The Secondary Impact of Variation Orders: A Qualitative Analysis

by
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DECLARATION

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ABSTRACT

Variations made to the original scope of works are part of construction projects. Varying the scope of works has a cost and time impact, also referred to as the direct impact of V.Os. The direct impact is generally well understood by both contractor and client. Over and beyond the direct impact, V.Os also have a secondary impact on a project. Unlike the direct impact, the secondary impact appears not to be well recognised and managed by South African contractors.

The principal aim of the research is to understand the secondary impact of V.Os. Based on this understanding, it then aims to give guidelines and recommendations to assist contractors to manage the secondary impact of V.Os. A variety of methods are used in this thesis. It includes literature review, questionnaire surveys and interviews.

The qualitative analysis consists out of a pre-investigation which provided insight on how contractors deal with the secondary impact of V.Os. The JBCC and the GCC were analysed, which provided an understanding on how the contract deals with V.Os and its secondary impact. A definition was developed for the secondary impact. Key terms in the definition were analysed that assist with its understanding. Through means of a detailed literature review of relevant literature, a collection of delay and disruption events were identified that could be triggered by V.O. Studies are presented that proves V.Os cause a loss of productivity on construction projects. A comprehensive and systematic overview was given that explains the secondary impact of V.Os on construction projects. The main events discussed in the overview were validated for the South African contractor through means of interviews conducted with 2 contractors and questionnaires sent out to 44 individuals.

It was found that in general, some South African contractors have accepted the secondary impact as part of construction projects. Contracts do not explicitly consider the secondary impact of change, nor does it provide clear guidelines as to how it should be addressed by the parties in contract. It was concluded that the secondary impact is unforeseen loss of productivity on the unchanged work due to the synergistic effect of the disruption caused by a multitude of V.Os (Jones, 2001, Hanna, 2004 and Ibbs, 2005). The secondary impact is an impact on human factors such as morale, self-esteem, motivation and the cause of difficult working conditions. It is a disruption that prevents project activities and events from starting and ending at the planned time and also prevents contractors from executing activities as

planned. The cost due to the secondary impact is a combination of increased labour cost and also the increased cost of completing the unchanged work.

It is clear that to pro-actively manage the secondary impact of V.Os will require the cooperation from the contract, the contractor and the client. In short contractors will need to understand the secondary impact, be aware of and prepared for delay and disruption events, keep record of the impact, monitor and control labour productivity and maintain a good relationship with the client.

OPSOMMING

Veranderinge aan die oorspronklike omvang van die werk is deel van konstruksie-projekte. Wanneer die omvang van die oorspronklikke werke verander word, het dit ‘n tyd en koste implikasie tot gevolg. Dit word na verwys as die direkte impak van veranderringe. Die direkte impak word oor die algemeen goed verstaan deur beide die kontrakteur en die kliënt. Bo en behalwe die direkte impak , het *variation orders* (V.Os) ook 'n sekondêre impak op 'n projek. In teenstelling met die direkte impak, word die sekondêre impak waarskynlik nie goed erken en bestuur deur die Suid-Afrikaanse kontrakteurs nie.

Die hoofdoel van die navorsing is om die impak van sekondêre V.Os. te verstaan. Op grond van hierdie begrip, het dit ten doel om riglyne en aanbevelings te gee wat kontrakteurs kan help om die sekondêre impak van V.Os. te bestuur. 'n Verskeidenheid van metodes word in hierdie tesis gebruik. Dit sluit in literatuurstudies, vrae-lys opnames en onderhoude.

Die kwalitatiewe ontleding bestaan uit 'n voor-ondersoek wat insig verskaf oor hoe kontrakteurs die sekondêre impak van V.Os hanteer en beleef. Die JBCC en die GCC is ontleed, met die doel om te verstaan hoe die kontrak V.Os en hul sekondêre impak hanteer. 'n Definisie is ontwikkel vir die sekondêre impak . Sleutelterme in die definisie is ontleed wat help met die begrip . Deur middel van 'n omvattende literatuuroorsig van relevante literatuur, is 'n versameling van die vertraging-en ontwrigtings gebeure geïdentifiseer wat deur V.Os veroorsaak kan word. Studies wat bewys dat V.Os 'n afname in produktiwiteit van konstruksie-projekte veroorsaak, is geraadpleeg . 'n Omvattende en sistematiese oorsig word gegee wat die sekondêre impak van V.Os op konstruksie-projekte verduidelik. Die belangrikste gebeurtenisse wat in die oorsig beskryf word, is bekragtig vir die Suid-Afrikaanse kontrakteur deur middel van onderhoude wat met 2 kontrakteurs gevoer is en vraelyste wat uitgestuur is aan 44 individue.

Daar is gevind dat in die algemeen, aanvaar sommige Suid-Afrikaanse kontrakteurs die sekondêre impak as deel van konstruksie-projekte. Kontrakte bevat nie duidelike riglyne wat verduidelik hoe kontrakteurs en kliënte die sekondêre impak van V.Os moet hanteer en aanspreek nie. Daar is tot die gevolgtrekking gekom dat die sekondêre impak ‘n onvoorsiene verlies van produktiwiteit op die onveranderde werk is. Dit is die gevolg van die sinergistiese effek van ontwrigting wat veroorsaak word deur 'n menigte van V.Os (Jones, 2001 , Hanna , 2004 en Ibbs , 2005) . Die sekondêre uitwerking is 'n impak op menslike faktore soos moraal, selfbeeld , motivering en die oorsaak van die moeilike werksomstandighede . Dit is 'n

ontwrigting wat verhoed dat die aktiwiteite en gebeure van die projek begin of eindig op die beplande tye. Ook verhoed die sekondêre impak dat die kontrakteurs aktiwiteite uitvoer soos wat vooruit beplan was. Die koste as gevolg van die sekondêre impak is 'n kombinasie van verhoogde arbeidskoste en ook die verhoogde koste om onveranderde werk te voltooi.

Dit is duidelik dat die samewerking van die kontrak, die kontrakteur en die kliënt noodsaaklik is om die sekondêre impak van V.Os op ‘n pro-aktiewe wyse te bestuur. Kortliks, vir kontrakteurs om die sekondêre impak te bestuur, het hul nodig om dit te verstaan, om bewus te wees van en voorbereid te wees vir die vertraging-en ontwrigtings gebeure wat plaasvind, rekord moet gehou word van die impak, die produktiwiteit van arbeid moet gemonitor en beheer word en 'n goeie verhouding met die kliënt moet nagestreef word.

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Chapter 1

INTRODUCTION

1.1 Background

Variations made to the scope of work are part of a construction project. At time of tender, both contractor and client are aware of the fact that the works which are tendered for at present, may and will be varied when construction commences. The general conditions of construction contracts permit clients to vary the works when necessary and appropriate to do so. In turn, clients must fairly compensate the contractor for implementation of variations. In addition, the general conditions also oblige contractors to execute duly, the desired variation.

Acknowledging the fact that construction contracts allow for variations to be made and that circumstances which require variations are likely to arise at time of construction, we cannot deny the underlying truth in the great Anglican theologian Richard Hooker's statement that *"change is not made without inconvenience, even from worse to better"* (Quotations from Richard Hooker, 1755). Many researchers have reported variation orders (V.Os) to cause conflict between contractor and client, to cause cost overruns and time overruns. It is commonly said that the claim industry developed thereof.

Hence, contractors resort to legal measures in an attempt to acquire compensation for damages incurred due to variations made by the client. However, it is well known that a project's contract value and duration would increase where variations are present, simply because most variations have a cost and time value to it. In addition most clients honour their contractual responsibilities and do compensate contractors for it. How then is it that conflict still occurs and cost and time overruns take place?

Although there is no real empirical evidence to support this conclusion made by previous researchers, they ascribe the cost and time overruns to clients not compensating contractors for the cost associated with the secondary impact of variations (Williams, 2002). Change rarely happens in isolation (Hanna, Camlic, Peterson & Lee, 2004). The disruption caused by a variation made to one task may impact other activities not directly changed through the ripple effect (Hanna *et al.*, 2004). This thesis refers to it as the secondary impact of variations. If the secondary impact of variation orders (V.Os) are not accounted for by means of compensation or mitigated by good management, variations made to a project are being undercosted resulting into issues such as conflict between the contract parties and cost and time overruns (Williams, 2002). The thesis attempts to qualitatively analyse the secondary impact of V.Os on construction projects with the aim to assist the management thereof.

1.2 Research Question

Varying the original scope of works has a cost and time impact, but other than this primary impact what implications do V.Os have and what can be done about it? Differently phrased, what is the secondary impact of V.Os on construction projects and how can it be managed?

Understanding the secondary impact of V.Os would assist better management thereof and would thereby minimise the degree of conflict it creates, minimise cost and time overruns associated with it.

1.2 Research Aims

Initially, the research aimed to quantify the secondary impact of variation orders (V.Os.). However, the secondary impact of change appears not to be as well recognised and managed amongst South African (S.A) contractors as in the case of contractors in the United States of America (USA). According to the conclusions made from a pre-investigation done by the researcher (Appendix D), it appears that South African contractors rarely consider the secondary impact of V.Os on their projects. The main reason appears to be the difficulties involved in identifying, quantifying and proving it. Furthermore, it appears that in general South African contractors have accepted the secondary impact as part of construction projects and rely on other measures to recover damages thereof. The report on the pre-investigation can be found in Appendix D.

Instead of quantifying the secondary impact of variation orders (V.Os) it was decided that a qualitative analysis be done to provide understanding on what it is and how it works, by using South African contractors as a point of reference. The principal aim of the research is to understand the secondary impact of V.Os. Based on this understanding, it then aims to give guidelines and recommendations to assist contractors to manage the secondary impact of V.Os.

1.3 Research Objectives

The thesis has the following objectives:

- Analyse the joint building contracts committee series 2000 principal building agreement (JBCC) and the general conditions of contract for construction works of year 2010 (GCC) to understand how the contract deals with changes.
- Investigate how South African contractors deal with the secondary impact of V.Os through interviews and questionnaires (Pre-investigation, Appendix D).
- Define the secondary impact of V.Os through the existing definition of the cumulative impact.
- Investigate the different delay and disruption events triggered by V.Os.
- Investigate factors that affect labour productivity on construction projects.
- Confirm through questionnaires and interviews the findings of existing literature regarding secondary impacts of variations.
- Give an overview statement of the effects of variations on projects and contractors in terms of a comprehensive and systematic overview based on findings of existing literature.
- Confirm through questionnaires and interviews the findings of existing literature included in the comprehensive and systematic overview.
- Provide recommendations that would assist contractors with the management of the secondary impact of V.Os.

1.4 Research Scope and Limitations

To ensure that the objectives of this thesis are achieved, the scope and limitations of this thesis need to be clarified.

- Firstly, the research considers the South African contractor's point of view.
- Secondly, the research considers civil engineering projects that are delivered through the design bid and build (DBB) project delivery strategy, with specific interest in the construction phase of the project.
- Thirdly, the research does not focus on one specific type of works, such as only civil engineering works or only general buildings works, but considers all works in general.

1.5 Research Design

The method taken by the researcher is twofold. Firstly a qualitative analysis is done, whereby the findings of previous research on the effects of variations are analysed. These are then validated for the South African contractor with the use of questionnaires. The second part of the research is to provide recommendations and guidelines that would assist contractors with the management thereof, based on the increase in the understanding of the secondary impact.

1.6 Research Methodology

A variety of methods were used in thesis:

The concept of varying the works, resides from the construction contract. The contract also governs the manner in which V.Os are to be addressed by contractors and clients. Hence, two general conditions of South African construction contracts namely the joint building contracts committee series 2000 principal building agreement (JBCC) and the general conditions of contract for construction works of year 2010 (GCC), are analysed to provide background on the general rules and regulations concerning V.Os. Where relevant, the potential impact is addressed of the rule or guideline stated in the contract, on the secondary impact of V.Os.

To gain insight on how some South African contractors experience V.Os and its related impacts on projects, a pre-investigation was done. The investigation involved a questionnaire survey and interviews. The purpose was not to reach consensus amongst South African contractors. The investigation answered certain questions relating to V.Os and its impact on construction projects for which the researcher needed to be answered before continuing with the formal analysis of the secondary impact of V.Os. The pre-investigation can be found in Appendix D.

It appears that advances made by the South African construction industry are slow in defining the secondary impact of V.Os. A workable definition is developed for the secondary impact of V.Os through the meaning of the cumulative impact of change as developed by the United States of America's courts and boards of contract appeals.

The definition however simply states what the secondary impact entails. To understand what the secondary impact is, it is necessary to analyse and investigate key terms in the definition for what they are. These terms include the following: delays and disruption, delay and disruption events, productivity and loss of productivity. This was done through means of a detailed review of relevant literature.

Once the key terms in the definition was understood as it is in the construction context, the cause and effect relationships stated in the definition were investigated. The first relationship is between V.Os and productivity. According to the definition, where V.Os are present, productivity suffers. Empirical studies were identified and presented that shows this to be the case. Another relationship stated in the definition and which were investigated is between V.Os and delay and disruption events. As the definition states, the loss of productivity is the result of delay and disruption events triggered by V.Os. By making use of literature review method and interviews, this relationship was explained in a systematic and comprehensive overview. Examples were given, scenarios were discussed and illustrations were made.

To investigate whether the events mentioned in the systematic and comprehensive overview of the secondary impact of V.Os applied to South African contactors, an electronic questionnaire survey was conducted.

Based on the information discussed in each chapter regarding the secondary impact, recommendations are given that could assist with the pro-active management of it. Taking everything into account, a conclusion is made as to what the secondary impact of V.Os is and a collection of recommendations are given that could assist contractors with pro-actively managing the secondary impact.

1.7 The Thesis's Chapter Outline

Chapter 2 Construction Contracts and Changes

A background is given about V.Os and the GCC and JBCC are examined to understand what the South African contract for construction works says about V.Os and its impact.

Chapter 3 Defining the Secondary Impact of V.Os

A definition is developed for the secondary impact of V.Os through the definition of the cumulative impact.

Chapter 4 Analysis of Delays and Disruption

Delays and disruption are investigated.

Chapter 5 Analysis of Causes of Loss of Productivity

Productivity is defined and a collection of delay and disruption events that could be triggered by V.Os are identified.

Chapter 6 Analysis of the Loss of Labour Productivity

Loss of productivity is defined and studies are discussed that prove that V.Os cause loss of productivity.

Chapter 7 Comprehensive and Systematic Overview

By means of literature review and interviews conducted with contractors a comprehensive and systematic overview is given of the secondary impact of V.Os.

Chapter 8 Questionnaire

The main events identified in the comprehensive and systematic overview are tested for South African contractors by means of an electronic survey. The results are discussed.

Chapter 9 Conclusion

The secondary impact of V.Os is concluded.

Chapter 10 Recommendations

Recommendations are given that can assist contractors with pro-actively managing the secondary impact of V.Os.

Chapter 2

CONSTRUCTION CONTRACTS AND CHANGES

2.1 Introduction

Before commencing with the investigation into the secondary impact of variation orders (V.Os), it is deemed necessary to, via the construction contract, first explore what V.Os are and how it should be addressed in practice. After all, the concept of varying the works is a concept that resides from the contract that binds the contractor and the client. The contract also governs the manner in which variations are to be addressed by the parties, although it might differ in practice. Hence, in this chapter the rules and guidelines concerning V.Os are discussed. Two different South African construction contracts are considered, the general conditions of contract for construction works of year 2010 (GCC) and the joint building contracts committee series 2000 principal building agreement (JBCC). Where relevant the potential impact will be addressed of the rule or guideline stated in the contract, on the secondary impact of V.Os.

The secondary impact of V.Os is defined as the unforeseen loss of productivity on the unchanged work due to the synergistic effect of the disruption caused by a multitude of V.Os. The cost due to the secondary impact, also referred to as the impact cost, is a combination of the cost for loss of productivity on unchanged work (increased labour cost) and also the increased cost of completing unchanged work (Jones, 2001). This definition is derived in the next chapter and the secondary impact is analysed in detail in the rest of the remaining chapters.

Firstly, information will be given concerning the different terminologies used in construction contracts, the different change clauses, and the different categories of changes present in construction projects. This is followed by the rules and procedures stated in the JBCC and GCC that focus on the individuals who may issue and accept variations, the valuation process of variations, the process followed when contractors fail to implement variations and the implied warranties of the construction contract.

2.2 Terminology for Changes

Due to the different terminology used in the various construction contracts, changes made during the construction hold different names. For example, the GCC refers to changes as variation orders (V.Os) whereas in terms of the JBCC changes are referred to as contract instructions (C.Is). Other contracts refer to them as change orders (C.Os). The thesis uses the term V.O(s).

2.3 Examples of Change Clauses

As mentioned before, the construction contract provides clients with the right to vary the scope of works during construction phase of the project. This is established by incorporating change clauses in the contract. The change clause in the GCC 2010 is clause 16.3.1 and it states: “If, at any time…..the engineer shall require any variation …… that may be necessary or appropriate, he shall have power to order the contractor to do …..so.” In a similar fashion clause 17.1 in the JBCC states that “The principal agent may issue contract instructions [V.O] to the contractor..”

It is noted that the two contracts phrases the change clause differently, nevertheless the importance of both phrases is the same. That is, it gives power to the engineer/principal agent to vary the works. What can also be derived from the change clauses is that the contracts do not limit the number of variations that may be issued on a project. Provided that the V.O is necessary, appropriate and issued before the certificate of completion it may be issued. Hence the number of V.Os that can be issued on a project is unlimited as long as it adheres to the provisions set by the contracts.

2.4 Types of Changes

There are many and different types of variations that take place during construction. They are however, all changes to the scope of work. The scope of work is understood as the whole of the works as described in the contract documents, and reflected in the offer of the winning contractor resulting from his interpretation of the contract documents (Schwartzkopf, 2004). The legal fraternity has categorised the many and different changes made to the scope of work into three categories, they are directed changes, constructive changes and cardinal changes (Schwartzkopf, 2004).

Directed changes represent the formal V.O issued by the client (Hanna & Swanson, 2007). These are explicitly stated in the contract. In the GCC they are stipulated under clause 6.3.1.1 to clause 6.3.1.5 and for the JBCC stipulated under clauses 17.1.1 and 17.1.2. Examples are addition or deletion of work, increase or decrease in quantities, rectification of discrepancy and errors and omission in contract documents etc.

Constructive changes are largely the result of the actions or inactions of the client (Change Management Best Practices for the Engineering and Construction Industry, 2009). They are not formally directed by the client, and therefore tend to be difficult for clients to recognize as a change (Change Management Best Practices for the Engineering and Construction Industry, 2009). Constructive changes include issues such as, failure to disclose material information, impracticality of performing the work as designed and untimely inspections (Change Management Best Practices for the Engineering and Construction Industry, 2009).

Not all changes in construction projects are legal. According to JBCC and GCC changes may not substantially change the scope of work. Such changes are categorised as cardinal changes and contractors are not obliged to adhere to them (Hanna & Swanson, 2007). The word “substantially” used in contracts is a continuous subject of debate especially within the legal fraternity due to its vagueness. A definition that shed light on the matter is that of Schwartzkopf (2004) who defines cardinal changes as, scope changes which cause the work to be completely different from how it is represented in the original contract.

The thesis addresses the secondary impact of written V.Os. According to the different categories of change, the type of changes covered by written V.Os is directed changes. However, the secondary impact is not exclusive of constructive and cardinal changes. For example, if a direct change causes constructive changes or cardinal changes to occur, their impact on unchanged work is considered part of the secondary impact. This is so, simply because they were the result of the written V.Os that were issued on a project.

2.5 Authority to Issue and Accept Variation Orders

According to Clause 6.3.1 of the GCC and Clause 24.6 of JBCC, variations may be ordered any time before the issue of the certificate of completion. All variations must be issued timeously and must be in writing, clauses 5.9.3 and 6.3.2 of GCC and clause 17.3 of JBCC.

The person appointed by the client or the person who has been authorised by the appointed of the client may issue variations. In terms of the GCC that person can be the engineer or his representative. The engineer's representative is appointed by the engineer himself, through means of a written notice to the contractor. In terms of the JBCC variations may be issued by the principal agent as well as other agents of the project. Hence, the contracts allow for more than one person to issue V.Os to the contractor.

Just like there are specific persons that represent the client who may issue V.Os, there are specific persons that represent the contractor who may receive the variations. The contractor must identify the person who will have the authority to receive instructions and communications from the engineer/principal agent and inform the client accordingly. In terms of the GCC this person is the contractor's site agent (clause 4.12.3) and in terms of the JBCC this person is the contractor's site representative (clause 6.2). Although it is possible for more than one person who represents the client to may issue the contractor with variations, there is one specific person that represents the contractor who may receive the variations.

2.6 The Valuation of Variations and Extension of Time

The contract provides for costs and time associated with variations. The guidelines set out in the GCC and JBCC regarding the valuation of variations and the extension of time (E.O.T) required will now be explained and discussed, separately.

2.6.1 The Valuation of Variations

In general when a variation is issued, its value is calculated by a representative of the client authorised to do so. In terms of the GCC that person is the engineer (clause 6.4.1) and in terms of the JBCC that person(s) is the principal agent in cooperation with the contractor (clause 32.1, clause 17.5). Hence, the contracts allow a specific person, the engineer/ principal agent to value a desired variation. Knowing who the contract holds responsible to value V.Os issued on a project, becomes important since this individual is most likely the one expected to comprehend the secondary impact that variations have in order to include its costs in the valuation.

According to both contracts, the valuation should take into account the character of the work and the conditions under which the work is to be executed, (clause 6.4.1 of GCC, clause 32.2

of JBCC). The priced document better known as the bill of quantities (B.O.Q) is also referred to during the valuation, (clause 6.4.1 of GCC, clause 32.1 of JBCC). It is important to note that the contracts speak of the valuation of the "works", the character of the "work', the conditions under which the "works" is executed in (clauses 6.4.1.1 – 6.4.1.4 of GCC, clauses 32.2.1 – 32.2.4 of JBCC). That per interpretation, the "work(s)" refers to the work the V.O comprises of. No mention is made of possible impacts that the "works" may have on the work not included in the present V.O, not to mention past and future V.Os. Hence, as per interpretation it is expected that in practice valuations of V.Os will generally focus on determining the cost for executing the work the V.O comprises of, which in other words is the primary or direct costs. It is thus highly likely for the costs associated with the secondary impact of V.Os (impact costs), to not be accounted for in practice when valuating V.Os.

After the V.O has been issued and the value has been calculated, the engineer must deliver to both contractor and client, in writing, the valuation of the V.O. If the valuation does not cover all of the expense and loss incurred by the contractor, the GCC and JBCC require certain procedures that must be followed. The GCC requires the contractor to submit a dissatisfaction claim to the engineer. The engineer is then responsible to consult with both contractor and client and make a ruling which he is to submit in writing to both client and contractor. This might resolve the disagreement, however, in the event that it does not and the contractor is still not satisfied, the GCC allows the contractor the right to dispute. The process of dispute will then be followed.

The JBCC on the other hand, requires a couple of steps that should be taken before resulting to something as serious as dispute resolutions. First the contractor is to notify the principal agent that he is not satisfied with the valuation. After the notification, the contractor must submit details of the expense and loss, once he is able to quantify it. The principal agent will either reasonably assess or fail to assess the compensation to be added. If the claim has not been assessed by the principal agent, it is deemed to have been refused. The contractor may than notify the principal agent in accordance to clause 40.1 to resolve the disagreement, and if not resolved, the notice will be deemed to be a dispute and follows the process thereof.

It is evident that both contracts make provision for instances where the original valuation of the variation did not consider all expenses resulting from the variations made. Earlier it was derived that the valuation of V.Os rarely includes impact cost due to the secondary impact of V.Os. It is therefore not strange that contractors may disagree with the original valuation made by the engineer/principal agent. Hence, by means of the provision it is expected that contractors could recover damages due to the secondary impact of V.Os on a project. However, by further interpretation of the provision, if the contractor is to seek damages due to this provision, he has to know what damages the V.O(s) will cause and how much it will cost. This can be difficult since the secondary impact per definition cannot be ascribed to one individual variation nor is it foreseeable at the time V.Os are issued (see Chapter 3). Hence, even though the contracts make provision for contractors to disagree with the original valuation, the requirement attached to the provision can restrict contractors from being compensated for expense and losses due to the secondary impact of V.Os.

On the whole then, the value of V.Os is calculated by the client's representative who can be the engineer, principal agent or the representative of the principal agent. This person ought to understand the secondary impact of V.Os in order to include it in the valuation. By interpretation it appears as if the valuation of V.Os primarily focuses on the direct costs and neglects possible impact costs. Contractors have the right to reject the original valuation if they are not satisfied with it. They however are expected to give an estimation and proof of the amount they feel the V.O will costs to implement. This requirement makes it difficult for contractors to negotiate expense and losses due to the secondary impact of V.Os because it is unforeseeable and therefore difficult to quantify. It can be assumed that in practice it can be difficult for both parties to effectively address expense and losses resulting from the secondary impact of V.Os.

2.6.2 The Extension of Time

The GCC and the JBCC both allows the contractor the right to a revision made to the date of practical completion in the event that the V.Os were the cause of the critical delay, clause 5.12 of GCC and clause 29.2.3 of the JBCC. The GCC does not elaborate much on the process that is to be followed however, by interpreting clause 5.12 the contractor is required to issue a claim. The JBCC on the other hand, requires specific steps that should be taken before the contractor issue a claim.

According to clauses 29.4.3 and 29.5 of the JBCC, the contractor should first notify the principal agent of its intention to claim for the extension of time before proceeding with a formal claim. The contractor will motivate the extended period claimed and include the calculation thereof. The principal agent shall grant in full, reduce or refuse the working days claimed, clause 29.7. If agreement cannot be reached the contractor may notify the principal agent to resolve the disagreement, clause 40.1. If still not resolved, the notice will be deemed to be a dispute and follows the process thereof, clause 40.2. In all this, the JBCC holds the contractor responsible to take reasonable steps that would avoid delays, clause 29.4.2. Hence, the contractor has the responsibility to claim for a revision to be made to the original project completion date, in the event that a V.O causes a critical delay.

Different to the process of the *valuation of V.Os* which focuses on the impact of individual V.Os; the process of awarding an *extension of time* (E.O.T) is not confined to the impact of an individual V.O on the completion date of the project. Clause 29.4.3 of the JBCC for example, requires the contractor to notify the principal agent about a delay within 20 working days after the contractor became aware of the potential delay. A delay could happen after a series of V.Os have been issued, in which case the synergy of the V.Os caused the delay. If instead, clause 29.4.3 of the JBCC stated that the contractor must notify the principal agent about potential delays at the time a V.O is issued, it would not be possible for a contractor to receive an E.O.T. for a delay caused by V.Os. For the mere reason that the delay was the result of a series of V.Os and not the result of one V.O in particularly. Fortunately the clause does not state this, making it possible for an extension of time (E.O.T) to be awarded to the contractor in the event that V.Os caused a critical delay. As per the definition, delays form part of the secondary impact of V.Os. From these interpretations it should be less difficult to be compensated for a delay caused by V.Os than it is to be compensated for expense and losses incurred due to V.Os.

2.7 When Contractors Fail to Implement V.Os

Although contractors are obligated by contract agreements to implement V.Os (clauses 4.1.1, 4.2.1 and 6.3.1.6, of GCC and clause 17.2 of JBCC) there might be instances where the contractor fails to honour his obligation. Both JBCC and the GCC allow the client the right to: 1) employ other parties to give effect to the contract instruction and recover expense and loss from the contractor, 2) or terminate the contract. Different from the GCC, the JBCC requires the principal agent to first notify the contractor to proceed with the variation allowing five working days to do so before resulting to the steps stated above.

Judging from the heavy consequences that arise from not implementing a variation as it is desired from the client and his representative, it should be rather rare for contractors to refuse to implement a desired variation.

2.8 Implied Warranties and Duties

In every contract there are certain warranties which are not defined in the terms of contract but are implied (Schwartzkopf, 2004). The warranties implied for the construction contract as stipulated by Schwartzkopf (2004) in his book "Proving and Pricing Construction Claims" are:

1. Implied warranty of the adequacy and sufficiency of the plans and specifications provided to contractor by client.
2. Implied warranty held by the client that materials are fit for their particular purpose.
3. Implied duty of the client to provide superior knowledge to the contractor. This would be knowledge that could assist the contractor to minimise impact on cost, schedule and performance if it was brought under his attention.
4. Implied duty of the client to act with reasonable diligence when issuing V.Os.
5. Implied warranty of the client to not hinder the performance of the contractor by intentionally delaying procedures.

Hence, even if the GCC and JBCC do not explicitly state the above listed warranties it is implied.

2.9 Chapter Summary and Conclusion

Different terminology is used for changes made in construction. Depending on the language used by the specific contract, changes can be termed as variation orders (V.Os), contract instructions (C.Is) or change orders (C.Os). Construction contracts contain change clauses that explicitly state the right of clients to vary. Variations made in construction are individually different but all are variations to the scope of works. A variation can be a direct order from the client, it can be due to the actions or inactions of the client and it can even be illegal if it substantially changes the scope of work.

Variations may be ordered any time before the issue of the certificate of completion. However, it must be issued timeously and must be in writing. In other words, the number of V.Os that may be issued on construction projects is unlimited. The individuals responsible to issue V.Os are the engineer, engineer's representative, principal agent and other agents. The contractor's site agent or site representative is the individuals that may receive V.Os.

The value of the V.O is calculated by the engineer or principal agent (clause 6.4.1 of GCC and clauses 32.1 and 17.5 of JBCC]. Hence, the engineer or principal agent should be able to comprehend the secondary impact of V.Os in order to include it in the valuation. In general, variations are valued individually at the time it is issued. This may create difficulties if the effects of variations require one to consider the synergy of all the variations. By interpretation of clause 6.4.1 of the GCC and clause 32.2 of the JBCC, it appears as if the valuation of V.Os primarily concentrates on the direct cost and neglects possible impact costs. The impact a V.O has on unchanged work is not explicitly addressed by neither the GCC nor the JBCC. Contractors have the right to reject the original valuation if they are not satisfied with it. They are however expected to give an estimation and proof of the amount they think the V.O will cost to implement. This requirement makes it difficult for contractors to negotiate expense and losses due to the secondary impact of V.Os, because it is unforeseeable and therefore difficult to quantify.

The GCC and the JBCC both allows the contractor the right to a revision made to the date of practical completion in the event where the V.Os were the cause of the critical delay, clause 5.12 of GCC and clause 29.2.3 of the JBCC. Different to the process of the *valuation of V.Os* which focuses on the impact of an individual V.O; the process of awarding an *extension of time* (E.O.T) is not confined to the impact of an individual V.O on the completion date of the project. It should be less difficult to be compensated for a delay due to the secondary impact of V.Os than it is to be compensated for expense and losses incurred due to the secondary impact of V.Os.

To claim, is a natural course of action available to contractors should they not agree with the valuation of variations or require an E.O.T. Due to heavy consequences for not implementing V.Os contractors are more inclined to implement V.Os than to refuse implementing it.

Over all, the two construction contracts do not explicitly consider the secondary impact of change, nor does it provide clear guidelines as to how it should be addressed by the parties in contract.

2.10 Chapter Recommendations

In managing V.Os, the contract has a role to play. The following recommendations can assist contracts to fulfill its role:

- The contract should include clauses that force both client and contractor to acknowledge that V.Os may have a secondary impact on the project.
- The contract should include guidelines that would assist clients and contractors when required to address the secondary impact.
- The contract should state the risks each party will have to carry as well as the responsibility each party has.
- The contract should be clear on how compensation for impact cost should be dealt with. That is, the clauses which discuss the valuation of the V.Os and the E.O.T, should make provision for the possible impact of all V.Os issued.
- The recommended changes made to the contract can be implemented by associations of contractors and engineers such as South African Federation of Civil Engineering Contractors (SAFCEC) and The South African Institution of Civil Engineering (SAICE).
- The engineer/principal agent should be knowledgeable of the secondary impact of V.Os since they are the main party responsible for its valuation. Hence, the experience and education of the engineer/principal agent should show some kind of exposure to V.Os and its impacts.
- The contractor is the party directly affected by the secondary impact and would therefore have information that could assist the engineer/principal agent during the valuation of V.Os. It is therefore necessary that contractors are involved in the process of valuation.
- The right to vary is unprecedented to the construction contract. It has implications and at the very least should be accompanied by a set of requirements clearly stated in the contract that, if met by a V.O, would qualify the V.O as necessary, appropriate and fair to be issued and implemented.

Chapter 3

DEFINING THE SECONDARY IMPACT OF VARIATION ORDERS

3.1 Introduction

The thesis questions and investigates the impact of V.Os over and beyond the direct impact and refers to it as the secondary impact of V.Os. Upon investigation on this topic it has become evident that different terms are being used by the construction industry of the USA. In the USA, the secondary impact of V.Os is referred to as the cumulative impact (Jones, 2001) of change. After a critical evaluation of what is meant by the cumulative impact of change in terms of how it relates to the research question, no fundamental differences were found other than a difference in terminology.

Hence, although it appears as if the advances made by the South African construction industry is slow in defining the secondary impact of V.Os, in the USA courts and boards of contract appeals have made significant advancements in developing a workable definition for what they refer to as the cumulative impact of change.

The objective of this chapter is to define the secondary impact of V.Os through the meaning of cumulative impact of change as developed by the USA's courts and boards of contract appeals.

To provide background, the history of the concept will first be discussed and thereafter a discussion will follow defining the secondary impact via the definition and characteristics of the cumulative impact of change.

3.2 History of Cumulative Impact

At present, the legal system of the USA acknowledges and accepts the cumulative impact of change (Hanna & Swanson, 2007). "[It also] has been the subject of many recent court and board decisions" (Jones, 2001). However, this has not always been the case.

Before the cumulative impact of change was accepted by the legal system of the USA, courts had denied its existence (Jones, 2001). The legal claim for damages due to the cumulative impact of change, Rice versus United States, was unsuccessful because the court refused to acknowledge the impact of changes on unchanged work (work that does not form part of the work included in the V.O) (Jones, 2001). The court's ruling allowed for an adjustment to be made for damages incurred for the changed work in other words the direct impact. As for the damages due to unchanged work, "the court held that it was not appropriate to allow an adjustment for the increased cost of completing the unchanged work" (Jones, 2001). According to the doctrine of precedent in the rule of law, courts are bound by prior decisions of supreme courts (Meintjies-van der Walt, 1961). Therefore, the judgement for the case of Rice versus United States, also known as the Rice doctrine, became a law which abandoned contractors from recovering damages incurred due to the cumulative impact of V.Os (Jones, 2001). Fortunately, late in the year 1967 the courts abolished the Rice doctrine due to its inequality (Jones, 2001).

The abolishment of the Rice doctrine involved a revision made to the standard federal change clause, to include language that would allow for the impact of changes on unchanged work (Jones, 2001). At the time the article "Lost Productivity: Claims for the Cumulative Impact of Multiple Change Orders" was published, the revised standard federal change clause read as follows: "If any change causes an increase or decrease in the cost of, or the time required for, performance of any part of the work under this contract, **whether or not changed by the [variation] order**, the Contracting Officer shall make an equitable adjustment in the contract price, the delivery schedule or both, and shall modify the contract" (Jones, 2001). After the Rice doctrine was abolished and up until today, the cumulative impact of change is accepted and recognised by courts and boards of contracts in the USA, as a legitimate claim (Hanna & Swanson, 2007). From the analysis of the GCC and JBCC in Chapter 2, there is no clause in any of the two South African contracts that states the incorporation of the secondary impact of V.Os as clearly as the standard federal change clause.

3.3 Defining the Secondary Impact of Variation Orders

The abolishment of the Rice doctrine resulted in contractors starting to claim again for damages due to the cumulative impact of changes (Jones, 2001). In turn, the increase in claims has resulted in a sophisticated definition of what is meant by the term cumulative impact of changes. It is from the analyses of the statements made by boards of contract appeals such as Veterans Affairs Board Contract Appeals (VABCA), General Services Board of Contract Appeals (GSBCA) and Armed Services Board of Contract Appeals (ASBCA) on cumulative impact claims that a definition developed (Jones, 2001).

Jones (2001), Hanna (2004), Ibbs (2005) and Hanna and Swanson (2007) have been at the forefront in developing a definition for cumulative impact of change by way of analysing the statements from courts and boards. The definition of cumulative impact will now be given and explained according to their analyses and the different board of contract appeals' statements as cited by Jones (2001) in his article "Lost Productivity: Claims for the Cumulative Impact of Multiple Change Orders".

3.3.1 The Definition

The cumulative impact of change (secondary impact of V.Os) can be summarised as the unforeseen loss of productivity on the unchanged work due to the synergistic effect of the disruption caused by a multitude of V.Os (Jones, 2001, Hanna, 2004 and Ibbs, 2005). The cost due to the secondary impact, also referred to as the impact cost, is a combination of the cost for loss of productivity on unchanged work (increased labour cost) and also the increased cost of completing unchanged work (Jones, 2001).

3.3.2 Characteristics of the Secondary Impact

There are distinct characteristics concerning the secondary impact that must be highlighted.

Firstly, the V.Os do not directly cause productivity loss on the unchanged work but indirectly (Jones, 2001). It creates causes of loss of productivity also known as delay and disruption events. The delay and disruption events interact and cause disruption on the project which results in a loss of productivity on the work not included in the V.Os (unchanged work).

Secondly, the secondary impact considers the impact of all V.Os issued on a project. The loss of productivity experienced on the unchanged work is not due to the delay and disruption events caused by an individual V.O. It is due to the synergy of delay and disruption events caused by all V.Os issued. Hence, the impact cost cannot be ascribed to one specific V.O.

Thirdly, the secondary impact is unforeseen by the contractor. More specifically the loss of productivity on the unchanged work is not foreseeable by the contractor at the time V.Os are issued. The nature of construction projects is such that for most V.Os issued on a project neither the engineer nor the client, who issued it, knew beforehand what its content would be, or the time it will be issued or even that it will be issued, even less the contractor. As explained by Ibbs and McEniry (2008) “a contractor cannot reasonably be expected to foresee a synergistic effect when it cannot foresee the number or size of changes [yet] to come.” This, together with the fact that the secondary impact is the impact of all V.Os issued on a project, cause some researchers to conclude that the magnitude of the secondary impact can only be known for sure, once the project is completed and all the V.Os have been issued (Williams, 2002).

Lastly, the use of the word “synergistic” is important in the definition and it is meaningful in its own right. In basic terms, it suggests that the combined effect of things is greater than the sum of its parts, “2+2=5 effect” (Williams, 2002). A simple and general example would be smoking and inhaling asbestos. Smoking can cause lung cancer and inhaling asbestos can also cause lung cancer. However, if a person smokes as well as inhales asbestos, that person would get lung cancer much quicker than if he just smokes or just inhales asbestos (Synergy, [s.a.]). Hence, the total effect is greater than the individual inputs. In the case of V.Os, the synergistic effect refers to the fact that individual V.Os create disruption but the disruption caused by all V.Os exceeds the sum of the disruption created by an individual V.O. Individually, the impact of individual delay and disruption events on labour productivity may appear insignificant but the combined impact of all delay and disruption events together is detrimental to a project’s productivity.

Hence, the definition of the secondary impact of V.Os can be schematically illustrated as given in Figure 3.1. The figure shows that many V.Os (indicated by the big circles) that are issued on a project trigger delay and disruption events (indicated by the smaller circles) that interact causing a disruption (indicated by the cloud) bigger than the sum of individual delay and disruption caused by the individual delay and disruption events and manifests itself in loss of productivity on unchanged work (indicated by the rectangle).

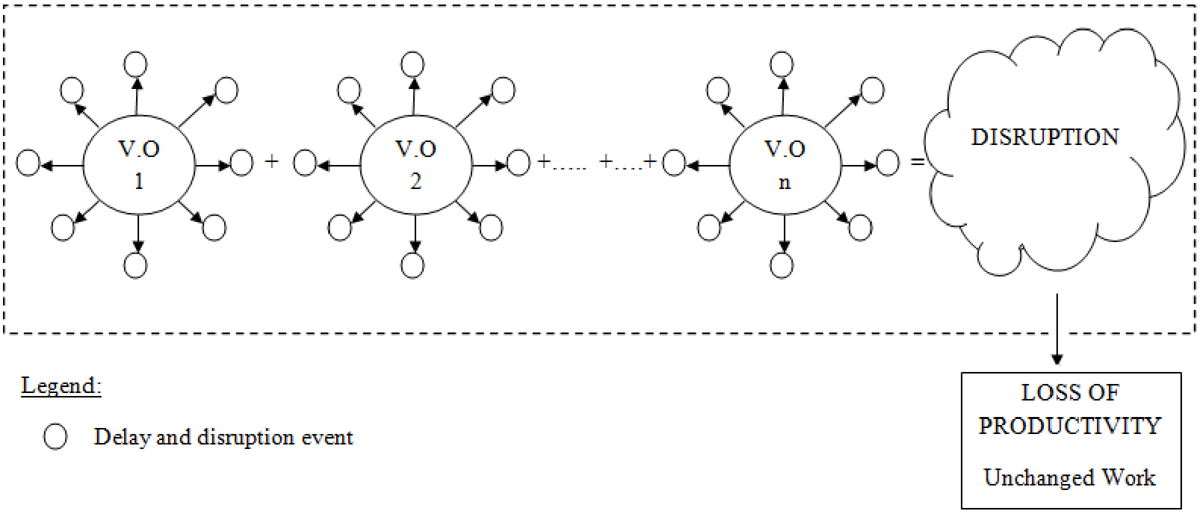

Figure 3.1: A schematically representation of the secondary impact of V.Os

3.4 The Significance of the Secondary Impact

The significance of the secondary impact can be explained by means of the following given scenario. Assume a (South African) contractor has been awarded a project contract. During the cause of the construction, V.Os are issued. Based on the analysis of the JBCC and GCC in Chapter 2, each V.O's direct cost is evaluated and awarded but the secondary impact is neglected by both parties. On site, conflict arise and stress levels are high as the contractor struggles with the delay and disruption events triggered by V.Os, perhaps even accepts it as part of the job. The contractor, unaware of the secondary impact, deals with the individual delay and disruption events as they occur which appears to look insignificant and manageable. However, as the delay and disruption events triggered by the different V.Os interact with each other causing a bigger disruption, the productivity on the unchanged work is impacted. At the end of the project, costs are significantly higher than what has been expected due to the increase in labour cost of the unchanged work. The contractor now convinced that the impact on productivity was caused by the V.Os due to hindsight, issues a claim. Or, it is also possible that the contractor accepts the losses in which case the losses are paid by the contractor self.

3.5 Chapter Summary and Conclusions

In this chapter the secondary impact of variation orders (V.Os) has been defined through the meaning of cumulative impact of change as developed by the USA's courts and boards of contract appeals. Its characteristics were also highlighted. The definition and characteristics however simply state what the secondary impact entails. The scenario used to illustrate the significance of the secondary impact on the other hand, simply gives a picture of what could happen if the secondary impact is ignored by contracts, contractors and clients. To understand what the secondary impact is, it is necessary to analyse and investigate key terms in the definition for what they are. These terms include the following: delays and disruption, delay and disruption events, productivity and loss of productivity. This will be done in Chapter 4, Chapter 5 and Chapter 6.

Once the key terms in the definition is understood as it is in the construction context, the cause and effect relationships stated in the definition need to be investigated. The first relationship is between V.Os and productivity. According to the definition, where V.Os are present productivity suffers. This requires a presentation of empirical evidence that shows this to be the case. This will be done in Chapter 6. The second relationship is between V.Os and delay and disruption events. As the definition states, the loss of productivity is the result of delay and disruption events triggered by V.Os. This relationship needs to be explained systematically and comprehensively using examples, scenarios and illustrations tested for S.A contractors. Chapter 7 and Chapter 8 will focus on this.

3.5 Chapter Recommendations

Based on the definition and the characteristics of the secondary impact of V.Os it is recommended that construction companies:

- Do not remain the victim of the secondary impact of V.Os but instead, accept its existence and take on the responsibility to manage it.
- Add change management to the list of specialities the company offers to its clients.
- Make provision for this service by incorporating an allowance for it in the tender price.
- Pro-actively manage the secondary impact throughout the duration of the project, but also quantify its impact on labour productivity and pursue compensation for it.
- Quantification of the loss of labour productivity and the pursued of compensation of corresponding damages should be done after all V.Os have been issued and executed.

On the whole then, by pro-actively managing the secondary impact, companies can attempt to minimise or eliminate the impact. Once this is provided for in the tender price, they can be compensated for it. However, managing the secondary impact does not necessarily guarantee that the contractor's labour productivity is not affected. For this, the contractor is required to quantify its productivity and claim for related damages.

For contractors to pro-actively manage delay and disruption events, it is recommended that they consider the following in their approach. Managing delay and disruption events triggered by V.Os is a matter of:

- knowing what will come
- being prepared for what will come
- recognising and communicating how the V.Os issued, lead to what came
- documenting all of the above (this will serve as proof and assist with lessons learned) (A "black box" of the project's life span.)

Chapter 4

UNDERSTANDING DELAYS AND DISRUPTIONS

4.1 Introduction

Part of the implication of the secondary impact of V.Os are delays and disruptions. In this chapter and the next, attention is given to explain and understand delays and disruption in the construction context. Typically, definitions will be given. Categories, causes and consequences will be identified. Where possible, mitigation strategies will be discussed. Finally delays and disruption will be compared. A discussion will then follow explaining how management's control actions can add to the disruption created by V.Os.

4.2 Delays

4.2.1 Definition of Delays

Delay is a term commonly used in everyday life. Thesaurus.com defines delay as "to wait, to hold up , when something is late" (Delay, [s.a.]). At its very basic, a construction project is a series of activities and events which are to be executed and take place on a certain pre-planned time and sequence. The dates on which the events and activities are to take place could be explicitly stated in the contract and or inexplicitly on the project's schedule. Either way they have been agreed to, approved by and accepted by both client and contractor. A delay has happened when any of the events or activities is prevented from starting or ending at the planned time. It is important that a planned date exists, without it the term delay has no real meaning (Caletka, 2009)

4.2.2 Categorising Delays

Upon review of literature, at least three ways could be identified in which delays on construction projects are categorised. The first category is in terms of the delay type, of which according to Williams, Ackermann & Eden (2003) could be an approval delay, information delay or a piece of work to be done later than originally planned. The second manner, in which delays are categorised, is based on its effect on the project. For instance a delay may extend a project completion date or it may not. A delay that extends the project completion date is referred to as a critical delay. A delay that does not extend the project's completion date, normally delays a contractor's progress instead, and is termed non-critical delay (The Society of Construction Law Delay and Disruption Protocol, 2002). Finally, delays can be categorised in terms of the party who has control over that which causes the delay. A delay is defined as excusable if it lies outside the control of the contractor and or client, and non-excusable if the contractor does have control over the delay (Caletka, 2009). Furthermore, a delay is compensable if the contractor has no control over the delay but the client does (Caletka, 2009). There are also delays which are outside the control of both contractor and client but part of the risks the client has accepted. These types of delays are also compensable. From there, delays can be classified as excusable compensable, excusable non-compensable or non-excusable non-compensable delays (Cushman, Carter, Gorman & Coppi, 2001).

Thus, in terms of analysing the delays happening on construction sites, one would first identify the delay event that caused the delay, then the delay type should be identified, followed by the identification of the effect and lastly one would identify the party who has control over the delay. For example, a delay such as "information delay" could be the result of the contractor having to request the engineer for information (RFI) due to errors and omissions (E&O) in drawings. This information delay would more likely disrupt the progress of the contractor than it would affect the project's completion date. The party who has control over the event is the engineer or principal agents who are responsible to respond to the RFI timeously. That is, the delay events are E&O in drawings and RFI, the delay type is an "information delay", the effect is a "disruption in progress" and the engineer or principal agent is the party who is responsible for the delay.

4.2.3 What causes Delays

It stands to reason that a delay is an end effect. An end effect must be brought about by certain events. The Society of Construction Law Delays and Disruption Protocol (2002) refers to these events as delay events. Delay events can be any event that causes or leads to a delay (critical or non-critical) and can be within the control of the client, contractor or engineer. The paper "Managing Construction Projects Managing Change" (2009) discusses different delay events that commonly cause delays on construction projects. They are given in Table 4.1 and categorised according to the party who has control over the delay event.

Generally no correlation exists between the significance of the delay event and the severity of the delay it causes. Slow decision making for instance might seem insignificant, however, if it were to delay an activity in the critical path the whole project will be delayed. Selecting improper equipment to execute critical work on the other hand, is problematic and would certainly impact the project's completion date.

OWNER/CLIENT Controlled	PROFESSIONAL TEAM Controlled	CONTRACTOR Controlled
Finance issues: non-payment for completed work	Poor contract management	Inadequate or incompetent site management
Interference with performance of contract	Poor coordination of information (RFI's, drawings)	Lack of experience
Slow decision making	Late preparation and approval of drawings and submittals	Mistakes during construction
Poor constructability/feasibility plan	Long waiting time for approvals or test/inspections	Improper equipment selection
	Late identification and resolution of drawings or specification errors and omissions	Inadequate planning or resourcing of activities
		Subcontractor coordination and subcontractor payment issues

Table 4.2: Common delay events that causes delays on construction projects (Caletka, 2009)

4.2.4 Consequences of Delays

Critical delays, delay the completion date of the project. This has two consequences at stake. Firstly, the contractor's stay on the project is extended and secondly the client is prevented from acquiring the product on the desired date. For both consequences, costs may be incurred by the contractor. If the contractor is to work on the project for longer than planned, all time-related expenses will increase. For example, home and field offices overhead costs. These are considered damages to the contractor. If the client is prevented from acquiring the product as planned, the client may incur losses. For example, a loss of future profit should the end product be used to generate income and the risk of market collapse which are referred to as liquidated damages (penalty fees) (Cushman *et al.,* 2001). If the delay is a non-excusable non-compensable delay, liquidated damages are added costs to the contractor.

As mentioned in Section 4.2.2, non-critical delays might not delay the completion date of a project but it may disrupt the progress of the contractor. In other words, delays may cause disruption. According to Eden, Williams, Ackerman and Howick (2001) delays act as disruptions. Hence, the damages due to delays may include those due to disruptions, see Section 4.3.3.

4.2.5 Mitigation of Delays

Two responses exist to avoid damages resulting from project finishing at a later date than planned. One is an extension of time (E.O.T) granted by the client to the contractor and the other is project acceleration measures. In the event of an E.O.T, the original project's completion date is legally changed, and the project continues as if the new completion date were the date which has been agreed to at the start of the project (The Society of Construction Law Delays and Disruption Protocol, 2002). E.O.T is stated in the contract as compensation available to the contractor where V.Os caused the delay, clause 5.12 of the GCC and clause 29.2.3 of the JBCC. Just like any other form of compensation, the contractor will first need to prove liability, responsibility and quantity to the client before compensation can be granted. More specifically, before compensation can be granted or denied, the contractor must first prove the extent of the delay and the damages it incurred due to the delays (Cushman *et al.,* 2001).

However, construction projects are generally time-driven and an E.OT is therefore not always possible. In this case, the second mitigation option is applied which is a decision to accelerate the project. The construction industry distinguishes between two types of acceleration, directed acceleration and constructive acceleration (Cushman *et al.,* 2001). A directed acceleration is a direct and clear instruction from the owner to the contractor to speed up the progress of the work (Cushman *et al.,* 2001). This is mostly due to a need of the client to have the project completed earlier than originally required or, in the event where the client needs to use a particular section of the work due to a change in circumstances.

The constructive acceleration, on the other hand, is not a direct order of the client to the contractor as in the case of the directed acceleration. The client will not order the client to accelerate, he would instead hold the contractor to his contractual responsibility to complete the project on the agreed time despite of delays that may have happened (Cushman *et al.,* 2001). The contractor is thus forced to accelerate the progress in order to honour its obligation to meet the specified completion date.

4.3 Disruption

4.3.1 Definition of Disruption

There are many definitions pertaining to disruption. In the Delays and Disruption Protocol of the Society of Construction Law (2002), disruption is defined as "disturbance, hindrance or interruption to a contractor's normal working methods, resulting in lower efficiency" Put differently, "[a disruption is] any change in the method of performance or planned work sequence contemplated by the contractor at the time the job was bid that prevents the contractor from actually performing in that manner" (Cushman *et al.,* 2001). From these definitions it can be derived that, when a disruption has happened the contractor is normally prevented from performing the disrupted work as originally planned, resulting in a loss of productivity on the disrupted work.

4.3.2 Categories of Disruption

A disruption can be categorised as non-compensable or compensable (Cushman *et al.,* 2001). A non-compensable disruption is one which the contractor was aware of or could have been reasonably foreseen. These types of disruptions are those issues which are communicated to contractors at tender stage via the contract documents (Eden *et al.,* 2000). Two classic examples are 'the presence of adverse soil conditions" and "the possibility of the contractor having to work in conjunction with another contractor" (Cushman *et al.,* 2001). The argument is therefore, the contractor had an opportunity to plan for these disruption events before commencing with the works and therefore, no compensation may be awarded (Eden *et al.,* 2000). Non-compensable disruptions are not only the ones mentioned in the contract but also those which are due to the contractor's own mistakes and actions (Cushman *et al.,* 2001). Examples are improper scheduling, inefficient material expediting, or the failure of a subcontractor or supplier to perform (Cushman *et al.,* 2001). Hence, a disruption is compensable if the contractor was not aware of it, could not have foreseen it and did not cause it due to own mistakes.

4.3.4 What Causes Disruption

Disruption, just like delays, is an effect of something present on a project. For delays, the Delays and Disruption Protocol of the Society of Construction Law (2002) has termed that "something" as delay events. In a similar fashion, that event which causes disruption can be termed disruption events.

It is often noted in literature that disruption should be analysed by means of the cause and effect method (The Society of Construction Law Delay and Disruption Protocol, 2002 and Cumulative Impact Claims, 2012). That is, if one is to identify what causes disruption, in other words disruption events, it is necessary to identify events that impact labour productivity since, the effect of disruption is loss of productivity. Hence, an event which has the potential to impact labour productivity is possible disruption events.

Upon review of available literature it was evident that there are a large number of events that could impact labour productivity. Borcherding and Alarcon (1991) for example, mention 38 factors that may impact labour productivity. That is to say that there exist at least 38 disruption events. It is not possible or even feasible to simply list or discuss all possible disruption events. Instead, the most common disruption events were identified and categorised in three broad categories namely *human factors*, *difficult working conditions* and *organisational constraints*. Due to the magnitude of the information, it is addressed in a separate chapter, Chapter 5. A summary of the categories and disruption events is given in Figure 4.1.

As illustrated in Figure 4.1 *human factors* include soft issues such as lower morale, low self esteem and low labour motivation. *Difficult working conditions* include conditions such as adverse weather conditions, acceleration methods, working out-of-sequence, interruptions and the impact on learning curve. *Organisational constraints* involve the competence of the contractor's supervisors in assisting labourers and providing them with the necessary resources to complete the work. In short, disruption events include issues such as lower morale, low self esteem, adverse weather conditions, acceleration strategies, a lack of resources such as tools and equipment etc.

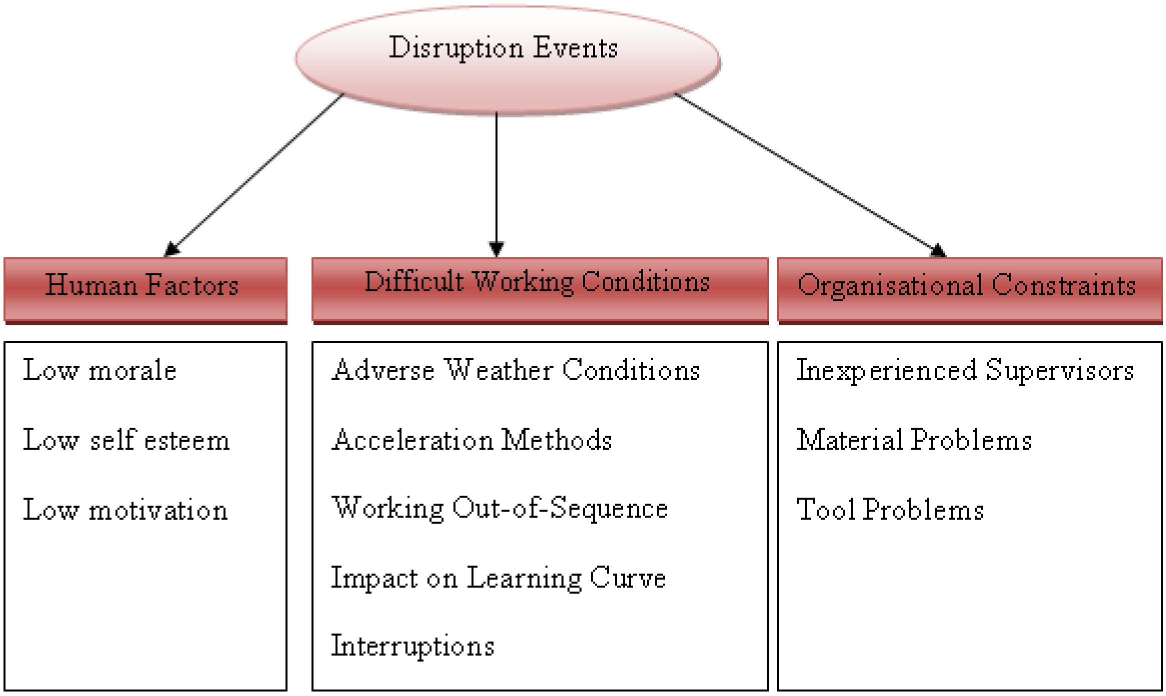

Figure 4.1: A summary of different categories of disruption events

4.3.3 Consequences of Disruption

As explained in Section 4.3.1, a disruption hinders a contractor from executing work in the manner it was planned at the time of the bid. The implication of this is a loss of productivity on the disrupted work. Hence, damages due to disruptions are mainly labour-related costs. Examples are, increased labour costs for additional employees used to perform extra work, increased costs for inefficiency caused by altered work conditions or overtime and increased equipment and material costs (Cushman *et al.*, 2001).

A disruption may cause a delay in the project's completion date (Williams, 2002). This might be due to the disruption itself or due to workers working at a slower rate because of the disruption. Hence, the damages due to disruption may include the damages related to delays discussed in Section 4.2.3.

4.4 Delays and Disruption Compared

The Delays and Disruption Protocol of the Society of Construction Law (2002) explicitly states that delays and disruptions are two separate things. A delay refers to lateness and disruption refers to a hindrance that prevents contractors from performing work as originally planned. However, from the statements made by different researchers (Eden *et al.,* 2000 and Williams *et al.,* 2003) and the knowledge gained from this chapter it can be interpreted that delays are disruptions but disruptions are not necessarily delays.

Eden *et al.* (2000) for example states that "delays are…a fundamental driver of disruption and delay." Acceleration methods are common disruption events, in Section 4.2.4 it is mentioned that managers apply acceleration methods to mitigate delays. This means that delays can lead to disruption events. Furthermore, (non-critical) delays disrupt the progress of contractors (impact productivity) as stated in Section 4.2.2. Disruption causes a loss of productivity which means delays can act as a disruption. On the whole then, delays drive disruption, lead to disruption events and act as disruptions.

Disruption on the other hand, could cause a delay but not necessarily (Williams et al., 2001 and The Society of Construction Law Delay and Disruption Protocol, 2002). It is not unusual for activities that have been disrupted to still be completed on time (The Society of Construction Law Delay and Disruption Protocol, 2002). The classic example commonly given that explains this scenario is the acceleration example. Acceleration is a disruptive event which is generally applied to prevent a delay in project completion date. The activity that is being accelerated is disrupted, since disruption events cause disruption. However, even though the activity has been disrupted the project may still be completed on time or even ahead of time due to it being accelerated. Hence, a disruption has occurred without causing a critical delay.

From the above reasoning, it can be concluded that disruptions are not delays but delays are disruptions. Hence, disruption is not just caused by disruption events but by delay events as well. It should be easy to understand now the part of the definition of the secondary impact that says V.Os trigger delay and disruption events which cause a bigger disruption and manifests itself in a loss of productivity on unchanged work. It is meant that the unchanged work is the work being **disrupted** by the delay **and** disruption events and due to the nature of **disruption** the unchanged works **productivity is impacted**.

4.5 Management's Response

One of the responsibilities of project managers is project control. Project control involves contractors monitoring the project and taking corrective actions when progress deviates from original plans and targets. Delays and disruption and the loss of productivity it causes generally impact a project's progress resulting in deviations from original project objectives. In response to the deviation noted in progress, contractors react by means of control actions. For instance, a project that is facing a critical delay will definitely be accelerated by contractors. The acceleration method is a control action taken by managers due to the deviation in project completion date. Control actions however, have the potential to magnify the productivity losses by causing delays and disruptions (Changes and Loss of Productivity in Construction: A Field Guide, 2012, Eden *et al.,* 2000 and Lee, Peña-Mora & Park, 2005). Acceleration results in loss of productivity as will be explained in detail in Chapter 5. The point is V.Os might trigger delay and disruption events which in turn cause delays and disruption on construction projects resulting in a loss of productivity on unchanged work. However, management plays a role in the process because of the control actions taken by them in response to the delays and disruptions caused by V.Os. This is illustrated in Figure 4.2.

Figure 4.2 illustrates how V.Os issued on a project may cause delay and disruption events which result in delays and disruption. The delays and disruption in turn, result in loss of productivity on unchanged work. Management respond to V.Os that are issued and to the loss of productivity experienced on unchanged work by implementing control actions. This in turn causes delay and disruption events that result in delays and disruption and the cycle continues.The control actions taken by management to counter act delay and disruption caused by V.Os are further discussed in Chapter 7 and 8.

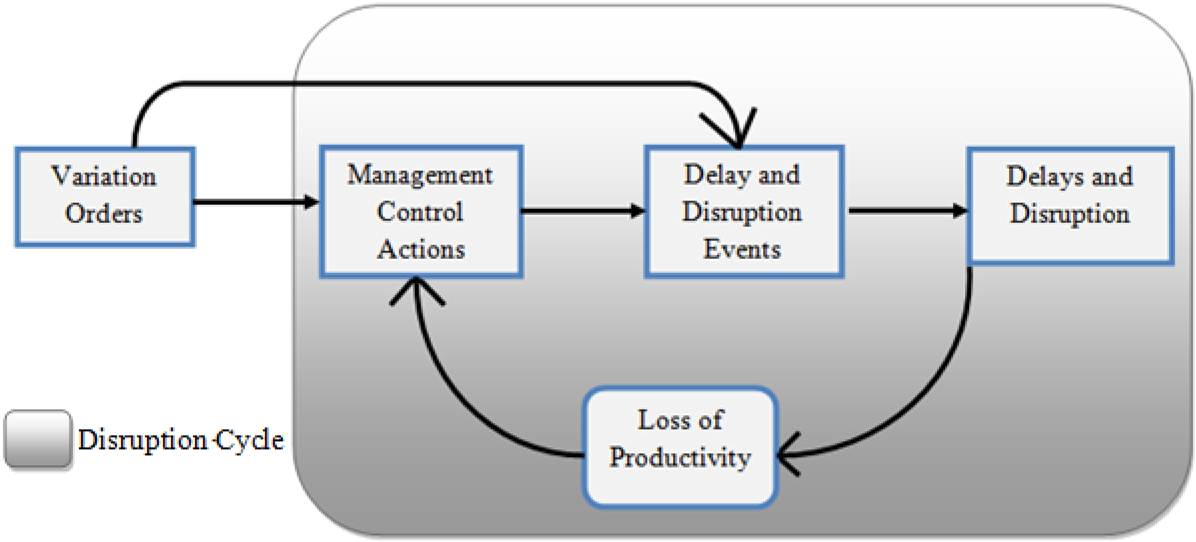

Figure 4.2: A system map showing disruption and the influence of V.Os and management's control actions [Modified from (Change and Loss of Productivity in Construction: A Field Guide, 2012)

4.6 Chapter Summary and Conclusion

In this chapter it is defined that a delay has happened when any event or activity in the project is prevented from starting or ending at the planned time. A project has experienced disruption if the contractor is prevented from performing an activity as originally planned and as a result the activity's productivity is impacted.

Delays can be categorised as per the type of delay, per the effect of the delay and per the party who has control over the delay. That which causes a delay is referred to as delay and disruption events. The consequences due to delays are an effect on time, cost and progress. Common mitigation strategies for delays involve extending the project's completion time or accelerating the project. Accelerating a project can be due to a direct order from the client to accelerate or due to the contractor's contractual obligation to deliver the project on time.

Disruption can be categorised as being compensable or non-compensable. It is caused by delay and disruption events. A loss of productivity, labour related costs and delays are some of the consequences of disruption.

After comparing delays with disruption it was concluded that delays are disruptions but disruption is not necessarily a delay. Hence, when referring to disruption in construction projects it includes delays. Furthermore, that which causes disruption is not constrained to disruption events but delay and disruption events likewise for delays.

An important observation that can be made about delays and disruptions is the strong reference to the original plan of execution. That is delays and disruption happen if the contractor is prevented from executing the project per the original plan. Disruption (includes delays) is part of the secondary impact V.Os have. Hence, part of managing the secondary impact of V.Os will involves managing disruption. Part of the solution in managing disruption is for site managers to have a sound understanding of the original plan. That is, know the original scope of work and the original plan of execution and understand the reasoning behind it.

External events such as V.Os may cause disruption on a project, but the control actions taken by site managers to counter act the disruption often add to the disruption. This can add to the confusion when contractors have to identify whether the disruption is compensable or not. Realising that management plays a role in the disruption created by V.Os is also important when considering ways in which to manage disruption. The control actions taken by management are necessary however, knowing that it can add to the disruption it is trying to mitigate will require wit from management. Instead of blindly and reactively implement control actions management should first evaluate and analyse the situation at hand and then choose an appropriate control action to implement.

4.7 Chapter Recommendations

It is recommended that:

- When delays occur, categorise them in terms of its type, its effect and the party who has control over the delay
- When accelerating a project, distinguish between directed accelerations and constructive accelerations
- When disruption occurs, identify whether it is compensable or non-compensable
- Know the original scope of work and the original plan of execution and understand the reasoning behind it. Refer to Chapter 7's chapter recommendations for more information

- Do not blindly and reactively implement control actions in response to disruption. Instead, evaluate and analyse the situation at hand and then choose an appropriate control action.

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Chapter 5

ANALYSING CAUSES OF LOSS OF PRODUCTIVITY

5.1 Introduction

In Chapter 4 an analysis is done on delays and disruption. However, the delay and disruption events which cause disruption and delays have not been identified as yet. The objectives of this chapter are to define productivity in construction and to identify various events that may occur on construction projects. The rationale is, the events which can be identified, are possible delay and disruption events which can be triggered by V.Os on a project.

As concluded in Chapter 4, in order to identify that which causes disruption, it is necessary to identify that which affects labour productivity. There however exist a plethora of factors that may affect labour productivity (Halligan et al., 1994). Instead of discussing each individual factor, which would not be possible in any case, it was decided to discuss common factors under three main categories. They are: *human factors*, *difficult working conditions* and *organisational constraints*.

This chapter is structured as follows. First, a discussion will take place that defines productivity on construction projects. There after the delay and disruption events will be identified for the three categories.

5.2 Defining Labour Productivity

Labour productivity, is an important factor that is taken into consideration when contractors estimate costs and plan the duration of activities (Lal, 2002). It is often the largest cost component and is known to be the most volatile and the most critical to control (The Analysis and Evaluation of Disruption, 2011). Productivity however, is a term which has many synonyms and holds different definitions. It is therefore important to clearly state and explain what is meant when referring to productivity.

For the purposes of this thesis, labour productivity is understood as either the units of work accomplished per man-hour or, man-hours expended per unit of work (Halligan *et al.,* 1994 and Jones, 2001). In other words, productivity is the rate at which workers are working. Definitions such as man-hours expended per week and man-hours expended per month are criticised for measuring intensity instead of productivity (Halligan *et al.,* 1994) and therefore, not suitable definitions. Appropriate synonyms for labour productivity are labour efficiency and worker's performance, and will be used interchangeably throughout the thesis.

Labour productivity cannot be explained just by definition, there are a number of factors with regards to it that must be considered as well. For instance, is there a difference between the perception of labour productivity at tender stage and the perception of labour productivity during construction? One would also like to know what the relation is between labour productivity and quality. Therefore, these topics are addressed in the following paragraphs.

When contractors estimate work and undertake fixed-priced contracts, labour productivity is usually taken as a constant value which is known as the unit rate (Halligan *et al.*, 1994 and Schwartzkopf, 2004). The unit rate is an estimation of the average man-hours required to complete one unit of work. How realistic and reasonable this value is, depends on various factors such as the experience of the estimator and the information available to him. At the time of construction however, it is no longer appropriate or practical to view the productivity of labourers as a constant rate. Whilst an activity is performed, its productivity varies continuously (Halligan *et al.,* 1994). Again, depending on how realistic and reasonable the estimated productivity (unit rate) is, the actual productivity measured, would vary within close proximity to it (Halligan *et al.,* 1994). Figure 5.1, graphically shows the difference between the estimated productivity and the measured productivity.

Lastly, the relation between productivity and quality is considered. In the context of construction, quality depends on whether the works completed, conform to the contractual specifications. Although it is the intention of contractors to execute work according to specifications, the work completed does not always conform to specifications. This gives rise to the possibility that even though workers work at a high level of productivity it does not imply that the work completed is of good quality (Cooper, 1993). A graph, such as Figure 5.1, might portray good productivity, meanwhile, the output of the work is unacceptable and the work has to be executed again. For the purpose of this thesis however, when it refers to productivity it is assumed that the quality of work performed by labourers is indeed in accordance with specifications. For Figure 5.1 it is assumed that the specifications are met.

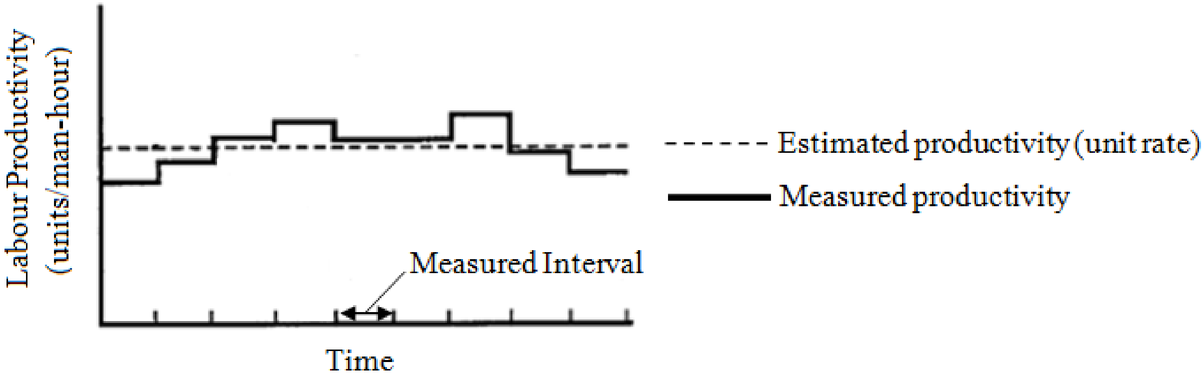

Figure 5.1: Estimated productivity compared to measured productivity (Adapted from Halligan *et al.,* 1994)

5.2 Human Factors

A common cause noted in literature for loss of productivity is low morale also referred to as low self-esteem or low motivation (Sun & Meng, 2008, Alnuaimi, Taha, Mohsin & Al-Harthi, 2010). This section investigates the importance of a low morale to the productivity achieved by workers and the delay and disruption events that cause it. This is done by identifying factors required from an individual to successfully complete a given task and identifying and analysing that which negatively impact the factors. According to Maloney and McFillen (1983) the three factors required from an individual to successfully accomplish a given task are: ability, knowledge and skills (know-how), and effort. The aim is to analyse aspects that negatively impact these factors causing labourers to be less efficient and thereby identifying the delay and disruption events that impact labour motivation. This is done for each factor and discussed separately under the next three subsections.

5.2.1 The Ability of Workers

Ability questions whether the individual is physically and mentally capable of successfully completing a construction task (Maloney & McFillen, 1983). It requires an individual to be physically fit to perform manual work, and mentally capable of following instructions. In construction, this can be expected of all workers and therefore the least liable for workers working at a slower rate.

5.2.2 Knowledge and Skills of Workers

Know-how considers the knowledge the worker possesses regarding a task, and the skills of the worker which help him to perform the specific task (Maloney & McFillen, 1983). The more a worker knows about a certain activity and the more he knows how to perform the activity, the more efficient he will be. The factors that can be expected to influence the knowledge and the skills a worker possesses are issues such as: a lack of training and the procurement of untrained and or inexperienced labourers. In construction certain events can force contractors to employ untrained and inexperienced labourers.

5.2.3 Labour Motivation

To complete a construction activity at the required level of productivity, a certain amount of effort must be invested by the worker. Effort is defined as the physical expenditure of energy directed towards the accomplishment of a task (Maloney & McFillen, 1983). Whether the required amount of effort will be expended by the worker, depends on the worker's state of motivation (Maloney & McFillen, 1983). In other words, a motivated worker is more willing to expend the required effort necessary to complete a task than a de-motivated worker. According to the theory of expectancy and worker's performance, motivation is a function of the worker's expectancy and instrumentality (Maloney & McFillen, 1987). Expectancy of workers and instrumentality of workers will now be analysed separately.

Expectancy of Workers

Expectancy entails the worker's "belief that he can convert his effort into a specific level of performance [productivity]" (Maloney & McFillen, 1987). It is influenced by the individual's level of self-esteem and whether he was successful in the past instances in converting his effort into a certain level of performance despite facing challenges (Maloney & McFillen, 1983). An individual with a high self-esteem, who is willing to expend the required effort to complete a task despite the challenges he might face, simply because he has succeeded before in the past would have high expectancy and therefore high motivation.

A practical example to illustrate how past experience may cause workers to become de-motivated and therefore less efficient is as follows. Say for instance workers working on an activity are repeatedly interrupted due to the supervisor waiting on information concerning the activity being worked on. Due to the interruption their learning curve is impacted as well as their natural job rhythm, making it difficult for them to maintain progress. Nevertheless, workers are still determined to complete the activity on time. Let's assume that despite workers expending the necessary effort, they fail to complete the activity on time. The activity is eventually completed and workers move to the successor activity. If workers are interrupted again due to similar reasons then due to their bad experience on the first activity, they have learned that in such conditions it is not worthwhile to invest the required effort since it would be in vain. Hence, without trying; workers work at a rate acceptable to them and not the rate which is expected of them resulting in a lower productivity obtained by the workers.

Instrumentality of Workers

Instrumentality refers to the individual's "belief that a specific level of performance will result in his receiving certain rewards" (Maloney & McFillen, 1987). The rewards are both intrinsic and extrinsic by nature. Extrinsic rewards are benefits that workers receive for successfully executing an activity; it includes factors such as an increase in wages, promotions, praises from superiors, support and friendship from co-workers (Maloney & McFillen, 1983). Intrinsic rewards on the other hand, refer to benefits that workers receive from performing the activity; it includes feelings of achievement, accomplishment, growth, progress etc. (Maloney & McFillen, 1983). Basically, when these rewards are not available, labourers become de-motivated, the effort expended to execute a task is inadequate and a loss of productivity is experienced.

Examples of situations within a construction project where extrinsic and intrinsic rewards are likely to be absent are: dilution of supervision, changes in members of teams, rework and demolition, repeatedly being interrupted and basically any event that could impact labourers' progress and withholding them from completing a task.

On the whole then, labour motivation is a function of the worker's expectancy and its instrumentality. A highly motivated worker is one with a high expectancy and a high instrumentality. A worker that has a high self-esteem, and who repeatedly succeed in converting his effort into a certain level of performance despite facing certain challenges is a worker that possesses a high expectancy. A worker that is extrinsically rewarded for successfully executing activities and intrinsically rewarded for performing activities is a worker that possesses a high instrumentality. The factors that can be expected to influence labour motivation are issues that affect the labourer's expectancy and instrumentality. This can be any event that could impact labourers' progress and withhold them from completing a task. Examples are: dilution in supervision, changes in members of teams, rework and demolition, repeatedly being interrupted.

5.2.4 Section Summary

The level of productivity achieved by workers performing an activity depends on their ability, knowledge and skills (know-how) and level of motivation. Ability questions whether the worker is physically and mentally capable of performing construction activities. It is concluded that most construction workers are able to perform construction activities. Hence, the most likely reason for workers working at a slower rate must be due to them not having the required knowledge or skills and or due to them suffering from a low morale.

Possible delay and disruption events that could influence the workers know-how are:

- Lack of training
- Dilution of supervision
- Employment of inexperienced workers

Possible delay and disruption events that could influence workers motivation are:

- Dilution of supervision
- Changes in members of teams
- Rework and demolition
- Repeatedly being interrupted
- Basically any event that could impact labourers' progress and withholding them from completing a task.

5.3 Difficult Working Conditions

Apart from the worker's knowledge and skills and motivation, the working conditions may also cause workers to be less productive. The working condition generally has a physiological effect on labourers, which cause them to be inefficient. However; it may also affect their motivation and in that manner increases the probability of productivity loss. Working conditions commonly cited to be counterproductive for labourers to work in include:

- adverse weather conditions
- acceleration methods
- out-of-sequence work
- learning curve

- interruptions

These will be briefly discussed below.

5.3.1 Adverse Weather Conditions

Adverse weather is natural conditions which are detrimental to the construction of a project (Schwartzkopf, 2004). Adverse weather can be classified to fall under any one of two main categories namely, cold weather and hot weather. Cold weather includes extremely low air temperature, high surface wind velocity and precipitation. Hot weather includes extremely high air temperature, humidity, air movement and heat radiation. Loss of productivity due to adverse weather conditions is depended on the severity of the condition, the acclimatization of labourers, the nature of the task and also the health and safety of the labourers (Halligan *et al.,* 1994).

Cold weather and hot weather affect workers both physiologically and psychologically (Hancher and Abd-Elkhalek, 1998). Examples of physiological effects of adverse weather conditions are: reduction in manual dexterity, hypothermia, heat strokes, heat exhaustion, limited visibility, slip hazards etc. (Schwartzkopf, 2004, Change and the Loss of Productivity: A Field Guide, 2012). Examples of psychological effects of adverse weather conditions includes: restlessness, irritability, loss of enthusiasm for work (Hancher and Abd-Elkhalek, 1998). These in turn affect workers motivation which as explained in Section 5.2.3 above results in a loss of productivity.

Besides the effect of adverse weather on labourers, productivity loss due to adverse weather is also affected by the type of material and equipment used on a project. Bad weather causes work to be put on hold. Especially work that involves material and equipment that are sensitive to bad weather. An example of a study that was done to investigate the effect of hot weather on different construction activities is that of Hancher and Abd-Elkhalek (1998). They developed a model which shows productivity decreasing as temperature increases for the different construction activities given in Table 5.1. The table shows some of the different types of work with their related productivity curves, which in turn are shown in Figure 5.2.

Construction Process	**Productivity Curve**
Excavation (mechanical)	A
Sheet piling	B
Water Pumping	B
Formwork (steel)	C
Concrete reinforcement	C
Concrete placement (manual)	D

Table 5.1: Curves for Different Construction Processes (Hancher and Abd-Elkhalek, 1998)

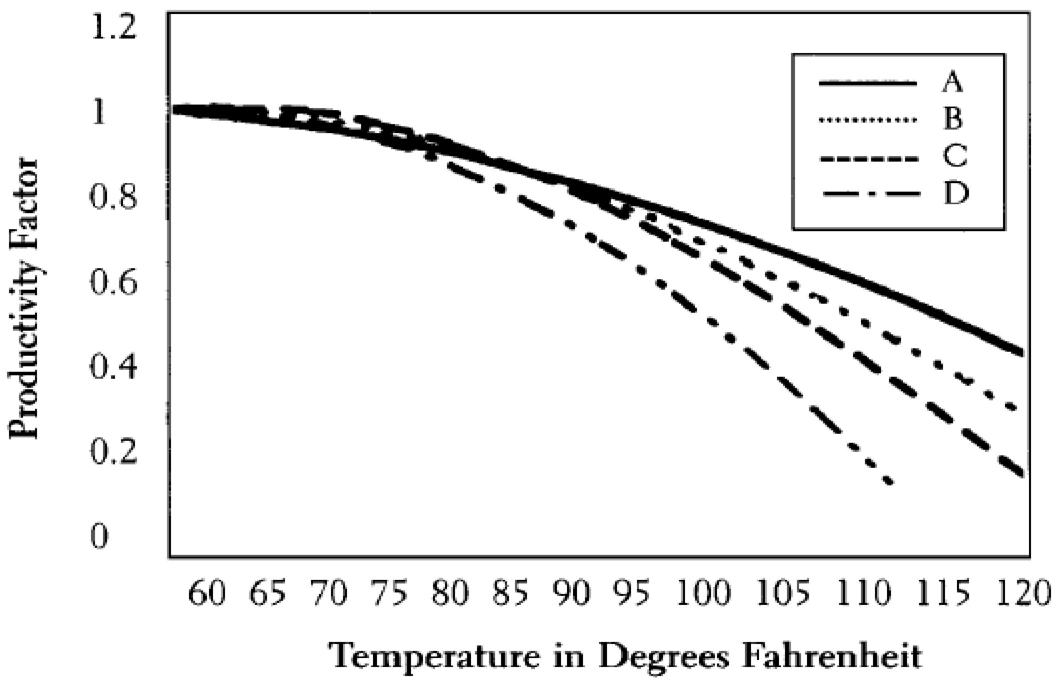

Figure 5.2: Productivity Curves (Hancher and Abd-Elkhalek, 1998)

Taking all the effects of adverse weather into consideration, no one graph could describe the magnitude of productivity loss due to weather conditions for a specific construction project because the impact varies from project to project, activity to activity and crew to crew (Halligan *et al.*, 1994). However, a graph commonly cited to explain the impact of hot and cold weather on labour productivity is that of Lee (2007) given in Figure 5.3. The figure shows that productivity decreases as temperatures increases or decreases from a level between 55 and 65 degrees Fahrenheit.

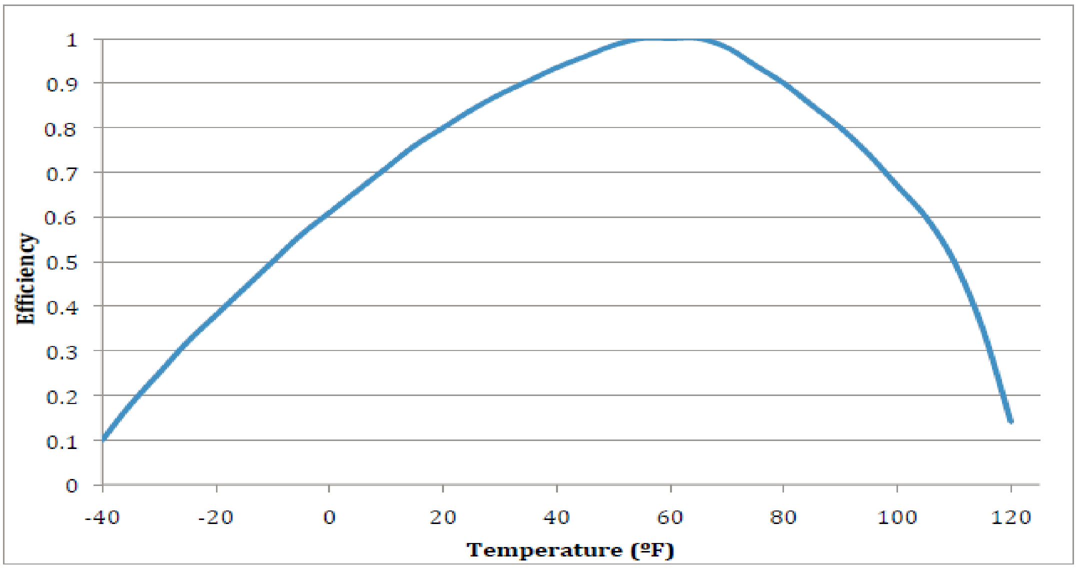

Figure 5.3: The effects of adverse weather on labour productivity (Lee, 2007)

It should be noted that working in adverse weather conditions are part of construction projects and therefore, it is expected that contractors do plan for inefficiencies as a consequence and price projects accordingly. Furthermore, it is expected that contractors, especially experience contractors, programme construction activities in such a manner that those which are better performed in hot conditions are performed in hot conditions and activities which are best performed in cold is performed during cold conditions. However, loss of productivity due to adverse weather conditions becomes important when contractors did not expect to execute weather sensitive activities during bad weather conditions.

5.3.2 Acceleration Methods

Acceleration methods such as extended overtime, shift work and adding additional labourers are common conditions that affect labour productivity.

Extended overtime occurs when workers work longer than 40 hours per week for extended periods of time (Schwartzkopf, 2004 and Halligan *et al*, 1994). When working overtime, workers become less efficient due to physical fatigue and reduced effectiveness of supervisors. These in turn may lead to factors such as lower motivation, absenteeism, poor workmanship, rework and demolition and increased accidents which further impact productivity (Williams, 2002 and Schwartzkopf 2004). Adrian (1987) published the productivity curves of concrete activities that show how productivity reduced due to extended overtime, see Figure 5.4.

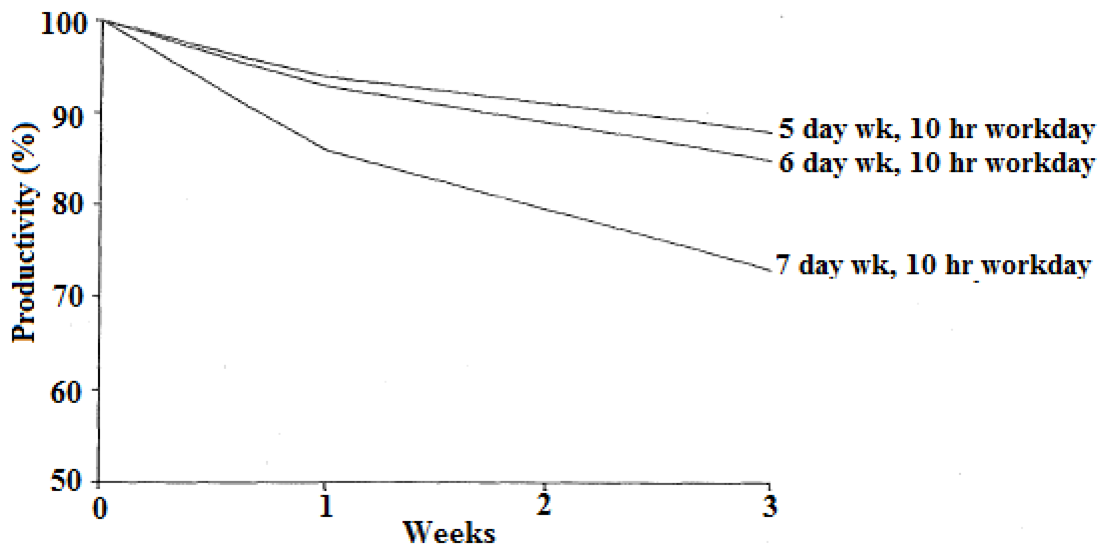

Figure 5.4: The effect of successive weeks of overtime on labour productivity [Adjusted (Adrian, 1987)]

In construction, shift work is known as the assignment of a second crew to perform work after the first crew (Change and the Loss of Productivity in Construction: A Field Guide, 2012). Reasons for productivity loss due to shift work are: disruption in normal sleeping habits, poor workmanship, increased accidents, decrease in supervision effectiveness, and a poor flow of information between shifts (Hanna, Chang, Sullivan & Luckney, 2008). Figure 5.5, shows how productivity reduces due to increase in shift work.

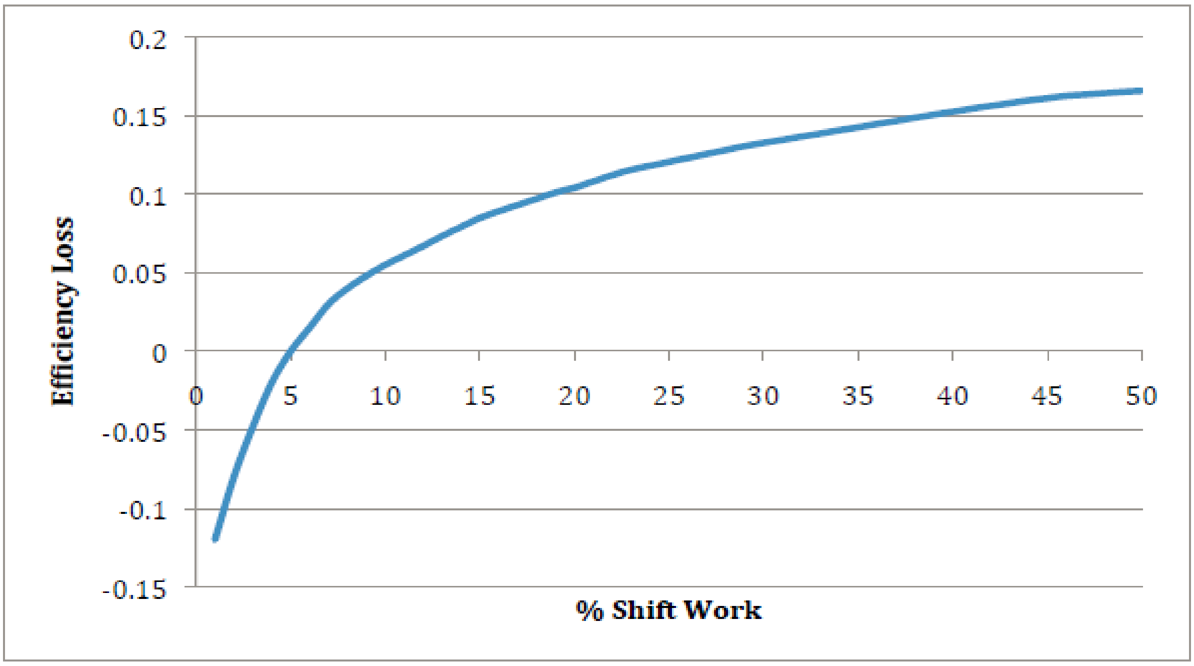

Figure 5.5: Effects of shift work on labour productivity (Hanna et al., 2008)

Increasing the size of a crew in order to accelerate progress, commonly results in overcrowding. In such conditions workers cannot function effectively due to the limited space available to them (Schwartzkopf, 2004). Stacking of trades, also results in lower productivity but due to crowding of different trades and not to over manning (Schwartzkopf, 2004).

5.3.3 Working Out-of-Sequence

Working out of sequence is commonly cited to cause productivity loss (Leonard, 1987). Construction activities are carried out in a predefined sequence which could be either a natural construction sequence (such as building the column footing before building the column) or a construction sequence preferred by the contractor (Managing Construction Projects, 2009). Whatever the sequence type, it will normally be logical and economical. When work is performed out of sequence it means that work does not proceed in the logical and orderly fashion as it was intended to, see Figure 5.6. Workers may slow their pace of work, and lose momentum and job rhythm which causes them to be less efficient.

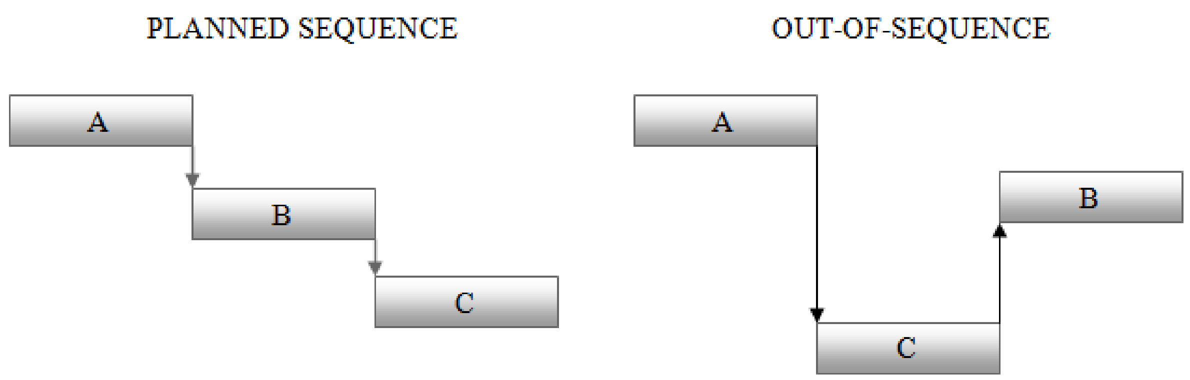

Figure 5.6: Sequence of Activities as Planned vs. Activities Performed Out-Of-Sequence

5.3.4 The Learning Curve

It is widely accepted that human beings go through a learning curve at the start of repetitive tasks. That is, when labourers commence with an activity, their productivity is lower than what reasonably can be expected. However, as labourers become familiar with an activity, they develop better techniques and methods for executing the activity and therefore, their initial productivity improve (Thomas, Mathews and Ward, 1986). An example of how productivity of an activity improves, due to the learning ability of workers is noted by Lal (2002) in his book, "Quantifying and managing disruption claims". The activity involved the erection of formwork. At the beginning of the project, it took the contractor six joiners to erect 76 m^2 of formwork in two days. However, as the activity continued the productivity rate of two day's work, became equivalent to one day's work.

The productivity of labourers working on repetitive tasks can be impacted if the labourers are in any way interrupted, simply due to the interruption of repetition. As stated by Schwartzkopf (2004) "if repetitive actions are delayed or interrupted, the action performed after the delay or disruption will not be at the same man-hour rate as prior to the disruption." This is illustrated in Figure 5.7.

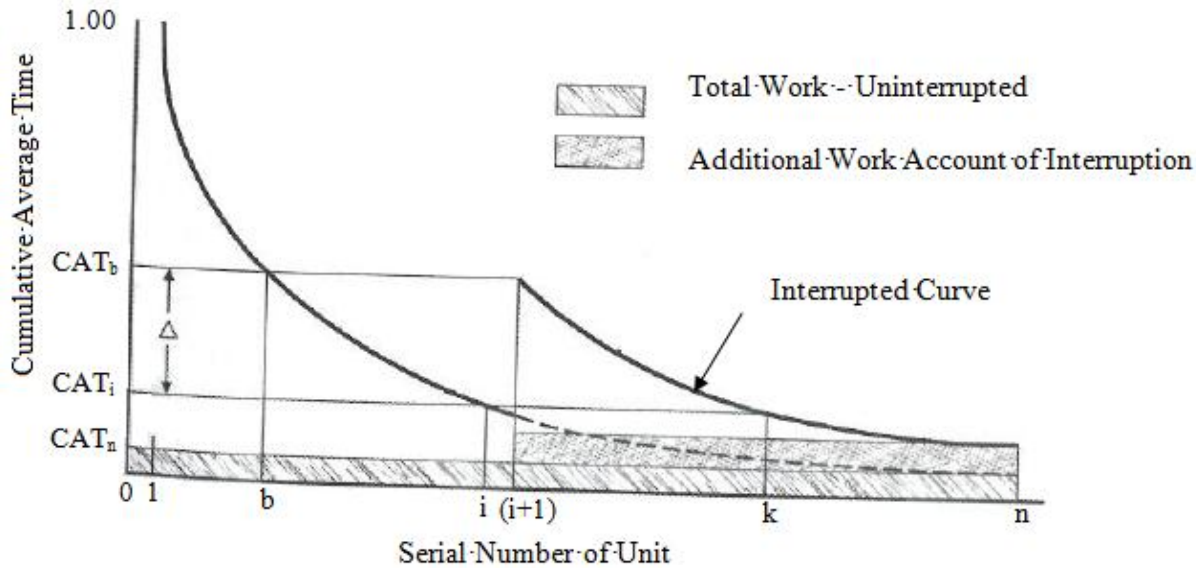

Figure 5.7: The effect of interruptions on workers learning curve (Gates and Scarpa, 1972)

5.3.5 Interruptions

Synonyms and examples of interruptions are idle time, work stoppages and waiting time. Common causes of interruptions are non-critical delays such as information and approval delays. The consequences of interruptions causing loss of productivity are: non-productive time, impact job rhythm and impact the learning curve which all result in reduced productivity. Lal (2002) investigated disruption on construction activities. Part of the investigation involved measuring the duration of common interruptions on construction activities. He found that the most common interruptions lasted between 15 and 60 minutes. Furthermore, Lal (2002) found that interruptions could reduce labour productivity of up to 40%.

5.3.6 Section Summary

This section explained some of the difficult working conditions found in construction projects and why it causes labourers to be inefficient. In terms of delay and disruption events, the working conditions itself as well as the events it causes can be viewed as delay and disruption events. It can be summarised as follows:

ADVERSE WEATHER CONDITIONS

- reduction in manual dexterity
- hypothermia
- heat strokes
- heat exhaustion
- limited visibility
- slip hazards
- restlessness
- irritability
- loss of enthusiasm for work
- executing work that involves material and equipment sensitive to bad weather in bad weather

EXTENDED OVERTIME

- physical fatigue
- reduced effectiveness of supervisors
- lower motivation
- absenteeism
- poor workmanship
- rework and demolition
- increased accidents

SHIFT WORK

- disruption in normal sleeping habits
- poor workmanship
- increased accidents
- decrease in supervision effectiveness
- poor flow of information between shifts

ADDING ADDITIONAL WORKERS

- overcrowding

OUT-OF-SEQUENCE WORK

- perform work in illogical and uneconomical manner
- slow their pace of work,
- lose momentum
- lose job rhythm

LEARNING CURVE

- interruption of repetition

INTERRUPTIONS

- idle time
- work stoppages
- waiting time
- information delays
- approval delays
- non-productive time
- impact job rhythm
- impact the learning curve

Difficult working conditions are undesirable and contractors would certainly plan a project in such a way as to avoid having it on their project. Hence, difficult working conditions are the cause of external factors. Variation orders may be one such factor.

5.4 Organizational Constraints

Organisational constraints are the category that appears to be unlikely the cause of V.Os. As will be obvious upon further discussion, organisational constraints are solely the result of the contractor itself. For this reason it cannot be the cause of V.Os. However, organisational constraints cannot be discarded completely since it is a reality in construction projects which have the potential to affect labour productivity. It is therefore necessary to discuss in order to be mindful of the fact that loss of labour productivity on construction projects is not only due to external factors such as V.Os but could be due to the contractor itself.

Organisational constraints question the competence of the contractor performing the work, and focus particularly on its planning and management abilities. Construction tasks require resources such as equipment, tools and materials. Additionally, labourers require the assistance of supervisors that would facilitate them with the necessary instructions and directions to successfully complete an activity. The contractor has a duty to provide labourers with the necessary resources to complete a task (Maloney & McFillen, 1983). Workers may have the ability, knowledge and skills and may be highly motivated individuals however, without the necessary resources provided by contractors it is impossible to complete an activity at the level of productivity which they are capable of (Maloney & McFillen, 1983).

It is logical that without the required resources, productivity of labourers will be lower than what reasonably can be expected. The significance however is, whether contractors do constrain labourers from being productive. Organisational constraints are a sensitive topic as contractors will most likely deny its existence. Fortunately, previous research such as Halligan *et al.* (1994) have captured instances where this has been the case. Perhaps more valuable, is the findings of a recent study done by Rivas, Borcherding, Gonzalez and Alarcon (2011) that confirms organisational constraints to be common on construction sites (Rivas *et al.,* 2011). These will now be discussed.

Firstly, an example is considered of loss of productivity due to the inexperience of a contractor. In the article “Action-Response Model and Loss of Productivity in Construction”

Halligan *et al.* (1994), report a case-study which involves the construction of a bridge. The project resulted in a cost overrun of nearly 50% due to a loss of productivity. A large part of the cost was due to the lack of experience of the contractor's site supervisors. Apparently, the contractor's job supervisors had no experience in the work that had to be done and therefore, could not adequately facilitate and direct the labourers who had to perform the work. Contractors are responsible to assist labourers with instructions and directions. Without it labourers cannot be efficient. This case study proves that the impact of organisational constrains can be severe, as can be judged from the significant increase in project cost. The case study however, is dated in the year 1994 and therefore, does not prove whether organisational constraints are still alive on construction projects today.

Recently, an investigation was done with the objective to identify factors that influence productivity in construction (Rivas *et al.*, 2011). The investigation was done for projects in a Chilean construction company. However, the authors concluded that the factors identified by their research are common to construction projects across boundaries (Rivas *et al.*, 2011). The study revealed, amongst others, the following material and tool problems to be present on construction sites which affect the productivity of labourers:

Material problems such as:

- lack of on-time delivery,
- lack of material available before work starts,
- material being far from work areas,
- insufficient equipment to move materials.

Tool problems such as:

- insufficient number of tools for people on field,
- tools unavailable when required,
- tools broken when needed and not replaced when broken,
- tool room too far from work area.

The researcher can identify with the problem regarding insufficient tools for workers. In the year 2012 the researcher was involved in a project with an original contract value of R 86 million. The project involved the construction of different concrete structures for a mine. On this specific project the steel-fixers kept losing the pliers they use to fix the reinforcement steel cages. The sub-contractor would supply them with new pliers but after a while refused to do so since it was expensive. The sub-contractor warned workers that should they continue to lose tools, the cost would be deducted from their wages. This barely solved the problem, in fact made it worse. The workers continued to lose their tools but this time around the worker would not report the missing tool and just stayed without it. This resulted in delays in the pouring of concrete due to the lack of progress on fixing of steel cages.

The construction industry is an established industry and it is hard to believe that organisational constraints are still rife today. In chapter 6 it will be explained how V.Os result in the factors discussed under section 5.2 and section 5.3 above, and therefore causing a loss of productivity. The importance of this section is that it highlights the fact that V.Os issued by clients is not the only cause of productivity loss but factors such as organisational constraints might also be at work.

5.4.1 Section Summary

The purpose of this chapter is to identify delay and disruption events that could be triggered by V.Os. As discussed earlier, organisational constraints are rarely the cause of V.Os. Hence, the summary of the delay and disruption events given under this section is simply for the sake of completeness.

Supervision problems:

- Inexperience site supervisors

Material problems such as:

- lack of on-time delivery
- lack of material available before work starts
- material being far from work areas
- insufficient equipment to move materials

Tool problems such as:

- insufficient number of tools for people on field
- tools unavailable when required
- tools broken when needed and not replaced when broken
- tool room too far from work area

5.5 Chapter Summary and Conclusion

On the whole then, labour productivity is a rate at which workers are working which can be expressed as the number of units accomplished per man hour or the number of manhours required to complete one unit of work. Factors that affect labour productivity in construction can be categorised under *human factors*, *difficult working conditions* and *organisational constraints*. Human factors include issues such as low morale, low self-esteem, low motivation. Difficult working conditions include issues such as adverse weather conditions, acceleration methods, working out-of-sequence, impact on learning curve and interruptions. Organisational constraints include issues such as inexperienced supervisors, material problems, tool problems etc. Unlike the factors under the categories *human factors* and *difficult working conditions* which can be triggered by external factors, factors under organisational constraints are primarily the result of the contractor self.

The factors under each category affect the productivity of labourers which is the same effect delay and disruption events have on labourers. Hence, these factors and delay and disruption events are one and the same. Since, organisational constraints are the cause of the contractor self it is unlikely that it could form part of the delay and disruption events directly triggered by V.Os. Hence, the factors under the categories *human factors* and *difficult working conditions* can be viewed as a collection of delay and disruption events V.Os could trigger on a project, see Figure 5.8. This will be further discussed in Chapter 7.

Having analysed causes of loss of productivity it should be easy to understand now how V.Os indirectly impact labour productivity via delay and disruption events. Take for example the delay and disruption event “adverse weather conditions”. Let’s assume in some kind of way V.Os issued have caused unchanged work to be executed in adverse weather conditions. Due to events such as reduction in manual dexterity, hypothermia, heat strokes, heat exhaustion, limited visibility, slip hazards etc that accompany adverse weather conditions labourers became ineffective. Hence, it is the V.Os that caused the unchanged work to have been executed in adverse weather conditions but it is the delay and disruption events that have caused the inefficiencies.

At this point one can appreciate the characteristic that individually delay and disruption events appear insignificant. For instance, interruptions such as idle time, information delays and work stoppages may appear insignificant, yet Lal (2002) found that interruptions could reduce labour productivity of up to 40%.

Another point that can be made after analysing delay and disruption events is that it is often not catered for in the contractor's original plan. The prime reason as to why these events will be present on a project is if it is triggered by external events such as V.Os. Put differently, delay and disruption events are signs or symptoms that the project suffers from external events. If so, then these symptoms and their potential effect on labour productivity are what contractors apart from their normal management responsibilities also need to manage.

On the whole then, delay and disruption events certainly cause disruption resulting in a loss of labour productivity. The question that still warrants an answer in the quest of understanding the secondary impact of V.Os is, is it possible for V.Os to cause these different delay and disruption events to occur? If so how? The next two chapters focus on answering these two questions.

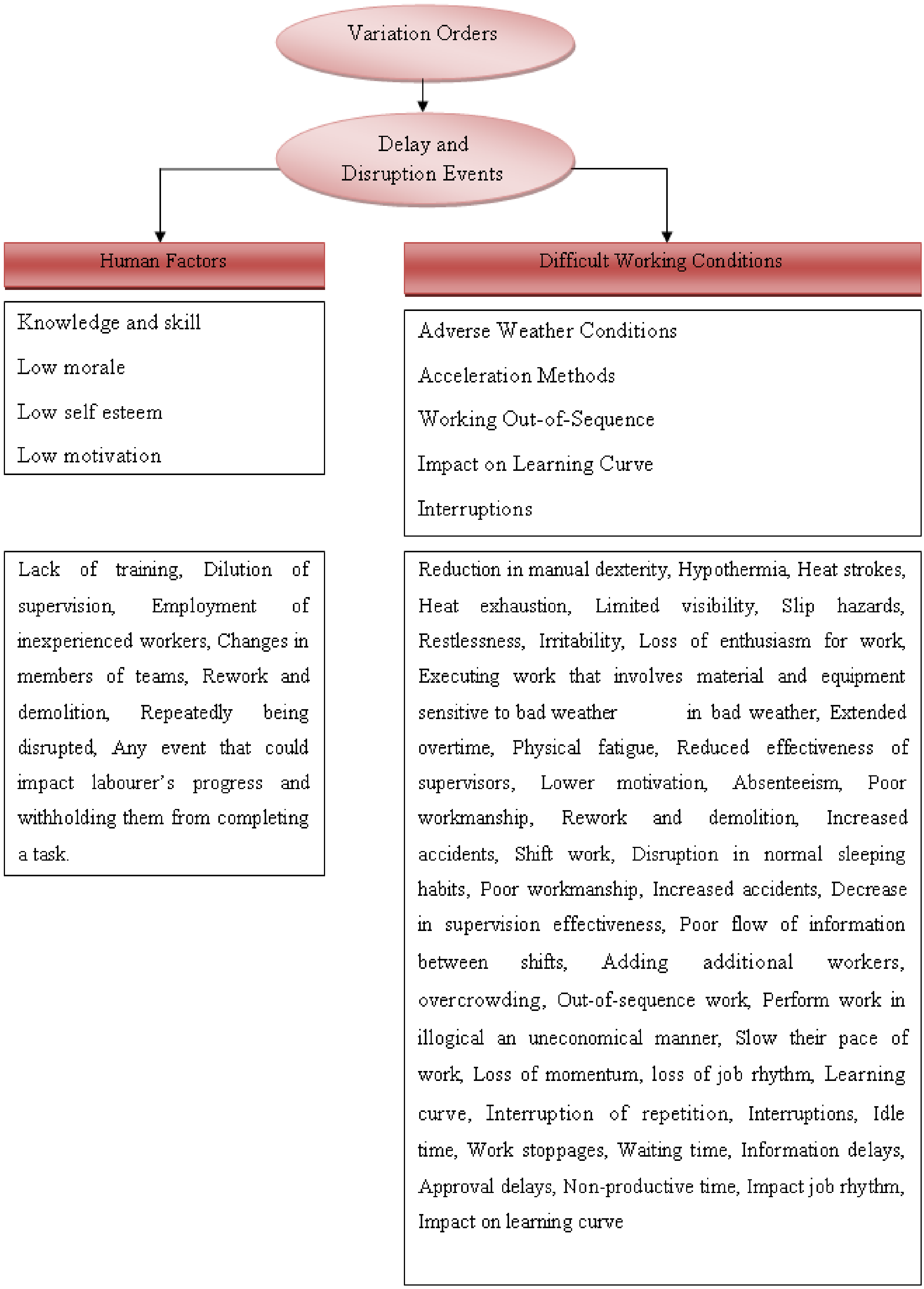

Figure 5.8: A collection of delay and disruption events that could be triggered by V.Os

5.6 Recommendation

For contractors to manage delay and disruption events the following is recommended:

- Equip oneself with knowledge concerning the psychological aspects involve in *human factors* and the physiological aspects involve in *difficult working conditions* which impact a labourer's productivity
- Identify mitigation strategies for each human factor and difficult working condition. Document and implement it.
- Keep record of delay and disruption events that realises on the project due to V.Os. This can be used as proof in claims and lessons learned.
- Measure, record and monitor labour productivity. The following methods can be used to measure productivity: 1) Total cost method, 2) Modified Total Cost Method, 3) Measured Mile Approach. For more information consult the article by Jones (2001) and Jones (2003).

Chapter 6

ANALYSING LOSS OF LABOUR PRODUCTIVITY

6.1 Introduction

The objective of this chapter is to investigate loss of productivity. This involves defining what is meant by loss of productivity, discussing previous studies that proved V.Os cause loss of productivity, and also studies that highlighted factors that could exacerbate the amount of productivity that is lost due to V.Os.

6.3 Defining Loss of Productivity

In Chapter 5, productivity was defined as the rate at which workers are working. In other words the units of work accomplished per man-hour or man-hours expended per unit of work (Halligan *et al.,* 1994 and Jones, 2001). In Chapter 5 it is also explained how labour motivation, difficult working conditions and organisation constraints may reduce labour productivity. However, what has not yet been discussed is what is meant by a loss of labour productivity. This section attempts to investigate what is meant by loss of productivity in the context of construction projects.

Upon review of literature, two theoretical ways were discovered of how to analyse loss of productivity on construction projects. The first is described by Halligan *et al.* (1994), and considers loss of productivity on an activity level. The second is described by Hanna and Gunduz (2004), and considers loss of productivity on a project level. Both will be explained shortly, however, it is worthwhile to first consider the significance of each analysis in the context of the secondary impact of V.Os.

In terms of the secondary impact of V.Os, loss of productivity is the sum of productivity loss of all work not directly changed by V.Os. From this there are two aspects concerning the loss of productivity resulting from implementing V.Os. The first is that loss of productivity is experienced on unchanged work, which implies analysing productivity on an activity level. However, the ultimate concern is not the loss of productivity experience on individual activities but, the sum of the loss of productivity on all unchanged work after all V.Os have been issued and the project is finally completed. This requires one to analyse loss of productivity on a project level taking the impact on all unchanged work into consideration.

Hence, analysing loss of productivity on an activity level assists with the understanding of the statement "the unchanged activity experiences loss of productivity due to disruption". Analysing loss of productivity on a project level on the other hand, assists with understanding loss of productivity on all activities caused by all V.Os issued on a construction project. Hence, both analyses assist with understanding loss of productivity and is necessary to look at. This will now be discussed.

Loss of Productivity on Activity Level

As mentioned elsewhere, contractors have an initial estimation of what the labour productivity for a certain activity will be. That initial estimation is also known as the estimated average productivity rate or unit rate. During construction, the actual labour productivity achieved by labourers varies within close proximity to the estimated average productivity rate (unit rate). However, a loss of productivity has occurred when the productivity that might have been achieved, is not achieved. Instead, a lower labour productivity is measured (Halligan *et al.*, 1994). This is illustrated in Figure 6.1.

Figure 6.1 shows loss of productivity on an activity level. The figure displays the various productivity curves for an activity that has been impacted by an unspecified event, such as the disruption caused by the delay and disruption events triggered by V.Os. Before the event occurred, the measured productivity (curve B) followed the trend of the estimated productivity (curve A). However, when the unspecified event occurs, the measured productivity deviates significantly from the estimated productivity, and a loss of productivity has occurred. It is worthwhile to note that the actual "might-have-been" productivity (Curve C) could never be known, and at best would be estimated. Logically, this provides difficulties to fairly quantify damages entitled to the contractor for productivity loss and therefore, it becomes a continuous point of debate between client and contractor.

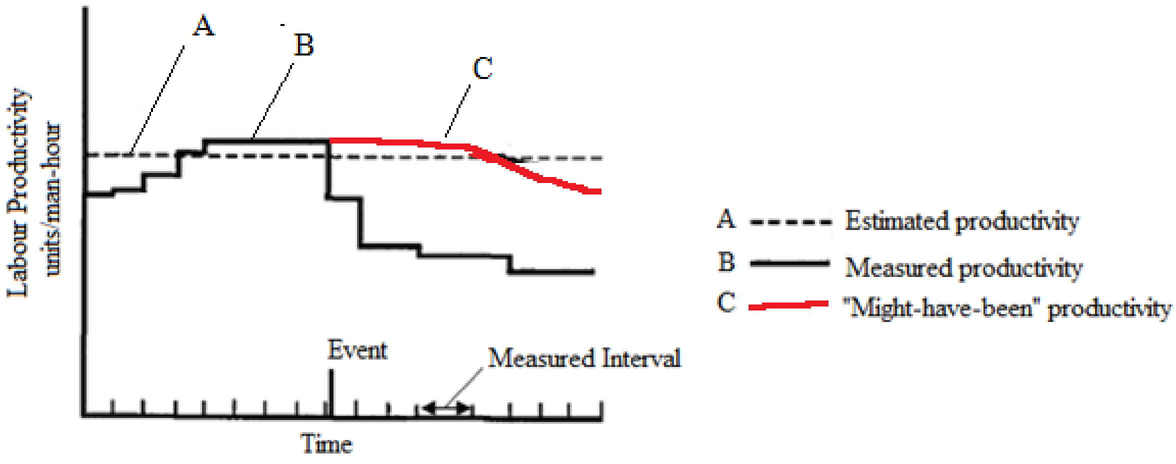

Figure 6.1: Loss of productivity on an activity level (Adapted from Halligan *et al.*, 1994)

Loss of Productivity on Project Level

Unlike loss of productivity on an activity level, loss of productivity on a project level takes into account the reduction in productivity on all unchanged work due to all V.Os issued on a project (Hanna *et al.*, 2004). This is achieved by comparing the actual labour hours spent to complete the construction project, with the estimated labour hours indicated in the contractor's bid (Hanna *et al.*, 2004). Consider the scenario where a multitude of V.Os are issued on a project. According to the theory of the secondary impact, the V.Os trigger delay and disruption events that interacts causing a bigger disruption which affects the unchanged activities. That means theoretically, the unchanged activities of the project impacted by the disruption will have a productivity graph similar to Figure 6.1.

Naturally, additional labour hours are required to execute the changed work and may be expected to be allowed for and approved due to the strict instructions of the contract to do so. If one is to disregard the approved V.O hours, and then compare the actual labour hours expended to complete the project, with the original estimated hours indicated in the bid, theoretically it is expected that they should be the same (Hanna, Camlic, Peterson & Lee, 2004). However, when the secondary impact is at play, a difference will exist between the estimated hours and the actual hours, see Figure 6.2. This difference in labour hours is the hours for which labourers were inefficient, due to the delay and disruption events triggered by V.Os.

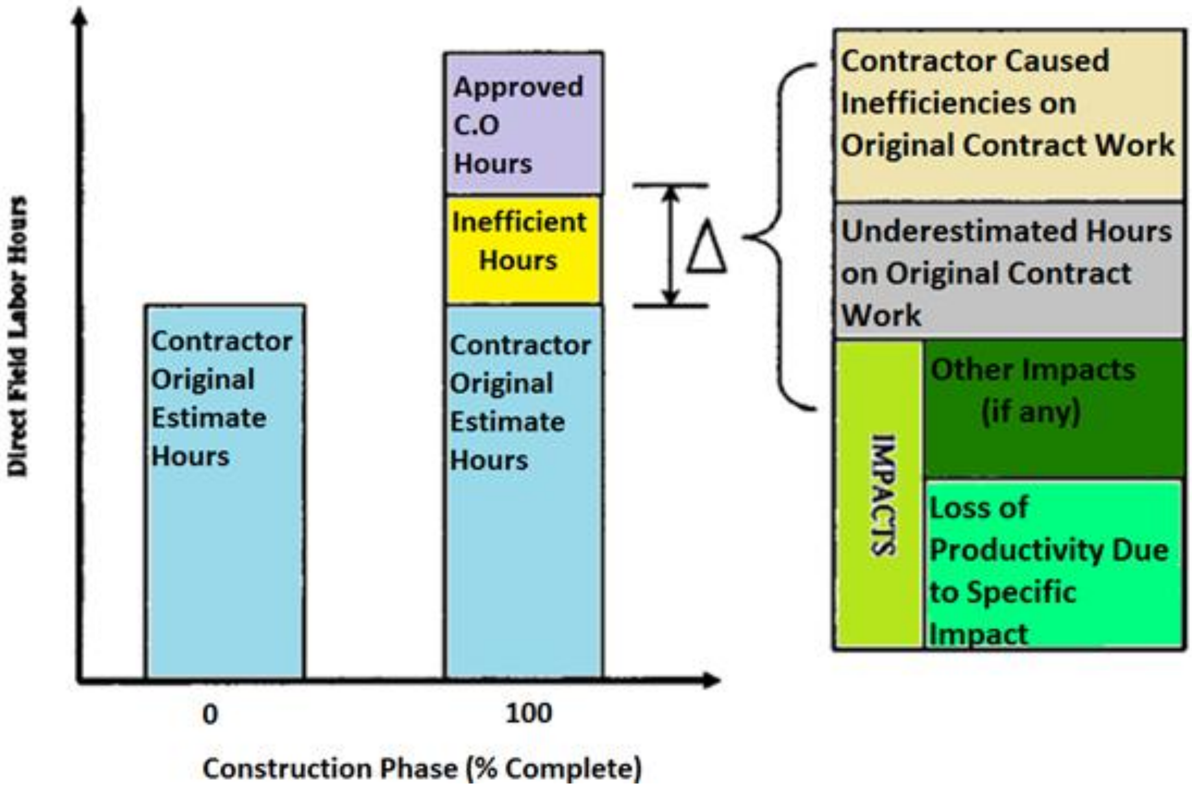

Figure 6.2: Loss labour productivity on the whole project (Hanna & Gunduz, 2004)

It must be noted that it is quite rare in practice that an activity experiencing inefficiencies is left without management intervening with control actions, especially if the project is time constrained. Hence, control actions such as increasing the number of labourers and working overtime, would certainly be applied to mitigate inefficiencies. In the analyses above the effect of management control actions is neglected for simplicity purposes. However, it should be kept in mind that control actions do play a role in terms of loss of productivity on both activity and project level.

6.4 Studies that Prove Variation Orders cause Productivity Loss

The definition of secondary impact simply states that V.Os cause productivity loss. In this section two different empirical studies widely-cited in literature will be discussed which statistically prove V.Os cause a loss of productivity. They are the work done by Leonard (1988), and the work done by Ibbs (2005). A brief description of the research and findings are given in the following sections.

6.4.1 Leonard's Study

Leonard's (1988) work is one of the first which successfully established a relationship between V.Os and loss of productivity. It is widely-cited by researchers studying the impact of V.Os and often referred to in legal documents. In his work, a statistical relationship was established between loss of productivity and V.Os, for both civil engineering and electrical-mechanical construction projects. The significance of Leonard's work for this research is the graphs generated by the statistical analysis for civil engineering construction projects. This is what will be discussed in the following paragraphs.

Leonard studied 90 cases of projects that experienced loss of productivity due to V.Os. The projects had all undergone the claim process, where contractors are seeking compensation for damages due to V.Os. Claim processes normally involve the compilation of important documents such as a claim statement by the contractor, claim evaluations done by arbitrators and testimonies of experts stipulated in reports. Therefore, a plethora of detailed and reliable information was available which made it possible for a statistical analysis to be done.

The data of cases were categorised in three groups, according to the cause for the loss in productivity. He refers to the groups as type 1, type 2 and type 3. Type 1 represents cases where V.O's were the main source of productivity loss. Type 2 contains the cases where productivity loss wass due to V.Os and one major cause. Type 3 represents the cases where V.O's and more than one major cause resulted in productivity loss. The major causes, included events such as, inadequate scheduling and coordination, acceleration and change in work sequences.

For each case, within the different groups, data was collected to calculate the percentage V.O's and percentage productivity loss. The percentage V.Os were calculated as the ratio of labour-hours required for executing the change, and the labour-hours spent by the contractor on the original scope of work. For each case, either a statement of the contractors' claim or reports from experts existed. Each of these documents included a calculation of the loss of productivity. Hence, the percentage of productivity loss for the cases was taken from the expert reports, as they were considered unbiased and trustworthy. The calculation included in the claims of contractors however, needed to be reassessed in order to illuminate inefficiencies due to the contractor self.

From the statistical analysis a high correlation was found between the percentage V.Os and the percentage productivity loss. This indicates that V.Os issued on civil engineering projects cause productivity loss. It was also evident that linear models better described the relationship between the percentage V.Os and the percentage productivity loss. More specifically, the greater the percentage of V.O hours required, the greater the amount of productivity loss. The results of the analyses are summarised in Figure 6.3.

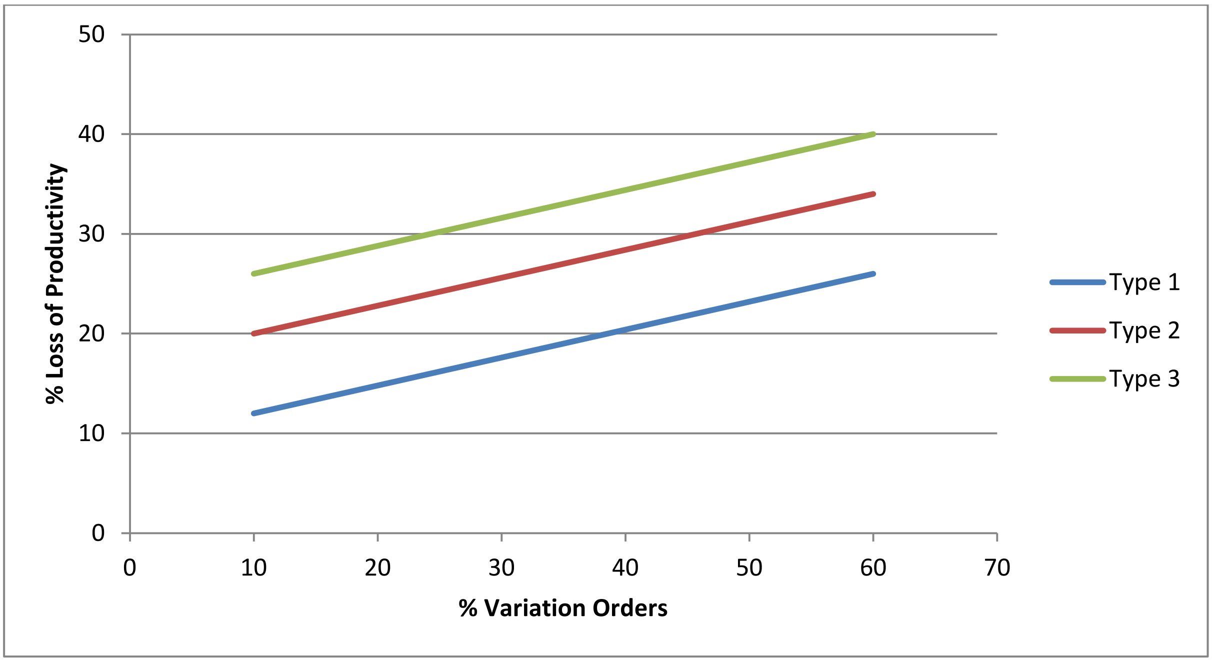

Figure 6.3: Leonard's curve for civil and architectural projects showing loss of productivity as a function of % change orders (Leonard, 1988)

6.5.1 Ibbs's Study

Ibbs (2005) studied construction productivity for many years and also published a number of papers which deal with the topic "Labour Productivity on Construction Projects". An important study conducted by him is the one where he statistically investigated the relationship between labour productivity and the number of V.Os issued.

For the study, data was collected from 162 construction projects over a period of nine years. The projects varied in terms of delivery systems and industry sectors. The number of change orders, the measured actual productivity, and the estimated planned productivity were collected at pre-identified stages of the projects' lives. Instead of productivity, the performance ratio was used which is the ratio between the actual productivity and the planned productivity. The performance ratio of each project was plotted against the percentage V.Os of each project, this is shown in Figure 6.4. From the figure it is clear that the projects' labour productivity declined as the number of V.Os issued increased.

Figure 6.4: Ibbs's curve showing the productivity ratio as a function of the amount of change experienced (Ibbs, 2005)

6.5 Exacerbating Factors that Increase Loss of Productivity

The studies discussed above simply proved in a statistical manner, that for projects where a multitude of V.Os are issued, loss of productivity is experienced. Apart from the V.Os that are issued which cause loss of productivity, the time when the V.O is issued also has an effect on the amount of productivity that is lost. This will now be discussed.

6.5.2 The Timing of the V.O

Part of the study done by Ibbs (2005) was to investigate the relationship between productivity and the number of V.Os (see Section 6.5.1), included an investigation of the impact of the time a V.O is issued, on a project's productivity. From the study, Ibbs (2005) concluded that a V.O issued late in a project is more disruptive to labour productivity than a V.O that is issued early in the project, see Figure 6.5.

The data for this study was collected from 162 construction projects over a period of 9 years (Ibbs, 2005). The data was collected at the 25, 50, 75, 80, 85, 90, 95, 100% milestones of the project and included cost, labour hour, schedule and change data. Instead of productivity, the performance ratio was used which is the ratio between the actual productivity and the planned productivity. The timing of a V.O was defined as the time when the contractor was either verbally notified or by a written notice. The projects were categorised into three categories according to the time the V.O was issued that is, early V.O, normal V.O and late V.O. This was plotted and given in Figure 6.5.

Figure 6.5 shows that for projects where V.Os were issued early, the loss of productivity experienced were not as significant as in the case of projects where V.Os were issued late. Ibbs concluded that V.Os that are issued late are twice as detrimental than V.Os issued earlier (Ibbs, 2005).

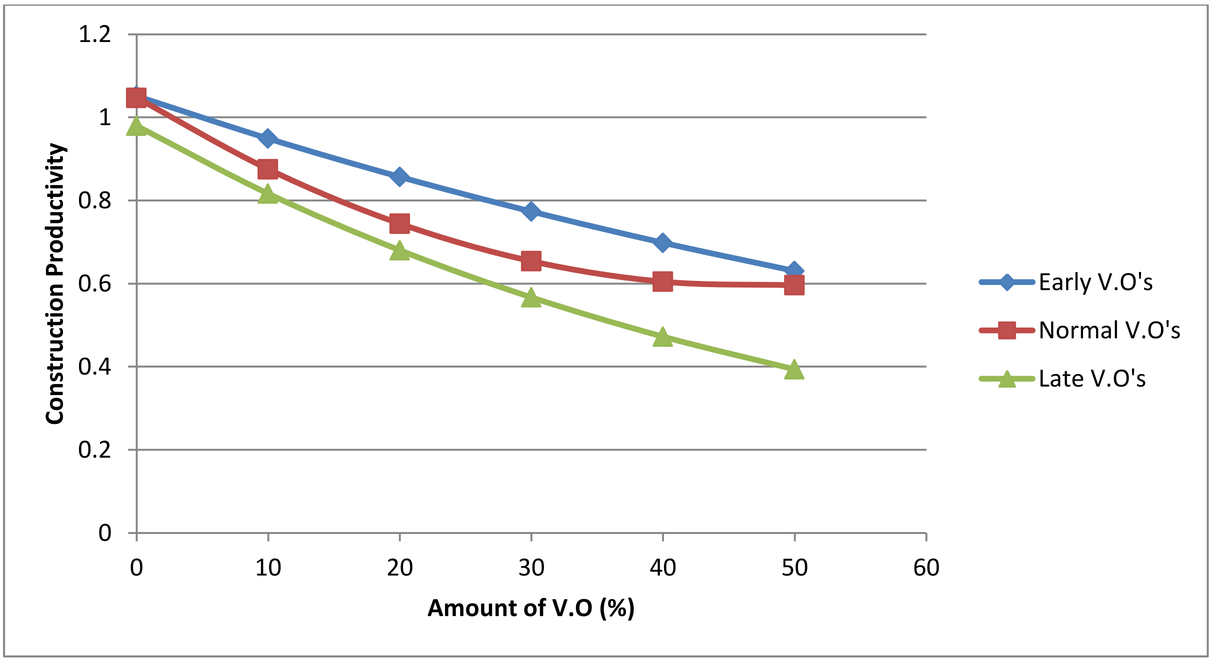

Figure 6.5: Construction productivity versus timing of change (Ibbs, 2005)

6.6 Chapter Summary and Conclusions

In this chapter loss of productivity has been defined on an activity level as well as project level. By means of the findings of previous studies it is concluded that V.Os do cause loss of productivity. Furthermore it is concluded that the number of V.Os issued as well as the time that V.Os are issued, play an important role in terms of the impact V.Os have on productivity. Hence, it is not just the fact that V.Os cause loss of productivity, but the number of V.Os and the time it is issued are also important and should also be taken into account when analysing the severity of the V.Os impact on labour productivity.

6.7 Recommendations

It is recommended that the contractor:

- Identify the desired rate of productivity per activity before commencing with construction
- Identify the method to measure, monitor and control productivity and implement it
- Write it down, communicate it to all members of site management and document it

It is recommended, as far as reasonably practical, that clients:

- issue V.Os at start of the project
- make known possible V.Os to the contractor as soon as possible
- limit the number of V.Os issued on a project

Chapter 7

SYSTEMATIC AND COMPREHENSIVE OVERVIEW

7.1 Introduction

As explained before, the secondary impact of V.Os is defined as the unforeseen loss of productivity on the unchanged work due to the synergistic effect of the disruption caused by a multitude of V.Os issued on a construction project. By further interpretation, this definition was schematically portrayed in Chapter 3, see Figure 7.1.

The main objective of this research is to qualitatively analyse the secondary impact of V.Os. However, thus far only the different aspects of the definition, shown in Figure 7.1, have been investigated. For instance, Chapter 4 investigated delays and disruptions which are indicated as a cloud in Figure 7.1. In Chapter 5, which is a continuation of the investigation of delays and disruption, the various delay and disruption events are identified which impact labour productivity and which could be triggered by V.Os. This is indicated as small circles in Figure 7.1. Finally, Chapter 6 investigated loss of labour productivity on the unchanged work. This is indicated as a rectangle in Figure 7.1

Although these chapters discuss the different parts of the definition, the impact is not completely analysed if the parts are not discussed in conjunction with one another. In other words, what is still required, is to explain how V.Os could cause delay and disruption events discussed in Chapter 5, how by interacting with each other the delay and disruption events cause delays and disruption on a project, and how the end result is a loss of productivity particularly on the unchanged work. This can be done through means of a comprehensive and systematic overview of the secondary impact of V.Os which is the objective of this chapter.

The methodology used by the author to gather the necessary information to write a comprehensive and systematic overview of the secondary impact of V.Os, will first be explained. Finally the comprehensive and systematic overview of the secondary impact is given.

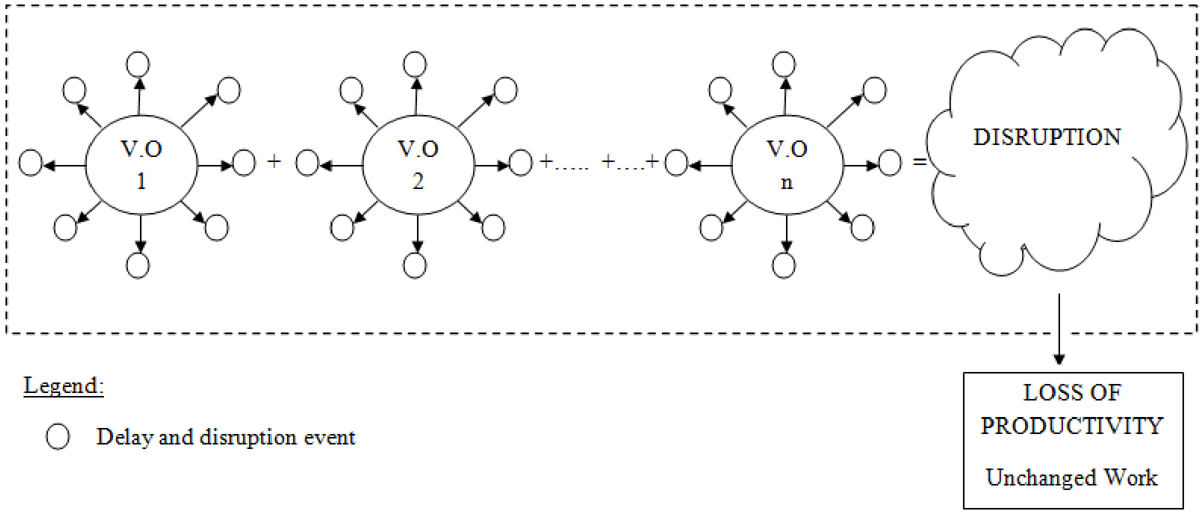

Figure 7.1: A schematically representation of the secondary impact of V.Os

7.2 Methodology

The objective of this chapter is to give a systematic and comprehensive overview of the secondary impact of V.Os. In order to accomplish this however, the author must gain an in depth understanding of how V.Os issued on a construction project cause delay and disruption events that result in loss of productivity. To achieve this, the author predominantly made use of the literature review method. In addition to this, information was gathered though means of unstructured interviews with contractors from two separate firms. The interviews were done during a pre-investigation of the secondary impact of V.Os. An in detail layout of the two interviews can be found in Appendix A.

Before it was decided to apply the literature review method for this research, two alternative methods had been considered. The first alternative method considered was direct observation. This method involves monitoring a construction project(s) for impacts of V.Os on the project(s). This also implies a study of the different documentary sources (e.g. daily site diaries, V.O lists, site instruction list, valuations of V.Os which were issued, EOT claims) generated during the project. The second alternative method considered is the analysis of contract claims from contractors claiming for the secondary impact of V.Os. This would require the assistance of South African construction claims consultant companies, to provide the author with various claim documents from which the necessary information can be extracted from.

The two alternative methods however, have different challenges to it which could not be met at the time this research was done. For instance, construction projects often span over a number of years. If the direct observation method was to be applied by the author, observation would have to be done for at least a year. Given the time constraints associated with all these, gathering information for a year would not be possible. Apart from the time constraints, it was seemingly difficult to acquire a South African company that specialises in preparing and evaluating construction claims to assist with the required information. Hence, the literature review method was considered reasonable for the task at hand.

As will be noted, the two alternative methods are applied by some of the authors of the literature that are reviewed (Eden *et al.,* 2000, Love *et al.,* 2002). Hence, although the author could not apply these methods herself, information delivered by the application of these methods could still be captured indirectly through the literature review method.

7.2.2 Targeted Literature Sources

The goal of any research study that makes use of the literature review method, is to target and gather as many published academic journal articles as possible. The fact that they are peer reviewed makes them the best form of data to be used when using the literature review method. However, upon initial literature review it was clear that there are only a limited number of published journal articles which discuss the secondary impact of V.Os. Hence, the author was compelled to expand the list of types of literature sources to include academic books, conference proceedings, reports and unpublished theses.

7.2.3 Gathering and Identifying the Literature

The relevant literature was identified and gathered using three methods. At first, the author endeavoured a broad literature review which involved keyword searching. Examples of the phrases that were searched for are "the secondary impact/effect of V.Os on construction projects", "the cumulative impact of V.Os on construction projects", "the impact of V.Os on productivity, "V.Os and rework" and "V.Os and delay and disruption". This method delivered most of the articles, books, conference proceeds, reports and theses used. The second method used was a specific literature search. This involved searching for specific articles and books which are referenced by the literature identified during the keyword search. Lastly, the author of a conference proceedings paper (identified during the keyword search), Warhoe (2012) identified (through personal correspondence) to the author the titles of books that could assist with the research.

The four main search engines that were used are Stellenbosch University's library's data bases named Compendix, Stellenbosch University's library backlog, Google Scholar and Google.

7.2.4 Analysis of Literature Data

From the literature search conducted, 3 journal articles, 3 academic books, 2 conference proceedings, 3 reports, and 1 unpublished thesis have been found. That is a total of 12 references. The identified literature were studied. Through means of Microsoft Excel 2007 the following information were captured for each reference namely the title, the authors' names, the year of compilation, the methodology used, the key ideas and the degree of importance to the research at hand. The degree of importance of a reference is determined by the opinion of the author after evaluating it. It indicates how much the information discussed in the literature assists the author with understanding the secondary impact of V.Os. The degree of importance of a reference can be either of low, medium or high importance.

7.2.4.1 Journal Articles

The 3 articles found were published in one of three different journals and all 3 articles were considered to be of high importance in terms of the value it brings to this research. The "Journal of Operational Research and Society" published 1 article in the year 2000, the "International Journal of Project Management" published 1 article in the year 2002 and the "Journal of Construction Engineering and Management" published 1 article in the year 2012.

Different research methods were applied by the authors of the articles. The authors of the article published in the year 2000 (Eden *et al.*, 2000), have been involved with post-mortem analysis of a number of projects in preparation of delay and disruption claims for a total of five years. The contract values of the projects analysed by the authors are said to range in the vicinity of tens' of millions of pounds. Europe, Canada, USA and the UK are the countries in which the projects were executed in. Based on the authors' experience, they discuss in the article delays and disruption which result from V.Os.

The author of the article published in year 2002 applied the direct observation method to gather information for their research (Love *et al.*, 2002). The authors monitored a construction project with the value of $A 10.96 million for effects of V.Os on the project performance. The authors studied different documentary sources generated during the course of the project and also conducted interviews with the contractual parties. With a rich database of information, the authors give an in detail explanation on how V.Os affected the project's performance.

The authors of the article published in the year 2012 (Han, Lee & Peña-Mora, 2012), applied the literature review method. By careful examination of the information given in the literature reviewed, the authors were able to discuss how V.Os cause the performance of construction projects to vary.

The above information is summarised in Table 7.1.

Article #	Degree of Importance	Authors	Year Published	Name of Journal	Methodology
1	H	Eden C, Williams T, Ackermann F, Howick S,	2000	Journal of Operational Research Society	Authors' Experience
2	H	Love PED, Holt GD, Shen LY, Li H, Irani Z	2002	International Journal of Project Management	Direct Observation
3	H	Han S, Lee S, Peña-Mora F	2012	Journal of Construction Engineering and Management	Literature Review

Table 7.1: Articles reviewed

7.2.4.2 Academic Books

The three books found were identified to be of medium importance to this research. The titles of the books are as follows, "Quantifying and Managing Delay and Disruption Claims", "Modelling Complex Projects" and "Calculating Loss of Productivity in Construction Claims". The first two books were published in the year 2002 and the last book was published in the year 2004.

The authors of the books made use of different methodologies. The author of the book "Quantifying and Managing Delay and Disruption Claims" (Lal, 2002) applied the direct observation method. Four different construction projects were monitored and an account is given in the book of the different delays and disruptions observed by the author. In the book "Calculating Loss of Productivity in Construction Claims" the author (Schwartzkopf, 2004) included a collection of 95 court cases of contractors that claimed for loss of productivity due to the secondary impact of V.Os. These cases are helpful in terms of describing the effects of V.Os on projects and providing reasons for the effects. In the third book "Modelling Complex Projects" the author (Williams, 2002) sheds light on the impact of changes on projects by theoretically addressing the cause and effect relationship of changes and its impact on construction projects. The information in this book mostly confirmed the findings of the other authors. It is worthwhile to mention that the author of the book "Modelling Complex Projects" (Williams, 2002), is one of the authors of the article published in the "Journal of Operational Research and Society" (Article "1").

The above information is summarised in Table 7.2.

Academic Books #	Degree of Importance	Name of Book	Authors	Year Published	Methodology
1	M	Quantifying and Managing Disruption Claims	Lal H	2002	Direct Observation
2	M	Modelling Complex Projects	Williams T	2002	-
3	M	Calculating Loss of Productivity in Construction Claims	Schwartzkopf W	2004	Court Cases

Table 7.2: Academic books reviewed

7.2.4.3 Conference Proceedings

From the two conference proceedings found, one was identified to be of high importance and the other of medium importance to this research. The one which is identified to be of high importance is published in year 1989 for the American Association of Cost Engineers (AACE) 33rd annual meeting (Heather, 1989). The method used by the author of this conference proceeding is a combination of the literature review method and the analysis of case studies. The other conference proceeding, identified to be of medium importance, is published in the year 2011 for the AACE international transaction CDR.501 (Warhoe & Giammalvo, 2011). The method used by the author is the literature review method.

The above information is summarised in Table 7.3.

Conference Proceedings #	Degree of Importance	Authors	Year Published	Name of Conference	Methodology
1	H	Heather PR	1989	AACE 33rd Annual Meeting	Case Studies
2	M	Warhoe SP, Giammalvo PD	2011	AACE International Transactions CDR. 501	Literature Review

Table 7.3: Conference proceedings reviewed

7.2.4.4 Reports

The three reports found were all recently published, see Table 7.4. Instead of adding to the understanding of the secondary impact of V.Os, the reports simply confirm the findings of the journal articles, academic books, conference proceedings and theses. For this reason the reports were identified to be of low importance for this research although it aided to confirm the information from the other sources.

From the three reports, one is a field guide (Ibbs & Vaughn, 2012) compiled for contractors and explains what change is and their possible effects on construction projects. Ibbs is one of the authors of the field guide and some of his articles have been referenced in previous chapters of this thesis.

The other two reports were published by two different construction claim consultant companies. The companies are Hill International, Inc. (Nelson, 2011) which has offices worldwide and Long International, Inc. (Long & Carter, 2012) which is US based. The purpose of both the reports was to aid contractors with information necessary when preparing a claim for damages due to the secondary impact of V.Os. The authors made use of the results of construction industry studies and lessons learned from claim cases.

Reports #	Degree of Importance	Title of Report	Authors/Firm	Year Published	Methodology
1	L	The Analysis and Validation of Disruption	Hills International, Inc.	2011	Construction Industry Studies, Case Law
2	L	Cumulative Impact Claims	Long International, Inc.	2012	Construction Industry Studies, Case Law
3	L	Change and the Loss of Productivity in Construction: A Field Guide	Ibbs W, Vaughn C	2012	-

Table 7.4: Reports reviewed

7.2.4.5 Unpublished Theses

The thesis found is considered to be of high importance to this research. It is the widely-cited research done by Leonard (1988) on the effects of V.Os on productivity. The thesis was submitted to Concordia University in Canada in 1988 as a requirement for the degree of Master of Engineering. Some of the findings of this thesis have been partially discussed in Chapter 6 already.

The methodology applied by Leonard (1988) is the analysis of contract claims due to contractors claiming for the secondary impact of V.Os. The exact documents from which information were extracted are claim statements by the contractor, claim evaluations done by arbitrators and testimonies of experts stipulated in reports. In his thesis Leonard (1988) discusses the effects of V.Os on the productivity of construction projects as identified during the analysis of the cases.

From the literature reviewed in this chapter, a third refers to the thesis by Leonard (1988). These include all three reports (Ibbs & Vaughn, 2012, Nelson, 2011 and Long & Carter, 2012) and the conference proceeding submitted to the (AACE) 33rd annual meeting (Heather, 1989).

The above information is summarised in Table 7.5.

Theses #	Degree of Importance	Title of These	Author	Year Submitted	Methodology
1	H	The Effects of Change Orders on Productivity	Leonard C	1988	Analyses of Construction Claims

Table 7.5: Unpublished theses reviewed

7.3 The Comprehensive and Systematic Overview

From careful consideration of the literature it is derived that:

1) The delay and disruption events triggered by V.Os originate in two phases in a project, Phase 1 and Phase 2.
2) Phase 1 occurs before the implementation of V.Os, see Figure 7.2.
3) Phase 2 occurs after the V.Os are issued, see Figure 7.2.
4) The delay and disruption events present in Phase 1, are depended on the processes followed when V.Os are issued.
5) The delay and disruption events evident in Phase 2, originate in consecutive stages, Stage 1, Stage 2 and Stage 3.
    - Stage 1 considers the disruption caused by the site management's control actions.
    - Stage 2 considers the disruption caused by the synergy of delay and disruption events resulting from Phase 1 and Phase 2.
    - Stage 3 considers the disruption caused by acceleration methods implemented on projects due to delays caused by delay and disruption events resulting from Phase 1 and Phase 2.

The following information is structured according to the two phases and its related processes and stages. It comes mainly from the references given under Section 7.2.4, unless explicitly stated otherwise.

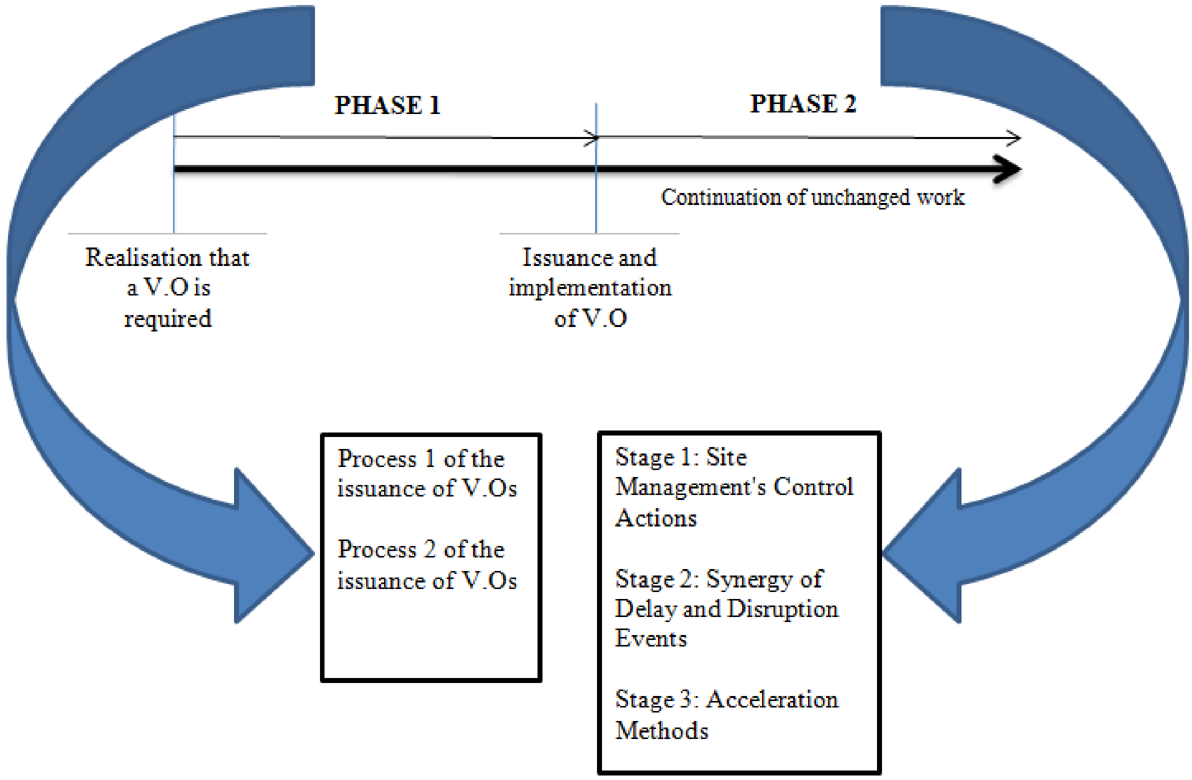

Figure 7.2: A schematic presentation of the phases, processes and stages under which delay and disruption events triggered by V.Os originate on projects

7.3.1 Phase 1: Delay and Disruption Events

Before a V.O is implemented, a process is followed. That is the engineer must issue a written order to the contractor that explains what the variation entails. For most types of construction projects, revised drawings will be issued as well. Thereafter the contractor should have the necessary information to implement the V.O. This can be viewed as a process (Process 1) which consists out of three steps, see Figure 7.3. If however, the cause for the variation is *unknown design deficiencies* or *errors and omissions* (E&O) in drawings, then logically the V.O will only be issued once the deficiencies and E&O become known to the engineer and client. Two extra steps are added to Process 1, which are depicted in Figure 7.4. First the E&O is discovered by the contractor, the contractor request the engineer for information (RFI) and clarification (RFC) relating to the E&O detected, and only thereafter will the written V.O be issued together with revised drawings and finally will the V.O be implemented. Hence, this process (Process 2) consists out of five steps see Figure 7.4.

In an ideal world these processes are followed in a systematic, orderly and timeous manner. However, in reality there are delay and disruption events that underlie these two processes. It causes delays and disruption on a project and eventually impacts the productivity of the project. These delays and disruption events will now be discussed.

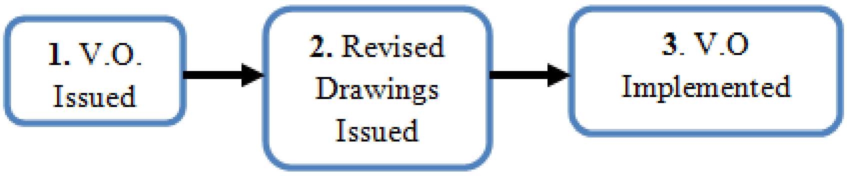

Figure 7.3: Process 1 of the issuance of V.Os

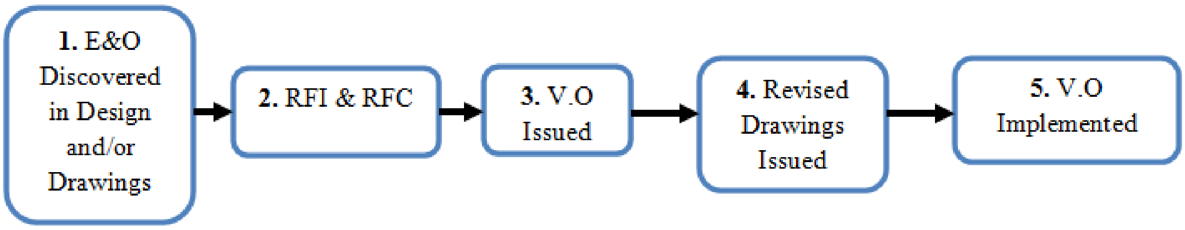

Figure 7.4: Process 2 of the issuance of V.Os

7.3.1.1 Process 1: Delay and Disruption Events

The process showed in Figure 7.3, Process 1, insinuates a process that is short and simple, which is also the ideal perception in practice. However, there are the following delay and disruption events concomitant to the process:

The Timing of V.Os

The first disruptive event is the probability that a V.O is issued late in the project. In Chapter 6 the timing of when the V.O is issued has been considered. It was concluded that V.Os which are issued late in the projects are more disruptive to labour productivity than a V.O issued earlier in the project. The fact that V.Os may be issued at any time during the construction of the project makes this disruptive event possible. There is thus no contractual control over the timing of the issuance of V.Os making it possible that contractors implement many V.Os late in the project. Hence, before the V.O is implemented, the fact that it is implemented late in the project causes it to affect the productivity of labour.

Drawings Issued Late

Secondly, the revised drawings could be issued late due to late approval by either the engineer or the client. In this case late is relative to a number of factors such as:

- the unreasonable time difference between the time the written V.O was issued and the time when the revised drawings were finally issued,
- how critical it is that the V.O be implemented immediately,
- the progress on the changed activity, and
- the degree to which the activity is interdependent on other related activities.

It is easy to overlook the possibility of this disruptive event since it is expected that the contractor will have the drawings by the time he needs to implement the desired variation. Waiting for drawings will result in the changed work to be put on hold which could delay the unchanged successor activities. It may also affect labour motivation.

Revised Drawings Erroneous

Thirdly, it is possible for the revised drawings which are issued to the contractor to contain errors, insufficient detail or be ambiguous and unclear. Naturally, one will not expect this to happen as it is expected that engineers take great care to issue quality products. Unfortunately, it does not always happen (Jerling, 2009). In the event that the revised drawings are erroneous, the contractor would be required to request the engineer for information (RFI) and clarifications (RFC) which may result in further revisions made to the drawings of which it is possible that the new revised drawings be issued late as well.

Dilution of Supervision, Poor Quality, Rework & Demolition

Attention should be given to administration tasks such as RFI and RFC as these are underlying events which are disruptive to the contractor and the project. Upon RFI and RFC the engineer is responsible to respond timeously. However, it is possible that the engineer either takes long to respond or responds in vague terms. RFI and RFC are known to be time consuming and tend to require considerable effort on the part of the contractor's site management (Eden et al, 2000). Delay and disruption events such as late response and vague response, not to forget the late issuance of drawings or the issuance of erroneous drawings, can add to the tediousness of these tasks and extend its duration. One consequence is that site management can consequently be prevented from providing supervision and technical support to foremen working on both changed and unchanged work. To the extreme, foremen may have to assist superior site management with their coordinating and planning responsibilities. Hence, dilution of supervision of both site management and foremen occurs. This not only impacts productivity of labour working on the changed and unchanged work but, may also result in poor quality of the works. For most cases, work that does not meet contract specifications will certainly have to be demolished and executed again, which further impacts labour productivity on the changed and unchanged work.

Another consequence is that conflict is likely to arise between contractor and engineer when the administration tasks are made difficult due to engineers repeatedly taking long to respond or respond in vague terms. The conflict between site management and the engineer may affect the flow of information between the two parties throughout the project. Such conflict is detrimental to both client and contractor, as contractors are dependent on information from engineers to maintain progress and to successfully complete the project.

7.3.1.1.1 Process 1 Revised

The delay and disruption events contaminant to Process 1 have now been discussed and can now be incorporated in the process (see Figure 7.5).

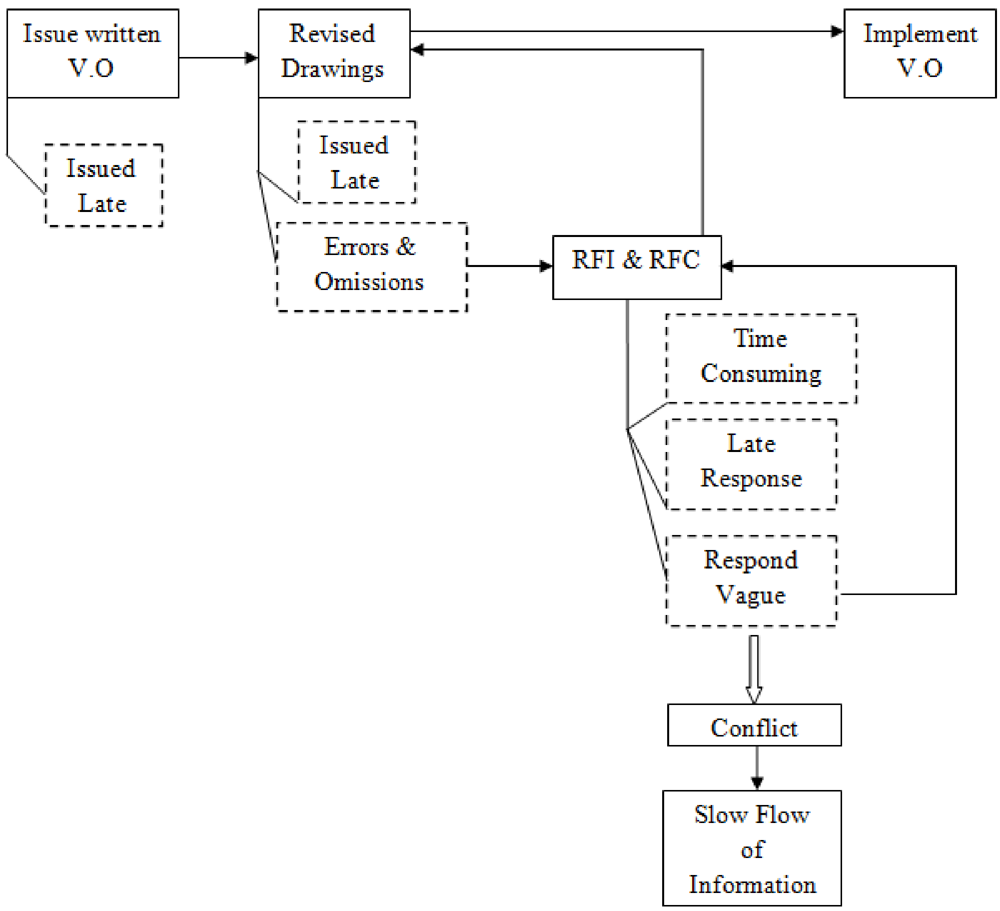

Figure 7.5: Process 1 with its underlying delay and disruption events

7.3.1.2 Process 2: Delay and Disruption Events

The delay and disruptive events associated with Process 1 (discussed above) are similar to the delay and disruption events associated with Process 2 (when changes originate from E&O). However, due to the additional steps in Process 2, additional feedback loops exist causing the delay and disruption events to be more disruptive than in the case of Process 1. The additional cycles present in the process of V.Os which result from E&O will now be highlighted.

The Timing of the V.O

The time when the V.Os are issued, is dependent on the speed at which the unknown E&O are discovered. Since the E&Os are unknown, it normally is only discovered at the time the contractor is executing the work of which the design or drawings are erroneous. Contractors have no legal responsibilities to identifying E&O in design and drawings. After all, in terms of the contract, the onus rests upon the engineer and client and not the contractor to do so. Therefore, the time at which the V.O is issued becomes a much more critical factor.

Dilution of Supervision, Poor Quality, Rework & Demolition

The administration activities, RFI and RFC, play a bigger role in this process (Process 2) than in the case of Process 1. The contractor has to submit a RFI and a RFC at the time the E&O are discovered in the original design and drawings. This is also needed when the revised drawings are ambiguous and unclear. The probability of dilution of supervision, poor quality, rework and demolition on changed and unchanged work therefore increases. In the same manner conflict due to the late and vague response of engineers to RFI and RFC is much more likely to arise between contractor and client which would certainly strain the flow of information between the two parties.

7.3.1.2.1 Process 2 Adjusted

By adjusting Process 2 shown in Figure 7.4 to account for the delay and disruption events and additional feedback loops identified and discussed above, a more realistic process is obtained, as depicted now in Figure 7.6.

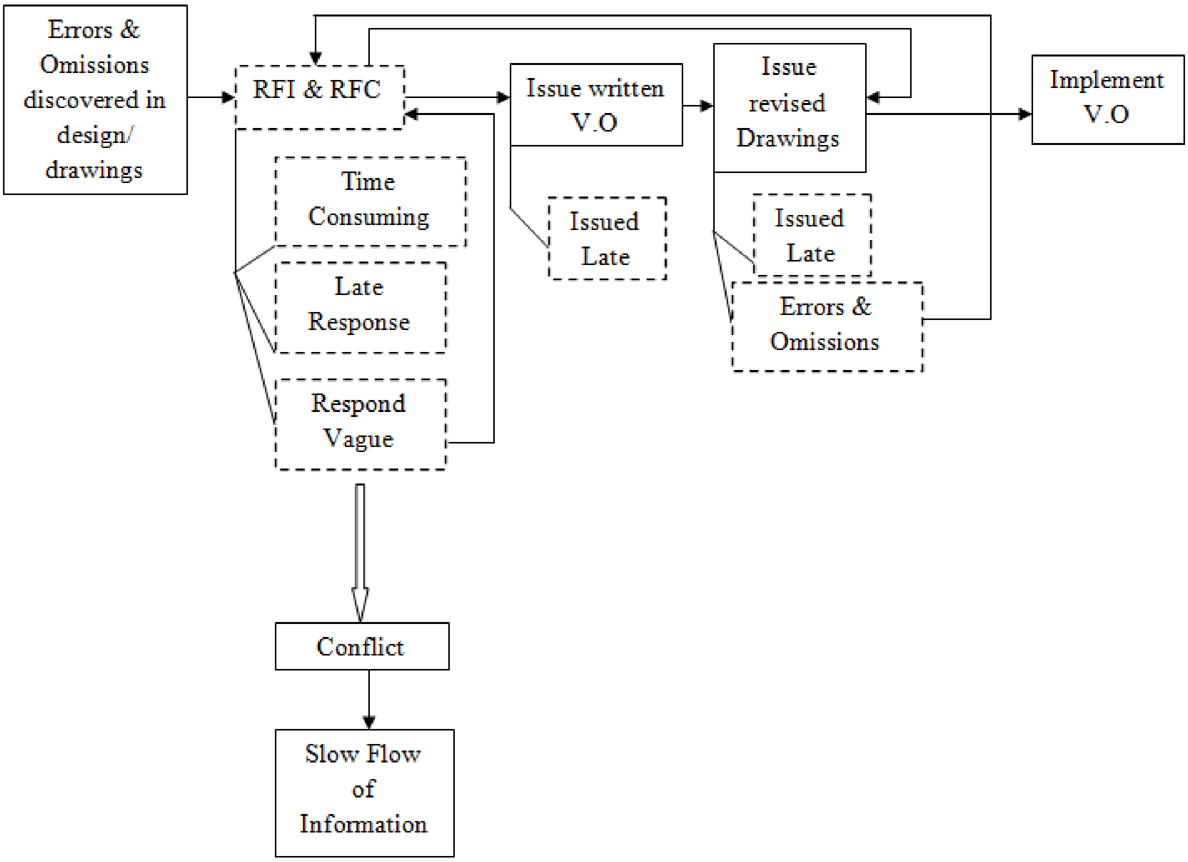

Figure 7.6: Process 2 with underlying delay and disruption events and feedback loops

7.3.1.3 Summary for Phase 1

Two processes are discussed with reference to a single V.O. For each process potential delay and disruption events triggered by a V.O are identified.

It is worthwhile to highlight that during a construction project, numerous V.Os may be issued at different times in the project. As a result, the two processes are repeated in a project for each V.O issued by the engineer. Hence, the disruption and delays caused by the underlying delay and disruption events of the two processes are present on the project for as long as V.Os are issued. In other words, a project is always subjected to the delay and disruption events discussed so far, since there is always a possibility that a V.O will be issued.

7.3.1.4 Recommendations for Phase 1

Having considered the cited references, it is now recommended that the client:

- Identifies variations before construction commences and issue V.Os in the early stages of construction.
- Makes sure that sound drawings are provided to the contractor at all times and as soon as reasonably practical
- Responds duly, effectively and unambiguously the contractor's RFI and RFC

Having considered the cited references, it is now recommended that the contractor:

- Allocates time and resources to identify common E&O in drawings in advance
- Acknowledges that RFI and RFC are time consuming activities and it interferes with other management responsibilities. Contractors can appoint a person that will take care of the administration tasks associated with V.Os. If not possible the administration tasks of V.Os should be identified and allocated as one of the key responsibilities of either the site manager or site engineer.

Having considered the cited references, it is now recommended that both client and contractor:

- conserve the relationship between each other

7.3.2 Phase 2: Delay and Disruption Events

As mentioned earlier, Phase 2 of the comprehensive and systematic overview of the secondary impact of V.Os includes everything that happens after V.Os have been issued, see Figure 7.2. From careful consideration of the information given by the literature it was possible to categorise in three stages the delay and disruption events that occur after the issuance of the V.O:

- Stage 1: considers the delay and disruption caused by the control actions taken by management in response to the direct impact (the impact on the changed work).
- Stage 2: considers the synergistic effect of all the individual delay and disruption events triggered by V.Os.
- Stage 3: considers the delay and disruption caused by the acceleration methods which are implemented by management, due to delays caused by the various V.Os issued on a project.

These three stages are analysed individually in the following three sections.

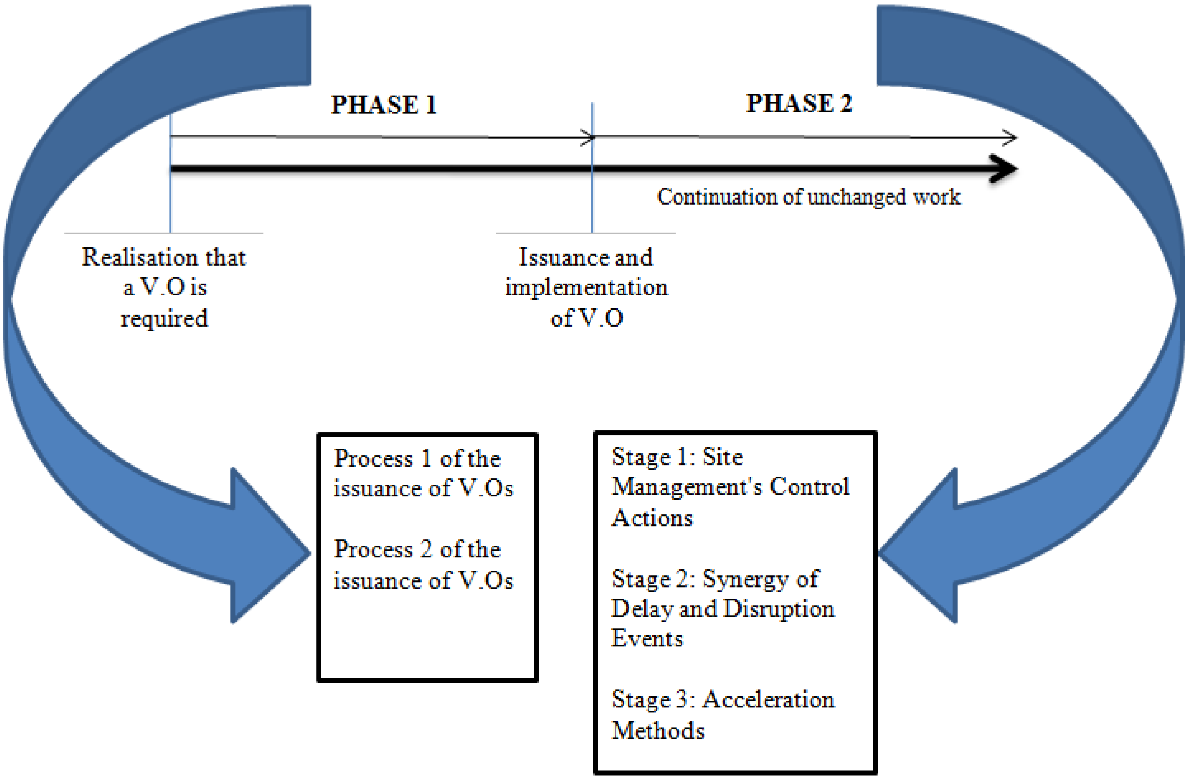

Figure 7.2: A schematic presentation of the phases, processes and stages under which delay and disruption events triggered by V.Os originate on projects

7.3.2.1 Stage 1: Site Management's Control Actions

Most V.Os involve something to be changed to a particular activity or activities. The approval and information delays associated with Phase 1 of the secondary impact of V.Os (see Section 7.3.1), generally disrupt changed activities, causing it to be put on hold and the assigned workers and resources to idle. This disruption to the changed work is considered part of the direct impact. In order to limit or avoid damages due to the disruption on changed work, contractors apply control actions (Han *et al.*, 2012). However, the control actions self are often disruptive to the unchanged work (Han *et al.*, 2012). Since the control actions are implemented due to the affect of V.Os on the changed work, the delays and disruption caused by the control actions are considered part of the secondary impact of V.Os.

This section of the chapter is concerned with the delay and disruption events that result from the control actions which consequently impact unchanged work. First, the different control actions will be introduced and thereafter its ramifications.

7.3.2.1.1 The Control Actions

Logically, the delay and disruption events triggered by control actions depend on the specific action the contractor will take. As a result the delay and disruption events identified in this section are limited to the number of control actions known and reported in literature (Han *et al.,* 2012, Long & Carter, 2012 and Leonard, 1988). In total, three control actions could be identified, they are:

1) *"Stop-and-go operations"*: this occurs when a contractor stops workers who are working on an activity and assigns them and the associated resources to temporarily assist with other activities. As information becomes available the workers and resources return back to the original activity.
2) *"Out-of-sequence":* There are two possibilities noted of how work can be performed out-of-sequence in construction projects. The first is where the planned order of the activities is changed. The second involves changing the sequence in the method statement of the activity, so the task itself is performed out-of-sequence. This is also referred to as re-sequencing of the method statement (Long & Carter, 2012). Either one could be applied when interruptions are present however, as noted by Leonard (1988), the first is most common. The second is commonly applied as an acceleration strategy and will be discussed under Section 7.3.2.3 which deals with acceleration.
3) *"Do Nothing":* A contractor might elect to stay with the changed activity which implies doing nothing.

The delay and disruption events triggered by these control actions will now be identified and discussed. Each control action will be addressed separately with one exception. There are certain delay and disruption events common to both stop-and-go operations and out-of-sequence work. In order to prevent repetition they will be discussed under a combined heading shortly after all three control actions have been discussed individually.

7.3.2.1.2 *"Stop-and-go Operations":* Delay and Disruption Events

"Stop-and-go operations" are applied to mitigate interruptions on changed work. However; it does not eradicate interruptions, but it causes them. This can be deducted from the following

logic: workers stop working on the changed activity, commence work on successor activities only to be stopped again and continue with the former (changed) activity. As discussed in Chapter 5, the interruptions affect a working crew's job rhythm, it impacts a working crew's learning curve and withholds workers from making progress. Therefore *"stop-and-go operations"* may cause a loss of productivity on the activities which are affected by it.

It must be realised that once workers start with a different activity it can be difficult to summon them back to the changed activity. This could delay the completion of the changed activity which in turn delays the commencement of successor activities (unchanged work). In instances where the starting dates of successor activities (unchanged work) are important, workers continuing work on the changed pre-decessor activity might need to rush in order not to delay the successor activities from starting at the planned date. Working in a rushed manner increases the probability of rework as mistakes are likely to occur. Since the rework takes place on the changed activity it directly affects the labour productivity on the changed work which further increases the duration of the changed activity. Hence, despite rushing the activity in order not to delay the commencement date of the successor activities the probability that the successor activity will be delayed is higher.

Furthermore, *"stop-and-go operations"* also reduce productive time available in a working day. This is achieved when stop-and-go operations initiates contributory and preparation work and increase the number of times contributory and preparation work have to be executed (Leonard, 1988). Examples of contributory and preparation work are:

- Packing of tools
- Return of materials to storage
- Obtaining new material
- Unpacking of tools
- Prepare work surfaces
- Take measurements

The time used to perform these activities, is time that should have been used to perform the actual activity which would add value to the project. Leonard (1988) calculated the percentage of hours spent on contributory and preparation work during a disruptive day. He found that nearly 45% of the total hours in a working day was spent on contributory and preparation work.

"Stop-and-go Operations" versus Secondary Impact

It is important to note that the majority of delay and disruption events due to stop-and-go operations discussed above result in a loss of productivity on the immediate successor activities. One argument may be that the impact on immediate successor activities should be foreseeable because it shortly follows after the impact on the changed activity. According to the definition of the secondary impact, the secondary impact is the **unforeseeable** loss of productivity due to the delay and disruption caused by V.Os. Hence, based on the argument that the impact of stop-and-go operations on the immediate successor activities is foreseeable, it should not form part of the secondary impact of V.Os but rather form part of the direct impact. A different argument however is that delay and disruption events such as *interruptions*, *difficulties in summoning workers back to changed activity*, *initiation of contributory and preparation work*, etc., do appear to be subtle events. For this reason it is highly possible that contractors neglect to foresee them. Therefore it is the author's opinion that the delay and disruption events caused by stop-and-go operations should be discussed as part of the secondary impact of V.Os. Furthermore, part of Phase 2 of the secondary impact is the disruption caused by the synergy of the delay and disruption events triggered by V.Os. This includes the delay and disruption caused by control actions such as stop-and-go operations, since it is due to V.Os that control actions are implemented. This is another reason why it is necessary that the delay and disruption events triggered by stop-and-go operations be considered part of the secondary impact of V.Os

7.3.2.1.3 *"Out-of-Sequence Work*": Delay and Disruption Events

As discussed in Chapter 4, working out-of-sequence often results in the contractor working in an illogical and uneconomical manner. A vast number of assumptions, reasoning, and considerations hide behind the project programme submitted by the contractor. They include factors such as prevailing working conditions, logistics, access to work areas, contractor's strengths and weaknesses. Changing the order in which activities are performed often results in changes in the original working conditions causing the initial assumptions to no longer hold true (Eden *et al.,* 2000). This has an impact on labour productivity on both changed and unchanged work and also tends to increase the cost of performing unchanged activities.

The best way to demonstrate the disruption cause by out-of-sequence work is by means of examples:

Example 1

The objective of this example is to illustrate how changing the sequence of activities due to changes, cause initial assumptions made in the original program to become invalid.

- This example is one of the case studies analysed in the conference proceedings for AACE 33rd annual meeting (Heather, 1989). The project involved the construction of a power plant in San Bernardino, California in the year 1971. This project was subjected to several problems and the contractor was directed to change the sequence of the activities. One of the problems had to do with the foundation of the penstock area which was adjacent to the power plant. The work on the power plant involved the use of cranes. In the original programme assumptions were made concerning the placement of the crane. However, due to the foundation problems of the penstock area the space which was assumed to be available for the placement of the crane was not available. As a result, the crane had to be erected in, and operated from less advantageous positions. This resulted in more handling operations than originally anticipated slowing down the progress of the power plant and increasing its costs. Hence, due to the change in sequence of activities, it appears as if the critical assumption made in the original program regarding the location where the crane will be erected was incorrect. Meanwhile, the assumption was reasonable when the program was compiled but due to the change in sequence which changed the original working conditions it became incorrect.

Example 2

The objective of this example is to illustrate how changes can force the implementation of out-of-sequence work, causing the contractor to perform work in an illogical and uneconomical manner.

- This example was given by the contractor interviewed in the pre-study (Company A, 2011). The project involved renovations made to a shopping centre in the year 2010. The contractor had an exact sequence of how he was planning to renovate the building, floor by floor working in a specific direction. Contractually the client was responsible for the tenants to move so that the shops which were to be renovated would be available as required by the contractor's programme. During the project however, problems arose as the tenants did not move when they were required to move. What made matters worse is the fact that there were no new agreed dates established that would indicate the new sequence in which tenants would evacuate their shops. The contractor ended up renovating shops as they became available, on different floors and different locations. As a result, the sequence of construction became a function of the availability of shops and not a function of normal construction logic and economics as foreseen in the original program. Working out of sequence resulted in the contractor claiming for expense and losses and E.O.T.

Common Occurrences

Occurrences which are not associated with a particular scenario, but are likely to occur when contractors work out-of-sequence, are difficult working conditions such as overcrowding and stacking of trades (Han *et al.*, 2012, Eden *et al.*, 2000). They occur because activities which were planned to start at a later date are executed early as contractors jump to different activities. As concluded in Chapter 4, difficult working conditions such as overcrowding and stacking of trades result in loss of productivity. In general, when work is performed out-of-sequence, the unchanged work is affected. Hence, it is the productivity of the unchanged work that is most likely affected by the occurrences resulting from performing work out-of-sequence.

Other Reasons for *"Out-of-Sequence Work"*

Out-of-sequence work is not only a control action taken by managers in respond to the impact V.Os have on the changed work. There are other reasons why a contractor performs work *"out-of-sequence"* due to changes. One reason in particularly is when clients and engineers make certain assumptions and take certain risks which the design is depended on, and allow construction to commence without finalising them. During the course of the project the assumptions may prove to be wrong and the risks may materialise. This causes changes to be made in the design and the contractor to adjust his program resulting in work performed *"out-of-sequence"*. For example:

Example 3

- The contractor interviewed in the pre-study [Company A, 2011] was working on a project which involved extensions made to a shopping centre. The principal agent together with the client assumed that permission will be granted by the municipality for right of way for delivery trucks. The shopping centre was designed with this critical assumption in mind. Unfortunately, permission was not granted which required the repositioning of one of the staircases. What made matters worse is, the information only became available when the contractor was busy with preparations for the construction of the staircase. This change in the position of a staircase resulted in the contractor executing unchanged activities in a different sequence than that given on the programme.

The difference between the reason for out-of-sequence work in this example and that of Example 1 and Example 2 is the fact that the principal agent was reasonably aware of the possibility that a V.O might have to be issued and what that V.O will entails. In general, it is assumed that neither the principal agent nor the client know beforehand what and how many V.Os will be issued on a project. This example proves that there are instances where the principal agent does know about certain V.Os that are likely to be issued during the project.

7.3.2.1.4 *"Stop-and-Go"* and *"Out-of-Sequence Work":* Mutual Delay and Disruption Events

Both *"stop-and-go operations"* and *"out-of-sequence work"* involve workers to leave the disrupted activity to work on a new activity. Hence, there are certain mutual delay and disruption events the two control actions have in common. As mentioned before, they will be addressed together under this section.

Firstly, during *"stop-and-go operations"* and working *"out-of-sequence"*, workers are often prematurely moved from the changed activity where they are originally assigned to, to work on the next activity. This could prevent contractors from keeping crews on repetitive tasks which in turn, deprive contractors from benefiting from gains in efficiency due to the learning curve. It could also interrupt job rhythm on both affected and unchanged work. As a result, the productivity is impacted on the unchanged work.

Secondly, workers are kept from making progress as well as completing activities they started. This in turn has an impact on their morale causing them to be less productive when commencing work on the new unchanged activity.

Thirdly, moving crews from one activity to the next could result in changes within the team member combination. If it is considered that workers' motivation depends on intrinsic rewards such as relationships between co-workers loss of productivity is sure to follow.

Lastly, *"stop-and-go operations"* and *"out-of-sequence work"* may cause contractors to lay off workers resulting in unplanned fluctuations in manpower levels. This may impact cost if new workers have to be hired and trained again.

7.3.2.1.5 *"Do Nothing":* Delay and Disruption Events

"Do nothing" signifies that the contractor prefers to stay with the disrupted activity rather than to apply control actions such as *"stop-and-go operations"* and *"out-of-sequence work"*. During this time, the contractor normally records damages such as standing time with the intention to claim. Workers on the other hand, are kept busy with non-value added activities (NVAA) such as housekeeping and barricading (Eden *et al.,* 2000). Non-Value Adding Activities (NVAA) are activities executed and effort utilised which generate no value to the project (Han *et al.,* 2012). It is also possible that contractors might lay off workers in an attempt to minimise damages.

There are different ramifications at stake when contractors claim for standing time, submit workers to NVAA and lay off workers. These ramifications have an impact on unchanged work in terms of productivity or costs. Submitting claims for instance, creates conflict and ruins relationships. Just like in the case of RFI and RFC, the strain placed on the relationship between the contractor and engineer may affect the flow of information necessary to maintain progress throughout the duration of the project. NVAA such as housekeeping on the other hand, are demoralising to workers (Rivas *et al.,* 2011). As explained by the expectancy theory discussed in Chapter 5, if a worker's morale or self-esteem is impacted it will lower their expectancy and therefore, the worker will be reluctant to expend the necessary effort when having to continue work on the changed activity. If in future, workers are again submitted to NVAA, given that in the past NVAA caused them to be less productive, the bad experience, according to the expectancy theory, could lower the workers' expectancy and therefore their productivity on the unchanged activities. Lastly, the layoff of workers results in unplanned fluctuations in manpower levels. This may impact cost if new workers have to be hired and trained again.

7.3.2.2 Summary of Delay and Disruption Events of Control Actions

To summarise the delay and disruption events associated with the control actions, a cause and effect matrix has been created and is given in Figure 7.7.

A Cause and Effect Matrix for Control Actions

	Stop-and-go	Out-Of-Sequence Work	Do Nothing		Impact Learning Curve	Impact Job Rhythm	Overcrowding	Stacking of Trades	Conflict	Demoralising	Rework and Demolition
	•			Interruptions		•					•
	•			Initiate Contributory and Preperation Work							
	•			Work in a Rush Manner							•
		•		Initial Assumptions Invalid							
		•		Change Working Conditions			•	•			
		•		Perform unchanged work in an Ilogical and Uneconomical Manner							
	•	•		Workers Prematurely Moved from One Activity to the Next		•					
	•	•		Changes in Crew Combination	•						
	•	•		Fluctuations in Manpower Levels							
			•	Claims					•		
			•	Perform NVAA						•	
• Implement Control Actions	•	•	•		•	•	•	•	•	•	•

Figure 7.7: Cause and Effect Matrix for Control Actions

7.3.2.3 Recommendations for Control Actions

Having considered the cited references, it is now recommended that the client:

- Makes known to the contractor assumptions about the project/design that could result in V.Os before construction commences
- Consults the contactor on solutions and ways as to how best to incorporate V.Os before issuing a V.Os

Having considered the cited references, it is now recommended that the contractor:

- Accepts that if V.Os are issued, control actions will have to be implemented and will cause delay and disruption events on the project

- Familiarises himself with the delay and disruption events associated with the control actions: *stop-and-go* operations, *out-of-sequence* work and *do nothing* as given in Figure 7.7 and discussed in Chapter 5
- Identifies mitigation strategies for the related delay and disruption events and processes that should be followed (this can be done by means of brainstorming and the use of project specific scenarios)
- Does not blindly and reactively implement a control action. Based on the related delay and disruption events and situation at hand, choose an appropriate control action.
- Adds new identified control actions to the matrix given in Figure 7.7. Possible delay and disruption events should be identified and prepared for.

During project execution record should be kept of the control actions implemented, the reasons why and the related delay and disruption events that were present because of it. To ensure that all delay and disruption events are recorded it should be done on site management level as well as a foremen level. This should then be discussed during production meetings and can be used for lessons learned.

7.3.2.3 Stage 2: Synergy of Delay and Disruption Events

The individual delay and disruption events that have been discussed thus far and which still will be discussed in Stage 3 of Phase 2 of the secondary impact of V.Os are known to have a combinatorial effect. In other words, together the small delays and disruptions have the potential to cause bigger disruptions on projects and, like most disruptions, the bigger disruptions impact the productivity of the project. Eden *et al.* (2000) refers to it as portfolio effects.

From studying the literature, different characteristics pertaining to portfolio effects could be derived. Firstly, portfolio effects mainly take place in the presence of numerous delays and disruptive events. As Eden *et al.* (2000) explains it, *"[portfolio] effects would probably not occur if only one or two [small delays and disruptions] had occurred"*. Secondly, portfolio effects are not readily foreseeable (Eden *et al.*, 2000 and Williams, 2002). They are gradually brought about by many and disparate small delays and disruptions, triggered and accompanied by V.Os which are issued at different times.

It appears as if the main reason why projects fall prey to portfolio effects is due to the false believe of managers that they can control the small delay and disruption events which give rise to the portfolio effects (Eden *et al.,* 2000 and Williams *et al.,* 2002). Hence, it is easy for managers to ignore and therefore neglect to prepare for the possible combinatorial effect that could realise and impact their project.

On the basis of the derived characteristics the following examples of portfolio effects were identified from the literature reviewed and from interviews with contractors.

<u>Portfolio Effect 1</u>

This example was identified in a court case (Schwartzkopf, 2004).

Many delay and disruptive events gradually cause the original contract work to fall behind schedule. In general the impact of V.Os on the unchanged work (work not included in the V.O) is normally not considered during the valuation of the V.O since it does not form part of the changed work. In this scenario however, the V.O has impacted the unchanged work but instead of linking the delay to the V.Os it appears as if though it was due to the contractor's own mistakes. Hence, the penalties and acceleration costs become the responsibility of the contractor. (The disruptions emanating from this portfolio effect is further discussed under Section 7.3.2.4.)

<u>Portfolio Effect 2</u>

This is a classic example that is addressed in the thesis (Leonard, 1988), the conference proceeding submitted to the AACE 33rd annual meeting (Heather, 1989) and the report which is a field guide for contractors (Ibbs & Vaughn, 2012).

Many delay and disruption events gradually shift weather sensitive work to be executed in adverse weather. The work shifted is future activities and therefore, unchanged activities. The fact that it has been shifted during the course of the project is an indication that the scenario has not been anticipated in the original program. Furthermore, the fact that it has been gradually brought about by the delay and disruption events triggered by V.Os is an indication that managers could not have effectively managed its impact on the project which is a loss of productivity as discussed in detail in Chapter 5. Hence, V.Os issued on a project can indirectly impact the labour productivity on unchanged activities by triggering delay and disruption events that shift weather sensitive work to be executed during adverse weather conditions.

Portfolio Effect 3

This example was given by one of the contractors, Contractor B (2012), interviewed by the researcher during the pre-study (Appendix D, 2011).

Many delay and disruption events gradually shift activities of different work packages, utilising the same expensive plant, in such a way that they have to be executed at the same time. Let's take for example a project that consists out of three different work packages which have the activity "excavation and backfill" in common. The plant required for excavation and backfill is generally expensive. Hence, contractors strategically schedule the execution dates of these activities in such a way that a minimum number of machines are sufficient to service all the activities in the different work packages, see Figure 7.8. However, when small delay and disruption events gradually shift these activities to be executed at the same time, the original number of plants becomes inadequate, see Figure 7.8. In this scenario it appears as if the contractor has made mistakes when compiling the program and preparing its bid when instead the program and bid was reasonable and the V.Os that was issued were the cause of the disruption. Hence, the client is reluctant to assist in negotiations to cover the additional cost of hiring more plant which becomes an expense and loss to the contractor.

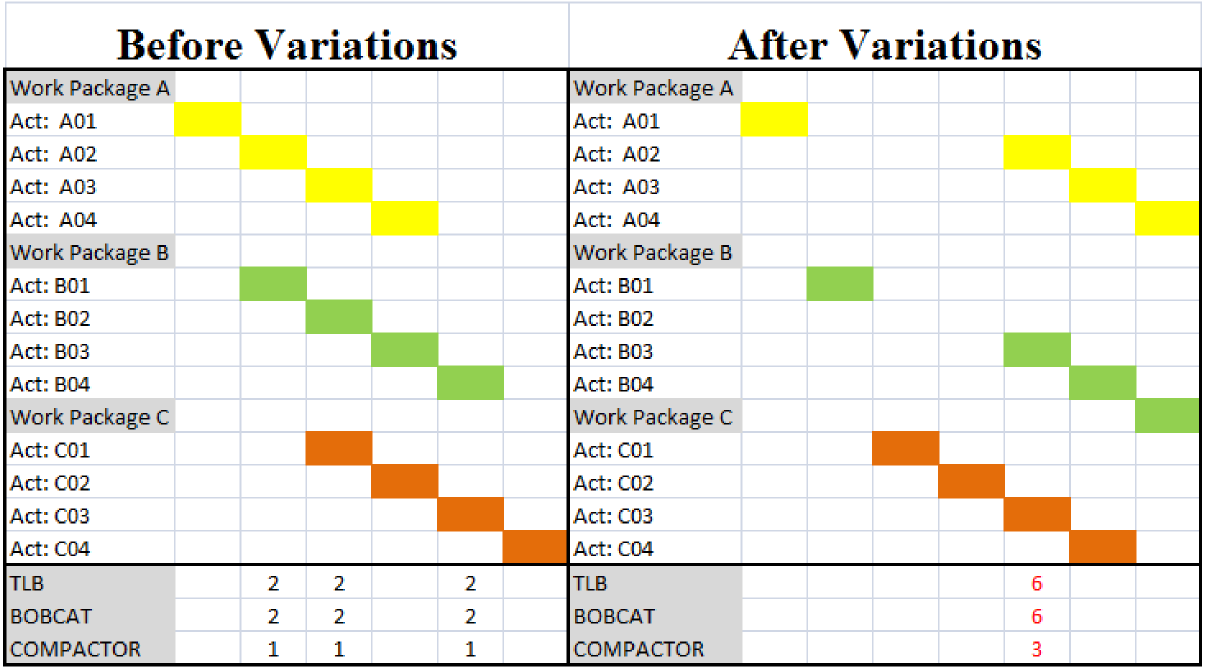

Figure 7.8: A factual program of a factual construction project of which expensive activities were shifted by delays and disruptions to fall on the same date (Contractor B, 2012)

Portfolio Effect 4

This is another classic example that is present on projects due to the disruption caused by V.Os that are issued. It is addressed in the unpublished thesis (Leonard, 1988), the conference proceeding submitted to the AACE 33rd annual meeting (Heather, 1989) and the report which is a field guide (Ibbs & Vaughn, 2012) for contractors. This example was also communicated by Contractor A (2011), interviewed by the researcher during the pre-study (Appendix D, 2011).

Many delay and disruptive events gradually deteriorate original programs resulting in orderly sequences of operations to be broken down into several isolated activities and also cause concurrent operations to occur. It should be noted that the mere deterioration of the construction programme is not simply evidence that the project was disrupted but evidence that scheduling became a function of the released V.Os and drawing revisions instead of using normal construction logic and economics. Under these circumstances productivity is normally impacted and expense and losses are normally incurred.

Note:

The examples given above are by no means exhaustive, they are for illustrating purposes. It is important to realise that because these effects are unforeseeable it is possible that there can be portfolio effects that have not occurred as yet and therefore not identified in literature as yet. Nevertheless, those that are known should be included in risk registers and monitored. Understanding the characteristics of portfolio effects should make it easier to be identified by contractors.

7.3.2.4 Recommendations for Portfolio Effects

Having considered the cited references, it is now recommended the contractor:

- Treats portfolio effects as project risks created by V.Os
- Familiarises himself with the delay and disruption events associated with acceleration methods as discussed in Section 7.3.2.3
- Identifies *weather sensitive work* and monitor its time of execution throughout the duration of the project
- Identifies *expensive activities* and monitor its time of execution throughout the duration of the project
- Keeps a watchful eye on progress made on original contract work as it can fall behind due to V.Os

When portfolio effects occur, the contractor must identify the reasons why it occurred, communicate it to client and document it. New portfolio effects should be added to the matrix and managed appropriately.

7.3.2.5 Stage 3: Acceleration Methods

It is possible that the delay and disruption events accompanied and triggered by V.Os, portfolio effects, and additional cause a critical delay on the project. The manner in which the JBCC and GCC deal with this is by allowing the contractor to claim for an E.O.T with or without compensation depending on the scenario. This would certainly resolve issues related to critical delays. However, due to various difficulties associated with construction projects it appears as if in the event that V.Os cause a critical delay the project will most likely be accelerated instead of changing the completion date of the project through means of granting an E.O.T.

One of the difficulties is that the critical delay caused by the delay and disruption events triggered by V.Os is generally unforeseeable. By the time it becomes apparent that an E.O.T will be required there is generally high pressure to complete the project by the original planned date. Instead of granting an E.O.T the contractor is instructed to accelerate the project.

Secondly, uncertainties may exist as to whether the contractor's own mistakes, his incompetence and own constraints put on his labour force might have contributed to the critical delay. Under these circumstances constructive accelerations are likely to occur. In other words the contractor is held accountable by the contract to complete the project on the agreed time whether or not the delay was due to delay and disruption events triggered by V.Os. Hence, in honouring its contractual obligations the contractor is forced to accelerate the project.

Lastly, if the contractor underestimates the impact of small delays and disruption on a project it would be difficult for the contractor to prove to the client that he is entitled to an E.O.T. Since the contractor is still to make sense of how small delays and disruptions could have resulted in a critical delay. In this case, the contractor would automatically take the responsibility for the delay and voluntarily accelerate the project.

Hence, when a project's completion date is impacted due to the secondary impact of V.Os the project is normally accelerated whether it is an instructed acceleration, constructive acceleration or a voluntary acceleration. As discussed in Chapter 5 and will be further addressed shortly, acceleration methods are disruptive to labour productivity. The acceleration method normally affects the unchanged activities since it is the unchanged activities that are being accelerated. Therefore, when acceleration methods are implemented due to a critical delay caused by V.Os its related impacts are part of the secondary impact caused by V.Os.

The following section addresses the ramifications of accelerating methods.

7.3.2.4.1 Acceleration Methods: Delay and Disruption Events

In Chapter 5 the delay and disruption events due to working overtime, shift work and additional manpower have been discussed. They include fatigue in labourers, dilution of supervision, impact on motivation of labourers, absenteeism, poor work performance, rework, disruption in sleep routine, poor flow of information between shifts, overcrowding and stacking of trades, see Figure 7.9. Hence, due to the critical delay caused by V.Os these disruption events are present on a project and affect labour productivity on the unchanged work and increases expense and losses.

An acceleration method that has not been addressed in Chapter 5 but has become evident, after studying the literature, as a method applied by contractors to accelerate the project, is the re-sequencing of method statements. In Section 7.3.2.1 it was introduced as a type of out-of-sequence work where the method statement of activities is executed out-of-sequence in order to execute the work faster than originally planned. A court case included in the book "Calculating Lost Labor Productivity in Construction Claims" illustrates constructive acceleration and out of sequence work (in the form of re-sequence of method statement) very well.

Practical Example

"P.J. Dick was awarded a contract by Veterans Administration (VA) to construct an addition to a medical centre in Ann Arbor, Michigan. P.J. Dick subcontracted the electrical work to Kent Electrical Services. Significant deficiencies and errors in the electrical design delayed the electrical work. P.J. Dick complained to the VA about these delays, but the VA refused to grant an extension of time and threatened to asses liquidated damages if P.J. Dick did not meet the completion date. P.J. Dick therefore directed Kent to accelerate performance of the electrical work. Kent's original plan of work had been to use three different crews: one installing branch circuit rough-in, one installing (pulling) wire, and one installing devices. Kent's plan was to move sequentially from floor to floor with one crew following the next. After receiving P.J. Dick's acceleration order, Kent used a single crew on each floor to install all three work elements. This reduced the efficiencies Kent had planned to achieve by using specialized crews. P.J Dick paid Kent for the increased labour cost, and then pursued this claim for lost productivity against the VA. The Board found that P.J. Dick had established that the deficient drawings and resulting constructive acceleration constituted a

change in working conditions that caused Kent's branch circuit installation to be less efficient than planned, and awarded the additional labour costs caused by such acceleration." (Schwarzkopf (2004), own underlining)

This example demonstrates four aspects discussed under this section:

1) How a contractor is forced to accelerate a project due to a critical delay which resulted from V.Os.
2) That re-sequencing of method statements is indeed a method applied by a contractor to accelerate a project.
3) That the benefits of the learning curve are taken into account when deciding on a method statement.
4) That the labour productivity of a project can be impacted due to the re-sequencing the method statement which result in expense and losses for a contractor.

7.3.2.5 Summary for Acceleration Methods

To summarise the delay and disruption events associated with the acceleration methods, a cause and effect matrix has been created and is given in Figure 7.11.

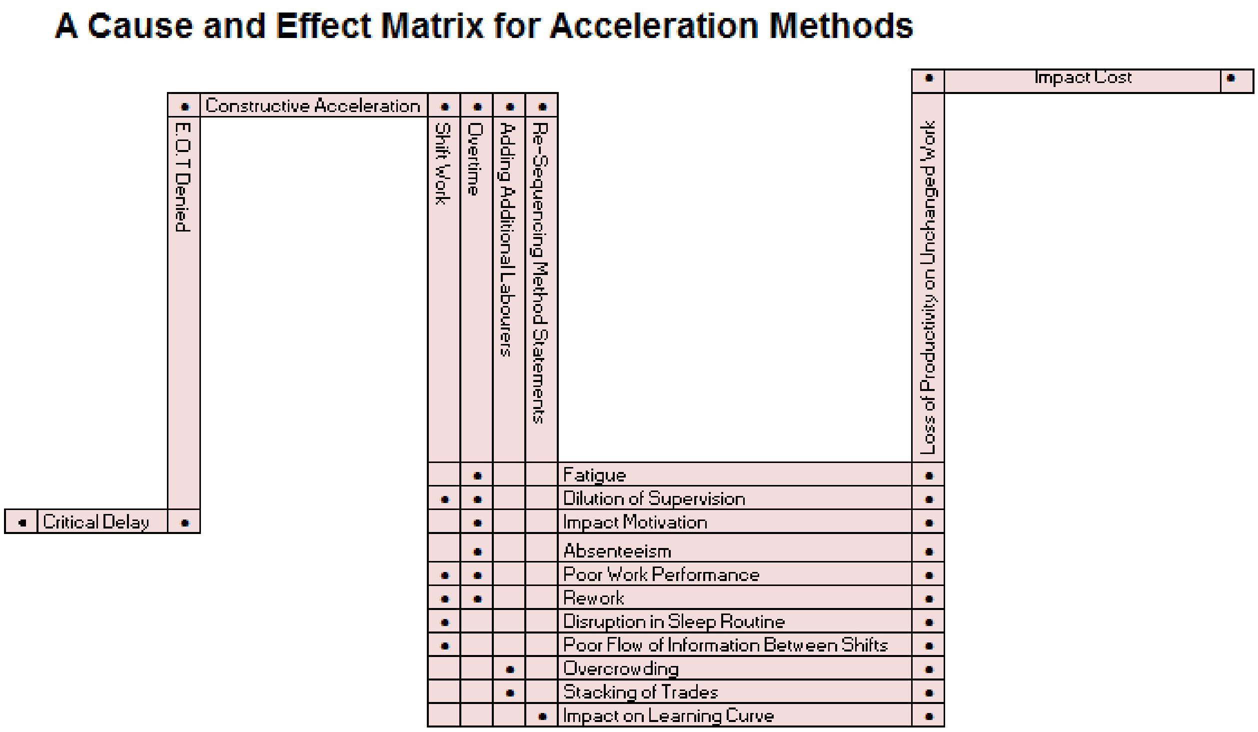

Figure 7.9: Cause and Effect Matrix for Acceleration Methods

7.3.2.6 Recommendations for Acceleration Methods

Having considered the cited references, it is now recommended that the contractor:

- Distinguishes between constructive accelerations and directed accelerations.
- Familiarises himself with the delay and disruption events associated with acceleration methods as discussed in Chapter 5 and given in Figure 7.9.
- Links the need for acceleration to the V.Os and its related delays and disruptions. Write it down, communicate it to the client and document it.
- Does not blindly and reactively accelerate a project. Instead compare the advantages and disadvantages of an E.O.T versus acceleration, discuss it with the client and agree on the best solution.
- Prepares for the delay and disruption events associated with the acceleration method that is being implemented.
- Keeps record of the delay and disruption events that realise on the project due to implementing certain acceleration methods.

7.4 Chapter Summary and Conclusion

The secondary impact of V.Os can be summarised as follows. The impact occurs in two phases. Phase 1 includes everything that happens before the V.Os are implemented and largely revolves around information and approval delays associated with the change processes. It also includes the difficulties associated with the process and administration of V.Os. Phase 2 includes everything that happens after the V.Os have been issued and implemented on a project. The delay and disruption events associated with Phase 2 can be categorised in three stages namely, control actions, portfolio effects and acceleration methods. Each stage has delay and disruption events which impact labour productivity.

Figure 7.10 shows the cause and effect matrix of the secondary impact of V.Os. It basically illustrated how V.Os triggered the various delay and disruption events as discussed in the systematic and comprehensive overview.

Phase 1:

In short, contractors discover errors and omissions in designs and drawings, and then contractors request the engineer for information and clarification. This activity is time consuming and in addition engineers often respond late or in vague terms which create conflict between the contractor and client and affect the flow of information between the two parties. V.Os are then finally issued but are issued late. The revised drawings are issued late and may again contain E&O. The contractor again requests the engineer for information and clarification. This leads to late issuance of V.Os, dilution in supervision, poor quality and rework and demolition which directly impact labour productivity.

Phase 2:

Due to the delay and disruption events of Phase 1, progress on unchanged work is affected and the changed work is disrupted. Management intervene by implementing control actions which include stop-and-go operations, out-of-sequence work and do nothing. This leads to issues such as interruptions, initiate contributory and preparation work, labourers working in a rush manner, invalid initial assumptions, change in working conditions, perform work in illogical and uneconomical manner etc. This further leads to demoralising, conflict, impact learning curve, impact job rhythm. All of the listed delay and disruption events interact causing portfolio effects such as deterioration of schedule, expensive activities executed at the same time, weather sensitive work executed in bad weather, contract work falling behind schedule. E.O.T is denied and the contractor implements constructive acceleration. Method statements are re-sequenced, additional labourers are added, and labourers are working overtime and night shift. Labourers are fatigued, absent, not motivated and the learning curve is impacted, stacking of trades and overcrowding are experienced. The end result is a loss of productivity on the unchanged work.

The objective of this chapter was to explain how V.Os could cause the delay and disruption events discussed in Chapter 5. When reading through the examples, scenarios, explanations, cause and effect matrixes it should be relatively easy to recognise the similarities between the delay and disruption events discussed in this chapter and that of Chapter 5. In the next chapter these events are tested for S.A contractors.

The Cause and Effect Matrix of the Secondary Impact of V.Os

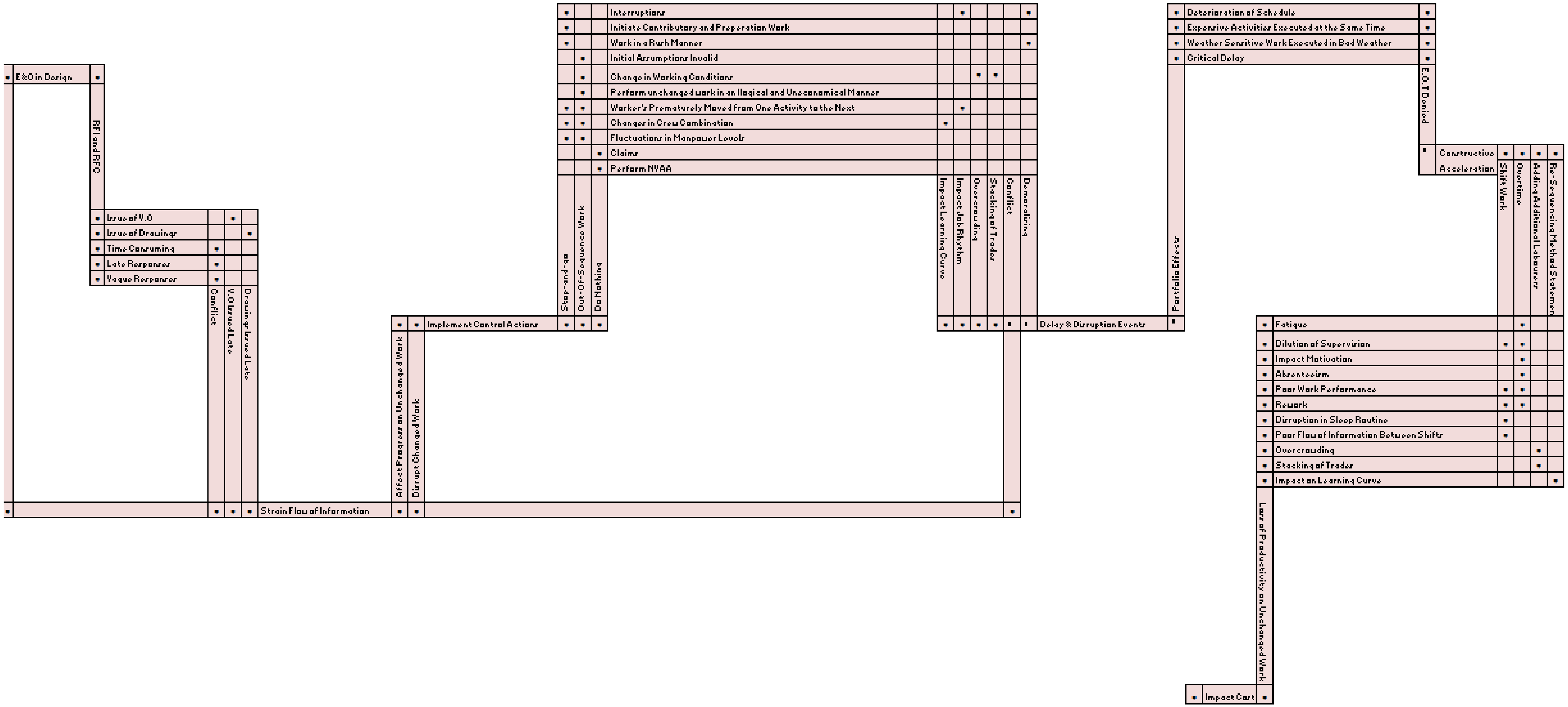

Figure 7.10: The cause and effect matrix of the secondary impact of V.Os

7.5 Chapter Recommendations

In this chapter recommendations were given per section. There are however, recommendations that follow from holistically looking at the information discussed under all sections. Hence, instead of repeating the various sections' recommendations here, the recommendations derived from information discussed under all sections will be given.

It is recommended that the site manager and everyone who was involved in the tender process such as the contract manager, the estimator and the planner should clearly define the project's scope of works, the plan of execution and the reasons behind the plan of execution before construction commences. By means of brainstorming the individuals should:

- give a description of the nature of the work and the nature of the primary activities
- describe the sequence in which the work and activities is to be executed in and give the reasons and an explanation of the logic behind it
- identify the factors that determined the plan of execution
- identify assumptions made regarding the execution of the work and the reasons behind them
- identify factors that determines the progress of the work
- describe the logistics involved in the plan of execution
- describe the characteristics of and identify the assumptions about the resources to be used
- discuss the importance of the time period the activities must be executed in
- identify the activities where the learning curve was taken into consideration at tender stage
- identify any critical assumptions made about the project at tender stage and the reasons behind it
- do a SWOT analyses of the production team/contractor

This information should be recorded in the form of a report which should be communicated and be available to all members of the site management team.

Chapter 8

QUESTIONNAIRE

8.1 Introduction

A large part of this thesis relies on findings from studies that were done in the past considering contractors from different parts of the world. It was necessary to confirm whether the events discussed in Chapter 7 still hold true today and if it applies to South African (S.A) contractors. Therefore, an electronic questionnaire survey was conducted. This chapter reports the rationale behind the questionnaire, the objectives of the questionnaire, the applied methodology and the analysis and synthesis of the results.

8.2 Questionnaire Rationale

The purpose of the research is to investigate the secondary impact of V.Os with the objective of improving existing change management processes to accommodate the secondary impact of V.Os. In Chapter 7, a comprehensive and systematic overview of the secondary impact of V.Os was given, using predominantly information given in literature. However, most of the literature identified to be of high importance were published between the years 1987 and 2002 (see Table 7.1, Table 7.3 and Table 7.5, Chapter 7). It can therefore be questioned whether the information is still valid for projects today. Furthermore, the studies by previous researchers were done in other parts of the world. It is not certain whether the impact would be the same on S.A contractors. Hence, it was necessary to confirm whether the events discussed in Chapter 7 still hold true today, and if it applies to S.A contractors. Therefore, an electronic questionnaire survey was conducted.

It can be challenging to develop a questionnaire that consists of all the possible events and scenarios explained in Chapter 7 and still keep it sufficiently short to be completed in a short period of time. Hence, instead of questioning respondents about the discrete delay and disruption events resulting from V.Os, it was decided to obtain respondent comments on the main events identified in Chapter 7. These are:

- The information and approval delays concomitant to the change process
- The impact on changed work

- The control actions
- The portfolio effects
- The acceleration methods

The rationale is, if these events occur on projects due to V.Os, then the delay and disruption events discussed in Chapter 7 are possible risks that realise or could realise on South African projects. That is to say, if these events are present it is likely that the possible delay and disruption events discussed in Chapter 7 are present as well.

As discussed in Chapter 5, the learning curve and physiological and psychological human factors play an important role in labour productivity. Hence, in addition to testing events discussed in Chapter 7 it was decided to question respondents about the importance of the learning curve and human factors on their projects.

8.3 Questionnaire Objectives

The objective of the questionnaire was to obtain answers to the following questions:

- Do contractors experience difficulties regarding delay events which accompany V.Os?
- Do contractors find the processing and administration of V.Os difficult?
- Do contractors apply control actions and/or are there other control actions?
- Do contractors experience portfolio effects?
- Do contractors apply acceleration methods instead of E.O.T when V.Os cause a critical delay?
- Do contractors acknowledge the learning curve when preparing a bid?
- Do contractors consider human factors when managing a project?

8.4 Methodology

The methodology used to gather information was an electronic questionnaire survey. Under this section the reason for using the questionnaire as the research instrument is given, including the different requirements to which respondents had to adhere to, and the manner in which access was gained to respondents. Also discussed, are the manner in which the questionnaire was distributed to the respondents, the design of the questionnaire and the analyses of the data.

8.4.1 Research Instrument

Since the main aim of the investigation was to test whether South African contractors experience the events discussed in Chapter 7, it was of high importance to involve a large number of respondents. Due to this requirement, interviews were disregarded and questionnaires were considered to be the best research instrument for the purpose.

8.4.2 Requirements of Respondents

In order for the data collected to be of value, the respondents had to comply with the following set of requirements:

- Must be employed by a S.A construction firm that are graded 9CE or 9GB by the construction industry development board (CIDB)
- Must be or have been directly involved with the management of V.Os on construction projects
- Must have more than 5 years' experience, the type of civil engineering project is irrelevant

8.4.3 Access to Potential Respondents

In order for the questionnaire to be distributed to the relevant individuals, contact details needed to be acquired of potential respondents. Three strategies were employed by the researcher. The contact details of the individuals who attended the Construction Management Programme (CMP) held at Stellenbosch University in years 2008, 2009 and 2011 were first obtained, since all comply with the above requirements. Besides the fact that the attendees of the CMP complied with the above requirements, having attended the CMP is an indication that they have a basic understanding of the topic of enquiry as it forms part of the programme curriculum. This assists with placing the questionnaire into context for the respondents which should enhance the credibility of the results. The contact details of attendees were collected from Miss A Slabbert (2012), the secretary of the CMP. Unfortunately the contact details of attendees for the year 2010 were not available at the time and could therefore not be used.

Secondly, different S.A construction firms were randomly selected and contacted via email to inform them about the survey. They were requested to make available the contact details of employees who complied with the above set of requirements. This approach however, was only partially successful. Only 2 out of 6 companies responded that they were interested to assist. The reason for this could be that the companies were not familiar with the researcher and therefore not comfortable with sharing their employees' contact details. The one responding company, Firm A is the company where the researcher was previously employed. This made it easy, as the company was acquainted with the researcher. The other responding company, Firm F, volunteered to assist with the research after an interview had been held with the researcher.

Lastly, some of the respondents provided contact details of colleagues whom they thought would want to participate in the survey and who has knowledge on the topic of enquiry.

8.4.4 Questionnaire Distribution

After the contract details had been obtained of potential respondents, an email was sent to inform them about the survey and inviting them to participate. The link to the survey was attached to the email allowing potential respondents easy access to the questionnaire. A copy of the cover letter that was attached to the e-mail is included in Appendix A.

Firm F suggested that they would e-mail the link of the survey to their employees themselves in order to assure that their employees do respond. Hence, only the link to the survey was provided to Firm F.

8.4.5 Questionnaire Design

A copy of the questionnaire can be found in Appendix B.

The questionnaire was designed to consist largely out of close ended questions and a minimum of two open-ended questions. It is commonly accepted that the questions of a questionnaire should be short and concise. From review of this questionnaire however, it will be noted that even though the researcher attempted to keep questions as short as possible most questions tend to be long due to the nature of the topic in question. This could be a concern, however, one of the respondents requested from the researcher a copy of the questionnaire in Pdf. format, as he felt that some of the questions were relevant to his day to day managerial management activities. This is evidence that in the light of this questionnaire, the length of the questions is not of great concern. Hence, credible information can still be extracted.

8.4.6 Data Analysis

Descriptive statistics were used to analyse data. This involved the use of frequencies, percentages and graphs such as pie charts, bar charts and tables. Microsoft Excel was the main software used to analyse data.

8.5 Results and Discussion

This section discusses the results from the analysis of the data obtained from the survey. Firstly the response rate to the survey is addressed. This is followed by the characteristics of respondents and finally the response to the questions is addressed.

8.5.1 Survey Response

Out of 116 questionnaires that had been distributed, 44 were returned. This represents a response rate of 38%. It must be added that, out of the 116 questionnaires that had been distributed to 8 different construction companies, 96 had been sent by the researcher of which 25 were returned. This represents a response rate of 26% which is lower than the overall response rate of 38%. The other 19 questionnaires that were returned are from Company Y, who had distributed the questionnaire themselves. It is not known how many questionnaires were sent out by Company Y and therefore its response rate cannot be calculated.

Advice given by Professor M. Kidd (2012) is that for a survey to be credible, the number of respondents should be at least 100. However, he admits that it is very rare that surveys succeed in obtaining that number of respondents. The results of this survey may not be a representation of the entire South African construction industry, but it at least represents the views of the 44 experienced South African employees, thereby giving good insight into the customs experienced in the industry.

The questionnaire was completed by respondents according to their individual fields of experience. Since projects are unique, and unless the respondents from Firm F all worked together on the same projects, (which is most unlikely), the fact that there is a large number of respondents working for the same company should not be of any concern.

8.5.2 Characteristics of the Respondents

The respondents held senior management positions at their companies. Site agents and contracts managers/directors constituted respectively 27% and 24% of the respondent population. Figure 8.1 shows the position distribution of respondents.

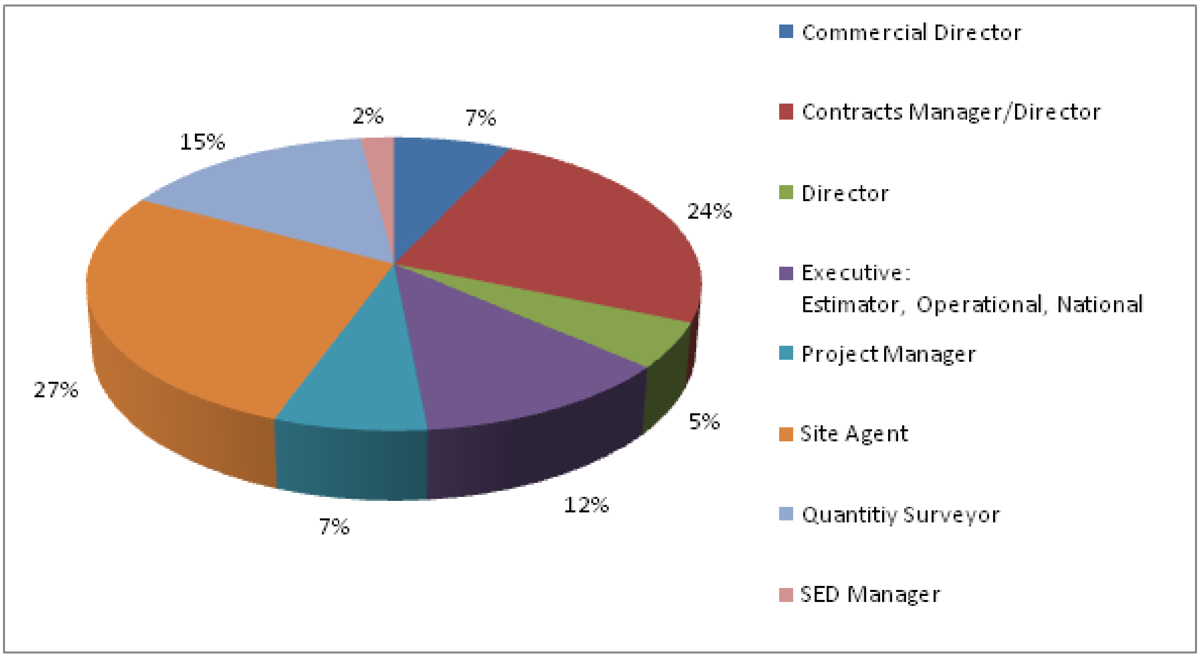

Figure 8.1: Positions of respondents

The years of experience of respondents in the industry range from 5 years to more than 31 years, see Figure 8.2. Respondents with experience that ranges between 11 and 15 years and respondents with experience that ranges between 16 and 20 years constituted both 27% of the respondent population. Overall, 86% of respondents have experience of 11 years and more.

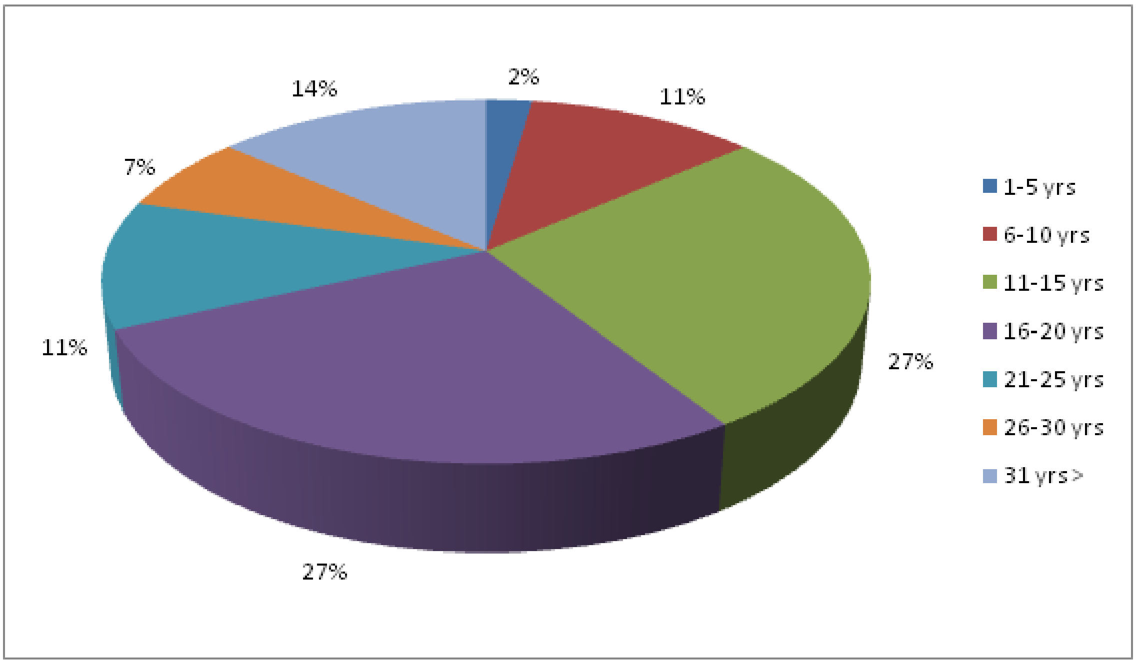

Figure 8.2: Years of experience of respondents

Figure 8.3 shows the market distribution within which respondents were active. Civils and roads (30%), civils (25%), and buildings (18%) are the three largest market segments of respondents.

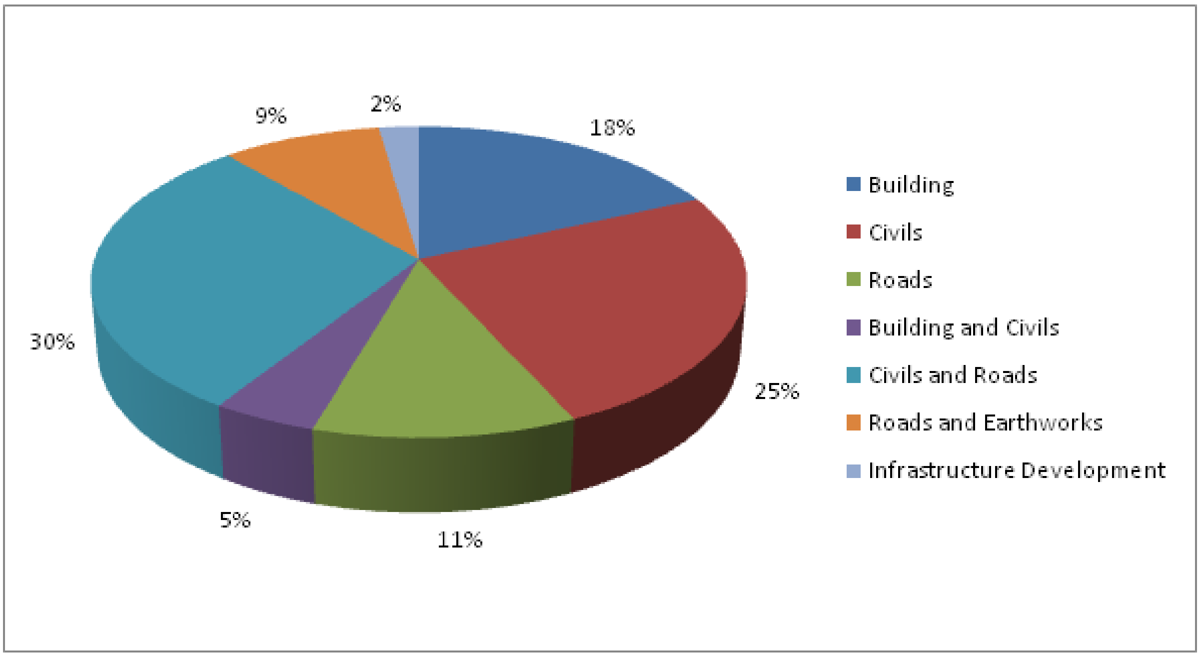

Figure 8.3: Market distribution where respondents were active

Respondents were divided into the nine different companies at which they were employed. Figure 8.4 shows the distribution of the number of respondents employed by the same company. As can be noted from Figure 8.4, Firm A and Firm F have significantly more respondents than the rest of the firms. The reason being, Firm A represents the company, at which the researcher was previously employed at and Firm F represents the company, which assisted with the distribution of questionnaires. Hence, the number of respondents from those two firms is more than for the other firms.

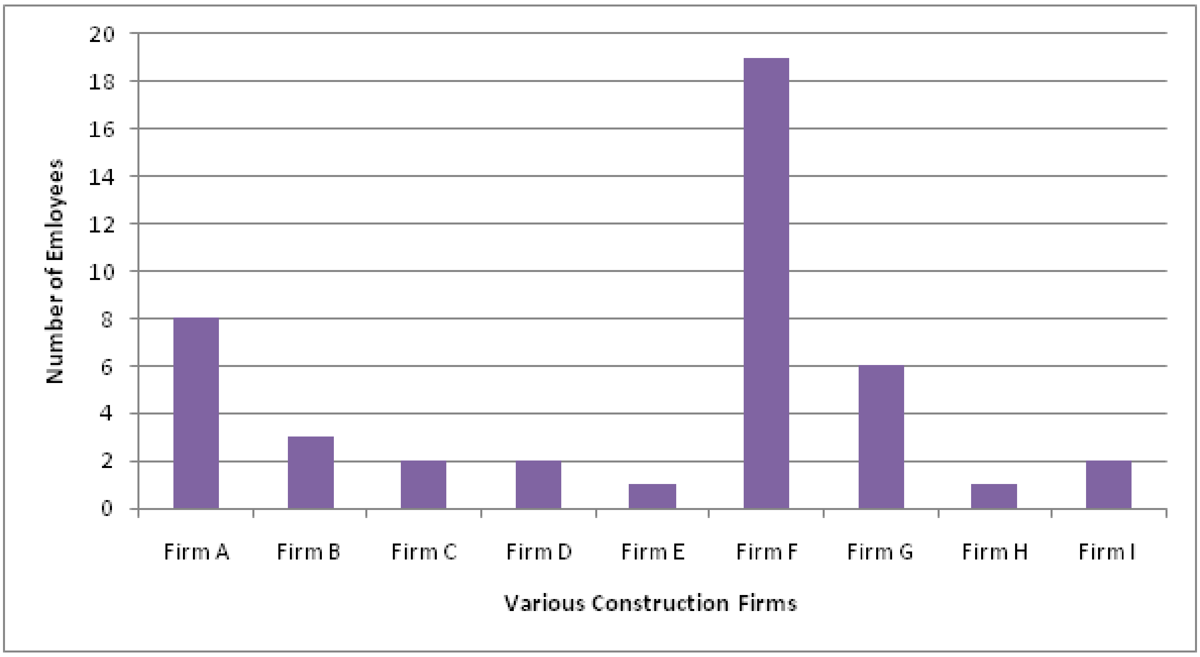

Figure 8.4: Number of respondent employed by the same company

All the firms, at which the respondents are employed, have a Construction Industry Development Board (CIDB) rating of either 9CE or 9GB, see Table 8.1. This implies that the firms have the capability of procuring contracts starting from the value of R 130 000 000 and above. Hence, the respondents of this survey have experience in the largest civil engineering construction projects and general building construction projects.

No.	Firm Name	CIDB Rating
1	Firm A	9CE, 9GB
2	Firm B	9CE, 9GB
3	Firm C	9CE
4	Firm D	9CE
5	Firm E	9CE, 9GB
6	Firm F	9CE, 9GB
7	Firm G	9GB, 9CE
8	Firm H	9CE
9	Firm I	9GB

Table 8.1: CIDB grading of the respondents firms

8.5.3 Delay Events Associated with V.Os

In Chapter 7, it is highlighted that approval delays and information delays are associated with V.Os. Respondents were asked whether they encountered any of these delays accompanied by V.Os on past projects. They were also asked to indicate how problematic the approval and information delays had been for the respondent. All respondents (100%) indicated that delays such as approval delays and information delays accompany V.Os more frequently than seldom. 98% of respondents indicated that the impact of the delays on projects is more severe than minimal. Hence, on the projects of the respondents, approval and information delays do accompany V.Os and are problematic for respondents.

Replies received from respondents on the two questions concerning delay events associated with V.Os are presented in Table 8.2.

Question	Answers			
	Frequent	Often	Seldom	Never
Have you encountered approval delays and information delays accompanied by V.Os on past projects?	55%	45%	0%	0%
	Severe	Significant	Minimal	No impact
How problematic are they for a contractor?	30%	68%	2%	0%

Table 8.2: Delay events associated with V.Os question responses

8.5.4 Processing and Administration of V.Os

Respondents were asked whether processing and administration of V.Os require considerable effort on the part of site managers. 98% of respondents either agreed or strongly agreed that the processing and administration of V.Os do require considerable effort on the part of site managers.

Furthermore, respondents were asked whether the processing and administration of V.Os interfere with the planning and coordination responsibilities of contractors' site management. 95% of respondents either strongly agreed or agreed that the processing and administration of V.Os do interfere with planning and coordination responsibilities of site management.

Hence, the processing and administration of V.Os are a cause for concern in terms of the effort it demands and its interference with other important tasks of site management.

Replies received from respondents on the two questions concerning the processing and administration of V.Os are presented in Table 8.3.

Question	Answer				
	Strongly Agree	Agree	Neither/Nor	Disagree	Strongly Disagree
The processing and administration of V.Os require considerable effort on the part of site managers?	59%	39%	0%	2%	0%
The processing and administration of V.Os interfere with planning and coordination responsibilities of contractors' site management?	50%	45%	2%	2%	0%

Table 8.3: Process and administration of V.Os question responses

8.5.5 Impact on Changed Activities

Respondents were asked whether delays accompanied with V.Os interrupt affected activities on their projects. The purpose of this question was to test the likelihood of interruptions to the changed work caused by the delays triggered by V.Os. That is, to determine if the delays accompanied with V.Os do affect the changed work and if it does more frequently than seldom, then the likelihood of the respondents responding to the impact should be high. 89% of respondents indicated that delays accompanied with V.Os do interrupt changed activities more frequently than seldom. Hence, there is a high likelihood for respondents responding to the impact on changed work.

Replies received from respondents on the question concerning the impact of V.Os on the changed activities are presented in Table 8.4.

Question	Answers			
	Yes, Frequent	Yes, Often	Yes, Seldom	No, Never
Have you experienced delays accompanied with V.Os to interrupt affected activities on any of projects you've worked on? In other words, do V.Os cause interruption?	34%	55%	11%	0%

Table 8.4: Impact on changed activities question responses

8.5.6 Control Actions

This question consisted out of three sub questions which will be discussed separately under this section.

The delays accompanied with V.Os normally disrupt changed activities causing labourers assigned to the changed activity to idle. Respondents were asked whether they apply *"stop-and-go operations"* and *"out-of-sequence work"* to avoid losses due to idle time. 96% of respondents indicated that they do apply *"stop-and-go operations"* and *"out-of-sequence work"* in such circumstances more frequently than seldom. Hence, *"stop-and-go operations"* and *"out-of-sequence work"* are commonly applied as control actions by most respondents to limit or avoid losses.

Next, respondents were asked to rate (using a rating of 1 most common, 2 common and 3 least common) the three control actions to be implemented on their projects when dealing with V.O's. From the results, *"out-of-sequence work"* tends to be most commonly applied followed by *"stop-and-go operations"*. The *"do nothing"* control action is indicated to be the least commonly applied of the three methods.

Lastly, respondents were asked to comment on the following statement: *"Although both "stop-and-go operations" and "out-of-sequence work" can be disruptive, "out-of-sequence work" tends to be the more disruptive as it often results in sequence changes from logical* *and economical to illogical and non-economical. Therefore, it is believed that out-of-sequence work is often a forced decision."* The purpose of this question was to test whether working in an illogical and non-economical way is as disruptive to projects as it sounds to be. Also, if it is the case then certainly one would expect the control action *"out-of-sequence work"* to be a last resort taken by site managers. Hence, part of the statement mentions that the control action is a forced decision. 98% of the respondents either agreed or strongly agreed that even though *"out-of-sequence work"* is the most commonly applied of the three methods, when contractors apply it, it is often a forced decision. In other words, they often have no choice but to work *"out-of-sequence"* due to disruption in circumstances.

From the three questions it can be concluded that the respondents apply the same control actions as noted in Chapter 7. From the three control actions *"out-of-sequence work"* is the most commonly applied and *"do nothing"* is the least commonly applied. In most cases working *"out-of-sequence"* is a forced decision.

Replies received from respondents on the three questions concerning control actions are presented in Table 8.5.

Question	Answer				
	Yes, Frequent	Yes, Often	Yes, Seldom	No, Never	
Have you ever employed *"stop-and-go operations"* and *"out-of-sequence work"*, to avoid losses due to idle time caused by interruptions resulting from V.Os?	55%	41%	5%	0%	
	#1	#2	#3	RANK	
With a rating of 1-3 (1 most common and 3 least common) rate the three responses as you experienced them to be implemented on your projects when dealing with V.Os					
"Stop-and-go operations"	36%	**64%**	0%	**2**	
"Out-of-sequence work"	**61%**	36%	2%	**1**	
"Do nothing"	2%	0%	**98%**	**3**	
	Strongly Agree	Agree	Neither/Nor	Disagree	Strongly Disagree
Although both *"stop-and-go operations"* and *"out-of- sequence work"* can be disruptive, *"out-of-sequence work"* tends to be the more disruptive as it often results in sequence changes from logical and economical to illogical and non-economical. Therefore, it is believed that *"out-of-sequence work"* is often a forced decision.	41%	57%	2%	0%	0%

Table 8.5: Control actions question responses

8.5.7 Other Control Actions

Respondents were asked to give examples of control actions taken when delays disrupt changed activities, other than *"stop-and-go operations"*, *"out-of-sequence work"* and *"do nothing"*. Table 8.6 lists the 10 different control actions given by 17 of the 44 respondents who answered the question. This question was an open-ended question. It could therefore be expected that a variety of different control actions would be given.

From the 10 different control actions given by respondents, the control action *"recording of standing time with the intention to claim"* (no. 4 on Table 8.6) is indicated by 5 out of 17 respondents who responded to this question. As explained in Chapter 7, *do nothing* actually implies that contractors keep record of damages with the intention to claim for it. The fact that some of the respondents indicated *"recording of standing time with the intention to claim"* as an additional control action is an indication that the control action *do nothing* was not defined clearly enough in the questionnaire. This might have an implication on the results of the question which tested the frequency of *"stop-and-go", "out-of-sequence work"* and *"do nothing"* operations.

An interesting control action listed by 2 respondents is the pro-active approach (no.10 on Table 8.6). The respondents indicated that due to their experience they can foresee disruptions on changed work and prepare in advance to mitigate it. Interestingly enough, both of the respondents have 18 years of experience and are employed by two different companies. Hence, experience plays a role when managing the secondary impact of V.Os.

From the results it can be concluded that the respondents do apply control actions other than *"stop-and-go operations"*, *"out-of-sequence work"* and *"do nothing"*. However, other than the control action *"recording of standing time with the intention to claim"* that was given by 5 out of the 17 respondents, the control actions given are not applied by many respondents. Hence, it cannot be accepted as commonly applied control actions as in the case of *"stop-and-go operations"*, *"out-of-sequence work"* and *"do nothing"*.

No.	Control Action	Number of Respondents Indicated
1	Stop the contract	1
2	Continue work without V.O	1
3	Re-deploy labour to other projects or lay them off	1
4	Record standing time and claim	5
5	Assign labourers to the client on daywork	1
6	Re-programme all work	1
7	Accelerate	2
8	Utilize the available resources to accelerate progress on activities that were delayed due to own (contractors) problems or inefficiencies	1
9	Appoint additional sub-contractors to complete V.O work	2
10	Pro-active approach: Foresee shortfalls and input early warning signs	2

Table 8.6: Other control actions given by respondents

8.5.8 Portfolio Effects

In Chapter 7, four portfolio effects are discussed. These were presented to respondents asking them to indicate whether they have encountered any of these on past projects. The results for each portfolio effect will now be discussed separately.

The first portfolio effect (Portfolio Effect 1) is where numerous delays and disruptions gradually shifted weather sensitive work to be executed in bad weather. 59% of respondents indicated that this has occurred on past projects and 50% of respondents indicated that it occurs more frequently than seldom. Hence, more than 50% of respondents have experienced delays and disruption triggered by V.Os to gradually shift weather sensitive work to be executed in bad weather. Furthermore, for 50% of the respondents, this happens more frequently than seldom. Hence, this portfolio effect does happen and it happens more frequently than seldom.

The second portfolio effect (Portfolio Effect 2) is where numerous delays and disruptions gradually shifted expensive activities to be executed at the same time. 83% of respondents indicated that this has happened on past projects and 28% indicated that it occurs more frequently than seldom. Hence, this portfolio effect does happen but not frequently.

The third portfolio effect (Portfolio Effect 3) is where numerous delays and disruptions gradually deteriorate original programs, causing the scheduling to become a function of drawing release instead of normal construction logic. 80% of respondents indicated that this has happened on past projects and 55% of respondents indicated that it occurs more frequently than seldom. Hence, for a large number of respondents, delays and disruptions have deteriorate original programs and more than 50% of respondents indicated that it happens more frequently than seldom.

The last portfolio effect (Portfolio Effect 4) is where numerous delays and disruptions cause the original contract work to fall behind schedule. 77% of respondents indicated that this has happened on past projects and 68% indicated that it happens more frequently than seldom. Hence, for a large number of respondents numerous delays and disruptions cause original contract work to fall behind schedule and more than 60% of respondents indicated that it happens more frequently than seldom.

From the results it can be concluded that for each portfolio effect listed in Chapter 7, at least 50% of respondents indicated that they have encountered them on past projects. This indicates that the four portfolio effects listed in Chapter 7 occur on the projects of respondents. Furthermore, from all four portfolio effects, Portfolio Effect 4 is the one indicated to have happened more frequently respondents' projects.

Replies received from respondents on questions concerning portfolio effects are presented in Table 8.7.

Question	Answers				
	Yes, Frequent	Yes, Often	Yes, Seldom	No, Never	N/A
Many delays and disruptions gradually shift weather sensitive work to be executed in bad weather.	18%	32%	9%	25%	16%
Many delays and disruptions gradually shift "expensive activities" (e.g. excavate and backfill) on different work packages to be executed at the same time.	14%	14%	55%	16%	2%
Many delays and disruptions deteriorate original programs resulting in orderly sequences of operations broken down into several isolated activities. Scheduling becomes the function of the release of approved V.Os and drawing revisions instead of normal construction logic and economics.	23%	32%	25%	14%	7%
Many delays and disruptions cause original contract work to fall behind.	45%	23%	9%	16%	7%

Table 8.7: Portfolio effects question responses

8.5.9 Examples of Project Specific Portfolio Effects

Respondents were asked to describe where possible, an example of any one of the portfolio effects discussed in Section 8.5.8 as it happened on past projects. This was the second open-ended question.

From the 44 respondents, 21 answered this question. Unfortunately 7 of the answers had to be disregarded as not enough background information had been given that would allow the researcher to understand the context of the example. From the 14 examples that are considered to be valuable, only 9 were applicable to the question. From the 9 examples 2 were new events not identified from the literature. The other 7 examples are project specific but are common examples and relatively easy to understand. Hence, in this section only the 2 new events will be discussed, the rest will be presented in Appendix C.

The other 5 examples which together with the 9, make up the total 14 examples were not applicable to the question. However, they are considered valuable to the research. The reason being, they give information on the different management strategies of respondents to the secondary impact of V.Os. Furthermore, they support statements concerning the process and administration of V.Os discussed in Chapter 7. Hence, together with the 2 new events that will be discussed in this section, the management strategies as well as the statements concerning the process and administration of V.Os will be discussed. Table 8.8, gives an outline of the responses of respondents to this question.

Distribution of Answers	#	Reference
Number of Respondents Answered	21	-
Examples Not Applicable	**7**	**-**
Examples Applicable	**14**	**Appendix X**
Bad Weather	5	-
Deterioration of Schedule	1	-
Original Contract Work Delayed	1	-
Embargo Seasons and Road Closures	2	-
Management Strategies	3	-
Processing and Administration of V.Os	2	-

Table 8.8: Outline of responses

8.5.9.1 New Events

In Chapter 7 an example is given of how delay and disruption events can shift weather sensitive work to be executed in bad weather. From the answers of respondents, two new examples were captured. The first is embargo seasons, which are seasons in which the government prohibits certain material which are used on construction projects from being procured. The respondent wrote as follows: "*SANRAL imposes an embargo on the placing of asphalt during winter months. D&D [delays and disruption] often result in an entire season being lost where work delays moves activities into an embargo season.*" Hence, it is not only weather sensitive work that is affected by delay and disruption due to V.Os, but also work sensitive to embargo periods.

Secondly, most portfolio effects discussed in Chapter 7 considered the impact of delays and disruption on the work performed by contractors. However, in this example the delays and disruptions did not affect the work itself but the manner in which the work had to be executed. Construction projects that involve working on existing roads are often subjected to working in road closures in road construction. It is likely that V.Os which are implemented in one road closure disrupt work in other road closures (unchanged work) causing a critical delay. The respondent wrote as follows: "*Work on existing roads under traffic is a function of working in closures. Additional work in closures affects the sequencing of the closures which ultimately determine the completion of the work, so closures need to be monitored rather than quantity of work in the closure. This can also affect other work as you cannot always have the number of closures required to continue normally with operations. Hence, subsequent work may have to be delayed in order to complete additional work ....*" Hence, the reasoning and assumptions concerning the sequence and number of closures were critical to this project. If its importance was to be neglected by the respondent, numerous delays and disruptions caused by V.Os could have resulted in the contractor performing work in an illogical and uneconomical manner.

8.5.9.2 Management Strategies

Three different management styles are captured in three different examples given by three respondents. Each example explains how the different respondent manages the secondary impact of V.Os. This was possible since each of the three respondents gave a scenario and their reaction to that scenario. This will now be discussed.

Respondent #1

This example illustrates a contractor that is reacting to the secondary impact of V.Os and his management strategy is to claim.

Scenario on Site:

> *"Multiple VOs on a time constrained contract at Century City. The completion date was not negotiable and had to be achieved for the opening of the shopping centre prior to the Christmas holidays. Numerous VOs and instructions caused a delay." [Statement by the respondent]*

Hence, due to multiple V.Os that had been issued on the project, the project faced a critical delay. [The researcher's interpretation]

What the contractor did:

> *"[The] disruption and extension of time claim ... was very complex. Ultimately the contractor only* ***recovered a portion*** *of the additional costs involved with "out-of-sequence work" and [of the effect of] adding additional resources through* ***negotiation*** *with the Client." [Statement by the respondent]*

Hence, due to the delay and disruption caused by the different V.Os the contractor issued a claim. However, the claim was not successful since only a portion of the impact costs were recovered. [The researcher's interpretation]

Lessons Learned:

> *"****Contractors are*** *... labelled as* ***claims conscious*** *for putting in valid claims for additional work and out of sequence work. In my experience the* ***actual effects of*** *multiple* ***VOs are seldom claimed for****, due to the complexity of proving acceleration on contracts through resource re-scheduling. As a consequence, the contract program becomes meaningless and everyone of site works over each other, with numerous contract charge claims between various sub-contractors where work is damaged due to overlapping activities in order to meet the fixed completion date of the project." [Statement by the respondent]*

In this paragraph three lessons can be identified which the contractor supposedly have learned. Firstly, to claim for the secondary impact of V.Os can cause a contractor to appear claim conscious. Secondly, it is difficult to prove to the client expense and losses due to the secondary impact of V.Os. Thirdly, the contractor realises the extent of the potential disruption resulting from V.Os. [The researcher's interpretation]

<u>Respondent #2</u>

This example illustrates a contractor that thinks he is managing V.Os when in fact he is accepting the impact of V.Os and reacts to the delays and disruptions caused by the V.Os.

Scenario on Site:

"Construction of Concrete bases and ROM tunnels at a coal mine where as-built information as well as new structural steel design[s] .... were incorrect and frequent changes to our scope ……. occurred." [Statement by the respondent]

Hence, V.Os were issued due to incorrect as-build information, deficiencies in designs and changes made to the scope of works. [The researcher's interpretation]

What the Contractor did:

"We tend to want to assist the client and end up absorbing a huge amount of D&D [delay and disruption] and missing out on entitlement." [Statement by the respondent]

The contractor assists the client with ideas as to the best way to incorporate the changes in the project but neglects to keep track of possible impact costs due to the secondary impact of V.Os. [The researcher's interpretation]

<u>Respondent #3</u>

This example illustrates a contractor with strong management capabilities who pro-actively managed V.Os and its secondary impact. It also illustrates how an engineer, by working together with the contractor, can contribute to the successful management of the secondary impact of V.Os.

Scenario on Site:

"On my last contract on the N1- Allendale Interchange, we had an integration of concrete structures and earthworks activities ***which needed to be done sequentially*** *but because we had* ***delays in the detailing of concrete drawings****, parts of the structure couldn't be built prior to the earthworks, which is common practice." [Statement by the respondent]*

Hence, due to delays in the issuance of drawings, the contractor had to change the original sequence of activities. [The researcher's interpretation]

What the Contractor did:

> *"So as an **experienced contractor**, we offered **alternatives** to the engineer, as there was a milestone date at hand for the opening of this interchange and we had to meet the date." [Statement by the respondent]*

The contractor worked together with the client to find a solution on how best to incorporate the required changes so as to have minimal impact on the project. [The researcher's interpretation]

What the Engineer did:

> *"The engineer **agreed** to the alternative and because this was **identified early**, **both parties managed** the effect of this delay as to prevent a negative impact." [Statement by the respondent]*

The engineer acknowledged the contractor in the process of finding a solution for the required changes. [The researcher's interpretation]

Lessons Learned:

> *"This obviously speaks volumes of the **relationship** that is needed at two levels, one with the **site production team**, to deal with the changes and the second the **contractor and the engineers**, to work together on practical and reasonable solutions to the delay. This for me is more important to get right than the delay itself. **Anything can be managed if you have a co-operative team."** [Statement by the respondent]*

In this paragraph one main lesson can be identified which the contractor supposedly have learned. That is, a healthy relationship between contractor and client, and of a contractor and his own team, is key to managing the secondary impact of V.Os. [The researcher's interpretation]

<u>Conclusion of Management Strategies</u>

It can be concluded that some contractors succeed in pro-actively managing the secondary impact of V.Os due to their strong management capabilities and experience and also due to the cooperation of the engineer. Others simply absorb the cost applying re-active management strategies and/or claim for damages.

8.5.9.3 Supporting Statements

As discussed in Chapter 7, the processing and administration of V.Os can be time consuming, resulting in a dilution of supervision on changed as well as unchanged work. The following statements of two respondents confirm this:

Respondent #4

> *"Keeping track of all the V.Os also becomes a huge problem. The administrative cost of V.Os is way under-estimated as well." [Statement by the respondent]*

Respondent #5

> *"Majority of delays in current projects are caused by drawings being issued for construction without being thoroughly checked for errors and interfacing issues by the responsible consulting engineers. Subsequently contractors submit technical queries that take "ages" to get responded to. Drawings also tend to be issued late. This obviously compounds the delay when errors occur on these late drawings." [Statement by the respondent]*

8.5.9.4 Section Conclusion

Despite the fact that many respondents did not answer this question as desired by the researcher, valuable information was still obtained. New events were highlighted, the management strategy of three respondents was captured, and statements regarding the processing and administration of V.Os were confirmed.

8.5.10 Acceleration Methods

When a project experiences a critical delay, contractors normally result to acceleration methods. In Chapter 7 it is mentioned that delay and disruption events triggered by V.Os may cause the original contract work to fall behind schedule in which case an E.O.T is required. Instead of granting the E.O.T a client/engineer might instruct the contractor to accelerate. Respondents were asked to indicate whether this has happened on past projects. 98% of respondents indicated that this does happen and 87% of respondents indicated that it happens more frequently than seldom. From the results, it can be concluded that on many projects, acceleration methods are applied instead of an E.O.T, when projects experience critical delays due to delay and disruption caused by V.Os.

Replies received from respondents on the question concerning acceleration methods are presented in Table 8.9.

Question	Answer			
	Yes, Frequent	Yes, Often	Yes, Seldom	No, Never
An interesting scenario reported by contractors is how the many delays and disruptions and additional work cause contract work to fall behind schedule. This has lead to an extension of time (E.O.T) required however, instead of granting the E.O.T the client/engineer instruct contractor to accelerate.	32%	55%	11%	2%

Table 8.9: Acceleration methods question responses

8.5.11 Control Actions and Acceleration Methods

In Chapter 5 it is discussed how out-of-sequence work, overtime, shift work, assignment of additional labourers etc. disrupt labour productivity due to factors such as dilution of supervision, fatigue in labourers, crowding of workers etc. Respondents were asked whether they consider strategic issues such as:

- readiness of workers to start new activity
- Learning curve related losses
- Dilution of supervision
- Fatigue in labourers
- Crowding of workers

when deciding to implement the different control actions and acceleration methods.

23% of respondents indicated that they formally consider it, 64% indicated that they do, but informally and 14% indicated that they rarely do. Hence, the majority of respondents informally consider the above listed issues when applying the control actions and acceleration methods. As should be obvious by now, the strategic issues mentioned above are in fact the reason why the control actions and acceleration methods eventually cause a loss of labour productivity on projects. It is therefore not enough that strategic issues are simply informally considered by site managers before applying the different control actions and acceleration methods.

Replies received from respondents on the question concerned with control actions and acceleration methods are presented in Table 8.10.

Question	Answers			
	Yes, formally	Yes, informally	Rarely	Never
When deciding on *"stop-and-go operations"*, *"out-of-sequence work"*, "working overtime", "assigning additional crews", "shift work" etc. do you take into account strategic issues such as: Readiness of workers, learning curve losses, overcrowding etc.	23%	64%	14%	0%

Table 8.10: Strategic issues question responses

8.5.12 Contractors and Human Factors

As discussed in Chapter 5, labour motivation plays an important role in terms of productivity. In order to understand whether contractors do consider labour motivation, respondents were asked to comment on the following statement: *"The impact on labour motivation is believed to be soft issues and therefore often neglected by contractors."* 57% of respondents either agreed or strongly agreed with the statement, 16% of respondents did not have an opinion and indicated neither/nor and 27% of respondents either disagreed or strongly disagreed. Hence, to more than 50% of the respondents, labour motivation is considered a soft issue and is being neglected.

Replies received from respondents on the question concerning human factors are presented in Table 8.11.

Question	Answers				
	Strongly Agree	Agree	Neither/Nor	Disagree	Strongly Disagree
The impact on labours motivation is believed to be a "soft issue", in other words not very important, and therefore often neglected by contractors.	5%	52%	16%	20%	7%

Table 8.11: Human factors question responses

8.5.13 Learning Curve

The learning curve plays an important role in labour productivity as discussed in Chapter 5. Respondents were asked whether, when preparing an offer for a project, they take into account the learning curve. 82% of respondents indicated that they do factor in the benefits of gains in productivity due to the learning curve when preparing a bid more frequently than seldom. Hence, most of the respondents do take into account the learning curve when preparing a bid.

Replies received from respondents on the question concerned with the learning curve are presented in Table 8.12.

Question	Yes, Frequent	Yes, Often	Yes, Seldom	No, Never
When preparing an offer for a project do you rely on the learning curve? In other words, gains in productivity due to labourers becoming familiar with an activity?	39%	43%	9%	9%

Table 8.12: Learning curve question responses

8.6 Chapter Summary and Conclusion

To recapture, the comprehensive and systematic overview of the secondary impact of V.Os were discussed in two phases in Chapter 7 see Figure 8.3. The main events within each phase were then incorporated in the questionnaire to test whether it applies to the respondents. A brief summary of the events and results will now be given to bring the findings of the questionnaire into context for the reader.

The main events tested in the questionnaire concerning Phase 1 of the comprehensive and systematic overview of the secondary impact of V.Os, are the approval and information delays that accompany V.Os, and the difficulties associated with the processing and administration of V.Os. From the results, the respondents still battle with approval and information delays that accompany V.Os and find them problematic. The processing and administration of V.Os are time consuming for respondents; it does require considerable effort from them and it does interfere with their other management tasks.

Phase 2 of the comprehensive and systematic overview of the secondary impact of V.Os consists out of three stages, see Figure 8.5. The main events tested in the questionnaire concerning the first stage are the delay and disruption caused by the control actions taken by management in response to the direct impact (the impact on the changed work). From the results, the likelihood that site managers will respond to the impact on changed work is high. It is clear that the respondents apply the same control actions today as noted in Chapter 7. Hence, the delay and disruption events triggered by the control actions as identified in Chapter 7 are highly likely to have been present on the projects of respondents. Due to the misunderstanding of the definition of the control action *do-nothing*, it was not possible to identify the most commonly applied control action of the three listed in Chapter 7. However, it was possible to confirm that respondents are reluctant to apply the control action *out-of-sequence work* because working in an illogical and uneconomical manner is so disruptive. Hence, when work is performed out-of-sequence due to V.Os it is most likely because the respondents had no other choice. Furthermore, it is also possible to conclude that there are no control actions that are commonly applied by the respondents other than the three identified in the literature review. Hence, the concern in Chapter 7 of whether all control actions have been identified is irrelevant.

The main event tested in the questionnaire concerning Stage 2, is the portfolio effects, see Figure 8.5. From the results, the four portfolio effects listed in Chapter 7 are still occurring today on the projects of respondents. Furthermore, from all four portfolio effects, Portfolio Effect 4 is the one which happens more frequently on the projects of respondents. This indirectly confirms that the need to apply acceleration methods due to V.Os is high. Two new portfolio effects have also been identified. These are embargo periods and working in closures. As mentioned in Chapter 7 the four portfolio effects given, are those which could be identified in literature and therefore, it is not the only portfolio effects that are present on projects as a result of V.Os. The two new examples identified in the questionnaire are evidence that this assumption is true.

Stage 3 considers the delay and disruption caused by the acceleration methods implemented by management as a result of V.Os, see Figure 8.5. In Chapter 7 it was explained that acceleration methods are applied due to the failure of the client to apply an E.O.T when projects experience a critical delay due to V.Os. From the results, this scenario holds true for many of the respondents. As mentioned, the question concerning the portfolio effects were not answered as hoped for by the researcher. Nevertheless valuable information was still obtained. For instance, from the results it became apparent that strong management capabilities, experience and a good relationship between contractor and engineer are some of the factors necessary to pro-actively manage the secondary impact of V.Os.

Throughout the comprehensive and systematic overview of the secondary impact of V.Os, it is repeatedly explained how the main events lead to different strategic issues and human factors which eventually cause a loss of productivity on projects. The strategic issues being dilution of supervision, fatigue in labour etc. The human factors specifically refer to labour motivation. Chapter 5 also explains in great detail the role strategic issues and human factors play in terms of the impact on labour productivity. From the results it was possible to conclude that the majority of respondents informally consider strategic issues when applying control actions and acceleration methods. Furthermore, more than 50% of the respondents consider labour motivation to be a soft issue and tend to neglect its impact on labour productivity. Judging from the important strategic issues and human factors in terms of the impact on labour productivity it is not adequate for site managers to simply informally consider strategic issues and to neglect labour motivation.

Apart from the strategic issues and human factors, the learning curve also plays an important role in labour productivity as discussed in Chapter 5. If the benefits of the learning curve are incorporated in the tender submitted by contractors, then it is possible that any impact on the learning curve can deprive contractors from benefiting from it. From the results, it was possible to conclude that most respondents do take into consideration the learning curve when preparing a bid. Hence, the projects of respondents are vulnerable to impacts on the learning curve.

It can be concluded that the main events listed in Chapter 7 do occur on the projects of most of the respondents. Hence, the explanations given in Chapter 7 on how V.Os cause delay and disruption events on construction projects are valid and more importantly they are valid for the projects of South African contractors today.

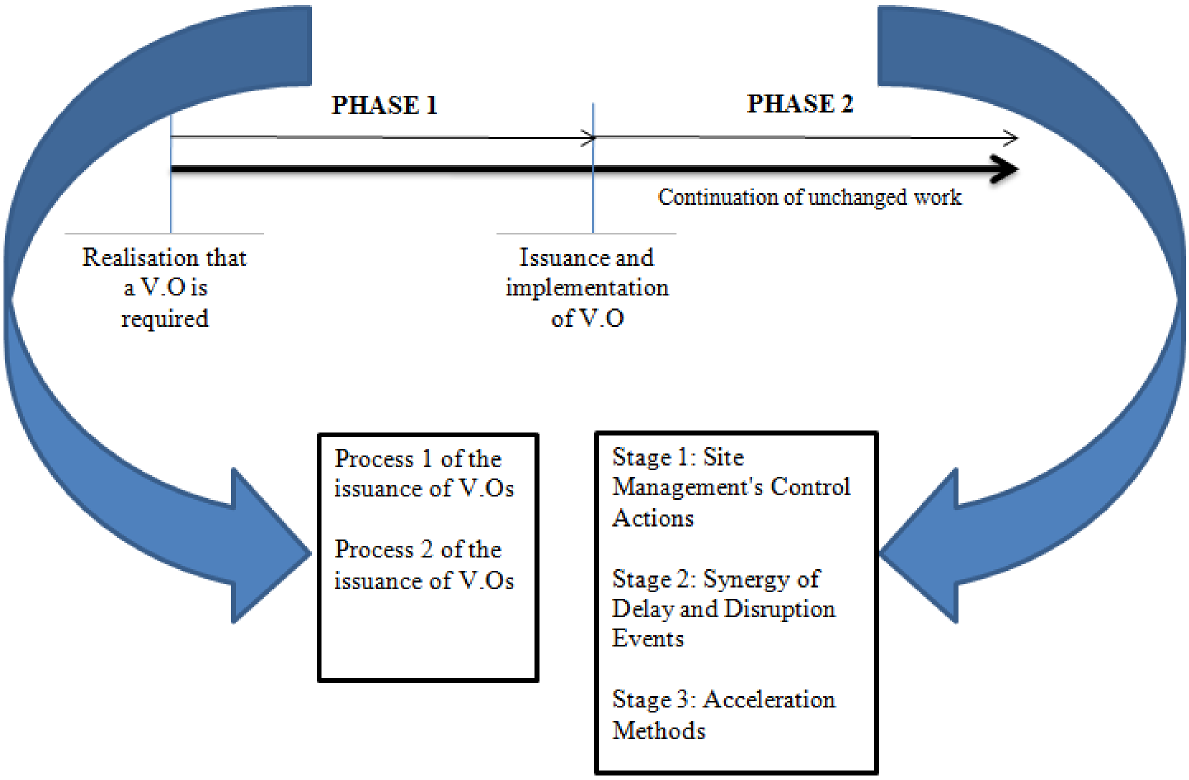

Figure 8.5: A schematic presentation of the phases, processes and stages under which delay and disruption events triggered by V.Os originate on projects

8.7 Chapter Recommendations

As concluded, the issues discussed in Chapter 7 are what the South African contractor still faces today. Hence, the recommendations for this chapter include that of Chapter 7 and the following:

It is recommended that contractors:

- Add *embargo periods* and *working in closures* to the other 4 portfolio effects listed in Chapter 7 and continuously seek to identify new events.
- Consider formally strategic issues associated with control actions before applying control actions
- View human factors such as labour motivation as important factor of labour productivity

Chapter 9

CONCLUSION

Research Question

Varying the original scope of works has a cost and time impact, but other than this primary impact what implications does V.Os have and what can be done about it? Differently phrased, what is the secondary impact of V.Os on construction projects and how can it be managed?

Research Aims

The principal aim of the research is to understand what the secondary impact of V.Os is. Based on this understanding it then aims to give guidelines and recommendations to assist contractors with the management of the secondary impact of V.Os.

Chapter 2: Construction Contracts and Changes

Two South African contracts namely the GCC and the JBCC were consulted to investigate how the contract deals with V.Os and its secondary impact. It was found that:

a) V.Os issued on construction projects are changes to the scope of works.
b) The number of V.Os that may be issued on construction projects is unlimited.
c) Variations are valued individually at the time it is issued. This may create difficulties if the effects of variations require one to consider the synergy of all the variations. Valuations primarily concentrate on the direct cost.
d) The impact a V.O has on unchanged work is not explicitly addressed by neither of the contracts.
e) Contractors have the right to reject the original valuation if they are not satisfied with it. They are however expected to give an estimation and proof of the amount they think the V.O will cost to implement. This requirement can make it difficult for contractors to negotiate expense and losses due to the secondary impact V.Os have, because it is unforeseeable and therefore difficult to quantify.
f) Due to certain provisions made in the contracts, it is however, less difficult for contractors to be compensated for a delay caused by V.Os than it is to be compensated for expense and losses incurred due to V.Os.

g) Over all, the two South African contracts for construction works do not explicitly consider the secondary impact of change, nor does it provide clear guidelines as to how it should be addressed by the parties in contract.

Appendix D: The Pre-Investigation

To gain insight on how some South African contractors experience V.Os and its related impacts on projects, a pre-investigation was done. The investigation involved a questionnaire survey and interviews. It was found that:

- Some South African contractors rarely consider the secondary impact of V.Os on their projects. The main reason appears to be the difficulties involved in identifying, quantifying and proving it.
- In general, some South African contractors have accepted the secondary impact as part of construction projects and rely on other measures to recover damages thereof.

Chapter 3: Defining the Secondary Impact of Variation Orders

A definition for the secondary impact of V.Os was developed through the meaning of cumulative impact of change as developed by the USA's courts and boards of contract appeals. In addition, various characteristics of the secondary impact of V.Os were discussed and the definition was schematically illustrated. This all aid the understanding of the definition.

<u>The Definition</u>

The secondary impact of V.Os was defined as the unforeseen loss of productivity on the unchanged work due to the disruption caused by the synergistic effect of a multitude of V.Os. The cost due to the secondary impact, also referred to as the impact cost, is a combination of the cost for loss of productivity on unchanged work (increased labour cost) and also the increased cost of completing unchanged work (Jones, 2001).

<u>Key Characteristics</u>

The following characteristics assist with the understanding of the definition:

1. The secondary impact considers the impact of all V.Os issued on a project.

2. The secondary impact is unforeseen to the contractor until all V.Os have been issued and implemented.
3. The use of the word "synergistic" is important in the definition and it is meaningful in its own right. The synergistic effect refers to the fact that individual V.Os create disruption but the disruption caused by all V.Os exceeds the sum of the disruption created by an individual V.O. Individually, delay and disruption events may appear insignificant but together it is detrimental to a project.
4. V.Os do not directly cause productivity loss on the unchanged work. It indirectly causes loss of labour productivity via the delay and disruption events it triggers.

The Definition Schematically Illustrated

Figure 9.1 schematically illustrates the definition of secondary impact of V.Os. The figure shows that many V.Os (indicated by the big circles) that are issued on a project trigger delay and disruption events (indicated by the smaller circles) that interact causing a disruption (indicated by the cloud) bigger than the sum of individual delay and disruption caused by the individual delay and disruption events and manifests itself in loss of productivity on unchanged work (indicated by the rectangle).

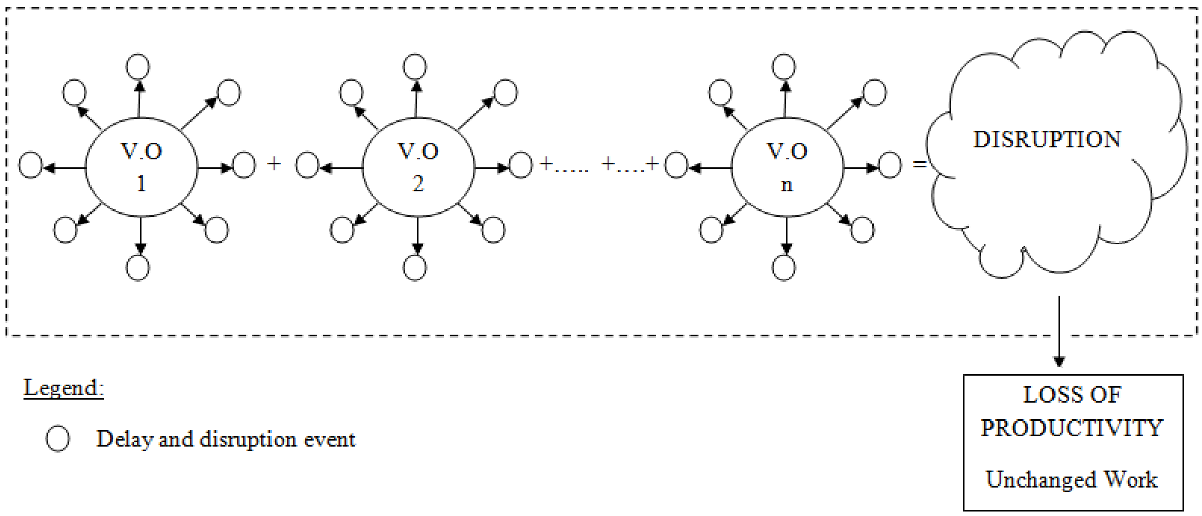

Figure 9.1: A schematically representation of the secondary impact of V.Os

Chapter 4: Understanding Delay and Disruption

Part of the implication of the secondary impact of V.Os is delays and disruption. Attention was given to explain and understand delays and disruption as it is in the construction context. The following were identified:

- A delay has happened when any event or activity in the project is prevented from starting or ending at the planned time. A project has experienced disruption if the contractor is prevented from performing an activity as originally planned and as a result the activity's productivity is impacted.

- Delays are disruptions but disruption is not necessarily a delay. Hence, in construction projects, when referring to disruption, it includes delays. Disruption is thus not only caused by disruption events but by delay and disruption events.
- An important observation were made that could aid in the management of disruption caused by V.Os. That is, delays and disruption happen if the contractor is prevented from executing a project per the original plan. Hence, if management know the original plan of execution, the original scope of works and has a sound understanding of reasoning behind it, management will be better prepared to manage disruption.

- It was found that site managers implement control actions to counter-act disruption. However, the control actions add to the disruption. This can contribute to the confusion when contractors have to identify whether the disruption is compensable or not. Realising that management plays a role in the disruption created by V.Os is also important when considering ways in which to manage disruption. The control actions taken by management are necessary however, knowing that it can add to the disruption it is trying to mitigate, will require wit from management. Instead of blindly and reactively implement control actions management should first evaluate and analyse the situation at hand and then choose an appropriate control action to implement.

Chapter 5: Causes of Loss of Productivity

The objectives of this chapter were to define productivity in construction and to identify various delay and disruption events V.Os could trigger. The following were found:

Labour productivity is a rate at which workers are working. It can be expressed as the number of units accomplished per man hour or the number of manhours required to complete one unit of work.

A collection of delay and disruption events which could be triggered by V.Os were identified and given in Figure 9.2. The delay and disruption events V.Os could trigger on construction projects can be categorised under *human factors* and *difficult working conditions*. *Human factors* include issues such as low morale, low self-esteem, low motivation. *Difficult working conditions* include issues such as adverse weather conditions, acceleration methods, working out-of-sequence, impact on learning curve and interruptions.

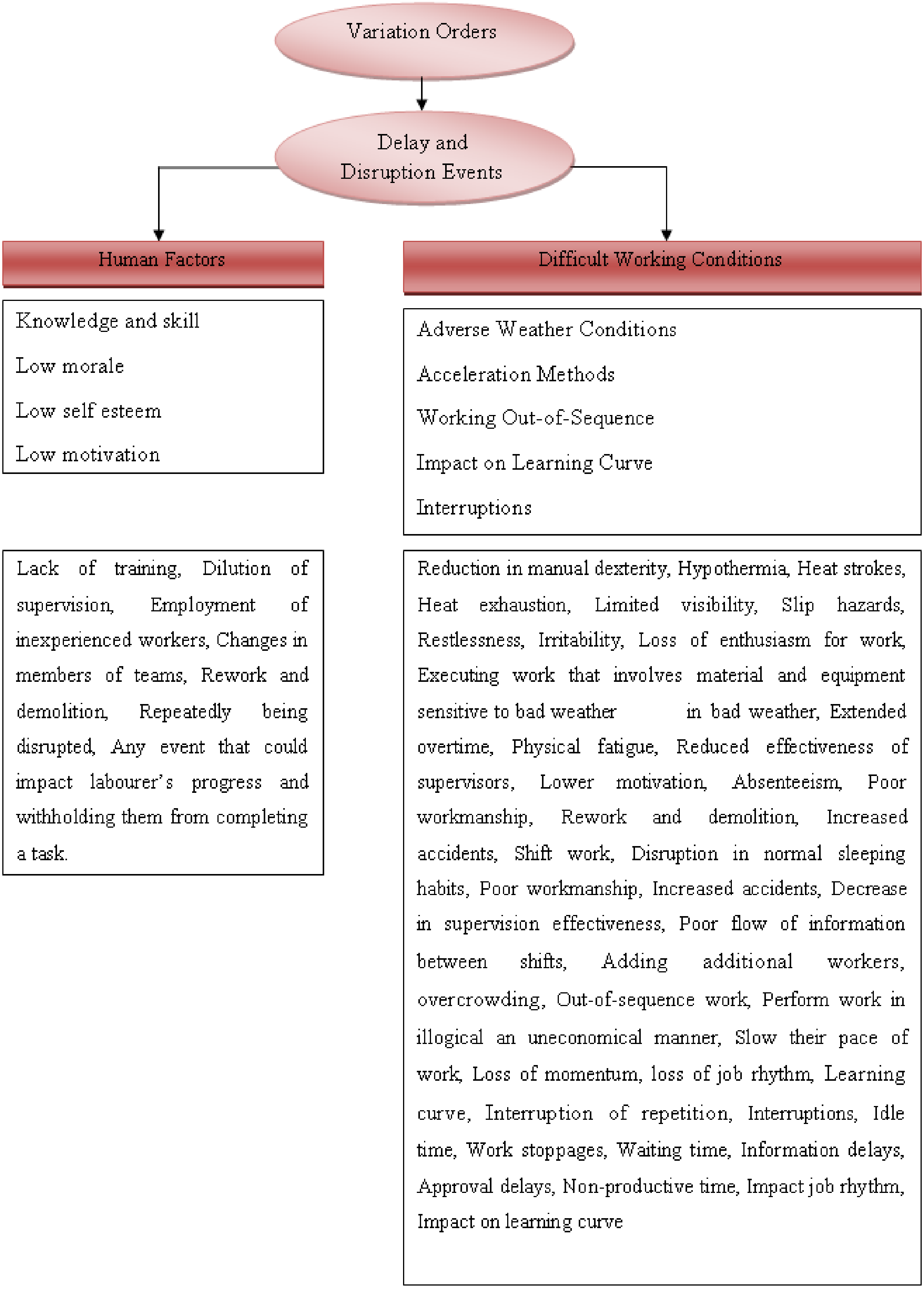

Figure 9.2: A collection of delay and disruption events that could be triggered by V.Os

Chapter 6: Loss of Labour Productivity

The focus of this chapter was to investigate loss of productivity in construction projects. Loss of productivity was defined and studies were discussed that proved V.Os cause loss of productivity. Also studies were considered that highlighted factors which could exacerbate the amount of productivity that is lost due to V.Os.

Loss of Productivity on Activity Level

Contractors have an initial estimation of what the labour productivity for a certain activity will be. That initial estimation is also known as the estimated average productivity rate or unit rate. A loss of productivity has occurred when the productivity that might have been achieved, is not achieved. Instead, a lower labour productivity is measured (Halligan et al., 1994), see Figure 9.3.

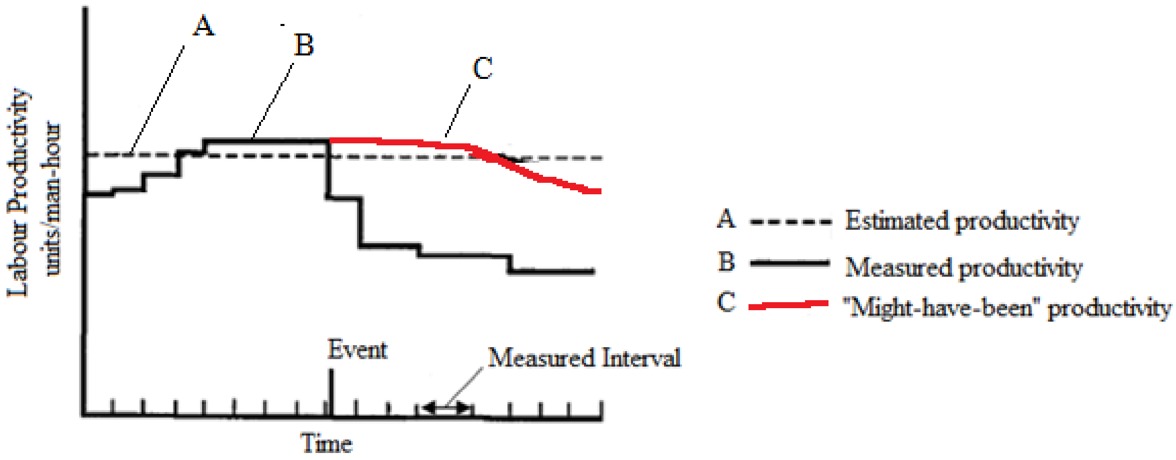

Figure 9.3: Loss of productivity on an activity level (Adapted from Halligan *et al.*, 1994)

Loss of Productivity on Project Level

Loss of productivity on a project level can be explained by comparing the actual labour hours spent to complete the construction project, with the estimated labour hours indicated in the contractor's bid (Hanna *et al.*, 2004) after project completion. A loss of productivity has occurred if a difference exists between the estimated hours and the actual hours, see Figure

9.4. In other words the actual hours spent are more than the estimated hours indicated in the contractors' bid. This difference in labour hours can be ascribed to labourers being inefficient, due to the delay and disruption events triggered by V.Os.

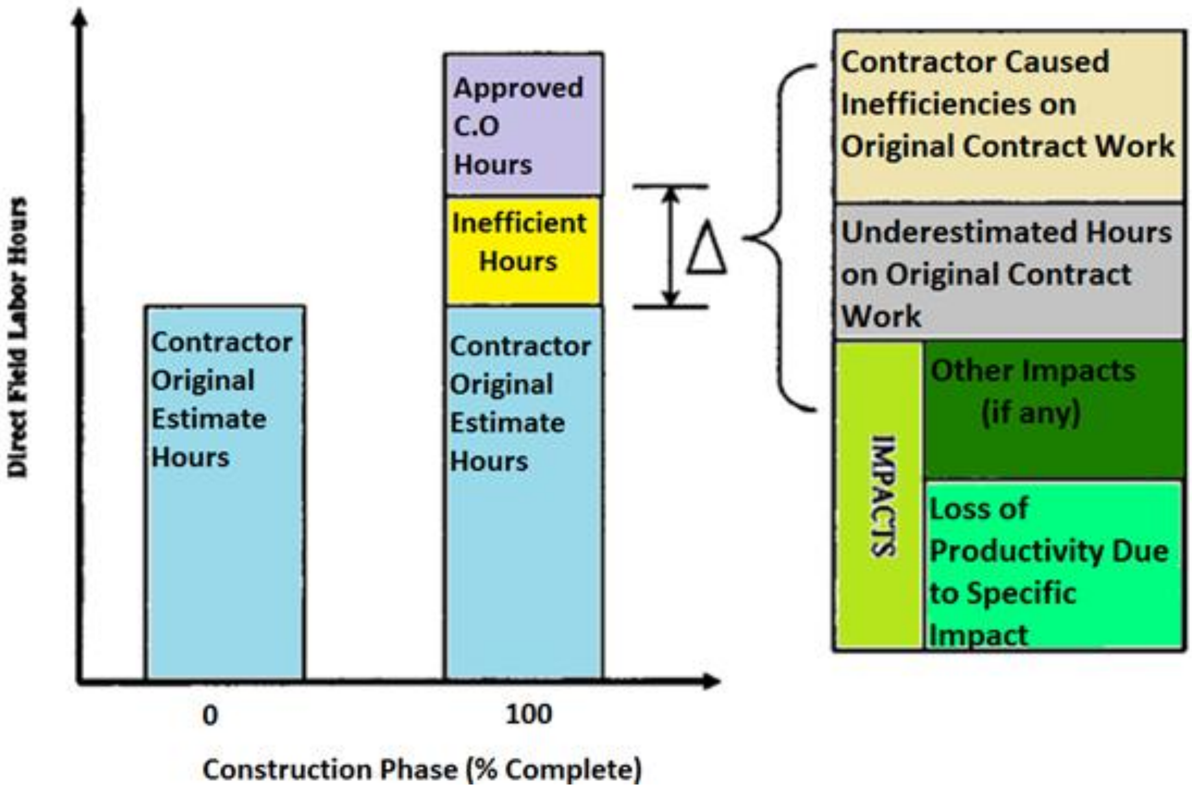

Figure 9.4: Loss labour productivity on the whole project (Hanna & Gunduz, 2004)

<u>Studies</u>

Studies done by Leonard (1988) and Ibbs (2005) proved the following:

1) The greater the percentage of V.O hours required, the greater the amount of productivity loss.
2) Projects' labour productivity declines as the number of V.Os issued increases.
3) V.Os that are issued late are twice as detrimental than V.Os issued earlier.

Chapter 7: Comprehensive and Systematic Overview

This chapter focussed on explaining how delay and disruption events are triggered by V.Os on construction projects. The methods used to gather the required information were literature review and interviews that were conducted. A comprehensive and systematic overview was given that explained how V.Os could cause delay and disruption events on construction projects.

It was concluded that V.Os trigger delay and disruption events in two phases. Phase 1 includes everything that happens before the V.Os are implemented. Phase 2 includes everything that happens after the V.Os have been issued and implemented on a project. The delay and disruption events prevalent in Phase 1 largely revolve around information and approval delays that are associated with change processes. It also includes the difficulties associated with the process and administration of V.Os. The delay and disruption events associated with Phase 2 can be categorised in three stages namely, control actions, portfolio effects and acceleration methods. Each stage has delay and disruption events which impact labour productivity. For a more detailed but concise overview, analyse the cause and effect matrix given Figure 9.5.

Chapter 8: Questionnaire

The main events in Phase 1 and Phase 2 were tested for the S.A contractors. The methodology used to test the events was an electronic questionnaire survey. Responses of 44 respondents were analysed. It was found that:

The main events tested in the questionnaire concerning Phase 1 of the comprehensive and systematic overview of the secondary impact of V.Os, are the approval and information delays that accompany V.Os, and the difficulties associated with the processing and administration of V.Os. It was found that:

- The respondents still battle with approval and information delays that accompany V.Os and find them problematic.
- The processing and administration of V.Os are time consuming for respondents; it does require considerable effort from them and it does interfere with their other management tasks.

Phase 2 of the comprehensive and systematic overview of the secondary impact of V.Os consists out of three stages. The main events tested in the questionnaire concerning the first stage are the delay and disruption caused by the control actions taken by management in response to the direct impact (the impact on the changed work). It was found that:

- It is highly likely that site managers will apply control actions if V.Os impact the changed work.
- Respondents apply the same control actions today as noted in comprehensive and systematic overview of the secondary impact of V.Os. Therefore, it is highly likely for the delay and disruption events triggered by the control actions, identified in Chapter 7, to be present on the projects of respondents.
- Respondents are reluctant to apply the control action *out-of-sequence work* because working in an illogical and uneconomical manner is so disruptive. When work is performed out-of-sequence due to V.Os it is most likely because the respondents had no other choice.
- There are no control actions that are commonly applied by the respondents other than the three identified in the literature review.

The main event tested in the questionnaire concerning Stage 2, is the portfolio effects. It is found that:

- The four portfolio effects listed in comprehensive and systematic overview of the secondary impact of V.Os are still occurring today on the projects of respondents.
- Portfolio Effect 4 happens more frequently on the projects of respondents. This indirectly confirms that the need to apply acceleration methods due to V.Os is high.
- *Embargo periods* and *working in closures* are two new portfolio effects that have been identified.

Stage 3 considers the delay and disruption caused by the acceleration methods implemented by management as a result of V.Os. It was found that:

- acceleration methods are applied due to the failure of the client to apply an E.O.T when projects experience a critical delay due to V.Os.
- Strong management capabilities, experience and a good relationship between contractor and engineer are some of the factors necessary to pro-actively manage the secondary impact of V.Os.

Throughout the comprehensive and systematic overview of the secondary impact of V.Os, it is repeatedly explained how the main events lead to different strategic issues and human factors which eventually cause a loss of productivity on projects. The strategic issues being dilution of supervision, fatigue in labour etc. The human factors specifically refer to labour motivation. It was found that:

- The majority of respondents informally consider strategic issues when applying control actions and acceleration methods.
- More than 50% of the respondents consider labour motivation to be a soft issue and tend to neglect its impact on labour productivity. Judging from the important strategic issues and human factors in terms of the impact on labour productivity it is not adequate for site managers to simply informally consider strategic issues and to neglect labour motivation.

Apart from the strategic issues and human factors, the learning curve also plays an important role in labour productivity as discussed in Chapter 5. It was found that:

- Most respondents do take into consideration the learning curve when preparing a bid. Hence, the projects of respondents are vulnerable to impacts on the learning curve.

It was concluded that the main events listed in comprehensive and systematic overview of the secondary impact of V.Os do occur on the projects of most of the respondents. Hence, the explanations given in Chapter 7 on how V.Os cause delay and disruption events on construction projects are valid and more importantly they are valid for the projects of South African contractors today.

The Conclusion on the Secondary Impact of V.Os

All things considered, it can be concluded that the secondary impact of V.Os is:

- unforeseen at the start of the construction project and also unforeseen during the construction project
- a synergistic effect
- the effect of all V.Os
- a loss of productivity on the work that is not included in the V.O (the unchanged work)

- a trigger of multiple delay and disruption events on a construction project
- the impact on human factors such as morale, self-esteem, motivation and the cause of difficult working conditions
- disruption that prevent project activities and events from starting and ending at the planned time
- disruption that prevent contractors from executing activities as planned

The cost due to the secondary impact is a combination of increased labour cost and also the increased cost of completing the unchanged work.

Chapter 10

RECOMMENDATIONS

One of the primary aims of the research is to provide recommendations that could aid contractors with the management of the secondary impact of V.Os. After examining different aspects of the secondary impact in each chapter, recommendations were made based on the information given in the specific chapter. This will now be given.

Recommendations from Chapter 2

In managing V.Os, the contract has a role to play. The following recommendations can assist contracts to fulfil its role:

- The contract should include clauses that force both client and contractor to acknowledge that V.Os may have a secondary impact on the project.
- The contract should include guidelines that would assist clients and contractors when required to address the secondary impact.
- The contract should state the risks each party will have to carry as well as the responsibility each party has.
- The contract should be clear on how compensation for impact cost should be dealt with. That is, the clauses which discuss the valuation of the V.Os and the E.O.T, should make provision for the possible impact of all V.Os issued.
- The recommended changes made to the contract can be implemented by associations of contractors and engineers such as South African Federation of Civil Engineering Contractors (SAFCEC) and The South African Institution of Civil Engineering (SAICE).
- The engineer/principal agent should be knowledgeable of the secondary impact of V.Os since they are the main party responsible for its valuation. Hence, the experience and education of the engineer/principal agent should show some kind of exposure to V.Os and its impacts.
- The contractor is the party directly affected by the secondary impact and would therefore have information that could assist the engineer/principal agent during the

valuation of V.Os. It is therefore necessary that contractors are involved in the process of valuation.

- The right to vary is unprecedented to the construction contract. It has implications and at the very least should be accompanied by a set of requirements clearly stated in the contract that, if met by a V.O, would qualify the V.O as necessary, appropriate and fair to be issued and implemented.

Recommendations from Chapter 3

Based on the definition and the characteristics of the secondary impact of V.Os it is recommended that construction companies:

- Do not remain the victim of the secondary impact of V.Os but instead, accept its existence and take on the responsibility to manage it.
- Add change management to the list of specialities the company offers to its clients.
- Make provision for this service by incorporating an allowance for it in the tender price.
- Pro-actively manage the secondary impact throughout the duration of the project but also quantify its impact on labour productivity and pursue compensation for it.
- Quantification of the loss of labour productivity and the pursued of compensation of corresponding damages should be done after all V.Os have been issued and executed

On the whole then, by pro-actively managing the secondary impact, companies can attempt to minimise or eliminate the impact. Once this is provided for in the tender price, they can be compensated for it. However, managing the secondary impact does not necessarily guarantee that the contractor's labour productivity is not affected. For this, the contractor is required to quantify its productivity and claim for related damages.

For contractors to pro-activitely manage delay and disruption events it is recommended that they consider the following in their approach. Managing delay and disruption events triggered by V.Os is a matter of:

- knowing what will come
- being prepared for what will come
- recognising and communicating how the V.Os issued, lead to what came

- documenting all of the above (this will serve as proof and assist with lessons learned) (A "black box" of the project's life span.)

Recommendations from Chapter 4

It is recommended that:

- When delays occur, categorise them in terms of its type, its effect and the party who has control over the delay.
- When accelerating a project, distinguish between directed accelerations and constructive accelerations.
- When disruption occurs, identify whether it is compensable or non-compensable.
- Know the original scope of work and the original plan of execution and understand the reasoning behind it. Refer to Chapter 7's chapter recommendations for more information.
- Do not blindly and reactively implement control actions in response to disruption. Instead, evaluate and analyse the situation at hand and then choose an appropriate control action.

Recommendation from Chapter 5

For contractors to manage delay and disruption events the following is recommended:

- Equip oneself with knowledge concerning the psychological aspects involve in *human factors* and the physiological aspects involve in *difficult working conditions* which impact a labourer's productivity
- Identify mitigation strategies for each human factor and difficult working condition. Document and implement it.
- Keep record of delay and disruption events that realise on the project due to V.Os. This can be used as proof in claims and lessons learned.
- Measure, record and monitor labour productivity. The following methods can be used to measure productivity: 1) Total cost method, 2) Modified Total Cost Method, 3) Measured Mile Approach. For more information consult the article by: Jones, R.M. (2001). Lost Productivity: Claims for the Cumulative Impact of Multiple Change Orders. *Public Contract Law Journal*, 31(1): 30-34

Recommendations from Chapter 6

It is recommended that the contractor:

- Identify the desired rate of productivity per activity before commencing with construction.
- Identify a method to measure, monitor and control productivity and implement it.
- Write the rate of productivity per activity down as well as the method that will be used on the project to measure, monitor and control productivity. Communicate this to all members of site management and document it.

It is recommended, as far as reasonably practical, that clients:

- Issue V.Os at the start of the project.
- Make known possible V.Os to the contractor as soon as possible.
- Limit the number of V.Os issued on a project.

Recommendations from Chapter 7

Recommendations for Phase 1

It is recommended that the client:

- Identifies variations before construction commences and issue V.Os in the early stages of construction.
- Makes sure that sound drawings are provided to the contractor at all times and as soon as reasonably practical.
- Responds duly, effectively and unambiguously to the contractor's RFI and RFC.

It is recommended that the contractor:

- Allocates time and resources to identify common E&O in drawings in advance.
- Acknowledges that RFI and RFC are time consuming activities and it interferes with other management responsibilities. Contractors can appoint a person that will take care of the administration tasks associated with V.Os. If not possible the administration tasks of V.Os should be identified and allocated as one of the key responsibilities of either the site manager or site engineer.

It is recommended that both client and contractor:

- Conserve the relationship between each other.

Recommendations for Control Actions

It is recommended that the client:

- Makes known to the contractor assumptions about the project/design that could result in V.Os before construction commences.
- Consults the contactor on solutions and ways as to how best to incorporate V.Os before issuing a V.Os.

It is recommended that the contractor:

- Accepts that if V.Os are issued control actions will have to be implemented and will cause delay and disruption events on the project.
- Familiarises himself with the delay and disruption events associated with the control actions: *stop-and-go* operations, *out-of-sequence* work and *do nothing* as given in Figure 7.7 and discussed in Chapter 5.
- Identifies mitigation strategies for the related delay and disruption events and processes that should be followed (this can be done by means of brainstorming and the use of project specific scenarios).
- Does not blindly and reactively implement a control action. Based on the related delay and disruption events and situation at hand, choose an appropriate control action.
- Identifies new control actions and adds it to the matrix given in Figure 7.7. The consequential delay and disruption events should be identified and prepared for.

During project execution, record should be kept of the control actions implemented, the reasons why and the related delay and disruption events that are present because of it. To ensure that all delay and disruption events are recorded it should be done on site management level as well as at foremen level. This should then be discussed during production meetings and can be used for lessons learned.

Recommendations for Portfolio Effects

It is recommended the contractor:

- Treats portfolio effects as project risks created by V.Os.
- Familiarises himself with the delay and disruption events associated with acceleration methods as discussed in Section 7.3.2.3.
- Identifies *weather sensitive work* and monitor its time of execution throughout the duration of the project.
- Identifies *expensive activities* and monitor its time of execution throughout the duration of the project.
- Keeps a watchful eye on progress made on original contract work as it can fall behind due to V.Os.

When portfolio effects occur, identify the reasons why, communicate it to client and document it. New portfolio effects should be added to the matrix and managed appropriately.

Recommendations for Acceleration Methods

It is recommended that the contractor:

- Distinguishes between constructive accelerations and directed accelerations.
- Familiarises himself with the delay and disruption events associated with acceleration methods as discussed in Chapter 5 and given in Figure 7.11.
- Links the need for acceleration to the V.Os and its related delays and disruptions. Write it down, communicate it to the client and document it.
- Does not blindly and reactively accelerate a project. Instead compare the advantages and disadvantages of an E.O.T versus acceleration, discuss it with the client and agree on the best solution.
- Prepares for the delay and disruption events associated with the acceleration method that is being implemented.
- Keeps record of the delay and disruption events that realise on the project due to implementing certain acceleration methods.

Chapter 7 overall recommendations

It is recommended that the site manager and everyone who was involved in the tender process such as the contract manager, the estimator and the planner should clearly define the project's scope of works, the plan of execution and the reasons behind the plan of execution before construction commences. By means of brainstorming the individuals should:

- Give a description of the nature of the work and the nature of the primary activities.
- Describe the sequence in which the work and activities is to be executed in and give the reasons and an explanation of the logic behind it.
- Identify the factors that determined the plan of execution.
- Identify assumptions made regarding the execution of the work and the reasons behind them.
- Identify factors that determine the progress of the work.
- Describe the logistics involved in the plan of execution.
- Describe the characteristics of and identify the assumptions about the resources to be used.
- Discuss the importance of the time period the activities must be executed in.
- Identify the activities where the learning curve was taken into consideration at tender stage.
- Identify any critical assumptions made about the project at tender stage and the reasons behind it.
- Do a SWOT analyses of the production team/contractor .

This information should be recorded in the form of a report which should be communicated and be available to all members of the site management team.

Recommendations from Chapter 8

It is recommended that contractors:

- Add *embargo periods* and *working in closures* to the other 4 portfolio effects listed in Chapter 7 and continuously seek to identify new events.
- Consider formally strategic issues associated with control actions before applying control actions.

- View human factors such as labour motivation as an important factor of labour productivity.

General Recommendations

Having recommended all of the above, it is clear that to pro-actively manage the secondary impact of V.Os will require that the contract addresses the secondary impact and will require the cooperation from the contractor and the client. The contractor has the biggest responsibility in the matter. For the contractor to pro-actively manage V.Os he must:

1) Understand what the secondary impact of V.Os is.
2) Be aware of the different delay and disruption events V.Os trigger.
3) Understand how the delay and disruption events impact productivity.
4) Prepare for the secondary impact of V.Os by having mitigation strategies and plan of actions in place and by monitoring and controlling labour productivity.
5) Keep record of all of the above by documenting it religiously. Use this as prove to support claims but more importantly use it to learn from.
6) Maintain a good relationship with the client and the client with the contractor.

Recommendations for Future Research

Develop management tools, which contractors can use to implement the recommendations given in this thesis effectively, systematically and with ease. Once these tools have been developed it should then be tested for the construction industry.

Having understood the secondary impact of V.Os on a qualitative level, it is necessary to quantitatively analyse the secondary impact of V.Os. Hence, develop research instruments that could be used to gather the necessary data that would enable one to quantitatively analyse the secondary impact of V.Os. Off course, one will first have to identify what data is required to quantitatively analyse the secondary impact as well as to identify the best ways in which the data can be presented.

One of the conclusions made in this thesis is that the contract for construction works does not provide the necessary guidelines on how contractors and clients should address the secondary impact of V.Os on projects. From the legal perspective research is required to identify what these rules and guidelines should be.

Chapter 11

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APPENDIX A

Dear Respondent,

My name is Melany Neff and I am a post graduate student from Stellenbosch University. I am currently undertaking a research project under Professor Jan Wium at our Chair for Construction Engineering and Management. For my final MScEng project, I am investigating the secondary impact of variations made to original scope, design and specifications during construction of projects.

An individual such as you regularly deal with variations on projects. We are therefore interested in your perspective concerning the impacts of variations on the projects you've been involved in. It would be greatly appreciated if you could complete the following online survey, which will take about 10 minutes of your time.

The findings of the survey will help us to improve change management processes which will assist contractors to effectively manage variation orders on projects.

The results will form part of a Masters degree and therefore will be used for academic purposes strictly.

Your name and the company you work for will be used only to keep track of the surveys as they are returned. In that way, follow-up reminders won't be sent to those who respond soon.

Contact information:
If you have any concerns about the survey feel free to contact me, Melany Neff on neff.melany@gmail.com (072 529 44 58).

Click here to take the survey.

Your participation is highly appreciated.

Kind Regards,
Melany Neff

APPENDIX B

Research Questionnaire

THE SECONDARY IMPACT OF VARIATION ORDERS

Questionnaire Brief

Variations requested by clients to the contractor during construction, are common to civil engineering projects. However, although it is common and part of contract agreement it has a disruptive effect on project performance which is often the reason for project cost and time overruns. **The objective of this questionnaire is to investigate how variations disrupt projects.**

It is believed that, the implementation of variation orders (V.Os) and the action of construction managers in response to the direct impact, causes disruption and delays, which changes the working condition under which the unchanged work is to be executed, resulting in a loss of productivity which is why increases in cost and time are experienced. **The questions are related to the disruptions and delays, the change in working conditions and the losses in productivity triggered and associated with V.Os**

Note: *There is no right or wrong answer. What is important is that the questionnaire is answered according to the experience of the respondent as a contractor and from subcontractors view.*

* Initials and Surname:

* Job Title:
(e.g. Contract Manager, Site Agent)

* Years of Experience:

* Years at Current Employer:

* Company Name:

* Project Type
(e.g. Buildings, Civils, Roads):

1) **Information delay** (prevalent when variations are issued due to errors and omissions in design and on drawings)
2) **Approval delay** (the processing time of approving variations and also approval of drawings)
3) **Activity to be done later than originally planned due to other reasons**

* 1.1 Have you encountered any of the first two types of delays, accompanied by V.Os on past projects?

- Frequent
- Often
- Seldom
- Never

* 1.2 How problematic are they for a contractor?

- Severe
- Significant
- Minimal
- No Impact

* 3. Processing and administration of V.Os interferes with planning and coordination responsibilities of contractors' site management?

- Strongly Agree
- Agree
- Neither/Nor
- Disagree
- Strongly Disagree

* 4. Have you experienced delays accompanied with V.Os to interrupt affected activities on any of the projects you worked on? In other words, do V.Os delays cause interruption?

- Frequent
- Often
- Seldom
- Never

5. Interruptions, especially the longer type, result in labourers assigned to affected activity, to idle. To avoid losses due to idle time, management responds in three ways:

1) Stop-and-go operations: whilst waiting for instructions labourers are assigned to other activities, when information become available they return back to original activity
2) Out-of-sequence work: the original sequence of executing work is changed
3) Do nothing

* 5.1 Have you ever employed any of the first two, to avoid losses due to idle time caused by interruptions resulting from V.O?

- Frequent
- Often
- Seldom
- Never

* 5.2 With a rating of 1-3 (1 most common and 3 least common) rate the three control actions as you experienced them to be implemented on your projects when dealing with V.O.

	1	2 *	3
Stop-and-go operations	○	○	○
Out-of-sequence work	○	○	○
Do nothing	○	○	○

* 5.3 Although both stop-and-go and out of sequence work can be disruptive, out-of-sequence tend to be the more disruptive as it often results in sequence changes from logical and economical to illogical and non-economical. Therefore, it is believed that out-of-sequence work is often a forced decision.

- Strongly Agree
- Agree
- Neither/Nor
- Disagree
- Strongly Disagree

5.4 Are there any control actions other than 1,2 and 3 above, employed to manage delay to V.O? If yes, please indicate at least one.

6. The **portfolio effect** is defined as the synergy of the many delays and disruptions caused by variation orders (V.Os), causing an impact greater than the sum of the individual delays and disruptions. (In other words, the whole is greater than the sum of the individual parts). **Four** examples reported by contractors will now be given briefly. ***Please read through them and indicate whether you have encountered any on past projects.***

	Frequent	Often	Seldom	Never	Not applicable to types of projects worked on before
A) Many delays and disruptions gradually shifted weather sensitive work to be executed in bad weather.	○	○	○	○	○
B) Many delays and disruptions gradually shifted "expensive activities" (e.g. excavate and backfill) on different work packages to be executed at the same time.	○	○	○	○	○
C) Many delays and disruptions gradually deteriorate original programs resulting in orderly sequences of operations broken down into several isolated activities. Scheduling becomes the function of the release of approved V.O and drawing revisions instead of normal construction logic and economics.	○	○	○	○	○
D) Many delays and disruptions caused original work to have fallen behind.	○	○	○	○	○

6.2 If possible, describe one such example experienced by you on any past project.

* 6.3 An interesting scenario also reported by contractors is how the many delay and disruptions and additional work have caused contract work to have fallen behind. This has lead to an extension of time (E.O.T) required but instead of granting the E.O.T the client/engineer instruct contractor **to accelerate.**

- Frequent
- Often
- Seldom
- Never

A sincere thank you for taking the time and effort to answer the questionnaire.

APPENDIX C

Examples of Bad Weather

- *Delays shifting Asphalt out into rain season.*
- *Dam projects are sensitive to the diff seasons. If work is pushed to a later date, the contractor might not get the programmed work done in time for the next rain season. Thus, a one week delay by client could push the contractor in to the next rain season and effectively delay construction by 6 months depending on the length of the rain season.*
- *Delays in contract approval resulted in work on site where clay was present to begin in July. This resulted in wet and muddy conditions and time delays due to the excess water.*
- *Fill Quantity of a dam floor increased by 120,000 m3 as per issued construction drawings. The increase in quantity resulted in:*

  1) the contract period being extended together with P&G Costs and
  2) shifted the lining work of the dam into the wet season.

  In addition, the contract price increased from R63 Million to R85 Million. The increased quantity of the floor directly impacted on the construction of the dam walls, which got delayed and pushed lining work into the rainy season and therefore making the lining constructability very difficult - because of the GCL (Clayish membrane) that should be laid dry and covered straight after with an LLDP or HDPE Liner to prevent the GCL from swelling once in contact with rain water. ***Example of work sensitive to weather was pushed into bad weather season.***

- *In a construction project that involved the construction of drains a V.O was issued. It was issued at a late stage resulting in an overrun on contract period. It also resulted in work being executed in adverse weather conditions. A loss of production and high material waste factor were experienced.*

Examples of Deterioration of Schedule

- *Late info received from the engineer for mining licence application. Mining license application took 3 months to be processed and approved which caused the work to be done out of sequence. This deteriorated the original program.*

Examples of Original Contract Work Delayed

- *Late information received from Engineer which initially formed part of the original scope of work. This information was received with 60% of the project time elapsed causing original work to fall behind.*

APPENDIX D

PRE-INVESTIGATION

1. Introduction

After the general conditions of construction contracts were reviewed together with a study of some of the available literature, the researcher needed to know if contractors in South Africa face the challenges identified in literature. It was decided that a pre-investigation will be conducted in the form of a qualitative study. The purpose of the pre-investigation is to gain insight on how South African contractors experience V.Os and its related impacts on projects. This was required before the researcher could continue with investigating the secondary impacts of V.Os.

This chapter reports the methodology used and the findings of the pre-investigation. The research instruments used during the investigation will first be discussed. Thereafter, the findings will be discussed that were obtained through each research instrument.

2. Methodology

Questionnaire surveys and interviews are the research instruments used in the investigation. The motivation behind the decision to use questionnaires is the advantage of acquiring information from the necessary individuals in a short period of time. Interviews allowed the researcher to gain better insight on issues identified by respondents on the questionnaire. Hence, interviews were conducted in support of the questionnaire.

It must be mentioned that the objective for the pre-investigation was not to reach consensus for the entire construction industry of South Africa. Therefore, the number of respondents to the questionnaire was not as important as the information obtained from it. Furthermore, the interviews conducted were informal and semi-unstructured, in the sense that it was a general discussion with the interviewee on his experience with V.Os and their impacts. No set list of questions exists and no interview was the same even though the objective for it was.

3. Method 1: The Questionnaire

2.2.1 Questionnaire's Objective

From the pre-reading of some of the available literature, five general questions aroused. It concerned V.Os and its secondary impact and needed to be answered before the commencement of the formal qualitative analysis of the secondary impact of V.Os. They are:

1) What type of V.Os is most commonly issued on South African construction projects?
2) At which time during a project are V.Os generally issued on South African construction projects?
3) Do South African contractors consider the impact cost associated with the secondary impact of V.Os or not?
4) Do South African contractors view V.Os as profitable or non-profitable?
5) If South African contractors were to claim for the impact cost of the secondary impact of V.Os, what would clients require from contractors to prove and explain to them what the secondary impact of V.Os is and/or will be?

The objective of the questionnaire was to obtain answers to these questions.

2.2.2 The Respondents

Each year an elite group of South African contractors, consultants and employees from South African government agencies in middle and upper management positions attend the construction engineering management programme (CMP) held at the University of Stellenbosch. The questionnaire was developed in year 2011 just before the CMP programme started. It was decided to invite the attendees representing construction firms and governments agencies of year 2011 to participate in the survey. Convenience of quick access to experienced individuals working in senior positions within construction industry is the main reason for inviting CMP attendees to participate in the survey.

2.2.3 Questionnaire Validation

It was important that the respondents understood the context in which the questions were asked. Change management in construction is one of the courses lectured during the CMP programme. This course together with the background included in the questionnaire assisted with placing the questions in the questionnaire into context.

2.2.4 Questionnaire Distribution

A hard copy of the questionnaire was distributed to representatives of construction firms and government agencies at the end of the lecture on change management. The potential respondents were not compelled to complete and submit the questionnaire straight after the lecture. Instead it was requested that, all questionnaires were submitted before the end of the CMP programme.

2.2.5 The Questionnaire

The questionnaire consisted out of three sections, the first section is a brief background to the questionnaire, the second section prompted respondents to share personal details and the third section consisted of the questions. The personal details required from respondents included their names, the position they were employed in, the name of the company they worked for, the type of company and the type of projects they have experience in. The questionnaire contained six questions of which one was directed to clients and the rest to contractors. Five of the questions were open-ended and one was close-ended. The questions are as follows:

Question 1:

Different types of V.Os are issued on construction projects for different reasons. Respondents were asked to indicate the type of V.Os which are most prevalent and costly on the projects they worked on.

Question 2:

V.Os which are issued late during a project or activity is considered to be more detrimental than if they are issued sooner (Ibbs W. , Impact of Change's Timing on Labour Productivity, 2005). Respondents were asked to indicate when most variations generally occur during a project and an activity. On the project level respondents could choose one of four options: 0%-25%, 25%-50%, 50%-75% or 75%-100% of project completion time. On the activity level, respondents were required to allocate a number between 1 and 3 (1-the most, 2-second most, 3-the least) to the following scenarios: a) before activity commenced, b) during activity execution, c) when activity is already completed.

Question 3:

Costs due to the secondary impact of V.Os are not normally considered by contractors when pricing V.Os (Williams, 2002). Respondents were asked to indicate the costs they normally consider when pricing a change.

Question 4:

Respondents were asked whether or not they could anticipate and quantify the consequent secondary impact of the requested V.O as to calculate what the total cost of the change would be. They were asked to give reasons for their answer.

Question 5:

If the secondary impact of V.Os is neglected, V.Os may appear to be profitable to contractors. Respondents were asked what their view was regarding the profitability of changes in scope.

Question 6:

A general principal in law is, if a contractor claims for damages, he must first prove liability, causation and quantity of the resultant damages to the court of law before compensation before a ruling will be made (Jones, 2001). Clients were asked what they require from contractors to explain and prove to them what the secondary impact of variations on the project is and (or) will be.

A copy of the questionnaire may be found in Appendix E.

3. Analysis, Synthesis and Discussions of Questionnaire

3.1 Personal Details of Respondents

The positions held by respondents range from construction managers, contract managers, senior contract managers, managing directors, project managers, site agents, senior site agents and site managers, see Figure D.1. Respondents represent 8 different South African construction firms, see Figure D.2. The different construction project types of which the respondents have experience on are buildings, civils, roads and a combination of civils and roads, see Figure D.3.

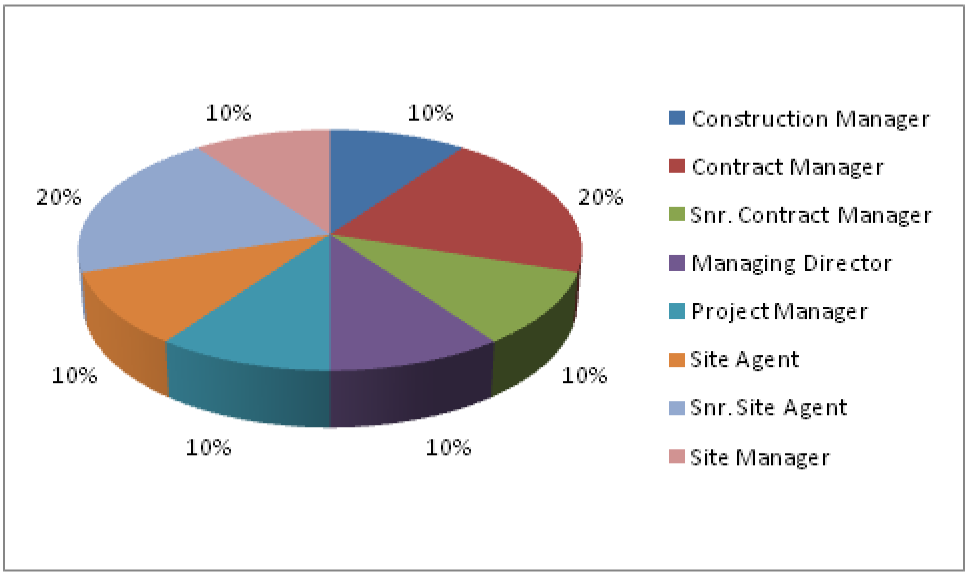

Figure D.1: Positions held by respondents

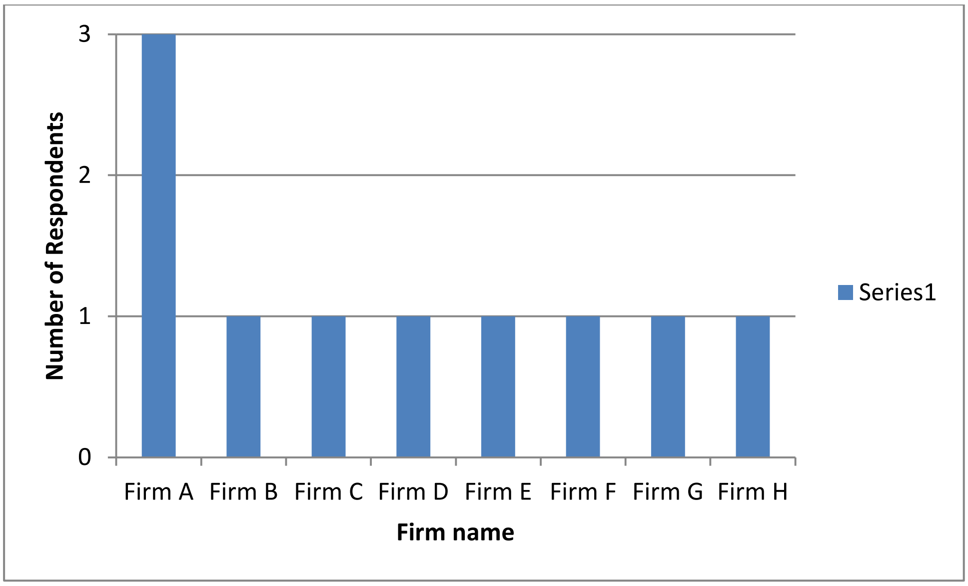

Figure D.1: Construction firms and the number of respondents

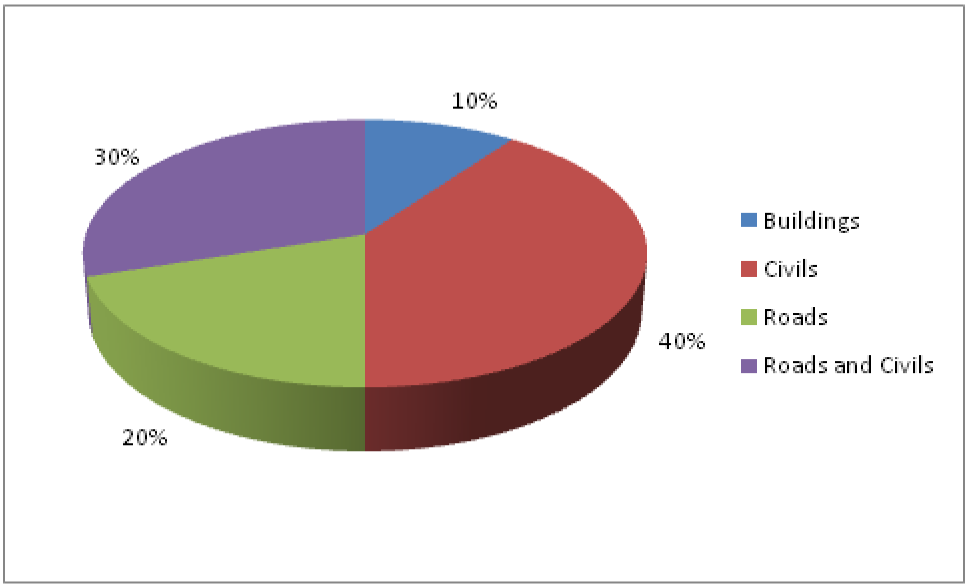

Figure D.2: Types of civil engineering projects

3.2 Number of Respondents

Altogether 10 questionnaires were completed by contractors and 13 were completed by clients.

3.3 Answers to questions

The results of each of the 6 questions will be analysed individually under separate subheadings. The questions addressed to contractors will precede the question addressed to clients.

Results of Question 1:

Design changes, *scope changes* and *errors and omissions in designs* (E&O) were indicated as the most common types of variations made on the projects the respondents have worked on. Others include *additional work* and *late supply of information*. An issue raised by many of the respondents concerning V.Os was the poor quality of designs and drawings which, according to their experience, is one of the main reasons why changes are made to the design and the scope of works. Like one respondent wrote "*if more time were invested on the design and preparation of drawings before construction started very few design changes and scope changes will need to be made*."

Judging from the type of V.Os indicated to be commonly issued on construction projects, it can be concluded that (for the ten respondents) clients and consultants are mostly responsible for variations made during construction projects. It is also evident from the comments of respondents that, for most of the V.Os that are issued on construction projects could have been prevented before construction commences.

Results of Question 2:

For each of the four options available (0%-25%, 25%-50%, 50%-75% or 75%-100% of project completion time) at least 2 out of the 10 respondents indicated it to be the time during a project when V.Os are issued, see Figure D.4. This implies that (for the ten respondents) V.Os are issued throughout the life of a project. It can also be concluded that most V.Os are issued after the project reached 25% completion status and therefore the secondary impact could be significant.

The question about the time when most V.Os are issued on an activity level was not answered as requested. Most respondents simply ticked one of the options and did not allocate a number to the options as stated in the question. The results are therefore disregarded.

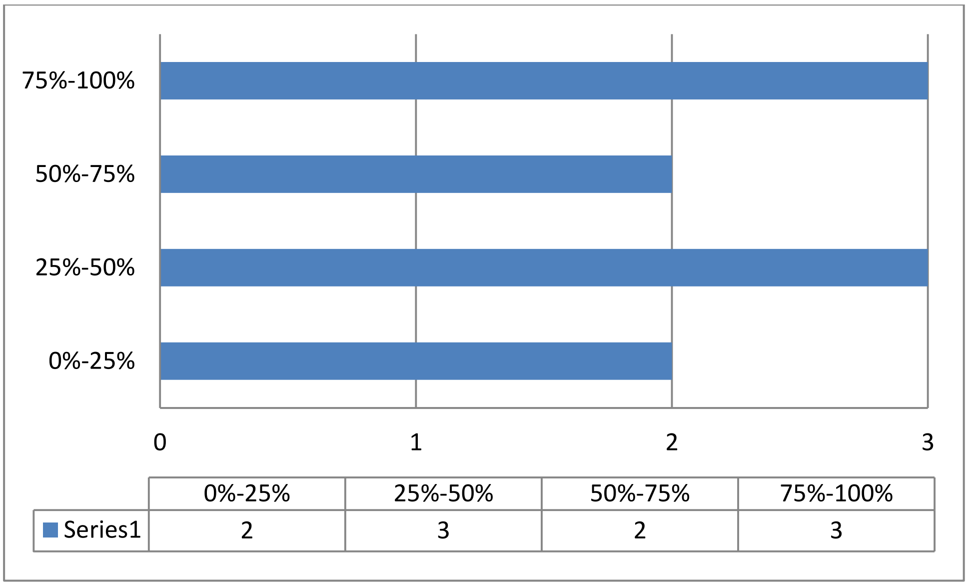

Figure D.3: A representation of the number of respondents and the option taken

Results of Question 3:

The following costs were indicated to be taken into account by respondents when preparing a quotation for V.Os:

	All Respondents	Respondents from Firm A	Respondent from other Firms
1	Labour	Inconvenience Cost	Cause and Effect
2	Plant	Risks Involved	Mark up
3	Material	Impact on other activities	
4	Preliminaries & Generals (P&G)		
5	Supervision		
6	Management		
7	Time		

Table D.3: Costs that respondents take into account when preparing a quotation for V.Os

All respondents indicated *cost of labour, plant, material, P&G, supervision, management* and *time* as costs which are generally included when preparing a quotation for a V.O, see Table D.1. 2 of the 10 respondents, employed by Firm A, listed *inconvenience cost, cost due to risks associated with V.Os, cost due to impact on unchanged work* as additional costs that they take into account when preparing a quotation for a V.O. 2 other respondents employed by different firms, other than Firm A, indicated *cause and effect* as a cost additional to the 7 indicated by all respondents.

The costs indicated by all respondents (*labour, plant, material, P&G, Supervision, management and time*) can be classified as the cost required to implement the V.O commonly referred to as the direct cost. Any cost other than the direct cost is referred to as indirect cost which is normally associated to secondary impacts. It can be concluded that for the 10 respondents most of them do not consider the indirect cost of V.Os when pricing a V.O.

Results of Question 4:

7 of the 10 respondents indicated they could anticipate and quantify secondary impacts of V.Os and the remaining 3 indicated that they could not do so. However, for the 7 who indicated they could, also indicated that it can be done only to a certain extent. A reason given for why the estimation is only done to a certain extent and not fully, is due to the added effort required to motivate its cost and the difficulty to justify it. Some of the 7 respondents stated that the secondary impact will be accounted for if it is known, obvious or could be anticipated. Some indicated that they only concentrate on the impact the variations have on the conceptual program. Furthermore, the respondents indicated that the quantification of the secondary impact is not an exact calculation but estimation. That experience of past projects is also used when quantifying secondary impacts of V.Os.

The 3 respondents who have indicated that they could not anticipate and quantify the secondary impact of V.Os seem to find the process too difficult and therefore simply ignore it. As the one respondent wrote "*we do not look at the bigger picture we concentrate on the area of change*."

It can be concluded that most of the respondents partially consider the secondary impact of V.Os. They do so when the impact is known, obvious and easy to anticipate. Furthermore, respondents find the quantification of the secondary impact of V.Os to be a difficult process that requires additional effort.

Results of Question 5:

Respondents indicated that V.Os such as *scope changes* could be an opportunity to increase profit. They also indicated that on some past projects, profit was increased due to scope changes. However, the respondents also indicated that changes to scope may also have a negative impact on profit such as decreasing it.

It can be concluded that respondents do not just see V.Os as a means of increasing profit but realise that the impacts of V.Os could have financial implications at stake.

Results of Question 6:

Respondents listed the following as what they as the client require from contractors to explain and prove to them the secondary impact variations had on the project.

They are:

- Detailed rate breakdown
- A presentation of the result of *do nothing* approaches
- Scenario analyses
- Causal loops
- Method statement of construction with the base program
- Any additional information and motivation as required by client

Some of the examples listed by clients are what is investigated and used by researchers studying the impacts of V.Os (Lee, Hanna & Loh, 2004, Eden *et al.,* 2000, Williams, 2000, Howick & Eden, 2001). They have proven to be complex and require time and know-how. For this reason it can be assumed that such analysis would not always be practical for construction managers to perform.

It is easy to wrongly assume that because the proof required by clients is complex and time consuming it must be unreasonable. This is not exactly true, because of the dynamics of secondary impacts, its indirectness and its very nature is complex to prove it will be difficult too. Therefore, analysis proposed by clients is required. The challenge however, is for researchers to find ways to make these analyses mechanical so that it can be applied for construction projects.

It should be noted that a correlation exist between the answer to this question and that of Question 5. In Question 5, contractors commented on the difficulty to recover the full cost of V.Os. They indicated that one of the challenges they have is to provide acceptable proof to clients. In this question the comments of clients support this challenge noted by the contractors.

3.4 Conclusion of Questionnaire's Results

Design changes, *scope changes* and *errors and omissions in designs* (E&O) were indicated as the most common types of variations made on the projects the respondents have worked on. Hence, clients and consultants are mostly responsible for variations made during construction projects. From the comments of respondents it is evident that, for most of the V.Os issued on construction projects, it could have been prevented before construction commences.

It was indicated that V.Os are issued throughout the life of a project of which most are issued after the project reached 25% completion status. Therefore for most projects the secondary impact is significant (Ibbs, 2005).

Most of the respondents consider the direct cost associated with V.Os and neglect its impact cost. It can be concluded that respondents do not just see V.Os as a means of increasing profit but realise that the impacts of V.Os could have financial implications at stake.

Respondents listed analyses such as *detailed rate breakdown, scenario analyses, causal loops* etc. as what they as the client require from contractors to explain and prove to them the secondary impact variations had on the project. The analyses have proven to be complex and require time and know-how. Researchers are to find ways to make these analyses mechanical so that it can be applied for construction projects.

4. Method 2: The Interviews

Two interviews were conducted with individuals from two different construction companies, Company A and Company B. The details of each interview will now be given followed by a discussion of the information obtained during each interview.

4.1 Interviews' Objective

The objective of the interviews is to gain insight on how South African contractors experience V.Os and its impacts.

4.2 Interview #1

The interview was conducted on the 31 July 2011 with a Contract Manager (CM) and Senior Quantity Surveyor (QS) working for the same construction company (Company A). The company is rated by the Construction Industry Development Board (CIDB) as a 9GB construction company. The CM and QS have 12 years and 30 years experience in construction, respectively. The interview took place at the site offices of a particular building project where the CM and QS were working on at the time. The interview was done in a separate but complementary manner in order to save time. The interviewees have a busy schedule it was thought best to speak with them individually and have them indicating the questions they thought the other had better insight on. The researcher would keep record of the particular questions and ask it to the relevant person.

The particular company was selected because of their interest to contribute to the research. At the time of the interview the company had a building project within Stellenbosch. The directors of the company felt that the CM and QS working on this particular project would be ideal to be interviewed due to its proximity.

4.2.1 Discussion of Interview #1

The contractor finds the process of identifying the secondary impact of V.Os, the quantification of its cost and the process of proving it to require too much effort and time. He mentions that his day to day activities and responsibilities do not allow him time to give the necessary attention it requires. That is, in general it would be ignored. However, he did say that in the event that the cost for the impact is significant and relatively easy to prove, it would be requested from the client. The contractor gave two examples where compensation was indeed requested which are used in Chapter 7.

With regards to the approach taken with dealing with V.Os and its impacts, this contractor explains that the idea is to guarantee the recovery for the direct cost and capitalise on the opportunities it brings. Instead of spending time quantifying the secondary impact the V.O may cause, much effort and care is taken to ensure the full recovery of the direct cost of the V.O. The opportunities he refers to are the benefits of additional work for which no rates exist in the contract (B.O.Q). As a general contractual agreement, if no rates exist for work ordered by the client the contractor is allowed to submit new rates. The advantage of this is the contractor can submit a rate he believes is fair and just, without the pressure from competitors competing against him. In such a case, the notion is to capitalise on V.Os within reasonable terms. As stated by the CM "*contractors make a killing when additional works are issued for which no rates exists.*"

He also mentioned that there is a disadvantage to this opportunity. Contractors could lose money if rates do exist for the work issued by the Engineer but which does not justify the expense for executing the work required. He explains that if the additional work had formed part of the original work for which he had tendered for, different rates would have been submitted.

It can be deduced that the contractor is of the belief that if direct cost is fully recovered and if profit is increased due to additional work for which no rates exist, it makes up for losses and for the inconvenience of dealing with impacts. If this is the case then it still leaves the question of how the contractor deals with secondary impacts on his project. In response to this question the contractor was given examples taken from literature and asked to explain how he deals with them on his projects. The contractor answered the question by associating the examples given to scenarios he was faced with on the project he worked on at the time. What was discovered is that the contractor has learned to "cope" with the secondary impact of V.Os. For each scenario the contractor has either found a way of dealing with it or believes he has not been affected by it. [What the researcher means with coping in this instance is that, the contractor applies either reactive management or no management at all.] Examples will be given that demonstrate the contractor's account for instances where the project was not impacted and instances where the project was. They will be discussed in two separate paragraphs.

Example #1

Part of the project involved the construction of a set of columns. In the original design column heads were not part of the works. As construction continued it was decided that column heads would indeed be necessary. The design had been changed and a V.O to construct the column heads was issued to the contractor. This decision was taken after the columns had been constructed and the tops of the columns had to be demolished to accommodate the construction of the column heads. One would obviously expect the successor activities which in this case the "casting of the slab on top of columns" (erection of formwork for the slab has already been done) to be affected (to the very least delayed). However the contractor experience was that the construction of the column heads did not interfere with the pour of the slab. That somehow the column heads were constructed before the time the slab was scheduled to be poured. Good management and good fortune is the account given by the contractor for why no impact was incurred.

Another reason for why the contractor did not feel the project has been affected is because some of the impacts, he felt, were part of the job. This type of scenario is exactly what lead Love (2002) to conclude and write that "*the danger of recurring documentation errors creep up and settle in an insidiously comfortable level which may be accepted as an industry norm*." Whilst Love (2002) addressed the issue of erroneous contract documentation, an analogy with secondary impacts can be drawn. If secondary impacts of V.Os are continuously disregarded it would cause contractors to accept them as the cost for doing business.

Example #2: Given by Senior QS

Examples of how the contractor copes with the secondary impacts are: in the case where additional work is ordered by client. Supervision is normally affected. Let's assume that the current supervisors (engineers) are already attending to as much activities as humanly possible. It is often uneconomical and not practical to bring an engineer to specially supervise the new work. The way the contractor would "cope" with this is by simply adding the additional work to any one of the engineers. Coping is not managing.

Another example given by the contractor where he just "coped" with the impacts of V.Os is: an extra part of the underground walls had to be gunited. This section of the works was done by a subcontractor. The instruction meant that the subcontractor would have to bring extra workers from somewhere else that would execute the additional work. This could have many consequences at stake as it was not part of the subcontractor's original plan but the contractor simply instructed the subcontractor do so which he did.

The contractor (QS) was asked how they dealt with the impacts V.Os have on the unchanged work such as the case where subcontracted work has to be executed at a later stage than what was planned. His reply was the subcontractor will be instructed to come when he is needed. If it is accepted that contractors in general find it difficult to justify secondary impacts, then the difficulty that arises between main contractors and clients is the same that arises between this contractor and his subcontractors. Only subcontractors are generally smaller in size than main contractors, and therefore unlike the main contractor may not have the resources to spend on proving to the main contractor what the expense and losses were due to the impacts the variation had on his work. This way of coping with the impacts of V.Os can be classified as not managing but rather shifting the impacts to the subcontractor.

4.3. Interview #2

Just like with the first interview, this interview was a general discussion of various issues concerning V.Os and its impacts. However, two particular issues namely the impact cost and loss of productivity (also referred to as inefficiency) enjoyed more attention than others. Therefore, the comments of the contractor concerning these two issues are discussed in the following paragraphs.

The interview was conducted on the 12 January 2012 with a Site Agent working for a construction company (Company B). The company is rated by the Construction Industry Development Board (CIDB) as a 9GB construction company. The interviewee has more than

5 years experience in construction. The interview took place at the site offices of a particular civil construction project where the Site Agent was working on as the site manager at the time.

The particular company was selected because of convenience of access. At the time the researcher was doing vacation work for the company and on the particular project. It was therefore ideal to interview the Site Manager of the project.

4.3.1 Discussions of Interview #2

The total cost of V.Os is its direct cost plus its impact cost. The direct cost is defined as the cost associated with implementing the V.O and the impact cost is defined as the cost associated with secondary impacts of V.Os. The perception of the indirect cost is if it is not included in the valuation of V.Os (in the case where secondary impacts were not mitigated) due to various reasons such as the difficulty of quantifying and proving it, it would eat into the profit of the contractor. The contractor was asked to comment on this.

According to this contractor, profit in construction projects is made from preliminaries and generals (P&G) and not on the money received for executing the work itself. He explains that the idea is to keep actual cost as close to the planned cost. If this can be achieved than there should not be a real impact on profit. In the case of a V.O the planned cost is substituted with a new value generated by the valuation of the V.O. He implied that if the new planned cost is being kept at, then no real losses should be made as the profit made from P&G remain unchanged.

Loss in productivity, also referred to as inefficiency, is an impact of V.Os commonly cited by researchers. As explained in more detail Chapter 3, the implementation of V.Os (together with management actions) causes delay and disruption which in turn lower the efficiency of labourers. This off course has an impact on project costs. Damages related to loss of productivity would be the increase in the contractor's performance cost. The contractor was asked to comment.

He explains that inefficiencies are part of construction projects. There are activities for which the contractor expects to be inefficient and for which he would not be fully compensated for. He explains that due to competition the rates submitted/amount paid by client for certain work is less than what it actually cost. This is of course due to the effect of competition. In such instances the P&G are to compensate for any losses.

It is understandable that due to the human effect, contractors cannot be efficient at all times at everything. Therefore, it is fair that provision is made to compensate for it. Contractors do not distinguish between the causes for the inefficiency experience on projects and do not keep record of it either. It just is not relevant to do so. Contractors also do not before hand put a value on the inefficiency they allowed for. For these reasons, even if the inefficiency experienced is due to V.Os it does not matter to this contractor as long as the P&G's compensate for it. Because no concrete value is placed on the inefficiency that may be allowed for no reference exist to which the inefficiency caused by factors other than contractors own mistakes for instance V.Os could be compared to.

4.4 Conclusion of Interviews

Contractors find the process of identifying, quantifying and proving the secondary impact of V.Os time consuming and that it requires too much effort. They will therefore rather accept it as part of construction projects than claim for it. They have learned to cope with the secondary impact of V.Os by accepting that damages and losses will be incurred for which they will not be compensated for and/or shifting the impact to subcontractors. Contractors will claim for damages and losses due to the secondary impact if the impact is significant and relatively easy to prove.

5. Pre-Investigation's Conclusion

From the analysis of the questionnaire and interviews it is evident these South African contractors rarely consider the secondary impact of V.Os on their projects. The main reason appears to be the difficulties involved in identifying, quantifying and proving it. Furthermore, it appears that in general these contractors have accepted the secondary impact as part of projects and rely on other measures to recover damages thereof.

APPENDIX E

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

CMP 2011

QUESTIONNAIRE ON THE TOPIC VARIATION ORDERS AND ITS SECONDARY IMPACT

QUESTIONNAIRE BRIEF

Change is a necessary fact of project life, as projects are about meeting contractual objectives and also achieving the outcome that end users require. Variations are known to have two types of impacts on project cost which is the direct impact and the secondary impact. The direct impact is the visible cost for implementing or accommodating the variation order (V.O). Secondary impact is the additional cost of performing the unchanged work due to lowered labour productivity, schedule disruption, out-of-sequence work, acceleration etc. It is the objective of this questionnaire to better understand how construction professionals in the South Africa understand, experience and quantify V.Os and its related impacts.

PERSONAL DETAILS

Initials and Surname:

Current Position:

Company Name:

Project Type (e.g. Buildings, Civils, Roads):

QUESTIONS for CONTRACTORS

1. Which types of V.Os are most prevalent and costly in your type of projects?

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2. In your experience, when do most V.Os generally occur?

- In terms of percent project complete (indicate with a circle)
  a) 0 – 25%
  b) 25 – 50%
  c) 50 – 75%
  d) 75 – 100%
- In terms of activities (Allocate: 1- the most, 2 - second most, 3 – the least)
  a) Before activity commenced ☐
  b) During activity execution ☐
  c) When activity is already finished ☐

3. What costs do you normally consider when pricing a V.O?

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4. What is your view regarding V.Os to the scope of the project in terms of profitability?

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5. Can you anticipate and quantify the consequent secondary impact of the requested V.O, to calculate what the total cost for the V.O would be?

a) Yes

b) No

5.1 If yes, please explain.

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5.2 If no, what are the challenges your organisation is faced with when having to quantify the secondary impact of V.Os?

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QUESTIONS for CLIENTS

6. What do you believe is required to explain to clients what the secondary impact of V.Os on the project is and will be?

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A sincere thank you for taking the time and effort to answer the questionnaire.