

## **Flexibility in a Lean context: empirical evidences from a manufacturing survey in Spain**

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### **Resumen**

*The main purpose of this contribution is to explore the relationship between Lean concepts and flexibility in manufacturing environments. Although both concepts –lean and flexibility- are complex to define and to measure, we approximate them through existing literature. This preliminary analysis gives hints on understanding the relationship between two strategically important competitiveness clues. Complementary future analysis would be necessary in order to fully understand the model from a holistic point of view.*

**Keywords:** Lean, flexibility, European Manufacturing Survey

### **1. Introduction**

In nowadays competitive environment success in manufacturing, even survival, is often linked to modern or agile production concepts closely related to technologies, in general, integrating partially or totally companies' internal and external value chain. However, there are many organizational innovations which are being applied in manufacturing firms, such as, time bank for flexible working hours, decentralisation of planning, operating and controlling functions or team work in production, related to flexibility.

A series of authors tackle the issue of flexibility in highly varied - in aim, scope and depth- approaches. Resulting taxonomies aim to classify, characterize and describe the concept putting special emphasis on benefits or impact on performance. There is a general agreement that manufacturing flexibility is a multidimensional and multifaceted concept. Authors also identify other typologies of flexibility such as labour flexibility (Voudouris, 2007), organizational flexibility (Tienari and Tainio, 1999) or strategic and managerial flexibility (Zhang, 2005).

#### **1.1. Flexibility in Manufacturing**

There is a general agreement that flexibility in general and manufacturing flexibility in particular is a multidimensional and multifaceted concept. Authors also identify other typologies of flexibility such as labour flexibility (Voudouris, 2007), organizational flexibility (Tienari and Tainio, 1999) or strategic and managerial flexibility (Zhang, 2005).

Different attempts have been made in defining manufacturing flexibility. Table 2 collects some of the representative definitions collected by D'Souza and Williams (2000) in their intent of building a theoretically grounded taxonomy of manufacturing flexibility dimensions and its operationalisation. Definitions are necessary but still too broad for serving as a sound basis for translations into variables that correctly assess whether and up to what degree firms' manufacture is flexible.

**Table 1.** Definitions of manufacturing flexibility. Source: based on D'Souza and Williams (2000)

Definition	Original source
The ability of the manufacturing function, to make adjustments needed to react to environmental changes without significant sacrifices to firm performance. Such adjustments are typically in the range of outputs and/or the mobility to respond to change.	D'Souza and Williams, 2000
The ability to change or react with few penalties in time, effort, cost, or performance.	Upton, 1994
The ability to implement changes in the internal operating environment in a timely manner at a reasonable cost in response to changes in market conditions.	Watts et al., 1993
Flexibility means the ability to adapt to changing conditions using the existing set and amount of resources. In the long run, it measures the ability to introduce new products, new resources and production methods, and to integrate these into the existing production system.	Olhager, 1993
The ability to respond effectively to changing circumstances.	Gerwin, 1987; Gupta and Gupta, 1991
The capacity of a manufacturing system to adapt successfully to changing environmental conditions and process requirements. It refers to the ability of the production system to cope with the instability induced by the environment.	Swamidass, 1988

For that purpose a multitude of dimensions are considered. Some examples include Sethi and Sethi's (1990) 11 dimensions, Gerwin's (1993) 7 dimensions, Gupta and Somer's (1996) 9 dimensions. More recently Braglia and Petroni's (2000) defined 7 dimension enclosing machine, routing, process, product, volume, expansion, layout flexibility while D'Souza and Williams' (2000) propose 4 dimensions grouped as volume, variety, process and material handling flexibility and their considered elements of range and mobility. These dimensions are closely linked to decision levels and whether they are internally- or externally driven. Recent work of Chang et al. (2006) relates three dimensions new product flexibility, product mix flexibility and volume flexibility to different performance measures (quality or defective rate, sales growth rate and net profit).

Going beyond definitions and classifications, flexibility is often regarded by researchers in the general framework of technology or manufacturing system's benefits (Chandra et al., 2005, Hoffman and Orr, 2005). It appears as an intermediary stage of performance having a demonstrated incidence on the ultimate objective, firm performance expressed in terms of sales, revenues, productivity, profitability, etc. Therefore, a stage-based model process contours between determinants of flexibility, flexibility and end-performance/success.

The consulted literature implicitly relates the concept of flexibility and innovation. The definitions showed in Table 2 abound in using constructs such as change, adaptation, reaction indirectly relative to a component of newness in terms of situation, product, system, etc. Focusing particularly on innovation, a main distinction should be made especially between technologies and organizational concepts that aim to produce flexibility. Organizational innovation defined by the Oslo Manual as "the implementation of a new organisational method in the firm's business practices, workplace organisation or external relations" and for the purpose of this present analysis some are described below.

Continuous Improvement Process (CIP) is an ongoing effort to improve products, services or processes. These efforts can seek "incremental" improvement over time or "breakthrough"

improvement all at once. Delivery (customer valued) processes are constantly evaluated and improved in the light of their efficiency, effectiveness and flexibility.

Time bank for flexible working hours is framed in the general mark of flexible human resource management relative practices, involving employees and adapting their working hours to their possible needs. Companies seeking work-life balance might increase employee satisfaction, that later turns into increased performance.

Another possible tool is *creating customer or product focused lines/cells in the factory*. Adapting the existing structure to different and changing customers and/or products confirms a firm's ability of changing rapidly and being able to focus on exact and limited tasks.

*Decentralisation* of some functions as might be planning, operating and controlling reflects the capacity of empowering other departments/employees (rather than management assuming them).

Finally, *teamwork in production* per se is defined by different authors as a limited number of various persons, characterized by multi-skill, multi-task and rotation, having different professional and organizational positions directly participating in making a good and/or service.

## **1.2. Lean Production**

In today's demanding marketplace, manufacturing firms need to redefine and redesign their production systems in order to maintain competitiveness (European Commission, 2004; Singh et al, 2006). Lean Production is one of the approaches that could help firms to attain the goal to be more competitive. This management philosophy is founded on the minimization of all resources used in company activities.

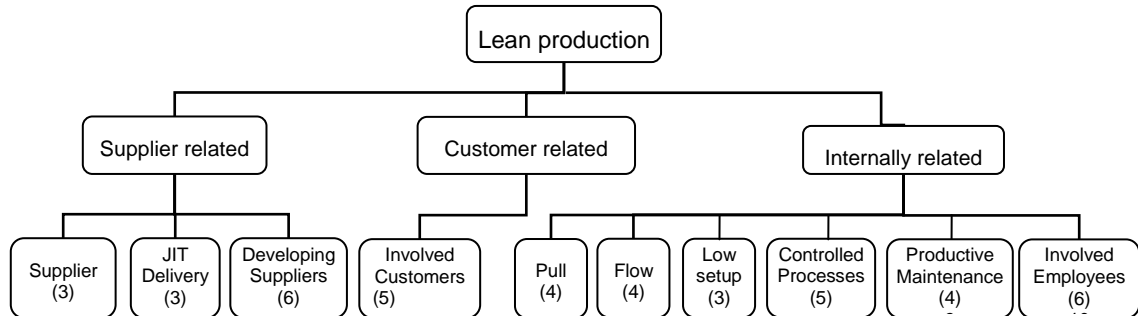
In the literature there are multiplicity of descriptions and terms used with respect to lean management. It is not a singular concept, and it cannot be equated solely to waste elimination, continuous improvement, JIT, pull production, Kanban, TQM or employee involvement. Lean is a philosophy carrying the motto 'Eliminate waste' or 'only be centered on adding value activities'. The concept of 'Lean' was first introduced by Womack et al. (1990) in order to describe the working philosophy and practices of the Japanese vehicle manufacturers and in particular the Toyota Production System (TPS). The essence of Lean thinking is specifying value and - by doing so - simultaneously uncovering waste. The initial concept of Lean was extended to five key principles by Womack and Jones (1996): Specify value; identify value streams; make value flow; let the customer pull value and pursue perfection. The ultimate goal is a production process without any of the seven deadly wastes: overproduction, waiting, transport, extra processing, inventory, motion and defects. However, as that situation is impossible to reach, Lean management is a continuous process towards perfection.

It is important to note that Lean is a philosophy and not a tool itself. Various techniques such as Single Minute Exchange of Dies (SMED), Kanban, Value Stream Mapping (VSM), 5S, Total Quality Management (TQM), Total Productive Maintenance (TPM), Visual Management, team work, cells oriented production, etc. are normally used in a Lean Company. Many of these techniques or tools identify and eliminate every activity that does not add value from the customer's point of view in the design of production and supply chain management related processes (Rother, 2004).

In a historical perspective, different approaches have been undertaken. However there is not an agreed definition of what lean production is and how to measure it. Therefore, one of the most important aspects is to identify key points and processes of a production system related to Lean Philosophy in order to confirm the impact on performance measures. Recently there

is some work where the main factors of Lean Production Systems have been noteworthy (Shah and Ward, 2007).

Adopting an evolutionary approach, define lean production as an integrated socio-technical system whose objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability. To manage this variability ten factors are proposed.



**Figure 1.** Lean production factors (Shah and Ward, 2007), first level the three underlying constructs, second level the ten operational constructs and in brackets the items considered

The model proposed by Shah and Ward (2007) is composed by 48 practices or tools to represent the operational space surrounding lean production and they become ten operational constructs that characterize the dimensions of a lean system grouped, again, in three underlying constructs: supplier related, customer related and internally related issues (Figure 1). Each operational construct represents a unique facet. They are:

1. Supplier feedback (SUPPFEED): provide regular feedback to suppliers about their performance.
2. JIT delivery by suppliers (SUPPJIT): ensure that suppliers deliver the right quantity at the right time at the right time in the right place.
3. Supplier Development (SUPPDEVT): develop suppliers so they can be more involved in the production process of the focal firm.
4. Customer involvement (CUSTINV): focus on a firm's customers and their needs.
5. Pull (PULL): facilitate JIT production including kanban cards which serves as a signal to start or stop production.
6. Continuous flow (FLOW): establish mechanisms that enable and ease the continuous flow of products.
7. Set up time reduction (SETUP): reduce process downtime between product changeovers.
8. Total productive / preventive maintenance (TPM): address equipment downtime through total productive maintenance and thus achieve a high level of equipment availability.
9. Statistical process control (SPC): ensure each process will supply defect free units to subsequent process.
10. Employee involvement (EMPINV): employee's role in a problem solving and their cross functional character.

The main focus of lean production is to eliminate waste by reducing this variability in supply, processing time and demand. Internally (related to the firm) and externally (related to supplier and customer) components need to be managed to achieve the central objective. Reducing

variability related to only one source at a time helps a firm in eliminating only some of the waste from the system; not all waste can be addressed unless firms can attend to each type of variability concomitantly.

Therefore, a well-developed lean strategy will include several dimensions simultaneously. As a consequence, variability in supply that occurs when suppliers fail to deliver the right quantity or right quality at the right time or the right place (Womack et al., 1990) cannot be eliminated unless time and demand variability are also reduced.

In an evolutionary approach, lean production is an integrated system composed of highly inter-related elements and its measure requires multi-dimensional variables. These ten factors model can be used to assess the state of lean implementation in firms and to test hypothesis about relationships between lean production and other firm characteristics that affect firm performance as we did in this contribution.

Lean production requires firms to implement a complete set of factors. Due to the difficulty in implementing several aspects of lean simultaneously, results are a valuable, sustainable competitive advantage difficult to imitate by competitors.

## **2. Aims and objective**

Firstly, the purpose of this study is to construct separate frameworks able to approximate lean concepts (based on Shah and War, 2007), on the one hand, and flexibility (see authors in table 2), on the other hand.

The second step to create a joint model to explain the relationship between both frameworks in order to understand the facts underlying. The results are based on survey data described below in the methodology section.

## **3. Methodology**

### **3.1. Sample and data collection**

Empirical data were collected from the Spanish sub-sample of the 2006 'European Manufacturing Survey' (EMS), which is a biannual international questionnaire that was first created by the Fraunhofer Institute for Systems and Innovation Research (ISI) in 1993 (Lay and Maloca, 2004). Among other things, the EMS conducts a detailed study of the utilisation of organisational and technological innovations by manufacturing companies at both the intra-organisational and inter-organisational levels. In 2006, the EMS received approximately 3500 responses from 12 European countries (Austria, Croatia, France, Germany, Greece, Netherlands, Slovenia, Spain, Switzerland, Turkey, United Kingdom, and Italy).

The Spanish sub-sample of the survey consisted of manufacturing establishments (NACE codes 15–37) that have at least 20 employees. Approximately 10% of such Spanish firms (4450 surveys) received the EMS questionnaire, which was sent out by postal mail in two rounds (April 2006 and June 2006). The final dataset for the present study consisted of 151 responses, which represented a response rate of approximately 3.5%. The relatively low response rate is likely to have been due to this being this particular survey's first run, and to the non-obligatory character of participation. Nevertheless, the responses had a confidence level of 83%, taking into account a margin of error of 5% ( $p=q=0.5$ ).

### **3.2. Measures**

All the considered variables for the purpose of the present study are collected and coded using a homogeneous 5-point Likert scale.

### **Flexibility:**

The EMS surveys a set of organisational innovations, among which are several of interest in the present study. The following organisational innovations were chosen for analysis of the concept flexibility on the basis of data from the EMS:

- Continuous Improvement Process (CIP)
- Time bank for flexible working hours
- Creating customer or product focused lines/cells in the factory
- Decentralisation of planning, operating and controlling functions
- Teamwork in production

### **Lean production:**

Although Shah and Ward (2007) defined lean production by means of ten operational constructs our data did not permitted to duplicate the whole model so we only introduced in our model 6 out of 10 factors. Following there are the variables used to raise these six factors:

- SUPPDEVT: cooperation with suppliers in production
- CUSTINV: Development of product according customer's specification
- PULL: Internal zero-buffer-principle (kanban)
- FLOW: Just-in-Time delivery to customer
- TPM: Quality Management based on the EFQM Model
- EMPINV: Regular individual appraisal interviews

## **4. Results**

Factor analysis and structural equation modelling (SEM) was used to propose and test a model linking the three underlying constructs related to 'lean production' and the construct, based on five organisational innovations, related to 'flexibility'.

### **4.1. Factor analysis and proposed model**

Two exploratory factor analyses were conducted to identify for both 'flexibility' and 'lean production' the dimensions derived from the data of the study. In both cases, the matrix of correlations was submitted to two tests: Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) index.

#### **Factor analysis of 'flexibility':**

The Bartlett statistic, with a value  $\chi^2 = 59.760$  (significance level of 0.000), confirmed the existence of linear dependence between the variables, and thus justified continuing with the procedure. The KMO (0.730) also confirmed that factor analysis was likely to generate satisfactory results (Visauta, 1998). The analysis extracted one single factor (see Table 2). The Kaiser criterion was used to retain only those factors that presented eigenvalues of one or greater. This unique factor retained almost 39% of the initial variance, which represented a good proportion.

Moreover, the factor had a Cronbach's alpha of 0.894 what rejects any doubt about the reliability of the construct.

**Table 2.** Exploratory factor analysis of flexibility

<b>Items</b>	<b>Component</b>
CIP	0,937
Time bank	0,804
Product focused lines/cells	0,878
Decentralisation	0,799
Team work	0,870

Extraction method: Main components analysis

### **Factor analysis of ‘lean production’:**

Using the varimax rotation method, weightings were obtained for each factor in each of the variables (see Table 3). It is apparent that all items correlated strongly with one or other dimension (‘supplier related’, ‘costumer related’ or ‘internally related’).

The reliability of the resulting three constructs was assessed using Cronbach’s alpha. The construct of ‘internally related’ had a Cronbach’s alpha of 0.570, which not exceeded Malhotra’s (2004) minimum criterion of 0.6 for demonstrating internal consistency. Although this suggested some doubt about the reliability of the second construct, the analysis proceeded (albeit with caution regarding any final conclusions thus obtained).

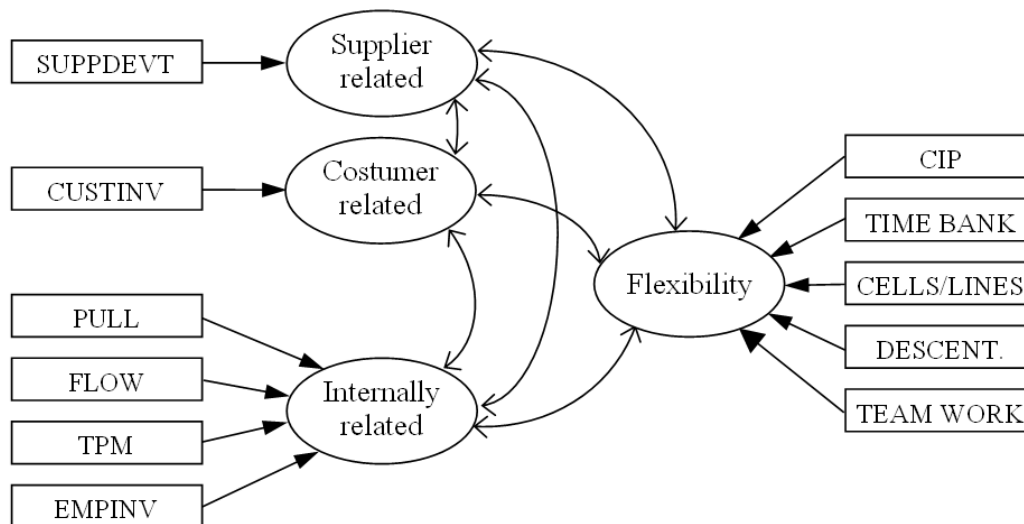
**Table 3:** Exploratory factor analysis of Leanness

<b>Items</b>	<b>Components</b>		
	<b>Supplier related</b>	<b>Costumer related</b>	<b>Internally related</b>
SUPPDEV	0,937		
CUSTINV		0,952	
PULL			0,724
FLOW			0,662
TPM			0,580
EMPINV			0,563

Extraction method: Main components analysis  
Rotation method: Varimax normalization with Kaiser  
Rotation converged in 5 iterations

### **4.2. Proposed model**

Drawing on the results of the study, Figure 2 shows a proposed model of the relationships among ‘flexibility’ and ‘lean production’ (represented by the constructs of ‘supplier related’, ‘costumer related’ and ‘internally related’).



**Figure 2.** Proposed model of 'flexibility' and 'lean production'

To test the model, structural equation modelling (SEM) was performed using the maximum-likelihood method on EQS software. As shown in Table 4, all the correlations between constructs were significant ( $p > 1.96$ ) except the correlation 'supplier related' - 'customer related'. Therefore, no such relationship could be established between 'supplier related' and 'customer related'.

**Table 4.** Correlations between innovation constructs and levels of quality management

Relations in SEM	p-value
Supplier related – Customer related	0.322
Supplier related – Internally related	2,897 *
Supplier related – Flexibility	2,817 *
Customer related – Internally related	2,221 *
Customer related – Flexibility	2,314 *
Internally related – Flexibility	7,174 *

\* indicates that the p-value is significant at .05 ( $p > 1.96$ )

## 5. Conclusions and further research

Lean concepts as well as flexibility are two common notions in manufacturing, but still far from generating homogeneous and well-agreed measures for their monitoring. In this paper we apply previously defined frameworks in order to measure each concept and their relationship.

Shah and Ward, 2007 propose a conceptual model, based on three underlying constructs and ten operational constructs inspired in previously identified OM literature. Due to a lack of data the present paper is unable to fully replicate the entire model in practical terms.

On the other hand, flexibility in terms of organizational facets is reproduced by five common workplace characteristic organizational innovations.

The main findings show that there is a relationship between the concept of flexibility and the three underlying constructs of lean – supplier, customer and internally related- areas. Surprisingly, the model does not provide a statistically significant relationship in the case of two out of the three underlying constructs of lean, namely supplier and customer-related items. One possible explanation for that result is the fact that the internally related construct is an intermediate and acts as a catalyst between suppliers and customers.



Some conclusions of the paper should be carefully interpreted and generalized since some goodness of fit parameters of the model are not reached.

Finally, this contribution is based on a literature review and is a first step of a PhD dissertation considering the relation of flexibility (ways to understand it) and philosophies of production, as Lean Manufacturing, Agile Management or Supply Chain management. This is a work in progress and the first step is focused on Lean Production Systems.

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