PAYMENT EVALUATION METHOD FOR CONTROLLING ENVIRONMENTAL DEFILEMENT IN ROAD CONSTRUCTION PROJECTS IN SRI LANKA

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ABSTRACT

Various attempts have been taken in order to achieve the objective of environmental soundness in road construction activities. Effectiveness of allocating the funds and the due payment for the contractor can create a great influence in achieving such an objective. Thus, this study aims to identify what is the optimum payment evaluation method of contractor's due payment for controlling environmental defilement in road construction projects. The aforesaid research problem was approached through a multiple case study including three road construction projects in Sri Lanka. Different environmental hazards occurred due to different road construction activities, related hazard mitigation methods, fund allocation for environmental hazard controlling and the associated existing payment methods for contractors could be identified through the data collected by means of semi-structured interviews conducted with the professionals who are involved in the projects having knowledge on both environmental and monetary aspects. Further, direct observations and documentary survey strengthened these findings. Quantitative data was collected from each case through a questionnaire survey and prioritized the payment method under each specific hazard controlling method using Relative Importance Index in terms of effectiveness to identify the optimum payment method to the contractor for controlling environmental hazard. Findings revealed that there are four types of such payment methods available including; payments by unit rate, payments where a provisional sum established in the contract; payments where fixed amounts are assigned in the contract and payments made along with some main work item in the contract which were identified being the optimum method under different hazard controlling methods. These findings would be useful for bidders and estimators at the pre-construction stages to develop more effective modes of payment evaluation and to improve effectiveness in estimation.

Keywords: *Due Payment; Environmental Hazards; Fund Allocation; Hazard Mitigation; Payment Evolution Methods.*

1. INTRODUCTION

The construction industry bears a substantial responsibility among the various causes of impacts on environment (Ashworth, 1996). According to Chaudhary (2011), when the road development is compared with other development projects, it involves in wide range of environmental impacts. As stated by Ashworth (1996), there is a growing trend of concern in society about the effects on the environment by the human activities. There by, environment related statutes, regulations, codes and general policies have lot of interferences for the construction industry (Ofori, 1992). According to one of the researches by Da Silva and Amaral (2009), there are costs to be identified in a process of controlling environmental hazards. ICF International, Venner Consulting, CH2M Hill and the University of Florida (2008) have described the environmental cost in road construction projects as the cost where the cost of labor, environmental staff members' or consultant's costs of travel, equipment or material usage, the cost incurs in producing of an environmental document, and the cost of constructing or performing an environmental mitigation feature during construction are directly involved. The builder is the one to incur the production cost in construction industry (Ferry, 1964). This replicates that the payment for the aforementioned

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builder or the contractor has an affiliation with the environmental protection because the contractor has the obligation on executing the construction works. In addition, Darrington (2010) has mentioned that a contractor can be encouraged in proper execution of work for some extent by the payment. Thus, selecting the most suitable method of fund allocation is an essential aspect which requires a thorough consideration. However, the 'Standard Specifications for Construction and Maintenance of Roads and Bridges' published in 1989 by the Road Development Authority of the Ministry of Highways in Sri Lanka, which plays a huge role regarding road construction, does not contain any direct fund allocation for controlling environmental hazards. As specified by Central Provincial Road Development Authority - Sri Lanka (2012), the cost of the services under environmental protection has to be covered under the rates of relevant work items. As stated in the Particular Specifications in bidding document of Miscellaneous Foreign Aided projects by Road Development Authority in Sri Lanka (2011), the payment for hazard controlling has been given as a 'Provisional Sum'. All these ensure that there are different ways of allocating a provision to cover the cost of environmental protection in a road construction project. Each of these different methods of payment may contain its own advantages and disadvantages. However, those have become mere modes of payment without a proper attention to it as a way of encouraging the contractor for proper protection of the environment as Darrington (2010) depicted. In fact, it is worth studying the connection between the payment for the contractor and the minimization of the environmental hazards as it is not yet been theoretically confirmed. Hence, this research intends to fill that research gap by studying the possibility and optimum ways of allocating the funds for controlling environment hazards and the most effective way of payment to the contractor under each environmental hazard in order to take the maximum control of it. However, this research is limited to studying the environmental hazard controlling only during construction phases of the road construction projects in Sri Lankan road network.

This paper is structured in five sections. Following the introduction, second section discusses the environmental hazards; the related controlling methods in road construction; fund allocation and payment for the prevention of environmental impacts. Third section elaborates the research methodology adopted, while fourth section depicts the research findings in detail. Finally, the conclusions drawn from the study is discussed in the fifth section.

2. ENVIRONMENT AND ROAD DEVELOPMENT

It is becoming increasingly difficult to ignore the fact that the attention to the development cannot be drawn without governing the environment. Even though it directs our attention to the importance of maintaining a proper balance between environment and developments, generally environment confronts with negative impacts. This is substantiated by Chen *et al.*(2000) through depicting that China is confronting a serious problem because of pollution and hazards due to urban civil construction projects. As explained by Chaudhary (2011), although road and highways development can be recognized as beneficial in terms of economic and social aspects, it can have substantial negative impacts on communities and natural environment. If this concept is abridged, the roadway construction is an unavoidable requirement of a country to be contented, but as a consequence, it leads to the destruction of natural environment. This replicates the importance of attention associated with the environmental protection.

2.1. ENVIRONMENTAL HAZARDS AND CONTROLLING METHODS RELATED TO ROAD CONSTRUCTION

When evaluating the impacts on environment by road development, the main attention is drawn to the activities appertain to the road construction. Chaudhary (2011) and Local Government of UK (2013), have described that construction include the activities such as: site clearance; construction camp establishments; mobilization of heavy plant; construction of earthworks; construction of structures and basic course/surfacing; excavation and compaction; operation of heavy machinery and equipment; erection of structures; metal joining and finishing; mechanical activities; transport of materials and supplies; generation of solid wastes and debris. As recognized by Chen *et al.* (2000), dusts; harmful gases; noises; solid and liquid wastes and ground movements can be identified as sources of pollution and/or hazards from road construction activities. The control of all human activities which have either considerable or minor harmful impact on the environment during the construction process can be identified as the pollution control in construction projects (Griffith *et al.*, 2000). According to the findings of Chen *et al.* (2000) and Deng *et al.* (2013), the actions related to mitigation of environmental hazards due to construction activities can be implemented in many different ways in terms of laws, Acts, regulations and specific environmental management strategies under different road construction projects. Table 1 elaborates actions taken to minimize the environmental issues in road construction works. Orr (2014) and Carter (2010) have come up with the opinion that all these environmental hazard controlling methods involves a price. Macek (2006) has identified that environmental hazard controlling cost can be given as a percentage of the total cost of a project and it generally varies from less than 1% to 25%. Therefore, it is obvious that the methods identified above may also include a monetary value, hence, fund allocation becomes essential for executing the environmental hazard elimination.

Table 1: Actions Taken to Minimize the Environmental Issues in Road Construction Activities

Environmental Issue	Generated Source / Activity	Action taken to Minimize the Issue
Generation of dust	Road way excavation ABC laying Material transportation Excavations Clearing and grubbing	Frequent water spreading Covering of materials while transporting Locating stockpiles and dumping yard away from sensitive receptors Speed limitations Cleared areas rehabilitated progressively Washing the wheels of carriage prior to entering into residential area
Vibration	Rock blasting Rolling to compact materials	Managing vibration with the use of sand bags in rock blasting Reducing the level of vibration roller and increasing passes Undertaking a condition survey
Dumping of debris	All construction works By third parties	Removing all debris after finishing of each work. Make aware the surrounding communities. Proper disposal practices
Soil erosion	Clearing and grubbing Roadway excavation Removal of vegetation Embankment constructions	Providing turfing at necessary locations Planting fast growing plants (e.g. Mana) Creating earthen bunds when necessary, with the advice of consultant.
Noise pollution	Rock blasting By machineries and vehicles	Controlling the noise generated by rock blasting Proper maintenances of all vehicles and machineries
Contamination of soil and water	Soil erosion due to constructions Leaking of fuel, oil etc.	Taking actions to prevent soil erosion Disposing derbies in a proper manner Programming of construction activates closer to the water stream in dry season
Disruption to road users	All construction works	Implementation of a good traffic management system Dispose all derbies in proper manner
Blockage of drains	All construction works	Clearing of blocked drainage paths periodically
Impact on flora and fauna	Clearing and grubbing Road widening, excavation Embankment constructions Removal of trees	Proper identification and management after commencing the project Obtaining approval for removal of trees from consultant

Source: Adapted from Lakmal (2013)

2.2. FUND ALLOCATION AND PAYMENT FOR THE PREVENTION OF ENVIRONMENTAL IMPACTS

As the contractor is the executor of the work, costs of environmental hazard controlling may have a direct influence on the contractor. According to Bass and Avolio (1993), everyone has a price required for the motivation of work. As explained by Darrington (2010), economic human motives play a key role in job performance. It reflects that the motivation of contractor through due payment is a considerable factor when it comes to the environmental hazard controlling. Further, it could be argued that the contractor can be motivated for proper execution of environmental protection through the due payment.

United States Department of Agriculture (2011), Florida Department of Transportation (2013) and Iowa Department of Transportation(2005) have identified the main types of available payment methods for environmental hazard controlling as 'lump sum payment in equal basis', 'lump sum payment depending on the completion of a work item', 'using a unit price' and 'including in the contract price'. Several examples for deferent payment methods proposed by the existing literature can be elaborated as follows.

As declared by the United States Department of Agriculture (2011), pollution controlling of road construction project is considered as a pay item in the contract. According to their specifications, there are 3 main methods of payment. As the first method, payment for each item is made at the contract unit price of that item where unit prices are assigned. In the second method, payment is made as the work proceeds considering the expenses, where a lump sum price is established in the contract. Third method is used for some items of work where lump sum prices are assigned in the contract. Here, the payment is provided in equal amounts on pro-rata basis in each month. Further, Iowa Department of Transportation (2005) suggests payment for most of the water pollution control items to be paid depending on a unit price rate.

However, a properly defined way of measuring and paying method for environmental hazard controlling items does not exist in extent literature. Further, no literature popular for identifying ways and means for proper control of environmental hazards through allocation of funds and due payment for the contractor in road construction projects. Thus, Figure 1 depicts the framework developed by reviewing the extent literature for studying the same.

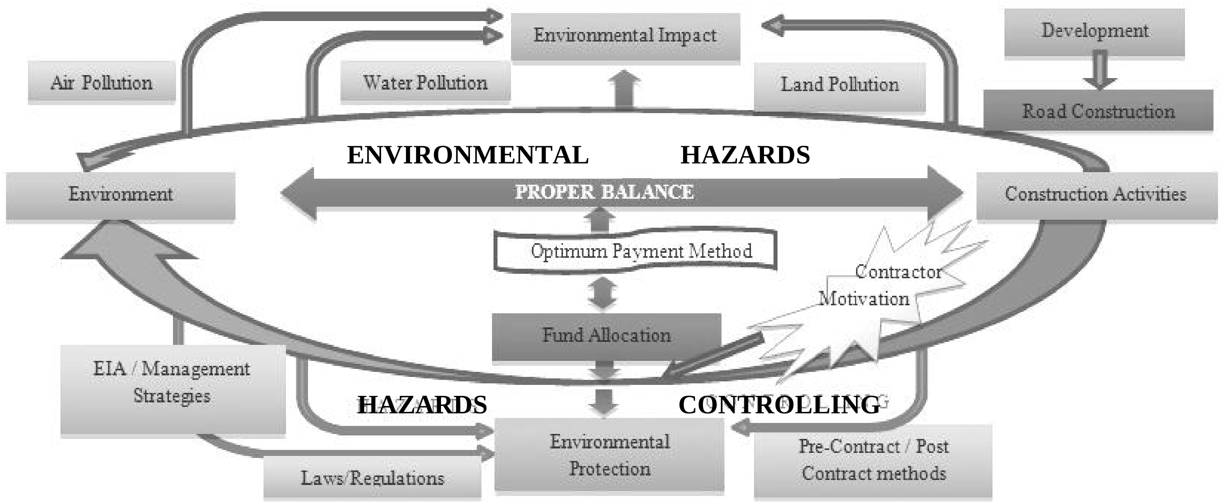

Figure 1: Conceptual Framework for Establishing Correlation between Environmental Hazard Controlling and Monetary Aspects

According to the conceptual framework in Figure 1, construction activities are the interconnecting aspects of environment and the development which is depicted through the curved arrow. The upper arrow replicates the path where the environment is harmed with the construction activities whilst the lower arrow imitates the path where the proper balance is achieved. Activities executed in road construction projects, directly involve in generating environmental hazards. These hazards lead to impacts on the environment mainly in terms of land, water and air pollutions. Conversely, on the other path, environmental hazard controlling methods are followed. For proper execution of work, a fund allocation is done. As this may lead to motivation of the contractor, effective environmental protection can be expected. However, literature review has consistently shown that many methods of payment for contractor exist in construction industry. Therefore, in order to achieve the proper balance between the environment and development, the optimum method of payment to the contractor should be identified. The next section elaborates the research methodology adopted to study the optimum payment evaluation method of contractor's due payment for controlling environmental defilement in road construction projects in Sri Lanka.

3. RESEARCH METHODOLOGY

As the literature revealed, the impacts and extent of hazard mitigating methods vary according to the characteristics of the project. Thus, case study was selected as the research strategy for this study due to the required in-depth investigation into the project specific construction activities and environmental hazards to identify the optimum payment method for contractor's due payment. According to Yin (2003), when the boundaries between a phenomenon and the context are not clear, a case study offers an in-depth investigation into a contemporary phenomenon in its real-life setting. Therefore, a qualitative approach has been embraced for in depth investigation of the selected projects. Further, as the ultimate expectation of the study was to identify the optimum payment method for the contractor under each environmental hazard controlling method, a quantitative approach had been adopted to provide a measurable image.

Therefore, embedded multiple case study design under mixed research method had been selected as the research design. While designing the case study, 'the road construction project' was selected as the unit of analysis and three cases were selected. The three projects (projects A, B and C) were selected including projects A and C adopting traditional procurement method and project B adopting design and build procurement method. Details of the selected cases are provided in Table 1. Data collection was done in two stages. At the initial stage, interviews, direct observations and documentation were used as data collection techniques and at the second stage, a questionnaire survey was used for the data collection. Interviews were conducted with five professionals from each project, who are aware of both environmental and monitory aspects of the project to identify possible environmental hazards, hazard controlling methods and payment methods for the contractor. These interviewees were professionals such as Environmental officers, Quantity Surveyors and Project Managers. The quantitative data has been collected through questionnaire survey with the same sample within each case separately to recognize the optimum payment method for the contractor which provides maximum controlling of environmental hazards on each identified hazard controlling method. Case study data has been analyzed with content analysis and cognitive maps while questionnaire findings were analyzed through RII (Relative Important Index) method.

Table 2: Details of the Cases

Case	Case A	Case B	Case C
Type	Road improvement	Road improvement	New construction
Project Cost (Rs.)	1.2 billion	1.8 billion	45 billion
Project Duration	20 months	18 months	36 months
Stage Completion % up to month of August 2014	82% completed	28% completed	68% completed
Procurement method	Traditional Method	Design and build	Traditional Method
Payment Method	Measure and pay	Lump sum	Measure and pay
Scope	Total length of the road is 31km and carriageway width is 6.2 m for each side 31km long road	A linking road which makes a short cut and its length is about 16.7km	2km embankments, 2km cut sections and 4.9km viaducts construction
Location	Mannar; lagoon area	Eheliyagoda	Colombo District
Physical condition	Dry, hot and windy Very less population	Rainy and wet climate. Less populated	There are many soft grounds
Particulars of projects	Located near preservation.	Area is supplied with water by a community water supply system	Site requires lots of soft ground treatments

4. CROSS CASE ANALYSIS AND FINDINGS

Cross case analysis was carried out on the main areas indicated in the developed frame work which include: road construction activities; environmental hazards; hazard mitigation and fund allocation for environmental hazard controlling and payment to the contractor. These are discussed in detail in the following sections.

4.1. ROAD CONSTRUCTION ACTIVITIES IN THE SELECTED CASES

As revealed by the empirical study, most of the construction activities identified found to be common to the selected three cases. Those main activities include: site survey and investigation; site clearance; establishing construction camps; demolition of structures; excavation, rock blasting and disposal; sub base construction; base course construction; laying of wearing course; material transportation; construction of structures; mobilization of heavy plants to the site could be identified. These main road construction activities were very much similar to the construction activities elaborated by Chaudhary (2011) and Local Government of UK (2013) discussed in literature review.

4.2. ENVIRONMENTAL HAZARDS OCCURRED UNDER EACH CONSTRUCTION ACTIVITY

Although the construction activities are common to each selected case, when it comes to the involvement in occurrence of environmental hazards, several similarities as well as differences could be notified. Main environmental hazards highlighted through the cross case analysis include: loss of trees; interference with services; dust nuisance; noise; vibration; water pollution from sanitary and other wastes; reduction in land quality on abandonment; erosion/sediment deposition; interference with natural drainage patterns; reduction in water quality; oil spillage; reduction of rare/endangered species by trapping and temperature differences. The cognitive map which elaborates the relationships of road construction activities and environmental hazards are presented in Figure 2. According to the Figure 2, it is obvious that some construction activities individually contribute to several environmental hazards. Additionally, it could be verified that same environmental hazard can be arisen under several construction activities. Therefore, it becomes apparent that environmental hazards and construction activities are interrelated in a manner where disparity is difficult.

Other than the empirical findings through interviews, observations had revealed several environmental issues in the cases. In ***case A,*** where the road is spread out through a forest area, there is a tendency of disturbance to the natural lives of the animals. As it could be observed in ***case B***, the construction work includes using materials such as asphalt and chemicals used for rock blasting which had been identified as a cause of harmful gases which is an environmental hazard in literature review. Further, inconveniences for the public due to muddy surrounding which is a result of improper handling of disposal material like soil is another environmental hazard not highlighted through the interviews. In ***case C*** the site is located near the river. In order to make the construction work easier, the contractor has acquire a part of the river with the use of a coffer dam. That space is being used as a working space which assists the bridge construction. It is obvious that it becomes harmful for the bio-diversity as it interferes with aquifers. Further, as it could be revealed, there is evidence of the area near the river being under a danger of getting flooded due to the reduction of the capacity in river by embankments getting narrowed by the temporary construction works. In summary, the main hazards that could be identified within the selected cases include harm to bio-diversity; solid and liquid wastes; oil spillage; destruction to utility services, drainage facilities and structures; vibration; noise; dust, air pollution; temperature differences; reduction in water quality; erosion; interference with natural drainage patterns. Most of these hazards can be identified commonly within the three cases.

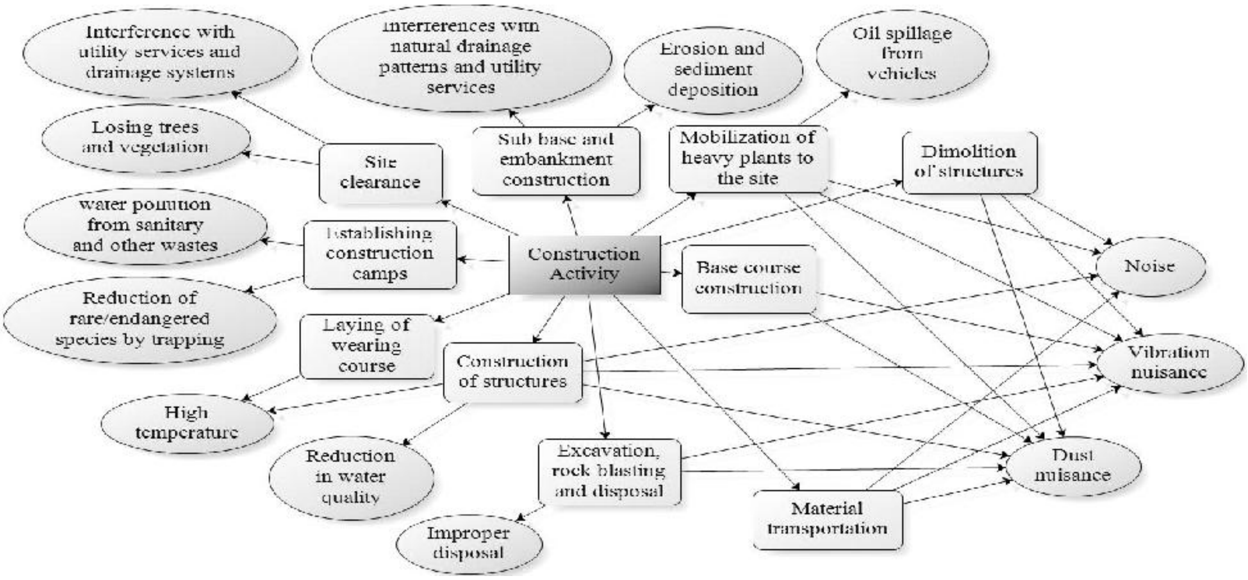

Figure 2: Cognitive Map which Elaborates the Relationships of Road Construction Activities and Environmental Hazards

4.3. ENVIRONMENTAL HAZARD MITIGATION METHODS FOLLOWED IN THE SELECTED CASES

There were several similarities as well as differences in the ways of addressing environmental hazards within each case. Each elimination method followed in the selected cases under identified environmental hazards had been recognized (see Table 2) through interviews as well as documentary survey. According to the empirical data, it was revealed that the magnitudes and effects of environmental hazards differ according to the case characteristics which has affected on environmental hazard controlling being highlighted within the case. However, most of the activities addressed within the cases were found to be common. It is obvious that some of the hazard mitigation methods are to be followed in all the selected cases due to the similarities in construction process.

4.4. FUND ALLOCATION FOR ENVIRONMENTAL HAZARD CONTROLLING AND PAYMENT TO THE CONTRACTOR

As illustrated in Figure 2, there is an obvious relationship among the construction activities and environmental hazards. According to the empirical data, it could be identified that different ways of fund allocating have been followed within the selected cases for addressing these environmental hazards. The empirical data revealed that the cases have been funded for controlling environmental hazards mainly under O/H (overhead), P (profit), provisional sums (PS), as work items and under a main work item. Therefore, it becomes obvious that the environmental hazard controlling costs for the contractor are covered through the contract sum of the project.

Furthermore, the fund allocation within the cases can be categorized under **direct funds** where the payments are done as PS, lump-sum or under unit rates. The direct funding in the selected cases can be highlighted through the mitigation methods adopted within the project such as; 'top soiling' used in case A, 'constructing retaining walls'' in case B and 'chemical blasting' in case C where the payments are done under the work item. Further, **indirect funds** can be identified as O/H, P and covered under a main work item. 'Using secondary containers to store oil' in case A, 'using sand sacks to cover blasting areas' in case B and 'moistening transported material such as ABC' in case C can be identified as some of the examples from the selected cases for indirect funding. Additionally, hazard controlling methods where **no fund** is allocated within the project could also be identified in case A where they had initiated environmental friendly activities going in line with ISO (International Standardization Organisation) 14000 standards. According to the case studies, it was revealed that some unexpected hazard controlling methods had been funded under **variations or project contingencies** such as constructing of bypass roads to avoid unexpected water level increments in case A.

Four types of payment methods cold be derived from the empirical findings named as; Payment methods A, B, C and D which are indicated as existing payment method in Table 2 and further described next. According to the empirical findings, **payment method A** describes the work items where the payment is done according to **a unit rate**. It becomes obvious that according to the sorted out list of hazard controlling methods which are paid under payment method A, mainly each work has significance in providing a basis to be measured. Therefore, it can be identified that where a measurement is directly visible, this payment method has been adopted. For an example, the controlling methods such as using hammers and excavators as alternatives to vibrator machines; backfilling pits after tree removal; top soiling and turfing can be paid considering the area of the work. Further, the methods such as planting shrubs; embankment shrubs; planting interchange palm trees; foliage plants and planting informal hedge trees can be measure either by numbers or linear meter. Additionally, according to contractor Quantity Surveyor (QS) of case A, if the hazard can be identified, justified and quantified, in the initial stage, it can be included under a unit rate. However, System Management Engineer of case A stated that; *"other methods are much effective than including as rate. Most of the hazards are unforeseeable. If the contractor is well experienced, it can be effective for him. If the contractor couldn't cover the cost within the budget, he may not try to control the environmental hazards"*.

According to the **payment method B**, a specified item is covered under a **PS** which is paid to the contractor considering the actual costs. The research findings revealed that the work items such as maintaining standards and conditions of waste disposal; constructing temporary structures; rehabilitating utility services; repositioning utility services; design changes on utility services locations and identifying the species that can be affected by construction activities and planning to mitigate the damage are paid under this payment method. Normally, conflicts can occur if a payment is not allocated for environmental issues which are foreseeable but the occurrence is unpredictable. The empirical findings reveal that in order to avoid such circumstances, payment methods like PS can be followed. Further, as revealed by Contractor QS of case B, provisional sum is better as it deals with the actual cost during the execution of the works. Moreover, Consultant QS case B stated that; *"if the cost of a controlling method is included in the rate, the contractor can implement it or neglect it as no one notices. But if it is given as a provisional sum, then it can be forced to be done. And also it is paid if only required. If it is given as a lump sum, then even if the work is so small, the full payment has to be done"*.

For some items of work where fixed amounts are assigned in the contract, payment is provided in **equal amounts on pro-rata basis** in each month as identified in **payment method C**. According to the empirical findings, mainly the controlling methods such as conducting base line survey within the project in order to monitor the work generating waste; establishing fuel stations; using an environmental emergency preparedness plans which describe how to mitigate the impact on environment are paid under this payment method. However, the controlling methods are identified as paid under this method as well as under the payment method of D. As revealed by Residential Engineer of case C; *"monthly payment under a rate is more effective as it can be used to influence the contractor by monitoring him against it. If there is something like a check list, then the contractor is forced to do the work. If the payment is reduced, then he knows what he missed to conduct. The specification should include a breakdown with percentage indicating the items to cover by the payment"*. Therefore, it can be argued that the payment method C becomes more suitable when there are work items to be paid a certain amount periodically during project duration. However, it was revealed that the limitation that can be found in lump sum payment is estimating the amount. Only a well experienced person can predict a sufficient amount at the beginning of the project.

As revealed by empirical findings, the **payment method D** is used where the cost of the item is included under a certain main item in the contract. The payment for the main work item can either be given as a PS or a unit rate. Work items such as; establishing separate disposal yards; using water bowser to spray water; using the minimum area to excavate pits when removing trees; cutting trees piece by piece can be categorized under this payment method. It was evident that the items where a direct expense cannot be determined without the assistance of main items are categorized under this payment method. However, Contractor Project Manager (PM) of case A revealed that; *"if the mitigation cost is included in the BOQ* *rate, it might be difficult as the expected impacts vary with the perspectives of a person. It cannot be properly measured. If the hazard controlling is included under a rate and if the contractor failed to implement it, an amount can be deducted from the payment. That will be disadvantageous for the contractor. Therefore, it is better if there is a separate item. Then there is no risk of losing the payment for the completed work".* Next, the optimum payment method for environmental hazard controlling process is discussed.

4.5 OPTIMUM PAYMENT METHOD FOR ENVIRONMENTAL HAZARD CONTROLLING PROCESSES

In order to find the most effective payment method, a questionnaire survey was conducted usng the same participants of the interviews and analysed the survey data seperately for each case. The main intention of conducting the survey was to summarize the environmental hazards of each project found through the inteviews, observations and documentary survey and select the most effective payment evaluation method applicable if a proper control of environmental hazards to be obtained. The questionnaire was distributed in order to prioritize the payment method for hazard controlling considering the effectiveness. As the characteristics as well as environmental hazards of the cases were found to be different to each other, 3 different questionnaires had to be developed. Relative Important Index method was used to rank the payment methods under each environmental hazard elimination method. Analysis of the quanititative data was done for each case seperately without aggregating the data. The summarized optimum payment methods under each environmental hazard controlling method of the three cases are tabulated in Table 3.

The payment methods highlighted in bold letters owns the highest RII value when several methods available. Table 3 disclosed that according to the analysis, the optimum payment methods of the contractor for controlling environmental hazard in the selected cases can vary from the existing method. Moreover, it could be identified that certain controlling methods do not contain any optimum payment methods while the second best option of certain payment methods does not reach the expected effectiveness level of the next best payment method.

Table 2: Optimum Payment Method(s) for Hazard Controlling Process

	Hazard controlling method	**Payment method**			
		Optimum method(s)	**Next best method(s)**	**Moderately effective method(s)**	**Existing payment method(s)**
CASE A	Using the minimum area to excavate pits when removing trees	D			D
	Cutting trees piece by piece	D			D
	Backfilling pits after tree removal	A	D		A
	Top soiling	A/D			A
	Identifying the species that can be affected by construction activities and planning to mitigate the damage	B/C			B or C
	Providing sanitary facilities	C			D
	Maintain standards and conditions of waste disposal	C	B		B
	Conducting base line survey within the project in order to monitor the work.		B/C		C
	Advising labourers on disposing litter like polythene in a proper manner.			D	D
	Following criteria to properly dispose the waste.			D	D
	Establishing fuel stations	C			C
	Using secondary containers to store oil.			D	D
	The labours are instructed to use a tray to avoid spillage				D
	Using environmental emergency preparedness plans		C		C
	Rehabilitate utility services	B		C	B
	Cleaning the drainage paths and channels	A		B	A
	Design changes on utility services locations	B		C	B
	Covering generator and crusher plant with rubble mountings	D		C	D

	Hazard controlling method	**Payment method**			
		Optimum method(s)	**Next best method(s)**	**Moderately effective method(s)**	**Existing payment method(s)**
	Following standards when using vehicles	D			D
	Proper monitoring when demolishing structures	D	A		A
	Using hammers and excavators as alternatives to vibrator machines	A	D		A
	Chemical blasting	A	D	C	A
	Measuring and monitoring noise levels			C	A
	Establish separate disposal yards		C/D		C
	Proper disposal of excess asphalt	D			D
	Using shoring	A	D	B/C	A
	Using bitumen bowser as an alternative for manual bitumen spraying	D		B/C	D
	Using water bowser to spray water	C	B/D		C
	Spraying water when demolishing structures	D		C	D
	Constructing asphalt plant to emit the air into a covered water bay		D	B	D
	Turfing	A			A
	Rip rap protection for embankment slopes	A			A
	Constructing lead away structures	A	B		A
	Construction of concrete structures	A			A
	Constructing temporary structures	B	D	C	B
CASE B	Changing the design by shifting the centre line		A/B	D	A
	Providing sanitary facilities	B	A/C	D	D
	Establish separate disposal yards	B	A/C/D		D
	Rehabilitate utility services	B		C/D	B
	Repositioning utility services	B			B
	Chemical blasting	A		B/C/D	A
	Using sand sacks to cover blasting areas		C/D	A/B	D
	Using steel safety nets around blasting areas		B/A/D	C	D
	Proper maintenance of vehicles	B	A/C	D	A
	Maintaining noise level less than 20,000Hz.			C/B/D	D
	Using polythene layer to cover the surface of transported material like ABC	C	B	D	D
	Using tar polythene layer when demolishing structures			B/C/D	D
	Spraying water when demolishing structures	C		B/D	D
	Treating water used for concreting before releasing to the environment	C	B	D	D
	Constructing retaining walls and protection walls	A	B	C/D	A
	Turfing	A		B/C/D	A
	Constructing lead away structures	A	B	C/D	A
	Using polythene layer to cover up erodible areas	C		B/D	D
	Constructing earth drains	A	B	C	A
	Constructing concrete U drains	A	B	C	A
	Top soiling	A		B/C/D	A
	Rehabilitate the old culvers	C	B	A	D
CASE C	Planting shrubs, embankment shrubs, turfing and the like	A/B	C		A
	Planting interchange palm trees	A/B	C	D	A
	Planting interchange foliage plants	A/B	C	D	A
	Planting informal hedge trees	A/B	C	D	A
	Planting informal hedge shrubs	A/B	C	D	A
	Providing sanitary facilities	D		B/C	D
	Rehabilitate utility services	B	D	C	B
	Covering generator with cement blocks	B	A/C	D	A
	Change the machinery when not suitable to work			B/D	D
	Chemical blasting	A	D	B/C	A

Hazard controlling method	Payment method			
	Optimum method(s)	Next best method(s)	Moderately effective method(s)	Existing payment method(s)
Checking and monitoring the status of vehicles	B/C	D		A
Conducting a crack survey	B/C			D
Using ITI technique to monitor vibration	C	B		A
Establish separate disposal yards	C/D	B		A
Using dust barriers	D	A/B	C	D
Using water bowser to spray water	B/D		A/C	D
Moistening transported material like ABC	D	B		D
Following safety regulations		B/C/D	A	A
Covering asphalt while transporting	D		B/C	D
Using a cooling system when placing concrete	D		B/C	D
Stone masonry slope protection	A	B	C	A
Cut slope ground cover	A	B	C	A
Diverting the drain systems	B	C		D
Reconstructing drain systems	B/C			D

5. CONCLUSIONS

For this study, only the activities where the direct involvement of the contractor was visible were taken in to consideration and the environmental hazards within the selected cases had been identified. The identification mainly included with the activities such as site clearance; establishing construction camps; demolition of structures; excavation, rock blasting and disposal; sub-base and embankment construction; base course construction; laying of wearing course; material transportation; construction of structures and mobilization of plants to the site and machinery usage. However, the selected cases revealed that the activities such as borrow pit establishment which had been identified by Chaudhary (2011) as construction activities in road projects are not directly conducted by the contractor due to the involvement of the subcontractors. Therefore, taking such activity in to consideration for the study had to be evaded. The empirical data revealed common as well as project specific environmental hazards in road construction projects under the execution of the selected construction activities. Environmental hazards such as loss of trees; interference with services; dust nuisance; noise; vibration; water pollution from wastes; interference with natural drainage paths; reduction in water quality; oil spillage; reduction of rare species by trapping and temperature differences were identified within the selected cases. Further, the hazards such as gas emission through asphalt which had been addressed as an environmental hazard by Chen *et al.* (2000) have not been recognized within the case studies.

Subsequently the hazard controlling methods followed in the construction industry for achieving proper control of environmental hazards in road construction were discovered. However, the hazard mitigation methods identified by Chaudhary (2011), such as 'supervising archaeologists for excavation to avoid any damage to the relics and objects' had not been addressed within the selected cases. The case study findings were then used to identify the methods of fund allocation in road construction projects for environmental hazard controlling in Sri Lankan context. Accordingly, four main fund allocation methods for environmental hazard controlling in road construction projects could be revealed as direct fund allocation, indirect fund allocation, non-fund allocation and variations or contingencies. Even though U.S. Department of Transportation-Federal Highway Administration (1997) has identified that the fund allocation for environmental hazard controlling can be given as a percentage of the total contract sum, the case study revealed it becomes impracticable to do the allocation accurately due to the difficulty in identifying the costs independently.

The main methods of payment for the contractor for environmental hazard controlling include; (A)-payments where a unit price is assigned; (B)-payments where a provisional sum is established in the contract; (C)-payments where fixed amounts are assigned in the contract and (D)-payments made along with some main work item in the contract.

Further, with regard to the outcome of the study recommendations could be provided for selecting the optimum payment method considering the features of the hazard mitigation method used. Thus, the payment method A becomes more suitable for the mitigation methods where a visible measurement is involved. When the cost of a mitigation method is not acutely predictable but can be roughly estimated, method B becomes most suitable. If the mitigation method occurs repetitively and periodically under a certain cost, method C can be recommended. The method D becomes more effective where the cost of the mitigation method is not directly visible. Table 2 summarizes the aforementioned four payment methods selected as the optimum payment method against each environmental hazard controlling mechanism.

Hence, it could be suggested that these findings could be important for bidders/estimators mainly in the pre-contract stage where an effective control of environmental hazards is expected through the due payment for the contractor in a road construction project.

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