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# IMPACT OF FACTORS IMPEDING ORIGINAL EQUIPMENT MANUFACTURER (OEM) INTENSIVE CAPITAL PROJECTS

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## ABSTRACT

*The capital platforms like aircraft, ships etc. are hybrid of systems/machinery and needs to put out of service for repairs and maintenance to avoid catastrophic failures. The OEM intensive overhauling projects of Pakistan public sector are experiencing delays resulting in non-availability of these capital platforms. The purpose of this study is to identify the delay factors and their impact (effect) on project completion so that a comprehensive corrective strategy could be formulated to mitigate the effect of most delay causing factors and deliver the project on time. An explanatory approach has been adopted in this case and factor analysis was done to find out the significant factors. During factor analysis, 59 contributors were identified which were divided into four groups namely Supply Chain (SCM), Resource Management (RM), Obsolescence (OBS) and Project management (PM). The quantitative analysis was done on population size of more than 300 by using a close ended questionnaire. The results depicts that obsolescence has the maximum contribution towards delay, whereas, the subsequent factors are PM, SCM and RM respectively. It was also observed during the study that obsolescence is a factor that can be mitigated to a great extent by improving supply chain and project management practices.*

***Keywords:*** *Supply chain management (SCM), Obsolescence, Capital projects, Mitigation, Acquisition, Inter-dependencies.*

## 1) INTRODUCTION

Delays in original equipment manufacturer (OEM) intensive capital projects related to overhauling and refitting are common in Pakistan's public sector. These delays are often results in non-availability of capital assets like ships, aircrafts, rolling stock of railways etc. at critical hour of need. These delays can be mitigated if the factors causing these delays along with their impact

can be timely identified for their appropriate counter measures. It is an exploratory as well as explanatory research and the area of study is presently under explored not only in Pakistan but in regional context. The dynamic, multi-facet and risky nature of OEM intensive overhauling projects of capital platforms has made the realization of project completion on-time gradually unachievable (Nohzatullah & Samiullah, 2016). According to Ahmed *et al.* (2003), delay is generally acknowledged as the most common, costly, complex and risky problem encountered in projects which are heavily OEM dependent. Ren, Atout, & Jones (2008), surveyed the causes of delays in mega projects as seen by major stake holders, and examined the factors affecting productivity. The study revealed difference in perceptions between stake holders, depending on their experiences.

Generally the design of machinery fitted on capital assets has been changed drastically over the last couple of decades due rapid expansion in the "field of electronics" (Paul & Gaulbitz, 2011). Since, the manufacturers have to improve their designs on regular basis for better control compared to previous variant, therefore, machines have short product life cycle (Solomon, Sandborn, & Pecht, 2000). In order to market new derivatives, manufacturers have to discontinue supportability of their previous product. This led previously available product obsolete with induction of its new variant. Regular induction of new products with short product life cycle and continuous up-gradation of existing one has adversely affected the progress of public sector (Solomon, Sandborn, & Pecht, 2000). The technological advancement and change in business concept have transformed mechanical machines into controller based. This has increased the working efficiency and accuracy however, the same has drastically reduced machine life cycle with use and throw principle (Paul & Gaulbitz, 2011). Further, short product life cycle has augmented the intricacies involved in overhauling capital projects of public sector core machinery.

Morteza & Kamyar, (2009), carried out a study in which significant success factors were identified and considered to be the most important factors in successful completion of projects. However, no study has comprehensively explained the causes of delay in OEM intensive overhauling projects of capital platforms in public sector of Pakistan. The study is mainly focus to identify the impact of factors causing delays and risks associated with OEM intensive projects related to overhauling of capital maritime platforms in Pakistan.

## 2) LITERATURE REVIEW

The capital maritime platforms are hybrid of machinery, systems and needs to be put out of service for defect rectification and routine maintenance to avoid catastrophic failures. To attain high system availability it is necessary that spare parts required for undertaking the repairs and maintenance work must be present well before time (Sleptehenko, Heijden, & Harten, 2003). Further, Sleptehenko & Harten, 2003 have proposed two methods to improve the system i.e. increase spare part inventories and secondly to invest for additional repair capacity. Moreover, Cohen, Zheng, & Agrawal, (1997) has pointed out that such a trade-off from OEM will not be straight forward in the presence of complex structure for spare part repair and supply network. However, aspect of supply chain for non-availability material/spares and its effect on timely completion of overhauling projects of maritime sector have not been covered in the said study.

Projects of capital nature in developing countries heavily depend on systems and procedures defined by OEM. Correct implementation of these procedures is only possible if the required set of resources is available when needed to ensure optimization of efforts in capital projects. Effective application of resources can allow organizations to enhance competitive advantages by acquiring capabilities and resources which are necessary and valuable (Barney, 1991 & Peteraf, 1993). Effective control of these strategic resources including explicit (systems, equipments & spare parts) as well as implicit (Information, communication etc.) resources act as a power tool for handling unforeseen events (Werner felt, 1984; Barney, 1991 & Peteraf, 1993). The aforesaid research mostly covers benefits of resources related to business environment and slightly touches the advantages of intangible implicit resources which are deeply imbedded in management system and are difficult to replace (Joseph T., 2001, Barratt & Oke, 2007). However, their impacts on the performance of OEM dependent overhauling projects have not been covered in the study.

The study of NIU, Thomas, & JIANG (2010), deals the project in two very important phases; conceptual phase and operational phase as shown in Figure 1. According to study these phases are first conceptualized, tested and if qualify, only then the project is perceived to be successful. However, author reiterates in the said research that project success in terms of time, cost, performance, quality and safety will depend on how the "project management" functions and individual perceive project success from their

own perspective. The aforesaid point has also been highlighted by Svetlana Cicmil, Williams, Thomas, & Hodgson, (2006) in which the role of project actors and managers is explained as 'implementers' and then converges their role to the issues of control-time/cost and planned scope of work. According to the author this assumes rationality, universality, objectivity, and ability of an individual to collect data, analyse and communicate information for solving real time problems related to project work and make timely decisions. The letirature does not cover the impact of project management as a factor in OEM dependent overhauling projects of capital nature.

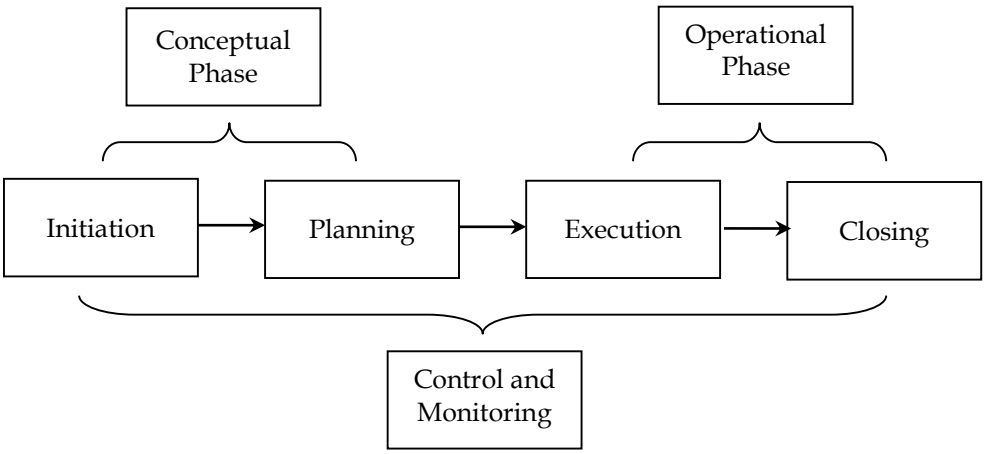


***Figure 1: Major Phases of Project Management***

Another important factor which revealed during literature review is obsolescence attributable towards late availability of maritime platforms after overhauling. This problem has adversely affected Canada's submarine program (Byers & Webb, 2013) where project director of Victoria class program in 2005 has attributed delays due shortage or lack of spare parts. Main cause explained in the study was OEM either no longer exists or has moved on to other designs. Therefore, HMCS Victoria was made operational after cannibalization from HMCS Chicoutimi. In this particular case submarine was only made available for operations after stopping a similar class submarine with an overall delay of three years. Canada had to pay a heavy price that includes $11 million, extra time of three years and a platform of same class to make the submarine available for operations and deployment.

In congruence with the conceptualization narrated during literature review and considering the current scenario of public sector arena in Pakistan this

has been concluded that quantitative approach should be adopted for further procession and validation of existing study. This will check the impact of each factor robustness of present system, confirm the existing factors and help to find additional factors along with their impact towards delay in completion of mega overhauling projects. This warrants a comprehensive research methodology to un-earthed contributing factors buried in the data and find the impact of each factor towards delay in the project.

## 3) RESEARCH FRAMEWORK

Since the area of study is under explored in Pakistan, therefore, it is an exploratory research and the research pattern adopted in this case consists of application, purpose and approach. The application is applied, purpose will be exploratory during identification of critical factors and then it will be explanatory with quantitative approach to establish the impact of each identified factor. The combination of qualitative and quantitative analysis in this study will also allow to validate and counter check the identified factors through triangulation method. The primary data was collected via interviews and survey through close ended questionnaire focusing professionals directly engaged with projects which are OEM dependent in maritime sector of Pakistan. A mixed or varied respondent approach is an important condition to ascertain the impact of various factors on OEM dependent projects (Sambasivan & Soon, 2007). Therefore, selected group of respondents engaged in OEM intensive capital overhauling projects were approached for the study.

## 4) CONSTRUCTION OF QUESTIONNAIRE

The preparation and correct classification of questionnaire attributes is a very critical step towards successful research. Since a lot of work have already been done on identification of causes of delays in mega projects, therefore, an explicit set of attributes available in literature have been used for preparation of questionnaire. Initially, 59 attributes were selected under five broad groups, i.e. material availability related, human resource/equipment related, work preparation/scheduling related, obsolescence related and performance related. The basic design of the questionnaire was based on five point likert scale with "one" being strongly disagree and "five" as strongly agreed. The close ended questionnaire was then tested for its reliability and validity before its formal circulation among the professionals directly involved in the projects of capital nature. The Cronbach's alpha test was applied for reliability check

whereas, test re-tests method was used to ascertain its validity. The results of Cronbach's alpha are shown in table 1:

***Table 1: Reliability Statistics of Factors Causing Delays on OEM Intensive Capital Projects***

| **Attribute** | **Cronbach's Alpha** |
|---|---|
| Material availability related | 0.889 |
| HR/Equipment related | 0.785 |
| Work preparation/Scheduling related | 0.766 |
| Obsolescence related | 0.768 |
| Performance related to on time delivery | 0.749 |

The survey was conducted by circulating questionnaire in person, by email and through telephone discussions. In this research two statistical techniques i.e. factor analysis and regression modeling have been used (Doloi, 2009, Field, 2009). These techniques helped to reduce attributes for exploring the clustering effects and for deriving a predictive model based on best-fit factors for on time delivery of capital projects (Doloi, 2009, Field, 2009). Moreover, Relative Importance Index (RII) has been used as descriptive analysis tool to indicate the relative importance of each factor as reported by the respondents (Assaf *et al*, 1995, Faridi & El-sayegh, 2006). The results and their analysis are enumerated in ensuing paragraphs.

## 5) RESULTS AND ANALYSIS

The value of cronbach's alpha is well between 0.7 ~ 0.9 reveals that the attributes of each group are valid and the questionnaire can be floated for data collection. The sample size of greater than 300 was selected for authentic results. Close ended likert scale questionnaire was distributed among population size of 400. In response more than 390 questionnaires were received. Assaf *et al*, 1995, Faridi & El-sayegh, 2006 is of the view that mean and standard deviation is not a suitable measure to assess over all ranking. Therefore, the method of RII was prefered by using following equation:

$$Relative\ Important\ Index\ \ (RII\ ) = \ \sum w/A \times N \longrightarrow \text{Equation 1}$$

In this equation 'w' represents the weight given to each attribute by respondent, A is for highest weight and N is total number of respondents. In

results, value close to one indicates that it has a maximum impact on the delay and the value near zero indicates other way round. However, RII does not cater for inter-variable relationship. In factor analysis, adequacy of survey data is evaluated using Kasier-Meyer-Olkin (KMO) test and Bartlett's test. The criteria of a minimum value of 0.5 as suggested by (Kaiser, 1974) were used and total of 33 attributes out of 59 were selected in five groups on the bases of correlation with KMO value of 0.95 and the remaining were excluded from the study due non significant correlation. The attributes are divided into five discrete sections comprised of supply chain (SCM), resource management (RM), project management (PM), obsolescence (OBS) and project performance in terms of on time delivery. A parallel between identified categories and groups segregated from literature review was drawn so that a linear multiple regression can be applied for developing a predictive model of OEM intensive capital projects. For this purpose, first four variables were considered as independent (IV) and the last variable was considered as dependent variable (DV). The relationship between IVs and DV is shown in Fig 2:

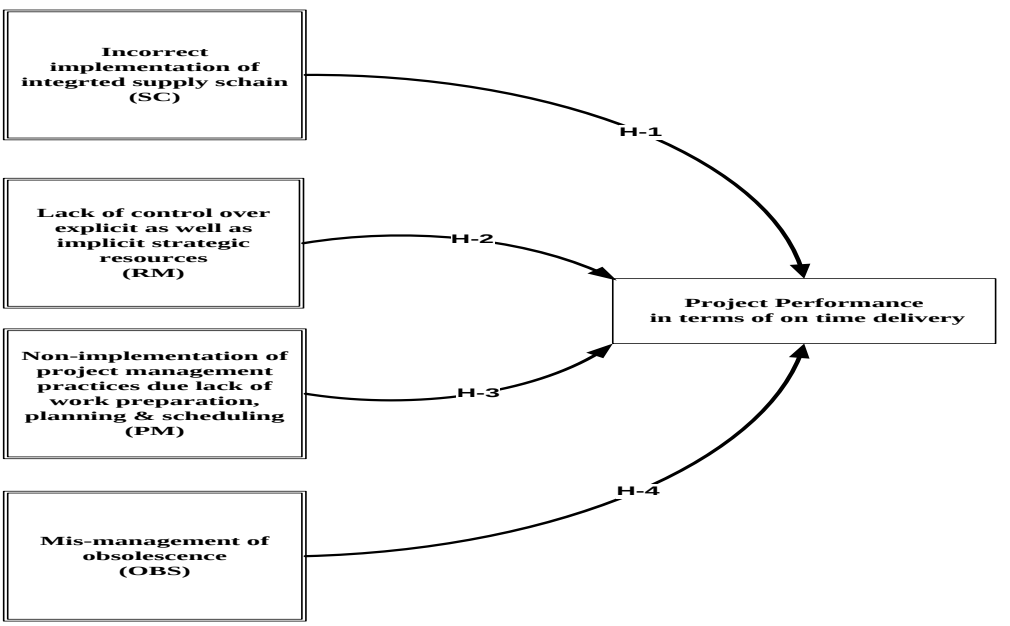


*Figure 2: Relationships between DV and IVs*

The first test conducted was to find out the descriptive statistics to identify correctness and fitness of collected data for further processing. The results of descriptive statistics are shown in table 3.

*Table 3: Results of Descriptive Statistics*

| | Mean | Std. Dev | Skewness | Kurtosis |
|---|---|---|---|---|
| **SCM** | 3.7376 | .85788 | -1.416 | 1.781 |
| **OBS** | 3.6558 | .82403 | -1.078 | 1.318 |
| **RM** | 3.6779 | .80413 | -1.142 | .943 |
| **PM** | 3.7336 | .80631 | -1.328 | 1.271 |
| **PP** | 3.6771 | .84313 | -1.015 | .628 |

The descriptive statistics shows that data is concentrating near the mean and has a narrow peak. Whereas, the value of kurtosis varies between +3 ~ -3, therefore, correlation and regression is tenable and can be run on the available data (Field, 2009).

The Pearson's Correlations analysis reveals that the correlation between SC and PP (r = .822, p = 0.000), indicates that a high correlation exists between supply chain and project performance in terms of on time delivery. Similarly, the correlation calculated for resource management, project management and obsolescence comes out to be (r = 0.846, p = 0.000, r = 0.856, p = 0.000, r = 0.794, p = 0.000). The results indicates that RM, PM and OBS are highly correlated with on time delivery of overhauling capital project. The results of Pearson's correlation are given in table 4.

*Table 4: Pearson's Correlation between IVs and DV*

| | SCM | OBS | RM | PM | PP |
|---|---|---|---|---|---|
| **SCM** | 1 | | | | |
| | .000 | | | | |
| **OBS** | .841 | 1 | | | |
| | .000 | .000 | | | |
| **RM** | .856 | .821 | 1 | | |
| | .000 | .000 | .000 | | |
| **PM** | .832 | .791 | .866 | 1 | |
| | .000 | .000 | .000 | .000 | |
| **PP** | **.822** | **.794** | **.846** | **.856** | **1** |
| | .000 | .000 | .000 | .000 | .000 |

Further, the model summary and analysis of variance depicts that the coefficient of determination adjusted $R^2$ comes out to be 0.794. The value of F = 353.891 provides a good gauge of substantive size of relationship between predicting or dependent variable and predictor or independent variables. The results of F-test suggest the rejection of null hypothesis and the model is fit for regression. The detailed results of model summary and analysis of variance are given in table 5:

*Table 5 Values of Coefficient of Determination & Analysis of Variance*

| R | $R^2$ | Adj $R^2$ | F | Sig |
|---|---|---|---|---|
| **.891[a]** | **.794** | **.792** | **353.891** | **.000** |

a. Dependent Variable: PP
b. Predictors: (Constant), OBS, PM, SCM, RM

The independent variables used are the identified factors, whereas, dependent variable has a negative impact on successful completion and on time delivery of the project which has been asked separately to every respondent focusing on OEM intensive capital projects. These factors are entered into regression model as categorical variables. Thus the regression model framed to measure the overall impact of delay caused by individual factor that can be expressed generally as follows:

$$\mathbf{Y = a + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots\ldots\ldots\ldots + \beta_n X_n \pm e} \longrightarrow \text{Equation 2}$$

Where 'Y' is dependent variable, 'a' is constant and intercepts at Y axis; $\beta_1$ to $\beta_n$ are estimated regression coefficients; $X_1$ to Xn are values of predictor or independent variables, e is error. In order to formulate the regression model, predictor variables having significant correlation with respect to dependent variable were identified and used. The results are then analyzed and on the basis of correlation strength $R^2$ the optimum model is selected (Doloi, Sawhney, Lyer, & Rentala, 2012). The value of adjusted $R^2$ and $R^2$ indicates how well the model simplifies predictive strength of dependent variable (Doli, 2009). Ideally speaking, values of $R^2$ and adjusted $R^2$ should be the same. However, difference between $R^2$ and adjusted $R^2$ shows predictive strength of the model. According to Field, (2009) lesser the difference between $R^2$ and adjusted $R^2$, stronger will be the model. Based on these grounds, values shown in Table 6 are acceptable with reasonable strengths.

*Table 6: Regression Model*

| | Un-Std Beta | Std Beta | Sig |
|---|---|---|---|
| **SCM** | .159 | .162 | .003 |
| **RM** | .145 | .142 | .003 |
| **PM** | .267 | .254 | .000 |
| **OBS** | .406 | .389 | .000 |

The results of statistical analysis, factors identified during literature review and the organizational frame work are all same, therefore, the proposed frame work is said to be robust. The results and analysis of regression, factor analysis and relative importance index provides the basis where these results can be discussed in light of frame work conceptualized during literature review and organizational framework. The impact of identified factors along with few mitigations is given in the ensuing paragraph.

## 6) DISCUSSION

The most significant factor identified during the course of regression analysis and rejects the null hypothesis is obsolescence taking a toll towards project delay. Since obsolescence is a dependent variable, therefore, it cannot be considered as the main cause of delay shown by regression analysis of the collected data. Apparently it seems from the results that on time delivery of the project is affected due obsolescence, however, obsolescence can be controlled by re-aligning inventory management and customer-supplier relationship. Obsolescence also becomes negatively momentous on the performance of project particularly when the project planning is weak (Liyu, Raymond, Janis, & Peter, 2013). Therefore, issue of obsolescence can be mitigated to a great extent by improving SCM and PM practices.

The second most significant factor is the planning process which is contributing towards project delay. Presently, planning process is also not geared up to cover fundamentals of project management. The planning and initiation phase lacked clarity and objectiveness due to which activities are neither comprehensively conceived/realized nor these activities are properly scheduled (Young & Brian, 2009). Deficiencies in planning processes are often shadowed behind late response from OEM for various supplies. However, incorrect work scope assessment, human resource/infrastructure optimization, lack of communication among departments and management

are the grey areas of planning (NIU, Thomas, & JIANG, 2010). Therefore, lack of preparation during initiation phase results in major reworks, unnecessary equipment degradation and nonproductive activities.

The result of regression model clearly rejects the null hypothesis and shows that non-availability of material, delay in material delivery and poor procurement planning (José Roberto do Rego & Marco Aurélio de Mesquita, 2011) have a maximum impact on overall project Delay. Due to high level of complexity and unpredictability of future events (Christopher & Holweg, 2011), a resilient and a robust supply chain network is required. Key elements of which could be aligned supply chain and strategy with that of organizations' strategy, exhaustive approach to risk management and coordination between companies operating within same supply network.

The results of regression shows that there is a positive relation between resource management and on time project delivery. Incorrect human resource deployment and its timely information to the planing department is considered one of the reason for accumulation of delays. To mitigate the effect of RM, the unforeseen event needs to be handled by controlling the explicit as well as implicit strategic resources as explained in the study done by Wernerfelt (1995), Barney J, (1991) and Peteraf, (1993). Moreover, the advantages of intangible implicit resources need to acrued to deliver the project ontime.

It has been observed that in various studies e.g. study done by Doloi Hemanta, Anil, K, & Sameer, (2011), G, R, Abu, & A, (2008) etc. supports linear regression. The same method was used in this study as well. It was observed that most of the studies have to carryout an intricate exercise of factor analysis before selecting the method of linear regression for data analysis to obtain significant results. During regression analysis, curve fit was also calculated in order to check that model is linear or not. It has been observed that best curve fit for ascertaining the delays on capital projects comes out to be either "power" or "s-curve" which could be obtained by applying non-linear regression. Therefore, it is anticipated that if non linear regression with "s" or "power-curve" is applied, results could be more strongly correlated, conspicous and authentic. Though application of non-linear regression is not covered in scope of this study, however, same could be undertaken as a future work.

# 7) CONCLUSION

In the course of study the major causes along with their impact on the progress of OEM intensive overhauling projects of capital maritime platforms undertaken by the public sector of Pakistan was investigated. The research was done using explanatory approach through interviews and survey questionnaires focusing professionals directly engaged with projects of capital nature. The study identified four most important causes of delays towards on time completion and delivery of capital projects. The broad categories include timely availability of required material/supply chain issues, project management, resources management and obsolescence. The identified factors have direct relationships with on time delivery of mega overhauling projects. According to the results of the study, obsolescence came out to be the most progress affecting factor taking a toll towards project delay. However, obsolescence can be controlled by realigning supply chain strategy with that of organizations strategy and improving the project management practices. It is assumed that the outcome of this study can be beneficial to the professionals directly engage with mega projects as well as for the academicians. The results can help experts to understand various facets of project management and make attempt to mitigate the effects of delays. The researchers can make use of these findings to carry out studies of similar nature for other sectors around the world to ascertain causes of delay and suggest ways for mitigation. However, some causes and effects may be unique to certain countries.

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