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# LEAN SIX SIGMA PRACTICES EFFECT ON WASTE REDUCTION BEHAVIOR TO OPERATIONAL PERFORMANCE OF THAILAND'S PHARMACEUTICAL FIRMS

## *O IMPACTO DAS PRÁTICAS LEAN SIX SIGMA NO COMPORTAMENTO DE REDUÇÃO DE DESPERDÍCIO E NO DESEMPENHO OPERACIONAL DAS EMPRESAS FARMACÊUTICAS DA TAILÂNDIA*

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**Abstract**
The six sigma lean practices are crucial and synergized managerial practices that mainly focus on enhancing production practices and investigating real product problems. In a different organization, it is used effectively under the measurement, analysis and improvement steps. The crucial purpose of the given paper is to find out the impact of six sigma lean practices on the operational performance of the pharmaceutical companies in Thailand, with the help of waste reduction behavior as a mediating variable. For the data collection process, the survey questionnaire technique is used in which the data is collected on the basis of self-administrated questions. A survey of 400 respondents was conducted, from 188 were female and 212 were male respondents. Moreover, under the analysis, the results of the SEM model have revealed that the total production maintenance and focused on metrics have a positive impact on operational performance while process control has an insignificant impact on the operational performance of the pharmaceutical companies. Further results also examined that waste reduction behavior has also a significant

***Resumo***
*As práticas Lean Six Sigma são práticas gerenciais cruciais e sinérgicas que se concentram principalmente em aprimorar os processos de produção e investigar problemas reais dos produtos. Em diferentes organizações, elas são utilizadas de forma eficaz nas etapas de medição, análise e melhoria. O objetivo principal deste artigo é determinar o impacto das práticas Lean Six Sigma no desempenho operacional das empresas farmacêuticas na Tailândia, utilizando o comportamento de redução de desperdício como variável mediadora. Para o processo de coleta de dados, foi utilizada a técnica de questionário de pesquisa, na qual os dados são coletados com base em perguntas autoaplicáveis. Foi realizada uma pesquisa com 400 respondentes, dos quais 188 eram mulheres e 212 eram homens. Além disso, na análise, os resultados do modelo SEM revelaram que a manutenção total da produção e o foco em métricas têm um impacto positivo no desempenho operacional, enquanto o controle de processos tem um impacto insignificante no desempenho operacional das empresas farmacêuticas. Outros resultados também examinaram que o comportamento de redução*

mediating role in enhancing the impact of six sigma lean practices on the operational performance of the firms. Finally, it is recommended that the companies and all firms should require these practices in their production process so that the efficiency and performance of the companies increased.

**Keywords:** Six Sigma Lean Practices. Waste Reduction Behavior. Operational Performance.

*de desperdício tem um papel mediador significativo no aumento do impacto das práticas Lean Six Sigma no desempenho operacional das empresas. Por fim, recomenda-se que as empresas e todas as firmas adotem essas práticas em seus processos de produção, de modo a aumentar a eficiência e o desempenho das empresas.*

***Palavras-chave:*** *Práticas Lean Six Sigma. Comportamento de Redução de Desperdício. Desempenho Operacional.*

## 1 INTRODUCTION

The organizations are employing different practices like Lean manufacturing, 6 sigma and lean 6 sigma for continuous process improvement and enhance final value added by the final product or service (Snee, 2000, 2010). The focus of lean focuses eradicating the wasteful activities (Hines & Holweg). The practice of Six Sigma focuses on identifying and eliminating the reasons for mistakes that cause errors and defects in the business processes and reduces the cost of quality in the manufacturing process.

Lean Six Sigma is unique in that it has integrated the strengths of both practices to improve the bottom line results, improves the product quality and production process, hence enhancing the performance of organizations. For the same reason, lean six sigma practices have been gaining wide adoptability in a variety of industries (Drohomeretski, Gouvea da Costa, Pinheiro de Lima, & Garbuio, 2014). There exist numerous notable lean six sigma tools (Costa, Godinho Filho, Fredendall, & Ganga, 2020), however this study will focus on statistical process control (SCP), total productive maintenance (TPM) and focus on metrics (FOM).

Indeed prior researchers have worked on impact of six sigma and lean on the performance(Arumugam, Antony, & Linderman, 2014; de Souza & Carpinetti, 2014; M. K. Hassan, 2013; Myerson, 2012; Shafer & Moeller, 2012), however limited body of research is available on how firms can integrate the two practices to yield better performance (Costa et al., 2020; Gupta, Jain, Meena, & Dangayach, 2018; Shan, Ahmad, Hamid, & Mustapha, 2018). The current paper has the aim to fill this contextual gap in literature by addressing the implementation of lean six sigma practices from the

perspective of pharmaceutical companies. This study has the following research objectives:

- To investigate the influence of 'Statistical Process Control' on Operational Performance
- To investigate the influence of 'Total Productive maintenance' on Operational Performance
- To investigate the influence of "focus on metrics' on Operational Performance
- To investigate if Waste Reduction behavior while drug making mediates these relationships

The prime agenda behind this study is to investigate if Lean six Sigma practices enhance the operational performance of the pharmaceutical firms in Thailand. Theoretically, the results have integrated the theories of Contingency and Practice Based View. It also contributes to the academic knowledge by investigating 'waste reduction behavior' as the potential path in the relationship among lean six sigma practices and operational performance of the pharmaceutical firms. Practically, this study has implications in improving managerial awareness regarding the application and implementation of the lean six sigma practices to boost the profits and improve the operational performance of the pharmaceutical firms.

This paper is structured as ahead. Starting with the Introduction part, second section presents a detailed literature review. The next section highlights the research methodology, followed by results and their analysis. Finally, the conclusion, research limitations and implications are given.

## 2 LITERATURE REVIEW AND THEORETICAL BACKGROUND

This study is based on the Contingency theory and the Practice based view (PBV). The contingency theory describes the effectiveness of the Operations (Sousa & Voss, 2008). PBV explains the benefits and reliability of such practices that variety of firms can put into action to enhance their operational profits (Betts, Super, & North, 2018; Bromiley & Rau, 2014; Treacy, Humphreys, McIvor, & Lo, 2019).

### 2.1 Impact of statistical process control

For improving performance by identifying and fixing errors in case when the products are not produced according to the defined specifications and limitations, a process under statistical control needs adjustments. SPC is a solution which is specifically established for easy and rapid collection of data to be analyzed, which, in turn, boost the profitability (Godina, Pimentel, Silva, & Matias, 2018). Through SPC, the process can be monitored, causes of unexpected variations can be identified and corrective actions can be determined and taken(Gupta et al., 2018). SPC implies that the firms make sure that every process has the ability to provide units or products that are free from any defect or error to the next process in manufacturing (Costa & Godinho Filho, 2016; Fullerton, Kennedy, & Widener, 2014; Netland, 2016; Yadav & Desai, 2016) to improve long term performance (Abreu-Ledón, Luján-García, Garrido-Vega, & Escobar-Pérez, 2018; Costa et al., 2020; Godina et al., 2018; Negrao Filho; Shafer & Moeller, 2012). Hence, direct relation exists between them. So, this study hypothesizes:

*H1: Statistical Process Control is significantly linked to operational performance*

### 2.2 Impact of total productive maintenance

TPM comprises of three words, the first word total means that all employees working at any level. By the second word which is productive, is meant the assurance of efficiency in the operations and the last word maintenance implies the good working condition of equipment. The TPM practice is considered to be a pillar of the total quality management process and is effectively used for the main functions of planning, organizing, monitoring and controlling (Ahuja, 2011; Ananth & Vinayagam, 2015; Sardana & Sinha, 2011), that leads to improved firm effectiveness (Ahuja, 2011; Costa et al., 2020; Fam et al., 2018; Okpala, Anozie, & Ezeanyim, 2018; Shan et al., 2018). This implies that the practice of TPM has direct relation with the firm's operational performance, so, this study hypothesizes:

*H2: Total Productive Maintenance is significantly linked to operational performance*

### 2.3 Impact of focus on metrics

In the practice of Six Sigma FOM, the firm makes use of quantitative metrics in order to measure the performance and set goals for further improvement. These metrics involves measures like defects per unit, sigma level, process capability index and yield. This involves setting strategic goals for improving the quality that contributes to the financial and operational performance of the firms. Studies have shown that sustainable performance metrics enables firms to improve their performance accordingly (Costa et al., 2020; Gong, Simpson, Koh, & Tan, 2018). Hence, direct relationship exists between them. So, this study hypothesizes:

*H3: Focus on Metrics is significantly linked to operational performance*

### 2.4 Mediation of waste reduction behavior

The process of Lean stresses on increasing the perceived value of a product or a service by identifying and removing the activities that cause their waste for the conservation of the environment by adopting the waste reduction techniques. Through WRB generated as a result of the tools of process statistical control, maintaining the productivity as a whole and focusing on the performance metric allows the firms to reduce the waste in their processes so as to avoid wastage of the raw material and improve the efficiency of the process(Bergmiller & McCright, 2009; de Souza & Carpinetti, 2014; Fercoq, Lamouri, & Carbone, 2016; M. K. Hassan, 2013; Mason, Nieuwenhuis, & Simons, 2008; Myerson, 2012). Hence, the effect of WRB as a mediator in these relationships can be investigated. So, this study hypothesizes:

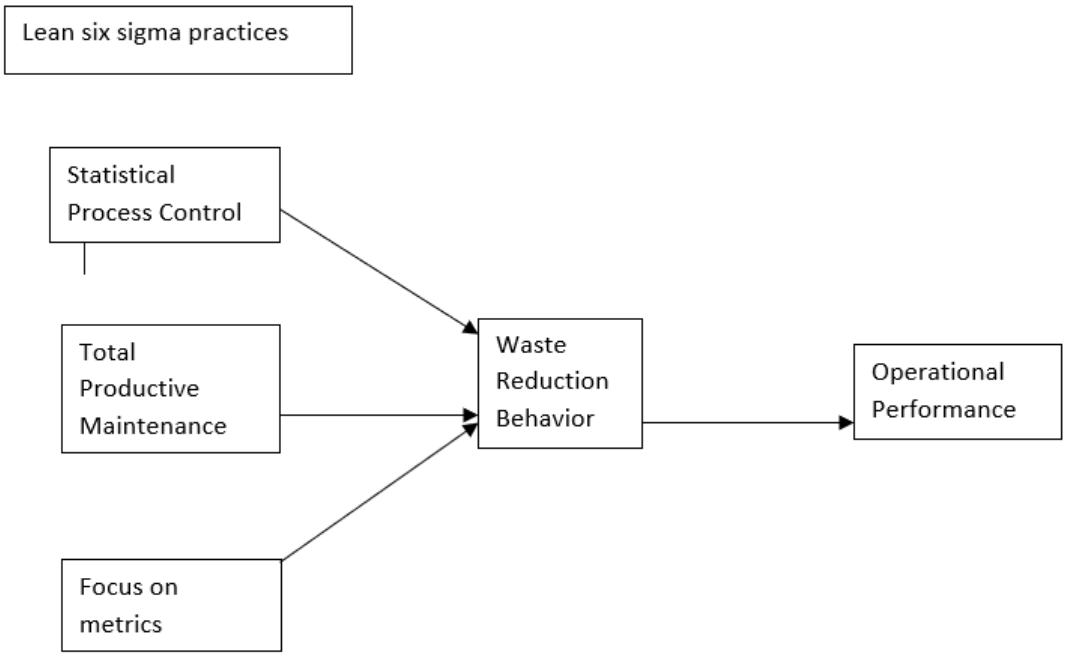
*H4a: Waste Reduction Behavior significantly mediates the relationship of Statistical Process Control and operational performance.*

*H4b: Waste Reduction Behavior significantly mediates the relationship of Total Productive Maintenance and operational performance.*

*H4c: Waste Reduction Behavior significantly mediates the relationship of Focus on Metrics and operational performance.*

**Figure 1**

*Research framework*




## 3 METHODS

### 3.1 Sample and data characteristics

The survey design was questionnaire based. The method of convenience sampling was employed in order to collect data form the manufacturing and production officers of Thailand's pharmaceutical companies. The data was collected on the basis of a self-administered questionnaire. The researcher applied the method of item response theory, following the criteria of twenty responses against each item i.e. 20*20=400. However a total of 400 questionnaires were distributed among respondents.

### 3.2 Measures

The construct was developed after extensive literature review was conducted on all of the variables. The scales which have been deemed reliable and consistent by a

plethora of studies were finalized to be included in our study. However, in order to ensure the content validity and relevance of scale items the questionnaire was verified by two different academicians and then it was pretested on MBA final year students. Some adjustments were made in the questionnaire following their directions. All scale items were measured on a five point Likert scale ranging from "1=strongly disagree" to "5=strongly agree"

### 3.3 Lean six sigma practices

There are a number of lean production and six sigma practices, the following three were selected due to the relevance with the objectives of the study.

### 3.4 Statistical process control

A multi-item construct for measuring lean manufacturing practices, lean production, was developed by Shah and Ward (2007) and the scale for six sigma practices was developed by Zu, Fredendall, and Douglas (2008). The items for statistical process control were extracted from these studies and then adapted according to the requirements of the current study. The scale comprised four items. A sample item includes "Large amount of process/equipment on the shop floor is currently under Statistical Process Control".

### 3.5 Total production maintenance

A multi-item construct for measuring lean manufacturing practices, lean production, was developed by Shah and Ward (2007) and the scale for six sigma practices was developed by Zu et al. (2008). The items for total production maintenance were extracted from these studies and then adapted according to the requirements of the current study. A total of four items were included in the scale. A sample item includes "We dedicate a portion of everyday to planned equipment maintenance related activities".

### 3.6 Focus on metrics

A multi-item construct for measuring lean manufacturing practices, lean production, was developed by Shah and Ward (2007) and the scale for six sigma practices was developed by Zu et al. (2008). The items for focus on metrics were extracted from these studies and then adapted according to the requirements of the current study. A total of four items were included in the scale. A sample item includes “Our plant systematically uses a set of measures (such as defects per million opportunities, sigma level, process capability indices, defects per unit, and yield) to evaluate performance”.

### 3.7 Waste reduction behavior

Waste reduction behavior was measured on the basis of the scale developed by Simmons and Widmar (1989). The items of the scale were adapted and changed according to the requirements of the current study.

### 3.8 Operational performance

Operational performance was measured on the basis of the construct developed by Delery and Doty (1996). The questions were adapted and modified to fit the requirements of the current study.

## 4 RESULTS

### 4.1 Demographics

A total of 400 employees belonging to the pharmaceutical industry of Thailand were contacted for the purpose of this survey. Out of these 55.5 percent of the respondents identified themselves as male and 44.5 percent identified themselves as females. The disparity is observed because more men are employed in manufacturing and operations units in comparison to women and the survey was directed at the manufacturing and

operations managers working in the pharmaceutical sector. The experience of 74.4 percent of the respondents is between 2 and 8 years and the age of 73.4 percent of the respondents is up to 35. The elevation is observed because senior managers and supervisors were the recipients of questionnaires.

### 4.2 Descriptive analysis

The mean values are leading towards 4, showing the assertion of the participants with the statements of the variables. The skewness values also establishnormality of the data, as the values are within the prescribed range of +1-1. However, outliers do not persist in the observations as the minimum and maximum values are in accordance with the utilized scale, a five point Likert scale.

**Table 1**

Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation | Skewness | |
|---|---|---|---|---|---|---|---|
| | Statistic | Statistic | Statistic | Statistic | Statistic | Statistic | Std. Error |
| StaProCo | 400 | 1.00 | 5.00 | 3.2222 | .890 | -.189 | .119 |
| FocOnMet | 400 | 1.00 | 5.00 | 3.2921 | .894 | -.360 | .119 |
| TotProMa | 400 | 1.00 | 5.00 | 3.5311 | .876 | -.558 | .119 |
| WasRedBeh | 400 | 1.00 | 5.00 | 3.5468 | .796 | -.473 | .119 |
| OperPerf | 400 | 1.00 | 5.00 | 3.3665 | .873 | -.461 | .119 |
| Valid N (listwise) | 400 | | | | | | |

### 4.3 KMO

The sample is deemed adequate as the KMO measure is above 0.6 and is approaching 1.The sphericity of Bartlett’s is also significant, refer to table 2, and demonstrates the non-relevance among the construct items, thus they can be taken further for factor testing.

**Table 2**

*KMO and Bartlett's Test*

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .909 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 8056.754 |
| | df | 190 |
| | Sig. | .000 |

## 4.4 Factor Loading

All of the individual scale items are significant and contribute in the overall variance of the construct, as the values of loadings are greater than 0.7. The problem of cross-loading hasn't been observed as well.

**Table 3**

*Rotated Component Matrix*[a]

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| SP1 | | | | .820 | |
| SP2 | | | | .869 | |
| SP3 | | | | .834 | |
| SP4 | | | | .794 | |
| GM1 | | | | | .751 |
| GM2 | | | | | .749 |
| GM3 | | | | | .781 |
| GM4 | | | | | .821 |
| TP1 | | .821 | | | |
| TP2 | | .834 | | | |
| TP3 | | .856 | | | |
| TP4 | | .874 | | | |
| WP1 | | | .804 | | |
| WP2 | | | .827 | | |
| WP3 | | | .863 | | |
| WP4 | | | .849 | | |
| OP1 | .844 | | | | |
| OP2 | .829 | | | | |
| OP3 | .922 | | | | |
| OP4 | .919 | | | | |

## 4.5 Convergent and discriminant validity

The CR values are greater than 0.7 (S. G. Hassan, Hameed, Basheer, & Ali, 2020; Iqbal & Hameed, 2020) and AVE values are greater than 0.5, indicating the convergent validity. The MSV values are less than the AVE values and self-correlation coefficients

are also higher than those of the variable-variable correlation. Thus discriminant validity is also present.

**Table 4**

*Convergent and Discriminant Validity*

| | CR | AVE | MSV | WB | SP | GM | TP | OP |
|---|---|---|---|---|---|---|---|---|
| **WB** | 0.926 | 0.758 | 0.323 | **0.870** | | | | |
| **SP** | 0.919 | 0.739 | 0.353 | 0.480 | **0.859** | | | |
| **GM** | 0.882 | 0.652 | 0.353 | 0.568 | 0.594 | **0.808** | | |
| **TP** | 0.940 | 0.797 | 0.252 | 0.493 | 0.487 | 0.502 | **0.893** | |
| **OP** | 0.949 | 0.823 | 0.213 | 0.375 | 0.356 | 0.440 | 0.461 | **0.907** |

### 4.6 Model fitness

CFA test is used to confirm the model fitness. CMIN is under 3, GFI is greater than 0.8, CFI and IFI are above 0.9 and RMSEA is less than 0.08 therefore the model is proclaimed fit.

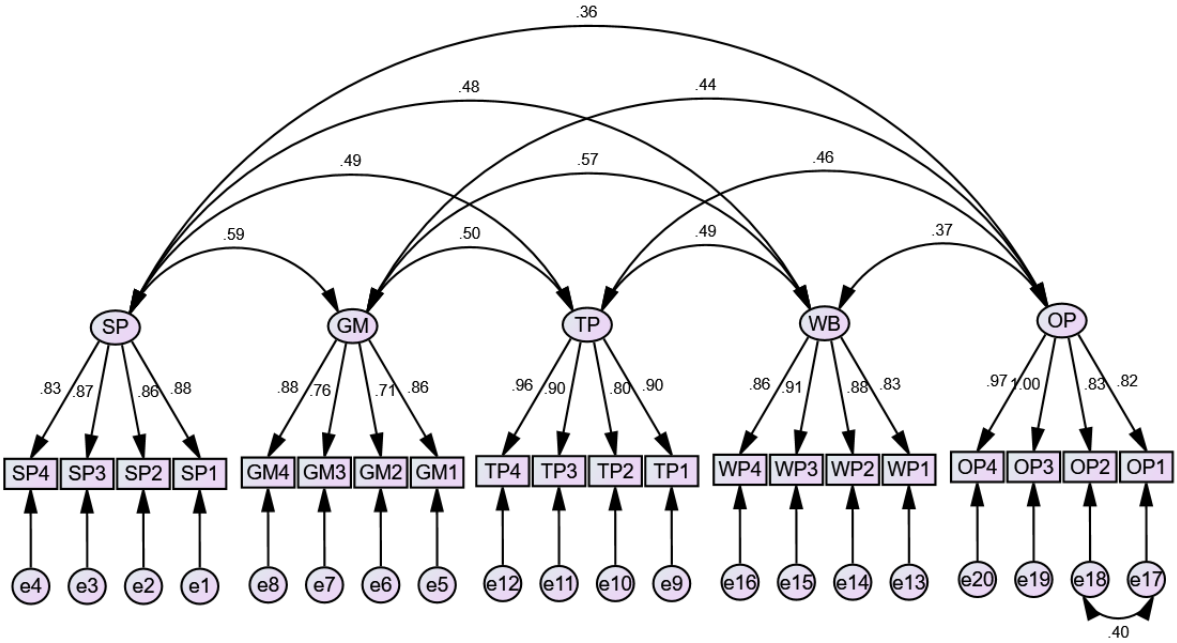
**Table 5**

*Confirmatory Factors Analysis*

| Indicators | Threshold range | Current values |
|---|---|---|
| CMIN/DF | Less or equal 3 | 2.775 |
| GFI | Equal or greater .80 | .907 |
| CFI | Equal or greater .90 | .965 |
| IFI | Equal or greater .90 | .965 |
| RMSEA | Less or equal .08 | .065 |

**Figure 1**

*CFA*




## 4.7 SEM

A unitary increase in FocOnMet influences a variation of 18.4 percent in OperPerf. The hypothesis is accepted as the relationship is significant. A unit increase in TotProMa will produce a variation of 30.7 percent in OperPerf, the relationship is significant and the hypothesis is accepted. A unit increase in StaProCo will produce a minor variation of 7.9 percent in OperPerf the relationship is insignificant and the hupothesis is rejected. The mediation of WasRedBeh is significant. It produces an effect of 5.1 percent through FocOnMet, 3.4 percent through TotProMa and 2.3 percent through StaProCo. Although the variances are minute still the hypotheses are accepted due to significant relationships.

**Table 6**

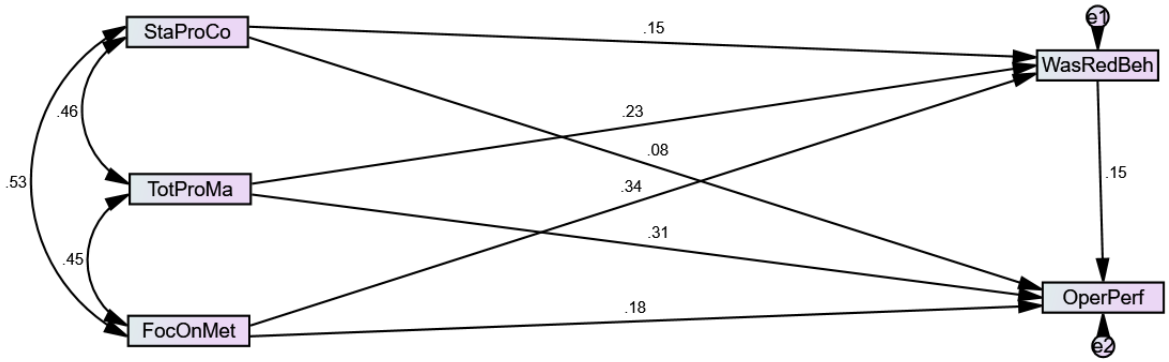
*Structural Equation ModelingTotal Effect*

| **Table 6: Structural Equation ModelingTotal Effect** | **FocOnMet** | **TotProMa** | **StaProCo** | **WasRedBeh** |
|---|---|---|---|---|
| WasRedBeh | .344*** | .230** | .154** | .000 |
| OperPerf | .235** | .341*** | .102 | .149** |
| **Direct Effect** | FocOnMet | TotProMa | StaProCo | WasRedBeh |

| | | | | |
|---|---|---|---|---|
| WasRedBeh | .344*** | .230** | .154** | .000 |
| OperPerf | .184** | .307*** | .079 | .149** |
| **Indirect Effect** | FocOnMet | TotProMa | StaProCo | WasRedBeh |
| WasRedBeh | .000 | .000 | .000 | .000 |
| OperPerf | .051** | .034* | .023* | .000 |

**Figure 2**

*SEM*




## 4.8 Discussion

By practicing lean six sigma strategy the operational performance of the firm can be affected because a lean six sigma strategy can reduce the costs of products and services provided by the firm (Ben Ruben, Vinodh, & Asokan, 2017). The measurements of the results and findings suggest that the impact of statistical process control on the operational performance of the firm will be significant. Statistical process control can aid the process of operational performance of the firm in many ways such as reduced scrap and rework and improved the process of resource utilization. Therefore, the hypothesis regarding the direct effect of SPC on operational performance has been accepted. Total production maintenance is another practice of six sigma that provides huge benefits to firms and sectors. According to the research study by Hooi and Leong (2017), the total production maintenance can provide a safer and effective working environment that positively influences the process of operational performance and enhance the overall performance of the sector.

According to the results of the research, it can be found that waste reduction behavior significantly mediates the relationship between six sigma practices and the

operational performance of the pharmaceutical sector of Thailand. Waste reduction behavior of a sector can ensure less use of natural resources and this directly influences the operational performance of the firm (Chuang & Huang, 2018).

## 5 CONCLUSION

The major purpose of this research study is to identify the impact of six sigma practices which include statistical process control, focus on metrics, and total production maintenance on the operational performance of the pharmaceutical sector of Thailand. The study also aims to understand the mediating role of waste reduction behavior of the sector in enhancing the different relationships in the study. A survey of 422 employees of pharmaceutical firms of Thailand was conducted and then evaluated with the help of the SEM and KMO technique.

### 5.1 Implications and limitations

The positive findings of the study help managers of the pharmaceutical firm of Thailand to understand the significance of lean six sigma practices in improving the operational performance of the sector and also gain experience using the tools of six sigma. The results and verdicts of this research paper can give wider insights into the process of six sigma and its significance for improving the operational performance of any particular sector thus this study help sector that wants to practice six sigma strategy. Limitations of the study are that the given study is restricted to the use of six sigma in the pharmaceutical sector, thus, future studies suggested that they should conduct this research in other sectors as well. Another limitation of the study is that this study is limited by the country of investigation, only Thailand, so further researches must investigate other countries and regions of the world.

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## Authors' Contribution

All authors contributed equally to the development of this article.

## Data availability

All datasets relevant to this study's findings are fully available within the article.

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