the concepts as well as the phrases themselves. But what about JIT in maintenance operations? Is it simply a division of JIT in manufacturing? Is it an expected fall in behind by-product result of implementing JIT manufacturing practices? To a great extent to the mortification of many manufacturing organizations, whose attempts to execute JIT practices have been disastrous and ignominious, JIT in maintenance is neither a division nor a fall in behind by-product of JIT in manufacturing. It is a substitute and prerequisite for victory as a JIT manufacturer (Azadivar and Shu, 1999).

2. JIT in Maintenance

JIT in maintenance is a moderately new term that came into the role in the 90s of the twentieth century, but the philosophy is well conventional in total productive maintenance (TPM) (Shahanaghi and Yazdian, 2009). JIT in maintenance in addition to TPM approach applies some innovative techniques to render an additional structured accomplishment path, tracing its original roots back to Henry Ford with modern refining born in Japanese industries, exclusively the Toyota Production System (TPS). JIT in maintenance is the relevance of JIT principles in maintenance environments (Monden, 1998). JIT system recognizes seven forms of waste in maintenance. They are over production, waiting, transportation, process waste, inventory, waste motion and defects. In JIT in maintenance, the seven deadly wastes are recognized and hard work is made for the uninterrupted improvement in procedure by eliminating these wastes. Thus, JIT in maintenance leads to maximize yield, productivity and profitability. JIT in maintenance basically focuses on tools reliability and reduces need for maintenance troubleshooting and repairs. JIT in maintenance protects equipments and system from the root causes of malfunctions, failures and downtime stress. For the sources of waste, uptime can be improved and cost can be lowered for maintenance (Swanson, 1997).

2.1 Definition

JIT in maintenance means that maintenance is there just before you need it, not too early and ever too late! Discover what you need to do to have that sort of service and the resulting Production performance you get from it!

JIT in maintenance means taking a piece of equipment off-line for servicing when it needs it, rather than according to a fixed schedule. It is expensive and time consuming to shutdown critical machines like motors, generators, pumps, fans and turbines for maintenance, so plant operators would like to be sure that the equipment needs servicing before they schedule it (Ahmed *et al.*, 2005).

JIT in maintenance is a down to business maintenance operation employing scheduled and planned maintenance activities throughout. TPM practices use maintenance activities developed through the submission of reliability-centered maintenance assessment practices and logic by empowered (self-directed) action teams using the Kaizen improvement events, 5S process, and autonomous maintenance collectively with multi-skilled workers. Maintenance technician performed maintenance throughout the committed use of their computer-managed maintenance system or enterprise asset management) system and their work order system (Laura Swanson, 1997; Cua *et al.*, 2001).

2.2 Seven types of wastes in maintenance

There are mainly seven wastes recognized in the maintenance of the organizations. We are discussing them one by one as follows:

(1) Overproduction – doing more maintenance than is needed, gaining little or no comprehensible reliability improvement. Are maintenance executives maintaining equipment that ought to instead be permitted to run, to failure and then to be replaced? We often find maintenance mechanics going out and re-checking equipment over and over without ever finding either any deterioration or failure – and yet, the maintenance has not changed in years. All of this contributes to unnecessary "overproduction." Pointless effort of this kind can work in either direction, i.e., maintenance is still done despite recurring breakdowns – which means that the maintenance is useless all along – or maintenance is being done "ritually" for systems that rarely fail, whether inspected or not, or which fail at predictable intervals. In either case, maintenance is having little or no effect. Maintenance only "adds value" if it enhances equipment longevity. You have to constantly reevaluate and reassess these relationships. Look at the failure histories that drive the maintenance schedule. Be sure that they are still reasonable and appropriate. Other examples of "overproduction" include items such as excessive recordkeeping, tracking, looking or assorted busy work.

(2) Waiting – When maintenance personnel are forced to sit idly for parts to come, or wait for some other event or when people are not in motion and they should be, they do not add any value. That again is a sort of waste. The lack of good coordination between task elements is a common problem in maintenance. One solution to this problem is that schedulers should get more feedback from the crews to understand where bottlenecks or mistimings happen and why. Waiting is also caused in scores due to othe reasons, such as from outdated or bad work procedures, or lack of training. For example, an operator's machine goes down and needs repair. In such a condition, the operator commands to a nearby mechanic who spends more than half an hour time in troubleshooting and in ineffectiveness, because the machinist does not know that the proper procedure is to report the problem to a maintenance scheduler, or the operator does not know how to generate an accurate work order and enter it on the computer terminal. To eliminate these waste areas, you have to explore all the steps that occur, and then identify those that add importance or contribute to progress in responding efficiently. Look at what is necessary, and look at what can be removed.

(3) Transportation – ask everyone in the plant what did he say? He sees that what maintenance working class doing and he will often answer walking or driving around. Tools stored far away from the situation or task-at-hand, repetitive or

common use of spare parts that have not been kitted or preassembled, documentation that ought to be found and work orders for machines that are not available for shutdown are common causes. Each activity requires transportation and most do not add implication to the maintenance process. Crisscrossing and long passage times, with techs shuffling back and forth to stores or to engineer's offices, etc., or doing tasks with elements unnecessarily spread out, are major sources of waste. In sprawling facilities, the cumulative loss can be high. As for machine documentation, typically, you may desire to set up some kind of centralized library system where all documents are well organized. Whether the maintenance person or the planner obtains documentation, such a system can eliminate much of this excess motion. In addition, make copies of key data sheets and diagrams, etc., to hang next to each pertinent piece of equipment. Efficiency gains from these movements will be composited by improved reaction times, increased productivity, faster recognition of imminent breakdown, higher machine reliability and better overall communications.

(4) Processing – this category includes typical maintenance bottlenecks, such as an inefficient or haphazard work order system, excessive or time-consuming reporting forms, and ineffective training which fails to convey needed instructions and must be continually retaught, etc. Studying the problem can develop solutions to wasteful processing. Typical measures may include JIT in maintenance upgrade, workflow reassessment and workflow process analysis. They also include streamlining, better recognition of actual root problems, clarity of instructions, improved technical training, systematizing of work order forms, and better work planning throughout the use of an enthusiastic scheduler/planner and instilling a healthier work ethic and the fortitude to "do things right every time."

(5) Inventory – quite often a major contributor to waste in both time and overhead cost is repair parts and storage. Frequent "stock-outs," large stock of obsolete parts and large inventories of infrequently used and/or expensive or limited shelf life items are most common. Formulas are available for determining appropriate stock quantity and reorder points. Integration of MRO storeroom inventory control with JIT in maintenance is exceptionally effective in eliminating this area of waste. It is also essential to consider storeroom layout and processing flow and item cataloging efficiency so that retrieval takes minimal time. Are rooms logically arranged, with high-demand items quick to get? How about shelves and bins? Are they well-marked, so that parts are easily accessible? Good storeroom management has an impact such that bringing in a consultant or obtaining training will easily justify the investment, especially if your system has not recently been examined.

(6) Motion – maintenance personnel also often burn inordinate time searching for key information: manuals, parts lists, and schematic diagrams, repair histories, all of which are important to servicing, but scattered and unorganized. To plug up such gaps, do some basic time-and-motion studies, quantifying the unnecessary movement factors. It is also important to think how your parts, stores, tools, people and equipment might be better repositioned to make them closer, handier and logistically more accessible. For example, in JIT manufacturing, a common "proximity improvement" is called point-of-use tooling, i.e., "getting tooling and supplies close to where they are mortal used, as opposed to having them off somewhere else thoughtlessly.

(7) Defects – relative to maintenance defect is instances of reworking, redoing and repeatedly repairing an item due to failure to identify the root source of a failure. Defects in the maintenance processes also revolve around preventive maintenance

tasks that do not add value to the output. For illustration, a periodical oil change on a machine that has not been operated in three years should be extended based on an actual lubricant condition as determined by oil analysis. In processing, defects like these are solved by studying the problem. Creation of a maintenance engineering function whose responsibilities include root cause failure analysis and maintenance effectiveness evaluations to identify ineffective or incorrect maintenance task procedures or incorrect scheduling (frequencies) can quickly identify and correct this type of waste.

3. Research methodology

This section explains the methodology used in the survey of manufacturing firms, data analysis and interpretation of analysis results. Literature indicates that survey is a very potential tool to explore the applicability of any concept in real sense. Since the focal point of this research is to describe how certain tools and technologies are being applied in maintenance of the industries, a survey method is very suitable here. A questionnaire-based survey method is used to pull together the responses from the manufacturing community regarding JIT practices in maintenance. Therefore, six phases of survey methodology will be used here to reach on the conclusion. These are questionnaires design; data collection; data preparation; data analysis; reliability testing; and hypothesis testing and ranking of maintenance wastes.

3.1 Questionnaire design

Questionnaire was premeditated as a research instrument with the intention to make a sincere effort to tap the collective wisdom of the professionals within the industry, who truly care for it, in categories to assess the relative importance of JIT Philosophy in maintenance. A structured questionnaire was developed on a five-point Likert scale, where very low equals to 1, low equals to 2, medium equals to 3, high equals to 4, very high equals to 5. Respondents were formally asked for to rate the degree or extent of practice of each element based on the five-point response scale.

Questionnaire was premeditated using the 18 JIT elements highlighted in Table I (Phogat and Gupta, 2017), then the questionnaire was separated into two sections A and B to assist data interpretation: the aim of the section A was to build general information of participants, type of organization, number of employees, annual turnover, type of maintenance system in the organization, etc., and Section B was also a structured questionnaire developed based on a five-point Likert scale for assessing the expected wastes reduction benefits in the plant maintenance of maximum of automobile vehicles manufacturing and repair industries.

As this research addressed one set of hypotheses and seven sets of sub-hypotheses, maximum care was taken in developing the questionnaires which will address them properly. On the basis of theoretical in-depth study of the available literature, interviews with eight maintenance professionals of automobile vehicles manufacturing industries were carried out to identify different type of JIT elements which were necessary to implement JIT in maintenance in order to build up a survey questionnaire. The most important 18 identified JIT elements from the interviews and the reviewed literature were included in the survey questionnaire. The complete questionnaire was pilot tested. Pilot testing was carried out in two stages. In the first phase, an outline of the questionnaire was sent to four academicians and they were formally asked for critically appraise the matter from the point of view of article specificity and intelligibility of structure. Based on critique received, some items were revised to improve their specificity and clarity. The second stage involved administering the questionnaire to maintenance professionals of automobile vehicles manufacturing and repair industries. The professionals were asked to modify the revised questionnaire and indicate any

JIT element	Role of element
Continuous improvement (kaizen)	To improve machine availability and decrease maintenance time
Effective communication	To coordinate among the team and with others for perfect maintenance
Employee involvement	To improve involvement and skills
Flexible/Multi-skilled workforce	Even in non-availability of skilled human resource, the work should not get effected and to improve workforce flexibility
Total productive maintenance	To reduce breakdown maintenance
Workers centered quality control	Improve responsibility and work quality
Education and training	Employee remains updated with latest technological changes in maintenance
Set up time reduction	Increase production by reducing time
Statistical quality control	Learn from past experience
Total quality control	Reduce rejections
Layout improvement	Reduce complexity
Under capacity Scheduling	Improve workforce flexibility
Zero defects	To reduce scrap and rework tasks
Waste reduction	Reduce cost of maintenance
Role of top management in maintenance	Enhance feelings of responsibility among workforce
Autonomation (Jidoka)	Improves quality
JIT purchasing	Reduces inventory cost
Process simplification	Reduces maintenance time and cost

Source: Phogat and Gupta (2017)

Table I.
List of JIT elements

ambiguity or other difficulty they experienced in responding to the items, accompanied by to offer any modifications they deemed suitable. The pilot testing was completed with the three practitioners from reputed manufacturing industries. After the second pilot testing, the questionnaire was reviewed based on expert's comments and phrasings of some items were modified to make the final research instrument more effective.

3.2 Data collection

The method of questionnaire administration was chosen as mail-survey. The questionnaire was send to respondents in the form of hard copy, pdf file and an online link of goggle form. The questionnaires were mainly targeted to minimum mechanical engineer level to middle- or upper- level management which has a good knowledge of JIT philosophy and maintenance activities. The sample group was contacted either by phone or by e-mail to seek agreement to participate in the survey. Prior appointments were taken from participants to visit their offices/plants for the survey. The questionnaires were sent throughout e-mail and at some places questionnaires were handed over to the respondents in person.

A database of 421 industries in India was generated to which the questionnaire was sent. The respondents were asked to allocate a score as per the actual level of importance of the elements according to their expertise. The respondents were asked to talk about questionnaire over telephone or internet with the researcher regarding any doubts or queries they had related to the questionnaire. In total, all companies were contacted through e-mail and subsequently number of reminders were mailed and some people were contacted personally over telephone. In some of the cases where professionals were extremely busy, after briefing about the survey, they promised to return the questionnaire as per their convenience within a week or two. These respondents were reminded by phone/e-mail if they had not sent back the questionnaires within the period they promised (Table II).

Out of 421 companies, 142 company responses were received. However, there were nine questionnaire which were incomplete and were not valid and hence we had 133 valid responses. The overall response rate was 31.59 percent. The response rate was acceptable compared with some other surveys with the help of literature, such as Saraph *et al.* (1989), Black and Porter (1996), Shah and Murphy (1995), Bennet and Whittaker pointed out that the expected response rate for industry is of the order of 25–30 percent. Non-response analysis has been conducted to clarify the reasons for not returning completed questionnaire. The method selected was direct telephone contact of randomly selected sub sample of 15 non-respondents to determine why they did not respond. The main explanation for non-response by the respondents was the lack of time to fill up questionnaire. All the non-respondents gave this reason. Non-respondents were not different from respondents in terms of organizational demographics. Therefore, the actual replies received were assumed to constitute the valid responses of the original sample.

3.3 Data preparation

Proper data analysis requires effective data preparation and management. The length of the questionnaire, the number of completed surveys anticipated and data analysis software to be used all had to be considered in selecting a database-management system. A rational database-management program, Microsoft excels and SPSS software were chosen for this purpose. Survey responses were coded in the database. Both qualitative and quantitative, open-ended responses were recorded for possible future analysis. This also helped to clarify quantitative responses.

3.4 Data analysis

The analysis of the data from the survey was divided into two parts, descriptive analysis and statistical analysis. The descriptive statistic was used to count the frequencies of the demographic information, calculate the proportion and present the results in tables. The statistical analysis was used to find out the relationship between the variables and validate the performance measures/factors. A proper analysis requires the investigation of the descriptive characteristics of the organization and experts accompanied by statistical examination of the factors.

Analysis of the data commenced with an investigation of the descriptive characteristics of the sample using Microsoft Excel and SPSS software. The descriptive analysis was used to calculate the proportion, count the frequencies and present the results in tables from 133 different firms.

Table III summarizes descriptive data of the respondents surveyed. The responses were classified based on the size of organization, in terms of number of employees; the respondents were evenly divided among the five regions.

Table II.
Statistics of responses

Number of questionnaire sent	421
Responses received	142
Valid responses	133
Response rate	31.59%

Table III.
Respondents by size of organization

No. of employees	% Response
Less than 100	8.27
101–500	21.8
501–1,000	19.55
1,001–2,000	25.56
More than 2,000	24.81

Table IV summarizes descriptive data of the respondents surveyed. The responses were classified based on the annual turnover of organization; the respondents were evenly divided among the five regions.

Table V summarizes descriptive data of the respondents surveyed. The responses were classified based on the designation of the respondents; the respondents were evenly divided among the three regions.

Table VI summarizes descriptive data of the respondents surveyed. The responses were classified based on maintenance sector with which the respondents were working; the respondents were evenly divided among the three regions. Table V shows that the 84.96 percent of organizations are manufacturing organizations and 10.53 percent are service organizations.

Figure 1 shows the pie chart of summarized surveyed data of the respondents. The responses were classified based on the willingness of the implementation of JIT in the maintenance of respondent's respective organizations; the respondents were evenly divided among the two regions of yes or no. Figure 1 shows that the 71.43 percent of organizations are interested in the implementation of JIT in maintenance in their organizations and remaining 28.57 percent are not interested.

Figure 2 shows the histogram of summarized surveyed data of the respondents. The responses were classified based on the dependency level of the different organizations on the maintenance for effective running of the organizations; the respondents were evenly divided on a five-point Likert scale, where very low equals to 1, low equals to 2, medium equals to 3, high equals to 4, very high equals to 5. Figure 2 shows that mean value is 4.05, which shows that all the surveyed organizations are highly dependent on maintenance for their effective running.

Figure 3 shows the histogram of summarized surveyed data of the respondents. The responses were classified based on the scope for the implementation of JIT in maintenance of the different organizations; the respondents were evenly divided on a five-point Likert scale, where 1 means very low, 2 means low, 3 means medium, 4 means high and 5 means very high. Figure 3 shows that mean value is 3.89, which shows that all the surveyed organizations have approximately a high scope of JIT implementation in the surveyed organizations.

Annual turnover (Rs in Crores)	% Response
Less than 100	13.53
100–500	25.56
500–1,000	20.30
1,000–2,000	15.03
More than 2,000	25.56

Table IV. Respondents by annual turnover of firms

Designations	% Response
Top management (G.M/AGM, etc.)	15.79
Upper middle level (Manager/Deputy Manager/Assistant Manager)	48.12
Middle level (Senior Engineer/ Engineer/Trainee Engineer)	36.09

Table V. Respondents by designations

Organization type	% Response
Maintenance sector of a manufacturing organization	113 84.96
Maintenance sector of a service organization	14 10.53
Any other	6 4.51

Table VI. Type of organization

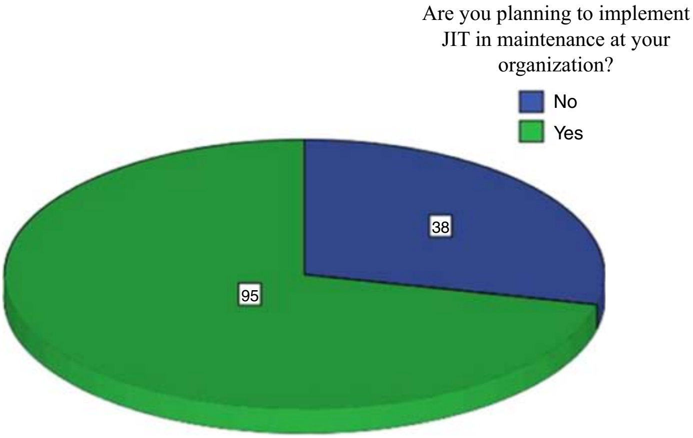

Figure 1.
Are you planning to implement JIT in maintenance at your organization?

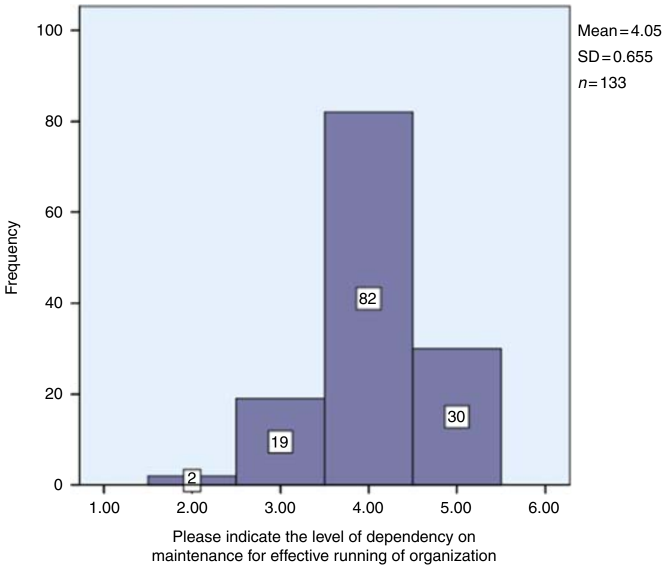

Figure 2.
Maintenance dependency level for effective running of organization

3.5 Reliability testing

Cronbach's α test is conducted to measure the internal consistency, that is, how closely related a set of items are as a group. It is considered to be a measure of scale reliability. The α coefficient as shown in Figure 4 for the seven items is 0.912, suggesting that the items have a high internal consistency.

3.6 Hypothesis testing

A research hypothesis is a predictive statement, capable of being tested by scientific methods, that relates an independent variable to some dependent variable. In the context of statistical analysis, we often talk about null hypothesis and alternative hypothesis. If we are to compare method A with method B about its superiority and if we proceed on

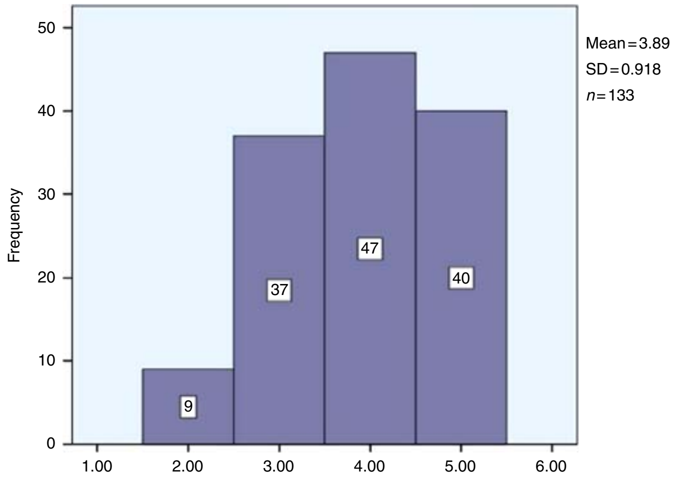

Figure 3. Scope for implementation of JIT in maintenance at your organization

Case Processing Summary

		n	%
Cases	Valid	133	100.0
	a	0	0
	Total	133	100.0

Listwise deletion based on all variables in the procedure

Reliability Statistics

Cronbach's α	No. of Items
0.912	7

Figure 4. Cronbach's α test results

the assumption that both methods are equally good, then this assumption is termed as the null hypothesis. As against this, we may think that the method A is superior or the method B is inferior, we are then stating what is termed as the alternative hypothesis. The null hypothesis is generally symbolized as H_0 and the alternative hypothesis as $H1$. There are mainly two types of tests for hypothesis testing, i.e., parametric test and non-parametric test. Data collected in the survey are parametric in nature so we go for the parametric test.

Further, there are four types of hypothesis testing method for parametric data as shown in Figure 5. But we go for the Z-test because the population of collected data is not normal in nature, sample size of population is large and variance of the population is not known. The Z-test was conducted at the 5 percent level of significance to analyze expected maintenance waste reduction benefits after implementing JIT in maintenance of industries. The following hypotheses were formulated for Z-test:

H_0. All expected maintenance waste reduction benefits listed in Table VII could not be achieved through JIT implementation in maintenance of industries.

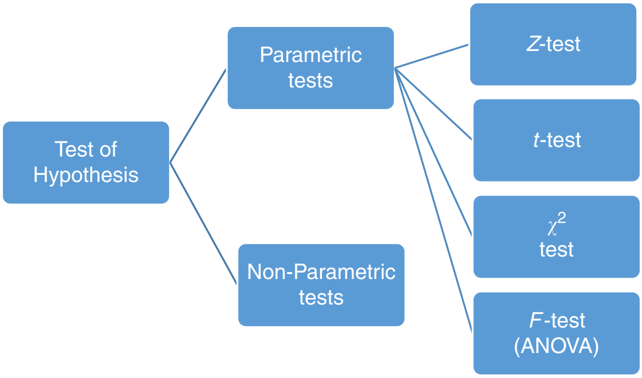

Figure 5.
Hypothesis test diagram

H1. All expected maintenance waste reduction benefits listed in Table VII could be achieved through JIT implementation in maintenance of industries (H_0 will be rejected if surveyed companies have achieved any expected maintenance waste reduction benefits and *H1* will be accepted).

The result of *Z*-test is given in Table VII. The study indicates the JIT philosophy implementation in maintenance on a 1–5 scale, implying that the perfect implementation of JIT philosophy in maintenance is slightly difficult in maintenance of industries. While conducting *Z*-test H_0 is assumed equal to 3.75 on the basis average mean value of all the seven wastes; waste of inventory in terms of spare parts storage and obsolesce, etc., rejects the null hypothesis at the value of 3.75 and accepts the alternate hypothesis at the value of 4.0 on the scale of 1–5. Waste of over production/excessive maintenance activity also rejects the null hypothesis at the value of 3.75 and accepts the alternate hypothesis at the value of 3.9 on the scale of 1–5. Waste of rejects/rework/scrap in case of poor maintenance, waste of processing, waste of the transport of spares and waste of motion accept the null hypothesis at the value of 3.75 on the scale of 1–5. Waste of waiting for spares rejects the null hypothesis at the value of 3.75 and accepts the alternate hypothesis at the value of 3.5 on the scale of 1–5.

Table VII.
Results of expected maintenance waste reduction benefits after implementing JIT at respondents under consideration

JIT expected waste reduction benefit	Mean	SD	Rank	*Z*-test results (at the 5% Level of significance) $H_0 = 3.75$	
Waste of inventory in terms of spare parts storage and obsolesce etc.	4.0602	0.9109	1	3.926818071	H_0 rejected and $H1 = 4.0$ (accepted)
Waste of over production/Excessive maintenance activity	3.90977	0.89999	2	2.047368971	H_0 rejected and $H1 = 3.9$ (accepted)
Waste of rejects/rework/scrap in case of poor maintenance	3.9023	0.9603	3	1.828473136	H_0 accepted
Waste of processing that leads to increase in maintenance	3.7669	0.9526	4	0.20481493	H_0 accepted
Waste of the transport of spares	3.7594	0.9704	5	0.111695145	H_0 accepted
Waste of motion	3.6466	0.8807	6	−1.353732995	H_0 accepted
Waste of waiting for spares	3.4812	0.8927	7	−3.47234708	H_0 rejected and $H1 = 3.5$ (accepted)

Note: $n = 133$

It has been found that waste of inventory in terms of spare parts storage and obsolesce, etc., in maintenance can be highly reduced after implementing JIT philosophy in maintenance and gets the rank one on the basis of mean score in all the seven types of wastes. Waste of over production/excessive maintenance activity in maintenance and waste of rejects/rework/scrap in case of poor maintenance can also be highly reduced after implementing JIT philosophy in maintenance and get the rank two and three, respectively, in all the seven types of wastes. Waste of processing, waste of the transport of spares and waste of motion all the three wastes approximately have equal weightage in their reduction after the implementation of JIT philosophy in maintenance and get the rank four, five and six, respectively, in all the seven types of wastes. Waste of waiting for spares has the least weightage in their reduction after the implementation of JIT philosophy in maintenance and gets the last rank in all the seven types of wastes.

4. Conclusion

This questionnaire study has indicated that in today's world which is full of new competitive challenges, all the organizations are highly dependent on maintenance for the effective running of their respective organization and there is a great scope of the implementation of JIT philosophy in maintenance of industries. In terms of the expected maintenance waste reduction benefits, we conclude that maintenance department have a large inventory of spare parts and consumes a large capital; if we have an inventory of spares according to the requirement, then we can utilize the saved cost of maintenance inventory in some other useful purposes and the maintenance professionals can address the large excessive maintenance issues such as an inefficient work order system, time-consuming reporting forms, and ineffective training which results in the failure to convey needed instructions; if we implement the JIT elements successfully in maintenance, we reduce all the above-discussed extra activities of maintenance professionals to a high extent. Waste of rejects/rework/scrap in case of poor maintenance, waste of processing, waste of the transport of spares and waste of motion all the four wastes have approximately equal weightage in their reduction after the implementation of JIT philosophy in maintenance, which shows that if we successfully implement JIT elements in maintenance, then we can reduce all the four wastes of maintenance near to a high level. Waste of waiting for spares gets the last rank in all seven types of wastes.

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