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Rusty Bolts and Broken Valves: A Study on The Plant Technology, Size, And Organizational Structure of Plant Turnaround Maintenance in Malaysian Process-Based Industries

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Plant turnaround maintenance, a crucial asset management in technology intensive industries is carried out to revitalize, maintain, and improve the plant facilities for optimal and efficient performance. This paper discusses the relationship of plant technology, size, and organizational structure in plant turnaround maintenance of 58 companies in six process-based industries in Malaysia. Seven hypotheses were tested using nonparametric statistical analysis. The test results support the hypotheses and provide evidence that plant technology influences the organization of turnaround maintenance. Results of the analysis also showed differences in the size of the turnaround maintenance that point towards variation in the six types of plant technology employed by the companies covered in the study.

Field of Research: Plant Turnaround Maintenance, Technology, Size, Organizational Structure

1. Introduction

The organizational aspects of plant turnaround maintenance are a little understood subject in management circles. The dearth in knowledge regarding turnaround maintenance stood in stark contrast to the mushrooming of plants in the manufacturing sectors of the fast-expanding Malaysian economy notably in the past three decades. Indeed, numerous studies in practically all aspects of management and business both by local and foreign scholars have failed to attract turnaround maintenance as a topic worthy of research enquiry. In comparison to the accrued knowledge on turnaround maintenance from the engineering perspective, rather limited knowledge is available with respect to the management and organization of one of the most important and critical activity in plant management. Currently, whatever studies available on turnaround maintenance are descriptive and highly narrative in nature.

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Written by former engineering consultants and those familiar with the technicalities of the turnaround processes, these studies seldom go beyond individual experience pertaining to turnaround management. Empirical research on the organizational structures of turnaround maintenance is, at best, highly limited. The present study is a modest attempt in filling the intellectual void relating to the relationship between plant technology, size, and organizational structure of plant turnaround maintenance in Malaysian process-based industries. The objective of the study is to provide empirical verification that plant technology pervades the organization of turnaround maintenance. Significant differences in the size of the turnaround events and configuration of the turnaround organizational structures point towards variation in the plant technology employed by the companies.

2. Plant Turnaround Maintenance

Plant turnaround maintenance, or simply 'turnaround' in engineering circles, is a multi-facetted process comprising three broad elements of engineering, business, and organization (Lenahan, 1999; Levitt, 2004). The event is normally carried out during a planned plant shutdown and covers activities such as inspection, overhaul, modification, and the installation of new parts or equipments. Activities which could not be performed when the plant is in operation are also carried out during the shutdown period. These include preventive and corrective maintenance, and plant cleaning. The turnaround event is duration driven and the frequency is largely determined by variables such as plant technology, the required level of plant reliability, and the legal requirements associated with the operation. In Malaysia, the event must conform to the statutory requirements of the Department of Safety and Health and the Department of Environment.

The scope of work involved in turnaround exhibits considerable variations among plants. It is dependent upon, among others, the age and type of plant technology. Perhaps, the most distinctive aspect of turnaround is that the scope of work remains uncertain until the actual activities begin. Despite the series of inspections, tests, and assessments that were carried out prior to the turnaround event, the operational status of equipments simply could not be determined until they are actually opened and inspected. Consequently, the situation harbors risk of uncertainties with respect to escalation of the work scope leading to the lengthening of the turnaround period.

The duration of turnaround event is short and utilizes large manpower resources that include plant and maintenance personnel, technicians, craftsmen, skilled and specialist contractors. The enormous magnitude of inter-related activities of the turnaround event requires stringent control and coordination. Depending on the size and complexity of the turnaround tasks, substantial effort and time are allocated for planning and work scheduling. The monetary loss due to production stoppage is often huge if the planned duration of the shutdown is exceeded. It is obvious that turnaround activities entail efficient organization, coordination, and control to ensure its successful implementation. Successful implementation of turnaround ensures availability and reliability of equipment and assets (Lenahan, 1999), and thus profitability of the company (Murthy *et al.*, 2002).

The organizational structures commonly established for turnaround include the project, matrix, and functional types structures (Levitt, 2004). Under the project driven organizational structure, the personnel in the organization become members of the turnaround team and report to the Turnaround Manager. They leave their normal jobs when they are needed to perform turnaround activities. In contrast, the main features of the matrix type include personnel having dual reporting relationships. They report to both the turnaround manager and their functional manager. Lastly, the functional driven organizational structure is characterized by personnel who report strictly to their functional manager and handle the turnaround project responsibilities as part of their normal work. Scholars are divided over the best type of organizational structure governing turnaround activities. Levitt (2004) and Lenahan (1999) concurred that the project-driven type of organizational structure is best suited for turnaround. Others took a different view. Kelly (1997), for instance, highlighted the matrix type of organizational structure adopted by some electric power generating plants as the preferred organizational structure for turnaround. At this juncture, no single organizational structure is deemed appropriate to fit all instances of turnaround.

The need for turnaround is driven by the kind of technology used in the plants. Hence, technology as an independent variable is central to the present study. Technology is one of the decisive factors of organizational structure considered by the technological imperative school of thought. Harvey (1968), for instance, proposed that technology is one of the factors to be considered when formulating explanatory or predictive propositions about variations in organizational structures. In the same vein, Carlisle (1973) put forward that technology is one of the essential factors that affect organizational size, structure and management systems. Apart from organizational structure and technology, size also influences organizations in more ways than one. Size is an essential characteristic of all organization (Ford *et al.*, 1988). Indeed, size has been considered as one of the major contingency factors in many organizational studies. Size as the determinant of organizational structure was suggested by a number of theorists (Pugh *et al.*, 1968; Child, 1973; and Marsh and Mannari, 1981).

3. Operational Definitions

This section discusses the operational definitions of the variables considered in this study namely plant technology, size of the turnaround event, and organizational structure of the turnaround.

3.1 Plant Technology

Plant technology refers to an organization’s physical capabilities, attributes, and knowledge. Technology consists of the techniques to change the organization’s inputs into outputs. It has been used by researchers to signify conversion process, mechanization, operation technology, tasks diversity to routineness, and task variety and variability (Woodward, 1965; Khandwalla, 1974; Amber and Amber in Marsh and Mannari, 1981; Weiner and Mahoney, 1981; and Kast and Rosenzweig, 1985). Abdel-Aal *et al*. (1992) explained that the process designs were influenced by the end products. The degree of process complexity varies from simple to complex or to fully integrated-process and it depends on the number of products produced by the plant. Watermeyer (2002) and Abdel-Aal *et al*. (1992) proposed two differentiating features among process plants:

- Nature of materials to be processed: fluids or solids, hazardous or non-hazardous, minerals, bio-matter or water.
- Types of final products: fuels, chemicals, metals, and foods.

Based on the above explanation, the technology used by the large process-based industries covered in this study can be differentiated based on the nature of the final products being produced. The degree of process complexity or technology varies according to the final products produced. In this study, the plant technology is represented by six different types of process-based industries namely manufacturers of petroleum-based products; fertilizer and nitrogen compound; electric power generating plants; cement; basic chemicals; and vegetable oils, palm oil, and fats.

3.2 Size Of Turnaround

Organizational size has been measured in many ways. These include the number of employees, number of products or services, volume of total sales, revenue, assets, profits, and the number of divisions (Burton and Obel, 2004). Other proposed measurements of organizational size include the use of physical, fiscal, input, and output dimensions (Kimberly in Burton and Obel, 2004). As such, size of the plant turnaround maintenance is determined by the total number of workers employed to execute the maintenance work, the total cost of the turnaround event and the planning duration for the turnaround event. These measures are adopted in this study.

3.3 Organizational Structure Of Turnaround

Organizational structure is a map of how organizational activities and processes are arranged. It portrays the pattern of relationships among the components or parts of the organization for the accomplishment of common goals (Flippo, 1984; Kast and Rosenzweig, 1985). Organizational structure is a consequence of divisionalization of jobs, responsibility and coordination of task as the management responds to its environmental situation (Gerloff, 1985). The purpose of the organization structure is to assist in regulating and directing the efforts put forth in an organization so that they are coordinated and consistent with organization objectives. A common representation of the physical configurations of organizational structure is the organization chart. For the present study, the physical configurations of turnaround organizational structure are represented by Model A, Model B, and Model C as shown in Appendix A.

4. Hypothesis

Turnaround involves large volume of maintenance activities that are classified into three major categories. Firstly, major tasks that require engineering input such as overhauling of large boilers and air compressors, re-traying of large distillation column, replacing refractory linings of cement kiln, replacing catalysts, to name a few. Secondly, small tasks, that include cleaning and inspection of machine and equipment. The third category is the bulk work where large number of small items such as valves, pumps, and motors are overhauled. It is obvious that the size of the turnaround activities depends on the extent of the scope of work. In turn, the scope of the work is contingent on the plant technology. Hence, the following hypothesis is suggested.

Hypothesis H1: The size of the plant turnaround maintenance relates to the plant technologies that are represented by six process-based industries.

The technology-size relationship was based on the view by Carlisle (1973); Hickson, Pugh and Pheysey (1969), who advocated plant technology as one of the imperative factors that effect organizational size, organizational structure and management systems. In the present study, size of the turnaround is represented by the cost of the turnaround event, duration of planning, and number employees involved. Therefore, the following sub-hypotheses are put forth.

Hypothesis H1a: The cost of the plant turnaround maintenance activities relates to the plant technology.

Hypothesis H1b: The duration of planning for the plant turnaround maintenance activities relates to the plant technology.

Hypothesis H1c: The numbers of employees involved in the plant turnaround maintenance activities relates to the plant technology.

There exist variations in the configurations of the organizational structure of plant turnaround maintenance in the process-based industries. One of the contributing factors is the nature of the maintenance activities that are being carried out. This in turn, is contingent upon the plant technology used by the organization. In other words, organizational structure responds to the demands posed by the plant technology. This view is supported by the findings of the earlier organizational theorists.

Pugh *et al*. (1969) were able to demonstrate that size and technology were predictors of organizational structure. This result was based on their research into forty-six diverse work organizations in Birmingham, England. Child (1973) proposed that organizational size, automation of technology, and the number of operating sites were seen to exert influence upon the structure of an organization. His finding was based on a sample of eighty-two British business organization or known as “National” sample. Daft and Bradshaw (1980) put forth size and technology as the two causes of organizational structure differentiation. Marsh and Mannari (1981) highlighted the relative importance of size and technology on organizational structure based on their study of a sample of fifty Japanese factories. Based on the aforementioned discussions, the following hypotheses are suggested.

Hypothesis H2: The configuration of organizational structure of plant turnaround maintenance is related to the plant technology.

The present study also suggests the relationship of the size of plant turnaround maintenance and organizational structure of the plant turnaround maintenance.

Hypothesis H3: The configuration of organizational structure of the plant turnaround maintenance is related to the size of the turnaround maintenance event.

Since size of the plant turnaround maintenance is characterized by the number of employees for the turnaround activities, duration of planning, and cost of the plant turnaround maintenance event, the following sub-hypotheses are put forth.

Hypothesis H3a: The configuration of organizational structure of the plant turnaround maintenance is related to the cost of the plant turnaround maintenance.

Hypothesis H3b: The configuration of organizational structure of the plant turnaround maintenance is related to the duration of planning for the plant turnaround.

Hypothesis H3c: The configuration of organizational structure of the plant turnaround maintenance is related to the number of employees involved in the plant turnaround maintenance activities.

5. Research Methodology

The population of this study is the large companies in the process-based industries in Malaysia that performed plant turnaround maintenance. According to the Small and Medium Industries Development Corporation, Malaysia (SMIDEC), large companies are those with annual sales turnover exceeding RM25 million or employing more than 150 full-time staff. Hence, these two measures are adopted in the present study to differentiate the large companies from other small and medium size companies. Small and medium sized companies are excluded since they do not have significant plant turnaround maintenance activities. The list of companies drawn from the directory of the Federation of Malaysian Manufacturers (FMM) showed a total of 24 industry groups that are classified according to the International Standard Industrial Classification (ISIC) Codes. These groups consist of small, medium and large companies. However, only the large companies are selected for the study. The final list of the large process-based industry groups consists of 110 companies from the manufacturers of palm oil, vegetable oil and fats, sugar, refined petroleum products, basic chemicals, fertilizers and nitrogen compounds, energy, cement, rubber and plastic products, and basic metals. The diverse mix of companies is representative of the industries and enhances the external validity of the study. This will allow generalization of the research findings across the large process-based industries in Malaysia. Questionnaires with instructions were dispatched to the General Manager, Plant Manager or Maintenance Manager of each of the identified companies in March – May 2008. A total of 58 companies responded to the questionnaire constituting 52 percent of the total number of large process-based companies.

6. Salient Characteristics Of Companies

The 58 large companies from the process-based industries covered in the study differ not only in the plant technology employed in conducting their business operations but also in other prevailing characteristics that include, among others, the size of manpower, the number of years in operation, the frequency of the turnaround, duration of the turnaround event, costs of the turnaround, and planning duration of the turnaround.

6.1 Activities And Location Of The Companies

These companies are classified into seven categories based on their main manufacturing activities, vis-à-vis the final products that they produced (Table 1). These categories represent various plant technology employed by the companies. As evident from Table 1, 43 percent of the companies covered in the study consist of manufacturers of petroleum-based products. This is followed by 10 electric power plants that form 18 percent of the sample. The manufacturers of cement, basic chemicals, vegetable oils and fats each form 10 percent of the sample respectively. The remaining nine percent of the sample is made up of manufacturers of fertilizers and nitrogen compound. The companies are located at various states of Malaysia. An overwhelming majority (90.0 percent) of the companies are located in Peninsular Malaysia while the remaining in East Malaysia (Sarawak and the Federal Territory of Labuan).

Table 1: Categories of Companies Based on Manufacturing Activities

	Activities of Companies	Frequency	Percent
1	Petroleum-based products	25	43
2	Fertilizer and nitrogen compound	5	9
3	Electric power plants	10	18
4	Cement	6	10
5	Basic chemicals	6	10
6	Vegetable oils, palm oil and fats	6	10
	Total	58	100

6.2 Size Of Manpower

The size of manpower employed by these companies varies in the range of 60 to approximately 1200 employees. An overwhelming 82.0 percent of the companies employ 500 or less people including 42.0 percent that employ staff strength of 100 – 300 persons. The remaining 18 percent of the companies have staff strength of more than 500 including one company that have staff strength of more than 1100 people.

6.3 Number Of Years In Operation

Analysis on the number of years that the plants have been in operation shows 32.0 percent of the companies have been in operation for 10 years or less. Those that have been operating between 11 – 25 years constitute almost one-half (48.0 percent) of the plants covered in the study. Those that have been operating for more than 30 years constitute 10.0 percent of the plants. The latter group of plants reflects the ageing facilities and assets they are using in conducting their manufacturing activities.

6.4 Frequency Of Turnaround Maintenance

The large companies in the process-based industries utilize multi-million dollars facilities and assets to conduct their business. These facilities that are normally designed to last for 25 to 30 years demand continuous maintenance and upkeep including the periodic shutdown for turnaround maintenance. Analysis of the data on the frequency of turnaround maintenance revealed that 38% of the companies perform the turnaround maintenance once a year. This is followed by 30.0 percent of companies that that conduct their turnaround event every three years. Companies that conduct turnaround twice a year constitute 12.0 percent of the companies covered in the study. Companies that perform their turnaround maintenance once every two years, once every five years, and once every six years constitute 7.0 percent, 10.0 percent, and 3.0 percent respectively. No companies covered in the study reported conducting their turnaround activity once in four years.

6.5 Cost Of Plant Turnaround Maintenance Event

Cost of plant turnaround maintenance generally include turnaround planning and management; local labor that covers companies' plant personnel; contractors; specialists; spare parts and materials to repair defects or replacement; equipment purchase and hire; logistics that include temporary stores, workshop, accommodation, mess room, changing rooms, and site offices; utilities, and other contingencies. Analysis on the data shows that more than one-half (52 percent) of the companies covered in the study belong to the 'large-scale' (>RM500,000) cost of plant turnaround maintenance. The remaining 48 percent of the companies are equally divided into 'medium scale' (RM500,001 to RM5,000,000) and 'small scale' (RM500,000 or less) costs of turnaround maintenance.

6.6 Planning Duration Of Plant Turnaround Maintenance

The complexities associated with turnaround maintenance require substantial effort and time on planning and preparation to ensure smooth execution and timely completion. In fact, planning is the major phase of the turnaround maintenance process. Stretching the planning duration to two or three years is not uncommon in industrial circles. Nevertheless, the duration of planning for the turnaround maintenance differs amongst the companies. Majority of the companies (49 percent) spend between one to six months for the planning and preparation. This is followed by 21 percent that require seven to twelve months of planning time. One and one and a half years of planning time were reported by 23 percent of the companies covered in the study. The remaining seven percent of companies require more than 18 months of planning duration.

6.7 Duration Of Plant Turnaround Maintenance Event

The duration of the turnaround maintenance event is dependent upon the work scope. The latter is almost always constrained by the demands on the production and the availability of sufficient funds to finance the event. In view of these constraints, the shutdown period must allow for a minimum scope of turnaround maintenance work to ensure optimal and efficient performance. Results of the analysis showed that 22 percent of the companies allocated not more than 10 days for their turnaround maintenance. Another 31 percent of the companies spend in between 11 to 20 days to complete the turnaround and a similar proportion of companies require three to four weeks to complete the turnaround. The remaining 16 percent of the companies covered in the study reported utilizing more than 30 days to execute the turnaround including two percent that requires 51-60 days to execute their turnaround activities.

6.8 Size Of Manpower For Turnaround Maintenance Event

Plant turnaround maintenance involves voluminous maintenance work that requires large number of manpower, since the work has to be completed within a very short duration. In addition, it is quite common for a turnaround event to include new projects that can only be implemented when there is complete shutdown of the plant adding further demand on human resource. Hundreds, even thousands of maintenance man-hours is required depending on the volume of the work. Among the companies included in this study, two significant groups are observed. At one extreme, 33 percent of the companies require less than 100 workers to execute the turnaround maintenance while at the other extreme, 36 percent of the companies need more than 600 people for their turnaround event. In between these two extremes, 10 percent of the companies employ in a range of 100 to 200 workers for their turnaround, 15 percent of the companies have manpower size of between 201 to 500, and five percent employ between 500 to 600 maintenance workers.

7. Analysis And Discussion

The Hypotheses H1a, H1b, H1c, H3a, H3b, and H3c are tested using Kruskal-Wallis Test, while Hypothesis H2 is tested by Chi-Square Test.

The statistical outputs from the Kruskal-Wallis Test indicate that costs of plant turnaround maintenance significantly differ across the six plant technologies (refer to Table 1) used by the process-based industries. The chi-square is 32.794 and the level of significance is 0.001. This value is well below the alpha level of 0.05 and is therefore significant. This finding supports the Hypothesis H1a, $\chi^2(5, N=49) = 32.794$, $p = 0.001 < 0.05$. The cost profile of the turnaround maintenance much depends on the volume of activities of the event. Comparatively, the volume of turnaround maintenance activities of the manufacturers of petroleum-based products, fertilizers and nitrogen compounds, and some of the electric power generating plants are bigger than the other industries. Hence, the costs of their turnaround events are relatively higher.

The statistical outputs from the Kruskal-Wallis Test indicate that planning duration of plant turnaround maintenance significantly differs across the six plant technology used by the process-based industries. The chi-square is 32.418 and the level of significance is 0.001. This value is well below the alpha level of 0.05 and is therefore significant. As such, Hypothesis H1b is supported, $\chi^2(5, N=58) = 32.418$, $p = 0.001 < 0.05$. Customarily, the manufacturers of petroleum-based products and fertilizers and nitrogen compound spend longer time in planning than the electric power generation plants, cement manufacturers, basic chemicals manufacturers, and manufacturers of vegetable oil, palm oils, and fats. This is in view of the voluminous amount of work involved in the turnaround maintenance that requires extensive planning and scheduling. On the other hand, shorter planning duration prevails in the companies that manufacture basic chemicals, vegetable oil, palm oil, and fats.

The results of the Kruskal-Wallis Test confirm that number of employees for turnaround maintenance significantly differs across the six plant technology used by the process-based industries. The chi-square is 33.504 and the level of significance is 0.001. This value is well below the alpha level of 0.05 and is therefore significant. Basing on these facts, Hypothesis H1c is supported, $\chi^2(5, N=58) = 33.504$, $p = 0.001 < 0.05$. It is common that the manufacturers of petroleum-based products, fertilizers and nitrogen compound, and the large electric power generating plants employ large number of employees for the execution of their turnaround maintenance than the cement manufacturers, basic chemicals manufacturers, and manufacturers of vegetable oil, palm oils, and fats. A number of electric power generating plants, manufacturers of cement, basic chemicals, vegetable oils, palm oil, and fats employ less than 200 workers to execute their turnaround maintenance. However, most of the manufacturers of petroleum-based products, fertilizers and nitrogen compound and few of the large electric power generating plants require large size of manpower of more than 500 workers to implement their turnaround.

The companies included in this study have designed and established different structures for organizing their plant turnaround maintenance. Using Pearson Chi-Square Test the Hypothesis H2 that advocates the relatedness of the configuration of organizational structure of the turnaround and plant technology is tested. The Pearson Chi-Square value is 39.686 and the significant level is 0.001. This significant value is well below the alpha level of 0.05 and is therefore significant. This leads to the conclusion that configuration of organizational structure of the turnaround maintenance is related to the plant technology employed by the various companies studied, $\chi^2(5, N=58) = 39.686$, $p = 0.001 < 0.05$, and so the Hypothesis H2 that was put forth is supported.

Evidently, there is no single perfect and correct organizational structure that fits all organization. Different organizations have different structures that are designed to meet its objectives. Previous organizational studies have demonstrated that organizational structures were influenced by many external and internal environmental factors. The dimensions of organizational structure are influenced by many factors such as strategy, age and size of the organization, technology, and management style (Burton and Obel, 2004). The findings of this study shows that Model C organizational structure is more established in the turnaround organizations of petroleum industries. Model A organizational structure is largely established in the non-petroleum industries. The organizational structure of Model C reflects the additional functions of managing the contractors and projects. On the other hand, Model A and Model B organizational structures prevail in the medium and small scale turnarounds where the work scope and the number of turnaround employees are comparatively smaller. The turnaround events are manned by plant maintenance personnel and in most cases supplemented by a small number of semiskilled and unskilled workers from the contractors. Thus, the situation does not entail a separate function to manage the small number of contractors. Similarly, where necessary, projects are manageable without the need to have a separate project team. Hence, the organizational structures are leaner than the ones that are found in large turnaround maintenance.

The Hypothesis 3a that put forth the organizational structure of the turnaround maintenance is related to the cost of the turnaround maintenance is supported by the hypothesis testing. The results of the Kruskal-Wallis Test confirm that the organizational structure of the turnaround maintenance significantly differs across the three cost categories of the turnaround maintenance. The chi-square value is 27.175 and the significant level is 0.001. This significant value is well below the alpha level of 0.05 and is therefore significant. Evidently, the hypothesis H3a is supported, $\chi^2(2, N=45) = 27.175$, $p = 0.001 < 0.05$. It is apparent that the large scale turnaround activities are organized with Model C organizational structure while medium and small scale turnarounds are organized with Model B and Model A respectively.

Hypothesis H3b which suggests that the organizational structure of the plant turnaround maintenance is related to the duration of planning is also well supported. The results of the Kruskal-Wallis Test confirm that the organizational structure of the turnaround significantly differ across the four categories of planning duration of the turnaround maintenance. The chi-square value is 23.234 and the significant level is 0.001. This value is below 0.05 and is therefore significant. Hence, hypothesis H3b is supported, $\chi^2(3, N=54) = 23.234, p = 0.001 < 0.05$. Longer planning duration is necessary due to the large volume or work that has to be planned and scheduled. In other words, the duration of planning reflects the volume of work that is scheduled for implementation during the turnaround. As the work activities are mapped by the organizational structure, the higher the volume of activities the more complex the organizational structure is.

Finally, the Hypothesis H3c that suggests organizational structure is related to the number of employees involved in the plant turnaround maintenance activities is supported. Kruskal-Wallis Test results indicate the chi-square is 31.403 and the level of significance is 0.001. This value is well below the alpha level of 0.05 and is therefore significant. This leads to the conclusion that the configuration of organizational structure of the turnaround maintenance significantly differ across the seven categories of number of employees involved in the turnaround, $\chi^2(6, N=54) = 31.403, p = 0.001 < 0.05$. It is apparent that turnaround organizations with large number of employees are structurally more complex than the ones with lesser strength of employees.

Longer planning duration and larger number of employees are necessary due to the large volume of maintenance work that has to be planned, scheduled, and executed. As the work activities are mapped by the organizational structure, the higher the volume of activities the more complex the organizational structure. In large turnaround, maintenance activities involved work on turbine, compressors, pumps, reactors, electrical, instrumentation and controls, and other project-related work to name a few. These tasks need to be handled and supervised by specialized employees. Therefore, it is usual that separate units are established to ensure easier supervision and management. The number of different units established depend on the extent of specialized tasks that have to be accomplished (Mintzberg, 1979). Concurrently, the need for coordination intensifies as the number of different units increases (Lawrence and Lorsch, 1986). One of the coordination mechanisms is having taller hierarchy to coordinate through direct supervision. As a result, large turnaround activities that are represented by large number of employees are organized with structures that are taller as mirrored by Model C organizational structure.

8. Conclusions

This study shows that there are differences in the size of the turnaround events and configuration of the organizational structures of turnaround that reflect the variations in the six types of plant technology employed. The findings support the technology imperative proponents and ascertained the influence of plant technology on the organization of turnaround maintenance (Woodward, 1965; Harvey, 1968; Hickson, Pugh, and Pheysey, 1969; Carlisle, 1973). The finding lends support to counter the claims of the previous researchers such as Hickson, Pugh and Pheysey (1969), and Child and Mansfield (1972) that noted the absence of any significant relationship of technology and structure. The differences in the findings are due to the operationalization of the plant technology adopted by the earlier studies that focused on the organization-wide structure-technology relationship. The present study, on the other hand, has focused on the structure-technology relationship of plant turnaround maintenance organization, which is one of the functional departments within the large process-based companies. All the activities within the turnaround maintenance organization are shaped by the plant technology thereby the structure-technology relationship is discernible. It is plausible to conclude that the influence of plant technology does not affect the entire organization but it is more localized in nature.

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Appendix A

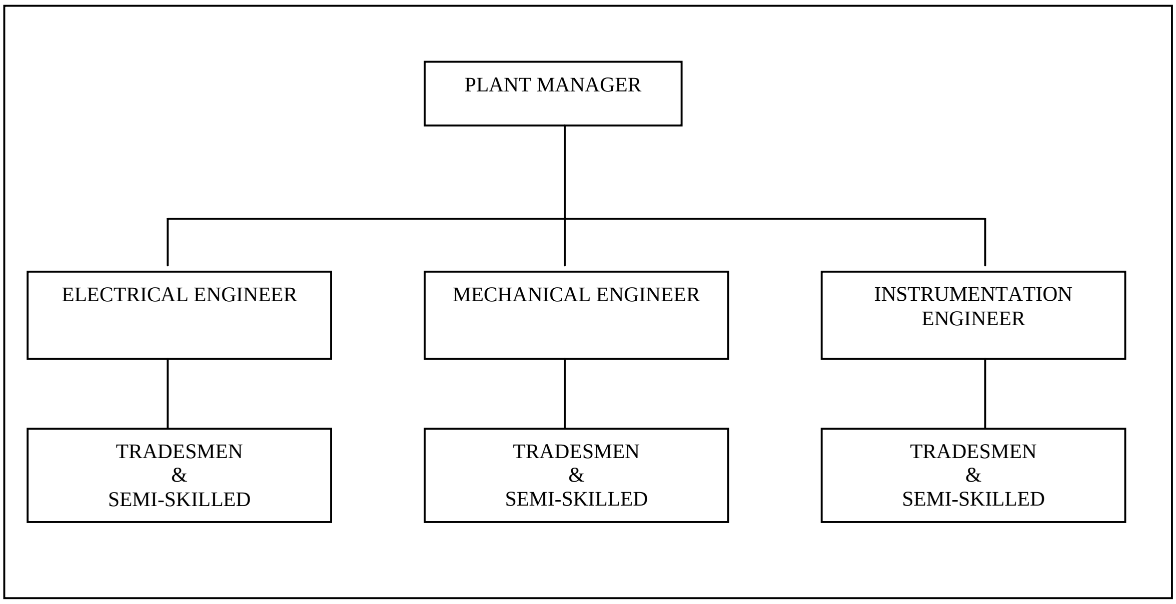

Figure 1(a): Organizational Structure – MODEL A

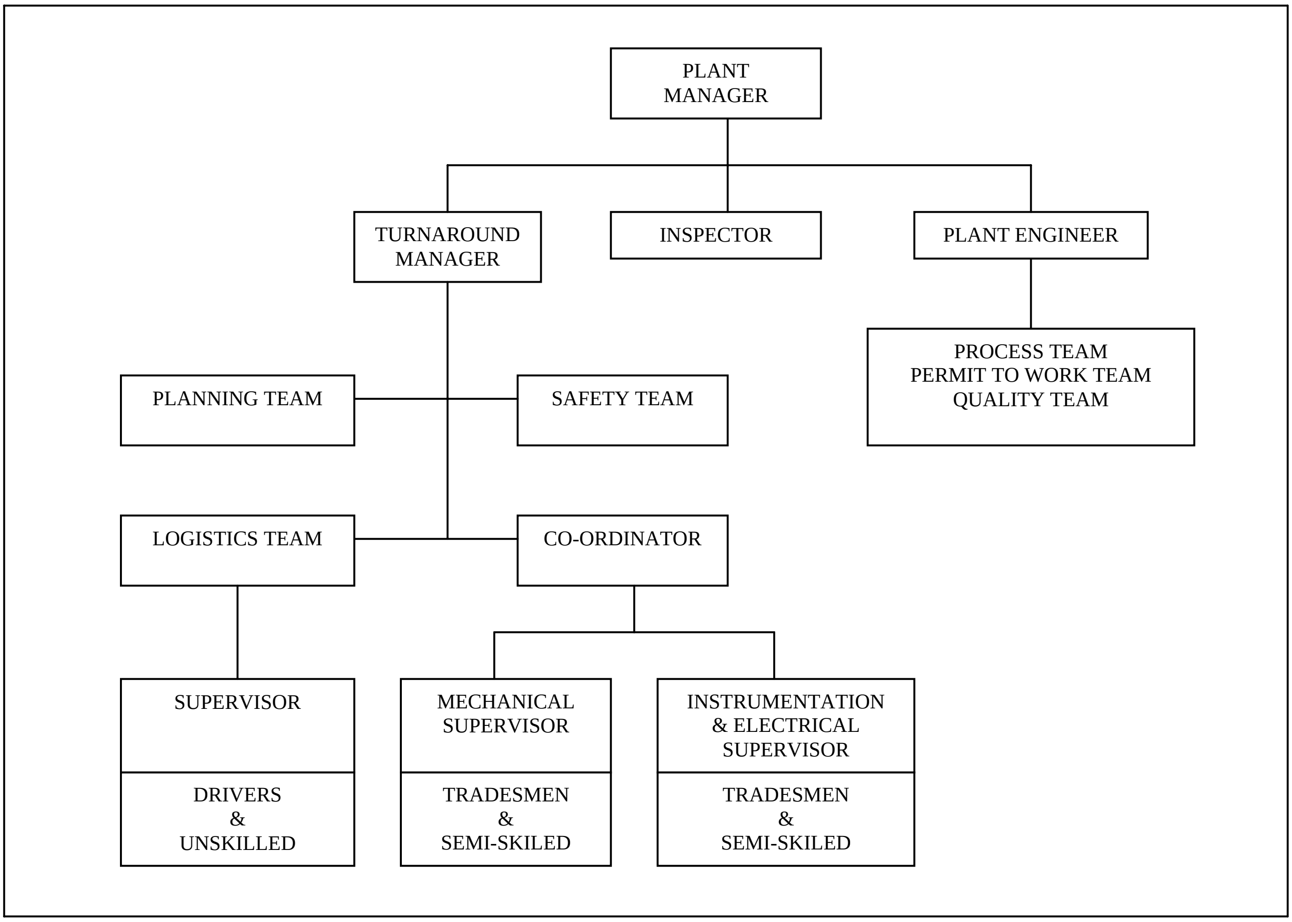

Figure 1(b): Organizational Structure – MODEL B
(Source: Lenahan, 1999)

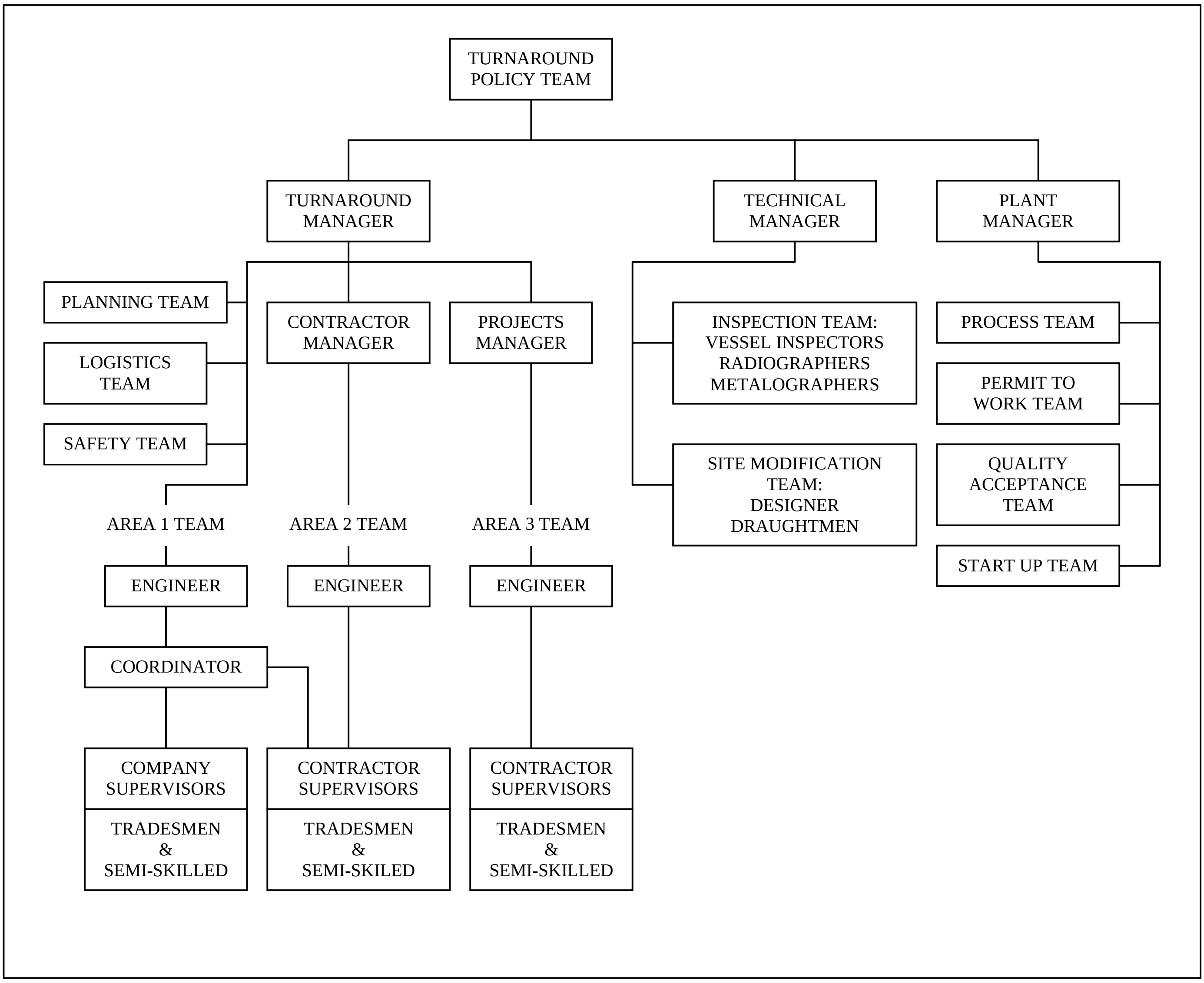

Figure 1(c): Organizational Structure – Model C
(Source: Lenahan, 1999)