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Just in Time - performance link: The moderating role of demand variability

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Abstract. Just-in-time (JIT) is a very useful methodology to improve operational performance. However, researchers argue that this methodology could be applied in contexts characterized by a stable customer demand. This paper aims at investigating the role of demand variability in the impact of JIT on efficiency and responsiveness performance. A questionnaire-based international survey was used to investigate the research questions. Data from a sample of 244 companies were analyzed using a Structural Equation Modeling (SEM) procedure and following the "Ping 2-step approach" [1]. The analyses demonstrate that demand variability does not significantly moderate the relationship between JIT and efficiency, whereas it negatively moderates the relationship between JIT and responsiveness. Thus, if demand variability is very high, JIT could be counterproductive in terms of responsiveness performance.

Keywords: Just-In-Time, demand variability, operational performance, structural equation modeling.

1. Introduction

It was empirically demonstrated that JIT helps to dramatically improve operational performances by eliminating all sources of waste from production processes [2] and [3]. However, almost all of successful JIT stories came from firms with a stable and predictable customer demand [4] and [5]. The general belief is that the use of JIT practices in a context characterized by high demand variability is not useful mainly because demand fluctuations make *takt time* (i.e. the maximum production time needed to meet the customer demand pace) dynamic, thus inhibiting production smoothing [5] and [6]. In the operations management the study of customer demand effects on operational performance is fundamental [7]. The level of demand variability could result in a moderating effect on the relationship between JIT and performance. Thus, our research aims to verify the existence of a moderating effect of demand variability on the JIT – efficiency and JIT – responsiveness relationships. A questionnaire-based survey was used to obtain the main purpose of the research. We used data from the High Performance Manufacturing research project dataset [8] to test our hypotheses included in the theoretical framework (see Figure 1). 244 international manufacturing plants represent the sample of our analysis. A Confirmatory Factor Analysis validates our measurement model, while a structural equation model was used to test our hypotheses, following the "Ping 2-step approach" [1]. This study demonstrates that the demand variability negatively moderates the relationship between JIT and responsiveness, while it doesn't interact with the relationship between JIT and efficiency. This paper is organized as follows. Firstly, we review the existing literature and define the theoretical framework of this research, focused on the impact of JIT on operational performances and the role of demand variability on

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these relationships. Then we explain the methodology adopted to test our model, followed by the structural equation model (SEM) results. Finally the discussion of the main results concludes this work.

2. Literature review

JIT is a methodology that aims at eliminating waste from manufacturing processes [9]. JIT requires the use of a specific set of practices, such as Kanban system, production smoothing, lot size reduction, setup time reduction, cellular manufacturing and JIT links with suppliers [10]. Production smoothing and kanban system are techniques that decreases short-term demand variability [11]. The reduction of setup time minimizes overproduction waste, increases machine flexibility and lowers cycle time [12].Cellular manufacturing consists in a group of multi-functional machines dedicated to the production of product families, that allows to make the production flow continuous, by the reduction of employees and materials movements [13]. JIT links with suppliers improve flexibility and reduce inventory costs because suppliers deliver the right quantity of material, in small lot sizes, following the takt-time of the kanban system [14]. Based on the above mentioned analysis, JIT improves efficiency, by reducing manufacturing costs, cycle time and inventory levels, and responsiveness, by increasing machine flexibility and delivery capabilities. This positive effect of JIT on operational performance is largely supported by researchers (e.g. [2] and [3]). According to this analysis, we argue that:

Hypothesis 1: JIT is positively related to efficiency

Hypothesis 2: JIT is positively related to responsiveness

In order to maintain an acceptable level of responsiveness, companies generally respond to the variability of customer demand in two ways. The first solution is to build inventory buffers during periods characterized by low volumes in order to have extra inventory of finish products during demand peaks [15]; the second solution is to protect production processes with extra capacity in order to be able to respond to any demand change [16]. A JIT company rarely adopts the first solution because JIT methodology identifies in inventories and overproduction the most important source of waste, which must be eliminated, thus, resulting in responsiveness problems [15]. To be responsive, if demand variability is high, companies implementing JIT must protect themselves with excess of production capacity, since WIP inventories are kept to a minimum level only to smooth out small demand variability, and this increases costs. The product mix variability makes JIT systems inefficient since the supermarkets of finished products are likely to have obsolete products, as well as Heijunka boxes could hold obsolete WIP [16]. Moreover, some scholars pose that JIT needs a stable customer demand to operate effectively. Monden [17] argued that kanban system must be used only with small demand fluctuation because it suffers suddenly takt-time changes. On the same vein, Agarwal *et al.* [18] suggested to implement JIT systems only to produce standard products in high volumes to guarantee a stable demand. The abovementioned studies suggest that demand variability could influence the relationship between JIT adoption and operational performance. Thus, we pose that demand variability interacts with JIT practices by negatively moderating the impact of JIT on performance (see Figure 1):

Hypothesis 3: demand variability negatively moderates the relationship between JIT and efficiency

Hypothesis 4: demand variability negatively moderates the relationship between JIT and responsiveness

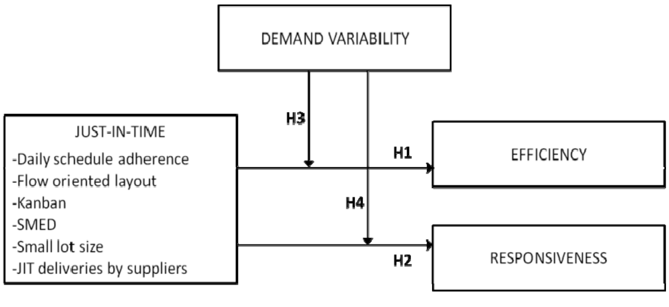

Fig. 1: Theoretical framework.

3. Methodology

This research uses data from the third round of the High Performance Manufacturing (HPM) project data set. The questionnaire was distributed to a selection of manufacturing enterprises from different countries (i.e. Finland, US, Japan, Germany, Sweden, Korea, Italy, Austria and Spain) and operating in machinery, electronic and transportation components sectors. A total of 266 responses were returned, 22 incomplete responses were discarded, this study uses a sample of 244 manufacturing plants to test and analyze the hypotheses. Respondents within each plant were specifically asked to give answers on Just In Time practices adopted, demand variability and operational performance obtained. The variables of interest were conceptualized as first-order constructs and they were measured with multi-item scales. To operationalize our research framework depicted in Figure 1, we used either scales validated in previous scientific studies where possible (Just-In-Time, demand variability and efficiency), or scales based on an extensive literature review (responsiveness). Just-In-Time has been measured by a six item scale, we adapted the Furlan *et al.* [19]'s scale about internal JIT, adding an item that refers to JIT deliveries by suppliers, to cover all the JIT dimensions commonly accepted by researchers. Two items composed demand variability variable [20]. With regard to operational performance, efficiency has been measured by a three item scale [21], while responsiveness has been measured by a four item scale, based on the work of Holweg [22]. The specifics questions are presented in Table 1. It is important to note that for the items composing Just-In-Time and demand variability constructs, we asked respondents to indicate on a 7 point Likert scale to what extent each practice proposed was adopted in the plant (1 means "not at all" and 7 "to a great extent"). As to the items composing efficiency and responsiveness constructs, we asked respondents to provide their opinion about plant's performances compared with its competitors on a 5 point Likert scale (1 is for "poor, low" and 5 is for "superior").

Table 1: Measurement scales, factor loadings, composite reliability coefficient (*italics*) and t-values.

Latent Variable		**Item**	**Factor Loading**	***composite reliability* and t-value**
Just-In-Time	JIT1	We usually complete our daily schedule as planned.	.69	*.78*
	JIT2	The layout of our shop floor facilitates low inventories and fast throughput.	.76	8.97
	JIT3	Suppliers frequently deliver materials to us.	.51	6.65
	JIT4	We use a kanban pull system for production control.	.50	6.42
	JIT5	We have low setup times of equipment in our plant.	.63	7.90
	JIT6	We emphasize small lot sizes, to increase manufacturing flexibility.	.53	6.67
Demand Variability	DV1	Manufacturing demands are stable in our firm.	.81	*.80*
	DV2	Our total demand, across all products, is relatively stable.	.79	11.06
Efficiency	EFF1	Unit cost of manufacturing	.52	*.71*
	EFF2	Inventory turnover	.67	5.69
	EFF3	Cycle time (from raw materials to delivery)	.79	5.73
Responsiveness	RESP1	On time delivery performance	.76	*.78*
	RESP2	Fast delivery	.71	9.08
	RESP3	Flexibility to change product mix	.53	7.09
	RESP4	Flexibility to change volume	.63	8.34

The measurement model was tested by a confirmatory factor analysis (CFA) using LISREL 8.54. As suggested by Bozarth *et al*. [20], we standardized the data by country and by industry before applying the CFA because they could affect the results. Convergent validity is assured because all observable variables load significantly at 0.01 level on their respective latent constructs and all standardized factor loading coefficients are greater than .50, moreover fit indices indicate that the measurement model is acceptable (χ^2 = 164.95; d.f. = 85; χ^2/d.f. = 1.94; RMSEA = .062; CFI = .947; see Table 1 for the values of factor loadings and t-values). We assessed discriminant validity using the Chi-square test that consists on the comparison of two nested models for each pair of constructs. The first model was set with an unconstrained correlation between the two constructs, whereas in the second model the correlation was fixed to 1. If the difference between the Chi-square of the two models is significant, then we can argue that the two constructs are discriminate. Delta Chi-square between all pairs of constructs resulted statistically significant at 0.01 level, indicating discriminant validity. Finally, all composite reliability values, showed in Table 1, are greater than .71, thus ensuring the reliability of the constructs. To test our hypotheses on the existence of the direct and moderation effects, we employed structural models, estimated with the Maximum Likelihood Method, following the "Ping 2-step approach" [1]. We standardized our data to eliminate biased results due to the multicollinearity. Then we analyzed the main effects of JIT and demand variability on efficiency and responsiveness (first step). For the second step we computed the x, $\lambda^x$and $\theta^\delta$of the moderating variable, as suggested by Ping [1] and we analyzed the complete model. Based on Lisrel output, our analysis indicates that JIT has a positive and statistically significant effect on efficiency (γ = .56; t-value = 4.52) and on responsiveness (γ = .52; t-value = 5.83); the main effect of demand variability on both performances isn't statistically significant, however the structural model reveals that demand variability moderates the relationship between JIT and responsiveness (γ = -.21; t-value = -2.11) but doesn't moderate the impact of JIT on efficiency. Fit indices reveal that the model is acceptable: χ^2 = 198.21; d.f. = 98; χ ²/d.f. = 2.02; RMSEA = .065; CFI = .934. Thus, in relation to the hypotheses, this study empirically demonstrates that: the effect of JIT on efficiency is positive and statistically significant (H1 supported); the effect of JIT on responsiveness is positive and statistically significant (H2 supported); demand variability doesn't moderate the relationship between JIT and efficiency (H3 not supported); demand variability negatively and significantly moderates the relationship between JIT and responsiveness (H4 supported).

4. Discussion and Conclusions

This research presents implications both for academics and practitioners. Our work is consistent with the previous literature contributions concerning the direct and positive impact of JIT on efficiency and responsiveness (e.g. [2] and [3]) and provides evidences that fill the lack of literature regarding the interaction between demand variability and JIT. The main findings of this research suggest a guidance for managers to understand whether JIT is always beneficial. Data analysis reveals that demand variability doesn't affect the benefits of JIT adoption on efficiency, while practitioners have to give maximum attention when responsiveness is a key priority. Indeed, with increasing demand variability, JIT benefits on responsiveness are attenuated. Even worse, when the demand variability is extremely high, JIT seems to be counterproductive. With changes in customer demand, JIT is robust regarding efficiency aspects, however it suffers high demand variability when companies try to be responsiveness due to the fact that JIT exposes to a greater risk of stock outs, delivery and flexibility problems because it avoid inventories, overproduction and extra capacity [11] and [18]. The research is subject to the normal limitations of survey research. This study focused on the role of demand variability as a contingency factor, future research should analyze the effect of other factors on the Just In Time – performance relationship. Moreover, 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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