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Relationship among Green Production Benefits: A Causal Model

José Roberto Mendoza Fong[1], José Roberto Díaz Reza[1], Viridiana Reyes Uribe[2], Adrián Salvador Morales García[3], Jorge Luis García Alcaraz[3]

[1] Universidad Autónoma de Ciudad Juárez,
Departamento de Ingeniería Eléctrica y Computación,
Mexico

[2] Instituto Tecnológico de Ciudad Juárez,
Departamento de Ingeniería Industrial y Logística,
Mexico

[3] Universidad Autónoma de Ciudad Juárez,
Departamento de Ingeniería Industrial y Manufactura,
Mexico

{al164438, al164440, al194561}@alumnos.uacj.mx,
vreyes@itcj.edu.mx, jorge.garcia@uacj.mx

Abstract. Green production processes are becoming increasingly important, as consumers not only demand quality, economical and durable products, but also products that are environmentally friendly. Manufacturers are therefore wondering how feasible it is to transform their traditional production process into a green production process, since such transformation involves economic investment and the relationship between these two dimensions is unknown. This article presents a model of structural equations where four different types of benefits are associated: process benefits, quality benefits, market benefits, and green benefits that can be obtained by implementing a green production process and facilitating manufacturers' decision making. The model is validated with information from 559 responses from managers who have applied the concepts of green production processes in the Mexican manufacturing industry. The partial least squares technique is used to validate the models and the results indicate that the four benefits have a direct and positive effect on each other and the most significant is that there are process benefits and quality benefits.

Keywords: green production processes, environmental benefits, manufacturing industry, green product.

1 Introduction

Some of the most important factors in green activities are green production processes (GPP), which are important in the development of green supply chain management, as the generation of green products will increase competitive advantages and improve the environment [1].

GPPs are a key step in achieving sustainability and ensuring the environmental, social, and economic aspects of manufacturing a product [2]. A GPP can be defined as a new manufacturing paradigm that incorporates diverse ecological strategies, drivers, and techniques to be more eco-efficient [3]. GPP refers to making products that consume less materials and energy, incorporating renewable and non-toxic materials, and reducing unwanted outflows, waste, emissions, and recycling [4].

However, implementing a GPP is not fast and manufacturers are wondering whether integrating green thinking into their production processes actually brings economic and environmental benefits. For this reason, this research presents a model of structural equations composed of four latent variables that associate a series of benefits that can be obtained by implementing a GPP in a certain organization.

1.1 Literature Review: Definition of Variables and Hypotheses

Manufacturers must design, manufacture, and distribute eco-friendly products to meet the demands of environmentally committed consumers. However, the question is whether manufacturers with a green perspective can realize benefits associated with the production process, sales, and quality. Fortunately, some researchers have shown that a GPP generates benefits [5-7].

First of all, one could ask what benefits can be gained in the production processes by having a GPP. For example, Gao, Xiao [8], Zhu and He [9] mention that GPP makes better use of resources, eliminates waste, achieves green process design and greater efficiency, competitiveness, productivity, and reduced cycle time.

Additionally, Shankar, Kumar [5] and Xie, Huo [10] mention that, by increasing efficiency, productivity, and reduction of cycle time, the quality of the product and process are improved and green processes and products are obtained. Therefore, the following hypothesis is defined:

> H_1: The *Process Benefits* have a direct and positive effect on the *Quality Benefits* in a GPP.

The efficiency of green production processes and the use of resources have a direct impact on customer service and the final consumer [11]. It is also believed that when designing sustainable products there will be an expansion in the market with consumers committed to the environment. [12] The following hypothesis is therefore defined:

> H_2: *Process Benefits* have a direct and positive effect on the *Market Benefits* in a GPP.

Therefore, manufacturers seek to distribute and develop eco-friendly products for national and international markets [13], which forces them to manufacture quality green products to improve their sales and increase their reputation with their customers.

Therefore, the implementation of a GPP improves the ecological performance of products and rebuilds an industrial system that reduces reprocesses and reduces cycle times for the customer. [14] Therefore, the hypothesis is defined:

> H_3: *Quality Benefits* have a direct and positive effect on the *Market Benefits* in a GPP.

With GPP-enhanced production processes, all that remains is to analyze how consumers judge green products and how they influence the purchasing decision process. [15] In addition, consumers not only analyze the green products they buy, but also how they were manufactured, and the resources used, so that the brand image is related to what consumers think and the products they buy, which defines the following working hypothesis:

> H_4: The *Process Benefits* have a direct and positive effect on the *Green Benefits* in a GPP.

When a brand is perceived as having a green image, its products are linked with quality in the mind of the consumer. A green product image helps companies attract more customers by affecting consumer choice and improving consumer brand loyalty. [10] Since there are many consumers who want to buy products from companies that respect the environment and few companies that generate these types of products, the consumption of these types of products has increased. [16] Therefore, the following working hypothesis is defined:

> H_5: *Quality Benefits* have a direct and positive effect on the *Green Benefits* in a GPP.

On the other hand, investing in GPP innovation helps prevent companies from facing environmental protests and legal sanctions, allows them to develop new market opportunities, and improves customer service. [17] Now, companies have an ecological competition to increase sales, strengthen the ecological image, and improve their acceptance in society. [10] The following hypothesis is therefore proposed:

> H_6: *Market Benefits* have a direct and positive effect on *Green Benefits* in a GPP.

The hypotheses defined above are illustrated in Fig. 1.

2 Methodology

2.1 Collection of Information

A literature review is carried out in relation to the GSC and GPP, approximately 100 different scientific articles were analyzed to identify the most mentioned and commonly obtained benefits of applying GPP, which were classified into categories (as indicated in Table 1) and are the items in each latent variable of the model analyzed.

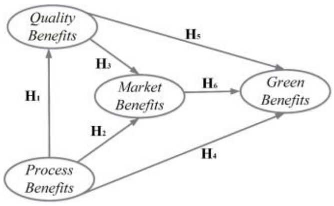

Fig. 1. Hypothesis.

Table 1. Benefits Classification.

Process Benefits [10, 18, 19]	*Manufacturing Benefits* [20-22]
Reduction of cycle time. Improved product design. Reduction of cycle time. Higher competitivity, productivity and efficiency. Better use of available resources.	Expansion of the world market. Better customer service. Improved reputation with customers and competitors.
Quality benefits [3, 23, 24]	*Green benefits* [13, 25, 26]
Improved process quality. Less product reprocessing. Higher quality in the final product.	Image of a sustainable company. Better acceptance of products in society. Integration of the company in society.

Table 2. Descriptive analysis of latent variables and items.

Process Benefits	Median	IR
Reduction of cycle time	3.48	1.808
Improved product design	3.718	1.577
Higher competitivity, productivity and efficiency	3.721	1.514
Better use of available resources	3.743	1.52
Manufacturing Benefits		
Increasing the quality of your processes	3.697	1.549
Reduced product reprocessing	3.604	1.626
Increase in the quality of the final product	3.786	1.563
Market Benefits		
Expansion of the world market	3.695	1.66
Better customer service	3.805	1.547
Improved reputation with customers and competitors	3.823	1.587
Green Benefits		
Image of a sustainable company	3.56	1.704
Better acceptance of products by society	3.693	1.66
Integration of the company into society	3.793	1.683

With these benefits, a survey was designed as a tool to gather information on the situation of manufacturing companies, which is applied to managers and engineers responsible for GGP and which was answered on a Likert scale. The information obtained is captured in a database built in the Statistical Software SPSS 24 ®.

2.2 Items Analysis

The median is used as a measure of central tendency. Low values indicate that the benefit is not obtained, while high values indicate that they are always obtained. In addition, the interquartile range (IR) is used as a measure of dispersion, where low values indicate consensus among responders and high values indicate lack of consensus.

2.3 Execution of the Model of Structural Equations

The structural equation model (SEM) is evaluated in the software WarpPls 6.0 ®, which integrates the partial least squares technique that uses standardized values and is used in small samples and data that do not tend to normality.

The following indices are used to validate the latent variables in Figure 1: Average R-square (ARS), Average adjusted R-square (AARS), Average path coefficient (APC), Average variation inflation factor (AVIF), Average total collinearity VIF (AFVIF) and Tenenhaus Index.

For APC, ARS y AARS, p-values are analyzed, setting 0.05 as the limit and testing null hypotheses in which APC, ARS y AARS = 0, against the alternative hypothesis APC, ARS y AARS ≠ 0. The values of AVIF and AFVIF should be less than 5 and for the Tenenhaus Index (GoF), it is recommended to have values greater than 0.36.

In the SEM, three types of effects are measured in the model: direct, indirect and total. The direct effects are the arrows that directly connect two latent variables, the indirect effects are represented by routes with two or three segments and the total effects is the sum of the direct and indirect effects. For statistical significance a 95% confidence level is used, testing the null hypothesis: $\beta i = 0$, versus the alternative hypothesis: $\beta i \neq 0$.

3 Results

3.1 Descriptive Item Analysis

Table 2 shows the descriptive analysis of the items, where the second column indicates the median and it is observed that 12 of 13 thirteen benefits have an average greater than 3,500 which denotes that these benefits are important for a GPP. The last column illustrates the IR and it can be seen that all benefits have a value less than 2 and it is concluded that there is consensus among respondents regarding the importance of these benefits.

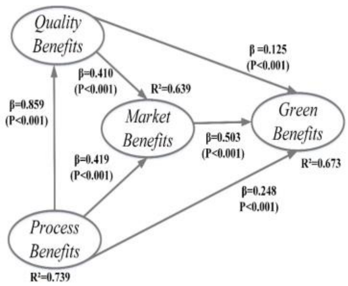

Fig. 2. Evaluated model.

Table 3. Validation of hypotheses.

Hypothesis	Independent Variable	Dependent Variable	β	Effect Size	P-Value	Decision
H_1	*Process Benefits*	*Quality Benefits*	0.859	0.739	P< 0.001	Accepted
H_2	*Process Benefits*	*Market Benefits*	0.419	0.323	P< 0.001	Accepted
H_3	*Quality Benefits*	*Market Benefits*	0.410	0.316	P< 0.001	Accepted
H_4	*Process Benefits*	*Green Benefits*	0.248	0.184	P< 0.001	Accepted
H_5	*Quality Benefits*	*Green Benefits*	0.125	0.091	P< 0.001	Accepted
H_6	*Market Benefits*	*Green Benefits*	0.503	0.398	P< 0.001	Accepted

3.2 Equation Model Validation

Fig. 2 shows the model obtained, where each arrow indicates a direct effect between two latent variables, and this includes a beta parameter. (β), a p-value for the hypothesis test and an R2 value as a percentage of the explained variance of the latent variables. The validation indices of the latent variables are:

- Average path coefficient (APC) = 0.427, P<0.001,
- Average R-squared (ARS) = 0.684, P<0.001,
- Average adjusted R-squared (AARS) = 0.683, P<0.001,
- Average block VIF (AVIF) =3.854, acceptable if <= 5,
- Average full collinearity VIF (AFVIF) = 3.813, acceptable if <= 5,

Table 4. Sum of indirect and total effects.

Sum of indirect effects			
		To	
From	*Quality Benefits*	*Market Benefits*	*Green Benefits*
Process Benefits		0.353 (P<0.001) ES=0.272	0.495 (P<0.001) ES=0.369
Quality Benefits			0.206 (P<0.001) ES=0.150
Sum of total effects			
Process Benefits	0.859 (P<0.001) ES=0.739	0.771 (P<0.001) ES=0.595	0. 743 (P<0.001) ES=0.554
Quality Benefits		0.410 (P<0.001) ES=0.316	0.331 (P<0.001) ES=0.241
Market Benefits			0.503 (P<0.001) ES=0.398

— Tenenhaus GoF (GoF) = 0.728, small >= 0.1, medium >= 0.25, large >= 0.36.

Table 4 presents the validation of the six defined hypotheses and the conclusions.

3.3 Total and Indirect Effects

At this point, Table 5 will be presented, which contains the indirect effects as well as the total effects presented by the model. First, you will see the indirect effects, which are in two and three segments. Then the total effects are presented, which is the sum of direct effects (β) and indirect effects.

4. Conclusions

It is concluded that by transforming a traditional production process to a GPP, benefits are obtained in processes, quality, market and image; since the model proposed here demonstrates quantitatively that the four latent variables have a direct, positive and significant effect on each other.

It is observed that when obtaining *Process Benefits* the obtaining of the *Quality Benefits* is guaranteed, since this is the biggest and significant effect in all the model and which was of 0.859 (H_1), in addition to the fact that Das, Rukhsana [3, 7] demonstrated that when it comes to optimizing product processes, these improvements will be seen in the quality of the product, as well as in the optimization of the use and consumption of resources.

Finally, today, apart from the fact that the product that the consumer is looking to be green, it is important the image of the brand of the company that is manufacturing the product is green.

This is also important when marketing the product because consumers are focusing more and more on how that green product is produced and this is verified in the $H_{6,}$ since the market benefits are fundamental to be able to obtain the *green benefits*, a statement that detonates [15] in our investigation.

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