Analyzing Process Capability Indices (PCI) and Cost of Poor Quality (COPQ) to Improve Performance of Supply Chain

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Abstract

Many ports have inefficient and ineffective activities in the entire of Supply Chain. Many methods and tools are used to analyze performance of Supply Chain. This study based on our practical experience in implementation of Six Sigma Methodology in port. The main purpose of our research is to analyze Process Capability Indices (PCI) and Cost of Poor Quality (COPQ) for improving performance of Supply Chain in port. PCI and COPQ is performance indicator of Six Sigma Methodology as one of Quality Improvement Method. Case study has been taken in CDG Port, Indonesia. Three big cargos handling have been selected to be analyzed PCI and COPQ, as follow: fertilizer, slab steels, and iron ore. Data were collected by direct observation and interview with Logistics Service Department of CDG Port. The result of Process Capability Indices in handling of cargo is 0.06 in average. This result shows that process capability in cargo handlings have not capable to meet the customer requirements. Meanwhile, Cost of Poor Quality in cargos handling is about 700,449 USD in average and 39.02 % from the sales in average. This cost is still high if it is compared with the sales. Many potential improvements to increase process capability and decrease cost of poor quality. With Six Sigma Methodology, Process Capability Indices and Cost of Poor Quality can be analyzed for improving performance of Supply Chain in port.

Keywords: capability process indices, cost of poor quality, six sigma, port

1. Introduction

Nowadays, every country tries to improve performance in their ports for getting competitiveness. Each port in a country shows how the quality of the trading health. Most of export and import activity have been done in their ports. So, ports in a country have an important role in trading and development. With complexity problems in port, many efforts have been carried out both of concept and practical. All countries try to reduce ineffective and inefficient activities in ports. The entire of Supply Chain in port has become a target to be analyzed its performance.

Many methods and tools have been used to analyze performance of Supply Chain. In this research, Six Sigma Methodology has been implemented as a method to improve quality dramatically. This method can be implemented not only for manufacture companies but also for service companies, including in ports. Originally, Six Sigma has been developed by Motorola in 1986 as a new breakthrough in quality management. Six Sigma approaches allow 1.5 □ shifting so it's only 3.4 Defect per Million Opportunities (DPMO) is allowed for product or services. Six Sigma is not only using tools of statistics for quality improvement but also using this value as a standard of industry performance and business strategy.

Supply Chain has become a key business strategy to achieve competitive advantages. Therefore, Supply Chain processes must be arranged and well organized so Supply Chain Management (SCM) concept has developed. Bases on the Global Supply Chain Forum (GSCF), SCM is the integration of key business processes from end user through original suppliers that provides products, services, and information that adds value for customers and other stakeholders.

This research based on practical experience in implementation of Six Sigma methodology in ports, especially in Supply Chain flow of cargos handling. In this research, focus to analyze step of Six Sigma methodology with analyzing the Process Capability Indices (PCI) and the Cost of Poor Quality (COPQ). In the research before, Define and Measure step of Six Sigma methodology, Ridwan (2013, p.144) resulted some performance indicators and performance baseline of sigma value is 1.64 in supply chain flow at CDG port. Many researchers have calculated the process capability. Kane (1986) introduced calculation of the beginning of capability process. Somerville and Montgomery (1996) proposed to calculate Cp or Cpk for a non-normal distribution and making inferences about the process fallout or Part Per Million (PPM) non conforming. Huang and Chen (2003) proposed an integrated Process Capability Indices for multiprocess product. Chen et al. (2003) proposed a generalized capability measure for processes with multiple characteristics. Wang (2005) developed a procedure for constructing Multivariate Process Capability Indices (MPCIs) based on Principal Component Analysis (PCA) and Clement’s method for short-run production. Kurekova (2011) showed some deficiencies of three most applicable methods for calculation of the measurement process capability and Cpm represents best the real measurement process capability instead Cp and Cpk.

Also, many researchers have done a research to get the optimum of Cost of Poor Quality(COPQ). Tsai (1998) proposed to integrate Cost of Quality (COQ) and Activity Based Costing (ABC) framework. Ramudhin et al. (2008) integrated the vital concept of Cost of Quality into to the Supply Chain network designs to minimize a series of costs. Salonen and Deleryd (2011) proposed Cost of Poor Maintenance (CoPM) as a new concept to improve maintenance performance.

This research aims to implement an analyzing the Process Capability Indices (PCI) and the Cost of Poor Quality (COPQ) in supply chain flow at port. With this analyzing, process capability of cargos handling in port can be determined. Also, cost that is caused by poor quality in cargos handling at port can be determined. PCI are a measurement that process can fulfill customer requirements or customer specifications. Whereas, COPQ consist of: prevention cost, appraisal cost, and failure cost both of internal and external failure. Analyzing PCI and COPQ in CDG Port are expected become a basic to improve performance of supply chain flow that is focused in material flows from the ship to the warehouse. CDG port is a logistics provider company in Indonesia and provides freight services, both dry bulk and liquid, operational vehicles, operators, machinery required, packaging process the goods until delivery to the warehouse destination (Ridwan et al., 2013).

2. Literature Review

Many methods and tools were used to improve performance of Supply Chain, especially in ports. This research focused to improve Supply Chain performance with Six Sigma approach. Six Sigma Methodology is one of quality improvement method.

2.1 Supply Chain

Many methods and tools are used to improve performance of logistics and Supply Chain. The Council Logistics Management defines Logistics is the part of the Supply Chain that plans, implements, and control the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption to meet customer requirements. Supply Chain Management is to apply a total systems approach to managing the entire flow of information, materials, and services from raw materials suppliers through factories and warehouse to the end customer (Chase et al., 2004). Logistics and Supply Chain have become a key or strategic function in companies in achieving competitive advantages.

2.2 Six Sigma Methodology

In the beginning, Six Sigma is implemented in manufacturing area, and then it is implemented in service area, including ports. The initial methodology of Six Sigma was focused on process improvement and accordingly DMAIC (Define-Measure-Analyze-Improve-Control) approach was universally adopted, but as time progressed, the need of implementing Six Sigma at design stage of product or process (Ball et al., 2010). Each steps of Six Sigma Methodology contain tools and techniques. Define step determine the objectives of project and organizing the people. Measure step determine a key performance indicators and measure of sigma value. Analyze step determine Process Capability Indices and calculate the cost of poor quality. Improve step use many tools to improve quality like FMEA (Failure Mode Effect Analysis), design of experiment, etc. Control step maintain quality in control with control chart.

Besterfield (2003) states Six Sigma was simply a Total Quality Management (TQM) process that uses process capability analysis as a way of measuring progress. Process capability analysis is very important to know capability when products is made or services is given. Pyzdek (2001) states that Six Sigma involves an intense effort to reduce process variation to a minimum, so that processes consistently meet or exceed customer expectations and requirements. Process control using control chart to control process variation and process mean. Pande and Holpp (2002) states that adopting Six Sigma methodologies are to improve customer satisfaction, work processes, profitability, speed, and efficiencies.

2.3 Process Capability Indices (PCI)

Cp and Cpk are indicators that use to determine process capability. Pearn et.al (2005, pp.513) states "Process Capability Indices are practical and powerful tools for measuring process performance". Kane (1986, pp.44-45) state "Cp index measures potential process performance since only the process spread is related to the specification limits and Cpk index is related to the Cp index but utilizes the process mean and considered a measure of the process performance". Kane (1986, p.41-45) formulated Cp and Cpk as follow:

$$\mathrm{Cp} = \frac{\text{allowable process spread}}{\text{actual process spread}} = \frac{USL - LSL}{6\sigma}$$

$$\mathrm{Cpk} = \min(\mathrm{CPU}, \mathrm{CPL})$$

$$\text{CPU} = \frac{USL - \mu}{3\sigma} \text{ and CPL} = \frac{\mu - LSL}{3\sigma}$$

with: USL = Upper Specification Limit, σ = Natural Tolerance
LSL = Lower Specification Limit, μ = Process Mean

Cpk index is actual measurement based on shifting of process mean. Whereas, Cp index show potential capability of the process or services.

Based on Gryna on Juran's Quality handbook (1999, p.22.17), there are two types of process studies, as follow:

1. Process capability that estimate the inherent or potential process capability
2. Process performance that measures the present performance of the process.

The formulation for process capability and process performance are shown below:

Process Capability	Process Performance
$Cp = \frac{USL - LSL}{6\sigma}$	$Pp = \hat{Cp} = \frac{USL - LSL}{6\sigma}$
$Cpk = \min\left(\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right)$	$Pp = \hat{Cpk} = \min\left(\frac{USL - \mu}{3\sigma}, \frac{\mu - LSL}{3\sigma}\right)$
$Cpm = \frac{USL - LSL}{6\sqrt{\sigma^2 + (\mu - T)^2}} = \frac{Cp}{\sqrt{1 + \left(\frac{\mu - T}{\sigma}\right)^2}}$	$Pp = \hat{Cpm} = \frac{USL - LSL}{6\sqrt{\sigma^2 + (\mu - T)^2}}$

Tab. 1: Process Capability and Process Performance (Gryna on Juran, 1999, p.22.18)

Senvar and Tozan (2010, p.259) state Cpkm is a third generation that is derived from the second generation Process Capability Indices (PCI): Cpk and Cpm. Formulation of Cpkm as follow:

$$Cpkm = \frac{Cpk}{\sqrt{1 + \left(\frac{\mu - T}{\sigma}\right)^2}}$$

With: T = Target of specification, midpoint from Upper Specification Limit (USL) and Lower Specification Limit (LSL)

Both of Cpm and Cpkm are used to calculate PCI with processes that have a target of specification. Cp and Cpk can be measured if the process condition under control statistically. If the process is out of control, so it must be controlled statistically.

Comparation of Cp value and total product outside from specification limit can be seen in the table below:

Process Capability Indices, Cp	Total product outside two-sided specification limits*
0.5	13.36 %
0.67	4.55 %
1.00	0.3 %
1.33	64 ppm
1.63	1 ppm
2.00	0

*Assuming the process is centered in midpoint between the specification limits

Tab. 2: Process Capability Indices,Cp and Product outside Specification Limits (Gryna on Juran, 1999, p.22.18)

Six-sigma concept of process capability recognizes 1.5 standard deviation shifts in the process average and so the product or the process must achieve a Cp of at least 2.0 (Gryna in Juran, 1999). Process capability does not meet the specification of customer; it is caused by variability of process and not centralized to target of process. Montgomery (2001, p.331) states there are two reasons that cause poor process capability are: a). poor process centering and b). Excess process variability, as follow:

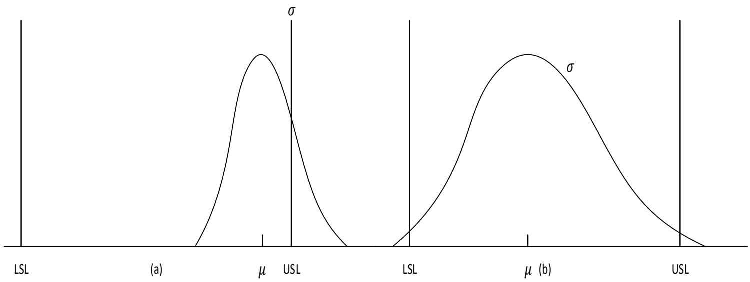

Fig. 1: Some reasons for poor process capability: a) poor process centering b) excess process variability (Montgomery, 2001, p.331)

2.4 Cost of Poor Quality (COPQ)

It is analyzed Cost of Poor Quality to know how many influence between the quality of process in product or services and the cost. Regarding Gryna on Juran's Quality handbook (1999), Cost of Poor Quality (COPQ) identified and analyzed with 3 reasons, are: to quantify the size of the quality problem to help justify an improvement effort, to guide the development of that effort, and to track progress in improvement activities. The quality costs in the range of 10 to 30 % of sales or 25 to 40 % of operating expenses.

Many categories to classify of Cost of Poor Quality (COPQ). Based on Gryna on Juran's Quality handbook (1999. p.8.5), categories of COPQ are:

1) Internal Failure Cost, costs of deficiencies discovered before delivery which are associated with the failure.
    a. Failure to meet customer requirement and need, for example: scrap, rework, reinspection, redesign, downgrading, etc.
    b. Cost of inefficient processes, for example: variability of product characteristics, inventory shrinkage, Non Value Added (NVA) activities, etc.
2) External Failure Costs, cost associated with deficiencies that are found after product is received by customer.

a. Failure to meet customer requirement and needs, for example: warranty defection, complaint adjustment, returned material, penalties, etc.
b. Loss opportunities for sales revenue, for example: customer defection, loss because of quality

3) Appraisal Cost, costs incurred to determine the degree of conformance to quality, for example: incoming inspection and test, final inspection, document review, audit, evaluation of stocks, maintaining accuracy of test equipment.etc.
4) Prevention cost, cost incurred to keep failure and appraisal costs a minimum, for example: process planning, new product planning, process planning, process control, quality audit, supplier quality evaluation, training, etc.

The scenario of integrated Cost of Poor Quality (COPQ) in Supply Chain network design will ensure the lowest overall cost, because it reduces the probability of defects and hence the probability of additional cost which might be due to corrective action (Ramudhin et al.,2008). Analyzing COPQ can be improved a chance to get higher profit. Failure cost must be decreased as a minimum so operational cost become smaller. Prevention and appraisal cost can be increased in appropriate level to avoid or prevent failure in the next process. Optimum cost for poor quality can refer to model of Gryna on Juran's Quality handbook (1999, p.8.22) as follow:

Based on the figure 2, failure cost cannot be decreased until zero because it is needed costs of appraisal and prevention more. Industries intend to get a failure cost in minimum and expend prevention and appraisal cost in appropriate cost. So, total quality cost is optimum when quality of conformance less than 100 percent. Many methods are used to get optimum value of the Cost of Poor Quality (COPQ). Based on Gryna in Juran's Quality handbook (1999, p. 8.16), they come from a reduction in variability of product or process characteristics and process losses such as redundant operators, sorting inspections, retrieving missing information and other non value added activities.

Now, industries try to eliminate non value added activities in their process from upstream to downstream. They used many tools to eliminate non value added analysis like value stream mapping with lean manufacturing approach. Lean manufacturing focuses on the methodologies and approaches that can help an enterprise to reduce the waste factors in its processes (Khataie and Bulgak, 2013). Many researchers try to integrate Cost of Poor Quality (COPQ) with other tools like Tsai (1998) states the long term goal of the integrated Cost of Quality (COQ) and Activity Based Costing (ABC) system is to eliminate non value added activities.

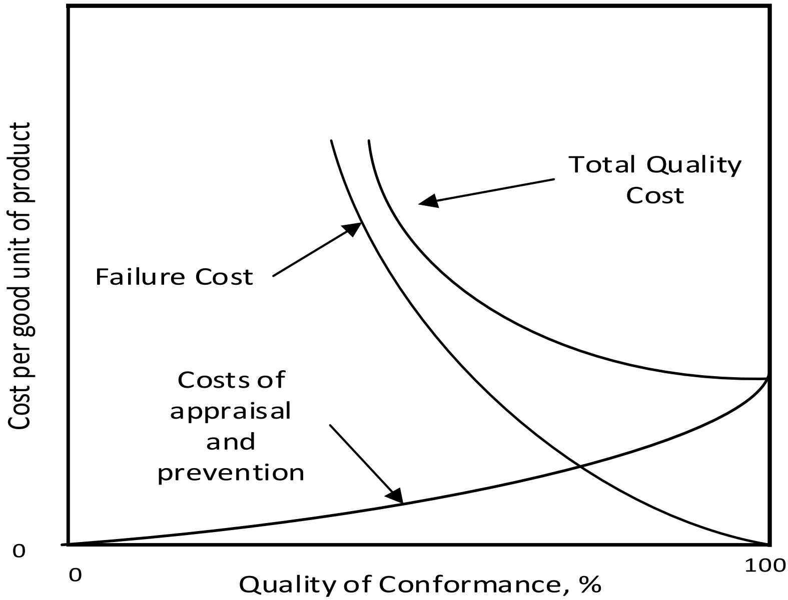

Fig. 2: Model for Optimum Quality Costs (Gryna on Juran, 1999,p.8.22)

3. Research Methodology

Data were collected by direct observation and interview with Logistics Service Department of CDG Port. This research follows Six Sigma methodology with

DMAIC (Define–Measure-Analyze-Improve-Control) steps. This research focused to Analyze steps to analyze Process Capability Indices (PCI) and Cost of Poor Quality (COPQ). Process Capability Indices is important to be analyzed to know the capability of process. This research proposed calculating Process Capability Indices in Supply Chain flow in port based on Kane (1986, p.41-45) as a measurement of actual process performance. Cpk is selected for calculating the Process Capability Indices (PCI) in actual process. It means, calculating PCI with considering the shifting of process mean. Cpkm cannot be used because all performance indicators in supply chain flow do not have Target of specification (T) or midpoint of Upper Specification Limit (USL) and Lower Specification Limit (LSL). These processes only have Upper Specification Limit (USL).

Ridwan (2013) states all performance indicators of Supply Chain flow in CDG port were obtained from all process that becomes a critical problem. So, all performance indicators in this research based on critical problem on Ridwan's research before. Data collection based on observation and discussion with person in charge at Logistic Service Department of CDG port, calculation of the Process Capability Indices took three cargos handling as example and represented cargos in CDG Port, as follow: fertilizer, slab steels, and iron ore. All performance indicators for cargos can be seen on next table (page 11, 12, and 13).

Cost of Poor Quality (COPQ) is analyzed to know impact of poor quality to the cost. This research refer to model for optimum quality cost from Gryna Juran's Quality handbook (1999), applied in supply chain flow of cargos handling at port. After classification of COPQ in prevention cost, appraisal cost, and failure cost, then calculation percentage of COPQ to sales. Also, data collection based on observation and discussion with person in charge at Logistic Service Department of CDG port, for three cargos handling as example and represented cargos in CDG Port, as follow: fertilizer, slab steels, and iron ore. In the end of research, improvements are proposed to improve performance of supply chain flow, especially in cargos handling at port.

4. Result and Discussion

The results of research based on implementing in CDG Port as follow:

4.1 Calculate the Process Capability Indices

It is measured Process Capability Indices to know how the process can meet the requirement of customer. The Process Capability Indices indicate variation of process and capability of centered-process. This table below is summary of Process Capability Indices in Fertilizer cargo handling.

Cargo: Fertilizer

No	Process (performance indicators)	Upper Specification Limit /USL (minutes)	Average	Deviation Standard	Process Capability Indices
1	Unloading Fertilizer from the ship to hopper with Grab	1.2	1.24	0.172	-0.08
2	Loading fertilizer from hopper to the Truck	4	4.14	0.776	-0.06
3	Weighing time in weighing area	5	5.11	0.683	-0.05
4	Transportation to KBS Warehouse	15	12.87	2.241	0.32
5	Unloading fertilizer in the Warehouse	3	2.26	0.348	0.71
6	Bagging fertilizer in the KBS Warehouse	0.2	0.21	0.023	-0.14
7	Loading fertilizer from warehouse to the truck	1.5	1.50	0.081	0.01
				Average	0.10

Tab. 3: Summary of Average, Deviation Standard, Control Limit, and Process Capability Indices in Fertilizer cargo handling

Example for calculation: (no. 1, on page 11)

Unloading Fertilizer from the ship to Hooper with Grab

N = 100

Calculation of $\bar{X}$ as follow:

$$\bar{X} = \frac{\sum_{i=1}^{N} Xi}{N} = \frac{124.22}{100} = 1.24$$

Calculation of deviation standard as follow:

$$\sigma = \sqrt{\frac{\sum(Xi - \bar{x})^2}{N}} = \sqrt{\frac{2.948}{100}} = 0.172$$

Cargo: Slab Steels

No	Process (performance indicators)	Upper Specification Limit /USL (minutes)	Average	Deviation Standard	Process Capability Indices
1	Unloading slab from ship to the truck	6	6.07	0.738	-0.03
2	Transportation to KBS stockpile	15	15.36	1.638	-0.07
3	Unloading slab from truck in the KBS Stockpile	1	0.99	0.115	0.02
4	Loading Slab to the Truck in KBS Stockpile	1.75	1.80	0.152	-0.11
5	Transportation to KS stockpile	65	62.18	7.855	0.12
				Average	-0.01

Tab. 4: Summary of Average, Deviation Standard, Control Limit, and Process Capability Indices in Slab Steels cargo handling.

The company determines a target of unloading process of fertilizer is maximum of 1.2 minutes or Upper Specification Limit (USL) =1.2 minutes. There is no

Lower Specification Limit (LSL). With data is assumed to be normally distributed, so the calculation of Process Capability Indices (Cpk) as follows:

$$Cpk = \min[\text{CPU}, \text{ CPL}] = \min\left[\frac{\bar{X}-\text{LSL}}{3\sigma}, \frac{\text{USL}-\bar{X}}{3\sigma}\right] \text{because there is no LSL, so}$$

$$Cpk = \text{CPU} = \frac{1.2-1.24}{3\,(0.172)} = \frac{1.2-1.24}{3\,(0.172)} = -0.0775 = -0.08 \text{ (be rounded)}$$

Cargo: Iron Ore

No	Process (performance indicators)	Upper Specification Limit /USL (minutes)	Average	Deviation Standard	Process Capability Indices
1	Unloading Iron Ore from Ship to Conveyor	2	1.98	0.476	0.02

Tab. 5: Summary of Average, Deviation Standard, Control Limit, and Process Capability Indices in Iron Ore cargo handling

This table below is summary of Process Capability Indices (PCI)

Cargo	PCI
Fertilizer	0.10
Slab	-0.01
Iron Ore	0.02
Average	0.06

Tab. 6: Summary of Cost of Process Capability Indices (PCI)

The result of Process Capability Indices (PCI) in handling of cargo is 0.06 in average. This result shows that process capability in cargos handling at CDG port have not capable to meet the customer requirements. Upper Specification Limit (USL) was determined by customer and CDG port has not met the customer specifications. PCI become one of performance indicator in the process capability of cargos handling. Based on Gryna in Juran's Quality

Handbook (1999, p.22.17), if Cp <1, so heavy process control, sorting, and rework must be done for actions. For Six Sigma implementation, process must achieve Cp value at least 2.0 (Gryna in Juran, 1999).

Calculation of these PCI is focused in performance indicator for cycle time to get an optimal time for loading and unloading material from the ship to the warehouse. Speed of loading and unloading material in Supply Chain flow in port is very important to get the effective time in cargo handling. If the time is over from the contract, this port must pay a demurrage cost that is known quite expensive.

Causes for low PCI consisted of variation of process is high and centering of process is low (Montgomery, 2001). Based on observation and discussion in the field, variation and centering of process were caused dominantly by delay for equipments and supporting equipments for loading and unloading material like trucks or container trucks, cranes, loaders, excavators, etc. Delay for equipments and their supporting were caused by lack of maintenance and insufficiency of equipment and its equipment. Improvement plans have been proposed to solve the problems like upgrading equipment, periodical shutdown maintenance, selecting skilled operator for equipment, outsourcing for equipment, etc. Major improvement is proposed to implement Total Productive Maintenance (TPM) in maximizing overall equipments and running small group activities.

4.2 Cost of Poor Quality (COPQ)

Calculation of the Cost of Poor Quality (COPQ) was performed in three cargos handling and represent in CDG Port as follow: Fertilizer, Slab Steels, and Iron Ore. Based on observation and interview with person in charge at Logistic Service Department, Cost of Poor Quality (COPQ) for handling in Fertilizer, Slab Steels, and Iron Ore cargo as follow.

Based on the table 7 on p.16, prevention cost is 312,625.76 USD or about 49 % from Cost of Poor Quality (COPQ) and Appraisal cost is 110,462.77 USD or 17 % from COPQ. Also, prevention and appraisal cost is 423,088.52 USD or about 66% from COPQ. Meanwhile, failure cost is 217,612.85 or 34 % from COPQ.

Failure cost is still high although prevention and appraisal cost already have been increased. For next improvement strategy, prevention cost is decreased in the appropriate level and appraisal cost is kept. Cargo: Fertilizer:

No.	Item Cost	Cost (USD)
	Prevention Cost	
1	Repair and maintenance of cranes	90,350.53
2	Repair and maintenance of dump trucks	212,752.22
3	External training	333.33
4	Security services	7,500
5	Repair and maintenance of heavy equipments (forklift and front loader)	1,689.67
	Total	312,625.76
	Appraisal Cost	
1	Calibration of scales	4,560
2	Calibration for certificates	3,000
3	Vehicles testing and taxes for truck	447.92
4	Draft survey	2,980.38
5	Supervision from dock until destination warehouse	12,541.67
6	Custom Clearance from customs and excise	30,989.15
7	Re-bagging because stitching of bagging is not good	8,606.98
8	Emission of CO2 test for trucks and heavy equipments	458.33
9	Stevedoring companies	46,878.35
	Total	110,462.77
	Internal Failure Cost	
1	Loss of content from ship to warehouse	54,453.13
2	Bagging is damaged (dirty or trampled)	116,875.00
3	Delay of trucks, cranes, excavators, loaders, and workers	34,201.39
	Total	205,529.51
	External Failure Cost	
1	Demurrage (penalty)	0
2	Warranty	12,083.33
3	Accomplishment of Customer (loss of content, bagging is damage or dirty, etc.)	0

No.	Item Cost	Cost (USD)
4	Returned product	0
	Total	12,083.33
	Grand Total Cost of Poor Quality (COPQ)	640,701.37
Sales (USD)	1,871,000.00	
Percentage COPQ to Sales	34.24 %	

Tab. 7: Cost of Poor Quality of Fertilizer (Logistics Services Department of CDG Port, 2013)

Composition of the Cost of Poor Quality is shown below:

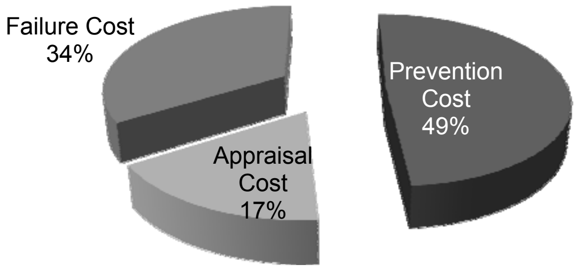

Fig. 3: Composition Prevention, Appraisal, and Failure cost for Fertilizer Cargo handling

Cargo: Slab Steels

Based on the table 8 on p.18, prevention cost is 111,942.82 USD or about 8 % from COPQ and Appraisal cost is 1,111,824.22 USD or 82 % from COPQ. Also, prevention and appraisal cost is 1,223,767.03 USD or about 90% from COPQ. Meanwhile, failure cost is 136,041.67 USD or 10 % from COPQ. Composition of the Cost of Poor Quality is shown below:

No.	Item Cost	Cost (USD)
	Prevention Cost	
1	External training	333.33
2	Repair and maintenance of cranes	111,609.48
	Total	111,942.82
	Appraisal Cost	
1	Supervision and labors for unloading on Jetty	41,782.77
2	Custom Clearance from customs and excise	27,703.70
3	Rent of forklifts	297,137.92
5	Stevedoring companies	668,049.00
6	Lift off process of slab steels from the truck	59,917.50
7	Installation and supervision of dunnage/block	5,083.33
8	Supervision by checkers	12,150.00
	Total	1,111,824.22
	Internal Failure Cost	
1	Delay of transportation (trucks), ship crane troubles, and delay of workers	136,041.67
	Total	136,041.67
	External Failure Cost	
1	Demurrage (penalty)	0
2	Warranty	0
3	Accomplishment of Customer Complaint	0
4	Returned product	0
	Total	0
	Grand Total Cost of Poor Quality (COPQ)	1,359,808.70

Tab. 8: Cost of Poor Quality of Slab Steels (Logistics Services Department of CDG Port, 2013)

Appraisal cost for this cargo is too high although failure cost is low. For next improvement strategy, appraisal cost must be decreased to appropriate level. Based on the table 9 on p.20, prevention cost is 37,536.49 USD or about 37 % from COPQ and Appraisal cost is 12,015.63 USD or 12 % from COPQ. Also, prevention and appraisal cost is 49,552.12 or about 49% from COPQ.

Meanwhile, failure cost is 51,284.72 USD or 51 % from COPQ. Composition of the Cost of Poor Quality is shown below:

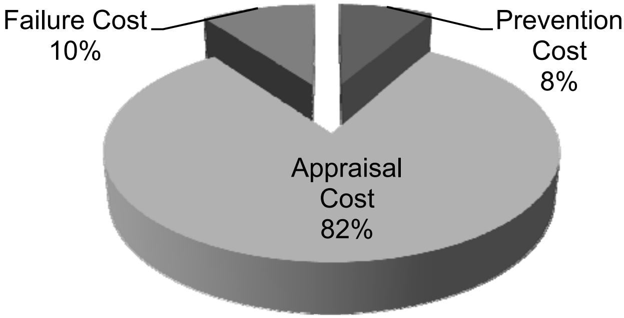

Fig. 4: Composition Prevention, Appraisal, and Failure cost for Slab Steels Cargo handling

Cargo: Iron Ore

No.	Item Cost	Cost (USD)
	Prevention Cost	
1	Repair and maintenance of ship unloaders	37,203.16
3	Internal trainings	333.33
	Total	37,536.49
	Appraisal Cost	
1	Supervisions and labors for unloading on Jetty	8,608.96
2	Cleaning process on Jetty	490.00
3	Port administration and sweeping	2,916.67
	Total	12,015.63
	Internal Failure Cost	
	Delay of ship unloaders, conveyors, stackers	51,284.72
	electrical, and mechanical	
	Total	51,284.72
	External Failure Cost	
1	Demurrage (penalty)	0
2	Warranty	0
3	Accomplishment of Customer Complaint	0
4	Allowances	0
	Total	0
	Grand Total Cost of Poor Quality (COPQ)	100,836.85
Sales		1,666,666.67
Percentage COPQ to Sales		6,05 %

Tab. 9: Cost of Poor Quality of Iron Ore (Logistics Services Department of CDG Port, 2013)

Failure cost for this cargo is too high. For next improvement strategy, failure cost must be decreased in appropriate level. This table below is summary of Cost of Poor Quality (COPQ).

The Cost of Poor Quality (COPQ) in cargos handling is 700,449 USD in average and 39.02 % from the sales in average. Percentage COPQ to sales for Slab Steels cargo is too high. It is caused by appraisal cost is too high. Meanwhile, percentage COPQ to sales for Iron Ore cargo has been effective.

Based on Gryna in Juran's Quality Handbook (1999, p.8.16), improvement strategy focused to decrease failure cost and appraisal cost and increase more prevention cost. For this research, all cargos must be decreased failure cost and appraisal cost. Whereas, prevention cost must be kept in appropriate level.

Fig. 5: Composition Prevention, Appraisal, and Failure cost for Iron Ore Cargo handling

Item	COPQ	Sales	Percentage COPQ to Sales
Fertilizer	640,701.37	1,871,000	34.24
Slab	1,359,808.70	1,771,583.33	76.76
Iron Ore	100,836.85	1,666,666.67	6.05
Average	700,449	1,769,750	39.02

Tab. 10: Summary of Cost of Poor Quality (COPQ)

Improvements are proposed to eliminate wastes in Supply Chain flow with lean in Supply Chain approach, so it can decrease failure and appraisal cost. Ridwan et al. (2013, p.47) resulted the biggest waste in the flow of fertilizer Supply Chain at CDG Port is transportation until 52.05%. So, it is focused to map all routes and optimize in each stream of Supply Chain flow. Annahhal et al. (2014, pp.157) state wastes of transportation is decreased, it means materials is delivered just in time, so another waste like inventory, can be decreased.

5. Conclusion

Process Capability Indices (PCI) in Supply Chain flow of cargos handling at port is 0.06 in average. It indicate that process capability in cargos handlings have not capable to meet the customer requirements. Meanwhile, the Cost of Poor Quality (COPQ) in Supply Chain flow of cargos handling at port is 700,449 USD in average and 39.02 % from the sales in average. This cost is still high if it is compared with the sales. Some improvements have been proposed for increasing PCI and decreasing COPQ. Major improvement to increase PCI with Total Productive Maintenance (TPM) approach to improve overall equipments for loading and unloading cargos. Whereas, major improvement strategy to decrease COPQ with Lean Supply Chain approach to eliminate wastes in Supply Chain flow.

6. Future Research

For the future research, it is investigated a model for causal relationship between Process Capability Indices (PCI) and Cost of Poor Quality (COPQ) with system dynamic approach. Then simulation is required to optimize all variables that can influence PCI and COPQ. With this research, it can be optimized all process in supply chain flow in ports to get high quality performance with the lowest cost.

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Innovative Methods in Logistics and Supply Chain Management

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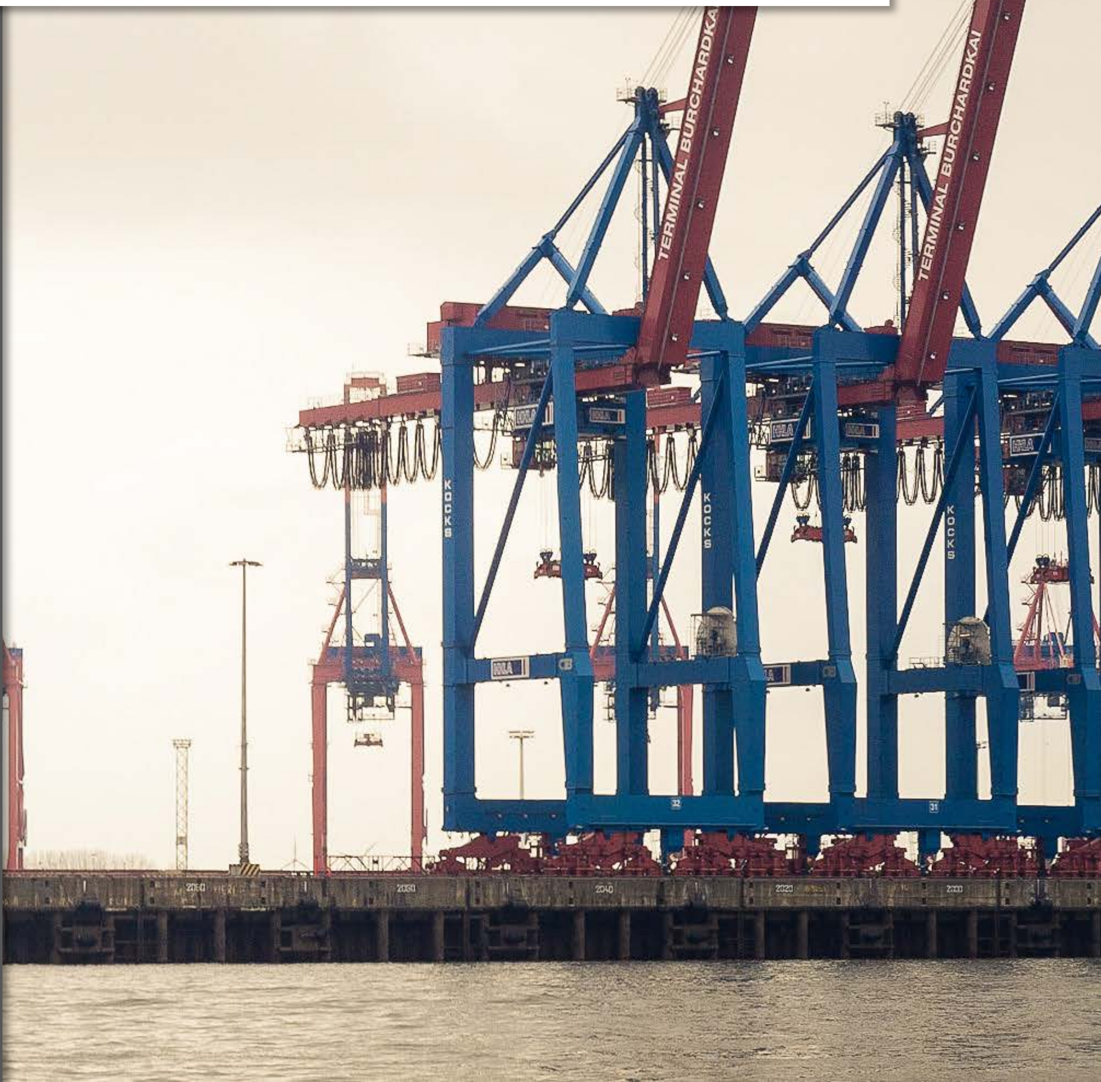

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Current Issues and Emerging Practices

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Preface

Innovation is increasingly considered as an enabler of business competitive advantage. More and more organizations focus on satisfying their consumer's demand of innovative and qualitative products and services by applying both technology-supported and non technology-supported innovative methods in their supply chain practices.

Due to its very characteristic i.e. novelty, innovation is double-edged sword; capturing value from innovative methods in supply chain practices has been one of the important topics among practitioners as well as researchers of the field.

This book contains manuscripts that make excellent contributions to the mentioned fields of research by addressing topics such as innovative and technology-based solutions, supply chain security management, as well as current cooperation and performance practices in supply chain management.

We would like to thank the international group of authors for making this volume possible. Their outstanding work significantly contributes to supply chain management research. This book would not exist without good organization and preparation; we would like to thank, Sara Kheiravar, Tabea Tressin, Matthias Ehni and Niels Hackius for their efforts to prepare, structure, and finalize this book.

Hamburg, August 2014

Prof. Dr. Thorsten Blecker
Prof. Dr. Dr. h. c. Wolfgang Kersten
Prof. Dr. Christian Ringle

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About HICL

Since 2006 the annual conference Hamburg International Conference of Logistics (HICL) at Hamburg University of Technology (TUHH) is dedicated to facilitate the exchange of ideas and contribute to the improved understanding and practice of Logistics and SCM. HICL creates a creative environment which attracts researchers, practitioners, and industry thinkers from all around the world.

Innovation is increasingly considered as an enabler of business competitive advantage. More and more organizations focus on satisfying their consumer's demand of innovative and qualitative products and services by applying both technology-supported and non technology-supported innovative methods in their supply chain practices. Due to its very characteristic i.e. novelty, innovation is double-edged sword; capturing value from innovative methods in supply chain practices has been one of the important topics among practitioners as well as researchers of the field.

This volume, edited by Thorsten Blecker, Wolfgang Kersten and Christian Ringle, provides valuable insights into:

- Innovative and technology-based solutions
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