

## The relationship of continuous improvement and cleaner production on operational performance: An empirical study in electronic manufacturing firms, Taiwan China

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**Abstract.** Recent research has pointed out the limitations of achieving commitment and continuous improvement in cleaner production program implementation. And cleaner production designed to reduce wastes and emissions at source can improve the environmental, as well as economic performance of participating organization. However, there is inadequate empirical evidence or model to prove the relationship of cleaner production, continuous improvement and operational performance existed. This paper investigates the effects of continuous improvement and cleaner production on operational performance. A conceptual model is developed and three research hypotheses are empirically examined using structural equation modeling. The data were collected via a survey of Taiwan electronic manufacturing firms. The result indicated that cleaner production has a positive influence on operational performance as well as on the continuous improvement on cleaner production and operational performance. Theoretical, managerial and research implications are discussed.

**Keywords:** cleaner production, continuous improvement, operational performance

### 1 Introduction

Cleaner production was designed to show that the prevention or reduction of wastes and emissions at source can improve the environmental, as well as economic performance of participating organization. [22] described “cleaner production takes a methodological approach and creative questioning of daily activity to make transparent. Not all problems could be solved with cleaner production only. Cleaner production works best if it becomes a continuous improvement process.” Recent research has pointed out the limitations of cleaner production program implementation as continuous improvement<sup>[37]</sup>.

Continuous improvement activity can be generated and sustained through the promotion of a good improvement model and management support. In fact, it is not so easy in reality. The improvement case may fail without carefully examining the problem in the activity<sup>[40]</sup>. The continuous improvement program is to ensure that the cleaner production be implemented into sustainable. Yet, The major spirit of cleaner production on good housekeeping, information, training and awareness raising focus on transfer of environmentally sound technologies combined with financial services, which means translating the implemented policies into profit<sup>[14, 42]</sup>. Thus, the aim of this study is to explore the relationship between continuous improvement and cleaner production and further its influence on operational performance.

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However, there is inadequate empirical evidence or model to prove the relationship of cleaner production, continuous improvement and operational performance existed. The need to address this gap in the literature arises from increasing concern over under performing continuous improvement and cleaner production initiatives. Our study is motivated by the lack of empirical evidence on the impact of cleaner production on the relationship between the use of continuous improvement and operational performance.

Using empirical data collected from electronic manufacturing firms in Taiwan, this study attempts to achieve two primary objectives. First, it seeks to find the inadequacy in empirical evidence, which have appeared in the literature concerning the relationships among cleaner production, continuous improvement and operational performance. And, second, to the study of cleaner production by added continuous improvement to improve operational performance and constructs an organizational theoretical model.

This paper is organized as follows. Section 2 discusses the literature review and research hypotheses. Section 3 addresses the research method while Section 4 presents the empirical results. Section 5 presents the discussion and conclusion of the paper.

## 2 Review of literature and research hypotheses

The literature review is presented in three sections. The first sections deals with the relationship between cleaner production and operational performance as this provides a basis for understanding the other two relationships (i.e. between cleaner production and continuous improvement and between continuous improvement and operational performance).

### 2.1 Cleaner production and operational performance

Cleaner production has the potential to save 0.5-1.5% of the total costs of producing companies by investments paying back according to present economical standard<sup>[22]</sup>. [36] described “The Michigan housing sustainability study was development thirty-eight recommendations to move the organization toward sustainability and assessed in terms of their importance, cost and implementation time to produce priority”. The concept of cleaner production has been accepted and has been put into effect by more and more countries. And, it becomes the fundamental pattern for many industries in the 21st century. Cleaner production, is a preventative integrated continuous strategy for modifying products, processes or services, and it has been considered as the best technological strategy and good housekeeping toward sustainable development<sup>[24]</sup>. The major spirit of cleaner production focus on transfer of environmentally sound technologies combined with financial services, which means translating the implemented policies into profit<sup>[14, 42]</sup>. The description of success cleaner production implementation can give often both environmental and economic benefits; it promotes facility efficiency, reduces the need for expensive end-of-pipe treatment and disposal technologies, improved material, energy efficiency, quality system and reduces the long-term liabilities associated with releases into the environment<sup>[31]</sup>. However the measurement is on the specific point of cost saving on business organization<sup>[19, 28, 32]</sup>. [38] shows the result that On-going improvement is essential for sustainability to be achieved and commitment is necessary for on-going improvement to occur. Commitment involves the internalization of a value system. Therefore, the following hypothesis is proposed based on the literature discussion.

**Hypothesis 1:** Cleaner production is positively associated with operational performance.

### 2.2 Continuous improvement and operational performance

Operational and strategic controls are linked. Concern with using manufacturing performance measures for operational control provides the capability to recognize when specific parts of the manufacturing process are moving out of control and signal a need for process adjustment and go to a cycle of continuous improvement by daily operations<sup>[26, 27, 30]</sup>. The application of common cleaner production methods and tools is particular a waste and emissions prevention assessment and product life cycle assessment. The cleaner production process suggests that continuous improvement must incorporate with its implementation<sup>[38]</sup>. Very little detail is provided on exactly what needs to be done to ensure that continuous improvement will occur

in the process. [23] approached continuous improvement from the improvement of all its products, services and production process and the compliment of existing and potential customers. The traditional guidance also tends to be top-down and mechanistic in their approach, apparently relying on the ability of an executive of its continuous improvement on cleaner production process.

Continuous improvement creates value for the customer since it seeks to march demands and it is a mechanism for eliminating waste, so allowing costs to be cut<sup>[6, 29, 41]</sup>. This mechanism increased profit margins to achieve the greater profitability<sup>[12]</sup>. Moreover, the practices and techniques that help to achieve continuous improvement include processes analysis. Their application contributes toward a reduction in process variation and percentage of defects. The effect of continuous improvement on operational performance may be justified by organization strategic goal setting. According to goal setting theory, goals will be motivating people if they are specific and difficult, and people accept them as their own<sup>[33]</sup>. Given that continuous improvement on problem solving involves a process control of setting new performance goals, it achieve may favor organizational excellence. In sum, the literature review shows that continuous improvement might improve on the operational performance. The following hypothesis is proposed based on the above discussion.

**Hypothesis 2:** Continuous improvement is positively associated with operational performance.

### 2.3 Continuous improvement and cleaner production

Based on the definition of some experts<sup>[7, 10, 17, 18]</sup>, the goals of continuous improvement can be summarized as:

- (1) a company-wide focus to improve process performance;
- (2) a gradual improvement through step by step innovation;
- (3) organizational activities with the involvement of all people in the company from top managers to workers;
- (4) creating a learning and growing environment.

However, continuous improvement is a continuous activity like a production process. From its output we can judge if the production process is proper.

Cleaner production can generate short- and long-term environmental and social improvements, well beyond those possible with regulatory compliance programs. It can also improve the competitiveness of industry by increasing revenues and decreasing non-product output. [22] resulted on Austrian Preventive environmental protection approaches in Europe (PREPARE) project that the process water could be saved by reusing cooling water as process water:

- (1) Water usage could be avoided by optimizing the use of water through better process control.
- (2) Operational sequences have been changed to avoid waste.
- (3) The operators were trained to calculate the exact demand of chemicals to avoid bath rests.
- (4) Wasted dyeing baths are reused.

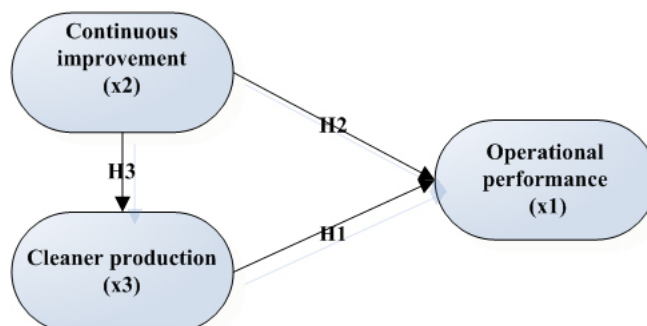
[5] studied on 69 members of the industrial association join the Industrial Ecology project (INES) project and provides confidential information about the resources, product and waste streams to the research team. Resulting the development of an INES project in a relatively big area is time consuming and needs many feedback loops to participants.

The feedback loops take place both at the level of a social process and the level of commitment development and an expanding number of stakeholders as well as at the level optimizing cleaner production approaches. [9] analyzed the contribution of pollution prevention to the transformation of industry by evaluating the results of various pollution prevention projects with different formats that have been carried out in the Netherlands during the last 8 years. It resulted that pollution prevention has proven to be a valuable concept, because prime focus on material flows and the emphasis on minimization of environmental effects. It leads to improvements in efficiency and reductions in waste and emissions. The product orientation is undervalued in pollution prevention. Pollution prevention can be an important path of companies towards a more sustainability-based strategy.

The study of [3] presented that Operational performance indicator (OPIs) as a possible limiting factor for benchmarking and rating. Significant differences were found with respect to the studied production emission and pollution were depended on raw materials, production process and varying performance of investments in

air pollution control systems. Electricity was saved. Hazardous waste could be reduced. However, the measurement of cleaner production implementation needs to base on the process control and continuous improvement measurement. In sum of the discussion, the following hypothesis is proposed based on the above discussion.

**Hypothesis 3:** Continuous improvement is positively associated with cleaner production.



**Fig. 1.** Research framework and hypotheses

Fig. 1 summarizes the three research hypotheses tested in this study. The figure outlines the conceptual framework of the subject being examined. In guiding the direction of the analysis, three of research hypotheses were developed based on the finding identified in the literature review.

### 3 Research instrument and data collection

#### 3.1 Data collection

Testing the above hypotheses requires data obtained from a survey on electronic manufacturing firms in Taiwan. Samples for the study were collected from Taiwanese high-tech companies with 690 firms selected from “2004 Industry Benchmark”. Data were collected from participating firms predominantly with vice president and executives/ managers in charge of the manufacturing function. Since the administrators are widely believed to provide reliable information regarding the basic relationship among continuous improvement and cleaner production<sup>[38]</sup>, senior managers or firm presidents represent the most appropriate informants. The subject companies were mailed the questionnaire, along with a cover letter and pre-paid reply envelope. Various efforts, for example follow-up telephone calls and faxes as well as personal connections were employed to encourage respondents to complete and return the questionnaires. A total of 223 responses were obtained during the 3 month period following the distribution of the questionnaires. Discounting the number of unusable questionnaires, it yielded 215 surveys that were used for the final analysis in this study, representing a response rate of 31.1%

#### 3.2 Research instrument

Measures for operationalizing the constructs were developed on the basis of an extensive literature review that identified the major measurements are derived from different previous study to satisfy content validity<sup>[15]</sup>. And, this study used measures that were adopted in related studies such as sensitive testing of instruments and careful selection of variables. All constructs were measured with multiple-item scales.

Prior to data collection, the survey instrument was pre-tested for content validity in two stages. In the first stage, six experienced researchers were asked to criticize the questionnaire for the ambiguity, clarity and appropriateness of the items used to operationalized each construct, based on feedback received from these researchers, the instrument was modified to enhance clarity and appropriateness of the measures purporting to tap the constructs. In the second stage, the survey instrument was mailed to five management executives. These executives were asked to review the questionnaire for structure, readability, ambiguity and completeness. The

final survey instrument incorporated feedback received from these executives, which enhanced the clarity of the instruments. This process yielded a survey instrument that was judged to exhibit high content validity. Ultimately, the indicators used to measure the theoretical constructs are based on an extensive review of related literature.

The measurement is generally adopted as six points Likert scale. The dependent and independent variables were derived from various previously studies following the cleaner production, continuous improvement and operational performance. The major constructs were as following.

### 3.2.1 Cleaner production

This study assessed cleaner production designed by [13]. This dimension employed four items on a six-point Likert-type scale. Respondents are asked to determine the degree to which each of the questions reflects their concern on cleaner production (1 = Strongly Unimportant; 2 = Less Unimportant; 3 = Unimportant; 4 = Important; 5 = Less Important 6 = Strongly Important). Although questionnaire is a relatively new instrument and it has been validated by recent empirical study<sup>[14]</sup>, the study suggests that there is reasonable reliability estimates. According to the suggestion of the authors of the instrument, this study assessed cleaner production at the individual and organizational levels. This study used the sum scores for these measures to indicate the constructs. The goodness of fit showed  $\chi^2$  (Chi-Square) /  $df$  (degree of freedom) (2) = 2.045, Root Mean Square Error for Approximation (RMSEA) = 0.079; Standardized Root Mean Square Residual (SRMR) = 0.045, Goodness-of-fit index (GFI) = 0.93, Normed Fit Index (NFI) = 0.92, Comparative Fit Index (CFI) = 0.95.

### 3.2.2 Continuous improvement

This study employed four items for assessing continuous improvement with six-point Likert-type scale. These measurement items were taken from previous studies<sup>[4, 23]</sup>. Respondents are asked to determine the degree to which each of the questions reflects their concern on continuous improvement (1 = Strongly Disagree; 2 = Less Disagree; 3 = Disagree; 4 = Agree; 5 = Less Agree; 6 = Strongly Agree). The results identified the goodness of fit as  $\chi^2/df$  (2) = 0.435, RMSEA = 0.000; SRMR = 0.047, GFI = 0.98, NFI = 0.91, CFI = 1.00.

### 3.2.3 Operational performance

Operational performance was measured using four items adapted from [39]. Many researchers have used manager's subjective perceptions to measure beneficial outcomes for firms. The constructs, each item used six-point Likert-type scale that ranged from 1=extremely bad through 6 = extremely good to asked to evaluate their firm's operational performance for the last three years, measured as market share growth, level of satisfaction customer, level of defects in the products/services, and the products/ services quality to meet or exceed customer's demand. The results identified the goodness of fit as  $\chi^2/df$  (2) = 1.245, RMSEA = 0.065; SRMR = 0.063, GFI = 0.96, NFI = 0.98, CFI = 1.00.

## 4 Data analysis

The variables assigned to each of the dimensions have been subjected to factor analysis to ensure that they are reliable indicators of those constructs<sup>[34]</sup>. A cutoff loading of 0.45 has been used to screen out variables that are weak indicators of the constructs. Also, follow [1], we purified the measures by assessing the reliability and unidimensionality of each construct. We first examined item-to-total correlation within each constructs and deleted items with low correlation. Tab. 1 shows the revised constructs for the three dimensions, which are cleaner production, continuous improvement and operational performance. The variables are identified with their detail which shows the factor loading and cronbach's alpha (cleaner production cronbach's  $\alpha$  = 0.817; continuous improvement cronbach's  $\alpha$  = 0.702 and operational performance cronbach's  $\alpha$  = 0.746). Reliability was operationalized using the internal consistency method that is estimated using Cronbach's alpha

[16]. Typically, reliability coefficients of 0.70 or higher are considered adequate. The constructs developed in this study are strongly grounded both in the literature and this analysis. The factor loading presented evidence of convergent validity.

**Table 1.** Factor loading and reliability scale: cleaner production

Cleaner production	Factor Loading	Reliability (Revised Construct)
Raw material extraction is important to take into account regarding purchasing decisions	0.840	0.817
Conserving water and energy is important for production process	0.813	0.817
Increase ability of product/material recycling	0.802	0.817
Improve the quality defect rate to reach the target of reduce material/energy/ manpower waste	0.778	0.817
Continuous Improvement		
Problem solving and continuous improvement process based on facts and systematic analysis	0.821	0.702
Cost of quality process to track re-work, waste rejects and for continuous improvement	0.797	0.702
Many of our products/services have been improved in the recent past	0.754	0.702
The use of the customer surveys and feedback process and tracking of other key measures to assess customer satisfaction	0.697	0.702
Operational Performance		
Market share growth	0.882	0.746
Level of satisfaction customer	0.822	0.746
Reduce level of defects in the products/services	0.749	0.746
The products/ services quality to meet or exceed customer's demand	0.591	0.746

Tab. 2 correlation matrix lists descriptive statistics and correlations among indicators. The pattern of correlations generally supported the proposed hypotheses. The three dimensions included in this research exhibited significant correlations, indicating moderate correlations among cleaner production, continuous improvement and operational performance.

**Table 2.** Descriptive statistics and bivariate correlations matrix of variables in research model

	1: Cleaner production ( $x_1$ )	2: Continuous improvement ( $x_2$ )	3: Operational performance ( $x_3$ )	Mean (sum)	S.D
$x_1$	1			15.30	2.926
$x_2$	0.489 (0.006)	1		15.57	1.906
$x_3$	0.432 (0.017)	0.380 (0.038)	1	16.23	2.144

Note: corresponding P values are in parentheses. N = 215

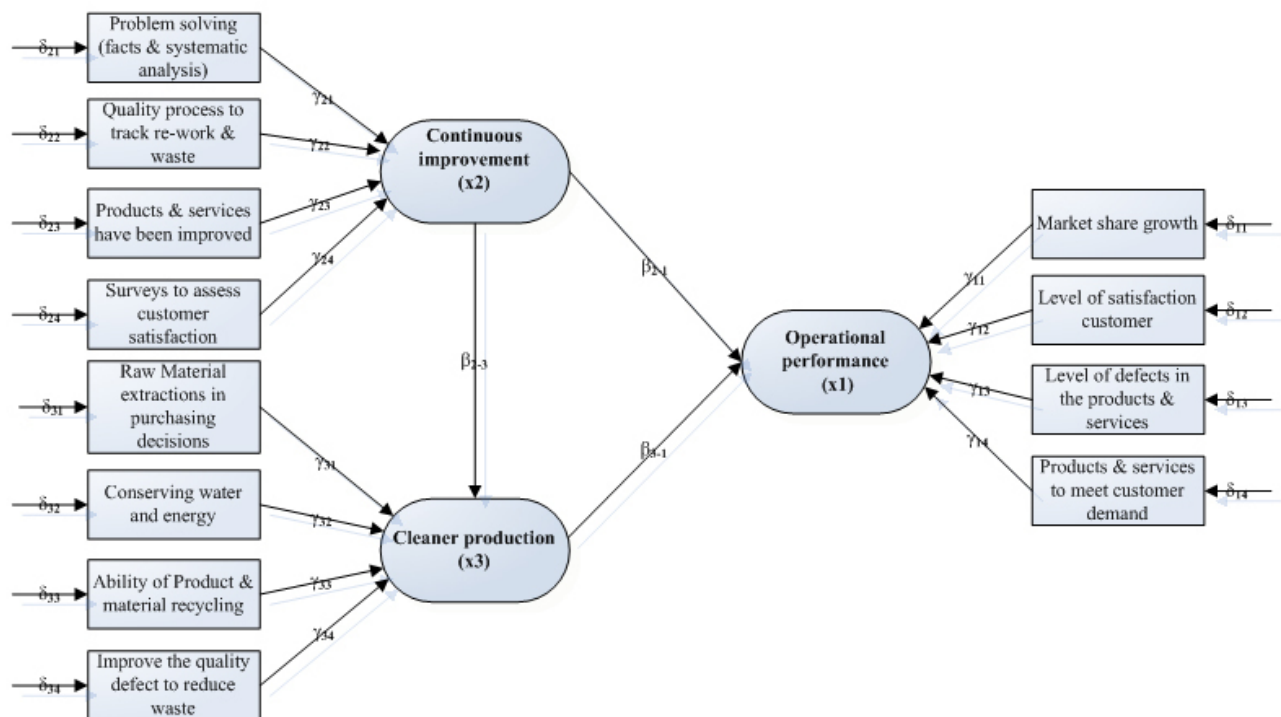
The direct and indirect influences of independent variables on dependent variables were tested using the Structural Equation Model (SEM) technique, which is discussed below. We assess the discriminant validity of each construct following [2] as well as [20].

SEM results for the measurement model of the study shown in Fig. 2, Tab. 3 and Tab. 4, in which demonstrated the parameter and t value of proposed model. Fig. 2 shows the basis of the model proposed, together with the hypotheses to be tested. We used recursive non-saturated model, taking three latent variables are

**Table 3.** Observed variables of hypothetical model

Parameter		t value	Parameter		R <sup>2</sup>	t value
$\delta_{11}$	0.62	4.37	$\gamma_{11}$	0.62	0.38	4.01
$\delta_{12}$	-0.34	-3.39	$\gamma_{12}$	1.16	0.91	10.67
$\delta_{13}$	0.47	4.28	$\gamma_{13}$	0.73	0.53	4.73
$\delta_{14}$	0.50	4.31	$\gamma_{14}$	0.71	0.50	4.56
$\delta_{21}$	0.80	1.46	$\gamma_{21}$	1.10	0.60	3.46
$\delta_{22}$	1.66	3.5	$\gamma_{22}$	0.58	0.17	1.94
$\delta_{23}$	1.55	3.35	$\gamma_{23}$	0.67	0.23	2.26
$\delta_{24}$	1.20	2.57	$\gamma_{24}$	0.90	0.40	2.96
$\delta_{31}$	0.38	2.92	$\gamma_{31}$	0.79	0.62	4.86
$\delta_{32}$	0.25	2.21	$\gamma_{32}$	0.87	0.75	5.56
$\delta_{33}$	0.37	2.9	$\gamma_{33}$	0.79	0.63	4.89
$\delta_{34}$	0.45	3.17	$\gamma_{34}$	0.74	0.55	4.43

continuous improvement ( $x_1$ ), cleaner production ( $x_2$ ) and operational performance ( $x_3$ ). Through flexible interplay between theory and data, this structural equation model approach bridges theoretical and empirical knowledge to allow a better understanding of the real world. Such analysis allows for modeling based on both latent and manifest variables, a property well suited to the hypothesized model, where most of the represented constructs are abstractions of unobservable phenomena.



**Fig. 2.** Measurement model of hypothetical model

**Table 4.** Observed variables of hypothetical model

Parameter	Standard path	
	coefficient (SPC)	t value
$\beta_{2-1}$	0.29	1.93
$\beta_{3-1}$	0.38	2.33
$\beta_{2-3}$	0.67	3.85

**Table 5.** Test results of the measurement models and structural model

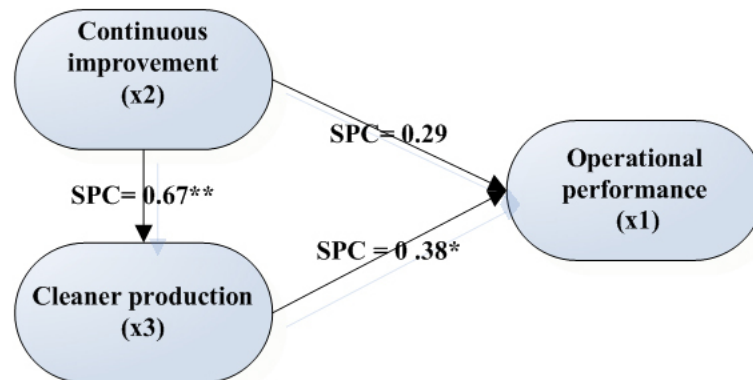
Goodness-of-fit statistics	Measurement model for			Structural equation model	Recommended values forsatisfactory fit of a model to data
	$x_1$	$x_2$	$x_3$		
$X^2/df$	2.49/2 = 1.245	1.47/2 = 0.435	4.09/2 = 2.045	17.91/51 = 0.335	< 3 <sup>a</sup>
RMSEA	0.065	0.00	0.079	0.00	< 0.08 <sup>b</sup>
GFI	0.96	0.98	0.93	0.91	> 0.9 <sup>b</sup>
NFI	0.98	0.91	0.92	0.77	> 0.9 <sup>b</sup>
SRMR	0.063	0.047	0.045	0.068	< 0.08 <sup>b</sup>
CFI	1.00	1.00	0.95	1.00	> 0.95 <sup>b</sup>

<sup>a</sup> [8], [25]; <sup>b</sup> [11]

Where,  $x_1$ : operational performance;  $x_2$  : continuous improvement;  $x_3$ : cleaner production.

However, the SEM revealed that the path coefficient of the direct effect of continuous improvement on operational performance was negligible (standardized coefficient was 0.29). Fig. 2 illustrates the final tested model and the estimates of the structural coefficients. The overall chi-square for the model was 17.91, with 51 degrees of freedom. The value of the three incremental fit indices displayed adequate model fit to the data (GFI = 0.91, NFI = 0.77, CFI = 1.00), and the hypothesized model showed a relatively small quantity of residuals (SRMR = 0.068, RMSEA= 0.000). Furthermore, all of the structural paths included in the proposed model yielded significant parameter estimates. Together, these results support the proposed model and Hypotheses 1-3.

Structural equation models generally use ellipses to represent constructs (latent variables), and a line with one arrow between two constructs indicates the influence of one construct on the other. The number near the line is the statistic denoting standardized path coefficients (SPC), and can be considered a standardized regression coefficient for one latent variable in relation to another when the effects of all other variables are partial out. This study indicates continuous improvement considerably and positively contributed to cleaner production (SPC = 0.67,  $p < 0.01$ ). Furthermore, cleaner production significantly contributed to operational performance (SPC = 0.38,  $p < 0.05$ ). Although, continuous improvement is inconsiderable and positively to operational performance (SPC = 0.29,  $p > 0.05$ ). To summarize, the results of the structural equation analysis indicate a close correlation between the three latent variables.

**Fig. 3.** Structural equation model for operational performance

## 5 Conclusion

The result of this investigation demonstrates that the proposed structural model closely fits the sample data the hypotheses tested in this research received full empirical supported. The results were consistent with

the evidence from the literature that the limitations of cleaner production program as organizational change agents- on going improvement<sup>[37]</sup>.

Cleaner production is possible that consideration of the need for continuous improvement would occur at the end of organization manufacturing process. There are several implications that may be draw from the results. First, the significance that cleaner production program place with continuous improvement, and apparent result of this research, suggest that mechanisms for ensuring that continuous improvement occurs need to be given more prominence at the implementation of program and be incorporated into its design process.

Second, in addition, the results of the evaluation of research model, the continuous improvement might not be able to direct improve on operational performance, and yet continuous improvement plays a significant role of cleaner production implementation<sup>[35]</sup>. This phenomenon possibly may partially explain many management program implementation must re-examine through the process of continuous improvement. Continuous improvement tends to be embedded in any management process of firm alignment with firm's strategic goals. Ultimately, cleaner production significant influences operational performance.

While this study assesses the impact of continuous improvement on the cleaner production and operational performance of electronic manufacturing companies in Taiwan, the study itself was not completely free from limitations. The limitation of this study is that all of our measures were collected using the same method (self-report), relationships among variables might be inflated by common method variance. The future studies are required that included a broader sample of firms from other industries and some other assessments of organizational performance such as employee and financial performance which has been discussed on other researches<sup>[21, 23]</sup>. Despite these limitations the study does have important implications for organization seeking to implement cleaner production. For these firms the evidence suggests that continuous improvement should include direct measure in the cleaner implementation process.

The future studies suggest including of operational personnel in planning. The performance of employee might also need to be evaluated further to the cleaner production implementation. In conclude, [38] pointed out the limitations of cleaner production implementation on leadership, support, communication, involvement and program design might include in the future studies with structural equation modeling.

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