# The Moderating Role of JIT Links with Suppliers on the Relationship between Lean Manufacturing and Operational Performances

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Pietro Romano[1], Pamela Danese[2], Thomas Bortolotti[3,*]

[1] Department of Electrical, Managerial and Mechanical Engineering, via delle Scienze 208, 33100 Udine, Italy. E-mail: pietro.romano@uniud.it

[2] Department of Management and Engineering, Stradella S. Nicola 3, 36100 Vicenza, Italy. E-mail: pamela.danese@unipd.it

[3] Department of Electrical, Managerial and Mechanical Engineering, via delle Scienze 208, 33100 Udine, Italy. E-mail: thomas.bortolotti@unibg.it

*Corresponding author

**Abstract.** Lean manufacturing impacts several operational performances. The usefulness of JIT links with suppliers is also well known. However, literature lacks strong empirical evidences to exhibit the relationship between lean manufacturing, operational performances and JIT linkages with suppliers. This paper aims to investigate this relationship. A questionnaire-based international survey was used to obtain the main purpose of the research. Data from a sample of 200 companies were analyzed using a multiple regression methodology. The analysis demonstrates that JIT linkages with suppliers positively moderate the impact of lean manufacturing on punctuality, while the moderating effect is absent when considering efficiency and throughput time performance.

**Keywords:** Just-In-Time, Survey, Multiple regression analysis

## 1 Introduction

Literature generally agrees that lean manufacturing impacts a number of operational performances: efficiency [1], [2] and [3], throughput time [3] and [4] and on time delivery [2] and [5]. JIT links with suppliers are also useful to improve operational performances listed above [1], [3], [6] and [7]. However, in literature we didn't find an empirical evidence to demonstrate whether companies implementing JIT links with suppliers and lean manufacturing practices show better operational performances than companies that don't implement JIT links with suppliers. In other words, this paper aims to investigate whether the relationship between lean manufacturing and operational performances – such as efficiency, throughput time and on time delivery – is positively moderated by the presence of JIT linkages with

suppliers. A questionnaire-based survey was used to obtain the main purpose of the research. A total of 200 complete responses taken from the High Performance Manufacturing research project dataset [8] and used to test and analyze three hypotheses included in the theoretical model: JIT linkages with suppliers positively moderate the relationship between lean manufacturing and efficiency (hypothesis H1), throughput time (hypothesis H2) and on time delivery (hypothesis H3).

## 2 Methods

### 2.1 Data collection and sample

The sampling universe is formed by manufacturing firms operating in machinery, electronic and transportation components sectors (SIC code: 35, 36 and 37). During the identification stage of the reference population, we selected for medium and large enterprises. Finally, we randomly selected, from this population, companies from different countries (i.e. Finland, US, Japan, Germany, Sweden, Korea, Italy, Australia and Spain). An international team of researchers collected data via questionnaires, that were administered by individual visits or sent by mail. The questionnaires were sent to different respondents within each company, such as production control managers, inventory managers, supervisors, and so on. Respondents gave answers on lean practices adopted (lean manufacturing and JIT links with suppliers) and operational performances obtained. A total of 266 responses were returned. We discarded 66 incomplete responses. Data analysis were based on a sample of 200 firms.

### 2.2 Research variables and measures

Two multi-item and three mono-item constructs were identified: lean manufacturing (LM), JIT links with suppliers (JITsup), efficiency (EFF), throughput time (TT), and on time delivery (OTD). As to the items composing LM and JITsup constructs, we asked respondents to indicate on a 7 point Likert scale to what extent each practice proposed was adopted in the company (1 means “not at all” and 7 “to a great extent”). As to the items composing the three mono-item constructs (EFF, TT and OTD), we asked respondents to provide their opinion about company’s performances compared with its competitors on a 5 point Likert scale (1 is for “poor, low” and 5 is for “superior”). Table 1 reports the five constructs with their items, the results of factor analysis after Varimax rotation of factors and Cronbach’s α. Convergent validity of the two multi-item constructs is demonstrated since factor loadings are all above 0.679 and only one component for each construct was identified with total variance explained above 52.18% [9]. Reliability was ensured by the high values of Cronbach’s α, all above 0.70 [10]. Finally, scientific literature gave theoretical validity to the multi-item constructs:

(1) lean manufacturing: this is a six-item scale that measure the ability of a company to obtain a continuous production flow using appropriate tools and methods, such as 'cell' design (shop floor), SMED, and Heijunka. The cell provides remarkable benefits in terms of stream continuity, decrease of total lead time and stocks, flexibility performance and goods transfers [11]; SMED is a technique designed to improve dies and tools exchanges, minimizing set-up time, therefore maximizing machines capacity ratio [12]; Heijunka consists in a production balancing tool, related to production processes. It allows to balance production activities minimizing supply fluctuation [13].

(2) JIT links with suppliers: this is a three-item scale that measure the integration of JIT techniques and methods (kanban and pull systems) between the company and its suppliers. Kanban can be defined as a labels-based system, designed to mark and optimize materials and goods transfers along the production line and the supply network [14]; pull system implies that in a supply network nothing is produced upstream before a real request downstream [15].

Table 2 shows basic statistics for the five constructs.

**Table 1.** Validity test of measures.

| Factor | Item | Factor Loading | Variance explained | Cronbach α |
|---|---|---|---|---|
| Lean manufacturing (LM) | We have laid out the shop floor so that processes and machines are in close proximity to each other | 0.689 | 52.18% | 0.81 |
| | The layout of our shop floor facilitates low inventories and fast throughput. | 0.778 | | |
| | We are aggressively working to lower setup times in our plant | 0.750 | | |
| | We have low setup times of equipment in our plant | 0.715 | | |
| | Our workers are trained to reduce setup time | 0.720 | | |
| | Our manufacturing capacity is balanced throughout the entire manufacturing process. | 0.679 | | |
| JIT links with suppliers (JITsup) | Suppliers fill our kanban containers, rather than filling purchase orders. | 0.879 | 67.65% | 0.76 |
| | Our suppliers deliver to us in kanban containers, without the use of separate packaging. | 0.860 | | |
| | Our suppliers are linked with us by a pull system. | 0.719 | | |
| Efficiency (EFF) | Unit cost of manufacturing | Mono-item mono-respondent | | |
| Throughput time (TT) | Cycle time (from raw materials to delivery) | Mono-item mono-respondent | | |
| On time delivery (OTD) | On time delivery performance | Mono-item mono-respondent | | |

**Table 2.** Constructs basic statistics.

| Variables | Mean | S.D. | Range |
|---|---|---|---|
| Lean manufacturing (LM) | 4.90 | 0.70 | 2.83-6.50 |
| JIT links with suppliers (JITsup) | 3.61 | 1.01 | 1.44-6.44 |
| Efficiency (EFF) | 3.20 | 0.86 | 1.00-5.00 |
| Throughput time (TT) | 3.41 | 0.74 | 2.00-5.00 |
| On time delivery performance (OTD) | 3.79 | 0.87 | 1.00-5.00 |

## 3 Data analysis

The research aims to investigate whether the relationship between lean manufacturing and operational performances is moderated by the presence of JIT linkages with suppliers. Moderated relationship is reflected in the concept of statistical interaction. The equation (1) describes the logic of moderated regression [16]:

$$y= \beta_0 + \beta_1 x + \beta_2 z + \beta_3 xz + \varepsilon \quad (1)$$

where x is LM, the focal independent variable [17], z is JITsup and y, the dependent variable, is any of operational performances. The 'xz' term in (1) is called interaction term. We used a hierarchical regression procedure, Table 3 and Table 4 display the results of the analysis. We considered firm size and sector as control variables. The size was measured by the number of firm's employees. The sector was insert in the model, by creating dummy variables (Electronics and Transportation components). For every operational performance, firstly, we studied the main effects of independent variables - i.e. lean manufacturing and JIT links with suppliers - , then, we introduced in the model the product term xz (LM X JITsup) to analyze the interaction effects. If the coefficient of the product term ($\beta_3$) is statistically significant and $R^2$ increases when this term is introduced in the model, the existence of a moderated effect on x-y relationship is demonstrated [17].

## 4 Results

As shown in Table 3 and Table 4, firm size and sector control variables don't result significantly related to operational performances. The non-significant values of both $\beta_3$-coefficients exposed in Table 3 do not confirm hypotheses H1 and H2 about the moderating role of JIT links with suppliers on the relationship between lean manufacturing and efficiency and throughput time performances. To the contrary, the significant and positive $\beta_3$-coefficient shown in Table 4 suggest that it is possible to confirm the existence of the moderating role of JIT links with suppliers on the

relationship between lean manufacturing and on time delivery performance (hypothesis H3). Additional support is the significant increase of $R^2$ when the interaction effect was introduced in the model (from 0.084 to 0.126).

**Table 3.** Hierarchical regression analysis (efficiency and throughput time).

| | EFF | | TT | |
|---|---|---|---|---|
| | **Main effects** | **Interaction effects** | **Main effects** | **Interaction effects** |
| Constant ($\beta_0$) | 0.849* | 0.318 | 0.952* | 1.753 |
| Size | 0.000 | 0.000 | 0.000 | 0.000 |
| Electronics | -0.280 | -0.276 | -0.014 | -0.020 |
| Transp. Comp. | -0.091 | -0.086 | -0.121 | -0.127 |
| LM ($\beta_1$) | 0.583*** | 0.671* | 0.499*** | 0.337 |
| JITsup ($\beta_2$) | -0.085 | 0.070 | 0.020 | -0.215 |
| LM X JITsup ($\beta_3$) | | -0.031 | | 0.047 |
| $R^2$ Adjusted | 0.187 | 0.183 | 0.192 | 0.190 |
| F test | 9.097*** | 7.568*** | 9.198*** | 7.712*** |

The value reported are unstandardized regression coefficients
* p-value <.05 level; ** p-value <.01 level; *** p-value <.001 level

**Table 4.** Hierarchical regression analysis (on time delivery).

| | OTD | |
|---|---|---|
| | **Main effects** | **Interaction effects** |
| Constant ($\beta_0$) | 1.703*** | 6.060*** |
| Size | 0.000 | 0.000 |
| Electronics | -0.019 | -0.048 |
| Transp. Comp. | 0.064 | 0.029 |
| LM ($\beta_1$) | 0.414*** | -0.469* |
| JITsup ($\beta_2$) | 0.020 | -1.253** |
| LM X JITsup ($\beta_3$) | | 0.256** |
| $R^2$ Adjusted | 0.084 | 0.126 |
| F test | 4.249** | 5.224*** |

The value reported are unstandardized regression coefficients
* p-value <.05 level; ** p-value <.01 level; *** p-value <.001 level

The promising results exposed in Table 4 led us to a detailed study on the marginal effect of the Lean manufacturing (variable x) on the on time delivery performance (variable y), for different values of JIT links with suppliers (variable z), as suggested by [16] and [17].

We calculated that the marginal effect of LM on OTD depends on JITsup, according to the following formula:

$$\partial OTD/\partial LM = -0.469 + 0.256 JITsup \quad (2)$$

T-test reveals that equation (2) is significant at a 0.05 level for the values of JITsup greater than 2.57. Figure 1 shows how the marginal effect of LM varies when JITsup increases. It is easy to see that LM has an increasing impact on OTD performance when the level of JITsup is greater than 2.57.

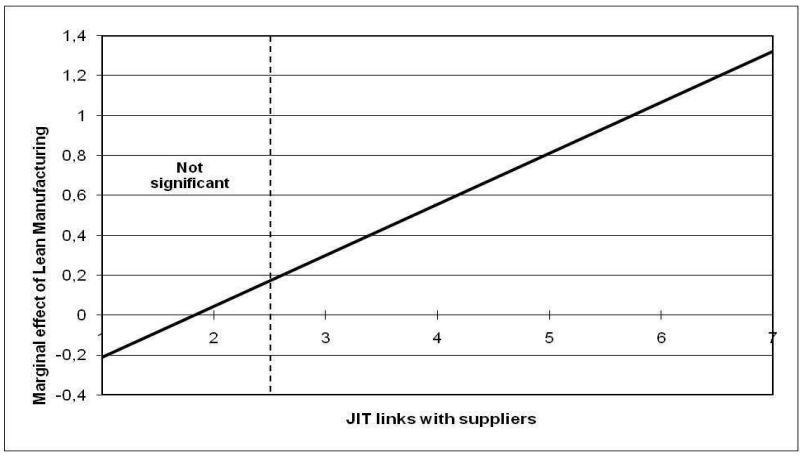


**Fig. 1.** The influence of JIT links with suppliers on the marginal effect of lean manufacturing

To gain an intuitive understanding of the interaction effect between LM and JITsup, we computed and graphed the slope of OTD performance on LM at few different values of JITsup. Our strategy was to evaluate the effects of LM on OTD at "low" and "high" values of JITsup, where "low" is defined as one standard deviation below the JITsup mean (i.e. = 2.598), and "high" as one standard deviation above the JITsup mean (i.e. = 4.616) [18]. Starting from the relation found out from the hierarchical regression analysis (ODT = 6.060 – 0.469LM – 1.253JITsup + 0.256LMJITsup) and using the two mentioned values of the variable JITsup, two linear equations of OTD performance, depending on LM, were created. Figure 2 reports the graph of the equations. Jaccard and Turrisi classifies this trend as 'disordinal interaction' [17], an interaction in which the regression line that regresses y onto the focal independent variable for a given level of the moderator (high JITsup) intersects with the correspondent regression line for a different level of the moderator (low JITsup). The intersection corresponds to a level of lean manufacturing of 4.89 (49% of the sample is below this score). Within the LM range (2.83 - 6.50), all values of OTD are above the minimum acceptable level (2.26 > 1.00) and below the maximum acceptable level (4.91 < 5.00).

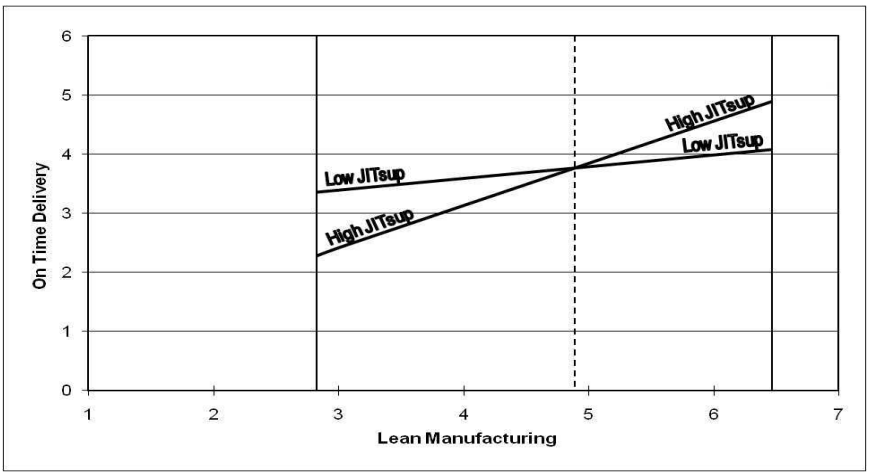


**Fig. 2.** On Time Delivery performance slope at low and high levels of JIT links with suppliers

## 5 Discussion and conclusions

The multiple regression analysis demonstrates several key findings:

Finding 1: companies adopting lean manufacturing don't show an additional contribution to efficiency (unit cost of manufacturing) and throughput time by implementing also JIT linkages with suppliers. Both performances are significantly explained by the implementation of lean manufacturing.

Finding 2: JIT linkages with suppliers moderate the impact of lean manufacturing on punctuality. For a company that has high values of LM (e.g. LM = 5.60) and medium values of JITsup (e.g. JITsup = 3.61), a one-point increment of LM increases OTD of about 11%; whereas a one-point increment of JITsup increases OTD of about 4.4%. It is always better to increase LM rather than JITsup to improve OTD. However, the hierarchical regression highlights a "disordinal interaction" (Figure 2). This interaction suggests to implement only lean manufacturing practices firstly, and then (when LM overpasses the 4.89 value, which corresponds to the intersection point) implement both lean manufacturing and JIT links with suppliers practices.

Finding 3: the effect of LM could be even negative for levels of JITsup lower than 1.83 (Figure 1). This means that, when companies have not JIT links with suppliers, Lean Management effects on punctuality could be counterproductive. Nevertheless this result is not statistically significant, therefore this finding would be interesting to test on a wider sample of companies in a future study.

In conclusions, the study presents implications both for academics and practitioners. Our work confirms most of the previous literature contributions and provides to fill the lack of literature concerning how JIT with suppliers impacts lean manufacturing and operational performances. It also suggests the correct sequence to implement Lean Manufacturing inside a company and JIT with suppliers to obtain

maximum levels of punctuality (OTD). As a matter of fact, data analysis reveals that for companies which haven't good levels of lean manufacturing is better to improve these practices first, and then direct their efforts also towards JIT links with suppliers.

The research is subject to the normal limitations of survey research. The model tested in this study used a selection of medium and large enterprises operating in machinery, electronic and transportation components sectors. Thus, future studies should include firms operating in other industries or small enterprises.

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