

Chiller Assembly Line Optimization Using a Six Sigma DMAIC Approach

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Abstract

The primary objective of this study was to optimize the production line of chillers equipped with free-cooling capability and multi-fan condenser systems, with a focus on enhancing operational efficiency and final product quality at a manufacturing plant located in northeastern Mexico. A quantitative approach was adopted using a pre- and post-intervention experimental design within the Six Sigma framework, following the sequential DMAIC methodology. The sample comprised operational and quality data collected directly from the production line at critical control points, where out-of-tolerance dimensional deviations and electrical continuity issues were identified. Data collection and analysis instruments included SIPOC and QFD diagrams, check sheets, Pareto charts, control charts, process capability studies, as well as cause-and-effect matrices and process-level FMEA for risk quantification. The results revealed that the primary sources of defects were associated with inconsistencies in harness design, insufficient dimensional control during material receiving, and the lack of standardized assembly procedures. Following the implementation of corrective actions, such as comprehensive drawing reviews, supplier standardization, process reconfiguration, and cross-training of personnel, rework was eliminated, cycle time was reduced by more than 20%, and costs related to additional materials were significantly decreased. Financial analysis confirmed a positive net present value (NPV) and a substantial reduction in monthly operating costs. In conclusion, the disciplined application of the Six Sigma DMAIC methodology, supported by statistical tools, enabled sustainable improvements in complex manufacturing processes, strengthened the culture of continuous improvement, optimized resource utilization, and enhanced competitiveness within the industrial heating, ventilation, and air conditioning (HVAC) sector.

Keywords

DMAIC, Six Sigma, Process optimization, Statistical process control and Continuous improvement.

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Biographies

Azucena Minerva García-León is received the Bachelor of Science degree in industrial engineering and the Master of Science degree in industrial engineering from the *Universidad de las Américas-Puebla*, the master's degree in industrial engineering from the *Institut National Polytechnique de Grenoble* (INPG), France, the Ph.D. degree in applied economics from the *Université Grenoble Alpes* (UGA), France, and the Postgraduate degree in data science

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Iván Guillermo González Palomo holds a degree in Industrial and Systems Engineering (Industrial Engineering Administrator), a Master's degree in Industrial Engineering with a specialization in Total Productivity, and a Ph.D. in Philosophy with a concentration in Administration. Since 2015, he has served as a research professor at the Faculty of Chemical Sciences at the Autonomous University of Nuevo León, where he has built a solid academic career distinguished by methodological rigor and a strong commitment to student development. In his teaching role, he delivers courses such as Applied Statistics, Probability, Quality Control, and Operations Research. Through these subjects, he fosters analytical thinking and data-driven decision-making skills. His pedagogical approach combines theoretical foundations with practical applications, enabling students to strengthen their quantitative and strategic competencies in real-world contexts. His research work bridges social sciences and engineering, with a particular focus on service quality and experimental design. He is dedicated to developing evidence-based solutions that contribute both to the advancement of knowledge and to continuous improvement within organizational and academic environments.

Carolina Solís-Peña holds a Ph.D. in Philosophy with a specialization in Administration and a Master's degree in Administration with a concentration in Supply Chain Management from UANL. She has professional experience in the automotive industry in areas including Manufacturing, Industrial Safety, Environmental Management and Sustainability, Logistics, Planning, and Materials Purchasing. She is a Full-Time Professor in Industrial and Systems Engineering at UANL, where she teaches undergraduate courses in Industrial Safety, Operations Planning and Control, and Supply Chain Management. She also teaches at the graduate level in the Faculty of Mechanical and Electrical Engineering in the Logistics and Supply Chain program. Her research interests include supply chain management, operations optimization, sustainability in industrial systems, and logistics strategy. She holds the PRODEP Desirable Profile recognition granted by the Ministry of Education (SEP) and is recognized as a Level 1 Researcher.

Patricia Gómez-Fuentes is a full-time Professor and Coordinator of Basic Area in Industrial Engineering Department at the School of Chemical Sciences of Universidad Autónoma de Nuevo León (UANL), Dr. Gómez-Fuentes teaches courses such as Industrial Engineering and Operations Research. She earned a B.S. in Industrial Engineering with minor in Management and M.S. degree in Industrial Engineering from Universidad Autónoma de Nuevo León. She holds a Doctorate in Strategic Management from Warden International Institute. She has got experience in manufacturing industry with expertise in the areas of business administration. She has been recognized with PRODEP Desirable Profile awarded by Mexico's Ministry of Education (SEP). Dr. Gómez-Fuentes is a member of the UANL-421 Academic Team "Design and Optimization of Productive Systems". Her research interests include design and optimization of operations and education and engineering linkage in production systems.