

<https://doi.org/10.23913/ride.v13i26.1497>

Artículos científicos

Factores Críticos del Éxito de Proyectos Seis Sigma y de Manufactura Esbelta

Critical Success Factors of Six Sigma and Lean Manufacturing Projects

Fatores Críticos de Sucesso de Projetos Six Sigma e Lean Manufacturing

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Resumen

La literatura de factores de la eficiencia de proyectos de Manufactura Esbelta y Seis Sigma es extensa, incluye reportes de sus cuestionables resultados y se observa la falta de explicaciones razonables, objetivas ellos. En la búsqueda de los factores de los proyectos ME/SS la literatura no es concluyente. Por ello, el objetivo de este proyecto de investigación es determinar esos factores. Para ese propósito, se realizó una revisión de literatura, determinado una lista de 29 factores en 48 artículos, dicha lista se redujo a 21 por Meta-Análisis. Con los factores se construyó un cuestionario, con 4 constructos y 25 indicadores, mismo que se validó con las pruebas de KMO y Bartlett. El cuestionario se aplicó a una muestra de 225 ingenieros con experiencia en proyectos de ME/SS desarrollados en plantas industriales que operan tecnologías de alto nivel. La especificación del modelo estructural inicia con un Análisis Factorial Exploratorio con rotación oblicua y por el método de Componentes Principales con rotación Promax y se aplicaron varios indicadores para la evaluación empírica. Se determinaron los factores críticos del éxito de proyectos de ME/SS y se comprobó la bondad de los métodos de ecuaciones estructurales. Se presenta y discute el modelo estructural y sus componentes.

Palabras Clave: Análisis Factorial, Factores Críticos del Éxito, Manufactura Esbelta, Modelado con Ecuaciones Estructurales, Seis Sigma.

Abstract

Literature is extensive regarding the increases of efficiency by Six Sigma and Lean Manufacturing (SS/LM) projects, including reports of questionable results and the lack of reasonable explanations about those cases. In the search of the factors influencing the success of the projects, the literature is inconclusive. Therefore, the objective of this work is to determine the factors influencing the success of those projects. For which, a literature review was carried out finding that 48 publications gave a list of 29 factors, which is reduced to 21 by a Meta-Analysis study. These factors are used for the development of a questionnaire with 4 constructs and 25 indicators, which is validated with KMO and Bartlett's tests. To identify the factors used in the industrial practice and their contributions to success, the questionnaire was applied to a sample of 225 engineers with experience in Six Sigma and Lean Manufacturing projects working in high tech manufacturing companies. The specification of the structural model starts with an exploratory factorial analysis-oblique rotation and the method of Principal

Axes with Promax rotation, afterward for the empirical evaluation several indexes were used. The critical success factors and the usefulness of SEM for these purposes were determined. The structural model and its components are presented in this paper.

Keywords: critical success factors, factor analysis, lean manufacturing, six sigma, structural equations modeling.

Resumo

A literatura sobre os fatores de eficiência do projeto Lean Manufacturing e Seis Sigma é extensa, inclui relatórios de seus resultados questionáveis e carece de explicações razoáveis e objetivas para eles. Na busca dos fatores dos projetos ME/SS, a literatura não é conclusiva. Portanto, o objetivo deste projeto de pesquisa é determinar esses fatores. Para tanto, foi realizada uma revisão da literatura, determinando uma lista de 29 fatores em 48 artigos, esta lista foi reduzida para 21 por Meta-Análise. Foi construído um questionário com os fatores, com 4 construtos e 25 indicadores, o qual foi validado com os testes KMO e Bartlett. O questionário foi aplicado a uma amostra de 225 engenheiros com experiência em projetos de ME/SS desenvolvidos em plantas industriais que operam tecnologias de alto nível. A especificação do modelo estrutural inicia-se com uma Análise Exploratória de Fatores com rotação oblíqua e pelo método de Componentes Principais com rotação Promax e vários indicadores foram aplicados para avaliação empírica. Foram determinados os fatores críticos para o sucesso de projetos de ME/SS e verificada a qualidade dos métodos de equações estruturais. O modelo estrutural e seus componentes são apresentados e discutidos.

Palavras-chave: Análise Fatorial, Fatores Críticos de Sucesso, Manufatura Enxuta, Modelagem de Equações Estruturais, Seis Sigma.

Fecha Recepción: Junio 2022

Fecha Aceptación: Diciembre 2022

Introduction

Global companies face intense pressures due to several factors, like the high rivalry for market share, higher quality, and more strict legislation for the protection of the environment. Companies must respond by increasing their competitiveness with better quality, higher productivity, and innovative technologies. Among the strategies deployed for these purposes are the applications of Six Sigma (SS) and Lean Manufacturing (LM) projects.

Six Sigma is a methodology based on a set of quality improvement techniques and statistical methods applied by highly trained work teams focused on finding the causes of variation in a process and applying the corrective measures needed for its reduction. This methodology is applied in five stages: Define, Measure, Analysis, Improve, and Control, these stages include a high diversity of contents and applications (Erdogan and Canatan, 2015). Lean Manufacturing is a methodology and a set of techniques based on Just in Time and Total Quality Management for the systematic identification and elimination of waste activities, organizing people on a continuous search for improvement (Phan et al., 2019), it is a tool to improve the operational performance of industrial processes (Zhang et al., 2020).

In manufacturing environments SS and LM projects improve product technologies, production equipment, and processes; enhance innovation and technology capabilities, leading to the creation and development of competitiveness (Swarnakar, Singh, and Tiwari, 2019) and deployment of the company's strategy (Osorio et al., 2014). Commonly, their success is measured by the benefits, times, costs, quality, or productivity. In Ciudad Juarez 400 plus maquiladora industrial plants SS/LM projects are a standard for the improvement of quality and productivity, nonetheless, also are reports of lesser than expected benefits. That is why it is important to determine the factors influencing the success of those projects.

The remaining part of this study is structured in five sections, as follows: the second section is devoted to the review of the literature about the factors of Six Sigma and Lean Manufacturing projects. The third section, methodology, presents the research methods, followed by the statistical analysis tools. The fourth section presents results and the model, followed by conclusions, discussions, and limitations, including the recommendations for future research.

Literature Review

Despite that SS/LM projects provide competitive advantage and possess the utmost importance, their effectiveness is a high concern issue, reports abound about the late delivery, over budgets and lesser than expected performance. Because the success of the project depends on the understanding of the factors influencing it, management must focus the attention on their control and potential effects (Baccarini, 2009; Sánchez and Terlizzi, 2017). In the search of factors, the literature is extensive and inconclusive because the lists of factors vary depending on the type of industry, the projects, and the theory of Project Management. There are two types of factors to consider, the factors of the project performance, and those that influence the project management.

Regarding the former, the quantity of factors influencing the performance of a project is wide and they are not discriminated by their relative contribution to performance, although the theory and practice of SS and LM are quite standard. Besides, Marzagão and Carvahlo (2016) comment that not all the factors mentioned in the literature have significant contribution to project performance. Some reports pinpoint the relative contributions, while others only identify the critical success factors, with some differences regarding the quantity and the factors. Fortune and White (2006) report the lack of agreement regarding the quantity of the factors and consensus in the listings, their review of sixty-three publications gave a list of 27 factors; while Tabish and Jha (2011) found 36 factors; Gudienė et al. (2013) list 71, Van Loenhout (2013) reports 19 factors; Alias et al. (2014) report 25; García et al. (2017) report 27; Radujković and Sjekavica (2017) report 21 related to the management of the project; Tsigas et al. (2017) identify 58 success factors, and Yadav et al., (2021) report 18 factors. Table 1 presents a list of factors.

About the management of SS/LM projects because they are complex, unique, and with different theoretical contents and technologies, and work teams vary from project to project under diverse application contexts, management and deployment are not repetitive tasks. A common practice is to have internal development because there is no generally accepted industrial practice to manage the SS/LM application. In this sense, Collins and Baccarini (2004) confirms a positive relationship between project management and project success, its efficient deployment requires effective management (Zhang, 2020) and Alias et al. (2014) recommend the use of critical success factors given they predict success.

Therefore, this work follows the concept of Critical Success Factors, (CSF's). In the context of Project Management, when properly managed CSF led to the project's success

(Milosevic and Patanakul, 2005; Iram et al., 2016; Iram et al., 2017), specifically, those few variables or factors that leaders and teams must manage carefully to assure the effectiveness of the project (Amade et al., 2015), certain inputs of the project leading directly or indirectly to success (Alias et al., 2014). Although Prabhakar (2017), comments that neither theory nor practice coincides regarding what is a successful project, it is an elusive idea, the success of SS/LM projects commonly is measured with the accomplishments of the objectives, and the successfulness of management by the accomplishments of on-time delivery, budget, quality, and its effective management (Radujković and Sjekavica, 2017; Hajiali et al., 2020). A predictor type relationship is assumed between factors and output variables, in this case, affecting the project performance (Haleem, 2012), with variables such as “planned accomplishments of goals” to measure the success of the project (Srimathi, 2017). Four success criteria were identified: 1) Time, 2) Quality, 3) Budget and 4) Successful Project Management, which contain the factors reported in the reviewed literature.

The factors related to the management of projects reported in the literature have a wide variation, there are authors who report up to 45 factors (Westerveld, 2003) while others who report 13 factors (Cruz-Villazón et al., 2020) or even 11 factors (Iram et al., 2017). In general, the factors found in the literature are highly coincidental and critical for the effective project management, such as organizational knowledge (Spalek, 2015), Competent Team (Jaturanonda and Nanthavanij, 2011), Lindsjörn et al. (2016) Focused Team -on goals and customer satisfaction-, Serrador and Turner (2015); Management Support (Kostalova et al., 2015); Laureani and Antony (2018) point out that the most important factors are project management, leadership, selection of top talented people and financial accountability. While others are evidently, only present in certain industries, such as Local Capabilities (Andersen and Bøllingtoft, 2011) in International Development Projects.

Because of the multifactorial variation, it has been difficult to establish the most important factors influencing the project's effectiveness and therefore, the management of the project. The theory is in full development for the identification of factors, relationships, and associations among intangible variables and the construction of models capable to predict the successful management and deployment of a project. In this search and to enhance the explanation capability, more empirical evidence is required to obtain a better and more general explanation of successful SS/LM projects.

Table 1: Factors of Projects Success and Effective Management

| Factor | Author |
|--|---------------------------------|
| Leadership and Team; Policy and Strategy; Stakeholder management; Resources; Contracting; Project management; Scheduling; Budget; Organisation; Quality; Information; Risks | Westerveld (2003) |
| Support from senior management; objectives; Strong plan; Good communication/ feedback; Client involvement; Skilled staff/team and project manager; Resources; Use of Technology; Realistic schedule; Risks managed; Effective monitoring/control; Adequate budget; Organizational culture/structure; Training provision; Political stability; Project management methodology/tools; Environmental influences; Experience; Project size, Level of complexity, People involved. | Fortune and White (2006); |
| Top management's support; Owner's need; Monitoring and feedback; Scope of work; Adequate staff for planning and execution; Timely and valuable decision; Skills of project manager and staff; Availability of resources; Timely finalization; Regular design and construction control meetings; Schedule and budget updates; quality control and assurance activities; Adequate communication. | Tabish and Jha (2011); |
| Project efficiency: Meeting schedule and budget goal; Skill development. Customer: functional performance; technical specifications; Customer satisfaction. Business success: Commercial success; Creating a large market share. Preparing for the future: Creating a new product line and a new market; Developing a new technology. | Serrador and Turner (2015) |
| Communication, Coordination, Balances of member contribution; Mutual support; Effort; Cohesion; Team performance; Team members' success. | Lindsjörn et al. (2016) |
| Support from senior management; Objectives; Plan; Communication; Involvement; Team; Competent project manager; Business Case; Resources; Leadership; Schedule; Proven Technology; Risk Management; Monitoring; Senior Responsible Owner; Budget; Organization; Suppliers; Planned Close; Training; Project Management Methodology; Environment; Politics; Learning. | Frijns et al. (2017) |
| Technical competence; Behavioral competence; Contextual competence; Project team's competence; Coordination; Organization; Organizational structure; Organizational culture. | Radujković and Sjekavica (2017) |
| Project success; Mission; Top management; Project schedule; Client consultation; Personnel; Technical task; Client Acceptance; Monitoring feedback; Communication; Troubleshooting | Iram et al. (2017) |
| Experience, organization size, emphasis on cots quality and time, ability to brief, decision making, roles and contribution, expectations and commitment, influence. Support given to project head, support to critical activities, understanding of project difficulty and stakeholder influence. Project type, size, nature, complexity, design, resources allocation. Coordinating and motivating skills, communication and feedback, conflict resolution skills and organizing skills. Planning and control effort, team structure and integration, safety and quality program, schedule and work definition, budgeting and control of subcontractors. Contract type, tendering and procurement process. | Tsiga et al. (2017) |
| Funds/Resource Availability; High-Volume and Low-Variety Set-up; Project Management Skills; Use of Technology to manage the project; Mechanism of | Yadav et al., (2021) |

| | |
|---|--|
| <p>Feedback-to-Processes, Corrective-Action from Data-Analysis; Skilled-Employees; Automation; Use of Data-Analysis and Prediction System; Prior Quality-Management-System; Use of Line-Balancing and Production-Levelling Practices; Change Management Culture; Timely and Accurate Data Availability.</p> | |
|---|--|

Source: Self-made

Methodology

Research begins with a literature review of the factors influencing the project performance of SS/LM to obtain a list of factors, followed by a Meta-Analysis. The CSF SS/LM literature is a review of 52 publications from 2015 to this date, from EBSCO, Elsevier, Emerald, Springer, and Taylor and Francis. The publications gave a list of 29 factors and by Meta-Analysis the list was reduced to 21 factors, as Garcia et al. (2017) report. The operationalization of constructs is done with the list of factors and key variables for their measurement, applying several tests for the validation of the questionnaire.

The questionnaire measures the differences between theory and practice of SS and LM and identifies the factors influencing a successful deployment of a project. A Likert five scale is used, where 1 is the lowest level (or not important) to 5 as the highest. The constructs are Time, Quality, and Budget, commonly referred as evaluation criteria in the literature (Alvarenga et al., 2020; Cooke-Davies, 2002). The CSF are contained in 16 items identified by Garcia et al. (2017). An additional construct, Successful Project Management (SPM) has 7 items, using a total of 23 indicators for the measurement.

The results of reliability by Cronbach's Alpha are 0.891, 0.918, and 0.899 for the three constructs (Time, Quality, and Budget), being reliable according to decision rule (0.70) proposed by Hair et al. (1999). The construct SPM gave 0.564, although by elimination of the item S-OT, Alpha increases to 0.749, therefore, this indicator is not included in the model's specification.

Data Recollection. 225 questionnaires were distributed among professionals working in areas deploying SS/LM projects in a list of 82 high-tech industrial plants owned by multinational companies. From the 120 returned, 8 were discarded due to lost data, the Little MCAR Independence test of the random trend of lost data gave a p-value higher at 0.05 and the lost data is given by the expected maximization imputation method (Stavseth, Clausen, and Røislien, 2019). 54% of the questionnaires came from general manufacturing operations, followed by 17.8% from automotive parts, 10.7% from information and environmental

businesses, and 17.5% from other high-tech companies. 61.6% of the respondents are engineers or middle managers (operations or quality), 20.7% Project Management professionals, 17.7% other middle management positions involved in improvement projects.

The Statistical Analysis follows two stages. First is an exploratory factorial analysis - EFA-, with oblique rotation (Hair et al., 2019), which is the base for the specification of a structural equations model (Byrne, 2010), following Tlapa's (2016) five stages process, Specification, Identification, Parameter Estimation, Fit Evaluation, and the Modification. The specification bases on the EFA with the method of Principal Axes with Promax oblique rotation adequate for high multicollinearity data, using the Maximum Likelihood method for the parameter's estimation (Hair et al., 2017).

The empirical evaluation of the model is tested with the statistical significance χ^2 (Chi Square) and the correspondent p-value, given that it tends to reject models because of the sample size, is used the Byrne (2010) normalized index, (χ^2 /Degrees of Freedom), accepting a value lower than 2. Jak (2015) uses the Root Mean Square Error Approximation to correct the χ^2 trend to reject large models, with too many variables. A value lower than 0.05 indicates a close, good adjustment and up to 0.08 are satisfactory. Also is used the Comparative Fit Index, (CFI), indicates a relative lack of fit, [0,1] values close to 1 indicate good fit, and it is insensitive to the model size. The Tucker-Lewis (TLI) compares the fit by degrees of freedom between the model and a model without relationships among its variables, values of 0.9 and higher indicate good fit (Hair et al., 2005). The Expected Cross Validation Index (ECVI), recommended by Byrne (2010) for the evaluation of how good the model as a predictor is, selecting the best from a set with the lowest ECVI. Also, with the value and significance of the standardized regression coefficients are evaluated the quality of the model's parameters, indicating the force with which the observable variables are measuring the latent variables.

Results

This Section presents the specification, identification, fit of the model, and parameters estimation. Regarding the specification and identification, beginning with the adequacy of the sample, the Kaiser-Meyer Olkin Measure of Sampling Adequacy gave 0.79; the Bartlett's Test of Sphericity of 4.45 and Approx. Chi-Square, 4.45; with 1326 DF and a significance of 0.000. With these results is concluded that the variances - covariance's matrix is not an identity one, having relationships among the indicator variables.

Table 2. Final Pattern Matrix.

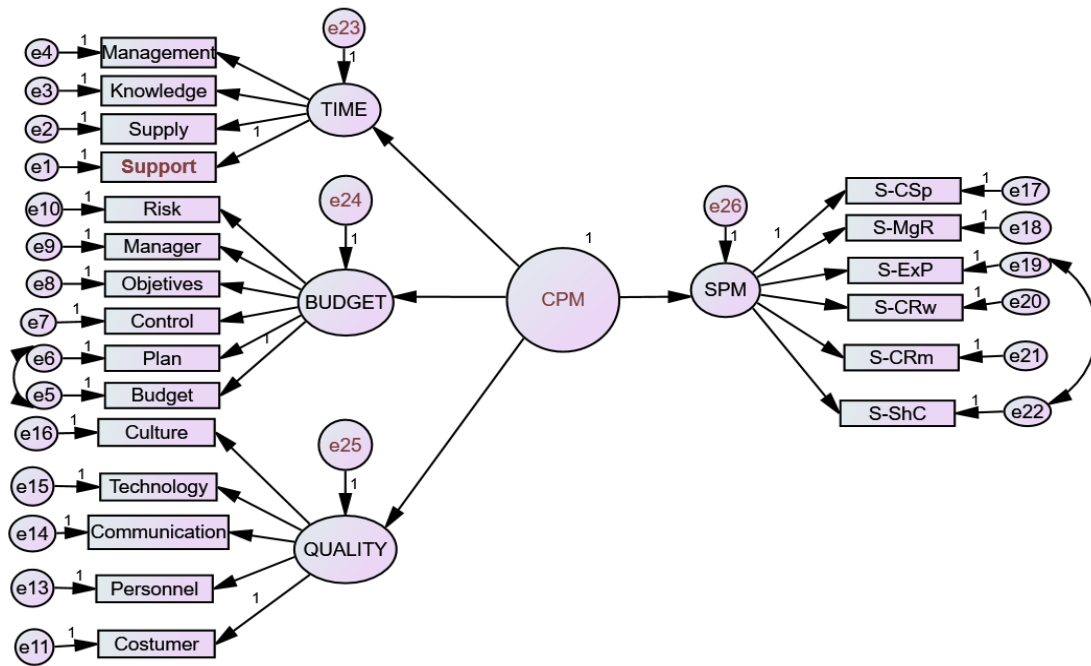
| Pattern Matrix | Component | | | |
|------------------|-----------|------|------|------|
| | 1 | 2 | 3 | 4 |
| B. Budget | .882 | | | |
| B. Plan | .840 | | | |
| B. Control | .744 | | | |
| B. Objectives | .726 | | | |
| B. Manager | .716 | | | |
| B. Risk | .593 | | | |
| T. Knowledge | | .843 | | |
| T. Supply | | .746 | | |
| T. Management | | .707 | | |
| T. Support | | .635 | | |
| Q. Costumer | | | .752 | |
| BQ. Personnel | | | .700 | |
| Q. Support | | | .660 | |
| Q. Communication | | | .589 | |
| Q. Technology | | | .586 | |
| Q. Culture | | | .563 | |
| S-CRm | | | | .752 |
| S-CRw | | | | .745 |
| S-CSp | | | | .656 |
| S-MgR | | | | .578 |
| S-ExP | | | | .552 |
| S-ShC | | | | .549 |

Source: Self-made

In relation with the final pattern matrix, table 2 shows the results of the factorial analysis using the method of extraction of principal axis with a PROMAX rotation with Kaiser normalization. Rotation converged in 6 iterations, having four constructs corresponding to the latent variables of Time, Quality, Budget, and SPM, identifying several crossed items, and eliminating the ones with factorial loads lower than 0.5, and the explained variance given by this solution is 50.4%.

Figure 1 shows the model's final version, composed by a second-order variable with three dimensions, which relate to the criteria and classification of the CSF identified in the literature. The second-order latent variable predicts the variable success. Table 3 gives the Model's fit indexes, complying with the decision criteria and their values.

Figure 1. Final Structural Model



Source: self-made

Table 3. Model's Adjustment Indexes.

| Model | CMIN/DF <2 | TLI >0.90 | CFI>0.90 | RMSEA <0.08 | ECVI |
|--------------------|------------|-----------|----------|-------------|--------|
| Default model | 1.417 | 0.906 | 0.920 | 0.061 | 3.217 |
| Saturated model | - | - | 1.000 | - | 4.162 |
| Independence model | 5.455 | 0.000 | 0.000 | .200 | 10.699 |

Source: self-made

Table 4 gives the factorial loads of the latent variables and the corresponding indicator variables. Also presents the path values. The less important factors are related to Time (0.595) having Budget and Quality a higher contribution to the project success with estimation values of 0.92 and 0.888, respectively; although the prediction relationship is moderate, with a significance value of $p=0.028$.

Table 4. Standardized Regression Weights of structural paths.

| Structural Paths | Criteria | Estimation |
|-------------------------------|-----------------------------|------------|
| TIME | Criteria Project Management | 0.595*** |
| BUDGET | Criteria Project Management | 0.920*** |
| QUALITY | Criteria Project Management | 0.888*** |
| Successful Project Management | Criteria Project Management | 0.254* |

*** p<0.001, **p<0.01, *p<0.05

Source: self-made

Table 5. Standardized Regression Weights of factorial loads.

| Factorial Loads | Criteria | Estimation |
|------------------|------------------------------------|------------|
| T. Support | <--- TIME | 0.765*** |
| T. Supply | <--- TIME | 0.718*** |
| T. Knowledge | <--- TIME | 0.567*** |
| T. Management | <--- TIME | 0.765*** |
| B. Budget | <--- BUDGET | 0.585*** |
| B. Plan | <--- BUDGET | 0.732*** |
| B. Control | <--- BUDGET | 0.723*** |
| B. Objectives | <--- BUDGET | 0.802*** |
| B. Manager | <--- BUDGET | 0.708*** |
| B. Risk | <--- BUDGET | 0.696*** |
| Q. Customer | <--- QUALITY | 0.667*** |
| Q. Personnel | <--- QUALITY | 0.631*** |
| Q. Communication | <--- QUALITY | 0.797*** |
| Q. Technology | <--- QUALITY | 0.572*** |
| Q. Culture | <--- QUALITY | 0.700*** |
| CSp | <--- Successful_Project Management | 0.441* |
| MgR | <--- Successful_Project Management | 0.291* |
| ExP | <--- Successful_Project Management | 0.262* |
| CRw | <--- Successful_Project Management | 0.966*** |
| CRm | <--- Successful_Project Management | 0.909*** |
| ShC | <--- Successful_Project Management | 0.313* |

Note: CSp: Compliance with project specifications; MgR: Efficiency in the administration of project resources. ExP: Execution of the project program; CRw: Renewal of the

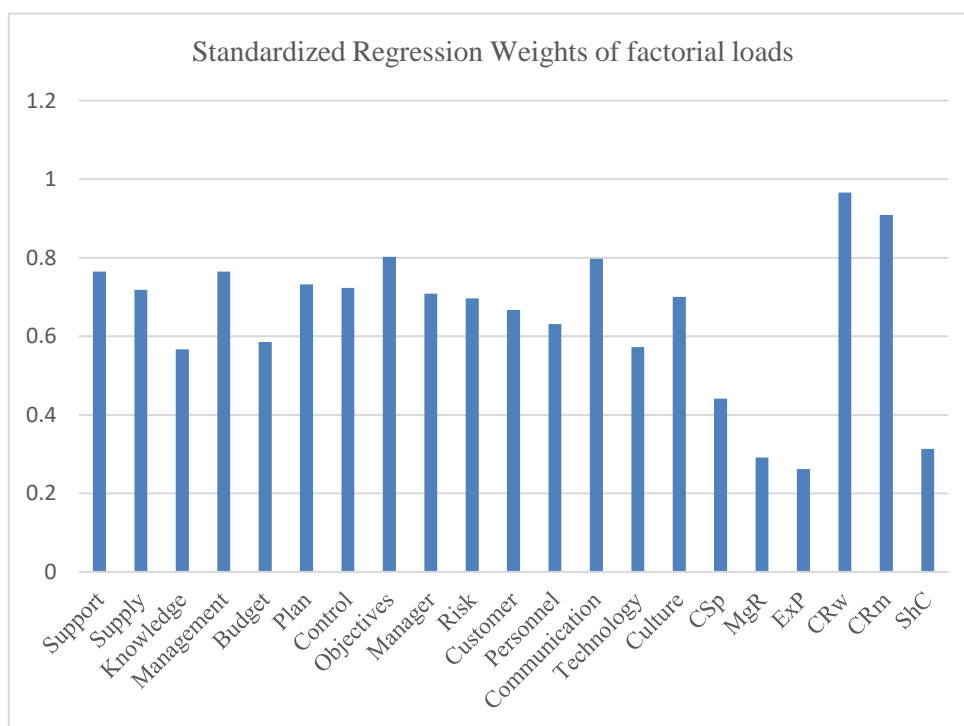
company contract. CRm: Company recommendation; ShC: Compliance with the programmed budget.

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

Source: self-made

Table 5 presents the factorial loads for each factor by criteria. The factors for criteria “on-Time delivery of the project” are four. The factors with higher value of estimation of this criteria are support (0.765) and supply (0.718); for “Budget” criteria the success factors are six, in this case the factors with higher estimation value are objectives and plan whit estimation values of 0.802 and 0.732, respectively; while Quality criteria has five factors, its factors with the highest estimation value are communication (0.797) and culture (0.700); finally, the factors for successful project management criteria are six and the factors with major importance are: CRw: Renewal of the company contract and CRm: Company recommendation, whose values are .966 y.909, respectively. In manufacturing industry of Ciudad Juárez the factor with lowest contribution is Efficiency in the administration of project resources and Execution of the project program; In figure 2 we show graphically contribution of each factor.

Figure 2. Estimation of factorial loads



Source: self-made

The model predicts a successful project when is managed mostly depending on the accomplishment of the goals, the managerial efficiency of the resources, the execution of activities, and the budget.

Discussion

The effective management of the factors influencing the successful deployment of SS/LM has three essential variables confirmed by the empirical significance of the sample. The CSF related to the on-Time variable have lower predictive relevance than the factors related to Budget. This is understandable given that external, environmental conditions, influence on-Time delivery, which are factors with low control by management; while for Budget and Quality variations, management exerts more control. This explains because SS/LM are projects quite standardized, deployed on the floor, projects have highly technical contents, deployed in the floor, with experience in the improvement of products, equipment, processes, and operations.

Regarding the predictive relevance of the CSF in CRw (More Contracts) and CRm, (Competitive Position) they are top management tasks and strategic topics, although not directly related to the deployment of SS/LM projects, their influence is high. While, with lower relative weights, the CSF related to CSp, MgR, Exp and ShC, explains their moderate importance, because management personnel of SS/LM projects are project champions and leaders that just keep execution control and supervision to rather well-trained teams. Although, the indicators of operational performance still depend on external conditions, distinct to the time, budget, and quality factors.

Conclusions and Recommendations

The main purpose is the determination of the factors influencing project success, developing a list of factors, and discriminated by relative contributions. Because the empirical evidence indicates that the effective management of the factors influencing the on-time delivery, budget, customer' perceived quality, possess the utmost importance for the accomplishment of operational performance and competitiveness goals, objectives are accomplished. Although more research is needed to establish objectively, under a general accepted model, the factors with higher influence to project effectiveness, the factors of effective management and, also about adequate definitions of what is project success and the

indicators for its measurement, we have determined the listing mentioned and the usefulness of SEM for these purposes. No less important is the development of management models to deploy projects considering these factors.

We consider with a high importance, the replication of these types of projects in diverse manufacturing environments, to gather more empirical evidence and look for general model with more explanation power.

Final Remarks

The results obtained are important to understand the feasibility of applying Six Sigma and Lean Manufacturing projects, as well as showing the factors that can be a barrier. This importance lies in the fact that the economic development of the study region is based on the manufacturing industry, which is a field of application of these methodologies, since they offer an improvement in the processes.

Although the main limitation of the study is the size of the sample, several aspects indicate that the study is still valid. These include:

- Kaiser-Meyer Olkin Measure of Sampling Adequacy gave 0.79.
- Bartlett's Test of Sphericity of 4.45.
- Approx. Chi-Square 4.45.
- 1326 DF, and
- significance of 0.000.

This work constitutes evidence that SEM is a powerful tool to determine the influence factor to apply projects of Six Sigma and Lean Manufacturing.

An invitation to researchers, consultants and professionals in academia and industrial plants to test the proposed listings while managing SS/LM projects.

Future Research Line

As mentioned, and according to the results, the replication of these types of projects in diverse manufacturing environments, to gather more empirical evidence with the purpose to look for a general model with more explanatory power. Therefore, necessary future line research is to apply the measuring instrument designed in this work to obtain decisive results.

Special thanks to Consejo Nacional de Ciencia y Tecnología - CONACYT for the support given to Eduardo Rafael Poblano Ojinaga through the Estancias Posdoctorales por México 2022 Program, for his participation in this paper.

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ANNEX A. Questionnaire-Survey: Main Factors and Criteria for Project Management

General Information

Instructions

Assume you are the general manager or project manager-leader, or team member, please answer accordingly to your experience.

1. Name:
2. Company Name (optional):
3. Years of Experience in Six Sigma Lean Manufacturing

1-2 Years 4-6 Years 6-8 Years 8-10 Years More than 10

4. Actual Position in the Company: _____

Section 1. General Characteristics of the Projects

5. In which industry is located most of your operations?

Construction Defense / aerospace Information Systems

General Manufacturing Automotive Products & Servicios Environmental

Other (specify): _____

6. Size of Projects, number of activities:

Less or equal to 100 More than 100

7. How are linked the projects to the organizational structure?

They are part of a functional department or division

The project is independent from the corporation headquarters

The project is subcontracted in your company

8. Which criteria are used to measure the success (or failure) of the Project?

Cost Time Quality Customer Satisfaction

Other (explain): _____

9. How frequent projects finish is late?

Always Commonly Sometimes Never

10. ¿Which types of costs or penalties are associated to tardiness-late Project finish?

Money penalties Penalties in points Customer losses Credibility loss

Other (explain): _____

Section 2. Main Factors of Project Management

Indicate which of the factors listed are the most important, with more influence in the project's success. If there are missing factors, please include them in the corresponding group.

11. Factors related to the project:

Size and value Adequate activities Density of Activities Web
 Life Cycle Urgencies Other (explain): _____

12. How many projects are commonly executed at the same time?

Only 1 From 1 to 5 More than 5

13. How many times are used PERT or Critical Path:

Only 1 From 1 to 5 More than 5 None

14. Which software is used for project control?

Timeline Primavera MS Project for Windows Project Scheduler
 Super Project Harvard TPM No software is used
 Other (specify): _____

15. Factors related to the Project manager:

Capable of delegating authority Capable of compensation Capable of coordination
 Knowledge of own rol and responsibilities Talent Commitment
 Other (s) (explain): _____

16. Factors related to team members:

Technical training Communication Problem Solving Commitment
Other (s) (explain): _____

17. Factors related to the organization:

Top Management Support Project Organizational Structure
 Support of Middle Mgmt. Team Chaampion
 Other (explain): _____

18. Environmental Factors:

Political Economic Social Tecnological Nature-climate
 Customer Competitors Sub-contracts
 Other(s) (explain): _____

19. For project's deployment and control, software used:

Timeline Primavera MS Project for Windows Project Scheduler
 Super Project Harvard TPM No software is used
 Other (s)(specify): _____

Information of suppliers and contractors

20. ¿Average quantity of external support you contract as support of projects?
 1 From 2 to 5 More than 5 None

21. ¿Average frequency of tardiness (after expected finish) attributed to contractors?
 Less than 10% of the times From 10% to 50% 50% a 80%
 All tardiness is attributed to contractors.

Projects Accomplishments

This section explores the results of the projects.

22. ¿The Project fulfilled the expectations and goals?
 From 90% to 100% From 80% to 89% From 70% to 79% Non Acceptable

23. ¿How did the leader managed resources?
 Very Good Good Moderately Good Had problems

24. ¿Does the teams follow strictly the program-activities?
 Always 100% Very close Relatively close No, follow-up is lost

If you have been managing Projects externally (consulting), see the next two questions:

25. ¿How probable is to be hired again?
 Very probable Probable Moderately Probable Not probable

26. ¿Have you been recommended by this Company? Yes No

How close have been your results against expected results and objectives, (costs and times)

Explain: _____

27. ¿Budgets and real cost coincide?
 100% Very Close Relatively close Not at all

Relation between critical success factors and criteria of SS/LM projects

Objective: measurement of the relative influence of factors on success.

Section I

Success Criteria: Accomplishment of ON TIME FINISH of the Project



Question 1. How much does the factor *Good Sound Program of Activities* influence on time finish?

No influence Low Influence Sufficient High Influence Indispensable

Question 2. How much is the influence of the factor *Top Mgmt. Support* upon the finish on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 3. How much does the factor *Highly Prepared Team Members* influence on time finish?

No influence Low Influence Sufficient High Influence Indispensable

Question 4. How much is the influence of the factor *High Business Experience as sound foundations* on the on time finish?

No influence Low Influence Sufficient High Influence Indispensable

Question 5. How much does the factor *Adequate Risk Management* influence on time finish?

No influence Low Influence Sufficient High Influence Indispensable

Question 6. How is the influence of the factor *Clear and Feasible Objectives* on finishing the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 7. What is the influence of the factor *Management of Corrective Actions (adjustments)* on the on time finish of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 8. How is the influence of the factor *Effective Control and Follow-up* on finishing the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 9. What is the influence of the factor *Highly Trained Team Members* upon the on time finish of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 10. How is the influence of the factor *Competent Project Manager* on finishing the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 11. How is the influence of the factor *Use of Sound (and known) Technologies* on finishing the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 12. What is the influence of the factor *Flexible Organizational Structure (power of adaptation)* upon the on time finish of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 13. What is the influence of the factor *Adequate (sufficient) Budget* upon the on time finish of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 14. How is the influence of the factor *Learning by Experience (use of past knowledge)* on finishing the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 15. What is the influence of the factor *Adequate Communication and retrofeeding* upon the on time finish of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 16. What is the influence of the factor *Collaboration of Customer (or users)* upon the on time finish of the project?

No influence Low Influence Sufficient High Influence Indispensable

Section II

Success Criteria: Accomplishment of the QUALITY OBJECTIVES of the Project

Question 1. What is the influence of the factor *Sound and Detailed Plan/Program* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 2. How is the influence of the factor *Support and Commitment of Top Mgmt.* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 3. What is the influence of the factor *Highly Qualified and Sufficient Team Members* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 4. How much is the influence of the factor *Business Experience* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 5. What is the influence of the factor *Adequate Risk Mgmt.* upon the quality

measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 6. How is the influence of the factor *Clear and Feasible Objectives* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 7. What is the influence of the factor *Management of Corrective Actions (adjustments)* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 8. How is the influence of the factor *Effective Control and Follow-up* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 9. What is the influence of the factor *Highly Trained Team Members* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 10. How is the influence of the factor *Competent Project Manager (Leader)*. on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 11. What is the influence of the factor *Sound and Known Technologies* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 12. How is the influence of the factor *Flexibility of the Organizational Structure (power of adaptation)* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 13. What is the influence of the factor *Adequate and Sufficient Budget* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 14. How is the influence of the factor *Learning from Past Experiences* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Question 15. What is the influence of the factor *Good Communication and Retrofeed* upon the quality measures of the project?

No influence Low Influence Sufficient High Influence Indispensable

Question 16. How is the influence of the factor *Collaboration of Customers and Users* on the quality measures the project on time?

No influence Low Influence Sufficient High Influence Indispensable

Section III

Success Criteria: Termination of the Project within BUDGET

Question 1. What is the influence of the factor *Sound and Detailed Plan/Program* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 2. How is the influence of the factor *Top Mgmt. Support and Commitment* on the finishing the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 3. What is the influence of the factor *Highly Qualified and Sufficient Team Members* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 4. How is the influence of the factor *Sound Experience on Business* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 5. How is the influence of the factor *Adequate Risk Mgmt.* on the finishing the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 6. How is the influence of the factor *Clear and Feasible Objectives* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 7. How is the influence of the factor *Management of Corrective Actions (adjustments)* on the finishing the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 8. How is the influence of the factor *Effective Control and Follow-up* on the termination of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 9. How is the influence of the factor *Highly Trained Team Members* on the finishing the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 10. How is the influence of the factor *Competent Project Manager (Leader)* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 11. What is the influence of the factor *Use of Sound and Proven Technologies* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 12. How is the influence of the factor *Flexibility of the Organizational Structure (power of adaptaion)* on the termination of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Pregunta 13. How is the influence of the factor *Adequate and Sufficient Budget.* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 14. What is the influence of the factor *Learning of Past Experiences* upon the ending of the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 15. How is the influence of the factor *Good Communication and Retrofeed.* on the finishing the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Question 16. How is the influence of the factor *Collaboration of Customers and Users* on the finishing the project on Budget?

No influence Low Influence Sufficient High Influence Indispensable

Survey: Factors and Criteria of Project Management

The information required is confidential and just for research purposes, results available on request.

Name: _____

Company Name: _____

Experience in projects: 1-2 years 2-4 years 4-6 years 6-8 years
 8-10 years More than 10 years

Actual Position: _____

Section I Select the appropriate response, indicating it with an x

1.1 ¿Classify your products by industry:

- Construction

- Defense / aerospace
- Information Systems
- General Manufacture
- Automotive
- Services
- Environmental
- Others (explain): _____

1.2 The making of most of your products is by projects with:

- 100 or less activities
- More than 100 activities

1.3 ¿The linking of your projects to the organizational structure is:

- Projects are independent (not linked) from Headquarters
- Projects are part of a Department or Division of the Plant
- Projects are sub contracted.

1.4 ¿Criteria used to measure success of Projects:

- Cost
- Times
- Quality
- Customer Satisfaction
- Others (explain): _____

Section II

2.1 Factors related to the Project:

- Size and Value
- Clear and precise activities
- Density of the activities web (Independence between activities)
- Life Cycle
- Urgency

2.2 Factors related to manager:

- Capable to delegate authority
- Capable of Compensation
- Capable to Coordinate
- Perception of function and responsibilities

- Competence
- Commitment

Factors related to Team Members:

- Technical Capabilities and Competences
- Communication
- Problem Solving abilities
- Commitment

Organizational Factors:

- Top Mgmt. Support and Commitment
- Project' Organizational Structure
- Support of related Departments and Personnel
- Champion

Environmental Factors:

- Politics
- Economical
- Social
- Technological
- Nature (climate)
- Client
- Competitors
- Sub-contractors

Team Members Factors:

- Technical Capabilities
- Communication skills
- Problem solving abilities
- Commitment