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Role of quick setups on quality control in the Mexican maquiladora industry

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Abstract. The quick changeover in a production line facilitates the manufacture of small lots and a wide variety of products, where several variables must be controlled to optimize this process. This article presents a structural equation model relating three lean manufacturing tools as independent latent variables: quick setups, small lot production, and uniform production level, which are related to optimize a response variable: quality control. The variables are linked through six hypotheses and validated with the partial least squares technique that is integrated into the WarpPLS 6.0 software. The model is validated with data from 220 responses to a questionnaire applied to the manufacturing industry in northern Mexico. Findings indicate that a quick changeover guarantees small lots, better customization of standardized products, and appropriate quality for the customer by optimizing the production and delivery time.
Keywords: Manufacturing industry, Quick Changeover, Small lot production, Quality control

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1 Introduction

The stability and success of the Mexican manufacturing sector provide low cost goods for consumers in the United States of America (USA), which is a source of income for their companies as well as a tax base for their government [1]. These benefits are presented because several subsidiary companies from USA companies operating as maquiladoras, that are well known as "shared production" or "twin plants" are manufacturing or processing facilities located in Mexico along the border with the USA [2]. The maquiladora program in Mexico began in 1965 when the Mexican government invited American manufacturers requiring high hand labor to move into Mexico, which has allowed foreign companies to own and operate subsidiary companies. These maquiladora companies are characterized by a high level in raw material importation and finished products exportation, but with preferential tariff rates [2].

According to the National Institute of Statistics and Geography (INEGI), in March 2019, there are 5,115 maquiladora companies in Mexico registered in the Manufacturing Maquiladora and Export Services Industries (IMMEX). In northern Mexico, where there are the most manufacturing cities with maquiladora companies, with 1421 in total (27.78%), specifically, Chihuahua state has 505 companies while Ciudad Juarez has 329, where the maquiladora sector is a fundamental aspect, because the Mexican Institute of Social Security (IMMS) reports that they employ 305,313 direct jobs. In fact, the maquiladora industry is a direct source of foreign investment; in 2018 in Chihuahua state, that investment was 1138 million dollars, where the principal investors were the USA with 71.6%, Canada with 9.6%, the United Kingdom with 7.5%, and Spain with 7.2%.

Maquiladoras seek to optimize production methods as well as enable themselves to be competitive, flexible, as well as respond quickly to customer demands with a variety in products [3], as a result, lean production principles based on customer requirements are implemented, because companies are forced to produce smaller and customized lots; however, the production of products in small lots results in more changes in the production lines by producing setups from one product to another, which means that machines and operators must be idle [4]. Therefore, they must adopt Lean Manufacturing (LM) methodologies, such as Single Minute Exchange of Die (SMED), which is the process of changing production from one machine to another by changing tooling, waste, or accessories in less than

10 minutes, in this way, a better flexibility is obtained as well as the production processes are optimized with low setup times [5].

Therefore, SMED as an LM tool provides manufacturers a competitive advantage by reducing costs, improving productivity, quality, eliminates waste in appropriate spaces for machines and operators, gives flexibility and agility to small lots, and optimizes resources [6]. Also, Singh Sangwan and Bhamu [7] declare that the SMED benefits are associated with improved timeout production, processing time, cycle time, setup times, inventory levels, defects levels and waste, as well as effectiveness in the whole equipment. As a matter of fact, Zhang, Narkhede [8] mention that the reduction of lot sizes are associated with lower inventories, better quality, reduction of re-work, greater productivity and flexibility, lower space requirements, increment in general investments and manufacturing costs, as well as shorter delivery times Singh Sangwan and Bhamu [7]. Also, SMED and small lot sizes offer qualitative benefits including improved employee morale, effective communication, job satisfaction, standardized maintenance, and team decision-making, a better relationship with suppliers, production planning and control, increase capacity, better use of human resources, and a better variation of products. In other words, these tools help to optimize the companies' operations.

Similarly, the benefits gained from SMED are highly desired by manufacturing managers, since they improve the efficiency in the company, which has convinced them to apply it. However, the quantitative impact that SMED has on the benefits obtained for the company is limited; consequently, the literature review reports mainly qualitative associations [7]. For example, Díaz-Reza, García-Alcaraz [9] present a structural equation model (SEM) that integrates the four stages required for the SMED implementation, which indicates that the planning stage is the most essential. Also, Díaz-Reza, García-Alcaraz [10] report in another SEM how to measure the relationships between the SMED stages and the operational benefits, such as delivery time and accepted production orders.

Moreover, another issue is that SMED is not an isolated technique, since it needs support from others LM techniques or practices to guarantee the benefits for the company. Chen, Fan [11] indicate that SMED has a direct relationship with six sigma and quality, buy they did not measure it; Brito, Ramos [12] report a SMED and ergonomics combination for the industrial safety and hygiene; a more complete report is described by Stadnicka [13] that reports several combinations along with the lean manufacturing.

In order to contribute to this research area, the present paper is aimed to report an SEM that integrates three independent latent variables: Quick setups, Small lot production, Uniform production level, and as dependent variable, Quality control; variables that have never been analyzed before with SMED. Therefore, production managers will acknowledge a tangible relationship between those variables, where their effort and resources in critical success variables will be considered to guarantee a specific benefit, facilitating the resource optimization as well as the decision-making process.

The present paper is organized as follows; after this brief introduction, section 2 addresses a literature review related to the analyzed variables, as well as the proposed relationships between them that are shown as hypotheses, section 3 presents the methodology implemented to statistically validate the hypotheses, section 4 displays the results obtained, and finally, section 5 reports the findings and industrial implications.

2 Literature review and hypotheses

2.1 Quick setup (QS)

Nowadays, the market is demanding customized and a wide variety of products at a low cost, therefore, companies in order to survive this competitive market, they must perform quick setups on machines to reduce their *setup* time [14], consequently, they rely on an LM tool called SMED, which main objective is to reduce the idle time on machines and operators while changing production lines from one product to another. Specially, it intends to perform these changes while the equipment is operating in order to simplify subsequent activities, where two types of activities are identified; internal and external. The internal activities are those that are carried out only when the machine is not working, while the external activities can be performed while the machine is operating.

The SMED philosophy consists of four conceptual stages that are related to practical steps [15]: preliminary stage: external and internal activities are not separated, first stage: internal activities are separated from external activities, second stage: elements previously considered as part of internal activities are transformed into external activities, and third stage: each elementary operation for external and internal activities are improvements.

Lozano, Saenz-Díez [16] declare that short *setup* times facilitate the production in a small size lot, reduce wasting *setups,* decrease the labor cost, make the production system more flexible, reduce the product delivery time, improve productivity, as well as the active use and inventory reduction. For instance, Singh, Singh [14] report a case of study indicating that SMED reduces the *setup* time in 20.2% for the production process, and increases efficiency in equipment in 4%; Ciarapica, Mazzuto [17] report a SMED combination with other LM tools in the pharmaceutical industry, where findings indicate that the average *setup* time was reduced from 897 min to 345 min. In addition, Ekincioğlu and Boran [4] integrate SMED and diffuse the Taguchi method reporting that the *setup* time was reduced by 61.7%. However, SMED has also been implemented to reduce small stoppages as well as to improve the overall equipment efficiency [18].

In order to analyze if SMED is implemented in the maquiladora sector, the following items are validated [9-13, 16, 19]:

- Production employees perform their own machine setups.
- Is it focused on reducing machines setup times?
- Is it emphasized to place each tool in a normal storage location?
- Production employees do not have any trouble in finding the required equipment.
- Are production employees trained in machine setup activities?
- Could machine setups be performed quickly if there is a change in the process requirements?

2.2 Small lot production (SLP)

The lot production of highly customized products requires low production volumes [20]; although, a manufacturer may prefer to produce large size lots, but the consequence of having large inventories will be an increment in storage costs [21] therefore, the just-in-time (JIT) purchase will require frequent deliveries in small lots from nearby suppliers in order to avoid inventory accumulation [22]. In fact, for JIT suppliers, the shipping of small quantities according to the manufacturer needs will require a flexible production and transportation process, as well as a high cost [23].

In order to know if a company is working with small lots, the following items are analyzed [20-22]: 1. Is it producing frequently but with smaller lot sizes?, 2. Is it emphasized in producing a small number of items together in a lot?, 3. Is it focusing on reducing production lot sizes?, 4. Are products received from small lot suppliers with frequent deliveries?, 5. Is the production process strictly aimed to avoid the flow of one type of item in large quantities as well?.

In addition, the *setup* time is the type of time that is required to produce the last item in a particular lot to produce the first item in the next lot [24]. In general, reducing the *setup* time facilitates the small lot size production performance [25], because the company can make changes frequently. In fact, by reducing the size lots that are justified by low *setup* times, the runtime will directly decrease, in the same way, the improvements based in learning *setup* times and reworks will progressively allow to produce smaller lots and generate more profits in the supply chain [26]. Therefore, the following hypothesis can be proposed:

H_1: *Quick setups* in a production line for the maquiladora industry has a direct effect on the *Small lot production.*

2.3 Uniform production level (UPL)

Lean production lines attempt to maintain uniform production levels according to a metric or variable [27], which means that there is a production control; however, in order to achieve it, companies need personnel, equipment, and material needs. UPL is a method that defines the manufacturing sequence of several products in a mixed manufacturing model, mainly to balance production, improve efficiency and flexibility by eliminating waste as well as minimizing differences in workloads stations [28].

Furthermore, the principal idea about the workload control is to maintain the work in process (WIP) in the manufacturing system to the desired level, mainly by balancing orders and availability; however, the production flow created by the *pull* system, *kanbans*, small lots, and fast *setups* are only sustainable if production is relatively constant. Also, with a steady and uniform production level program, the same quantity is established for a product in each production line, where the production line is performed in regularly scheduled intervals [29].

The UPL implementation is reported by Bohnen, Maschek [30], who applied a clustering technique to separate different type of products in groups to generate a pattern based on the leveling product family, on the other hand, Grimaud, Dolgui [31] present an approach to managing the size lot that is controlled by *heijunka* through a smooth exponential.

In order to measure if a company is applying UPL, the following aspects are considered: 1. A more accurate forecast to reduce variability in production is emphasized, 2. Each product is assembled in a relatively fixed quantity per production period, 3. It is emphasized to equate workloads in each production process, 4. Daily production of different product models is arranged in the same ratio along with the monthly demand, and 5. By repeating the same combination of products from day to day is emphasized.

In conclusion, the key to success in manufacturing companies is to create a more agile, flexible, and responsive environment to apply a quick changeover from one product to another, since long changes make it almost impossible to run small lots of parts that are synchronized with the customers' demand. Thus, an efficient production level in terms of volume and mixing is crucial to eliminate overproduction, which is one of the fundamental objectives of lean manufacturing, as a result, *Heijunka* is implemented, and in this way overproduction is eliminated [32]; therefore, the manufacturing processes must achieve a production level using the takt time to synchronize them with sales, which is achieved through *setup* changes [33] that decrease the size lot and process variability [34]. Consequently, the following hypothesis can be proposed:

H_2: *Quick setups* in a production line for the maquiladora industry has a direct effect on the *Uniform production level.*

In order to balance the production loads, the company must be connected to materials flow, which involves working with one product at a time by mixing similar products with different codes within the same process [35]. *Heijunka* allows to dictate the production sequences of small lots, which would be inefficient without fast setups, because its main goal is to supply one or more customer processes with a constant flow in small lots and different parts, as well as generating continual part demands for upstream processes, reducing or eliminating the need for reserving capacity or stocks to cope with peaks of demand [36]. The diversity in product combination requires that any change between elements must be extremely simple and quick to guarantee a low inventory; however, this requires low *setup* times for a better delivery time, lot size production, and low WIP. In other words, a small lot production can generate a uniform production [37]. Therefore, the following hypothesis is proposed:

H_3: A *Small lot production* for the maquiladora industry has a direct effect on the *Uniform production level.*

2.4 Quality control (QC)

As a matter of fact, with intense global competition, QC becomes a critical challenge for the layout and manufacturing in the industry. Employees who receive extensive training in statistical methods can identify quality problems and improve them, since they can monitor and control the production [38]. Industrial statistical methods applied to QC help to reduce costs, increase production, improve and maintain the quality, where an essential tool is the statistical process control, which is used to detect uncontrolled conditions that may affect the product variation [39].

Therefore, the production systems must be designed considering the visible quality and instructions for the employee using *poka- yoke*, which is a device or mechanism that prevents defects [40]. Then, the quality improves when problems become visible, and employees are able to detect them quickly, as well as track them to their main source and finally fix them. Thus, QC allows to take advantage to see, understand, and react to any type of breakdown in a convenient and quick manner.

In this research, the following items are used to measure the QC: 1. Visual control systems are implemented, (such as andon/line-stop alarm lights, level indicators, warning signals, signboards, etc.) as a mechanism to make problems visible, 2. Quality problems can be traced to their source easily, 3. There are quality focused teams that meet each other regularly to discuss quality issues, and 4. Production employees are trained in quality control.

The importance of minimizing *setup* times relies on maximizing the production capacity and minimizing wastes [41]. The improved performance of *setups* will include faster and better changes, which arise by paying attention to quality in every change, because that type of quality affects the waste level, efficiency, and reliability [42]. In fact, the speed and agility required in the production system are based on training for employees, as well as on the use of visual aids that allow them to take decisions quickly [43]. In that sense, the following hypothesis is proposed:
H_4: *Quick setups* in a production line for a maquiladora has a direct effect on *Quality control.*

Similarly, the principal objective for a small lot is to minimize the inventory investment, reduce production time, downtimes and interruptions due to *setup* times, react quickly to changes in demand, and find any type of quality problems [44]. Small lots reduce variability in the system as it smooths production, improve quality, simplify programming, reduce inventory, enable Kanban, and encourage continuous improvement [45]. In addition, the small lot size is characterized by the reduction in *setups,* low reprocessing, and interruptions levels that may affect quality [46].

Likewise, in environments with a single workstation is easier to observe how quality, failure times, and repairments decrease with a small lot size [47]. Therefore, producing in smaller lots encourages a better quality [48], and the following hypothesis is proposed :

H_5: A *Small lot production* in a production line facilitates *Quality control* in product and processes.

In order to avoid overproduction, it is fundamental to implement Kanban to define the amount of products that are required by several processes to obtain benefits, such as increased flexibility in responding to customers' demands, small mixed lots, the simplification of information into production system, more processes integration, and the overproduction elimination [35]. In that case, Heijunka is compatible with the standardized work, where kaizen admits a fast adaptation to fluctuating in demand [49]. The uniform production level minimizes uncertainty, reduce costs, improve capacity utilization, and produce a better product quality and customer service. Kanban and Heijunka depend on performing quick changes in setups, visual management, capable processes with efficient methods of standardized work, which provides and help to apply jidoka to minimize and retain defects, as well as it depends on versatile employees to solve problems, and finally, it depends on having the appropriate machinery in the industry [50]. In that sense, the following hypothesis can be proposed:

H_6: A *Uniform production lot* in a production line is a precedent for *Quality control*.

In Figure 1, the six hypotheses previously defined are shown.

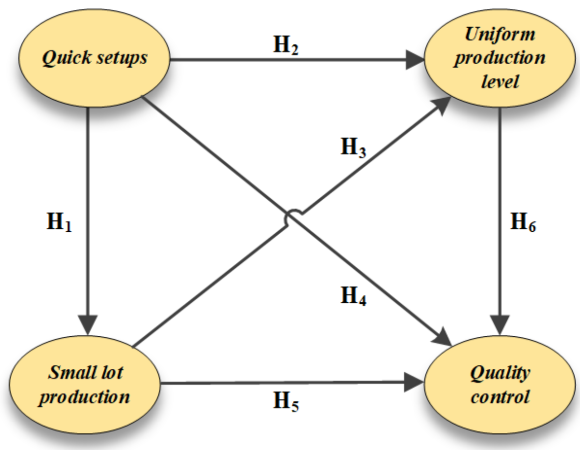

Figure 1. Proposed model

3 Methodology

In the following section, the methodology that is used to validate the hypotheses from Figure 1 is described.

4.1 Questionnaire design

In order to validate the hypotheses, it is required to collect data from maquiladora industries, therefore a questionnaire proposed by Nawanir, Lim [51] is used, which is integrated by 64 items divided into 10 constructs (latent variables), which is answered with a Likert scale between one and six [52], where number 1 (strongly disagree) while number 6 (strongly agree). Also, another section is added to gather demographic data about the company and responders, as well as the participant industrial sector, years of experience, job position, and gender.

In fact, it is important to mention that only four variables; *QS, SLP, UPL,* and *QC* are included in the model presented in this article while the other eight variables will be analyzed in another report.

4.2 Questionnaire application

The questionnaire was applied in the Mexican maquiladora sector, which was focused on managers, engineers, technicians, and production supervisors. The participants respond the questionnaire in a face to face interview; they must have at least 2 years of experience, because that allows to have a stratified sample; however, participants suggested some colleagues, therefore the snowball technique was applied.

4.2 Data debugging and registration

Data was registered in a database into the SPSS 24® software to debug it through the following steps [53]:

- Non-committed participants are identified through the standard deviation estimation in each questionnaire; if that value is lower than 0.5, then that questionnaire is not considered.
- Missing values are identified; if the percentage is greater than 10%, then the questionnaire is not considered, otherwise, the values are replaced by the median for each item.
- Extreme values are identified through the standardization in items; if the absolute value is greater than 4, then it is an extreme value which is replaced by the median.

4.3 Questionnaire validation

In order to validate the latent variables in Figure 1, different type of indexes are used, which were proposed by Kock [54]. In addition, to estimate the predictive parametric validity the R-squared and Adj R-squared values were used, where the minimum acceptable value is 0.2, in order to measure the predictive non-parametric validity the Q-squared index is used, where the recommended minimum value must be greater than zero and similar to the R-squared. Also, the internal validity is measured through the Cronbach's Alpha index and the Composite reliability, where the recommended minimum value is 0.7 [55]. The convergent validity was measured through the Average Variance Extracted (AVE), which estimates the variance from its indicators which minimum acceptable value is 0.5. Finally, the Variance Inflation Factor (VIF) index is used to measure collinearity, where values must be under 5.

4.4 Structural equation model

The (SEM) technique is used to validate the proposed hypotheses from Figure 1, which is widely used in behavioral sciences, which is a combination of factorial analysis and route regression analysis [56]. In the SEM, there are observed and latent variables, the observed variables are estimated directly, while the latent variables must be measured using the observed variables or items [57]. Also, analysis allows the latent variable to have a double role, as dependent and independent, like it is portrayed in Figure 1. In this case, the partial least square (PLS) technique is used that is integrated into the WarpPLS 6® software, which is widely recommended for ordinal, non-normal data distribution, and with small samples size. The model is validated with 95% of statistical confidence, therefore, it implies that the p-values associated with β must be lower than 0.05. Also, before interpreting the SEM, the following quality indexes proposed by Kock [54] were measured:

- Average path coefficient (APC) for the predictive validity of the model, where the p-value must be lower than 0.05.
- Average R-squared (ARS) and average adjusted R-squared (AARS) to measure the predictive validity, where p-values must be lower than 0.05.
- Average variance inflation factor (AVIF) and average full collinearity VIF (AFVIF) to measure the collinearity among the latent variables, which must have values lower than 5.
- Tenenhaus goodness of fit (GoF) to measure the data adjustment to the model, which must be greater than 0.36.

4.4.1 *Effects in SEM*

In the SEM, three different effects among the variables were measured; the direct, the indirect, and the total effects [58, 59]. The direct effects allow to validate the hypotheses in Figure 1, the indirect effects measure the relationships among variables where there are mediating variables, and the total effects are the sum of the indirect and direct effects.

4 Results

4.1 *Description of the sample*

Table 1 illustrates a sample description, where it is observed that the automotive sector has 71 responses, the medical sector 25, and so on. Similarly, it is observed that the job position with more participation is supervisors with 81 responses, operators with 29, managers with 25, and so on.

Table 1. Description of the sample

	Manager	Engineer	Supervisor	Technician	Operador	Total	Percentage
Automotive	11	1	32	20	7	71	37.6
Other	8	1	12	7	11	39	20.6
Medical	1	2	15	7	0	25	13.2
Machinery	0	1	4	7	8	20	10.6
Electronics	3	0	9	4	2	18	9.5
Electrical	1	0	5	3	0	9	4.8
Logistics	1	0	4	1	1	7	3.7
Total	25	5	81	49	29	189	

4.2 *Validation of latent variables*

Table 2 illustrates the validation for each latent variable, where it can be observed that based on the *R-squared* and *adj R-squared* values, there is enough predictive parametric validity, since the values are greater than 0.2, as a result, the Q-squared values are greater than zero, and it can be said that there is enough non-parametric predictive validity as well. Likewise, according to the Cronbach's Alpha values and the Composite reliability, it is observed that each variable has enough internal validity, since their values are greater than 0.7. Regarding the converge validity, each variable has an AVE value greater than 0.5, which is the minimum recommended value. Finally, there are no collinearity problems, since the AVIF values are lower than 5.

Table 2. Latent variables coefficients

	Quality control	*Quick setups*	*Small lot production*	*Uniform production level*
R-squared	0.455		0.084	0.214
Adj. R-squared	0.448		0.079	0.207
Composite reliability	0.859	0.861	0.860	0.866
Coronbach's alpha	0.794	0.805	0.797	0.805
Avg. Var. Extrac	0.549	0.509	0.552	0.566
Full collin.VIF	1.762	1.454	1.087	1.607
Q-squared	0.458		0.082	0.219

4.3 Structural equation model

In Figure 2, the evaluated model is presented, where the direct effects representing the six hypotheses are portrayed by arrows; five of them have a p-value lower than 0.05, which indicates that they are statistically significant. In Table 3, the quality indexes and model fit are illustrated, based on the p-value associated with the APC, ARS, and AARS indexes, it is concluded that there is enough predictive validity. Regarding the AVIF index, it can be stated that there are no collinearity problems in the model, which has enough explanatory power. Based on the previous information, the SEM interpretation can be described.

Table 3. Model fit and quality indexes

Index	**P-Value**	**Value**
Average path coefficient	P < 0.001	0.277
Average R-squared	P < 0.001	0.251
Adjusted R-squared	P < 0.001	0.245
Average variance inflation factor		1.172
average full collinearity VIF		1.478
Tenenhaus goodness of fit		0.37

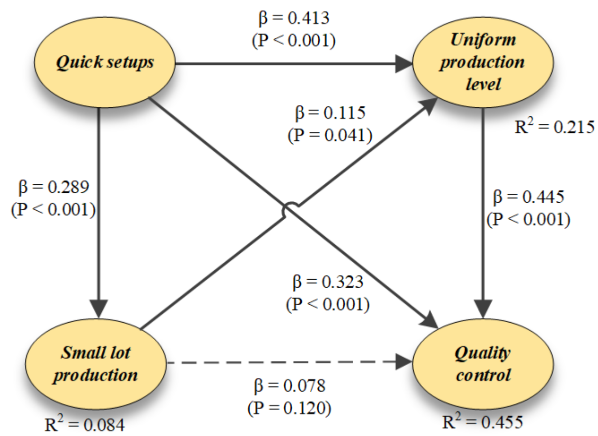

Figure 2. Evaluated model

4.4 *Direct, indirect, and total effects*

Table 4 illustrates a summary of the indirect effect and the conclusions on the proposed hypotheses. It is observed that according to the p-value, five hypotheses are accepted while only one is rejected. For instance, regarding to the hypothesis H_1, it is concluded that there is enough statistical evidence to declare that *Quick setups* facilitate production as well as it is a direct precedent of the *Small lot production*, since when the first variable increases its standard deviation in one unit, the second variable increases in 0.289 units, therefore, similar interpretations can be made with the other hypotheses.

In the same way, in Figure 2, the R^2 values in dependent variables are showed. Specifically, it is observed that the *Small lot production* has a $R^2 = 0.084$ value, which is explained by *Quick setups*, whereas the *Uniform production level* has an $R^2 = 0.215$ value, which is explained by *Quick setups* in 0.186 as well as by the *Small lot production* in 0.029, where it is indicated that the first variable is the most important. Finally, the *Quality control* has an $R^2 =$ 0.455 value, where 0.17 is due to *Quick setups*, 0.021 due to the *Small lot production*, and 0.263 due the *Uniform production level*.

Table 4. Direct effects and conclusions of the hypotheses

H_i	**Independent variable**	**Dependent variable**	**β-vaue**	**P -value**	**Conclusion**
H_1	*Quick setups*	*Small lot production*	0.289	<0.001	Accepted
H_2	*Quick setups*	*Uniform production level*	0.413	<0.001	Accepted
H_3	*Small lot Production*	*Uniform production level*	0.115	0.041	Accepted
H_4	*Quick setups*	*Quality control*	0.323	<0.001	Accepted
H_5	*Small lot production*	*Quality control*	0.078	0.120	Rejected
H_6	*Uniform production level*	*Quality control*	0.445	<0.001	Accepted

Furthermore, Table 5 portrays the three indirect effects among variables, their associate p-value, and the size effect (SE). It is observed that only the indirect effect between *Quick setups* and *Quality control* is statistically significant with a 0.117 value, while two indirect effects are not, since their associated p-value is greater than 0.05.

Table 5. Total Indirect effects

	Quick setups	*Small lot production*
Quality control	0.221 P < 0.001 ES = 0.117	0.051 P = 0.139 ES = 0.013
Uniform production level	0.033 P = 0.241 ES = 0.015	

Similarly, Table 6 presents the total effects, where it is observed that although two indirect effects were statistically non-significant when they are added to the direct effects, they become significant. Also, the size effect (SE) value is indicated, where it is demonstrated that all of them have a suitable explanatory power.

Table 6. Total effects

	Quick setups	*Small lot production*	*Uniform production level*
Quality control	0.544 P < 0.001 ES = 0.289	0.130 P = 0.025 ES = 0.034	0.445 P < 0.001 ES = 0.263
Small lot production	0.289 P < 0.001 ES = 0.084		
Uniform production level	0.446 P < 0.001 ES = 0.201	0.115 P = 0.041 ES = 0.029	

5 Discussion and industrial implications

As it can be observed in Figure 1, *Quick setups* are presented as an independent variable, where according to the maquiladora industrial sector in northern Mexico, specifically in Ciudad Juarez, the following can be concluded:

- The appropriate implementation of *Quick setups* has a direct and positive effect on the *Small lot production* with 0.289, which means that, as long as employees perform their tasks correctly on *Quick setups*, a *Small lot production* can be obtained, as Dupernex, Burcher [60] and Filho [34] have declared. Similarly, *Quick setups* improve the flexibility process, which agrees with what Pannesi [61] has mentioned.
- Also, *Quick setups* have a direct effect and facilitate the *Uniform production level* in a production line, and this agree with Deif and ElMaraghy [33], who claim that in order to have a balanced production level by implementing the takt time through the synchronizing of the production flow and sales, where it is crucial to integrate *Quick setups*, while Braglia, Frosolini [62] declare that delays in that process of change make difficult to have a *Small lot production* and synchronization with the customer resulting in losing flexibility.
- The *Small lot production* facilitates the *Uniform production level*, which means that producing small lots contributes in a small but in a significant manner to reduce the production variability, to balance work in production processed, to produce the same products according to monthly demands, as well as producing the same amount of products daily, In fact, the previous information coincides with Matzka, Di Mascolo [36], who indicate that the principal objective of *Heijunka* is to provide one or more processes to customers with a consistent small lots flow, as well as generate a regular demand of products.
- *Quick setups* have a direct effect as well as it is precedent of *Quality control,* where it can be stated that it is crucial that employees are trained regarding the SMED methodology and *Quality control*, since when there are an appropriate training and knowledge, it can be easier to track quality problems to the source, which allows performing a suitable customization in each setting to reduce waste and increment efficiency and reliability [63]. In this sense, these results are similar to Schonberger [64], who argues that *Quick setups* contribute to increasing the quality of a product through the required level control that is needed in the manufacturing system.

- *Small lot production* has no direct effect on *Quality control*. Specifically, there is a contradiction with Vörös and Rappai [46] who stablish that the size lots are characterized by time reduction in setups.
- The *Uniform production level* supports and facilitates *Quality control*. In other words, the production level is appropriate due to the implementation of tools as *Kanban,* which helps to assemble the right quantity of products that may be produced, *heiyunka* that benefits the *Small lot production* sequence through *Quick setups, kaizen* that cooperates to have continuous improvement, and finally, *jidoka* that contributes to the reduction and moderation of defects in order to improve *Quality control.*

Finally, the SEM that is reported has the limitation of being validated using information from the Mexican maquiladora industrial sector, therefore, other regions with a different culture and context may provide another type of findings; however, this SEM is presenting a general idea about the relationships among quick setups, small lot production, uniform production level, and quality control in a production line.

6. Conclusions

As a matter of fact, it is important that, within the maquiladora companies of northern Mexico, managers make sure that when a machine setup finishes, employees perform the required tasks quickly and appropriately, since, when there is an extremely variety of products, these changes are needed more frequently. Therefore, a process in which changes are done frequently, it means that there is a flexible process, which is able to adapt itself to fluctuations in demand. In this sense, rapid changes contribute to the production of small lots, which facilitates the production level. In the same way, managers must ensure that within the production processes, the products are manufactured in the correct amount, and that the setup changes in machines are performed in an appropriate manner, since this contributes to quality control in processes and products.

Finally, it is essential to mention that the SEM presented in this paper reports the relationship between four lean manufacturing tools or methodologies (latent variables) while the survey originally includes twelve, consequently, for future research it will be intended to address another type of relationships involving another tools, such as; pull system, cellular layout, total productive maintenance, among others.

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