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Benchmarking Product Service System of Generator Set Distributors

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Abstract

Power generation is an industry that is essential to sustain daily life and competes with generator set distributors. The product service system of distributors must be improved to survive the competition. This research aims to develop tools for benchmarking the product service system of generator set distributors. Benchmarking identifies gaps between a product and other competitors' products. In this work, a product service system board is used to visualize the current product service system of a generator set distributor. A PPIAF framework and a SERVQUAL framework are adapted to assess product performance and service quality, respectively. AHP is used as weighting method. The survey results provide ideas for improving the current product service system of generator set distributors. Further studies must use detailed measure weighting methods and implement the product service system board to assess service quality.

Abstrak

Benchmarking* Kualitas *Product Service System* dari Distributor Peralatan *Generator Set. Pembangkit listrik adalah sebuah industri yang penting untuk keberlangsungan kehidupan sehari-hari dan bersaing dengan *distributor* dari peralatan *generator set. Product service system* dari *distributor* harus terus dikembangkan agar dapat bertahan di dalam persaingan. Penelitian ini bertujuan untuk mengembangkan alat untuk *benchmarking product service system* yang dimiliki oleh perusahaan *distributor* peralatan *generator set.* Kegiatan *benchmarking* mengidentifikasi *gap* antara produk dari perusahaan tersebut dengan produk dari pesaing lainnya. Di dalam studi ini, sebuah *product service system board* digunakan untuk visualisasi *product service system* yang dimiliki oleh sebuah distributor peralatan *generator set*. Kerangka kerja PPIAF dan SERVQUAL diadaptasi untuk mengukur kinerja produk dan kualitas layanan. AHP digunakan untuk penentuan bobot dari ukuran. Hasil dari survey memberikan ide untuk peningkatan *product service system* yang ada dari sebuah *distributor* peralatan *generator set*. Pada studi lanjutan diperlukan metode penentuan bobot dari ukuran yang lebih terperinci dan implementasi dari *product service system board* untuk pengukuran kualitas dari layanan.

Keywords: product service system, product service system board, generator set

1. Introduction

Generator set or genset (G/S) is a set of generator and engines assembled in one package that runs on fuel, such as diesel, biogas, landfill gas, natural gas, or other fuel resources. A genset converts mechanical energy into electrical energy and is commonly used by big companies to generate electricity. A genset is essential worldwide because it provides electricity to sustain almost all activities of people.

The rapid increase in the need for electricity has led to its high demand; in this regard, the Indonesian government should venture with many private companies that specialized in producing electricity because its public company is insufficient and is only capable of water-to-electricity conversion. Thus, several businessmen aim to build private electricity-generation companies in Indonesia, resulting in high demand for genset procurement; this equipment can be sourced from well-known international companies, such as Caterpillar from America and Jenbacher from Austria, which specialized in manufacturing power generation devices.

Most power generation companies typically consider product-service related criteria to determine the type of genset to purchase. These criteria are important because purchasing a genset requires a great amount of money and affects the companies' financial state. Distributors should fulfill their customers' business requirements. As

such, decision analysis is should be performed initially before the companies select the best genset distributor that can cooperate with allocating resources. As clients, power generation companies should perform benchmarking of various types of gensets.

Product performance is one of the product-service related criteria that are commonly considered. The performance of a genset should be aligned with customer's business requirements, such as company goals and financial state. Service performance is also important to assist long-term genset operation. A genset distributor provides service to support the success of the client's project. A product with good quality will not be qualified if it is not provided with good service.

This study aims to identify and improve low-performance criteria within the company's product service system. Benchmarking is conducted to compare a genset distributor with other competitors by using PSS approach.

Arnold Tucker [1] stated that PSS is an excellent vehicle to enhance competitiveness and foster sustainability simultaneously. The implementation of PSS business models allows companies to create sources of added value and competitiveness because they fulfill customers' needs in an integrated and customized manner; the models also build unique relationships between the company and its customers to enhance customer loyalty and leads to rapid innovation because customers' needs are better addressed. Goedkoop, M.A [2] claimed that PSS can provide strategic market opportunities and fundamental business benefits of improving total value for customers by increasing service elements.

This work used PSS approach because it is considered a tool to enhance competitiveness and suitable for business competition, such as in terms of electricity generation. Given that PSS includes not only product-related business value but also service, companies can fulfill their customer needs in the most effective way possible.

2. Methods

This section explains the steps of conducting this research, starting from business process mapping to presentation of case study results.

Business process mapping. Business processes used by distributors are a collection of related, structured activities or tasks that produce a specific service or product for a particular customer or customers. Customers should be offered products and services before competitors can establish themselves, and the ability to respond to changing market requirements is a major factor of business success. A business process is considered to describe [3]: a) which activities are performed in the course of a process; b) which organizational units participate in process execution; c) what input and output data are used; d) which events and risks occur during process execution.

The distribution process of each distributor is mainly derived through the workflow of management and supporting processes. Although distributors begin with a mission objective to provide the best generator, they tend to be process oriented particularly in terms of customer services and avoiding functional silos. The business process of distributors should be visualized and analyzed to construct PSS. Business process identification is also required to construct a PSS board to list a breakdown of activities performed by the distributor in delivering product service specifically and in detail. The PSS board shows how the provider of PSS and its partners assist customers' job execution.

The business process mapping is divided into three phases: Levels 0, 1, and 2.

Level 0. Level 0 in business process visualizes the sequence of steps in a generic model that identifies the input and output of the business. The input of value-added activities in PT. XYZ is a project requirement based on customers' needs, product and aftermarket supply (spare parts) provided by the genset manufacturer, and local material (for example, battery) from vendors. The output generated in this business process is genset as product and post-procurement product support. Figure 1 depicts the business process of PT XYZ.

Level 1. Level 1 is a more detailed business process that contains a series of activities derived from Level 0. Main activities included in the business process are project preparation, project commissioning, maintenance, and project termination. The output of one activity will be the output of another activity in the next step. The process is depicted in Figure 2.

Level 2. Level 1 generates four detailed business processes, one for each activity. Each main activity has its detailed activities.

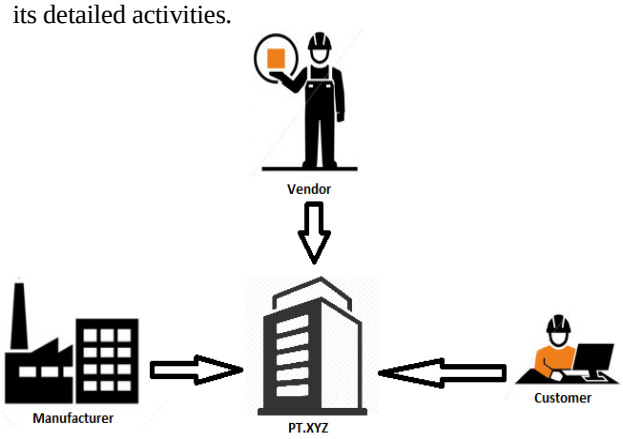

Figure 1. Business Process of PT. XYZ (Level 0)

Project preparation. The input of project preparation is project requirements based on customer's needs. These project requirements should be confirmed by performing a visit to the project site. All authorities are regarded by PT. XYZ as a trusted generator supplier in Southeast Asia to represent its manufacturer located in Austria. Site visit is performed by the engineering department of PT. XYZ. The output of site visit will be Requirement Verification Checklist (RVC) and Project Eligibility Confirmation (PEC) as Project Definition Phase (PDP) that will be the input of project budgeting. PDP is crucial in determining project cost to perform bidding and hand project proposal to participate in tender process. If qualified, then PT. XYZ will be engaged in contract and will proceed to the next step of activity, namely, project commissioning. The process of project preparation is depicted in Figure 3.

Project Commissioning. Project commissioning is initiated by PDP generated from project preparation. The PDP will be the base for project management department in making timeline of preparing task team and arranging fleet for genset delivery. The delivery of a product will be performed by Huangzhou hub, a subcompany of the product manufacturer, GE Power, which is also responsible in assembly and packaging of the product. After the task team is ready and the product has been delivered, project installation begins. Post installation activities include field quality control to ensure that the installation is aligned with the SOP and manuals for testing and commissioning. Customer will hire an independent engineer who will confirm whether the product is ready to operate and release Commercial Operation Date (COD). The engineer will provide a handover report, which will be used as an input to maintenance activities. Figure 4 depicts project commissioning.

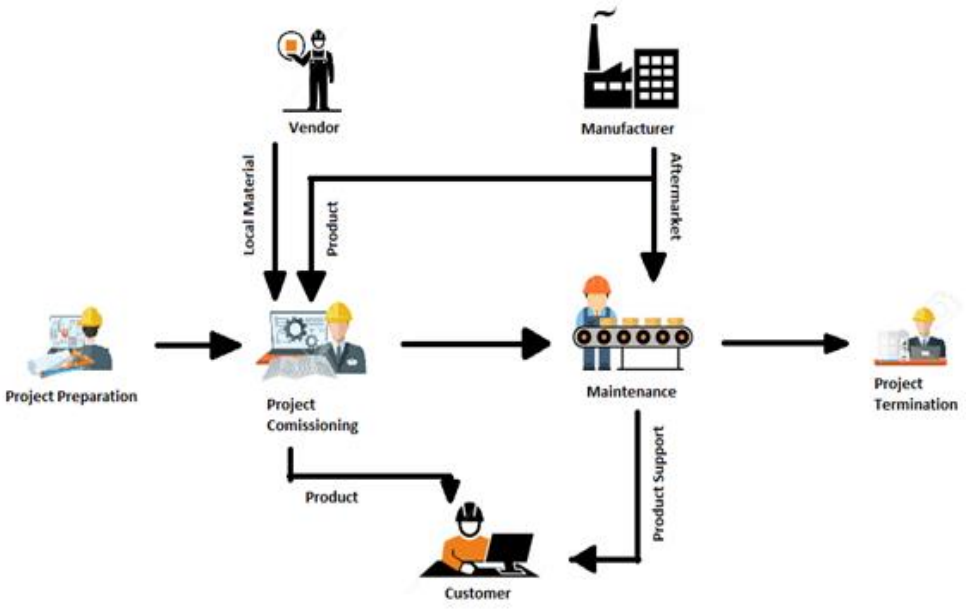

Figure 2. Business Process of PT. XYZ (Level 1)

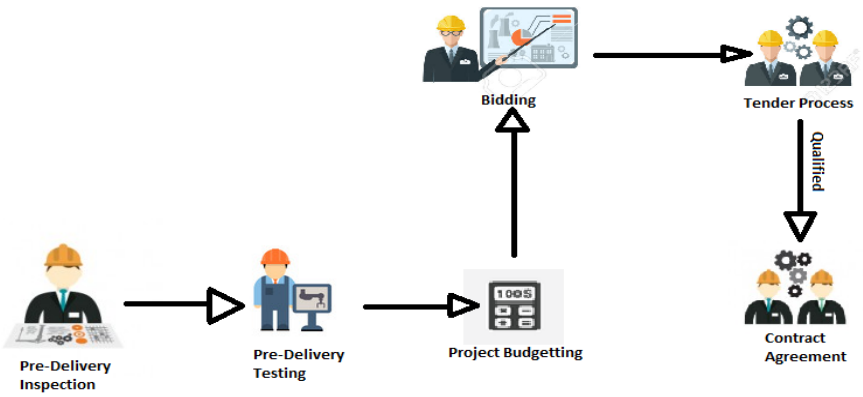

Figure 3. Project Preparation of PT. XYZ (Level 2)

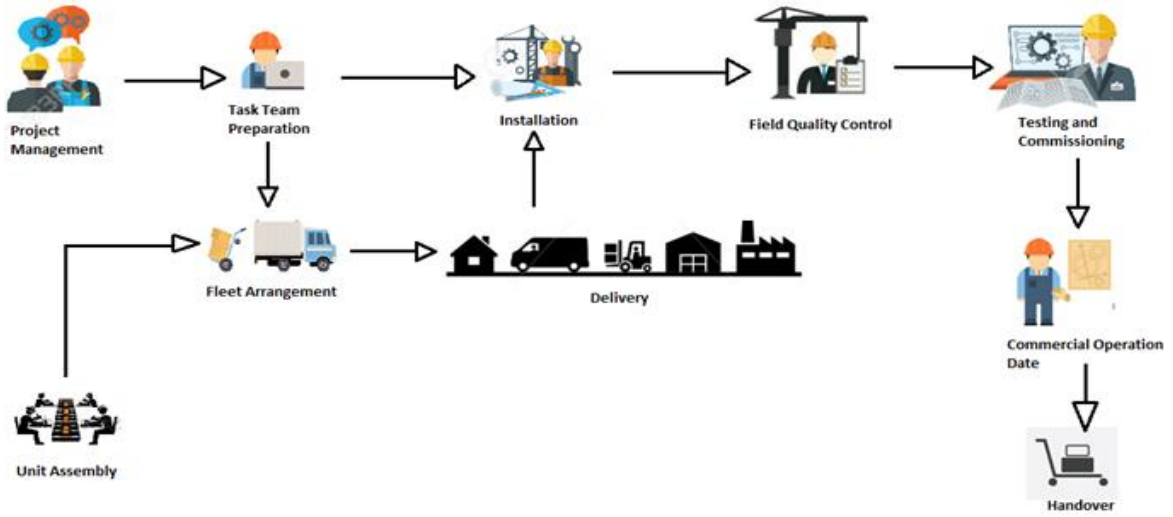

Figure 4. Project Commissioning of PT. XYZ (Level 2)

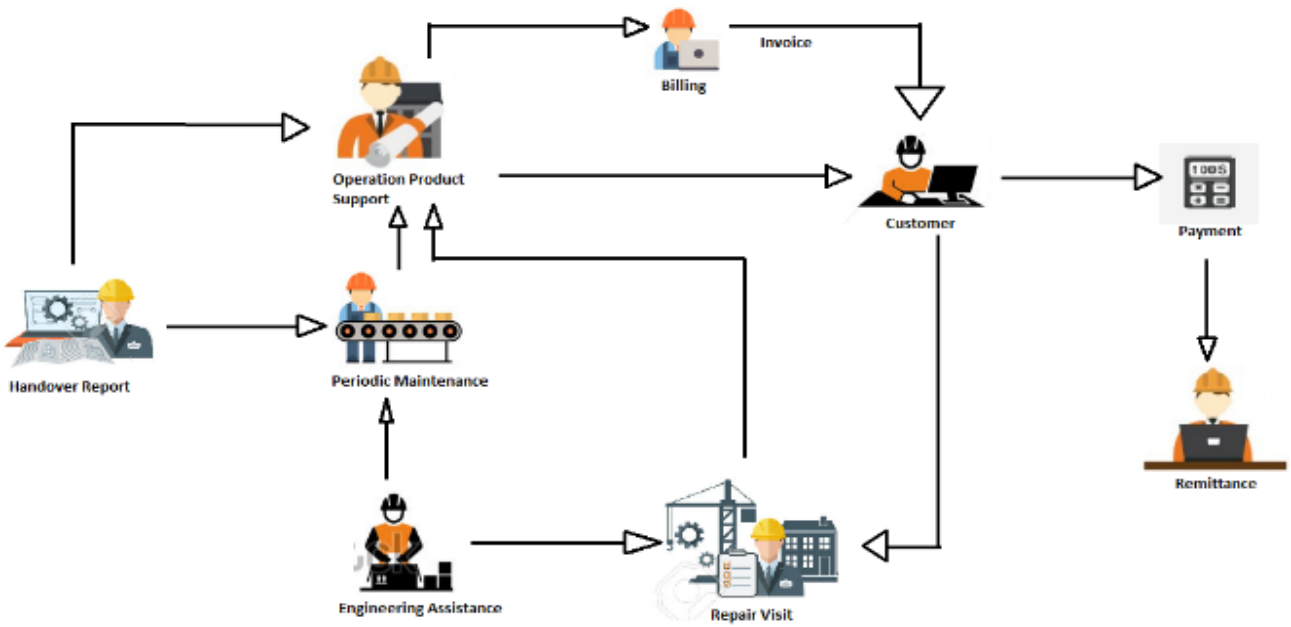

Figure 5. Maintenance of PT. XYZ (Level 2)

Maintenance. Maintenance support provided by PT. XYZ consists of periodic maintenance, repair visit, and operational product support. The handover report generated from project commissioning acts as an input to periodic maintenance and operational product support. Repair visit needs a direct input from the customer in the form of breakdown notification. Billing per repair or per visit is handled by finance department of PT. XYZ and given to the customer for payment. During repair visit and periodic maintenance, problem regarding genset operation is identified. If a problem is found, then parts should be replaced. When the maintenance support period ends based on the service contract agreement, maintenance department will terminate the project maintenance by releasing Contract Termination Date. The date can be extended; however, if the customer chooses to not extend, then instructions for discontinuation of maintenance support will be given. The process of maintenance is depicted in Figure 5.

Project termination. Project termination is initiated by the discontinuation of maintenance support instruction by the maintenance department. Termination Operation Date is released based on what is written on the contract agreement. The operational product support performed by the maintenance department will be terminated, and the project is considered complete. Project termination is depicted in Figure 6.

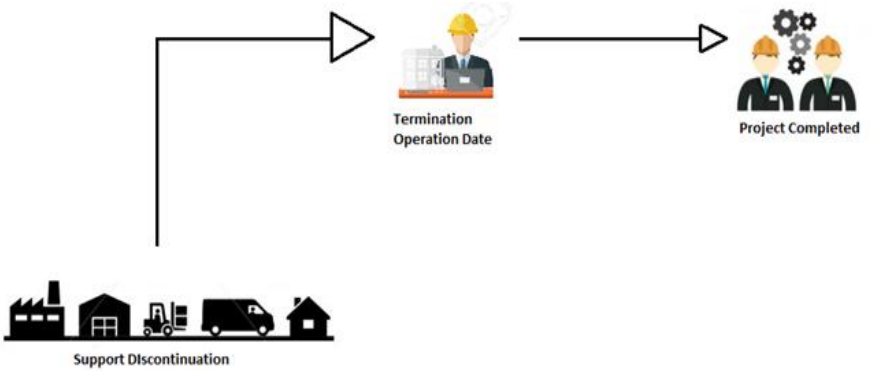

Figure 6. Project Termination of PT. XYZ (Level 2)

PSS board construction. Lim et al. [4] proposed a structured tool called PSS Board to visualize the PSS process. A PSS board is a matrix board where customer activities, product state, services, dedicated infra-structures, and partners are placed in rows, and the general PSS process steps are placed in columns. The PSS board shows elements that work in the same manner to satisfy customers' needs. The general PSS process steps are as follows [4]: a) *Define*: Directly define the product and the related plan to ensure success in overall job; b) *Locate*: Locate product and input required to ensure success in overall job; c) *Prepare*: Prepare things (e.g., knowledge or needed equipment for product use) to ensure success in overall job; d) *Confirm*: Confirm requirements and criteria to proceed with job execution and ensure overall success; e) *Execute*: Carry out the job; f) *Monitor*: Monitor or verify the conditions and result of job execution with products to ensure that the job is done successfully; g) *Resolve*: Resolve the problems of product or users caused by job execution; h) *Modify*: Make modifications or adjustments necessary to ensure success in overall job; i) *Conclude*: Conclude the process and prepare the next job execution.

The PSS board shows information on PSS components and customer activities through its rows, as shown below: a) *Partners*: The partners of the PSS provider; b) *Dedicated Infrastructures*: The dedicated infrastructures required to perform the job; c) *Services*: The services given by the PSS provider; d) *State of the Products*: The relevant information and issues of PSS from a product standpoint; e) *Customer Activities*: The role of customers in getting the job done.

According to Lim et al. [4], the initial steps of utilizing the PSS board are evaluation and improvement of PSS. The most feasible use of the PSS board is for measuring the strengths and weaknesses of a PSS process via visualization. The PSS board makes it easier to understand the relationships among PSS components. This visual association assists the evaluator to conveniently consider the gap between among the components.

During **Define** phase, PT. XYZ offers services of identifying customer's needs by providing them with detailed information about all potential genset types. To identify customer's needs, PT. XYZ performs a visit to the project site with the help of a contractor as the third party. After the needs are identified, the customer selects the genset suitable with their requirements. Thus, the state of product is that a model is selected based on customer requirements. During **Locate** phase, PT. XYZ locates task team to install and deliver the procured genset to the project site through the help of a logistic company. The customer only needs to inform PT. XYZ the precise location of the project site. The end state of the product during this phase is that the genset is delivered on the site. During **Prepare** phase, PT. XYZ prepares all tools and equipment (such as batteries and fuel tank) for performing genset installation with the help of a local material vendor. The customer assists PT. XYZ in installing the genset. In this phase, the end state of the product is that the genset is successfully installed according to the SOP and manuals. During **Confirm** phase, PT. XYZ conducts project site inspection, which includes genset testing. In the end of the phase, field quality control is conducted to ensure the quality of the genset installed in the project site. These two services are performed by PT. XYZ based on standards and regulations. The customer only verifies if the genset is functioning based on their requirements, also known as commissioning, through their private engineer. The end state of the product is that the genset is tested by PT. XYZ in compliance with the standards and regulations. During **Execute** phase, PT. XYZ performs maintenance service according to previous contract agreement. Hence, the customer can start operating the genset according to their requirements. All operation activities and maintenance activities should be performed by the customer and PT. XYZ, respectively, according to the provided manuals and standards. During **Monitor** phase, PT. XYZ regularly observes the

operation activities from the Operation Control Center (OCC) to rapidly resolve a problem if any normal behavior is detected. The customers also have a role in monitoring the operation and notify breakdown to PT. XYZ in the presence of any problem. If no problems are found, the customer keeps on simultaneously monitoring and maintaining the genset. **Resolve** phase only occurs if any problem persists during genset operation. This problem can be diagnosed during monitoring activities conducted by customers and/or during the regular observation conducted by PT. XYZ. If a problem is detected during the monitoring activities performed by the customer, then they should inform the break down to PT. XYZ. The role of PT. XYZ is to deliver service of solving the problem by conducting repair visits. **Modify** Phase occurs during routine genset operation when it needs to be maintained regularly. If no abnormal behavior is detected during the monitoring activities conducted by both PT. XYZ and customers, then the product service system will undergo the Modify phase. During **Conclude** phase, the project is stated as complete, and the contract is terminated. The project termination requires help from the contractors and logistic company and is performed after releasing the Termination Operation Date. From the PSS board of PT. XYZ, five major activities are defined in the product service system: customer need identification, delivery, installation, site inspection, and maintenance. Figure 8 depicts the PSS Board of PT. XYZ.

Framework construction. A framework was integrated from three other reference frameworks. PPFIA was originally established to assess the quality of power plants in Pakistan. SERVQUAL aimed to assess the service quality of a company. The PSS Board was used to identify major activities performed during service delivery. All the three frameworks were adjusted according to the needs of PT. XYZ, as a genset distributor company. For SERVQUAL, a scope limitation was applied. Gap identification which is a part of SERVQUAL method, was excluded. Only measures listed by SERVQUAL were used. The construction of the framework used for benchmarking is depicted in Figure 7.

Tool development. Tools include questionnaires and criterion weighting. Statements in the questionnaire are developed from the definition of each criterion listed in the framework and then validated. The purpose of criteria weighting is to determine the order of priority for each criterion. This process will make recommendations for improvement easy to define. The weight

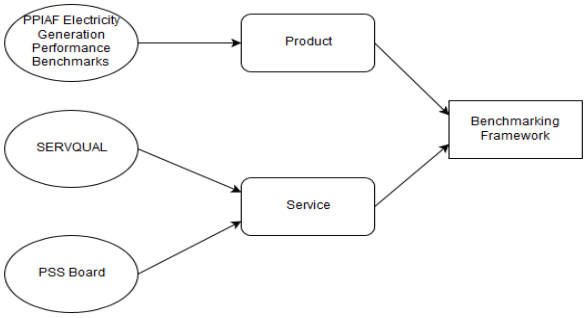

Figure 7. Benchmarking Framework Construction

Partners	Contractor	Logistic Company	Local Material Vendor						Contractor Logistic Company
Dedicated Infrastructures	Project Site Land			Compliance with Standards and Regulation		Operation Control Center (OCC)			
Services	Identify customer needs	Locate Task Team	Prepare required installation tools	Inspect project site Perform Field Quality Control	Maintain genset operation based on manual	Diagnose genset abnormal behaviour Observe Genset Operation	Conduct Repair Visit		
State of the Products	Model is selected based on customer requirement	Genset is delivered	Genset is installed	Genset is tested	Genset is ready to operate and maintained	Genset is monitored and maintained	Genset is ready to repair		Genset is no longer maintained
Customer Activities	Select required genset	Notify the project site location	Install genset	Test and commission genset	Project Execution (Genset Operation)	Monitorin g genset NOT OK OK	Notify breakdown	Maintain genset	Project complete
	DEFINE	LOCATE	PREPARE	CONFIRM	EXECUTE	MONITOR	RESOLVE	MODIFY	CONCLUDE

Figure 8. PSS Board of PT. XYZ [5]

of criteria will be used to compute weighted scores of all benchmarked gensets. The process of tool development is depicted in Figure 9.

Product benchmarking framework. The product benchmarking framework for PT. XYZ uses PPIAF constructed by Richwine (2013) [6] as reference. The PPIAF benchmarking framework originally consists of indicators to encourage improvements in power plants in Pakistan. Power quality is an essential technical parameter. However, adjustments should be conducted because this research needs a framework for an individual genset, not the entire power plant.

Every electricity generator uses a voltage regulator called Automatic Voltage Regulator (AVR). This device is used to control the generator voltage over a specific range of plus or minus percentage of rated voltage. Turbine governor operation measure is the droop percentage of each turbine speed governor operation. This measure was excluded because a genset does not have an individual turbine governor. Reactive capacity is defined as the capability of the electricity generator to perform operation at rated voltage and frequency at specific power factors and under reactive conditions. Every genset distributor and power generation companies have their own standardized specifications about power factors and reactive conditions of an electricity generator.

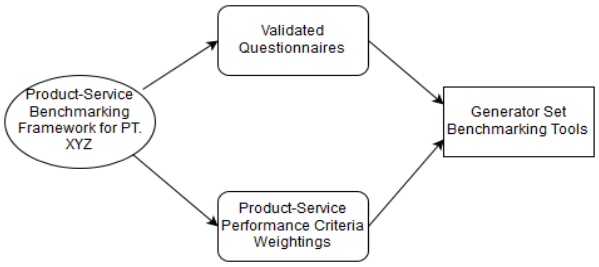

Figure 9. Tool Development

For environmental dimension, the PPIAF framework requires gas emissions to be measured (e.g., hydrogen chloride, chlorine, hydrogen sulfide, carbon monoxide, carbon dioxide). Emission rate considerably affects the environment. Liquid and gaseous fuel handling and consumption are the method parameters of processing liquid and gaseous fuel (e.g., fuel temperature, pH value of fuel, consumed grease and oil). Waste disposal is the system of disposing post-production wastes. Other measures are not specific because they depend on the surrounding environment of the power plant. For PT. XYZ, the most suitable measure is the Material and Packaging used for the genset. Table 1 shows the adjustment from the Original PPIAF Framework to the Product Benchmarking Framework of PT. XYZ.

Safety dimension is used to assess safety performance in a power plant. Lost-time accident rate is a frequency of occurrence that resulted in fatality, permanent disability, or time lost from work. Near misses are almost the same as LFTIR but only include loss of disability or time that has not yet occurred but is nearly happening. Vehicle accident rate is the frequency of occurrence in accidents related to vehicles, which are used around the power plant. Safety measure is excluded because the framework of PT. XYZ is for an individual genset instead of the entire power plant.

Table 1. Adjustment from the Original PPIAF Framework to the Product Benchmarking Framework of PT. XYZ

Criteria	Sub-criteria	No	Measures	References
Product	Power Quality	1	Voltage Stability	PPIAF - Electricity Generation Benchmarking Framework [6]
		2	Turbine Governor Operation (Excluded)	
		3	Reactive Power	
		4	Frequency	
	Environmental	1	Air Emissions	
		2	Gaseous Fuel Handling and Consumption (Revised)	
		3	Waste Disposal	
		4	Others: Material and Packages (Revised)	
	Safety (Excluded)	1	Lost Time Accident rates	
		2	Near Misses	
		3	Vehicle Accident Rates	
	Reliability, Availability, Maintainability (RAM)	1	Energy Loss Rate	
		2	Energy Availability Factor	
		3	Planned Outage Factor	
	Efficiency	1	Deviation from theoretical best achievable heat rate	
		2	Auxiliary Consumption (Excluded)	
	Cost	1	Average Unit Fuel Cost	
		2	Average Unit Non-Fuel Cost	
		3	Productivity Measures (Excluded)	

For Reliability, Availability, and Maintainability (RAM), energy loss rate (ELR, the amount of energy lost during electricity generation) is measured by percentage. EAF is the amount of time when a power plant can produce electricity over a certain period, divided by the amount of time in that period. POF is the amount of time the electricity generator spent in the unavailable state due to planned outages over a certain period (e.g., annual maintenance outages), divided by the amount of time in the period.

For efficiency dimension, deviation from the theoretical best achievable heat rate is the plus or minus percentage of the difference between actual heat rate on the field and the theoretical best achievable heat rate stated in the specifications. Auxiliary consumption is the amount of component used by the additional system to support the power plant (e.g., amount of water used to support auxiliary condenser for the entire power plant). This parameter was excluded because it is used to assess a power plant, not an individual genset.

For cost dimension, fuel cost is the cost of fuel to sustain the operation of the power plant and measured in local currency per megawatt-hour. Non- fuel cost is the cost of components other than fuel, such as equipment, environmental requirements, tax, inflation rates, and monetary exchange rates. This parameter is measured in local currency per megawatt-hour and per kilowatt of installed capacity in the power plant. Productivity is the cost of labor measured in local currency per megawatt and megawatt-hour per employee. This measure was excluded because it is meant for a power plant, not an individual genset.

Service Benchmarking Framework. The service benchmarking framework of PT. XYZ is derived from SERVQUAL and the PSS Board; the former is used to determine indicators of the measurement framework, and the latter is used as reference for determining subcriteria. Table 2 shows the adjustment from the Original SERVQUAL Framework to the Service Benchmarking Framework of PT. XYZ.

Tangibles are defined by four measures. Physical facilities are components used by service providers in delivering service (e.g., receptionist's desk, lobby, etc.). The technologies used by providers in delivering their service are also important. The appearance of the employees of the provider is considered tangible. Employee appearance represents the class of the provider level. Communication materials are used by providers to represent their company (e.g., presentations, manuals).

Reliability is the ability of service providers to perform their stated service. Timeliness is when providers perform their task right and on time according to the schedule from the contract agreement. Consistency indicates that providers perform their indicated task at a

Table 2. Adjustment from the Original SERVQUAL Framework to the Service Benchmarking Framework of PT. XYZ [7]

Dimension	Measures	Reference
TANGIBLES	Physical facilities (Excluded) Equipment: Condition Technology Employees: Appearance Communication materials	SERVQUAL Service Quality Framework
RELIABILITY	Timeliness Consistency Accuracy	
RESPON-SIVENESS	Willingness to help Prompt attention to request Problem resolution Complaint handling Flexibility (Excluded)	
ASSURANCE	Staff competence: knowledge Respect for stakeholders Credibility Probity and Confidentiality (Excluded) Safety and Security	
EMPATHY	Access: Customer Access: Employee Understanding the stakeholders Services appropriate for stakeholder's needs (Excluded) Individualized attention	

specific time according to the agreement. Accuracy is when service providers deliver service exactly right according to the agreement, standards, and manuals every time they perform a task. The result of the tasks is always right at the first time without any problem or errors.

Responsiveness is the ability of service providers to respond to customers in such an immediate and prompt manner. Willingness to help is when service providers are enthusiastic in assisting customers with service. Prompt attention to requests and questions is when service providers respond to customer requests and questions at any time. Problem resolution is the ability to respond to customers' complaints about any problem that persists and how service providers can immediately solve the problem. Complaint handling is when service providers establish a system to respond to the complaints of the customer (e.g., customer service). Flexibility is a way service providers respond to customers in a fully customized manner according to customer's needs, regardless of the time or tasks that should be performed.

Assurance is when service providers are expected to be experts of the services that they are delivering. Staff competence is the competencies possessed by employees in delivering service. Respect for stakeholders is when providers' employees are courteous with their customers during the service delivery. Credibility is the level of confidence instilled by the behavior of service providers. Probity and confidentiality indicate how great service providers are in protecting information of their customers. These measures were excluded because of lack of internal data shared between the customer and the distributor. Safety and security are when service providers do every task while considering safety and security.

The five major activities obtained from the PSS board of PT. XYZ are combined with SERQUAL measures. Each activity may have the same SERVQUAL measures, but their importance differs because the services performed also vary based on the activity.

Empathy is when service providers care about their customers as much as they care about their service. Easiness level of access to staff, service, and information provided by service providers defines how good providers express empathy toward their customers. This was divided into two major stakeholders, namely, customer and employee. Understanding stakeholders is the willingness of service providers in understanding the situation of their customers when delivering services. Services appropriate for stakeholders are measured to assess service quality when the providers perform services right according to customers' needs. This measure was excluded because the service types offered are rigid. Individualized attention is when service providers give special attention to their customers regarding their needs on the service performed.

Product service benchmarking framework. This framework is the final measurement framework used by PT. XYZ for benchmarking gensets to perform decision making in terms of product and service. This framework is a combination of product benchmarking framework and service benchmarking framework constructed for PT. XYZ. Tables 3 and 4 show the combination of activities from the PSS Board with Adjustment from SERVQUAL and the Product Service Benchmarking Framework for PT.XYZ, respectively.

Questionnaire design. The design of questionnaire is derived from the framework with additional statements regarding the explanation of each measure to avoid misunderstanding for the respondents in giving scores. The validation method was focus group discussion conducted among three experts in PT. XYZ and its partner consulting company.

Weighting. Seven experts from PT. XYZ were interviewed to identify the level of importance of each criterion and subcriterion. The presence of too many criteria makes pairwise comparisons in evaluating gensets a difficult and time-consuming process. Thus, the number of criteria and sub-criteria should be reduced [8]. The most important measures are selected by accepting sub-criteria with average scores above seven [9]. The scores were obtained from a total of seven experts. The performance in Power Quality, Customer Need Identification, and Delivery is considered less important for genset benchmarking. These three criteria were eliminated from pairwise comparisons. Table 5 shows the expert judgment for importance of benchmarking measures.

Reciprocal matrix. A reciprocal matrix can be generated from pairwise comparisons. The actual value of the weight is placed in the left side of "diagonal of 1" and the reciprocal value is placed in the right side of the diagonal if the weight for each subcriterion is placed in the area of actual judgment (less preferred). The reciprocal value is placed in the left side of "diagonal of 1" and the actual value is placed in the right side of the diagonal if the weight for each subcriterion is placed in the area of the reciprocal value (preferred). Tables 6 and 7 show the pairwise comparisons of subcriteria with respect to Product and Service Performance for PT. XYZ, respectively.

Priority vector. Priority vector is also referred as normalized principal Eigen vector [10] and is calculated using the normalized weights of subcriteria within the previous reciprocal matrix. The sum of each column should be 1 to normalize the value. The sum of each

row is converted into percentage. The percentage represents the priority of each subcriterion with respect to product performance and service performance. The decimal value is obtained from dividing the sum value for each subcriterion with the number of things. The decimal value is then converted into percentage, also referred as the principal Eigen vector. Table 8 shows the priority vector of product performance subcriteria for PT. XYZ.

Table 3. Combination of Activities from the PSS Board with Adjustment from SERVQUAL

Dimension	Measures	Ref	Service Category	Ref
TANGIBLES	Equipment: Condition	SERVQUAL Service Quality Framework	After sales (Installation, Site Inspection, Maintenance)	Validated PSS Board
	Technology		After sales (Installation, Maintenance)	
	Employees: Appearance		Sales (Customer Needs Identification), After Sales (Installation, Maintenance)	
	Communication materials		Sales (Customer Needs Identification), After Sales (Installation, Site Inspection, Maintenance)	
RELIABILITY	Timeliness		Sales (Delivery), After sales (Installation, Maintenance)	
	Consistency		After sales (Maintenance)	
	Accuracy		After sales (Installation, Maintenance)	
RESPON-SIVENESS	Willingness to help		Sales (Customer Needs Identification, Delivery), After Sales (Installation, Site Inspection, Maintenance)	
	Prompt attention to request		After sales (Maintenance)	
	Problem resolution		After sales (Site Inspection, Maintenance)	
	Complaint handling		After sales (Maintenance)	
ASSURANCE	Staff competence: knowledge		After sales (Installation, Site Inspection, Maintenance)	
	Respect for stakeholders		Sales (Customer Needs Identification, Delivery), After Sales (Installation, Site Inspection, Maintenance)	
ASSURANCE	Credibility		Sales (Customer Needs Identification), After Sales (Installation, Site Inspection, Maintenance)	
	Safety and Security		After sales (Installation, Site Inspection, Maintenance)	
EMPATHY	Access: Customer		Sales (Customer Needs Identification, Delivery), After Sales (Installation, Site Inspection, Maintenance)	
	Access: Employee		Sales (Customer Needs Identification, Delivery), After Sales (Installation, Site Inspection, Maintenance)	
	Understanding the stakeholders		Sales (Customer Needs Identification, Delivery), After Sales (Installation, Site Inspection, Maintenance)	
	Individualized attention		Sales (Customer Needs Identification)	
Product	Power Quality	1	Voltage Stability	PPIAF Electricity Generation Benchmarking Framework
		2	Reactive Power	
		3	Frequency	
	Environmental	4	Air Emissions	
		5	Gaseous Fuel Handling and Consumption	
		6	Waste Disposal	
		7	Others: Material and Packages	
	Reliability, Availability, Maintainability	8	Energy Loss Rate	
		9	Energy Availability Factor	
		10	Planned Outage Factor	
	Efficiency	11	Deviation from theoretical best achievable heat rate	
	Cost	12	Average Unit Fuel Cost	
		13	Average Unit Non-Fuel Cost	
Service	Customer Needs Identification	14	Employees: Appearance	SERVQUAL & Validated PSS Board
		15	Communication materials	
		16	Willingness to help	
		17	Respect for stakeholders	
		18	Credibility	
		19	Access: Customer	
		20	Access: Employee	
		21	Understanding the stakeholders	
		22	Individualized attention	
	Delivery	23	Timeliness	

Table 4. Product Service Benchmarking Framework for PT.XYZ

Criteria	Sub-criteria	No	Measures	References
Service	Delivery	24	Respect for stakeholders	SERVQUAL & Validated PSS Board
		25	Access: Customer	
		26	Access: Employee	
		27	Understanding the stakeholders	
	Installation	28	Equipment: Condition	
		29	Technology	
		30	Employees: Appearance	
		31	Communication materials	
		32	Timeliness	
		33	Accuracy	
		34	Willingness to help	
		35	Staff competence: knowledge	
		36	Respect for stakeholders	
		37	Credibility	
		38	Safety and Security	
		39	Access: Customer	
		40	Access: Employee	
		41	Understanding the stakeholders	
	Site Inspection	42	Equipment: Condition	
		43	Communication materials	
		44	Willingness to help	
		45	Problem resolution	
		46	Staff competence: knowledge	
		47	Respect for stakeholders	
		48	Credibility	
		49	Safety and Security	
		50	Access: Customer	
		51	Access: Employee	
		52	Understanding the stakeholders	
	Maintenance	53	Equipment: Condition	
		54	Technology	
		55	Employees: Appearance	
		56	Communication materials	
		57	Timeliness	
		58	Consistency	
		59	Accuracy	
		60	Willingness to help	
		61	Prompt attention to request	
		62	Problem resolution	
		63	Complaint handling	
		64	Staff competence: knowledge	
		65	Respect for stakeholders	
		66	Credibility	
		67	Safety and Security	
		68	Access: Customer	
		69	Access: Employee	
		70	Understanding the stakeholders	

A good performance on cost subcriteria has the lowest priority, followed by RAM, Efficiency, and Environmental. Hence, genset benchmarking in terms of product is mainly based on its cost, and environmental aspects become the least to consider. Meanwhile, performance on RAM and Efficiency is moderately and equally considered. Table 9 shows the priority vector of service performance subcriteria for PT. XYZ.

Service offered by the genset distributor should have the best performance during genset maintenance, which plays a crucial part in supporting genset operation. Site inspection becomes the least prioritized measure during genset benchmarking, whereas installation is moderately prioritized. Priority vectors are calculated using one formula (Teknomo, 2009) [10]:

w = $\frac{1}{n}$ (sum of each row of reciprocal matrix) (Equation 1. Priority Vector).

Table 5. Expert Judgment for Importance of Benchmarking Measures

No	Criteria	Sub-criteria	R1	R2	R3	R4	R5	R6	R7	Avg
1		Power Quality	6	7	6	8	7	7	7	6.9
2		Environmental	9	8	8	8	7	8	8	8.0
3	Product	RAM	8	8	8	9	8	8	8	8.1
4		Efficiency	9	8	8	7	8	9	8	8.1
5		Cost	8	9	8	8	9	8	8	8.3
6		Customer Needs Identification	7	7	6	7	7	7	7	6.9
7		Delivery	6	7	7	7	7	7	7	6.9
8	Service	Installation	8	8	9	9	8	8	9	8.4
9		Site Inspection	9	8	8	7	8	8	8	8.0
10		Maintenance	9	8	9	9	8	8	9	8.6

Table 6. Pairwise Comparisons of Subcriteria with Respect to Product Performance for PT. XYZ

	E	RAM	Ef	C
Environmental (E)	1	1/3	1/3	1/5
RAM	3	1	1	1 /3
Efficiency (Ef)	3	1	1	1 /3
Cost (C)	5	3	3	1
Sum	**12**	**16/3**	**16/3**	**28/15**

Table 7. Pairwise Comparisons of Subcriteria with Respect to Service Performance for PT. XYZ

	I	SI	M
Installation (I)	1	3	1/3
Site Inspection (SI)	1/3	1	1/5
Maintenance (M)	3	5	1
Sum	**13/3**	**9**	**23/15**

Table 8. Priority Vector of Product Performance Subcriteria for PT. XYZ

Sub-criteria	Decimal	Percentage
Environmental	0.0789	**7.89%**
RAM	0.2009	**20.09%**
Efficiency	0.2009	**20.09%**
Cost	0.5193	**51.93%**
Sum	1.0000	**100.00%**

Table 9. Priority Vector of Service Performance Subcriteria for PT. XYZ

Sub-criteria	Decimal	Percentage
Installation	0.2605	**26.05%**
Site Inspection	0.1062	**10.62%**
Maintenance	0.6333	**63.33%**
Sum	1.0000	**100.00%**

Table 10. Random Consistency Index [10]

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Data validation. The data obtained from the focus group discussion with seven experts of PT. XYZ need to be validated by checking if the judgment given by all respondents is consistent by: 1) Compute principal Eigen value (λmax). Eigen value (λmax) is obtained from the summation of products between each element of the Eigen vector and the sum of columns of the reciprocal matrix; 2) Compute Consistency Index (CI) $\boldsymbol{CI = \frac{\lambda\,max - n}{n-1}}$ (Equation 2. Consistency Index), where n = number of subcriteria; 3) Find Random Consistency Index (RI).

The value of RI is fixed depending on the number of sub criteria.

1. Compute Consistency Ratio (CR)

$\boldsymbol{CR = \frac{CI}{RI}}$...(**Equation 3.** Consistency Ratio)

Data are declared valid if the value of Consistency Ratio (CR) is less than 10%. Using the equations above, the value of Consistency Ratio (CR) for both product and service subcriteria is less than 10 %. (CR for Product = 2.18%, CR for Service = 4.77%). The judgment given by the respondents regarding subcriteria for product performance are then considered consistent.

Criteria weighting. After the data were ensured as valid, the weight of each criterion could be considered valid. Cost has the highest importance, whereas power quality has the lowest in terms of product. Maintenance has the highest importance, and delivery has the lowest in terms of service. Table 11 shows the weights of criteria.

Table 11. Weights of Criteria

No	Criteria	Sub-criteria	Weight	Normalized Weight
1		Power Quality	7.00	0.1769
2		Environmental	8.00	0.2022
3	Product	RAM	8.14	0.2058
4		Efficiency	8.14	0.2058
5		Cost	8.29	0.2094
6		Customer Needs Identification	7.29	0.1861
7		Delivery	6.86	0.1752
8	Service	Installation	8.43	0.2153
9		Site Inspection	8.00	0.2044
10		Maintenance	8.57	0.2190

3. Results and Discussion

A case study was conducted to implement the tools constructed using a list of gensets distributed by different distributors.

List of Alternatives Alternative 1.
Genset Type : Jenbacher J316
Theoretical Efficiency : 89.1% (50.1% thermal, 38.9% electrical)
Fuel : Landfill Gas
Electrical Output : ~800 ekW
Distributor : PT. XY

Alternative 2
Genset Type : Caterpillar CG132-16
Theoretical Efficiency : 80.9% (48.1% thermal, 42.8% electrical)
Fuel : Biogas
Electrical Output : ~800 ekW
Distributor : PT. PQ

Alternative 3
Genset Type : Caterpillar C27
Theoretical Efficiency : 89.1% (50.1% thermal, 38.9% electrical)
Fuel : Landfill Gas
Electrical Output : ~800 ekW
Distributor : PT. PQ

Respondent Profile.
The two respondents in this case study are.
1. Company Name : PT. A
Location : Bintaro, Jakarta, Indonesia
Current Project : Waste management in TPST Bantar Gebang, Bekasi, Indonesia
Status : A potential customer of PT. XY and PQ

2. Company Name : PT. B
Location : Surabaya, Indonesia
Current Project : Waste management in TPA Benowo, Surabaya, Indonesia
Status : Once a customer of PT. XY, currently a potential customer of PT. XY and PT. PQ

Results and Analysis. The results of the case study are shown in the form of ranked weighted scores. Jenbacher Natural Gas genset exhibits the best performance in power quality and efficiency over the two other gensets and is as good as Caterpillar Natural Gas genset in environmental and as bad as Caterpillar Natural Gas genset in cost. The environmental and cost performances are mostly the same because natural gas is used for the two gensets. Hence, gensets that run on natural gas are good for the environment but expensive to operate. The diesel genset leads to the worst impact to the environment but is the cheapest to operate. In terms of product performance, Jenbacher Natural Gas genset exhibits the best performance, followed by the Caterpillar Diesel genset and the Caterpillar Natural Gas genset in the last.

The Jenbacher Natural Gas genset exhibits the worst service performance in customer need identification, installation, site inspection, and maintenance. Meanwhile, the Caterpillar Diesel and Caterpillar Natural Gas gensets have equal value of service performance in all subcriteria due to the same manufacturer and distributor.

In terms of product and service performances combined, the Caterpillar Diesel genset has the highest performance, followed by the Caterpillar Natural Gas genset, and the Jenbacher Natural Gas genset in the last. Table 12 shows the ranks of weighted scores for the case study in PT. XYZ.

Table 12. Ranks of Weighted Scores for Case Study in PT. XYZ

Category	Rank	Alternatives	Weighted Score	Dimension	Rank	Alternatives	Score
Product	1	JB NG	6.34	Power Quality	1	JB NG	7.65
	2	CAT D	6.11		2	CAT D	7.20
	3	CAT NG	5.82		3	CAT NG	6.30
				Environmental	1	JB NG & CAT NG	7.20
					2	CAT D	1.80
				Reliability, Availability, Maintainability (RAM)	1	CAT D	7.65
					2	JB NG	5.40
					3	CAT NG	4.50
				Efficiency	1	JB NG	8.10
					2	CAT NG	7.65
					3	CAT D	6.75
				Cost	1	CAT D	7.20
					2	JB NG & CAT NG	3.60
Service	1	CAT D & CAT NG	7.20	Customer Needs Identification	1	CAT D & CAT NG	7.20
	2	JB NG	4.99		2	JB NG	3.60
				Delivery	1	CAT D, CAT NG & JB NG	7.20
				Installation	1	CAT D & CAT NG	7.20
					2	JB NG	5.40
				Site Inspection	1	CAT D & CAT NG	7.20
					2	JB NG	5.40
				Maintenance	1	CAT D & CAT NG	7.20
					2	JB NG	3.60
Product-Service	1	CAT D	6.64				
	2	CAT NG	6.49				
	3	JB NG	5.68				

4. Conclusion

After a research was conducted in PT. XYZ, a tool for benchmarking gensets was constructed using PSS approach to represent the characteristics of this industry. The PPIAF Electricity Generation Benchmarking Framework was used as base to assess product performance. The PSS activities of PT. XYZ visualized in the PSS board and the SERVQUAL service quality framework were used as bases to assess service performance. The PSS board of PT. XYZ shows the following five major activities performed to offer services: Customer Need Identification, Delivery, Installation, Site Inspection, and Maintenance. The SERVQUAL framework was used to define measures for each activity obtained from the PSS board.

A case study was conducted to benchmark three gensets, namely, Jenbacher Natural Gas, Caterpillar Diesel, and Caterpillar Natural Gas, by implementing the tools created. The Caterpillar Diesel genset is the best in terms of the combined product and service performance. In terms of product performance only, the Jenbacher Natural Gas genset has the greatest performance. In terms of service performance only, the Caterpillar Diesel and Caterpillar Natural Gas gensets exhibit the greatest performance in delivering service due to the distributor. Thus, in Indonesia, despite the higher weight in product performance, service quality plays a more important part in procuring gensets.

Recommendations. This paper presents several recommendations for future improvements in PT. XYZ. PT. XYZ has weak points in four major activities of delivering service to customers: Customer Need Identification, Installation, Site Ins-pection, and Maintenance. PT. XYZ also has weak points in all the service measures during the above activities.

Establishing solutions will lead to an improvement in the product service system in PT. XYZ by focusing only to important performance criteria. Minimal attention should be given to the remaining criteria. Appendix 1 shows the recommendations for service improvement in PT. XYZ.

Appendix 1. Recommendations for Service Improvement in PT. XYZ

Dimension	Measures	Recommendation
TANGIBLES	Equipment: Condition	Minimize oxidation by coating the tools for installing, commissioning, and maintaining genset with oil every after-use
	Technology	Reduce the procedures of manual installation and replace it with a modern one (e.g., automation)
	Employees: Appearance	Address the rules of conduct on which attires to be used on work sites during the activities of identifying customer needs, installing, and maintaining genset
	Communication Materials	Provide more visual materials for customers in the form of presentations, brochures, and manuals
RELIABILITY	Timeliness	Oblige the logistics company who performs delivery and the employees who perform installation and maintenance to go according to the agreed schedule. Apply penalties if anything goes beyond the plan
	Consistency	Evaluate the SOP of maintaining genset by assigning the frontman to conduct more than one rechecking schedule
	Accuracy	Allow the knowledge and experienced employees to have more time in performing installation and maintenance while strictly being monitored
ASSURANCE	Willingness to help	Increase employees' motivation by applying commissioning system. The higher the review of one employee given by customers in assisting them during all activities, the higher the commission
	Prompt attention to request	Assign a 24/7 system of request handling (e.g., email, voicemail) which is also aligned directly to the supervisors
	Problem resolution	Construct a QRT (Quick Response-Team) to specifically solve the problem filed by customers
	Complaint handling	Evaluate current customer service and improve by replacing low performance employees with more expert ones. Apply penalty if there is any report that the complaints have been not handled
	Staff competence	Conduct annual training for employees and monthly test
	Respect for stakeholder	Assign rules of conduct and behavior CHAMPS (Cleanliess-Hospitality-Accuracy-Maintenance-Product-Service) for employees and apply penalties if there is any rules violated
	Credibility	Consistently increase the quality of service
	Safety and Security	Have all activities performed according to SOP by employees to be directly supervised and reported to the headquarter
EMPATHY	Access: Customer	Construct a web-based tracking and monitoring applications for customers to access their data regarding services
	Access: Employee	Creating cloud computing system for employees in the company to make easiness of access toward details of project
	Under-standing the stakeholder	Conduct monthly counseling to give information to employees about how to understand the customers during service delivery
	Individualized attention	Assemble a task team which is specifically aimed for conducting discussion with the customers regarding the details of the services they need and make conclusion of which product-service is the most suitable for them

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