Best manufacturing practices and their linkage to top-performing companies in the US furniture industry

Henry Quesada-Pineda
Instituto Technologico De Costa Rica, Cartago, Costa Rica, and
Rado Gazo
Purdue University, West Lafayette, Indiana, USA

Abstract
Purpose – This study aims to examine the relationship between top-performing US furniture manufacturers and industry’s best manufacturing practices.

Design/methodology/approach – In the past studies, best manufacturing practices were mostly determined using qualitative methods. In this paper, a quantitative evaluating method to determine best manufacturing practices was designed by taking into consideration qualitative criterions. A sample of 122 manufacturing practices was observed in six US furniture companies, two of them considered world-class performers and the other four considered average. A logistic regression was used to examine the relationship between best manufacturing practices and top-performing companies.

Findings – Statistical analyses showed a positive relationship between top-performing companies and use of best manufacturing practices by these companies. A database of best manufacturing practices was created and shared with the participant companies.

Research limitations/implications – One limitation of this study is that the causal relationship between performance and best practices was not considered. Future studies could employ statistical methods such as structural equation model to better understand this causality. Other methods could possibly be developed to audit and classify manufacturing practices.

Originality/value – It is believed that the database of best manufacturing practices will help average or below-average performing companies to identify and adopt best manufacturing practices. It will also help top-performing companies in the cycle of continuous improvement.

Keywords United States of America, Best practice, Furniture industry, Manufacturing industries

Paper type Research paper

Introduction
Competition from offshore plants is causing a sharp decline in the US furniture manufacturing base. To regain competitiveness, US furniture manufacturers must refocus and define new and innovative strategies. Cost reduction mechanisms (outsourcing, technological advancements, and short-lead times), product innovation, flexibility, quality enhancement, and customer service are the most important strategies that need to be adopted by domestic furniture companies (Wisdom, 2004). However, the majority of US furniture manufacturers are struggling to adopt these strategies because they lack information and specific examples regarding how to adopt these practices (Schuler et al., 2002).
Kline *et al.* (2003) provide specific ideas on how to improve the manufacturing system by benchmarking from the best in the furniture industry. Other research in recent years has focused more on surveys (Buehlmann *et al.*, 2003), market research (Buehlmann and Schuler, 2002), and on stock analysis reports (Whelan and Maklari 2002). Research by Hoff *et al.* (1997) focused on sources of competitiveness for the furniture industry in the USA. This study was based on a literature review of previous publications. The conclusion of that study points out that internal firm processes, external market, and government policy factors affect individual companies and industry competitiveness.

A few private consultants address competitiveness of small and medium size furniture companies (Raymond, 2002; Raymond, 2000) through presentations at trade shows and conferences. Schuler *et al.* (2001) analyzed information from previous research in the US wood products industry in order to provide a summary of general strategies to follow to remain competitive. Cassens and Bradtmueller (1996) characterized the kitchen cabinet industry.

Many US furniture manufacturers have shifted their production overseas, and as a result, more than 160 furniture manufacturing sites have been shut down since 2000 (USDL, 2003). However, about half of all purchased furniture in the USA is still manufactured domestically. The goal of this study is to provide a specific set of best manufacturing practices that struggling companies can use to increase levels of competitiveness through competitive benchmarking. Top-performing companies can use this tool as well in their continuing improvement programs. According to Camp (1995), competitive benchmarking is perhaps the best total quality management tool to understand the differences among two or more companies and to determine which is performing the best. The ultimate objective of benchmarking is to organize the transfer of these practices to underachievers. By doing this, underachieving companies can remain in business.

**Literature review of relationships between best practices and performance**

In this section, a summary of main studies of the relationship between best practices and performance is offered in order to review methodologies that various researchers used to identify best manufacturing practices and their relationship to higher performance.

Voss *et al.* (1997) were probably the first to statistically test whether best practices lead to higher performance. They analyzed the relationship between benchmarking and performance among a group of European manufacturing companies. Specifically, they focused on two main objectives to:

1. determine to what extent firms adopted benchmarking; and
2. test whether benchmarking led to higher performance.

Results of their research showed that the use of benchmarking is linked strongly to both improved operational performance and business performance.

Morita and Flynn (1997) also investigated links between performance and the use of best practices. They compared a sample of companies being recognized as “world-class manufacturing” (WCM) firms against a random sample of companies not classified as WCM. Their methodology relates a list of performance metrics ranked by a plant manager against a list of practices rated by the employees and their perceptions.
concerning the use of these practices. The results showed that there is a high positive relationship between the use of best practices and performance.

Mapes et al. (1997) statistically tested whether or not company performance depends on strategic trade-offs. The authors suggest that the achievement of higher performance in one aspect will be obtained at the expense of lower performance in one or more other aspects, as opposed to other schools of thought that there are no trade-offs when achieving higher performance. The authors state that the primary objective of any manufacturing system is to increase reliability in terms of product, process, and supply chain. Based on this objective, they developed a model to obtain improvements as a result of greater reliability. Results of this research, based on UK manufacturing companies, show that most measures of operating performance have significant positive correlation with each other.

A causal model was used by Van Landeghem and Persoons (2001) in order to build a database of best practices. They based their research on a model proposed by Bilitici et al. (1997), which states that manufacturing companies have four main objectives, namely, flexibility, reaction time, quality and return on assets. For every objective, Van Landeghem and Persoons developed a list of performance metrics and best practices. Best practices were ranked and validated using a logistics approach. This logistics approach consisted of asking companies questions about the use of the supply chain reference model metrics and benchmark data from customers. Furthermore, the data was divided into eight groups according to the different domains of an enterprise (Brown et al., 1996). These domains were employees, planning and control, production and assembly, research and development, distribution, order handling, purchase and suppliers, and market and clients.

The study of the relationship between best practices and higher performance has been an important subject of research in the area of benchmarking. The main focus of these studies has been in determining the type of such relationships and also their causality. All previous studies used qualitative or perception techniques to discriminate between practices and best practices. It was our goal to find a quantitative approach to this problem.

**Methodology for determining and classifying best manufacturing practices**

Three main research questions were formulated: is there a quantitative way to classify practices into best practices? If there is such a way, then how can these best practices be ranked? And finally, is there a relationship between top-performing companies and the use of best manufacturing practices? The research hypothesis is shown below:

\[ H_0. \text{ Best manufacturing practices are positively related to top-performing US furniture companies.} \]

In order to answer the research questions and to test our hypothesis, following methodology was used. A 2003 list of top 300 US furniture manufacturing companies published annually by *Furniture Design and Manufacturing* magazine (Plantz, 2003) was used as a reference to select a sample of companies for this study. About 20 companies with plants in Indiana (due to travel considerations) were invited to participate, and four accepted. These companies made up an “average performers” group. In 2003, from a total of 15 companies world-wide who were awarded the Shingo Prize[1] for Excellence in Manufacturing, three were US furniture plants. We contacted...
all three; and two of them agreed to participate in this study. They constituted our “world-class performers” group, which allowed for a gap analysis between average performers and world-class performers. The most important reason why companies volunteered for this study was the promise of a final report, including the database with best manufacturing practices.

According to Sohal and Ritter (1995) manufacturing tours provide the researcher and participant company with the opportunity to observe and study the operations and practices of selected competitive manufacturing companies and thereby obtain a comparison of the practices of the higher performance plants visited and those of lower performing companies. All participating manufacturers were visited, a comprehensive plant tour was taken and data was collected. A 56-question survey was used as the guideline for the tour. Answers and pictures were collected to include in the best manufacturing practices database. Gap analysis is considered a key step when benchmarking (Camp, 1995), thus financial information was also gathered when possible as well as process documentation that allowed a gap analysis to be made among the companies under study.

Voss et al. (1997) prepared a questionnaire to gather information from manufacturing plants. They defined a plant as a self-contained unit, with its own personnel, facilities, products and management structure. Voss et al. focused on six key areas of manufacturing, namely, organization and culture, logistics, manufacturing systems, lean production, concurrent engineering, and quality. The same six key manufacturing areas were used by Voss et al. (1995) as the principal measures of performance to study the competitiveness of European manufacturing companies. Deviating slightly from Voss et al. (1997, 1995), in this study, we defined target plans using five key areas, namely, human resources, supply chain, product operations, innovation and research, and quality. This allowed us to better match the current structure of furniture companies, because this type of industry might not be strong in advanced manufacturing concepts such as concurrent engineering of lean concepts (Hoff et al., 1997).

For the first objective, a gap analysis was performed among the six participant companies in order to obtain an initial poll of manufacturing practices. Flow charts, process documentation, and matrices were the main tools used for the gap analysis. Once the gap analysis was performed, Camp’s (1995) criteria for deciding which practices produce the best results were used. These criteria were based on following arguments:

- The practice can be validated from several sources.
- The practice is clearly superior or leading edge.
- The quantified opportunity of the practice is large.
- The practice is validated by the expert judgment.
- The practice represents the organization’s core business.
- The practice is preferred if its outputs are offered for sale.

This list of criteria was used in a matrix where all manufacturing practices identified during each plant visit were given a score of either 0 or 1 for each of the six arguments. The sum of these scores determined the importance of the practice. A value between 5 and 6 classified that practice as best practice. A score under 5 meant that practice was
not “best.” A similar procedure was used by Mapes et al. (1997) and Morita and Flynn (1997) to measure performance trade-offs and linkages of best practices with other business areas.

For the second objective, relating manufacturing practices to performance, a logistic regression was used. The plants in the study were assigned a performing score (1 if plant was top-performer, 0 if it was not) based on financial and manufacturing measures. In the case of the Shingo Prize recipients, financial or process metrics were not available. However, these two companies were considered top-performers since their improvements and achievements in manufacturing have been recognized world-wide as Shingo Prize recipients in 2003.

Logistic regression was used for the analysis and prediction of a dichotomous outcome; in this case the outcome is performance (0 or 1). Ordinary least squares, regression or discriminant functions are not considered appropriate for this type of problem since they have strict statistical assumptions in terms of linearity, normality, and continuity for OLS regression and multivariate normality with equal variances and covariance for discriminant analysis (Peng et al., 2002).

The linear logistic model has the form:

\[
\text{logit}(Y) = \log\left(\frac{Y}{1-Y}\right) = \alpha + \beta'X
\]

where \(\alpha\) is the intercept parameter and \(\beta\) is the vector of slope parameters (SAS Institute Inc., 1999). The value of the coefficient \(\beta\) determines the direction of the relationship between \(X\) (manufacturing practices score) and the logit of \(Y\) (top-performance or not). If \(\beta\) is greater than zero, larger \(X\) values are associated with larger logits of \(Y\) (Peng et al., 2002).

Finally, once the manufacturing practices were ranked and related to performance, a database of best manufacturing practices was constructed for the participating companies. The database included information such as description of practice, images, documentation, metrics, and procedures for implementation.

**Results**

After statistically testing the linkage between best manufacturing practices and performance of furniture manufacturing companies, a database was created with the most important manufacturing practices. First, the statistical results of this relationship are shown.

The gap analysis provided us with a sample of 122 manufacturing practices. Table I shows the number of manufacturing practices by key area of manufacturing and by company.

All manufacturing practices were scored on a six point scale based on the Camp (1995) criteria for selection and identification of best practices (Table II). Next, companies were ranked (1 = top-performer, 0 = not a top-performer) according to their performance based either on financial and process metrics or acknowledgment of their manufacturing achievements and improvements.

Once the relationship between best manufacturing practices and high performance was statistically analyzed, a database with best manufacturing practices was created. Table III shows a general description of selected best manufacturing practices found in this study by key area of manufacturing.
Overall model evaluation
A logistic model must provide a better fit to the data than the intercept-only model (null hypothesis) to be considered a good fit. Three main statistical inferences are used to measure this improvement, namely, the likelihood ratio, score, and the Wald tests (Peng et al., 2002). In all three statistics, the null hypothesis that the model is not better than the intercept-model is rejected at $p < 0.05$ (Table IV). Therefore, the logistic model is better than the null hypothesis.

Test of individual predictors
The statistical significance of the regression coefficient is tested using the Wald $\chi^2$ statistic (Table V). It can be seen from Table V that the total score of manufacturing practices (total) is a significant predictor of the performance of a company ($p < 0.01$). This means that larger values of the independent variable (total) are associated with larger values of the independent variable (performance). Hence, the model indicates that best manufacturing practices are positively related with higher-performance in the furniture industry. Results also show that a model intercept is statistically significant ($p < 0.01$).
Goodness of fit test
This evaluation of the logistic model assesses the fit of the model against actual outcomes. The test shown in the Table VI is the Hosmer and Lemeshow (H-L) goodness of fit test. The H-L test is considered an inferential test. In this case, the test shows that the null hypothesis (the model fits well to the data) is not rejected ($p = 0.17, p > 0.05$). Hence, the null hypothesis of a good model fit to data was tenable.

Validation of predicted probabilities
Since, logistic regression predicts the logit of an outcome from a set or a predictor and the logit is the natural log of the odds (or probability/(1 − probability)), it can be...
transformed back to the probability scale. Therefore, the resultant predicted probabilities can be revalidated with the actual outcome (Peng et al., 2002). Table VII shows four measures of association to predict the degree of those probabilities of the model: Somers' D, Gamma, Tau-a, and the $c$-statistics.

According to rule of thumb (Blake, 2004), if $|\text{Gamma}| - |\text{Tau-a}| < 0.05$, then Tau-a should be used instead of Gamma, because Gamma tends to overestimated the grade of association. Also, the $c$-statistics is most commonly used to compare different models with the same set of data or different data with the same model and the Somers’ D statistic is an extension of the Gamma statistic; therefore the association statistic to be used here is the Tau-a statistic. Tau-a for the model is 0.301, which means that there was 30.1 percent fewer errors made in predicting the outcome by using the model than by chance alone.

**Discussion**

When we started contacting companies for this study, we immediately noticed that companies in this manufacturing sector are reluctant to participate in competitive benchmarking studies, mainly due to confidentiality issues. Benchmarking involves collection of sensitive financial and operational data, which most companies do not want to reveal to third parties. One way to overcome this reluctance is to demonstrate to them that benchmarking could make a beneficial difference in their performance. A good example of bringing companies together through benchmarking is a study by Underdown and Talluri (2002). A Breakfast Workshop Series was initiated for small companies in Texas. First, companies were invited to network together, and then the interested parties were taken to a top-performing company where they could start getting engaged with the idea of benchmarking. Later, companies established their own benchmarking partners. In some cases, the low performers are mentored by top performers in order to assure the implementation of best practices. Finally, involved companies continue to improve their operations in a never-ending cycle of success.

All data gathered for this study was obtained from interviews with a plant manager, a vice-president of operations, or a company president. It was found that high level executives tend to respond to questions differently from plant managers. Answers from

<table>
<thead>
<tr>
<th>$\chi^2$</th>
<th>df</th>
<th>Pr &gt; $\chi^2$</th>
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<tbody>
<tr>
<td>6.4685</td>
<td>4</td>
<td>0.1668</td>
</tr>
</tbody>
</table>

**Table VI.**

Goodness of fit test

*Hosmer and Lemeshow goodness of fit test*

<table>
<thead>
<tr>
<th>Effect</th>
<th>Point estimate</th>
<th>95 percent Wald confidence limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>2.514</td>
<td>1.769</td>
</tr>
</tbody>
</table>

**Odds ratio estimates**

**Association of predicted probabilities and observer responses**

<table>
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<tr>
<th>Effect</th>
<th>Point estimate</th>
<th>95 percent Wald confidence limits</th>
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</thead>
<tbody>
<tr>
<td>Percent concordant</td>
<td>72.5</td>
<td>Somers’ D</td>
</tr>
<tr>
<td>Percent discordant</td>
<td>12.8</td>
<td>Gamma</td>
</tr>
<tr>
<td>Percent tied</td>
<td>14.7</td>
<td>Tau-a</td>
</tr>
<tr>
<td>Pairs</td>
<td>3,720</td>
<td>$c$</td>
</tr>
</tbody>
</table>

**Table VII.**

Validation of predicted probabilities
high ranked executives are oriented towards general aspects and strategic issues rather than specific knowledge of specific processes. When appropriate, the manufacturing tour was guided by the process owner who knew every aspect of the process.

The gap analysis was based mostly on flow charts, comparison matrices, performance indicators, and other types of process documentation. The amount of information that plant managers have to manage, especially when there is a large number of variables, as is common in the furniture industry, can be overwhelming. We noticed that in top-performing plants, only a few process indicators such as shipments on time, customer returns, material yield, and quality problems, are being closely monitored by top managers. It appears that for the top-performers the delegation of supervising functions to lower level managers is the key to free up time to focus on the key performance indicators.

In the published benchmarking studies, ranking and evaluation procedures of manufacturing practices are the weak link. Available literature describes several subjective ways of identifying best manufacturing practices, but none of them use a numerical approach to select and rank the best practices. While Camp’s (1995) matrices relate and compare business processes to the areas of interest, they do not evaluate best practices based on a numerical procedure. In addition, the use of a dichotomous scale (yes or no) enables the elimination of ambiguity. The same approach was used by Van Landeghem and Persoons (2001).

A logistic regression is considered to be a very strong regression method when the outcome has a dichotomous scale. In this case, results show that there is a positive relationship between best manufacturing practices and higher performance. Research on the same subject was performed by Voss et al. (1997), and he obtained similar results. The method used by Voss et al. was based on answers to questionnaires and the use of OLS as the regression method to test the hypothesis. The causality of this relationship remains unclear because there is no way to know if best practices lead to high performance or whether the top-performing companies are using more best practices. This is a very important ramification of this analysis. The answer can be found using causal models. The study by Van Landeghem and Persoons (2001) tries to answer those questions based on results from Voss et al. (1997). The authors’ causal model was intended to trace back the effective actions (best practices) that need to be taken to improve performance.

Given the positive relationship found using logistic regression between best manufacturing practices and performance, a database of best manufacturing practices was constructed. Only selected best practices are published in this study. The six participating companies received the full set along with steps to implement some of the most important practices. Results of that implementation stage are not available at this time.

Conclusions and future research
When making the gap analysis it was found that top-performing companies keep higher levels of documentation than non top-performing plants. This trend may support the belief that top-performing companies dedicated more time to process documentation than non top-performing firms. Process documentation is a best practice. Most common process documentation found was flow charts and route sheets. However, the level of information found was sufficient to classify and rank practices
into best practices by designing a tool for this purpose. This evaluation and ranking tool for best manufacturing practices is considered to be an effective and easy-to-use tool for this purpose. This matrix is believed to fill a gap since most methods for best practices evaluation and classification are mostly qualitative. While this benchmarking research focuses on manufacturing practices of US furniture manufacturers, the methodology and some of the results are applicable to other industries. One of the most important results was obtained by using a statistical logistic procedure that showed that there is a positive relationship between best manufacturing practices and performance of companies in the furniture industry. Results agree with previous research on the subject. However, the causality of this relationship was not determined. Finally, after the research questions were satisfactorily addressed, a database of best practices was designed and developed for the use of the companies involved in this study. It is believed that this database will be of great help to average performing companies and to top performers who are involved in a cycle of continuous improvement. Future research on this subject should consider more models of causal relationships between performance and best practices. Statistical methods such as structural equation model could help to better understand this causality. Other methods could possibly be developed to audit and classify manufacturing practices.

Note
1. The Prize was established in 1988 to promote awareness of lean manufacturing concepts and recognize companies in the USA, Canada, and Mexico that achieve world-class manufacturing status (Shingo Prize, 2004).

References


**Corresponding author**
Rado Gazo can be contacted at: gazo@purdue.edu

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