Cause of Electricity Supply Disruption Casuistic Assessment

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Abstract. The port has a big role as a means of transportation in supporting the mobility of goods and people. The port is a meeting point between land and sea so that makes the port very important in the economic growth of a region. So that the operation of ports for loading and unloading must not stop or be interrupted. In many cases, one of the most frequent disruptions experienced by ports is disruptions due to electricity supply. The purpose of this study is to find the main cause of power supply disruptions in one of the container terminals as research objects. There are two factors that influence electrical supply disruption, namely external factors and internal factors. Within these factors there are several categories such as weather based, flow of transmission line, lack of maintenance, electrical current stability and lack of human resources or standard operating procedures. By analyzing the flow of electricity supply distribution in the power plants to the terminal, author can find out the main agents that cause disruption of electricity supply and the impact to the terminal. This research is expected to be used as a reference to open up insights to see all the agent that have the potential to cause disruption to the electricity supply in the terminal, so that later they can take further action.

1. Introduction
The port has an important role in the supply chain activities by facilitating the transfer of goods and the transfer of passengers which continues to grow every year. Ports can encourage and advance the economy of a region. The port's has very important role, so it is necessary to maintain the continuity of the port from disruption. One possible disruption is the disruption because of electricity supply or power outage. With the increasing logistical needs of goods and passengers, the greater use of electricity at the port \cite{1} and electricity supply increasingly playing a important role in terminal operational activities.
There are many causes of electricity disruption, it can be caused by a lack of terminal preparation in receiving electricity (internal factor) \cite{4} and due to non-arrival of electricity sources from the power plant (external factor) \cite{4} which results in the shutdown of business activities at the terminal. The effect of disruption of electricity supply can be shown up in many aspects. These aspects can result in a decrease in income, loss of reputation, the presence of energy waste and a decrease in equipment life \cite{2}.
In this study develops a modification from risk assessment process for potential agent that can result in disruption of electricity supply in one of the container terminals using the House of Risk modification method. The next step main agent from HOR modification will be modeling the impact on income, through Business Impact Analysis (BIA) method. In this study, it will involve parties related to electricity operations. After knowing the main agent and its impact, it can find out what actions are appropriate to reduce the duration disruption and impact of electricity supply disruption \cite{3}.
2. Method

2.1. Literature Review

Literature review is carried out to provide an overview of the potential risks that can cause disruption in electricity supply. Literature that author search is the electricity transmission system and the device used to distribute electricity from the power plants to the terminal [5] [10] and the potential risks in the flow that can cause disruption of the electricity supply. The author seeks this data through books and journals on the same topic and conducts interviews with experts in the field of electrical operations at the terminal. From figure 1 can be seen the flow of electricity supply distribution.

![Electricity Transmission flow from power plant to terminal](image)

Figure 1. Electricity Transmission flow from power plant to terminal

There are two factors that cause disruption of electricity supply, namely external factors and internal factors [4]. There are 2 categories included in the external factors that have the potential to cause disruption, because of the weather based [8] and the risk from the transmission system flow [6]. Internal factors are divided into 3 categories which can also cause disruption, including lack of maintenance [7], electrical current stability [4] and lack of human resources / standard operating procedures.

| Code | Disruption Category                        | Source |
|------|--------------------------------------------|--------|
| K1   | Weather based                              | [8]    |
| K2   | Flow of transmission system                | [6]    |
| K3   | Lack of maintenance                        | [7]    |
| K4   | Electrical current stability               | [4]    |
|      | Lack of human resources / standard operating procedures | From direct interview with respondent |

Needed to look for potential disruption agents with the right category to find the agent of disruption. The following table is a potential disruption agent.

| Code | Potential Disruption Agent                        | Source |
|------|--------------------------------------------------|--------|
| P1   | Strong winds                                     | [8]    |
| P2   | Storm                                            | [8]    |
| P3   | Lightning                                       | [8]    |
| P4   | Damage to substations                           | [6]    |
| P5   | Transmission control system failure             | [6]    |
| P6   | Animal crash the transformer                     | [6]    |
| P7   | Distribution transmission cable broken          | [6]    |
| P8   | Defect due to aging material                     | [7]    |
| P9   | Fire in the building                            | [7]    |
| P10  | Overloads and excessive transfers between areas  | [4]    |
| Code | Potential Disruption Agent | Source |
|------|-----------------------------|--------|
| P11  | Transmission low voltage conditions | [4] |
| P12  | Power system low frequency conditions | [4] |
| P13  | Out-of-step conditions (transient instability) | [4] |
| P14  | Miscommunication | [7] |
| P15  | Standard Operational Procedure are inefficient | From direct interview |
| P16  | Unreliable human resources | From direct interview |

2.2. House of Risk

The HOR by Pujawan and Geraldin is used to identify the risks that can occur and their consequences by knowing the ARP from the probability to the risk agents and the severity of the risk events also correlation between risk event (result from risk agent) and risk agent (entity that causing another risk event) [9]. HOR method is used to find the main risk agent, so that it can take preventive measures to prevent and reduce the impact of the agent. First step is by identifying the key activities and business function of the organization. Next, group of potential risk into risk agents and risk event that occur in the key activities of the company. The fourth stage, assess the frequency of each risk agent. The fifth stage is identifying correlation between risk agents and risk agents to find their correlation. And the final step to determining the value of Aggregate Risk Potential (ARP), the following is the formula to calculate ARP:

$$ ARP_j = O_j \sum_i S_i R_{ij} \quad (1) $$

Oj is the probability of occurrence of risk agent j, Si is the severity of risk event if i occurs and Rij is the correlation value between risk agent (j) and risk event (i). The calculation will produce a value to prioritize risk agents for further action and then ranking using the ARP value. The following table model HOR:

| Business Process | Risk Event (Xi) | Risk Agents (Aj) | Severity of risk event (Si) |
|------------------|----------------|------------------|-----------------------------|
| Plan             | $E_1$ $R_{11}$ $R_{12}$ $R_{13}$ | $A_1$ $A_2$ $A_3$ $A_4$ $A_5$ $A_6$ $A_7$ | $S_1$ $S_2$ $S_3$ |
| Source           | $E_2$ $R_{21}$ $R_{22}$ | $S_4$ $S_5$ $S_6$ $S_7$ $S_8$ $S_9$ |
| Make             | $E_5$ $E_6$ | $S_7$ $S_8$ $S_9$ |
| Deliver          | $E_7$ $E_8$ $E_9$ | $S_7$ $S_8$ $S_9$ |
| Return           | $O_1$ $O_2$ $O_3$ | $O_1$ $O_2$ $O_3$ $O_4$ $O_5$ $O_6$ $O_7$ |

Severity is the impact value of the consequences of the risk event. This value uses a scale from 1 to 9, where 1 has no impact and 9 has a large impact. After weighing the severity value later weighing the occurrence value. Occurrence defined as the possibility level of cause of the failure. Weighting the value of occurrence on risk agent using a scale from 1-9. Next, assess the correlation weight between risk events and risk agents using the correlation scale values. The next step is to calculate the
aggregate risk potential based on the risk agent, for the prevention step of the risk agent will be assessed using the Pareto diagram. Pareto diagram using 80:20 principle, a risk agent will be selected if the value is above 80% which can result in 80% of the damage.

2.3. Modification House of Risk Model
House of Risk modification is a casuistic valuation method that is used to look for risk agents that have the potential to cause direct disruption of electricity supply (in this paper mentioned disruption agent). The difference between the original HOR is the risk event in this modification there only 1 event, namely disruption of electricity supply. This modification method is carried out by measuring the level of correlation between the categories of disruption agents and electricity supply disruption (C). Next, determine the duration of disruption that caused by each categories (W) (this is a modification of severity in HOR by Pujawan), occurrence (O) from each disruption agents to get the value of the Aggregate Disruption Cause (ADC). This ADC calculation is used to determine the main cause of electricity supply disruption. The following is the formula from the ADC made by the author with combination from [9] and [8] for the severity modification.

\[
ADC = \sum C_i W_j O_j
\]  

Duration is the impact value of the consequences of the categories (D). This value uses a scale from 1 to 9, where 1 has short duration and 9 has a time-consuming duration. After weighing the duration value later weighing the occurrence value (O). Occurrence defined as the possibility level of cause of the failure. Weighting the value of occurrence on risk agent using a scale from 1-9. Next, assess the correlation weight between category and disruption event using the correlation scale values

Pareto diagram is made as the final stage of HOR 1 based on the ADC value of each cause of disruption. Pareto diagram is used to determine the priority of the main agents of disruption to be resolved. Using the principle of 80:20 it will be easier to determine which disruption agent is first followed up on. The cause of disruption above 80% will be chosen because it has a high correlation, the most occurrence, and the longest duration of disruption.

2.4. Business Impact Anlaysis
Business impact analysis (BIA) is an important part of BCM that functions to analyse business activities and the impact of incidents that may occur of these activities. BIA and Disruption Assessment are the main products that can be able to the basis of developing strategies to reduce the impact of these incidents [11]. BIA is used to analyze the organization to assess operational and financial losses. In operational losses related to non-monetary effects such as people, processes and technology affected by disruption incidents. For financial influence on revenue, costs and business sustainability [11].

In this paper discusses the impact on income of the main agents of disruption event from HOR method. This paper using [13] to determine the scenario assumptions in modelling and using [11] to illustrate the model against loss of income. Pre-planning address in particular the action that should be taken during disruption [14] after know about the impact and consequence. This can be used to find out important activities in the terminal to be recovered first [15].

3. Result and Discussion
In this chapter will explain the results of the analysis. The data used comes from books and journals, as well as direct interviews with experts through questionnaires. From each of the factors that have been identified, obtained 5 categories that can lead to disruption of electricity supply. From each of these categories then identified the agent that can lead to disruption event and obtained 16 disruption agents. The purpose of this stage will be to calculate the aggregate disruption cause (ADC) of each disruption agent that has been determined. This calculation is used to calculate the largest value which will be concluded as the main causative agent of disruption.
3.1. Duration of Disruption Result

In each category can affect the length of duration event because of 2 factors, namely external factors and internal factors. Further analysis is needed in to look for several categories that can cause electricity supply disruptions. A list of categories that have been identified based on literature can be seen in the table below.

Table 4. List of Category

| Code | Disruption Category                      |
|------|-----------------------------------------|
| K1   | Weather based                           |
| K2   | Flow of transmission system             |
| K3   | Lack of maintenance                     |
| K4   | Electrical current stability            |
| K5   | Lack of human resources / standard operating procedures |

Category will affect the duration of disruption occurring. This is caused by external and internal factors that have an influence on the duration of disruption. For example, the duration of disruption caused by weather (E1) will be different from that due to lack of maintenance (E3). That is because there are different factors that influence it (weather is an external factor and the electric current stability is an internal factor). The assessment is conducted via online questionnaire. The assessment is filled with electricity operations, this research took 10 as the respondents. The assessment is filled using the standard value taken from book and journal. Below is the duration standard table.

Table 5. Table of Duration Assessment Standard

| Value | Duration               |
|-------|------------------------|
| 1     | Less than 1 hour       |
| 3     | 1 hour> to 6 hours     |
| 5     | 6 hours> to 12 hours   |
| 7     | 12 hours> to 36 hours  |
| 9     | More than 36 hours     |

3.2. Occurrence of Disruption Result

Identification of disruption agents is carried out to understand the potential agent which will ultimately lead to the possibility of electricity supply disruption. All of the potential disruption agent that list in table 1 is disruption agent and how to determine it by literature analysis. Disruption agents will then be assessed based on the value of the event (occurrence). The higher the probability that may occur, the higher the risk agent produces the value of the event. Disruption agents are various points of determination that lead to disruption events. Below are the disruption agents identified from the literature study.

Table 6. List of Disruption Agent

| Code | Disruption Agent                      |
|------|---------------------------------------|
| P1   | Strong winds                          |
| P2   | Storm                                 |
| P3   | Lightning                             |
| P4   | Damage to substations                 |
| P5   | Transmission control system failure   |
| P6   | Animal crash the transformer          |
| P7   | Distribution transmission cable broken|
The value of the occurrence comes from assessments made through online questionnaires to experts. The assessment of the questionnaire has followed the standards made specifically for this case. Following is the standard from the occurrence assessment table.

| P8   | Defect due to aging material |
|------|------------------------------|
| P9   | Fire in the building         |
| P10  | Overloads and excessive transfers between areas within a control area |
| P11  | Transmission low voltage conditions |
| P12  | Power system low frequency conditions |
| P13  | Out-of-step conditions (transient instability) |
| P14  | Miscomunication |
| P15  | Standard Operational Procedure are inefficient |
| P16  | Unreliable human resources |

Table 7. Occurrence Assessment Standard

| Value | Occurrence               |
|-------|--------------------------|
| 1     | Less than 2 times a year |
| 3     | 2 to 4 times a year      |
| 5     | 5 to 11 times a year     |
| 7     | 12 to 18 times a year    |
| 9     | More than 18 times a year|

Correlation is made from the identification table relations between categories with disruption of electricity supply. This assessment was used to determine the correlation value between categories and disruption events. The following are the standard correlation assessments

| Table 8. Correlation Assessment Standard |
|------------------------------------------|
| Value | Correlation | Description                             |
|-------|-------------|-----------------------------------------|
| 2     | No Correlation | Category has no correlation with Disruption event |
| 4     | Weak Correlation | Category has little correlation with Disruption event |
| 6     | Medium Correlation | Category has medium correlation with Disruption event |
| 8     | Strong Correlation | Category is strongly correlated to Disruption event |

Correlation table 1 is used to find out how high or low the correlation between each categories is compared to electricity supply disruption. At this stage it uses a scale of 2,4,6,8 to determine the correlation value. Scale number 2 which means low correlation and up to number 8 which is high correlation.

3.4. ADC Calculation

Aggregate disruption cause calculation is needed to determine the main agent of disruption. This ADC is used to find out the main disruption agent which is highly correlated with electricity supply.
disruption. In addition, the main agent of this disruption is likely to have a high occurrence and result in a long-term duration of disruption event. Following is an example of ADC calculation:

\[
ADC_7 = \sum C_j W_j O_j
\]

\[
ADC_7 = 8 \times 3 \times 7
\]

\[
ADC_7 = 168
\]

Table 9. Aggregate Disruption Cause Calculation Result

| Code | Disruption Agent                                                                 | ADC  |
|------|----------------------------------------------------------------------------------|------|
| P1   | Strong winds                                                                      | 4    |
| P2   | Storm                                                                            | 4    |
| P3   | Lightning                                                                        | 12   |
| P4   | Damage to substations                                                            | 120  |
| P5   | Transmission control system failure                                              | 120  |
| P6   | Animal crash the transformer                                                     | 56   |
| P7   | Distribution transmission cable broken                                           | 168  |
| P8   | Defect due to aging material                                                     | 120  |
| P9   | Fire in the building                                                             | 8    |
| P10  | Overloads and excessive transfers between areas within a control area.           | 24   |
| P11  | Transmission low voltage conditions                                              | 72   |
| P12  | Power system low frequency conditions                                            | 24   |
| P13  | Out-of-step conditions (transient instability)                                    | 24   |
| P14  | Miscommunication                                                                  | 24   |
| P15  | Standard Operational Procedure are inefficient                                   | 72   |
| P16  | Unreliable human resources                                                       | 24   |

ADC value can be high because of the high correlation, occurrence and duration factors. After getting the ADC for each disruption agent, the next step is to make a Pareto diagram.

3.5. Pareto Diagram

From the diagram shown disruption agents that are above 80% there is only 1 agent, there are 2 agents that are exactly 80% and the remaining agents are under 80%. Below is ADC result table.

![ADC Value - Pareto Diagram](image)
### Table 10. ADC Ranking Result

| Code | Disruption Agent                                      | ADC  | ADC%  | Rank |
|------|-------------------------------------------------------|------|-------|------|
| P7   | Distribution transmission cable broken                | 168  | 80.82%| 1    |
| P4   | Damage to substations                                 | 120  | 86.30%| 2    |
| P5   | Transmission control system failure                   | 120  | 86.30%| 3    |
| P8   | Defect due to aging material                          | 120  | 86.30%| 4    |
| P11  | Transmission low voltage conditions                   | 72   | 91.78%| 5    |
| P15  | Standard Operational Procedure are inefficient        | 72   | 91.78%| 6    |
| P6   | Animal crash the transformer                          | 56   | 93.61%| 7    |
| P10  | Overloads and excessive transfers between areas within a control area | 24   | 97.26%| 8    |
| P12  | Power system low frequency conditions                 | 24   | 97.26%| 9    |
| P13  | Out-of-step conditions (transient instability)        | 24   | 97.26%| 10   |
| P14  | Miscommunication                                      | 24   | 97.26%| 11   |
| P16  | Unreliable human resources                            | 24   | 97.26%| 12   |
| P3   | Lightning                                             | 12   | 98.63%| 13   |
| P9   | Fire in the building                                  | 8    | 99.09%| 14   |
| P2   | Strong winds                                           | 4    | 99.54%| 15   |
| P1   | Storm                                                 | 4    | 99.54%| 16   |

Pareto diagram theory explains that of all the causative agents that occur only 20% are the main causes, the rest cause insignificant problems. With the existence of 20% can cause an impact of up to 80%. The diagram sorts the data classification from left to right to display the order from the lowest height. The conclusion drawn from the Pareto diagram is data that is above 80% and has the highest ADC value. Use this diagram to focus actions on the main problem (left of the data). So that in the final results of this study it was found that the main agent causing disruption to the electricity supply was due to the transmission cable transmission that was broken (P7).

### 3.6. Business Impact Analysis

Every time there is electricity disruption, electrical equipment cannot operate so that it will decrease the productivity, it can also inhibit incoming revenue. In this research, author calculate the income lost due to electricity disruption. Before do the calculation, author need to analyze and identification of all business activities at the terminal is needed, where activities require electricity or not. Then do the calculation of all business activities in the terminal. The author uses scenario that cable transmission broken is the main agent disruption to see the impact on lost income. After getting all the calculation of activity in the terminal can then be reflected through scenarios caused by the disruption event.

![Loss of Revenue](image_url)

**Figure 3. Impact from P7**
The following is a graph of scenario for lost income. The impact caused by a broken transmission cable (P7) resulted in a percentage decrease of 89.5% and duration of disruption for 13 hours.

4. **Future Research/Challenges**

Due to limited work time there are a number of things that can be improved in this paper. Furthermore, it can be expanded again regarding the agents causing disruption and retrieval of data in accordance with the latest conditions on the research object. The impact from the disruption of electricity can also be extended into several aspects, such as losing reputation and losing customers. Each research object has a different flow, so in-depth observations of the distribution flow are needed before determining the disruption agent. The results of this study can later be followed up by implementing mitigation to reduce the duration, occurrence and the impact from disruption. Another thing that can be done is by applying adaptations that can be done by the terminal if the duration of the disruption takes a long time. This adaptation allows the terminal to still be able to conduct some of business activities while electricity supply disruption occurs.

5. **Conclusion**

There are many factors that cause disruption of electricity supply in the terminal. Factors from outside the terminal and inside the terminal that allow to cause disruption. Therefore a disruption assessment is needed that reviews the flow of distribution from the generator to the terminal to determine the agent causing disruption. The use of House of Risk modification can be used to determine the main agent of disruption by conducting an assessment of the occurrence, duration and the correlation of the category of agent with disruption event. Based on the analysis of the calculation of aggregate disruption cause, the agent which is the main cause of disruption is "Distribution transmission cable broken (P7)". The impact of disruption is also dangerous for terminal operations, with the presence of Business Impact Analysis it can be seen the impact of disruption is more than 80% on revenue in one hour. After knowing the highest agent then the stakeholders can focus further action to overcome the disruption of electricity supply and minimize the impact on income.

6. **References**

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