Impact of Motivation and Manufacturing Methods on Productivity and the Lead Time

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ABSTRACT

Studies indicate that, when a worker Motivation was researched upon, two different practices were reported. While one suggested that Motivation is entirely unnecessary and has no effect on the organization's production level, the other makes one think otherwise.

A similar conflict was encountered in case of the Manufacturing Methods. Each of the methods had entirely independent advantages of their own. Hence not providing a clear understanding of which method should one go for, to improve the yield and also decrease the time taken.

The following study provides tested experimental results to substantially reduce the incomprehension and also bring about a relationship between workers' Motivation level (on account of Internal and External Impulses) and the manufacturing methodology adopted by that organization, with the workers' productivity and the lead time of production.

KEY WORDS: Division of Labour, Unification of Labour, Motivation, Incentives, Productivity, Lead Time.

INTRODUCTION

In any Organization, the production depends on four main things- Man, Machine, Material and Method. While the Machines and Materials are determined by the nature of the product and can change from product to product; Man and Method become universal for a certain kind of industry, independent of the product type in that industry. Hence the later are chosen for the analysis and determine that a change in which of the two could give higher Productivity and lower Manufacturing Lead Time. Also if it really does have an effect, then what change would anyone be better off with?

Considering method, question arose whether assembly line is the best way to be followed and how many tasks should a person do before the product in hand gets passed on to the next operator. In 'Sequencing in an Assembly Line with Blocking to Minimize Cycle Time' (1989)

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McCormick, S. Thomas; Pinedo, Michael L.; Shenker, Scott; and Wolf, Barry say that an assembly line successfully helps in reducing the manufacturing lead time. Also, Adam Smith in 'Wealth of Nations' (1776) gives priority to Division of Labour over any other working technique. But another school of thought promoted by Ohno, Taiichi in 'Toyota Production System' (1988), which states Hitori Yatai (one person does everything) considerably reduces the production lead time and also a significant increase in productivity is achieved.

Refflinghaus; Robert and Kern; Christian in 'Analyzing human error probabilities in manual assembly operations for saving production costs' (2012) say that a person's productivity depends on personnel factors like Experience and Motivation. Among the factors responsible for affecting the performance of a given task, Jaakko Peltokorpi, Sampsa Laakso, Juho Ratava, Mika Lohtander and Juha Varis in 'Relationships of Factors in a Manual Assembly Line Environment'(2013) lay emphasis on motivation as being the main factor. However, Dr. Deming, W. E. in 'Out of Crisis' (1982) elaborates on the futility of incentives indicating that usually the factors affecting output are outside the control of the operator but in the hands of the management of that organization; and extrinsive motivation is often ineffective and rewards and punishments tamper with a stable organizational system.

MOTIVATION

As defined by encyclopedia Britannica, "Motivation is a force acting either on or within a person to initiate a behavior. The word is derived from the Latin term motivus ("a moving cause")". It suggests the activating properties of the processes involved in psychological motivation can be influenced by our environment or by pre-prediction about a happening. When an individual gets lured by the final offer after a task, that individual has already imagined himself having received that offer.

Lawler, Edward E., III in 'Motivation in Work Organizations' (1973) states that there are four approaches to bring about motivation- paternalistic approach, scientific management approach, participative management approach, and a fourth called as the combination approach.

These approaches are applicable to any organization. The paternalistic approach is when an external person engages the workers and makes decisions on their behalf. This takes away a lot of pressure from the workers' mind and all they have to do is work on the allocated task without being concerned about any important decisions to be made. Taylor F. W. in 'The Scientific Management Approach' (2013) uses time and motion study and materialistic offers to the workers. This method though gives good results can lead to unhealthy competition among workers. There is the participative management approach, as explained by Branch, K. M. in 'Participative Management and Employee and Stakeholder Involvement' (2002), which involves decision making and troubleshooting by bringing the workers and their employers together. This works well in organizations dealing with complex knowledge based problems but the disadvantage for this being slowing down of the decision making process due to the large headcount. And lastly there is an approach which involves a combination of all or a few of the above.

The approaches to measuring motivation in an individual have been mentioned by Barrick, Murray R.; Stewart, Greg L.; Piotrowski, Mike in 'Test of the mediating effects of motivation among sales representatives' (2002). They say, the feeling of continuous striving for power, the extent of the need for attaining success, the urgency of possessing the sense of job completion and the amount of self persuasion are a few examples of the motivation measures. Thus, even a pat on the back during the performance of the task serves as a motivation.

MANUFACTURING METHOD

When it came to the manufacturing methods, the desire was to understand that one technique which gives a good combination of high Productivity and low Manufacturing Lead Time. It was also realized that the method can be dependent on the industry, the number of tasks per worker and kind of task as mentioned by Womack, J. P. and Jones, D. T. in 'Lean Thinking' (2003).

On one hand there is the division of labour (it can be compared to an assembly line production method) which encompasses advantages namely- requirement of less skilled labour, lower costs in case of mass production and the unskilled labour to be paid less for their services; while on the other there are the advantages of Hitori Yatai (also called as Unification of Labour; explained later) which belong to an entirely different set. The advantages are- the system reduces the amount of dependency of a worker on another worker; when a worker manufactures a large part of the final product, there is a sense of belonging towards that product for that individual; this leads to better quality of products; and lastly, in case of any rework required on a product, the person responsible can be traced and rework becomes faster.

Considering these points, an empirical study was designed to identify the impact of Motivation and Manufacturing Methods on Productivity and the Lead Time.

EXPERIMENT

Hypothesis:

Ho: There is no impact of Motivation and Manufacturing Method on either Personnel Productivity or Manufacturing Lead Time.

Ha: There is an impact of Motivation and Manufacturing Method on either Personnel Productivity or Manufacturing Lead Time or both.

In order to verify the hypothesis, experiments were conducted which consisted of making paper boats of a specified quality. This task was chosen because it represents the kind of work commonly required in industries where individuals work with their hands on assembly of small parts such as in the Toys Industry or perform operations on small parts such as in the Jewellery industry. Also, it was expected that since this task involves elementary origami skills, it would be within the capabilities of a large number of people, enabling a larger sample space.

The input variables selected were:

A. Motivation - this was varied at two levels, low and high, arbitrarily assigned as 1 and 2 respectively. At the low level, the subjects were merely told to do the experiments by the methods specified. This was the equivalent to no

motivation. At the high level, all the subjects were simultaneously exposed to motivational input by way of an authoritative person, who offered rewards to the best performers.

B. Manufacturing Method - This was also varied in two levels, low and high, arbitrarily assigned as 1 and 2 respectively. The method involving division of labour was defined one while the method of unification of labour which involves single piece flow, was assigned two. In the division of labour, the making of paper boats was broken up into three operations. The first required the raw material which was rectangular paper of standard size to be cut into square shape of a standard size. The second operation consisted of folding the square the square sheet and third consisted of unfolding a particular way to produce a paper boat. The subject was required to complete the first operation on eight sheets of paper and only then perform the second operation on all sheets and then the last operation. In the case of unification of labour, the subject picked up first sheet of paper made all three operations on it and make the entire boat single piece flow.

The output parameters were:

A. Personnel productivity measured as number of good paper boats made per person per minute

B. Manufacturing lead time measured as time elapsed from picking up of raw material of the first boat till it was completed as a finished product.

The experiment was conducted in a laboratory setting in a management Institute where eight right-handed respondents, four women and four men, were seated. Two observers were assigned to each subject for measuring the output parameters and ensuring that the experiments were conducted in the same specified order for all. Local Control was thus established.

Eight respondents were chosen on the basis of Randomization from among the people who had a comparable amount of Origami skills. However, a conscious effort was put into ensuring that the respondents comprised of 4 men and 4 women. This was done in order to introduce a Blocking Factor and incorporate the influence of gender on the sample chosen. The respondents belonged to the age groups ranging from 25 to 30 years of age representing the younger generation of workers who are commonly employed in industries for such desk bound manual work. A reasonable degree of Replication was introduced by conducting the set of four experiments eight times.

Before the start of the experiments, all the eight respondents were shown the quality of boats expected from them. This was done by the same quality inspector who went around checking the boat quality in all of the four experiments which followed. This was considered the Trial Round. Each of the subjects was given the necessary raw material for making eight paper boats. The trial round was an essential feature of the experiment since it was responsible for eliminating the Learning Curve effect for each respondent. The learning was in terms of manufacturing methods as well as to gain an understanding of the quality of papers boats expected of them. This round ensured all the subjects were at the same level of understanding when the actual experimentation started.

Moreover, the respondents were also given the freedom of discarding any raw material which they

thought had become out of further use. This ensured the quality of the final product was not affected due to any error detected early by the respondents themselves.

The experiments were based on the classic Two Variable Two Level Full Factorial Experimental Design; referred to as 2x2 Experimental Design. The data was collected was in the following form:

Experiment No.	Time Taken to make eight boats	Number of good Quality Boats made	Lead Time for one Boat

Table 1: Table format provided to observers for data collection

In order to introduce more randomization, four of the subjects were told to choose one side of the coin and as per the face of the coin; they were allotted which manufacturing method they can start with. Hence there were 4 subjects starting with unification and four with division method for the first experiment; and to carry out the other experiments in alternation with the method they start with.

As explained earlier, the combinations of low and high for the presence and absence of motivation, with the low and high for unification and division of labour methods are shown below. These give the four experiments:

Experiment No.	Motivation Level	Manufacturing Method	Explanation
1	1	1	Manufacturing with Division of Labour Method without any External Motivation or Incentive prerogative
2	1	2	Manufacturing with Unification of Labour Method without any External motivation or Incentive prerogative
3	2	1	Manufacturing with Division of Labour Method with External Motivation
4	2	2	Manufacturing with Unification of Labour Method with External motivation

Table 2: Type of Experiments carried out

In the first two experiments, the respondents were asked to perform the experiments in a quiet atmosphere. The quality inspector went to each respondent, check the quality of paper boats made and give a count to that respondent's observer about the number of good boats produced.

Right before the third experiment, the respondents were explained about an incentive. This incentive would be given to subjects with the highest productivity in the third and fourth experiments. In addition to this, the quiet atmosphere of first and second experiment was replaced by a continuous motivational talk provided by an authoritative person and a good deal of hoopla was created to encourage the subjects while they worked on the paper boats.

OBSERVATIONS AND ANALYSIS

The results of the four experiments are mentioned for each of the respondents in the following tables:

PRODUCTIVITY

Respondents =>	y1	y2	y3	y4	y5	y6	y7	y8	y'
Gender =>	F	F	F	F	M	M	M	M	-
Experiment 1	0.880	0.490	0.901	0.459	0.380	0.780	0.976	0.774	0.705
Experiment 2	0.920	0.610	1.081	0.488	0.840	0.909	0.984	0.507	0.792
Experiment 3	1.159	0.706	1.121	0.952	0.620	0.980	1.159	1.019	0.965
Experiment 4	1.420	0.735	0.990	0.726	1.060	1.200	1.137	0.857	1.016

Table 3: Productivity of each of the Respondents and their averages for the experiment

PRODUCTION LEAD TIME

Respondents =>	y1	y2	y3	y4	y5	y6	y7	y8	y'
Gender =>	F	F	F	F	M	M	M	M	-
Experiment 1	306	529	262	349	480	289	270	284	346.125
Experiment 2	64	99	59	63	72	62	53	61	66.625
Experiment 3	204	393	227	277	294	242	208	282	265.875
Experiment 4	39	70	65	67	66	53	42	63	58.125

Table 4: Production Lead Time of each of the Respondents and their averages for the experiment

When Table 3 is taken into consideration, the overall trend of increase in productivity in Experiment 2 after Experiment 1 becomes noticeable; and that of increase in productivity in Experiment 4 after Experiment 3. But there are a few cases which do not follow this development. Respondent y8 does not follow this trend in Experiment 1 and 2, while y3 and y3 do the same for Experiment 3 and 4. Hence it was realized that inspite of maintaining high level of Local Control, the variability crept in. This variability, called as the Inherent Variability, arises from person to person variation and any uncontrollable aspects like that of the environmental factors during the course of the experiments. Thus, it was decided to identify the Main Effect and the Interaction Effect of the two input variables by considering the average response (y').

The computation of the main and interaction effects is shown in Table 5 and Table 6 for productivity and manufacturing lead time respectively:

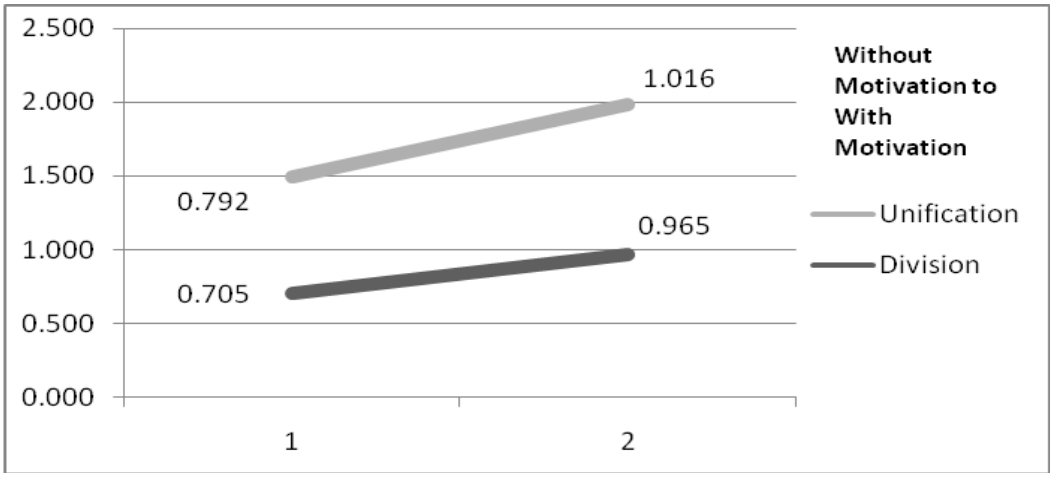
Random Order Trial Number	Standard Order Trial Number	Response Observed Values y	A (Motivation)		B (Division / Unification)		AB	
			1	2	1	2	1	2
Div	1	0.705	0.7049		0.7049			0.7049
Unif	2	0.792	0.7923			0.7923	0.7923	
Moti Div	3	0.965		0.9645	0.9645		0.9645	
Moti Unif	4	1.016		1.0157		1.0157		1.0157
TOTAL			1.4972	1.9802	1.6694	1.808	1.7568	1.7206
NUMBER OF VALUES			2	2	2	2	2	2
AVERAGE			0.7486	0.9901	0.8347	0.904	0.8784	0.8603
EFFECT			0.2415		0.0693		-0.0181	

Table 5: Main Effect and Interaction Effect computation for Productivity

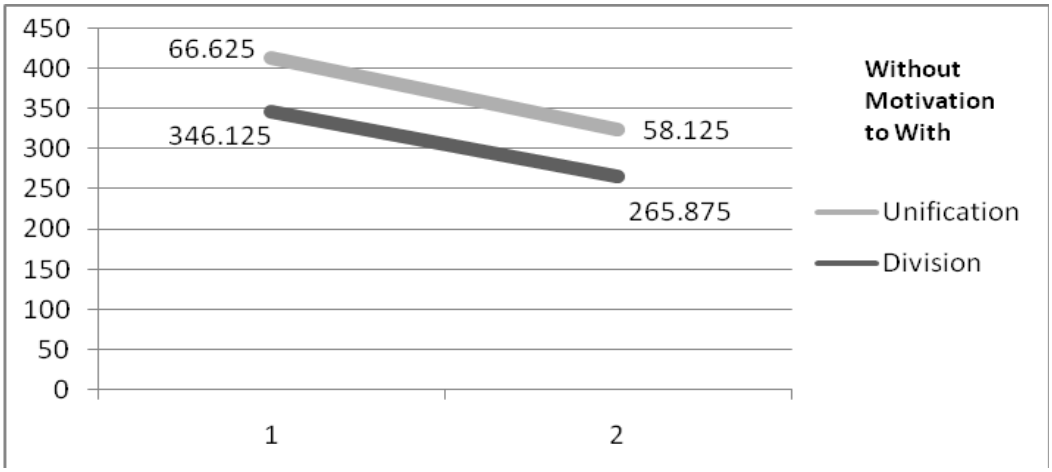
Random Order Trial Number	Standard Order Trial Number	Response Observed Values y	A (Motivation)		B (Division / Unification)		AB	
			1	2	1	2	1	2
Div	1	346.125	346.125		346.125			346.125
Unif	2	66.625	66.625			66.625	66.625	
Moti Div	3	265.875		265.875	265.875		265.875	
Moti Unif	4	58.125		58.125		58.125		58.125
TOTAL			412.75	324	612	124.75	332.5	404.25
NUMBER OF VALUES			2	2	2	2	2	2
AVERAGE			206.375	162	306	62.375	166.25	202.125
EFFECT			-44.375		-243.625		35.875	

Table 6: Main Effect and Interaction Effect computation for Manufacturing Lead Time

On plotting graphs depicting the two tables, the following is seen:



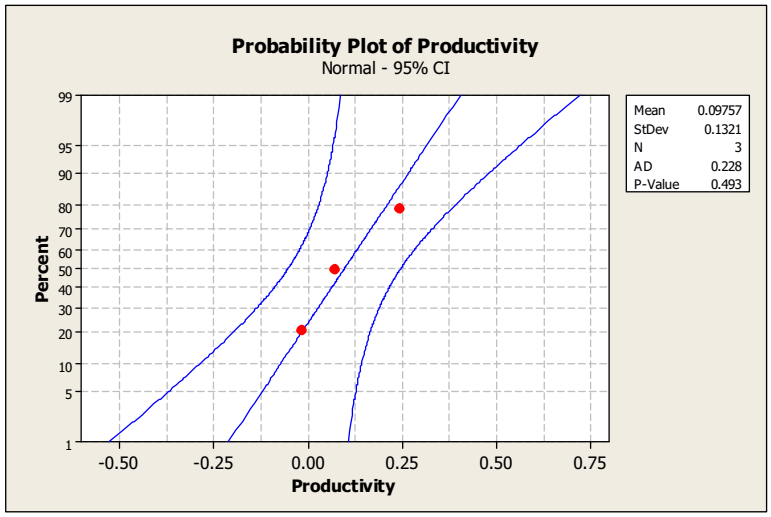
Graph 1: Increase in average Productivity in different Manufacturing Techniques when moving from absence of Motivation to its presence



Graph 2: Decrease in average Production Lead Time in different Manufacturing Techniques when moving from absence of Motivation to its presence

From these it is clearely seen that there is definitely an effect of motivation on the subjects in case of both manufacturing methods. But to find which had a greater effect, the main effect and interaction effect were plotted on Probability Graphs. And the following graphs with the points arranged on the graph in the sequence given in the table were obtained:

Interaction Effect AB	-0.0181
Main Effect B	0.0693
Main Effect A	0.2415



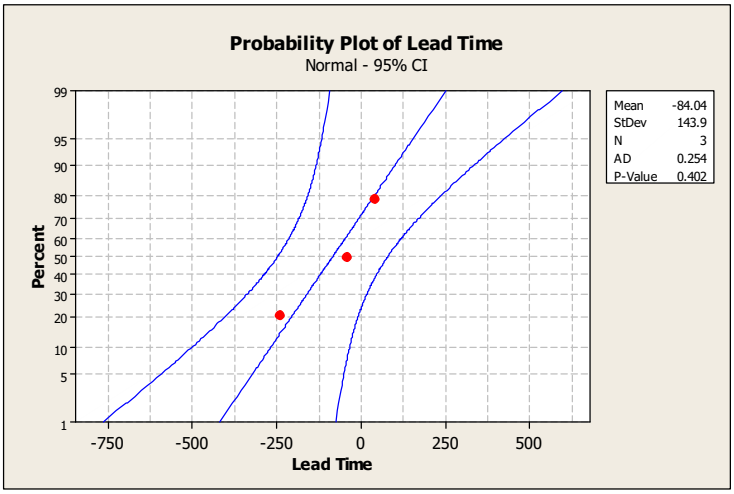
Graph 3: Probability Graph of Productivity

On the probability graph, one has to look at points which are farthest from the curve; these points are termed as SIGNIFICANT Points as these are the ones which are unlikely to have occurred by chance; while the points on the curve are deemed to be INSIGNIFICANT.

Main Effect B	-243.625
Main Effect A	-44.375
Interaction Effect AB	35.875

On looking closely at the probability Graph of productivity, the points made by main effect of A and B are SIGNIFICANT thus disproving the fact that such a result might have occurred due to chance are seen.

And on looking at the probability graph of manufacturing lead time, the main effects of A and B are SIGNIFICANT as compared to that of the AB interaction effect.



Graph 4: Probability Graph of Manufacturing Lead Time

ANALYSIS

The results of the experiments disprove the Null Hypothesis. And prove that motivation and manufacturing methods do play a role of comparable effect in altering the productivity and manufacturing lead time.

It was found that unification of labour was found to be a better option than division. This was due to increase in the total number of Non Value Added Activities done by a Subject. In case of unification, the subjects were continuously holding the boat (from its raw material stage till it became a finished product) in their hands and putting it down only after the paper boat was completely made. However in case of division of labour, they had to place the material down two times and work on the same step for all eight pieces only then proceed with the next step. This added a lot of non value added activities in the process of completion of one boat. And this undoubtedly added to the manufacturing lead time. It can be said that there was an involvement of internal motivation even when it came to understanding the effect of the manufacturing methods. There was sense of satisfaction among the subjects when they saw a completed product. This was more accomplishing than doing only step of the paper boat making process.

And it was also realized that a motivated subject produced better results in terms of productivity as well as lead time. This could be attributed to the fact that while the subjects were encouraged when they made the boats, they were also told about an Incentive to be given to the person who makes maximum number of good quality boats. This further enhanced their productivity.

IMPLICATIONS TO THE INDUSTRY

As mentioned earlier, the results of these experiments will be important in industries which involve people working with their own hands on small assembly parts. For example, when an operator in the Toy Manufacturing Plant is considered, the productivity will be significantly improved if a worker handles one entire section of the Toy (or sometimes the entire Toy) rather than just the sub-assembly of only one part of the toy. And while the productivity increases, the manufacturing lead time is considerably reduced due to the fact that the product never lies unfinished and unattended in the Work-In-Progress inventory. And for motivating the worker, the role of the authoritative figure played an important role. This can be replaced by people of higher designations from the organization, who will give visit the plant and while monitoring the work done, they also say an encouraging word or two to the operators. Furthermore, the organization can either declare an incentive scheme for the person with the highest number of good pieces produced that week, or in order to reduce the competition among the operators, the organization can pay an employee for each good piece produced. In this way, the employees continue to feel motivated and work more to get a higher pay and in return produce more good quality finished goods at a faster rate.

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QUOTES

Excellence is to do a common thing in an uncommon way.
Booker T. Washington

A total commitment is paramount to reaching the ultimate in performance.
Tom Flores

Excellence is not an exception, it is a prevailing attitude.
Colin L. Powell