Chapter 11
Causal Models of JIT Elements Associated with Production Process and the Obtained Benefits

This chapter addresses three models to associate JIT elements from production process with JIT benefits obtained. Readers may once more refer to methodology addressed in Chap. 5 for a full comprehension of the procedures here described concerning the planning, development, and execution of models. Moreover, since the category of JIT elements associated with the production process comprises 18 items required for the successful JIT production process, it was necessary to perform a factor analysis to identify how many latent variables were comprised in this category.

11.1 Factor Analysis of JIT Elements Associated with Production Process

The objective of this analysis is to identify the latent dependent variables to be integrated into the structural equation model according to methodology described in Chap. 5. Table 11.1 shows the factorability result of the analysis of these 18 items. It is observed that according to the median or adequacy of the sample or KMO index, it is possible to carry out an actuarial analysis, since the value obtained for that index showed to be higher than the minimum accepted value of 0.8. Moreover results of the Bartlett's sphericity test showed a *P*-value of 0.000, which is definitely lower than the maximum accepted value for a 95 % confidence level. Therefore, it can be concluded that correlation matrix of these 18 items is different from an identity matrix. It is thus inferred that correlations of that of correlation matrix are different from 0, indicating that variables are highly correlated.

Table 11.2 illustrates the total explained variability, which explains each of these elements based on the eigenvalues of the correlation matrix. It is observed that only three items have all values higher than the unit. They also explain 59.301 % of the variability contained in the 18 variables or initial items. Furthermore, Table 11.2 also shows that the first factor or found latent variable explains 42.79 % of the variability contained in the initial 18 items, while the second variable explains it in 9.48 %. Finally, the third latent variable found explains 7.03 % of the variability,

J.L. García-Alcaraz and A.A. Maldonado-Macías, *Just-in-Time Elements and Benefits*,
Management and Industrial Engineering, DOI 10.1007/978-3-319-25919-2_11

Table 11.1 KMO and Bartlett's test

Measure of sampling adequacy Kaiser-Meyer-Olkin		0.885
Bartlett's sphericity test	Approximate Chi-squared	1326.772
	gl	153
	Sig.	0

Table 11.2 Total variance explained

Factors	Initial Eigenvalues	Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	Percentage of variance	Percentage accumulated	Total	Percentage of the variance	Percentage accumulated	Total
1	7.702	42.790	42.790	7.702	42.790	42.790	6.163
2	1.707	9.484	52.274	1.707	9.484	52.274	6.262
3	1.266	7.032	59.306	1.266	7.032	59.306	3.507

Table 11.3 Structure matrix for elements in production process

Item	Factor loading	Factor name
Process flexibility	0.875	Lean techniques
Reduced work in process	0.762	
Small lot sizes	0.611	
Preparation time reduction (SMED)	0.599	
Just-in-time purchases	0.595	
Pull system	0.572	
Total preventive maintenance (TPM)	0.535	
Improved plant layout	0.501	
Kanban system	0.833	Production organization and material flow
Cellular manufacturing	0.765	
Group technology	0.736	
Kaizen system	0.720	
Use of robots	0.702	
Scheduling production below capacity	0.689	Capacity and inventory management
Safety stock	0.689	
Specialized factories	0.671	
Standardized containers	0.612	

which combined with the previous two latent variables, accumulates 59.306 % of the total variability explained.

Table 11.3 illustrates how items or elements analyzed are associated with each of the latent variables found. It is important to mention that the element or variable named Implementation of Process Control was eliminated, since it showed little association with latent variables and had no greater load factor than 0.5. Hence, while the first factor or latent variable named Lean Techniques is composed of eight items, the second factor or latent variable includes five items, all related to distribution of machinery and equipment, flow of materials, and continuous improvement of production process. Finally, the third factor or latent variable comprises four items related to aspects of plant capacity and inventory management.

11.2 Model 1. JIT Elements: Lean Techniques and Production Organization and Flow of Materials. Benefits: Production Process and Process Engineering

This model associates four latent variables. Two of them concern JIT elements of Lean Techniques, which includes eight items, and Production Organization and Material Flow, which comprises five items. On the other hand, the remaining two latent variables concern benefits of Production Process with seven items included, and Engineering Process with four items or variables included. Twenty-four variables were analyzed in total. Figure 11.1 depicts the model with the relationships proposed and the hypothesis to be tested for every relationship. None of these hypotheses has been previously tested and discussed.

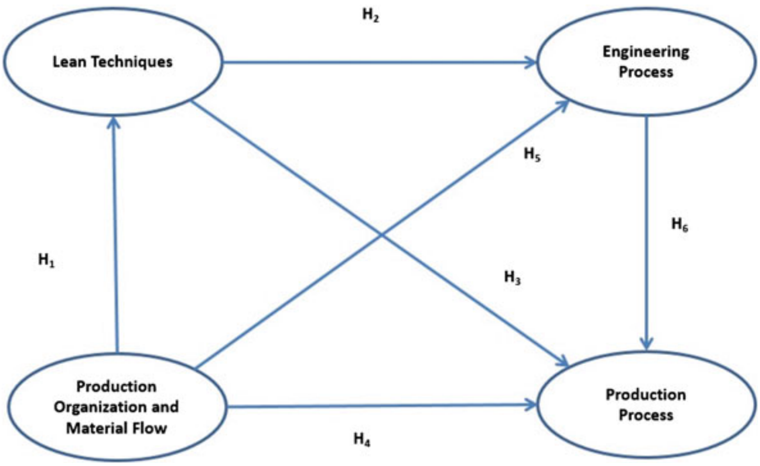

Fig. 11.1 Proposed model 1

11.2.1 Hypotheses Proposed of Model 1

The model associates two latent variables from category of JIT elements of the production process with two latent variables associated with the benefits received in the engineering and production processes. As a result of this association, six hypotheses were proposed and eventually tested.

Companies plan their plant distribution of machinery and equipment depending on the activities that these machines perform for raw materials processing. (Kia et al. 2014; Chen et al. 2011). For instance, while cellular manufacturing distribution groups activities associated with the same product family (Pattanaik and Sharma 2009; Ertay et al. 2006), and the same raw material is processed there from start to finish, technology groups integrate machines that develop similar activities (Jensen et al. 1996; Pourbabai 1988). However, despite their different approach, these forms of plan distribution rely on high technologies such as robots and computers that focus on minimizing the number of accidents and material handling. Moreover, companies support the efficiency of their production process with the implementation of lean manufacturing techniques, such as continuous improvement or Kaizen and Kanban system (Oropesa-Vento et al. 2015; Recht and Wilderom 1998; Radharamanan et al. 1996), which allows for the development of a pull system that can be effective but requires extensive knowledge of machinery maintenance and the ability of machinery to respond rapidly to changes from one product design to another. In order to contribute to this discussion, the following hypothesis is proposed.

H1: *There is a direct and positive effect between production organization and material flow and lean manufacturing techniques that can be applied in a production system in a JIT environment.*

Appropriate plant layout and pull system can contribute to minimize the movement distances of raw materials throughout the production system (Sundar et al. 2014; Selçuk 2013) and ensure better use of available space. Moreover, SMED technique should lead to rapid changes in engineering (Chiarini 2013; Almomani et al. 2013) and machinery and equipment to adapt to new designs and processes, which is closely associated with a suitable program of total preventive maintenance (Kumar et al. 2014). Similarly, just-in-time purchases indicate that companies rely on pull production systems (Al-Tahat and Mukattash 2006) that produce the exact quantity desired, which also results in a reduction of movement distances of raw materials, since companies are familiar with the exact process of that order. This means that since they produce what has been ordered, they purchase only the exact amount of material required to fulfill that order. Therefore, as a contribution to the present discussion, the following hypothesis is proposed.

H2: *There is a direct and positive relationship between lean manufacturing techniques applied in a production system during the implementation process of JIT and the benefits obtained in the engineering process.*

Just-in-time purchases and production process that follow the established methods and standards may certainly help achieve short deliveries to customers, which it now stands as one of the most significant metrics of efficiency in manufacturing (Selçuk 2013; Pragman 1996). However, total productive maintenance programs and rapid changes in the production process can also facilitate such short delivery times, since broken and damaged machines would certainly cause delays (Chan 2001; Kim and Tang 1997; Chiarini 2013; Cua et al. 2001). Similarly, the ability to make quick modifications in the production process from one design or prototype to another allows companies to accept several different orders and increase its production flexibility (Kumar et al. 2014; Kemal Karasu et al. 2014). This agility and flexibility allow manufacturers to cater for larger quantities of orders that will result in economic benefits for them (Ragin-Skorecka 2014; Huumonen 2011). Finally, high levels of expertise, education, and training of workers ensure a reduction of errors in the production process or waste, which also improves efficiency and increases productivity (Lee and Johnson 2012). Therefore, the following hypothesis was proposed as a contribution to this discussion.

H3: *Lean manufacturing techniques applied to the production process during the implementation of JIT have a direct and positive impact on efficiency indexes of production process.*

Competitive advantage can be measured with productivity indexes, a reduction of waste (Marodin et al. 2015; Deep and Singh 2015) and rework, and according to the integration of common or singular production activities (Calvo-Mora et al. 2014) that allow for the employment of highly trained workers. Therefore, machines and equipment used for the transformation of raw materials are distributed in such a way that they increase this competitive advantage of companies.

Similarly, techniques that support continuous flow of materials, such as Kanban, can reduce delivery times of finished products (Rahman et al. 2013a, b; Hou and Hu 2011; Lage Junior et al. 2010; Chan 2001). However, production processes also often require the implementation of continuous improvement programs, such as Kaizen, whose popularity is due to the fact that it enables the integration of operators into the improvement of production processes (Oropesa-Vento et al. 2015; Recht and Wilderom 1998; Radharamanan et al. 1996), since they are the most familiarized with this process, run the machines, and ensure the flow of materials. Therefore, as a means to contribute to the discussion, it was possible to propose the following hypothesis.

H4: *Production organization and material flow have a direct and positive impact on efficiency indexes achieved in the production process in a JIT environment.*

The use of Kanban system in a production system will result in a number of benefits associated with a reduced space requirements for the production process and should also help minimize movement distances of raw materials (Sylvain and Duguay 1997; Lummus 1995; Fukukawa and Hong 1993). Nevertheless, if this card system is implemented in group technology or manufacturing cells, profits could be much higher, since these centers are organized to bring together a certain number of similar activities (Spencer 1998; Jensen et al. 1996; Pourbabai 1988) or group of families of products, where operators become highly skilled in their activities (Tabassi and Abu Bakar 2009; Kassicieh and Yourstone 1998) and continuous improvement is achieved through innovative proposals that enable better production process, products, and distribution of machinery and equipment (Farris et al. 2009; Kumiega and Van Vliet 2008). Therefore, since physical organization of machines and equipment used in the production system equipment can generate a number of benefits reflected in the engineering process and its indexes, it is possible to propose the fifth hypothesis of this model.

H5: *Production organization and flow of materials in a production process has a direct and positive impact on efficiency indexes of engineering process in a JIT environment.*

An efficient engineering process reflects on the reduction of space requirements (Huang and Lin 2014), movement distances of raw materials (Ohno 2011; Chakravorty 2009), and rapid changes (Chiarini 2013; Almomani et al. 2013). Therefore, these indications would measure productivity of the production process based on a minimum of waste (Inman et al. 2011; Huq 1999; Huq and Huq 1994), an increased efficiency and flexibility, and thus short delivery times. However, for every action there is a reaction, and in order to statistically demonstrate the meaning of these facts, the following hypothesis is proposed.

H6: *Indexes of an engineering process have a direct and positive impact on the indexes associated with the production process in a JIT environment.*

11.2.2 Results of Model 1

Results of the model evaluation are illustrated in Fig. 11.2. Every segment includes a value or parameter that measures the relation between the two latent variables involved in that segment. Similarly, *P*-values are also included in segments as a measure of statistical significance (the level of significance in all models executed in this book is 0.05). Finally, every latent dependent variable shows an R-squared value as a measure of its explained variance.

The segment colored in red indicates that the direct effect for this relation cannot be considered significant with a 95 % confidence level but with a 90 % confidence level. Moreover, unlike models in Chap. 10, this relation was not eliminated since indirect and total effects that occur through this segment are significant.

11.2.2.1 Efficiency Indices of Model 1

Before describing the direct and indirect effects of this first model, it is necessary to determine whether it meets certain indexes of goodness of fit that permit drawing

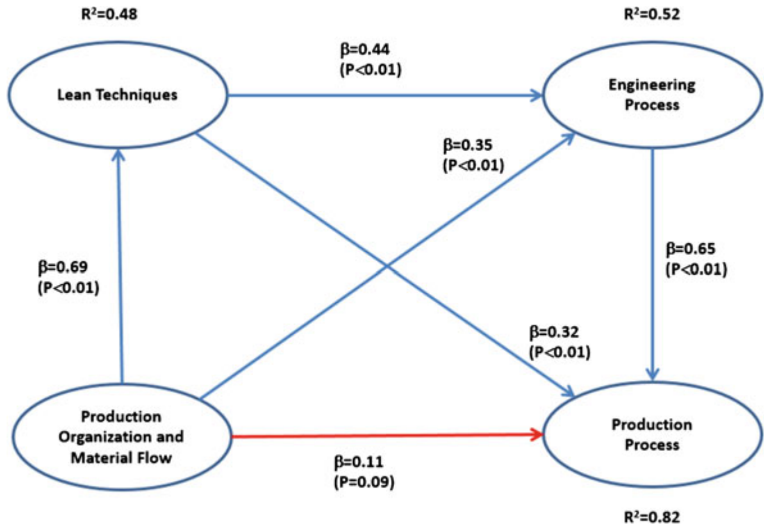

Fig. 11.2 Evaluated model 1—validating hypotheses

conclusions from it, since the objective of the model is to be as predictive as it is possible to determine the existing relations between variables. Efficiency indexes of this model are listed below.

1. Average path coefficient (APC) = 0.419, $P < 0.001$
2. Average R-squared (ARS) = 0.608, $P < 0.001$
3. Average adjusted R-squared (AARS) = 0.603, $P < 0.001$
4. Average block VIF (AVIF) = 2.080, acceptable if ≤5, ideally ≤3.3
5. Average full collinearity VIF (AFVIF) = 3.092, acceptable if ≤5, ideally ≤3.3
6. Tenenhaus GoF (GoF) = 0.609, small ≥0.1, medium ≥0.25, large ≥0.36
7. Sympson's paradox ratio (SPR) = 1.000, acceptable if ≥0.7, ideally = 1
8. R-squared contribution ratio (RSCR) = 1.000, acceptable if ≥0.9, ideally = 1
9. Statistical suppression ratio (SSR) = 1.000, acceptable if ≥0.7
10. Nonlinear bivariate causality direction radio (NLBCDR) = 1.000, acceptable if ≥0.7

According to the APC, AARS, and AARS indexes that show *P*-values to measure statistical significance, it can be concluded that the model is efficient, has predictive capacity, and, in average, all parameters measuring the relations between variables latent are statistically significant. It is important to be clear with the concept of "average" here addressed. It refers to the overall value of all relationships in the model, since as shown in Fig. 11.2, one of this relation is not statistically significant. Similarly, when the variance inflation factor was analyzed, no collinearity problems were observed among these latent variables studied in general or average terms. Similar interpretations can be proposed for the remaining indexes shown. However, note that GoF index, which is recommended to be greater than

0.36, shows a value of 0.609 in this model; this indicates that it is as an appropriate model fit.

11.2.2.2 Coefficients of Latent Variables of Model 1

Indices reported above indicate that the model is in general efficient and can be used to interpret the relations between latent variables. However, it is also important to analyze each of these latent variables. Table 11.4 depicts validity indexes for each of these variables.

The first two rows of Table 11.4 show that values of the R-squared and the adjusted R-squared are higher than 0.02. Therefore, all latent variables that are dependent or explained by independent latent variables have sufficient predictive validity from a parametric view. Moreover, Q-squared values of all latent variables are higher than 0 and close to their R-squared and adjusted R-squared values.

As for internal validity, Cronbach's alpha and composite reliability show values higher than 0.7 in all latent variables, which is the minimum accepted value. Therefore, all latent variables have sufficient internal validity. Similarly, AVE indexes have values greater than 0.5 in all latent variables, leading to the conclusion that they have by far convergent validity. Finally, all variables have adequate collinearity, since none of them have values greater than 3.3, the maximum value admitted. Therefore, based on the indexes above, it is concluded that the structural equations model is suitable and can be analyzed.

11.2.2.3 Direct Effect of Model 1

According to direct effect, the hypotheses can be tested and the following conclusions are given:

- H1: There is sufficient statistical evidence to declare that organization of production and material flow have a direct and positive effect on lean

Table 11.4 Coefficients of latent variables of model 1

	Lean techniques	Production organization and material flow	Production process	Engineering process
R-squared	0.481		0.820	0.522
Adj. R-squared	0.477		0.816	0.515
Composite reliability	0.907	0.886	0.916	0.891
Cronbach's alpha	0.880	0.838	0.892	0.836
AVE	0.553	0.609	0.610	0.672
FVIF	2.678	2.164	3.141	3.086
Q-squared	0.485		0.747	0.521

manufacturing techniques applied in a JIT production system, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.69 units.

- H2: There is enough statistical evidence to declare that lean manufacturing techniques applied in a JIT production system have a direct and positive impact on the benefits obtained in the engineering process. When the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable also increases by 0.44 units
- H3: There is sufficient statistical evidence to declare that lean manufacturing techniques implemented in a JIT production process have a direct and positive impact on its efficiency indexes, because when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable also increases by 0.32 units.
- H4: There is no enough statistical evidence to declare that production organization and material flow have a direct and positive impact on the efficiency indexes achieved in the production process in a JIT environment, since the *P*-value obtained from the significance test of the hypothesis showed a value above 0.05. Thus, with a 95 % confidence established, this hypothesis was rejected.
- H5: There is enough statistical evidence to declare that production organization and flow of materials in a JIT production process have a direct and positive impact on efficiency indexes of engineering process, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable also rises by 0.35 units.
- H6: There is sufficient statistical evidence to declare that efficiency indexes of engineering process have a direct and positive impact on indexes associated with the production process in JIT environment, because when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.65 units.

For dependent variables with R-squared values, it is important to apportion their total direct effect and discuss the percentage of direct effects that is explained through the different independent latent variables. Table 11.5 shows the effect sizes that independent latent variables have on dependent latent variables.

- Dependent latent variable Lean Techniques is explained in 48.4 % by latent variable Production Organization and Material Flow, since the R-squared value is 0.484. Note this variable is only explained by the independent variable.

Table 11.5 Effect sizes of model 1

	Lean techniques	Production organization and material flow	Engineering process
Lean techniques		0.484	0.546
Production process	0.238	0.032	
Engineering process	0.29	0.225	

- Latent dependent variable Engineering Processes is explained in 52 %, from which 29 % can be explained by independent latent variable Lean Techniques and 22.5 % by independent latent variable Production Organization and Material Flow.
- Latent dependent variable Production Process is explained in 82 % by three latent variables. Thus, 23.6 % of variability is given through Lean Techniques, 3.2 % originates from Production Organization and Material Flow (although the direct effect between these two variables was statistically not significant), and 54.6 % of variability originates from Engineering Process. Therefore, it can be stated that process engineering is the most important element to improve production process indexes, since it explains the greatest percentage of production process variable.

11.2.2.4 Sum of Indirect Effects

Table 11.6 depicts the sum of indirect effects between two variables given through a mediator variable. However, it shall not be forgotten that the same variable may have an effect on several variables, and such effects may occur through different other mediator variables. Note that the *P*-values for statistical significance of this effects were lower than 0.05; thus, indirect effects are considered statistically significant.

Based on the information shown in Table 11.6, it is possible to conclude the following:

– Latent variable Lean Techniques has an indirect effect on dependent latent variable Production Process, since when the first increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.286 units. Besides, this independent variable can explain up to 21.2 % of the variability of the latent dependent variable, since the R-squared value is 0.212.
– The independent latent variable Production Organization and Material Flow has a strong impact on dependent latent variable Production Process, since when the first increases its standard deviation by one unit, the standard deviation of the second rises by 0.649 units. Moreover, the independent latent variable can explain up to 38.1 % of the variability of the dependent latent variable, since the R-squared value is 0.381.

Table 11.6 Sum of indirect effects of model 1

To	From	
	Lean techniques	Production organization and material flow
Production process	0.286 ($P < 0.01$) ES = 0.212	0.649 ($P < 0.01$) ES = 0.381
Engineering process		0.305 ($P < 0.01$) ES = 0.197

– Independent latent variable Production Organization and Material Flow also has an indirect effect on dependent latent variable Engineering Process, since when the former increases its standard deviation by one unit, the standard deviation of the latter also increases by 0.305 units. The independent variable also accounts for up to 19.7 % of the variability of the dependent latent variable, since the R-squared value is 0.197.

As a conclusion, it can be stated that independent latent variable Production Organization and Material Flow is crucial when implementing a JIT system or, since several elements and benefits that companies can obtain depend on it, such as the implementation of Kanban system and Kaizen. The former is directly associated with the flow of materials, while the latter supports a continuous improvement of the entire production process.

11.2.2.5 Total Effects of Model 1

The sum of direct and indirect effects for every relation between variables is depicted in Table 11.7. Likewise, every parameter that measures the total effect among a relation includes a *P*-value associated with its statistical significance. The same table also introduces the size of the effects and allows for the conclusions offered below.

- All total effects are statistically significant, since the *P*-value of the statistical significance test for every relation was lower than 0.05, the maximum value accepted for a 95 % confidence level.
- One of the total effects has a value lower than 0.6, while the remaining five effects show values below 0.6. This demonstrates the importance of the relations of these latent variables.
- The relationship between Production Organization and Material Flow and Production Process shows the largest total effect; when the former latent variable increases its standard deviation by one unit, the standard deviation of the latter increases by 0.710 units. Moreover, the first latent variable explains 41.6 % of

Table 11.7 Total effects of model 1

To	From		
	Lean techniques	Production organization and material flow	Engineering process
Lean techniques		0.693 ($P < 0.01$) ES = 0.481	
Production process	0.609 ($P < 0.01$) ES = 0.450	0.710 ($P < 0.01$) ES = 0.416	0.652 ($P < 0.01$) ES = 0.546
Engineering process	0.440 ($P < 0.01$) ES = 0.297	0.653 ($P < 0.01$) ES = 0.422	

the variability of the latter, since the effect size equals 0.416. Also, the direct relation between these latent variables analyzed by H4 was not significant; thus, the indirect effects between them occur through latent variables Lean Techniques and Engineering Process.

- The relation between latent variables Production Organization and Material Flow and Lean Techniques was reported as the second relation with the largest size of total effects. When the standard deviation of the first variable increases by one unit, the standard deviation of the second also increases by 0.693 units. Also, the independent latent variable explains up to 48.1 % of the variability of the dependent latent variable, since the size effect is 0.481.
- The total effect from the relation between latent variable Production Organization and Material Flow and Engineering Process is also considerably high and reported as the third largest total effect. When the independent latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.653 units. Moreover, the independent variable explains up to 42.2 % of the variability of the dependent latent variable, since the effect size is 0.422.
- The relation between latent variable Lean Techniques and Production Process shows the fourth relation with the highest total effect size. It refers to the implementation of lean manufacturing techniques in the production line. When the former latent variable increases its standard deviation by one unit, the standard deviation of the latter rises 0.609 units. Moreover, the first latent variable explains 45 % of variability of the second latent variable, since the effect size is 0.45 %
- Similar interpretations were obtained for the remaining two relations between latent variables.

11.2.2.6 Conclusions of Model 1

This model associated four latent variables, from which two concerned JIT elements from production processes and two referred to benefits and production process. A total of 24 items or variables were analyzed within these four latent variables. Moreover, six hypotheses were proposed and analyzed to indicate the direct effect between latent variables; five of them were accepted since their *P*-values were lower than 0.05, the maximum allowed for a 95 % confidence level.

The latent variable Production Organization and Material Flow reported the highest total effect over the latent variable Production Process, although their direct effect was statistically not significant. Therefore, the total effect is mostly due from indirect effects occurring through latent variables Lean Techniques and Engineering Process. Moreover, latent variable Production Process is explained in 82 % by the latent variables that influence on it, which is one of the highest values obtained in the models proposed so far. Industrial implications of this model are stated as it follows:

- The implementation of a JIT program must be based on the physical distribution and organization of machinery and equipment within a plant, since many lean manufacturing techniques depend on it.
- Lean manufacturing techniques alone do not provide great benefits to the production process; they must be supported by effective engineering processes. Note that the direct effect that causes latent variable Engineering Process over Production Process is much higher than the direct effect between Lean and Production Organization and Material flow; however, their direct effect is not statistically significant.

11.3 Model 2. Elements: Lean Techniques and Production Organization and Material Flow. Benefits: Human Resources and Quality

This model associates four latent variables; two of them concern JIT elements of Production Process, which are: Production Organization and Material Flow and Lean Techniques. The remaining two refer to benefits obtained for human resources and quality in the production process. The former two latent variables together comprise 13 items or variables, while the latter two latent variables include eight items or variables. Thus, 21 items were integrated into the four latent variables of this second model. Similar to the previous model, latent variable Production Organization and Material Flow here is considered independent latent variable, while Quality is considered as dependent variable from all others.

Figure 11.3 shows the relationship between the four latent variables and displays six working hypotheses. Five of them are recent, while (H1) was previously tested and analyzed. It concerns the relation between Production Organization and Material Flow and Lean Techniques.

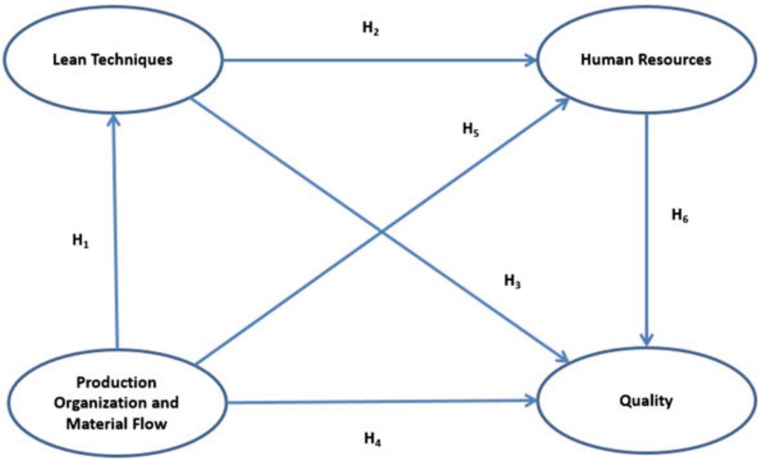

Fig. 11.3 Proposed model 2

11.3.1 Hypotheses Proposed of Model 2

This model seeks to associate two latent variables of production processes with two latent variables associated with the benefits gained after a JIT implementation. As mentioned above, one hypothesis was previously tested and analyzed in model 1, but is depicted in this model to provide the complete proposal. However, it will not be discussed once more.

Companies exist and grow as a result of human resources and their skills and abilities; thus, resources and techniques to bring greater motivation among them will be constantly sought and implemented. Besides, this motivation and encouragement will be reflected on improved work performance. For instance, flexibility depends on the capacity of human resources to perform diverse tasks (Chlivickas 2014), which impacts on a continuous material flow and can provide employees with satisfaction once they become multifunctional (Chlivickas 2014; Nen 2015); moreover, they feel more integrated. Several authors nowadays consider that human resources are top partners of any organization before suppliers (Crumpton 2015).

Another factor with a positive effect on workers motivation is their opportunity to rely on machinery and equipment that are properly calibrated by suitable programs of total productive maintenance. It results in satisfying work performance and a reduction of errors along the production process (Chiarini 2013; Thomas et al. 2006). However, companies must seek to implement other programs and plans associated with total productive maintenance, such as those that enable to perform quick changes between product designs. These other programs can also improve morale of workers and promote collaborative work as a result of communication (Chiarini 2013; Huang et al. 2009).

Another JIT crucial element is just-in-time purchases to highly reliable suppliers who become efficiently and highly integrated into the production system as a result of the communication skills of human resources (Gilbert et al. 1994; Macbeth et al. 1988). The importance of such suppliers is that they become the beginning of a supply chain, and without their ability to deliver raw materials on time, manufacturing companies cannot guarantee punctual deliveries of finished products to customers. This could significantly affect the motivation of employees when they consider they cannot achieve the goals of the company and theirs. Therefore, as a means to contribute to this discussion, the second hypothesis proposed states as it follows:

H2: *The implementation of lean manufacturing techniques along with a JIT philosophy has a direct and positive impact on the human resources of companies.*

Lean manufacturing techniques applied in the production process must—to any extent—impact on product quality. For instance, when companies produce in small lots, they force suppliers to deliver raw material in similar small quantities. This facilitates the inspection and audit of this material reaching the warehouses and consequently can lead to improved quality product (Absi et al. 2012; Lovell 2003; Kim and Ha 2003).

Similarly, total preventive maintenance programs can improve product quality, since properly calibrated and adjusted machines can reduce errors in the production process (Ahmad et al. 2012; Cua et al. 2001). However, although many authors discuss whether maintenance and quality are issues to consider separately, for others it is more convincing to believe that they are closely related aspects, since quality is the result of appropriate maintenance (Konecny and Thun 2011).

A reduction of work in process is also a JIT element considered by many as crucial to improve production processes. Companies can often struggle with great amounts of raw material being processed somewhere in the production process. For instance, feedstock is usually placed somewhere close to the machinery and equipment where it will be processed, resulting in obstructed aisles and hampered visibility that bring the impression of factories with little organization and planning. Moreover, this disorganization would affect quality indices due to an increasing handling of materials (Ohno et al. 2015; Bettayeb et al. 2014). Therefore, in order to support the relation between lean manufacturing techniques and quality product, the following hypothesis is proposed.

H3: *Lean manufacturing techniques applied in a JIT production process have a direct and positive impact on product quality.*

The organization for the improvement of material flows can group a product family in what might be called manufacturing cells (Pattanaik and Sharma 2009; Williams and David 1991), or a set of similar activities in what might be named group technology (Spencer 1998; Pourbabai 1988). However, companies must also seek to implement additional techniques that favor the flow of materials under such layout. Kanban, also known as the cards system (Sylvain and Duguay 1997; Reda 1987; Fiscus 1987), is a widely used technique that provides with exact instructions to operators on what must be performed with a certain component or subassembly. This can reduce errors within manufacturing cells and technology groups and thus improve quality of the final product (Liberopoulos and Koukoumialos 2005; Chan 2001). However, when problems or errors do arise within these plants, operators can be integrated and encourage to propose solutions to these issues. This is also a form of improving the production process and therefore the quality of the final product. Based on all information previously stated, it is possible to formulate the following hypothesis.

H4: *Production organization and material flow have a direct and positive effect on product quality within a JIT environment.*

Machinery and equipment of maquiladoras are usually designed and purchased overseas, and when these types of companies establish in the Mexican territory, some of their organization systems also arrive with a prearranged distribution of the physical space. This prearranged distribution was conceived according to the type of product to be manufactured. Nevertheless, the range of products often increases and several adjustments in the plant layout must be executed, which also involve a number of changes in human resources (Caggiano and Teti 2012; Yalcin 2004; Williams and David 1991).

Several techniques applied in a production process are executed simultaneously and can have an impact on product quality. For instance, as it was previously mentioned, Kanban system allows for a reduction of errors in the production process, and this can bring greater motivation to employees when they realize they are able to meet the goal of their companies (Liu et al. 2009; Ruckart and Burgess 2007). Similarly, Kaizen can improve product quality and material flow, since it aims to organize and integrate workers in the process of solving a specific problem of the production system. This promotes high levels of collaborative work and thus supports effective communication among operators, which often translates into a greater social coexistence (Knechtges and Decker 2014; Glover et al. 2011; Farris et al. 2009). Therefore, since it is considered that production organization can impact on human resources, the following hypothesis was proposed.

H5: *Production organization and material flow have a direct and positive impact on human resources within a JIT environment.*

Companies emerge and remain existent as the result of human resources and their skills and abilities, which is a reason that companies must strive to implement programs and techniques to integrate their workforces and make them feel an integral part of the organization (Rusu and Avasilcai 2014; Martínez-Jurado et al. 2014). Similarly, human resources are responsible for the flexibility and agility that companies wish to accomplish in their supply chains, since they can hold several positions and perform several different tasks so that the flow of material does not stop (Ragin-Skorecka 2014) and companies reach on-time deliveries. Moreover, authors have associated the capacity of innovation of companies with the quality circles established in them (Blaga and Jozsef 2014a), which generally results in an increased efficiency (Blaga and Jozsef 2014b; Lengnick-Hall et al. 2013).

As a conclusion, it has been stated that the success and performance of companies are largely due to the different roles of human resources (Farris et al. 2009; Power and Sohal 2000; Jayaram et al. 1999). Thus, the following hypothesis can be formulated.

H6: *The levels of satisfaction, motivation, and communication of human resources have a direct and positive effect on the quality indices of the product that is manufactured within a JIT environment.*

11.3.2 Results of Model 2

Figure 11.4 illustrates the results from the evaluation of this model according to methodology stated in Chap. 5. Every relation or hypothesis in the model shows a value of the beta parameter and a *P*-value from the statistical significance test to determine whether these hypotheses are accepted or rejected. Similarly, every dependent latent variable in the figure shows an R-squared value that measures its variability explained by independent latent variables.

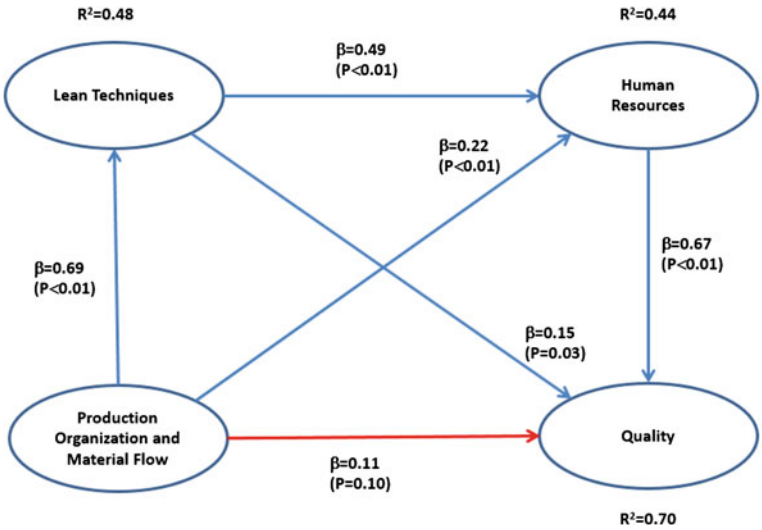

Fig. 11.4 Evaluated model 2—validation of hypotheses

The segment or hypothesis in red indicates that this relation between variables is not statistically significant at a 95 % confidence level. Its *P*-value is considerably high, while the beta value is visibly low. On the other hand, the remaining five relations were statistically significant, according to their *P*-value.

11.3.2.1 Efficiency Indices of Model 2

Before drawing conclusions from this second model, it is necessary to determine whether it meets certain indexes of goodness to accurately predict relations between variables.

1. Average path coefficient (APC) = 0.388, $P < 0.001$
2. Average R-squared (ARS) = 0.540, $P < 0.001$
3. Average adjusted R-squared (AARS) = 0.534, $P < 0.001$
4. Average block VIF (AVIF) = 1.935, acceptable if ≤5, ideally ≤3.3
5. Average full collinearity VIF (AFVIF) = 2.702, acceptable if ≤5, ideally ≤3.3
6. Tenenhaus GoF (GoF) = 0.580, small ≥0.1, medium ≥0.25, large ≥0.36
7. Sympson's paradox ratio (SPR) = 1.000, acceptable if ≥0.7, ideally = 1
8. R-squared contribution ratio (RSCR) = 1.000, acceptable if ≥0.9, ideally = 1
9. Statistical suppression ratio (SSR) = 1.000, acceptable if ≥0.7
10. Nonlinear bivariate causality direction ratio (NLBCDR) = 1.000, acceptable if ≥0.7

In APC, ARS, and AARS indexes their *P*-values to determine statistical significance are all lower than 0.05, which is the maximum value allowed for a 95 % confidence level. Therefore, relationships between variables are on average statistically significant and dependent latent variables have sufficient predictive validity.

Similarly, AFVIF and AVIF indexes demonstrate that there are no collinearity problems in latent variables analyzed and the model can be eventually interpreted. The remaining indexes are also suitable for the model. However, the Tenenhaus index in this model is 0.58, while the minimum value suggested is 0.36. This value is positively high and suitable for the model.

11.3.2.2 Coefficients of Latent Variables

Indices reported above indicate that the model is in general efficient and can be used to interpret the relations between variables. However, it is also necessary to analyze latent variables independently. Table 11.8 shows validity indexes for each of these variables.

- All R-squared and adjusted R-squared values are higher than 0.2; thus, all dependent latent variables have predictive validity from a parametric point of view. Similarly, Q-squared values of all variables are higher than 0 and close to R-squared and adjusted R-squared values. From a nonparametric point of view, all dependent latent variables have predictive validity.
- As for internal validity and reliability, it is observed that Cronbach's alpha and composite reliability indexes are higher than 0.7 in all variables analyzed. This indicates that all latent variables are properly integrated with their items.
- Value of AVES index for every latent variable is higher than 0.5—the minimum acceptable cutoff value. Therefore, it is that all latent variables analyzed have sufficient convergent validity and can be discussed.
- According to the index of variance inflation in all variables, there are no collinearity problems among them.

11.3.2.3 Direct Effects—Validation of Hypotheses of Model 2

Hypotheses initially raised in Fig. 11.3 were evaluated according to the established methodology, resulting in the values shown in Fig. 11.4 for the analyzed direct effects. The following conclusions can be stated from this last figure. Hypothesis 1 (H1) was discussed in the previous model.

Table 11.8 Coefficients of latent variables of model 2

To	From			
	Lean techniques	Production organization and material flow	Quality	Human resources
R-squared	0.481		0.702	0.437
Adj. R-squared	0.477		0.696	0.429
Composite reliability	0.907	0.886	0.885	0.887
Cronbach's alpha	0.88	0.838	0.805	0.841
AVE	0.553	0.609	0.72	0.612
FVIF	2.298	1.997	3.326	3.184
Q-squared	0.485		0.705	0.439

- H2: There is enough statistical evidence to declare that lean manufacturing techniques used along a JIT program have a direct and positive impact on human resources, because when the independent latent variable increases its standard deviation by one unit, the standard deviation of the dependent latent variable increases by 0.49 units.
- H3: There is sufficient statistical evidence to state that lean manufacturing techniques applied simultaneously with a JIT production process have a direct and positive impact on the quality of finished products, since when the independent latent variable increases its standard deviation by one unit, the standard deviation of the dependent latent variable increases by 0.15 units.
- H4: There is not enough statistical evidence to declare that production organization and material flow have a direct and positive effect on product quality in a JIT environment. The *P*-value obtained for the statistical test of the estimated parameter is greater than 0.05, the maximum acceptable value for a 95 % confidence level.
- H5: There is sufficient statistical evidence to point out that production organization and material flow have a direct and positive impact on human resources in a JIT environment. When the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable rises by 0.22 units.
- H6: There is enough statistical evidence to declare that levels of satisfaction, motivation, and communication among human resources have a direct and positive effect on product quality indexes in a JIT environment, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second variable increases by 0.67 units.

All latent dependent variables have a R-squared value that indicates the percentage of their variability explained by independent latent variables. However, some of these dependent latent variables are explained by more than one independent latent variable. Thus, it is important to apportion their total direct effect and discuss the percentage of direct effect that is explained through the different independent latent variables. Table 11.9 shows the effect sizes that independent latent variables have on dependent latent variables.

Figure 11.4 and data from Table 11.6 allow for the statement of the following conclusions:

- Latent variable Lean Techniques is explained in 48.1 % by latent variable Production Organization and Material Flow.

Table 11.9 Effect sizes of model 2

	Lean techniques	Production organization and material flow	Human resources
Lean techniques		0.481	
Quality	0.098	0.059	0.545
Human resources	0.316	0.12	

- Motivation, increased teamwork, and communication among human resources are explained in 44 % by two latent variables, since the effect size is 0.44. Therefore, 32.6 % of this variability is explained by latent variable Lean Techniques, while 12.4 % originates from Production Organization and Material Flow. Thus, it seems that lean techniques are more significant to increase workers motivation and collaborative work among human resources.
- Quality of a product is explained in 70 % by three latent variables, since the size effect is 0.70. Thus, Human Resources explains 54.5 % of this variability, 5.9 % originates from Production Organization and Material Flow, and 9.8 % of this variability can be explained by Lean Techniques employed in companies. Hence, it can be stated that human resources are the most significant factor to achieve quality in a production system.

11.3.2.4 Sum of Indirect Effects of Model 2

As shown in Fig. 11.4, it is possible that latent variables associated with JIT elements have an effect on latent variables with benefits through mediator variables. Table 11.10 illustrates the sum of the indirect effects between latent variables, the *P*-value of the statistical significance test of the parameter, and the effect size or variability that could be explained.

According to Table 11.10, all indirect effects are statistically significant, since the *P*-value for every one is lower than 0.05, the maximum accepted value for a 95 % confidence level. Moreover, it is possible to draw the following conclusions:

- Lean Techniques has an indirect effect on quality obtained in a product, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.328 units. Moreover, the first latent variable can explain 21.4 % of the variability of the second latent variable, since the effect size is 0.214.
- Latent variable Production Organization and Material Flow has a total indirect effect on quality of products, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.477 units. Moreover, the first latent variable can explain up to 26.8 % of variability of quality, since the effect size is 0.268.

Table 11.10 Sum of indirect effects of model 2

To	From	
	Lean techniques	Production organization and material flow
Lean techniques		
Quality	0.328 ($P < 0.001$) ES = 0.214	0.477 ($P < 0.001$) ES = 0.268
Human resources		0.342 ($P < 0.001$) ES = 0.189

11.3.2.5 Total Effects of Model 2

Table 11.11 introduces the total reported in this second model. Similar to previous analysis, every total effect shows the *P*-value of the statistical significance test, and the effect sizes are also shown to demonstrate the variability of a dependent latent variable explained from an independent latent variable. The same table also allows for the following interpretation of data.

- All total effects are statistically significant, since in all cases *P*-value is lower than 0.05, the maximum allowed value for a 95 % confidence level of 95 %.
- Four total effects are relatively high, since their values are higher than 0.5. Three of these concerned effects of latent variable Production Organization and Material Flow over the remaining latent variables, while one total effect refers to latent variable Human Resources over quality obtained in the final product.
- Latent independent variable Production Organization and Material Flow has the largest total effect over Lean Techniques. When the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.693 units. Moreover, the former explains up to 48.1 % of the variability of the latter. The effect size is 0.481 units.
- The second largest total effect is caused by independent latent variable Human Resources over latent variable Quality of the product, since when the former increases its standard deviation by one unit, the standard deviation of the latter increases 0.666 units. Moreover, the first latent variable explains up to 54.5 % of variability of the second latent variable, since the effect size is 0.545 units.
- The third most significant total effect is caused by independent latent variable Production Organization and Material Flow over latent variable Quality. When the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.582 units. Moreover, the former explains up to 32.8 % of the variability of the latter, since the value of the effect size is 0.328.
- The fourth most significant total effect is caused by the same independent latent variable Organization Production and Material Flow over latent dependent variable Human Resources. When the former increases its standard deviation by one unit, the standard deviation of the latter increases by 0.56 units. Also, the first latent variable explains 30.9 % of variability of the second latent variable, since the value of the effect is 0.309. Similar interpretations can be concluded for the remaining relations between variables.

Table 11.11 Total effects of model 2

	Lean techniques	Production organization and material flow	Human resources
Lean techniques		0.693 ($P < 0.001$) ES = 0.481	
Quality	0.479 ($P < 0.001$) ES = 0.312	0.582 ($P < 0.001$) ES = 0.328	0.666 ($P < 0.001$) ES = 0.545
Human resources	0.493 ($P < 0.001$) ES = 0.316	0.56 ($P < 0.001$) ES = 0.309	

11.3.2.6 Conclusions of Model 2

This model associated four latent variables, from which two of them belonged to JIT elements for production process, while the other two concerned benefits obtained after the implementation of JIT in production lines. It is assumed that Production Organization and Material Flow is the independent latent variable, while Quality of the final product was considered the dependent latent variable, since most latent variables had an effect on it. Moreover, from the six hypotheses initially raised, five were new and one (H1) had already been tested and discussed in the previous model. Finally, four from these new hypotheses were statistically significant and accepted, while one was statistically not significant and rejected.

Based on the results, it was proved that latent variable Production Organization and Material Flow is one of the most significant from a statistical point of view, since it has an effect on all others. However, its direct relation with Quality was not statistically significant, but indirect effects occurred between them through latent variable Lean Techniques and Human Resources. Therefore, production organization and material flow can have an impact on product quality if human resources properly implement and apply lean manufacturing techniques. Human resources here are crucial variable, since workforce is responsible for generating quality.

Finally, it was also observed that lean manufacturing techniques have a slightly low direct impact on quality; however, the total effect that the former causes on the latter is visibly high due to an indirect effect caused through human resources. Therefore, it can be stated that human resources are crucial to achieve the objectives of product quality.

11.4 Model 3: JIT Elements: Production Organization and Material Flow and Production Capacity and Inventory Management. Benefits: Material Handling and Economic Performance

This model also integrates four latent variables, from which two relate to JIT elements for the production process, while the other two latent variables concern benefits after a JIT implementation in production lines. Latent variables associated with JIT elements are:

- Production Organization and Material Flow
- Production Capacity and Inventory Management

On the other hand, latent variables associated with JIT benefits are:

- Material Handling
- Economic Performance

Six working hypotheses were proposed from the relation of these four latent variables. None of them has been previously analyzed. Moreover, this model

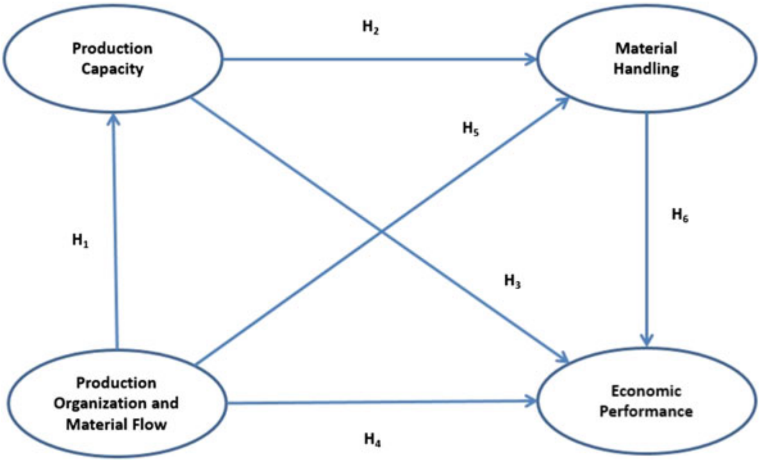

Fig. 11.5 Proposed model 3

assumes that surveyed maquiladoras have a defined and previously established organization of production and material handling and, as a consequence, all applied techniques and production schedules are based on production capacity of companies. Therefore, this latent variable is regarded as independent with an impact on all the others. Economic Performance is then considered the dependent variable since all other latent variables have a direct or indirect effect on it. Figure 11.5 depicts the model proposed with its six working hypotheses.

11.4.1 Proposed Model 3

Production planning is based on the production capacity and plant layout of every company, since when manufacturers produce above their capacity, they can compromise on-time delivery dates (Špicar and Januška 2015; Dong et al. 2015), or must outsource a portion of the amount order requested by the client and assume the risks it may entails (Gyulai et al. 2014). Thus, several manufacturing companies prefer scheduling production below their capacity to be able to fulfill the requested orders and avoid possible dissatisfaction from customers. However, since changes in the production system from one model to another can be expensive, companies must rely on high runs to prevent regular design changes, reduce the cost of production, and offer customers attractive discounts (Wu and Wu 2015; Jiang and Seidmann 2014).

Maquiladoras surveyed for this research are characterized by being highly specialized factories (Alcaraz et al. 2014; Sargent and Matthews 2009) that rely on advanced manufacturing technologies, either hard or soft. For instance, robots are employed for those movements of materials that can be dangerous or nonoptimal for people, while as for soft technologies, these companies generally implement systems of continuous improvement or Kaizen (Oropesa-Vento et al. 2015) and card systems or Kanban (Panayiotou and Cassandras 1999), which help improve the management of inventory in process and streamline the flow of materials. The implementation of these lean manufacturing techniques to support production processes is based on their production organization. Therefore, to support the relation between production organization and inventory management, it is possible to propose the following hypothesis.

H1: *Production organization and material flow have a positive and direct effect on production capacity and inventory management in a JIT environment.*

In addition to ensuring on-time deliveries of final product to customers, (Lagemann and Meier 2014; van der Laan et al. 1999), scheduling below production capacity can help reduce inventories and administrative costs due to high levels of inventory turnover (Kim and Ha 2003). Similarly, it allows companies to purchase small lots, which provides a direct—and perhaps closer—relationship with suppliers who must be integrated into the production system (David and Eben-Chaime 2003).

Moreover, although just-in-time philosophy focuses on minimizing inventories along the entire production system, one of its important elements is maintaining a safety stock that would help companies cope with possible sudden fluctuations in the demand (Amit et al. 2015; Hong et al. 2015) and prevent them from losing or rejecting an order due to missing parts or components. Similarly, the use of standardized containers for raw material components is crucial for JIT programs (Ji et al. 2015; Dong et al. 2015; Myung and Moon 2014), since it aims to minimize materials handling and accidents that might occur (Lortie 2012; Niskanen and Lauttalammi 1989), especially from mismanagement of raw materials or when they were not properly packaged. Therefore, in order to contribute to this discussion, the following working hypothesis was formulated.

H2: *Production capacity and inventory management have a direct and positive effect on benefits associated with materials handling in a successful JIT environment.*

It is traditionally stated that one of the major advantages of scheduling below installed capacity is that companies do not lose costumers due to late deliveries. However, the economic impact of this approach has been rarely analyzed, although it may be important (Pan and Nguyen 2015). That is, research has emphasized on the fact that companies do not lose costumers but little has been discussed about the economic costs of losing these costumers. Moreover, when the impact of safety stock on sudden changes in demand is analyzed, research tends to study the number of accepted orders rather than those rejected due to a lack of raw materials. Therefore, it may be suitable to direct research toward an analysis of the marginal profit of companies when they refuse these orders (Liberopoulos and Koukoumialos 2005; Lemak and Reed 1997).

The level of expertise of companies is also another important element to determine the production capacity to establish. Highly specialized industries are also high-technology industries that are suitable for mass production or to manufacture large lots or products with little variation (Teagarden et al. 1992). This favors the reduction of operating, production, and labor costs mainly due to automated machines found in the production line (Villa and Taurino 2013; Amasaka 2007), which also help minimize accidents of material handling, since robots become responsible for its management (Niskanen and Lauttalammi 1989). Based on this discussion, it is possible to propose the following hypothesis.

H3: *Production below capacity installed and inventory management have a direct and positive impact on the economic performance of the company in a successful JIT environment.*

Organizations seek to reduce material handling since it is a major source of accidents and fatal casualties (Nenonen 2011; Argilés-Bosch et al. 2014). Moreover, disability payments to workers can be high (Hajakbari and Minaei-Bidgoli 2014; Chinniah 2015; Fernández and Pérez 2015). Therefore, the planned flow of material must have an economic impact on the company; otherwise, it would not be justified unless it had implications associated with the health and safety of workers. Similarly, the cards system or Kanban can have an economic impact on companies, since it supports the flow of materials and thus increases inventory turnover. This allows for the proposal of two hypotheses.

H4: *Production organization and material flow have a direct and positive impact on the indexes of economic performance indices of companies within successful JIT environment.*
H5: *Production organization and material flow have a direct and positive effect on the reduction of inventories and accidents associated with materials handling. Moreover, they strengthen relationships between suppliers and the manufacturing companies and increases inventory turnover.*

Policies for inventory reduction that minimize material handling, favor the purchase of small lots, and encourage close relationships with suppliers, are also implemented since companies can obtain certain economic benefits. For instance, authors have widely discussed the economic impact of transmission and distribution systems and have pointed out that appropriate deliveries of raw materials and finished products can bring economic advantages (Arıkan et al. 2014; Schaefer and Konur 2015).

Inside companies, inventory reduction decreases the costs of its maintenance (Kouki and Jouini 2015; Avelar-Sosa et al. 2015). Similarly, effective relationships with suppliers may encourage collaboration to face uncertainty in demand (Chen and Jeter 2008; Humphreys et al. 2003; David and Eben-Chaime 2003), which can represent larger amounts of production orders accepted and not rejected due to missing components, which also increases economic performance. Likewise, successful relationships with suppliers allow for the procurement and purchase of small-sized lots (Kwak et al. 2006; David and Eben-Chaime 2003; Dong et al. 2001;

De Toni et al. 2000), which represent low inventory levels and a reduction in costs. Finally, little material handling implies that raw material is transported and moved only when it is necessary, since this transportation of raw materials does not add any value to the final product. Thus, raw materials should be moved only when they must be incorporated into a previously established activity. Kanban can certainly be useful in these cases. As a means to contribute to this discussion, the following hypothesis is proposed.

H6: *Benefits obtained in material handling in a JIT environment have a direct and positive impact on the economic performance of companies.*

11.4.2 Results of Model 3

Figure 11.6 introduces the results obtained after the evaluation of the model according to methodology described in Chap. 5. The two red segments indicate that these hypotheses or relations are statistically not significant, since their *P*-value of the statistical significance test was higher than 0.05, the maximum acceptable value for a 95 % confidence level.

11.4.2.1 Efficiency Indexes of Model 3

Before describing the direct and indirect effects of this model, it is necessary to determine whether it meets certain indexes of goodness of fit to accurately determine the existing relations between variables. Indexes are described below.

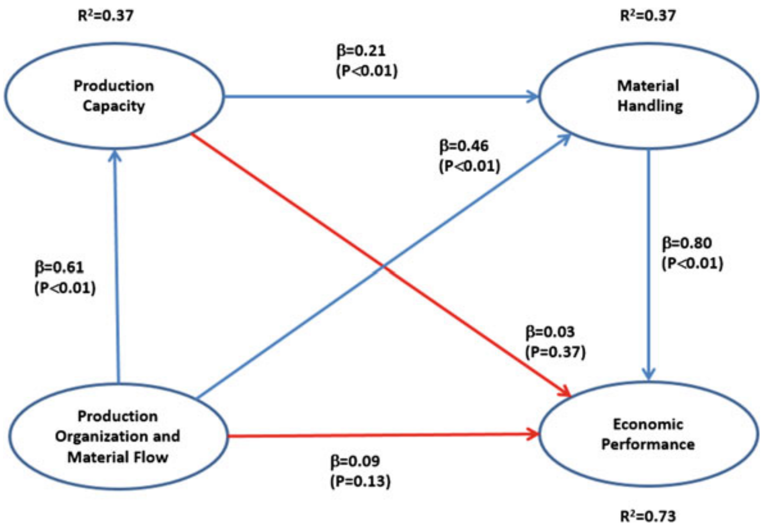

Fig. 11.6 Evaluated model 3—validation of hypotheses

1. Average path coefficient (APC) = 0.366, $P < 0.001$
2. Average R-squared (ARS) = 0.490, $P < 0.001$
3. Average adjusted R-squared (AARS) = 0.483, $P < 0.001$
4. Average block VIF (AVIF) = 1.603, acceptable if ≤5, ideally ≤3.3
5. Average full collinearity VIF (AFVIF) = 2.602, acceptable if ≤5, ideally ≤3.3
6. Tenenhaus GoF (GoF) = 0.549, small ≥0.1, medium ≥0.25, large ≥0.36
7. Sympson's paradox ratio (SPR) = 1.000, acceptable if ≥0.7, ideally = 1
8. R-squared contribution ratio (RSCR) = 1.000, acceptable if ≥0.9, ideally = 1
9. Statistical suppression ratio (SSR) = 1.000, acceptable if ≥0.7
10. Nonlinear bivariate causality direction ratio (NLBCDR) = 1.000, acceptable if ≥0.7

As for APC, ARS, and AARS indexes, we can conclude that the model has sufficient predictive validity, since *P*-values in these three cases were lower than 0.05, the maximum value accepted for a 95 % confidence level. Similarly, AVIF and AFVIF indexes show values lower than 3.3 units. Thus, it is concluded that there are no problems of collinearity between latent variables analyzed. In addition, note that the goodness of fit index of Tenenhaus has is considerably higher than 0.36, the minimum recommended value. Similar interpretations can be offered for the remaining indexes, which indicates that the model is appropriate and can be interpreted.

11.4.2.2 Coefficients of Latent Variables

Indexes above indicate that the model is in general efficient. However, it is also important to analyze latent variables separately. Thus, Table 11.12 shows validity indexes for every latent variable and allows for the interpretation of these indexes.

First, all latent variables show R-squared and adjusted R-squared values higher than 0.02, that is, the minimum acceptable value. Therefore, from a parametric point of view, all latent variables have enough predictive validity. Similarly, all

Table 11.12 Coefficient of latent variables—model 3

To	From			
	Capacity	Production organization and material flow	Material handling	Economic performance
R-squared	0.37		0.733	0.366
Adj. R-squared	0.366		0.727	0.357
Composite reliability	0.836	0.886	0.894	0.922
Cronbach's alpha	0.739	0.838	0.851	0.898
AVE	0.562	0.609	0.628	0.664
AFVIF	1.516	1.751	3.457	3.686
Q-squared	0.367		0.712	0.37

latent variables report Q-squared values higher than 0 and similar to R-squared values, which indicates that they have predictive validity from a nonparametric point of view.

Also, composite reliability and Cronbach's Alpha indexes in all cases show values higher than 0.7, the minimum acceptable value. Therefore, all latent variables of this model have enough internal reliability. Furthermore, AVE index in all cases is higher than 0.5. Thus, every latent variable has sufficient convergent validity. Finally, AVIF index shows values lower than 3.3, which indicates that there are no collinearity problems among variables analyzed.

11.4.2.3 Direct Effects

Figure 11.6 depicts the model proposed after its analysis and enables to interpret it as it follows:

- H1: There is enough statistical evidence to declare that production organization and material flow have a direct positive effect on production capacity and inventory management within a JIT environment. When the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable rises by 0.61 units.
- H2: There is sufficient statistical evidence to declare the production capacity and inventory management have a direct and positive effect on benefits of material handling in a successful JIT system, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.21 units.
- H3: There is not enough statistical evidence to declare that production capacity and inventory management have a direct and positive impact on the economic performance of companies in a successful JIT environment. The *P*-value obtained from the statistical significance test over the hypothesis was higher than 0.05, the maximum accepted value for a 95 % confidence level.
- H4: There is not enough statistical evidence to state that production organization and material flow have a direct and positive impact on the indexes of economic performance indexes of companies within a successful JIT implementation. The *P*-value obtained from the statistical significance test over the hypothesis exceeds 0.05, the maximum value allowed for a 95 % confidence level.
- H5: There is enough statistical evidence to point out that production organization and material flow have a direct and positive effect on the following aspects of Production Capacity and Inventory Management: reducing inventories and accidents, strengthening relationships between manufacturers and suppliers, and increasing inventory rotation. When the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable rises by 0.46 units.
- H6: There is enough statistical evidence to state that benefits of material handling in a JIT environment have a direct and positive impact on the economic

Table 11.13 Effect sizes of model 3

	Capacity	Production organization and material flow	Material handling
Capacity		0.37	
Economic performance	0.011	0.05	0.672
Material handling	0.1	0.266	

performance of companies, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.80 units.

Table 11.13 shows the effect sizes or amount of variability of dependent latent variables that is explained by independent variables. The table also allows for the interpretation of data.

- Latent variable called Production Capacity and Inventory Management is explained in 37 % by latent variable Production Organization and Material Flow.
- Latent variable Material Handling is explained in 37 % by two variables. Thus, Production Capacity and Inventory Maintenance can explain 10 %, while Production Organization and Material Flow explains 27 % of this variability.
- Latent variable Economic Performance can be 73 % explained by three latent variables. Thus, Production Capacity and Inventory Management explain 1.1 % of variability, while 5 % originates from Production Organization and Material Flow, and latent variable Material Handling can explain 67.2 %. Therefore, it can be stated that Material Handling has the most significant impact on the economic performance.

11.4.2.4 Sum of Indirect Effects of Model 3

Table 11.14 shows the sum of indirect effects of Model 3. All the estimated parameters are statistically significant, since the *P*-value in all cases is lower than 0.05, the maximum allowed value for a 95 % confidence level. The table also allows for the following conclusions:

Table 11.14 Sum of indirect effects of model 3

To	From	
	Capacity	Production organization and material flow
Economic performance	0.167 ($P = 0.002$) ES = 0.065	0.485 ($P = 0.004$) ES = 0.262
Material handling		0.127 ($P < 0.001$) ES = 0.074

- The largest indirect effect is caused by latent variable Production Organization and Material Flow over latent variable Economic Performance. When the first increases its standard deviation by one unit, the standard deviation of the second increases by 0.485 units. Moreover, the former latent variable explains up to 26.2 % of the variability of the latter.
- Production Organization and Material Flow has an indirect positive effect on latent variable Material Handling, because when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.127 units. Also, the first latent variable explains up to 7.4 % of variability of the second latent variable.
- Production Capacity and Inventory Management has an indirect and positive effect on Economic Performance, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable rises by 0.167 units. First latent variable can also explain up to 6.5 % of variability of the second latent variable.

11.4.2.5 Total Effects of Model 3

Table 11.15 shows the total effects from relations between variables and, according to it, all total effects are statistically significant, since the *P*-value of all estimated parameters was lower than 0.05, the maximum value accepted for a 95 % confidence level. The table also allows for the following interpretation of data:

- The largest total effect is also a direct effect caused by latent variable Material Handling over latent variable Economic Performance, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second variable increases by 0.8 units. This is also one of the highest values in the analyzed models, and the first latent variable explains 67 % of variability of the second latent variable.
- The second largest total effect is also a direct effect occurring from latent variable Production Organization and Material Flow over latent variable Production Capacity and Inventory Management, since when the former increases its standard deviation by one unit, the standard deviation of the latter

Table 11.15 Total effects of model 3

TO	From			
	Capacity	Production organization and material flow	Economic performance	Material handling
Capacity		0.608		
Economic performance	0.195	0.578		0.8
Material handling	0.209	0.585		

increases 0.608 units. Moreover, first latent variable explains 37 % of variability of second latent variable.

- The third largest total effect is caused by latent variable Production Organization and Material Flow over Economic Performance of companies, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second variable increases by 0.578 units. Moreover, the former latent variable accounts for 31.2 % of variability of the latter latent variable.
- The fourth total effect, according to its size, is caused by latent variable Production Organization and Material Flow over latent variable Material Handling, since when the first latent variable increases its standard deviation by one unit, the standard deviation of the second latent variable increases by 0.585 units. Moreover, the former latent variable explains up to 34 % of variability of the latter. Similar interpretations can be offered for the remaining relations between variables.

11.4.2.6 Conclusions of Model 3

This model associated four latent variables; two concerned JIT elements for the production process and two referred to benefits obtained from a successful JIT implementation. The results from the evaluation of the model, its hypotheses, and the relation among latent variables allow for the following final conclusions:

- Both latent variables Production Organization and Material Flow and Production Capacity and Inventory Management have no direct and positive effect on the financial performance of the company. The impacts are rather indirect through benefits associated with handling of materials, such as reduced material handling, close relationships between suppliers and manufacturers, increased inventory turnovers, and reduced lot sizes.
- Companies should always seek for benefits associated with material handling, since they have a direct and positive effect on their economic performance in a JIT environment.

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