An AHP-based Study of WCM Implementation Factors in ISO 9001 Certified Manufacturing Organizations in Trinidad and Tobago

Krystal Ramoutar, and Chanan S. Syan

***Abstract*—As global competitiveness intensifies, it is imperative that manufacturing organizations in developing countries can compete at a global level. This paper empirically identifies the critical factors associated with the implementation of World-Class Manufacturing (WCM) techniques in ISO 9001 certified manufacturing organizations in Trinidad and Tobago (T&T). The critical factors synonymous with successful WCM implementation were identified via a comprehensive review of WCM implementation literature. An analytic hierarchy process (AHP) framework is proposed. The application of the proposed approach and the contribution of this research are highlighted.**

***Index Terms*—Analytic Hierarchy Process, Manufacturing Performance Improvement, Trinidad and Tobago, World Class Manufacturing**

I. Introduction

Research has emphasised the importance of measuring the different facets of organizations performance in order to achieve a competitive advantage. Without the ability to understand or measure performance, reorientation or diversification of a company's strategies, operations, process, procedures and even benchmarking will be futile [1]. The need for effective deployment of business objectives down through the organization and the subsequent measurement of the organization's performance is well documented as key elements of sustainable competitive advantage [2], [3], [4].

WCM focuses on continuous improvement [5]. Hayes and Wheelwright (1984) introduced the term WCM to describe organizations which achieved a global competitive advantage through use of their manufacturing capabilities as a strategic weapon and described this as a set of practices that focus on continuous improvement, training and investment in technology [6]. Numerous studies have found that the implementation of WCM practices has led to superior performance [7], [8]. Voss (1995) states that "*the continuous improvement of best practice in all areas of the organisation will lead to superior performance capability leading to increased competitiveness [7].*" Greene (1991) gave an in-depth definition and it states that WCM companies are '*companies which continuously outperform the industry's global best practices and which know intimately their customers and suppliers, know their competitors' performance capabilities and know their own strengths and weaknesses. All of which form a basis of – continually changing – competitive strategies and performance objectives [9]. '* Since the term 'world-class' was introduced by Hayes and Wheelwright (1984), many researchers have expanded on the concept [6]. Schonberger (1987) even used WCM to refer to many techniques and technologies designed to enable a company to match its best competitors [10]. World-class status or best practices are relative terms, rather than an absolute standard. Thus, what is considered to be the best or 'world-class' also continuously changes. Therefore, global competitiveness requires that world-class status be an always elusive goal.

Many researchers believe that the actual process of implementation is critical to the successful improvement of organizations performance and requires more focus [11], [12], [13], [14]. However, there is an absence of practical and detailed guidelines specifically for the implementation of WCM practices to achieve excellence within manufacturing. Thus, investigating the critical factors that are driving and inhibiting the implementation of WCM techniques is recommended so that principle strategies and actions can be undertaken to remove any severe obstacle before the actual implementation.

Review of recent studies found that there was an absence of research contributing to the assessment of manufacturing performance and identification of areas for improvement in the manufacturing industry of T&T, even companies that are ISO 9001 certified [15]. Only a few studies on WCM implementation in developing countries were discovered [16], [17], [18]. Thus, this research, in the context of T&T, is novel yet practical and fulfils the identified, urgent need for manufacturing companies, even in T&T, to attain WCM status in order to remain competitive. The broad objective of this research paper is to identify the critical factors associated with the implementation of WCM techniques in

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T&T Manufacturing Sector. A model will be development which will aid decision makers within organizations to pinpoint areas whereby specific resources can be allocated for greatest performance improvement or the successful implementation of WCM techniques. To this end, this paper presents the findings of an empirical study conducted in T&T that investigated the percent weighting of critical WCM implementation factors in ISO 9001 certified manufacturing organizations. The AHP methodology has been adopted to facilitate the study and analyze the findings.

II. AHP Based Study

A comprehensive literature review was conducted to establish the critical factors associated with the successful implementation of WCM practices. However, it was observed that the evaluation of the critical factors is a complicated decision problem because of the following reasons:

- The relative difficulty to conceptualize and structure the numerous components of the evaluation problem into an analytical framework which may facilitate understanding.
- The nature of the critical factors - some are quantitative whereas others are subjective.
- There are a multitude of factors/attributes involved in the successful implementation of WCM techniques which are often conflicting and sometimes complementary. Many times, such factors/attributes are non-expressible in commensurable units and some might reflect psychological aspects such as qualitative considerations and intangibles.

A framework was developed which takes into account all of the mentioned decision problems using AHP. Among the different multiple criteria decision-making (MCDM) models, AHP has aroused considerable interest in practitioners and researchers in recent years. AHP was developed by Saaty (1980) [19]. In addition to simplicity, ease of use, and flexibility, intuitive appeal, the ability to mix qualitative and quantitative criteria in the same decision framework and its ability to handle complex and ill-structured problems has led to AHP's power and popularity as a decision making tool [20], [21]. Three features of the AHP differentiate it from other decision-making approaches [20], [21], [22]:

- Its ability to handle both tangible and intangible attributes;
- Its ability to structure the problems in a hierarchal manner to gain insights into the decision-making process; and
- Its ability to monitor the consistency with which a decision maker makes judgment;

Given the advantages of AHP, a novel framework/model based on the principle of aggregation is proposed. A detailed step-by-step procedure for the proposed framework is presented in the following section.

III. The Proposed AHP Framework

A. Stages of the AHP Study

The authors conducted a recent study on WCM implementation criteria and related sub-criteria in ISO 9001 certified manufacturing organizations in T&T. The aim of the study was to collect empirical evidence and consolidate a breadth of credible opinions on criteria towards the successful implementation of WCM practices in manufacturing organizations. The AHP methodology was used to determine the extent to which the criteria and sub-criteria of WCM implementation had affected the ISO 9001 certified organizations. The AHP methodology involves the decomposition of a complex problem into a multi-level hierarchical structure of characteristics and criteria. The AHP methodology is described below.

After the goal of the study had been established, relevant and important criteria and sub-criteria were identified from the comprehensive literature research conducted (Step 1). These criteria and sub-criteria were then structured into a hierarchy descending from the overall goal to the various stages and related sub-criteria in successive levels (Step 2). Step 3 is concerned with the collection of empirical data through the combined judgments of individual evaluators from five specifically chosen ISO 9001 certified manufacturing firms in T&T. Evaluators were chosen and interviewed based on their involvement in the implementation of techniques for improving organizations manufacturing performance. These companies were chosen are reflective of various aspects of the manufacturing sector in T&T such as (a) Assembly-type and related industries (b) Chemical and non-metallic materials (c) Concrete products (d) Food, Beverage and Tobacco (e) Steel Products. As such, their views adequately represented the expert opinions needed for analysis. A semi-structured interview approach was adopted whereby a questionnaire was designed based on Saaty's 9-point scale.

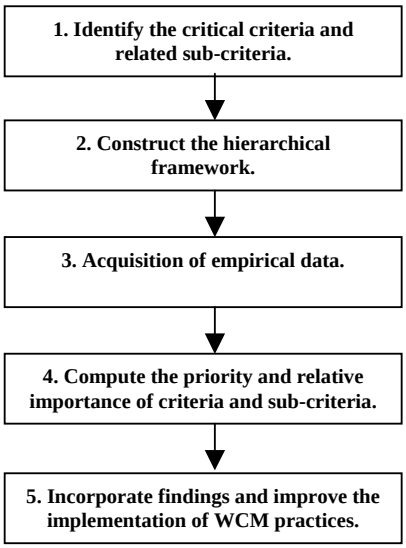

Figure 1: Process Flowchart for the AHP Study

Evaluators were required to assess the criteria of each hierarchy level by assigning relative scales in a pair-wise fashion with respect to the overall goal of the model [19]. After the acquisition of evaluators' views, step 4 followed with the computation of normalized weight priorities of the different hierarchies of criteria of the AHP model. This was done using the computer software, Expert Choice [23]. The relative importance of each factor was rated to provide numerical judgments corresponding to verbal judgments. The normalized Eigen values method is recommended when the data is not entirely consistent [24], [25]. Since different levels or hierarchy were interrelated, a single composite value of normalized weights for the entire hierarchy was determined. Both local priorities (i.e. relative to the parent elements) and global priorities (i.e. relative to the goal) were generated. These were represented by total and sub-total of priority scores. The weights of the criteria and sub-criteria were derived in a similar manner. The process was continued until all comparison judgment matrices were obtained. Step 5 incorporated the findings of this study for implementation of WCM techniques aimed at improving manufacturing performance. The process flowchart steps involved in the AHP study were outlined in Figure 1.

B. An Analytical Framework for AHP Analysis

Step 2 in the AHP methodology means creating a hierarchy of decision elements. Organizing criteria and sub-criteria in a hierarchy serves two purposes:

1. It breaks down the problem and provides an overview of the complex relationship inherent in the situation;
2. It aids evaluators assess whether the issues in each level are of the same order of magnitude, so homogeneity in comparisons is preserved [26].

Saaty (2000) suggests the guidelines for selection of the different levels of criteria and construction of the hierarchy [27]. Using these guidelines, an AHP framework was developed for facilitating the study as shown in Figure 2. Based on the above approach to this study, certain limitations arise, hence the nature of this empirical study.

1. The number of pair-wise comparisons required to develop the judgment matrix accumulates in the decision hierarchy [28], [29].
2. For effective results, AHP has to be conducted on the basis of face-to-face study and discussion. It cannot be carried out effectively as a postal questionnaire [30]. This is because a maximum interaction is necessary to ensure respondents understand their functions and how to make comparisons among criteria; all information on definitions, questions, and procedures must be made clear to respondents.

IV. Data Analysis and Findings

The characteristics of the five manufacturing firms (i.e. Companies A, B, C, D and E) involved in this study are summarized in Table I. The characteristics were chosen to reflect the unique characteristics of manufacturing organizations, in terms of their structure, procedures, behavior, culture, processes, people and contacts endemic in T&T. A '✓' means that the company possesses that characteristic, while an '**x**' means that it does not. The interviews were conducted with senior personnel including chief executive officers, general managers, production managers and operations managers of the organizations. These personnel are responsible for and/or involved in implementation of manufacturing practices and performance measures in their organizations. Their views provided a wide spectrum of experience and expertise within their organizations and across various industry sectors in T&T.

The local and global percent priorities of the different levels of performance criteria are depicted in Table II. The weightings of the criteria at each level will represent to varying degrees how important that criteria is towards the successful implementation of WCM techniques in T&T manufacturing sector. The criteria with that greatly influenced the implementation of WCM practices would be represented by the highest percent priority.

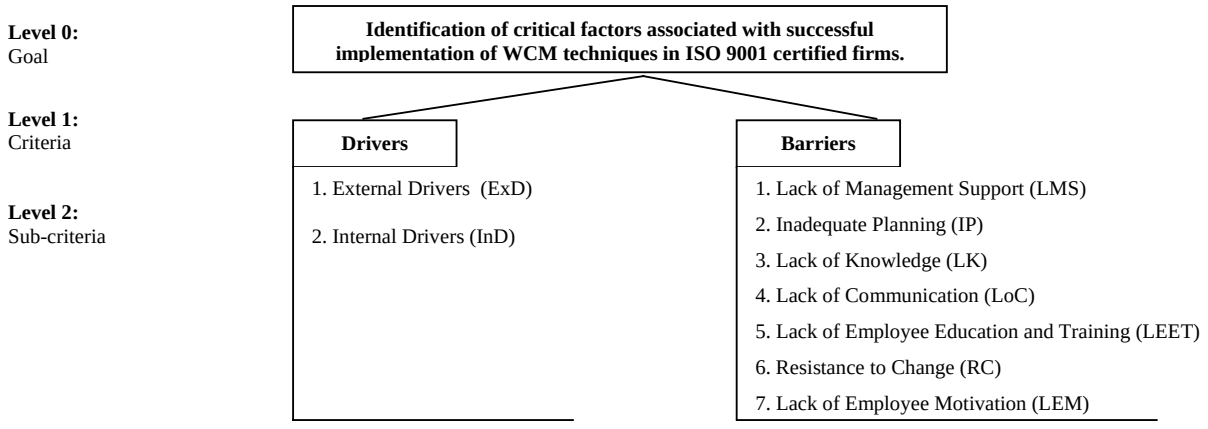

Figure 2: An Analytical Framework for AHP Analysis

Table I: Selection of ISO 9001 Certified Manufacturing Firms for the Study

Lists of selection items	Company A	B	C	D	E
Production type					
Job shop type	x	✓	x	x	x
Batch production type	x	x	✓	✓	x
Continuous flow	✓	x	x	x	✓
Service	x	✓	x	x	x
Project type	x	✓	x	x	x
Ownership					
Family owned	x	✓	x	x	x
Government owned	✓	x	x	x	✓
Sole proprietor	x	✓	x	x	x
Public company	x	x	✓	✓	x
Location					
Based in an industrialized area	x	✓	x	x	x
Based in the North Trinidad	x	x	✓	✓	✓
Based in Central Trinidad	x	✓	x	x	x
Based in South Trinidad	✓	x	x	x	x

Similarly, those with low percent parities would represent the criteria which poorly influence or had no influence on WCM implementation. It was found that T&T manufacturing sector put higher emphasis on the drivers towards WCM implementation than the barriers, with the mean weights (i.e. percent priority) of 8.53 percent and 1.46 percent respectively. This correlated with research conducted by Salaheldin (2007) and Saxena and Sahay (2000).

A closer examination of the percent priorities in the third level helped identify specific areas of strengths and weaknesses in T&T manufacturing sector. At level 3, ExD (i.e. ExD = 4.86 percent) was ranked higher than InD (i.e. InD = 3.67 percent) for the successful implementation of WCM techniques. For the barriers, RC (i.e. RC = 0.31 percent) and LK (i.e. LK=0.28 percent) were the leading sub-criteria. The lowest ranked sub-criteria was LMS (i.e. LMS = 0.13 percent). These weaknesses reflect the fact that the issue of culture and its alignment with improving an organizations performance needs in-depth research, specifically for T&T manufacturing sector.

Table III gives the overall ranking in terms of the percent priority of these sub-criteria. The inconsistency indices of the AHP analysis for Companies A, B, C, D, and E were 0.09, 0.08, 0.08, 0.08 and 0.05 respectively. These fall within the acceptable level of 0.10 as recommended by Saaty (1996). This indicated that the evaluators assigned their weight consistently on examining the priorities of decision criteria towards successful implementation of WCM techniques.

Table II: Priority weights of stages and sub-criteria from evaluators

Level I: Criteria	Level II: Sub-criteria	Priority Weightings (percent)					Mean Priority Weightings
		Company A	Company B	Company C	Company D	Company E	
Drivers	ExD	1.48	7.35	6.24	7.90	1.33	4.86
	InD	7.41	1.22	2.08	0.99	6.67	3.67
Sub-Total		**8.89**	**8.57**	**8.32**	**8.89**	**8.00**	**8.53**
Barriers	LMS	0.02	0.04	0.06	0.02	0.53	0.13
	IP	0.24	0.04	0.18	0.11	0.13	0.14
	LK	0.36	0.21	0.26	0.35	0.24	0.28
	LoC	0.09	0.13	0.26	0.24	0.36	0.22
	LEET	0.09	0.14	0.15	0.20	0.27	0.17
	RC	0.13	0.54	0.50	0.08	0.30	0.31
	LEM	0.17	0.33	0.27	0.11	0.17	0.21
Sub-Total		**1.10**	**1.43**	**1.68**	**1.11**	**2.00**	**1.46**

Table III: Rankings of the Percent Priority Weighting of Sub-criteria

Sub-criteria	Priority Weightings (percent)	Ranking
DRIVERS		
External Drivers	4.86	1
Internal Drivers	3.67	2
BARRIERS		
Resistance to Change	0.31	1
Lack of Knowledge	0.28	2
Lack of Communication	0.22	3
Lack of Employee Motivation	0.21	4
Lack of Employee Education and Training	0.17	5
Inadequate Planning	0.14	6
Lack of Management Support	0.13	7

V. Conclusions

The importance of evaluating and improving the performance of manufacturing organizations was emphasized in order to remain competitive. WCM techniques and practices are identified as competent in improving an organization's performance and sustaining continuous improvement. This paper identified how critical successful implementation of world-class manufacturing techniques/practices is in order to improve organizational performance. The aim of this study was to identify the factors influencing the successful adoption of WCM implementation in ISO 9001 certified manufacturing organizations in T&T. The factors were identified from a comprehensive literature review on various aspects of WCM implementation. It proposed a process model and employed the AHP methodology to acquire and analyse industry practitioners' opinions among the critical criteria and related sub-criteria associated with the successful implementation of WCM techniques. Senior personnel of five selected manufacturing firms in T&T who were directly involved in implementing manufacturing practices in their organizations to improve performance were interviewed. With the aid of the Expert Choice software package, the empirical data was collated and practitioners' opinions were analysed to determine the percent weighting of criteria and sub-criteria. The findings revealed that the need for WCM implementation emerged as a result of many business drivers, mainly those drivers external to the organizations. On the other hand, implementing WCM techniques has many barriers. With the ranking of the criteria and sub-criteria established, this can be used as a gauge to assist organizations towards the successful implementation of WCM techniques. Based on the results of this study, strategic plans can be formulated specifically geared towards the factors with the highest priority weighting that negatively affected manufacturing organizations implement WCM practices. Resistance to change and lack of knowledge are the most important barrier to implement the WCM. Therefore, management should foster a culture that encourages change within their organization. Reducing the resistance of change can be achieved through a process of mature learning and intense training programmes to increase the awareness to prepare employees for the potential change and provide all involved with the knowledge required for the change. Hence these two factors are interrelated and critical to ensure successful WCM implementation. With a better understanding of these issues involved in WCM, managers will be able to make informed decisions and allocate the necessary resources to make WCM implementation a success in the long-term. A logical progression of this study would be to carry out a similar study concerning manufacturing organizations that are non-ISO 9001 certified. Finally, similar studies in the Caribbean or other developing countries could be carried out and comparative studies can be conducted to find out the similarities and dissimilarities concerning the driving and resisting forces towards WCM implementation in different context.

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