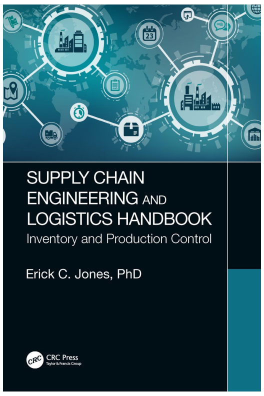


Supply Chain Engineering and Logistics Handbook
Inventory and Production Control

Erick C. Jones

TQM Case Study

Publication details
https://test.routledgehandbooks.com/doi/10.1201/9781315159096-12
Erick C. Jones
Published online on: 05 Dec 2019

12

TQM Case Study

Erick C. Jones

12.1 Introduction

Technical organizations often face the challenge of aligning their supply chain (SC). The technical manager faces challenges in coordinating data collection and analysis efforts to evaluate the SC in a cost-effective manner. In some organizations, it may be prudent to utilize current technical personnel to perform this analysis. Oftentimes companies consider utilizing costly software and consultants prior to using their in-house resources. Allowing the technical manager to utilize an internal team to provide an analysis is more cost effective for several reasons.

1. Data collected will be utilized again if consultants are deemed necessary.
2. The in-house team will understand the implications of solutions that the model may provide and can make adjustments for reality.
3. Simplified assumptions can be agreed upon by internal stakeholders.
4. The project will prepare personnel for change.
5. The project provides a cost-effective solution.

Also, this study will reveal if your SC network may be too complex to model using simply the Excel solver prior to investing in an extensive study. Though it is very important to perform SC analysis, many companies cannot justify the use of expensive software and consultant to perform these analyses continually. The technical manager can provide good solutions by creating this type of study.

Previously, a project team of students from the University of Nebraska-Lincoln and personnel from the City began a Six Sigma Project to reduce obsolete inventory. The SC consisted of a network of warehouses, storerooms, suppliers, and the internal end user who represented the customer. During the Six Sigma process improvement study, the team determined that customer service needs were not being met, obsolete inventory was being driven by purchasing behavior, and that facility costs could be reduced with facility consolidations. The team analyzed the SC network of the city's Public Works Department using modeling techniques to recommend which warehouses could be consolidated. Based on recommendations, 96,000 ft^2 could be reduced, and gross of \$ 3.5M would be saved over 5 years not including taxes and depreciation. This represents a cost reduction of 25%.

12.2 Background

A technical manager's goal when locating facilities and allocating inventory should maximize the overall profitability of the resulting SC network while providing customers with adequate service. Traditionally, revenues come from the sale of product, and costs arise from facilities, labor, transportation, material, and inventory holding. Ideally, profits after tariffs and taxes should be maximized when designing a SC network. In this scenario, the city government does not pay taxes or collect revenues, so their goals were to minimize overall operating cost and still be responsive to the customer.

Trade-offs must be made by the technical managers during network design. For example, building many facilities to serve local markets reduces transportation cost and provides fast response time, but it increases the facility and inventory costs incurred by the firm. Technical managers can use network design models in two different situations. First, those models are used to decide on locations where facilities will be established and the capacity assigned to each facility. Second, these models are used to assign current demand to the available facilities and identify lanes along which product will be transported. Managers must consider this decision at least on an annual demand basis, prices, and tariff charge. In both cases, the goal is to maximize the profit while satisfying customer needs. The following information must be available before the design decisions can be made:

1. Location of supply sources and markets
2. Location of potential sites
3. Demand forecast by market
4. Facility, labor, and material cost by site
5. Transportation costs between each pair of sites
6. Inventory costs by site as well as a function of quantity
7. Sales price of product in different regions
8. Taxes and tariffs as product is moved between locations
9. Desired response time and other service factors (Chopra and Meindl 2004).

Given this information, a choice of model type can be made. Previous literature highlights some general models that have differing goals. Each model has differing objectives; the models that were considered for this study were the Capacitated Plant Location Model and the Gravity Location Model. The Capacitated Plant Location Model seeks to minimize the total cost of the current SC network; the problem is formulated into an integer program. The Gravity Location Model's goal is to locate an optimal location based on cost inputs. Beyond optimization models, the technical manager could build a simulation of their SC.

In this study, we chose to use the Capacitated Plant Location Model (Chopra and Meindl 2004) in order to determine the minimal number of facilities that could hold inventory and meet customer demand. In our study, the City has chosen to consolidate warehouse facilities. Management is questioning whether all 12 facilities are necessary. They have assigned a SC Team of University of Nebraska-Lincoln and City personnel to study the network for the Public Works operations and identify the warehouses that can be closed. The goal is to formulate the model to minimize total costs taking into account costs, taxes, and duties by location. Given the taxes and duties do not vary between various locations, and that the city does not pay taxes, the team decided to use the existing facility locations and allocate demand to the open warehouses to minimize the total cost of facilities, transportation, and inventory.

12.2.1 The Capacitated Plant Location Model

The capacitated plant location network optimization model requires the following inputs:

N = number of potential locations
M = number of demand points
D_i = annual demand from market i
K_i = potential capacity of plant i
F_i = annualized fixed cost of keeping factory i open
C_{ij} = cost of producing and shipping one unit from factory i to marker j (cost includes production inventory, transportation, and duties)

and the following decision variables:

Y_i = 1 if plant is open, 0 otherwise
X_{ij} = quantity shipped from factory i to market j.

The problem is formulated as the following integer program

$$\text{Min}\left(\sum_{i=1}^{n} F_i Y_i + \sum_{i=1}^{n}\ \sum_{j=1}^{m} C_{ij} X_{ij}\right)$$

subject to

$$\sum_{i=1}^{m} X_{ij} D_{ij} \quad \text{for } j = 1 \ldots m \tag{12.1}$$

$$\sum_{j=1}^{n} X_{ij} \leq K_i Y_i \quad \text{for } i = 1 \ldots n \tag{12.2}$$

$$Y_i \in (0,1) \quad \text{for } i = 1 \ldots n \tag{12.3}$$

The objective function minimizes the total cost (fixed + variable) of setting up and operating the network. The constraint in Eq. 5.1 requires that the demand at each facility market be satisfied. The constraint in Eq. 5.2 states that no plant can supply more than its capacity. (Capacity is 0 if closed and K_i if it is open. The product of the terms $K_i Y_i$ captures this effect.) The constraint in Eq. 5.3 enforces that each plant is either open ($Y_i = 1$) or closed ($Y_i = 0$). The solution will identify the plants that are to be kept open, their capacity, and the allocation of regional demand to these plants. The model is solved using the Solver tool in Excel (Chopra and Meindl 2004).

12.3 Network Modeling Steps Incorporated into a Six Sigma Service Project

The typical Six Sigma DMAIC approach was used with the addition of a network model within the Analyze phase. DMAIC stands for Define, Measure, Analyze, Improve, and Control. These are the steps in a standard improvement model for a Six Sigma-directed project.

12.3.1 Define

The main work in the Define phase is for the team to complete an analysis of what the project should accomplish and to confirm their understanding with their sponsor(s). They should agree on the problem, understand the project's link to corporate strategy and its expected contribution to return on investment capital, agree on the project boundaries, and know what indicators or metrics will be used to evaluate success. The last two issues often prove particularly important in service environments (George 2003). The problem defined for this project was to reduce obsolete inventory.

12.3.2 Measure

One of the major advances of Six Sigma is its *demand* for data-driven management. Most other improvement methodologies tended to dive from identifying a project into Improve without sufficient data to really understand the underlying causes of the problem. The Measure phase is Six Sigma's stage for data collection and "measuring" the problem. This phase is generally broken into several steps, including establish baselines, observe the process, and collect data (George 2003). The measure of success was reducing the percent of obsolete inventory in the SC.

12.3.3 Analyze

The purpose of the Analyze phase is to make sense of all the information and data collected in Measure. A challenge to all teams is *sticking to the data* and not just using their own experience and opinions to make conclusions about the root causes (George 2003). There are many tools available in the Analyze phase, including network modeling. Network models provide a rich and robust framework for combining data, relationships, and forecast from descriptive models. They provide managers with broad and deep insights into effective plans, which are based on the company's decision options, goals, commitments, and resource constraints (Shapiro 2001). After using regression analysis and design of experiment analysis, the team chose to use SC optimization for a more robust solution.

The network model used within this project followed several steps including:

1. Collect Input Data and Establish Baseline.
2. Set Optimization Constraints.
3. Run Alternatives with the Capacitated Plant Location Model (Chopra and Meindl 2004).
4. Show Alternatives in Revenue, Savings, and Customer Service.
5. Select an Alternative.

These steps led to an alternative that minimized the cost of the SC. This alternative then directs the tasks within the Improve stage.

12.3.4 Improve

The sole purpose of the Improve phase is to make changes in a process that will eliminate the defects, waste, costs, etc. that are linked to the customer needs identified in the Define stage (George 2003). The Improve stage differs for every Six Sigma project. The common theme is that the improvements should be centered on the largest issues found in the Analyze phase. The recommendations for consolidating facilities (the SC model recommended) and using a more robust criterion for eliminating outdated inventory were recommended for the improvement.

12.3.5 Control

The purpose of Control is to make sure that any gains made will be preserved, until and unless new knowledge and data show that there is an even better way to operate the process. The team must address how to share what they learned with the process owner and ensure that everyone working on the process is trained in using any new, documented procedures. Six areas of Control are critical: document the improved process, turn the results into dollars, verify maintenance of gains continually, install an automatic monitoring system, pilot the implementation, and develop a control plan. Key performance indicators were identified to be tracked with Statistical Process Control charts for the following year. This is further elaborated in the results section.

The DMAIC process with the Capacitated Plant Location Model in the Analyze phase was utilized to study the City of Houston's Public Works Warehousing Operations.

12.4 Case Description

12.4.1 Organizational Description

The organization used for this case study is a city in Southwest United States, Public Works, Materials Management Branch (MMB). The MMB is responsible for the processing and coordination of all procurement and contract-related activities as well as warehousing and distribution of all general inventory items for the department.

The branch facilitates purchases ranging from pipes for restoration of sewer lines to computers and traffic signs. To promptly obtain goods and services, the department utilizes in excess of 800 commodity and service contracts. The branch is divided into three functional sections: Procurement, Contract Management, and Warehousing and Distribution. This study was centered on the Warehousing and Distribution section.

The MMB has the responsibility for Warehousing and Distribution of general and automotive inventory items, from cradle to grave, for the department. Two central depots serve as staging locations for inventory that is distributed to a network of ten general supply warehouses, nine automotive warehouses, and many storerooms located throughout the City. The inventory consists of a variety of items, e.g., pipe, valves, fittings, office, janitorial supplies, etc.

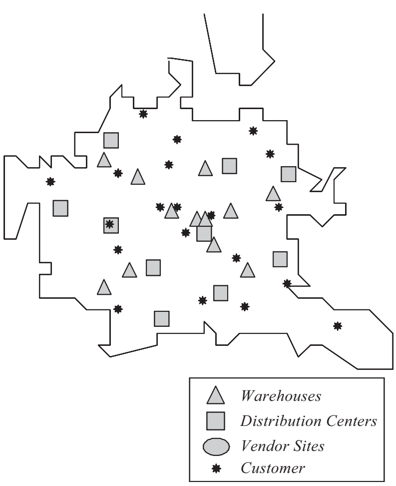
12.4.2 Project Description

The MMB had been audited in previous years, and the audits identified opportunities for improvement in the warehousing operations. The audits identified excess obsolete inventory, need to evaluate standard operating procedures, and labor productivity. Obsolete inventory is defined as inventory that has not had any requests for disbursement for over one year.

The current system contains 12 warehouses and 28 storerooms with an ongoing cost of $14.94M. Upon inspection, it was estimated that the warehouses have a maximum of 30% space utilization. The current SC is shown in Figure 12.1. Public Works owned $10.1M of inventory within the MMB warehouses. The inventory that was deemed as obsolete was valued at $3.6M or 35% of the total inventory.

The modeling steps were followed to complete the analysis.

1. Collect Input Data and Establish Baseline
   The current SC information was collected to form the input data for the network model. The inputs included costs for electricity, gas, data lines, and labor. Also, holding and transportation costs were estimated for each facility. The warehouses do not pay taxes or water costs since they are in a city building, so information as to lost water sales and lost taxes was also captured and used in the cost equations.
2. Set Optimization Constraints
   The optimization constraints included the size limitations of each facility and the future demand at each facility. The facility size was collected from operations. The future demand on inventory was estimated to be the same as last year's value.
3. Run Alternatives with the Capacitated Plant Location Model (Chopra and Meindl 2004)
   The costs and data that were collected in steps 1 and 2 of the modeling were input into Chopra's model in Excel and the Solver Add-In was utilized to run alternatives of the least cost model.



Operations	12 Warehouses / 28 Storerooms (DCs)
Policy	Emergency Credit Card Buys, Contract Buys, Non Contract Buys
Investment	N/A
Service	Over the Counter, Some Delivery
Cost	$14.9M (with transportation) W/Facility Acquisition $39M
Advantages	Meet Some Customer Demand
Disadvantages	High $0 Issue Inventory, Turns Lower than 1.0

FIGURE 12.1 Current SC description.

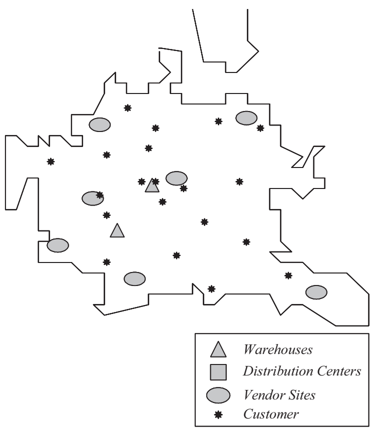
4. Show Alternatives in Revenue, Savings, and Customer Service

   The different alternatives were then evaluated for revenue and savings with a return on investment (ROI) calculation assuming the project had a 5-year life. The customer service provided in each alternative was evaluated by a team from operations.

5. Select an Alternative

   The optimal solution contains two warehouses, which are centrally located as shown in Figure 12.2. This gives a reduction of 96,000 ft^2 which translates into \$3.5M over 5 years. This solution will increase the space utilization to 65% and reduce the obsolete inventory to 10% of the total value held within the warehouses.

As the city moves to the optimized model, the Control phase of DMAIC will keep the improvements in place and running smoothly. The metrics that are given to continue the control are the Key Performance Indicators (KPIs) given in Figure 12.3. These should be measured and tracked utilizing Statistical Process Control (SPC). This data could then be used to repeat an optimization in the future.



Operations	2 Warehouse, No DCs
Policy	Vendor Credit Card, Emergency Credit Card, Contract, Non -Contract, Internet
Investment	Warehouse Management System (WMS), Consolidation, Delivery Operation Cost
Service	OTC, Delivery Service to Site
Cost	Additional Fleet Maintenance, New Racking, Project Manager
Advantages	Vendor Managed Inventory on Noncritical Fast Moving Items, Critical Items Better Managed, Reduced Labor, Reduced Facility Cost

FIGURE 12.2 Optimized SC.

Category	Metric	Definition
Service	Turns	Annual $ Issued Divided by Average
Service	% Obsolete Inventory	# of Commodity Codes (CC) that have not been Issued for over 1 Year Divided by the Total # of CCs
Cost	Cost / Pick	Total Labor Cost Divided by Total # of Picks
Cost	Cost / Order	Total Labor Cost Divided by Total # of Orders
Asset Management	Facility Utilization	# of Pallet Positions Utilized vs. Available
Future		
Transportation	Shipments / Division	Track the Number of Deliveries to Site for Each Division
Inventory	Velocity	Annual Revenue / Daily Overhead
Labor	% Productivity by Area / Task	Divide Actual Labor Hours by the Efficiency Standard for the Task and Track by Employee
Labor	Picks / Hour	Number of Pick Issues and Divide by Pick Labor Hours
Purchasing	PCard Spend by Category	PCard Spend by Contract, Non-Contract, and Emergency Usage vs. Total PCard Spend

FIGURE 12.3 Key performance indicators.

12.4.3 Lessons Learned

The lessons learned included model complexity changes and challenges and limitations which could be better met. The model complexity was chosen to reflect a first look at the SC and a simple optimization. A more complex model may have been used if better original data had been available. The data that was available could not be validated because it came from the enterprise resource planning (ERP) system which was antiquated. The model was validated with site tours and sampling for volumetric data. We note that the model is only as good as the data it is provided. A common term is "garbage in" to a model, and you get "garbage out". If a more complex model was utilized, software other than Excel would be needed as well as consultants.

It was difficult to reach agreement between divisions on what part of the cost data can be incorporated as reduced costs. For example, the portion of overall utility costs can be equated to warehouse space versus the other uses of the buildings today, and the percent of value can be used for holding cost because the city does not pay taxes and does not invest excess monies.

12.5 Implications for the Technical Manager

A technical manager should use this article to better understand their own first steps in SC optimization projects. This information should encourage the manager to begin to look at their information internally, before hiring a consulting team. The first look may give a viable answer that can be implemented for increased efficiencies and savings.

A technical manager can gather internal data and then use the methods in Excel Solver to create the appropriate SC model. The specific steps for using Excel can be found in different references; we recommend the steps outlined by Chopra. The technical manager can justify many good solutions for the SC by further using current technical personnel. This may provide another tool for the technical manager to justify his technical staff. If the internal team does not solve the problem, or the manager is ready for a second look at the issue, a consultant can be hired with very little lost to the company.

This study provided an overall method for performing continuous improvement projects using the Six Sigma methodology. Further, this study shows how in the Analyze stage, a technical manager can perform a SC analysis on current operations. The technical manager can use this study as a guide for both.

12.6 Conclusions

This chapter details a quick and relatively inexpensive way to perform an analysis for SC savings opportunities. The major benefit is that you utilize internal personnel who have been already budgeted for and may have a better understanding of operations than outside consultants. Also, the initial study may be modeled using existing spreadsheets before more costly software and consulting options are explored.

This simple analysis may not replace a complex SC analysis using some of the more advanced software which incorporates the CPLEX and ILOG modeling engines. These software companies allow for more constraints than the less powerful spreadsheet will allow. They have claimed to have 20%–50% more optimized results that may translate into more cost savings. This is contingent if consultants can better interpret data, future business strategies, and evaluate logistics networks including transportation traffic patterns.

From the case study application, we identified a workable set of challenges with lessons learned that can be valuable to organization when modeling the SC. The technical manager and his team can be a valuable asset when doing both continuous improvement projects and providing valuable SC modeling expertise.

REFERENCES

Bowersox, Donald J., David J. Closs, and M. Bixby Cooper, *Supply Chain Logistics Management*, Boston, MA: McGraw-Hill/Irwin (2002).

Chopra, Sunil, and Peter Meindl, *Supply Chain Management*, Upper Saddle River, NJ: Pearson Prentice Hall (2004).

George, Michael L., *Lean Six Sigma*, New York: McGraw-Hill (2002).

George, Michael L., *Lean Six Sigma for Service*, New York: McGraw-Hill (2003).

Johnson, James C., Donald F. Wood, Daniel L. Wardlow, and Paul R. Murphy Jr., *Contemporary Logistics*, Upper Saddle River, NJ: Prentice Hall (1999).

Kotnour, T.G., S. Barton, J. Jennings and R.D. Bridges, "Understanding and Leading Large-Scale Change at the Kennedy Space Center," *Engineering Management Journal*, 10:2 (1998), 17–21.

Kotnour, T.G., J. Matkovich and R. Ellison, "Establishing a Change Infrastructure through Teams," *Engineering Management Journal*, 11:3 (1999), 25–30.

Leach, Frederick J., and Jerry D. Westbrook, "Motivation and Job Satisfaction in One Government and Development Environment," *Engineering Management Journal*, 12:4 (December 2000), 3–9.

Michealson, Herbert B., *How to Write and Publish Engineering Papers and Reports*, iSi Press (1982).

Shapiro, Jeremy F., *Modeling the Supply Chain*, Boston, MA: Cengage Learning, Inc. (2001).

Turnquist, Mark A., and Linda K. Nozick, "A Nonlinear Optimization Model of Time and Resource Allocation Decisions in Projects with Uncertainty," *Engineering Management Journal*, 16:1 (March 2004), 40–49.

Vof, Stefan, and David L. Woodruff, *Introduction to Computational Optimization Models for Production Planning in a Supply Chain*, Berlin: Springer (2003).

Yoon, Chang and Harris Makatsoris, "Supply Chain Modeling Using Simulation," *International Journal of Simulation*, 2:1 (2004), 24–30.