A System Dynamics Model of Construction Output in Kenya

A thesis submitted in fulfilment of the requirements for the award of Doctor of Philosophy of the Royal Melbourne Institute of Technology

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List of Abbreviations

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<th>Abbreviation</th>
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<tr>
<td>ACO</td>
<td>Average Contractor Output</td>
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<tr>
<td>ARIMA</td>
<td>Autoregressive Integrated Moving Average</td>
</tr>
<tr>
<td>CCR</td>
<td>Construction Completion Rate</td>
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<tr>
<td>CDO</td>
<td>Construction Demand Outside Kenya</td>
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<tr>
<td>CER</td>
<td>Contractor Entry Rate</td>
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<tr>
<td>CO</td>
<td>Construction Output</td>
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<tr>
<td>COU</td>
<td>Construction Output Unit</td>
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<tr>
<td>CRP</td>
<td>Contractor Redundancy Percentage</td>
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<td>CRR</td>
<td>Contractor Redundancy Rate</td>
</tr>
<tr>
<td>DCR</td>
<td>Design Completion Rate</td>
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<tr>
<td>DCS</td>
<td>Demand for Constructed Space</td>
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<tr>
<td>FACO</td>
<td>Fraction of Average Contractor Output</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GNP</td>
<td>Gross National Product</td>
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<tr>
<td>MI</td>
<td>Misery Index</td>
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<tr>
<td>MTCO</td>
<td>Multiplier for Time to Complete Outstanding Work</td>
</tr>
<tr>
<td>NACO</td>
<td>Normal Average Contractor Output</td>
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<tr>
<td>NTCO</td>
<td>Normal Time to Complete Outstanding Work</td>
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<tr>
<td>OCW</td>
<td>Outstanding Construction Work</td>
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<tr>
<td>OPA</td>
<td>Outstanding Planning Approvals</td>
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<td>PAR</td>
<td>Planning Approval Rate</td>
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<tr>
<td>PCT</td>
<td>Practical Completion Target (in Chapter V) or Planned Completion Target (in Chapter VI) **</td>
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<tr>
<td>RC</td>
<td>Required Contractors (in Chapter V) or Reserve Capacity (in Chapter VI) **</td>
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<tr>
<td>SCS</td>
<td>Stock of Constructed Space</td>
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<tr>
<td>SD</td>
<td>System Dynamics</td>
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<tr>
<td>TAC</td>
<td>Time to Attract Contractors</td>
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<tr>
<td>TARC</td>
<td>Time to Adjust Reserve Capacity</td>
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<tr>
<td>TCO</td>
<td>Total Construction Output (in Chapter IV, Section 4.3) or Time to Complete Outstanding Construction Work (in Chapter V) **</td>
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<tr>
<td>TD</td>
<td>Time for Design</td>
</tr>
<tr>
<td>TPA</td>
<td>Time for Planning Approval</td>
</tr>
<tr>
<td>UDCS</td>
<td>Unsatisfied Demand for Constructed Space</td>
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**Note: PCT, RC and TCO have each been used to represent two different variables. All the same, no confusion is bound to arise from this because use of each of these abbreviations is restricted to only the text in the specified Section. No abbreviations are used in the diagrams of the system dynamics models.
Declaration

I, Titus Kivaa Peer Mbiti, hereby certify that except where due acknowledgement has been made, this study work is mine alone. It has not been submitted previously, in whole or in part, to qualify for any other academic award.

The content of this thesis is the result of work which has been carried out since the official commencement date of my Doctor of Philosophy (property, construction & project management) programme. Any editorial work, paid or unpaid, carried out by a third party is acknowledged. Ethics procedures and guidelines have been followed.

Signed: 

Date: 20/11/2008
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Great is acknowledgement of my fellow research students at the RMIT University – Atif Ali, Ehsan Gheraie, Gabriel Nani, Pon Vajiranivesa and Supaporn Chalapati – people of various talents, with whom I spent long hours of intense work on theses, coupled with most interesting discussions of all kinds of subjects in the school of life.

Lastly, I sincerely thank every one else who may have played a role in any way, to facilitate the execution of this research study.
Dedication

To my wife, Jemmimah Kavata, and my children – Amos Mwoni, Jessica Mwongeli and Sophia Muthoni – who had to bear with many days of my absence while I executed this study, and consequently gave me extremely high motivation to apply myself wholeheartedly to the work;

To my mother, Grace Kamama, and my father, Peter Sele, from whom I inherited an unquenchable thirst for knowledge and understanding;

And to God Almighty be great glory for He supplied all the resources that I needed to accomplish this exceedingly difficult task.
Abstract

This study investigates fluctuations of construction output, and growth of the output in Kenya. Fluctuation and growth of construction activity are matters of concern in construction industries of many countries in the developing as well as in the developed world. The construction industry of Kenya is therefore an exemplifying case for this phenomenon.

Construction activity in Kenya fluctuates excessively and grows very slowly. This remains a big challenge to policy makers, developers, consultants and contractors in their decision-making processes. Construction output cycles of relatively large amplitudes are the norm rather than the exception in the construction industry. The main causes of construction cycles are considered by the majority of construction industry participants in Kenya to be factors outside the construction industry system. However, systems thinking is somewhat opposed to that view; it explains the main determinant of a system’s behaviour to be the system’s own feedback control structure. In this study, systems thinking was applied to investigate the problem of excessive fluctuations and stunted growth of construction output in Kenya. The study developed a system dynamics model to simulate the construction output problem behaviour.

The modeling process started by drawing the construction industry’s system boundary. This identified entities that fall within the system boundary and those that fall outside it, and described interactions amongst the entities. Entities approximated to fall within the construction industry’s system boundary are legislators, consultants and contractors, while entities approximated to fall outside the industry’s system boundary – in the industry’s environment – are developers, policy makers, the general public, politicians, other government ministries, the economy as a whole, other countries and Bretton Woods institutions.

The historical behaviour of the construction industry was described using construction output data of a 40-year period – from 1964 to 2003. Line graphs of the historical data exhibited profiles that helped to identify the system archetypes operating in the construction industry of Kenya. From the profiles, it was deduced that the problem of fluctuations and slow growth of construction output in Kenya is encapsulated in two system archetypes, namely: (i) balancing process with a delay, and (ii) limits to growth. The relationship between construction output and its determinant factors from the construction industry’s environment was investigated using time series regression, which involved autoregressive integrated moving average (ARIMA) regression and multiple regression modeling of the output. Construction output was modeled as a self projecting variable as well as a dependent variable explained by two explanatory variables, namely: Gross National Product (Kshs Millions) and misery index (i.e. unemployment rate + Inflation rate, %). It was observed that the multiple regression model was more accurate than the ARIMA regression model. The Mean Absolute Percentage Error of the multiple regression model was 13% while that of the ARIMA model was 40%.

On the basis of the historical data analysis and the system archetypes identified, a system dynamics (SD) model was developed to replicate the problem of fluctuations and slow growth in the construction output. The data used to develop the system dynamics model was annual construction output in Kenya from 1964 to 2003. The model was then used: (i) to appraise policy changes suggested by construction industry participants in Kenya, aimed to minimize fluctuations and slow growth in the construction output, and (ii) to project construction output in
Kenya from year 2004 to year 2050, to establish the expected future fluctuations and growth trends of the construction output.

It was observed that three fundamental changes are required in the system structure of the construction industry of Kenya, in order to minimize fluctuations and foster growth in construction output in the country, in the very long run. The changes are: (i) setting long-term targets of annual construction output in the industry as a whole; (ii) incorporating reserve capacity in the production process; and (iii) expanding the system structure to capture a larger construction market.

The study recommends (i) regulation of the response of the construction industry of Kenya, to changes in construction demand in the market, and (ii) expansion of the construction industry’s market into the African region, and beyond.
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Chapter I

THE PROBLEM AND ITS SETTING

1.1 Background of the Problem
This study investigates fluctuations of construction output, and growth of the output in Kenya. Fluctuation and growth of construction activity are matters of concern in construction industries of many countries in the developing as well as in the developed world. From Bon (1992), Hillebrandt (2000) and Raftery (1992), it can be deduced that cycles in construction activity are a common occurrence in the construction industry worldwide. The construction industry of Kenya is therefore an exemplifying case for the phenomenon. In this Section, the behaviour of construction activity is described for the construction industry worldwide and then for the construction industry of Kenya. It will be pointed out that little research has been done in this area.

1.1.1 Worldwide Construction Industry
The construction industry is the sector involved with erection, repair and demolition of buildings and civil engineering structures in an economy. However, an all-inclusive definition of the construction industry is rather difficult; various writers define the industry somewhat differently, (see for example, Bon 1992, Harvey 1996 & Lavender 1992). A definition typical of national income accounts in use in most advanced industrialized countries is as follows: the construction industry entails “the assembly of building materials and/or components on site; the materials and components are supplied by a variety of industries in the manufacturing sector; they are delivered to the site by the transportation and trade sectors; the assembly proceeds in accordance with plans, designs, and management procedures supplied mainly by the business services industry in the service sector; most of the funds required for construction are supplied by the financial services industry in the service sector; and a significant part of the output supplied by the construction sector is delivered to the real estate industry in the service sector” (Bon 1992: 120). This definition is comprehensive enough to allow an exhaustive study of the production process in a construction industry as a whole.

From the definition of construction activity above, the construction industry and the property industry are intertwined; the construction industry handles the constructed-facility production process while the property industry handles the constructed-facility output. Demand for constructed facilities is satisfied either through the purchase or lease of a building from the existing stock (i.e. the property market) or by buying a new or rehabilitated building from the construction industry (Akintoye and Skitmore 1991, Briscoe 1992, Hillebrandt 2000, Raftery 1992). The function of the construction industry is therefore to serve the portion of total demand for constructed space in the economy that cannot be served with the existing stock of constructed space. Consequently, discussing a construction industry problem is likely to touch on many issues that may strictly be considered to fall in the property industry.

The role of the construction industry in the socio-economic development of a country cannot be overemphasized. The industry provides constructed physical facilities which provide space where other activities may take place (Hillebrandt 2000, Raftery 1992). The monetary value of all the buildings and civil
engineering works produced by the industry in a given period of time - normally a year – is referred to as the gross output of the construction industry. In the world as a whole, this output is probably about 10% of the Gross National Product (GNP), on average (Hillebrandt 2000). Although the percentage contribution of construction output to GNP varies considerably amongst various economies and geographical locations, this overall average contribution is large enough to justify a rigorous investigation of the dynamics of workload in the global construction industry.

The trend of the relative volume of construction output (i.e. relative to the Gross Domestic Product [GDP]) in a country evolves as the country develops from being a less developed country (LDC), through being a newly industrialized country (NIC), and into being an advanced industrialized country (AIC). Bon (1992) explains that the relative volume of construction activity in a country exhibits a bell-shaped pattern, whose maximum point occurs at the middle of the NIC phase and minimum points occur at the early stages of the LDC phase and at the later stages of the AIC phase. This phenomenon is shown diagrammatically in Figure 1.1.

![Figure 1.1 Share of Construction in GNP versus GNP per Capita](Source: Bon 1992: 121)

A major factor explaining this phenomenon is “the declining share of physical assets in investment” that tends to occur as an economy advances (Bon 1992: 121). This change occurs in the very long term, and takes place in addition to the usual occurrences of Kuznets and Kondratiev cycles in the economy (described in, for example, Bon 1992 & Samuelson 1976), whose periods are estimated at 15 – 25 years and 45 – 60 years, respectively. In a developing country therefore, the trend that would indicate high and continual growth of construction activity would be the upward trend.

Construction activity in a country at any of the three development phases - LDC, NIC or AIC – may be characterized by excessive fluctuation in levels. A study by the World Bank (1984) showed that construction output “varied more than either manufacturing or GDP for the following countries: Brazil, Columbia, Ethiopia, Federal Republic of Germany, Ghana, Italy, Japan, Kenya, Liberia, Malaysia, Peru, Sri Lanka, Sweden, UK, USA and Zambia” (Raftery 1992: 64) – i.e. for six developed countries and for ten developing countries. Hillebrandt (2000), Ofori (1988) and Ofori, Hindle & Hugo (1996) are some of the writers in construction
economics who have looked at construction output fluctuations and observed how stability and growth of construction activity remain elusive goals in construction industry policy. To keep the construction industry on a continuous growth and development curve, fluctuations in activity should therefore be minimized, if not eliminated; the reasons for this are outlined later.

Excessive fluctuations in construction output, and by implication, demand have very adverse effects on the reputation of the industry as a whole, the business performance of construction firms and the employment of the industry’s production resources. Ofori, Hindle & Hugo (1996) point out that output fluctuations of a relatively large amplitude introduce production inefficiencies. Generally, development of an efficient construction industry is an objective of policy of every economy. For that reason, a more intensive inquiry into the phenomena of fluctuations in construction activities in any of the sixteen countries mentioned in the paragraph above is worthwhile. This study focuses on Kenya.

1.1.2 Construction Industry of Kenya

Kenya is a developing country in East Africa, with a population of about 37 Million people, a Gross Domestic Product (GDP - purchasing power parity) of US Dollar 40.77 Billion and a GDP growth rate of 5.5% (CIA 2007). Historically, Kenya’s economy was mainly agricultural – with agriculture contributing over 50% of the GDP and providing employment of over 80% of the working population (Mbaya 1984) - up to early this decade. Today, though agriculture employs 75% of the country’s labour force, its contribution to the GDP is 16.3%, and is lower than contributions of industry or services, which are 18.8% and 65%, respectively (CIA 2007). Infrastructural support for the country’s economy is provided by the construction industry by way of buildings (housing, office space, retail space, factories, etc) roads, railways, irrigation schemes, water supply schemes etc.

The construction industry of Kenya contributes about 40% of the Gross Fixed Capital Formation (GFCF) and about 4% of the Gross Domestic Product (GDP) in the country. It employs about 80,000 people. Table 1.1 gives a snapshot of the role the industry has been playing in the economy over the years. It shows the construction economy indicators over a five-year period - from 1997 to 2001. The industry’s percentage contribution to the GDP fell from 6.5% in the 1980s (Mitullah & Wachira 2003, Wells 1999) to 4% in the early 2000s. This indicates an overall reduction in construction activity in the country in the 1990s.

In the last two and a half decades, construction research in Kenya has focused mainly on the entities that constitute the construction industry – particularly the projects, the contractors and the labour force – deducing the performance of the industry as a whole from the observations made on its parts. Key areas of research study over this period have been procurement methods (examples: Kithinji 1988, Mbatha 1993 & Mbaya 1984), project performance - cost overruns, time overruns and labour output (examples: Gichuge 2000, Talukhaba 1998 & Wachira 1996) and construction business performance – indigenous contractors, marketing and labour practices (examples: Bakuli 1986, Gitagi 1992, Magare 1987, Mitullah & Wachira 2003).
Table 1.1 Construction Economy Indicators in Kenya; 1997 – 2001; at Constant (1982) Prices

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Contribution to GDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP at factor cost; Kshs million</td>
<td></td>
<td>100,472.80</td>
<td>102,252.70</td>
<td>103,701.50</td>
<td>103,455.80</td>
<td>104,697.10</td>
</tr>
<tr>
<td>GDP per Capita; Kshs</td>
<td></td>
<td>3,575.54</td>
<td>3,550.44</td>
<td>3,515.31</td>
<td>3,425.69</td>
<td>3,399.26</td>
</tr>
<tr>
<td>Construction GDP; Kshs million</td>
<td></td>
<td>4,093.00</td>
<td>4,126.70</td>
<td>4,150.70</td>
<td>4,120.50</td>
<td>4,121.80</td>
</tr>
<tr>
<td>Construction GDP ÷ Overall GDP; %</td>
<td></td>
<td>4.07</td>
<td>4.04</td>
<td>4.00</td>
<td>3.98</td>
<td>3.94</td>
</tr>
<tr>
<td>(b) Contribution to GFCF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GFCF; Kshs Million</td>
<td></td>
<td>19,048.04</td>
<td>19,021.58</td>
<td>18,141.08</td>
<td>17,713.24</td>
<td>18,046.43</td>
</tr>
<tr>
<td>Construction GFCF; Kshs Million</td>
<td></td>
<td>7,923.34</td>
<td>7,504.68</td>
<td>7,504.78</td>
<td>7,314.73</td>
<td>7,405.75</td>
</tr>
<tr>
<td>Construction GFCF ÷ Overall GFCF; %</td>
<td></td>
<td>41.60</td>
<td>39.45</td>
<td>41.37</td>
<td>41.3</td>
<td>41.04</td>
</tr>
<tr>
<td>(c) Employment Provision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment (Number of employees)</td>
<td></td>
<td>79,800</td>
<td>79,300</td>
<td>78,700</td>
<td>78,600</td>
<td>76,700</td>
</tr>
</tbody>
</table>

Source: Calculations based on data published in the Economic Survey 2002 (Republic of Kenya 2002);
Note: 1USD ≈ 65 Kshs (approx); 1AUD ≈ 56 Kshs (approx.) as at 13 June 2007

Construction research on the industry as a whole has been relatively sparse. Wells (1999) observed that little research attention had been focused on the construction industry as a whole. For the purpose of understanding the behaviour and evolution of construction activity in the country, study of the construction industry as a whole appears to be the most comprehensive research approach.

1.2 Problem Statement

The problem addressed in this research is that construction output in Kenya fluctuates excessively and grows very slowly. In Rafferty (1992: 64) Kenya was included in the list of the countries in which construction output “varied more than either manufacturing or GDP”. Additionally, anecdotal evidence (for example: Thuo, 2000 and Wachira, 1993), shows that construction activity cycles are the norm rather than the exception in the construction industry of Kenya. An indication of the rate of growth in construction output can be given by observing the recorded data on the GFCF contributed by construction activity. For example, in the period 1991 to 2001, the output oscillated around Kshs 7,000 Million per Year, as shown in Figure 1.2. The growth rate from 1997 to 2001 was practically zero.
1.2.1 Excessive Fluctuations

As stated in Section 1.1, excessive fluctuations in construction activity are detrimental to the construction industry as whole and to the entities – firms, projects and workers – in it. For example, Ofori, Hindle & Hugo (1996) observe that a drastic fall in construction activity causes loss of the expensively built-up production capacity of the construction industry, which takes quite some time to recover in the event of a rise in the activity. Additionally, instability of construction activity inhibits long-term growth and development of a construction industry’s production capacity because it causes considerable uncertainty in: (i) the business of construction – contracting and consultancy; (ii) investment in technical development and innovation of construction; and (iii) career structure in construction. For example, construction tender prices become unpredictable; they fall to uneconomical levels when there is a severe scarcity of work and rise to very high levels when there is heavy workload in the industry. Construction activity fluctuations therefore remain a significant challenge to policy makers, consultants and contractors in their decision-making processes.

The empirical relationships between construction activity and the main factors that influence it in Kenya have not yet been rigorously established. This uncertainty in the economic environment and the lack of capacity of the construction industry, were identified in the Agenda 21 for Sustainable Construction in Developing Countries as barriers to sustainable construction (CSIR 2002). In practice, the dynamics of construction activity are explained in qualitative terms, which give inadequate insight to the construction industry participants engaged in policy making, investment appraisal, cost planning and contracting. This practice leads to unrealistic development targets, cost estimates and viability appraisals, leading to construction business failures.
1.2.2 Stunted Growth

Stunted growth in construction output implies *slow growth in the active production capacity* of a construction industry. This problem appears to be intertwined with the problem of excessive fluctuations in construction activity, as indicated above; slow growth of output and excessive fluctuations seem to be cause and consequence of each other. It is therefore rather difficult to handle the problem of excessive fluctuations without touching the problem of slow growth.

A zero (or reducing) growth of construction output is unexpected of a construction industry in a developing country, of which Kenya is an example. According to Bon (1992), the output growth trend that is expected of the construction industry of a developing country is the upward trend. This is because the production capacity of the construction industry is expected to grow proportionate to the national demand for physical infrastructure, which generally increases as the developing country progresses. The national needs for constructed facilities that are documented in the nine *National Development Plans* of Kenya (Republic of Kenya, 1965 to 2002) and the *Kenya Industrial Transformation to the Year 2020* (Republic of Kenya 1996) indicate that the required volume of construction output has been increasing continually since independence in 1963. The fact that the actual construction output has been rather stunted in growth implies that either the construction industry failed to deliver or the investment goals set in the national development plans were never realized.

In national development planning, needs for constructed facilities - roads, airports, water supply, housing, industrial development, etc – are documented. For example, in: the ninth *National Development Plan* of Kenya (Republic of Kenya 2002), the *Economic Recovery Strategy for Wealth and Employment Creation in Kenya* (Republic of Kenya 2003) and the *Kenya Vision 2030* (Republic of Kenya 2007). These needs imply that the construction industry of Kenya is expected to deliver a lot of physical infrastructure to support the rest of the economy. However, it is not clear whether the production capacity of the industry is objectively considered in the plans. It is therefore likely that infrastructure and housing development targets in Kenya have hitherto been technically infeasible.

1.2.3 Systems Thinking Adopted

One approach to problems of excessive fluctuations and/or slow growth of an organization’s output, which is observed to have given remarkable results elsewhere, is systems thinking. Viewing an organization as a system assists in solving problems in the organization, from a broader perspective, and is a relatively more realistic approach to investigating present-day organizational problems because they are increasingly complex (Forrester 1969, Schoderbek, Schoderbek & Kefalas 1980, Senge 1990). For example, Ford (1996) explained how dynamic reasoning was applied in the policies of the US energy sector, from the 1880s to the 1990s, and pointed out how spectacular the outcomes were in the long-run. In this study, systems thinking was adopted.

A particularized approach to systems thinking, named system dynamics was adopted in this study. According to Schoderbek, Schoderbek & Kefalas (1980), this approach is most well suited to study of complex organizations such as corporations, markets, industries and economies. For that reason, system dynamics is the most suitable systems approach for investigating fluctuations and trends of activity in the construction industry of Kenya.
1.3 Aim and Objectives

The aim of this study is to develop a *system dynamics model of construction output in Kenya*, for the purpose of understanding influences of various policy interventions on the behaviour of the construction industry. The specific objectives of the study are to:

1. Define the construction industry system boundary;
2. Describe the historical behaviour of the construction industry system;
3. Develop time series models of construction output;
4. Build a system dynamics model of the construction output problem - of excessive fluctuations and slow growth – in the existing system structure of the construction industry;
5. Explore possible changes to the system structure of the construction industry, and to the system dynamics model, which could minimize fluctuations and foster growth in construction output.

The five objectives listed above are meant to address various aspects of the research question - what causes *excessive fluctuations* and *stunted growth* of construction output in Kenya? Observations made in respect of each of the objectives are then used as basis for recommendations on ways to minimize the fluctuations and foster continual growth of construction activity of the construction industry of Kenya.

The objectives are amplified as follows. Firstly, the construction industry is conceptualized as a complex socio-economic system. Definition of a system’s boundary helps to visualize the system variables and their interactions, as clearly as practicable. It is a prerequisite to every system dynamics modeling (Forrester 1969). For that reason, definition of the system boundary of the construction industry of Kenya is the first step of this study.

Secondly, the historical behaviour of the construction industry of Kenya is described using time-variance of construction output in the country, from 1964 to 2003. A system’s behaviour (reversible changes) or evolution (irreversible changes) are normally represented by the time-variance of the stocks and flows in the system (Coyle 1996, Schoderbek, Schoderbek & Kefalas 1980, Pidd 1988). This description is aided by graphical time series analysis which focuses on the trends and oscillations of the construction output line graph. The time-variance of the construction output is compared with time-variances of existing generic systems to identify the system archetypes to which the research problem belongs.

Thirdly, after the underlying system archetypes are identified, more rigorous time series analyses are then applied on the data to establish the influence of various explanatory variables on construction output. The output is modeled as a self-projecting variable using autoregressive integrated moving average (ARIMA) regression analysis, and also modeled as a dependent variable explained by various predictor variables, using time series multiple regression. This time series modelling of construction output (or demand) is the approach that has been used by most researchers to study the behaviour of construction activity in other countries. Examples of such studies are: Akintoye & Skitmore (1991 & 1994), Bee-Hua (1996), Flaherty & Lombardo (2000), Killingsworth (1990) and Malizia (1990), and are amplified in the review of literature, which is presented in Chapter II. In the
literature reviewed, no records of prior research work on time series regression of construction activity in Kenya was found. For that reason, ARIMA and multiple regression models of construction output in Kenya are developed in this study.

Fourthly, a system dynamics model of construction output in Kenya is developed by reviewing the construction process at industry level, describing the influences at work in the construction industry system and quantifying these influences, to replicate the problem behaviour of construction output fluctuations and slow growth.

Finally, possible changes in the system dynamics model developed are explored to establish whether a different set of parameters or a different structure of the construction industry system could have exhibited better behaviour of construction activity in Kenya, in the period 1964 to 2003. Additionally, simulations of the behaviour of the construction industry are run up to year 2050, to show how change in the system structure is likely to minimize fluctuations and foster growth in construction activity in Kenya.

1.4 Research Hypotheses
There are two hypotheses in this study, namely: an econometric hypothesis and a dynamic hypothesis. The hypotheses are conceptualized from the literature reviewed, and are tested separately, as explained later.

1.4.1 Econometric Hypothesis
Construction output is influenced by its own past levels and also by factors in the construction industry’s environment. Therefore the output can be modeled as a self projecting variable as well as a dependent variable explained by two explanatory variables, namely: Gross National Product (Kshs Millions) and misery index (i.e. unemployment rate + Inflation rate, %). The literature reviewed shows that there are many more variables that explain construction output in a country. However, these two variables are the only ones whose data are available in Kenya for the whole of the study period, 1964 to 2003.

1.4.2 Dynamic Hypothesis
Construction output in Kenya is influenced by the: (i) overall demand for constructed space in the economy, (ii) existing stock of constructed space in the real estate industry (iii) work in progress in the construction industry, and (iv) delays in the construction process. The work-in-progress refers to outstanding design, planning approval and construction work in the industry as a whole, while the delays refer to inevitable hold downs - such as design time, planning authority approval time and construction time – which hinder immediate production of constructed facilities. It is the dynamic interaction amongst these variables that generates fluctuations and trends in construction output.

Construction demand itself fluctuates and may ultimately make the output fluctuate as well. According to Briscoe (1992), changes in the national economy and the government's management of the economy, lead to construction demand fluctuations which in turn lead to construction output fluctuations. However, as Hillebradt (2000) and Kummerow (1999) point out, construction output is likely to fluctuate even with a constant (or constantly varying) demand. This implies that the fundamental causes of excessive fluctuations of construction
activity are not necessarily ‘out there’ – in the economy and the government expenditure – as it is commonly thought; they are mainly ‘in here’ – inside the construction industry itself.

A sustained decay in the growth rate of construction activity implies that there is a significant limiting factor to the growth. Consequently, the construction activity is likely to remain at this level in the long run. Since the average output of contractors (Output/Contractor/Year) in the industry is likely to keep growing, the number of contractors required to execute the workload in the industry at a given time is likely to keep declining. Only a fundamental change in the limiting factor – either the factor is eliminated or its effect minimized – can bring the activity back to a continuous growth curve, thereby ensuring that the construction industry’s idle capacity is kept to a minimum.

1.5 Justification and Significance

The results of this study are of practical use in the construction industry and to academics. The model developed provides a laboratory where various construction industry policy options can be experimented with to gain sufficient insight into the response of the construction industry, before the policies are actually applied to the industry. The findings of the study show that there is a lot that the construction industry itself can do to boost its efficiency, without necessarily requiring additional government expenditure on capital investment. This is useful to the policy-makers, consultants and contractors in the construction industry.

The findings of the study also provide a basis for educating construction industry participants in managing fluctuations in construction activity, in imaginative and collectively beneficial ways. Anecdotal evidence (for example, Wachira 1993) shows that most contractors use intuitive judgment and quick reaction to changing market conditions for business survival and success, which makes them vulnerable to occasional unanticipated demand shocks. When an unanticipated slump occurs, many workers are laid off, firm profits are significantly reduced and many firms are operated on the verge of bankruptcy, or closed down completely. A relatively more stable construction industry should therefore improve the contractors’ business performance and the industry workers’ employment.

The simulation model can be used to explore effects of government policies applied to the construction industry in pursuit of the Habitat Agenda for Sustainable Human Settlements (UN – HABITAT 2003), Agenda 21 for Sustainable Construction in Developing Countries (CIB & UNEP-IETC 2002) and the Kenya Vision 2030 (Republic of Kenya 2007). As Upton (2000) pointed out, there are major gaps in the knowledge and techniques in many sectors about how to manage and develop in a sustainable way. The proposals of Agenda 21 for Sustainable Construction in Developing Countries (CIB & UNEP-IETC 2002) indicate that the construction industry in developing countries is one of the wanting sectors. The Agenda underlines the need to radically improve the capacity of government at all levels to play an active role in sustainable construction (CSIR 2002). This study to some extent redresses these gaps by providing a facility for systems learning of construction activity.
Researchers can adopt the methodology used in this study to investigate the behaviour of other systems. As stated before, the problem of fluctuations in construction output are found in many countries. In this study, the construction industry of Kenya is only an exemplifying case selected for practical reasons, as explained later. According to Senge (1990) and Schoderbek, Schoderbek & Kefalas (1980), one system structure can define the dynamic behaviour of many apparently different complex systems. Therefore the modeling process used in this study and the systems dynamics model developed in it are likely to be applicable to study of construction activity in other countries.

1.6 Scope of the Study

Although excessive fluctuations in construction activity are found in many countries, the scope of this study is limited to the construction industry of Kenya. The country was selected for the study mainly on the basis of practical considerations; it was the country where the researcher had had the longest industry experience which was certain to facilitate conceptualization of the systemic influences at work in the industry. This notwithstanding, the review of literature related to fluctuations in construction activity covers the construction industry worldwide. It is mainly in the research methods, data analysis and conclusions that the study focuses on Kenya.

The study mainly focuses on the supply-side of the construction industry. It concentrates on the production process of constructed facilities at the industry level, scrutinizing the dynamic complexity of production activities occurring between the time demand for constructed facilities is identified in the economy and the time the facilities are delivered to the economy. Although factors that stimulate demand for constructed facilities in the economy are also described, they are conceptualized as mainly falling outside the construction industry’s system boundary. The demand is therefore an exogenous variable to the industry, although it is an indispensable input to the industry’s production process.

In the study, the main model is developed using the system dynamics approach to systems thinking. However, before the system dynamics model is developed, conventional time series analysis (line graphs, ARIMA regression and multiple regression) of construction output is done in a bid to give a comprehensive description of the historical behaviour of the construction industry of Kenya. The system dynamics approach was chosen for modeling the construction output because a construction industry is a complex system. According to Kummerow (1999) and Ogunlana, Lim & Saeed (1998), system dynamics modeling is the method of choice where a system: (i) comprises multiple interdependent components, multiple feedback processes and non-linear relationships; (ii) is highly dynamic; and (iii) involves both ‘hard’ and ‘soft’ data. A construction industry has those system characteristics. A system dynamics model of construction activity in Kenya should therefore give significant insight into the behaviour of the construction industry, just as it has given in studies of similar social-economic systems (for example in: Bajracharya, Ogunlana & Bach 2000, Ford 1996, Forrester 1969 and Kummerow 1999).

The system dynamics model developed in the study is particularly for the total (i.e. building plus civil engineering) construction output. This is because the construction process of the industry as a whole is basically the same as the construction process of either of the two sectors - building construction sector or civil engineering.
engineering construction sector. Consequently, the feedback control structures of the sectors are the same, and resemble that of the industry as a whole. This suggests that the system dynamics model developed to learn the behaviour of the whole industry may also be used to learn the behaviour of the two major sectors. However, since variable values of the whole industry are different from those of the sectors, it is the variable values that would need to be changed, where the industry model is to be used to learn sectoral behaviour. For example, while Time to Complete Outstanding workload is about 3 years (on average) for the industry model, the Time to Complete Outstanding workload would be about 1 ¼ years (on average) for the building sector model, and 5 ¼ for the civil engineering model, as described in Section 5.4.3.

The period covered in the study is 40 years – 1964 to 2003. This is the period for which the relevant historical data are available. Using the system dynamics model developed in the study, simulations of the construction industry activity levels and rates are run up to year 2050, to show the expected outcomes of various policy measures on the construction industry of Kenya.

1.7 Limitations and Assumptions

The following are the limitations in this study:

1. The available data on construction output are for a rather short time series – spanning only 29 years, from 1975 to 2003. Consequently, construction output is proxied by the Gross Fixed Capital Formation (GFCF) contributed by the construction industry, whose available data are a longer time series – spanning 40 years, from 1964 to 2003. As explained in the Sources & Methods used for the National Accounts of Kenya (Republic of Kenya 1977), the GFCF contributed by the construction industry is approximately equal to construction output. This is amplified in Section 3.5.1. Therefore, construction GFCF is a realistic surrogate for construction output.

2. The available construction output data (i.e. construction GFCF) does not accurately include private sector building output. Almost all informal private building output is particularly excluded from the data (Wells, 2001). In this study, adjustment of the recorded construction output data to provide for the informal sector building output has been done using a multiplier derived from cement consumption in Kenya, as explained in Section 3.5.1 and Appendix E. The multiplier is a quotient of the index of cement consumption in Kenya and the index of private building activity in the country, and is based on the observation that more cement is used in building construction than it is used in civil engineering construction. Wells (2001; 268 & 273) points out that the “Economic Survey [of Kenya, 1996; p. 164] attributes the upturn in cement consumption in 1995 partly to the increase in private building construction activity ……. Cement is not used to any great extent in road construction” in Kenya. All the same, civil engineering construction in Kenya actually does consume a significant amount of cement. Consequently, the adjustment for informal sector construction output has some error. However, this error does not enter the regression or the system dynamics models because informal and non-monetary construction outputs are not included in the modeling processes. The informal sector adjustment only helps to give a relatively more comprehensive preliminary description of the construction industry as a whole. In absence of better alternatives, this adjustment method suffices because it produces a profile of private construction output, which represents the conditions generally felt in
the construction industry of Kenya from around 1980 (see for example: Mitullah & Wachira 2003 and Wells 2001).

3. The accessible data on numbers of contractors over the study period are very limited. From the documentary data (Appendix C References 1.5, 1.13 and 1.23) figures for the total numbers of contractors involved in formal construction activity in Kenya are inferred for the years 1981, 1988 and 2003 as being approximately 5000, 3000 and 1500, respectively. From these three points, the expected numbers of busy contractors for all the other years are estimated using curve interpolation and linear extrapolation of the average contractor output (Output/Contractor/Year), as described in Sections 3.5.2 & 4.3.5. These estimates are for contractors who could be considered as being fully engaged in the formal construction industry every year, at a given level of the average contractor output. It is from these estimates that the percentage of contractors getting redundant in the industry every year, due to shortage of work in the formal sector, is also estimated. The contractor estimates are therefore not for the contractors who existed in the industry. Additionally, contractors in informal sector activity are particularly excluded from these estimates because the feedback control structure of the informal sector activity is significantly different from that of the formal sector. Additionally, despite the vibrancy of the informal sector in the 1990s, key participants in the construction industry of Kenya generally felt that activity was quite low in the industry as a whole during that period (see Appendix C References 4.34).

None of the above-explained limitations renders the observations made in this study incomprehensive or invalid. Particularly, informal and non-monetary construction activities were actually not overlooked in the modelling; they were left out of the SD model developed, because their implementation process is quite different from that of the formal construction, as explained in Section 4.3.1. Their inclusion would therefore have required developing two different SD models, and combining them. That would have made the scope of this study unnecessarily larger. Since formal construction activity constitutes about 75% (on average) of all construction activity in Kenya, choice was made to focus on this larger portion of the construction industry, in this study. Later, the behaviour of the sub-sectors may be investigated. For that reason, development of SD models for the sub-sectors, including the informal one, is given as an area for further study.

After all, inclusion of the informal and non-monetary activity in the system dynamics model is unlikely to improve the behaviour of the construction industry. As explained in Section 4.3.1, the overall total construction output fluctuates excessively and grows slowly albeit slightly faster than the total monetary construction output. Omission of the informal and non-monetary activity from the SD model makes the projected output values smaller, but it does not significantly change the profile – frequency & amplitudes - of the construction output projected. For that reason, omission of the informal and non-monetary activity from the SD model developed in this study should not render the projected behaviour of construction activity in Kenya up to year 2050 unrealistic.

The following assumptions are made in the study: -
1. The number of contractors fully engaged in a construction industry depends on the construction demand in the industry. In the study, a contractor is defined as a recognized firm that has the requisite capacity to produce the construction orders placed on it. This definition is likely to exclude contracting businesses that may exist in theory – in people’s minds or briefcases – only to surface when there is a job. Additionally, that definition implies that high construction demand in a country is unlikely to exist side by side with idle contracting capacity, unless the idle ‘contractors’, for some reason, do not qualify to be contractors.

2. Most of the contractors engaged in formal construction work, even in the private sector, are generally registered with the Ministry of Roads & Public Works. Going by the percentage contribution to construction output, the government has remained the major client in the construction industry of Kenya since independence, even after allowing for the informal sector activity, as shown in Appendix G. The percentage contribution of the public sector output has never been significantly lower that 50% since 1963, only that public sector contribution in the building output reduced continually from about 30% in 1980 to only about 10% in 2003. Although the Ministry of Roads and Public Works records are only used as a rough guide to estimating the contractor numbers (as shown in Sections 3.5.2 & 4.3.5), a slight error may arise from the fact that there is a number, albeit small, of contractors that may not be found in the Ministry of Roads and Public Works records.

3. In estimating the average contractor output (Output/Contractor/Year), it is presumed that the output grew as a smooth curve from 1964 to 2003. This is because curve extrapolation links up the known data points of the average contractor output more accurately than linear extrapolation. The smooth curve assumption is not a potential source of error in this study. The difference that a linear pattern assumption would make is to give a different profile of the estimated number of contractors. The growth pattern assumed does not influence the annual construction output which is the actual field data. Also, the pattern does not influence the Demand for Constructed Space (DCS) whose estimation is based on the field data on construction output, as explained in Section 5.4.

4. The Stock of Constructed Space (SCS) in Kenya at the end of 1963 (start of 1964) is estimated at a quarter of all the construction output from 1963 to 2003. The monetary value of the quarter is about Kshs 60,000 Million (at Constant 1982 Prices). An exact initial value for this variable is quite difficult to assign since data on the existing stock of real estate developments in Kenya as at 1963 was not obtainable in this study. This SCS figure is therefore ‘arbitrarily’ selected. However, since SCS is a level variable in the system dynamics model developed, any initialization figure can work because the figure does not influence the profile of the SCS time series; it only defines the starting point of the time series. Additionally, the initial SCS figure is included in the estimates for construction demand in the economy. Therefore, the initial value of SCS does not adversely affect the profile of the simulated construction output time series, because the source of dynamic behaviour in the model is the difference between DCS and SCS. This point is amplified in Section 5.3.
In conclusion, the assumptions explained above do not influence the structure of the systems dynamics model developed in this study. They influence only parameter values in the model. The structure of the model is based on a systems conceptualization of the construction process observed at industry level, in Kenya. It is not based on the assumptions explained above.

1.8 Definition of Terms
The following are the definitions of the basic technical terms used in this study:

1.8.1 Construction demand
Construction demand is the value of contracts for new construction work awarded to main contractors, including speculative work undertaken on the initiative of firms where no contracts are awarded (Akintoye & Sommerville 1995). Construction demand normally leads to construction output spread over a period of time.

1.8.2 Construction output
Construction output is the amount payable to contractors for work done in the relevant period (Akintoye & Sommerville 1995). It is an indicator of workload or activity in the construction industry. Annual construction output is the rate at which the stock of constructed space is increased every year. If there were no productive resources lying idle in the construction industry, this output would represent the level of the production capacity of the industry.

1.8.3 System
A system is simply “a collection of parts organized for a purpose” (Coyle 1996: 5). A complex system is a system which has many parts and many interactions amongst the parts. Examples of complex socio-economic systems are: projects, firms, markets, industries and economies.

1.8.4 System’s boundary
A system’s boundary is the line demarcating the system from its environment. The boundary’s actual position is more or less arbitrarily determined by the observer of the system’s structure (Schoderbek, Schoderbek & Kefalas 1980). The boundary position is therefore greatly determined by the purpose of the systems study.

1.8.5 System Dynamics
System dynamics is the science of feedback behaviour in complex social systems (Schoderbek, Schoderbek & Kefalas 1980). It is “application of the attitude of mind of a control engineer, to the improvement of dynamic behaviour” in systems (Coyle 1996: 5).
1.9 Outline of the Study Report

The study report is organized in five chapters. Chapter I discusses construction activity fluctuations in the global construction industry, and describes the problem of excessive fluctuations and slow growth of construction output in Kenya. The need to establish a method for understanding the dynamics of construction activity in the country is discussed, and the objectives and research hypotheses stated.

Chapter II discusses construction activity and its global determinants and determinants in Kenya particularly. It describes the prediction methods used for predicting construction activity, gives a systems view of fluctuations in output and briefly describes the systems dynamics method. Research work previously done in the modeling of construction activity – using time series analysis and using system dynamics simulation – is discussed and finally the literature gap highlighted.

Chapter III discusses the methodology used in conducting the study. The research design, study period, data collection procedures, variables in the study and data analysis procedures are discussed.

Chapters IV, V and VI present analysis of the data and the results observed. Chapter IV gives a working definition of the system boundary of the construction industry of Kenya and describes the system behaviour of the industry, identifying the system archetypes operating in the construction industry and developing time series regression models of the construction output. In Chapter V the construction process is reviewed, the system dynamics model variables defined, and the model built up and tested. This model represents the feedback control structure existing in the construction industry of Kenya today.

Chapter VI presents an exploration of possible parameter and structural changes in the system dynamics model developed in Chapter V (i.e. the existing feedback control structure), in a bid to establish a more efficient feedback control structure. Structural changes necessary to produce an improved system structure of the construction industry are described, and policy changes suggested by construction industry participants in Kenya appraised. The improved structure model and the existing structure model are then used separately, to project the behaviour of construction activity in Kenya up to year 2050, showing the behaviour scenarios expected in the construction industry of Kenya in the next 42 years, if either of models is chosen for regulation of the industry.

Chapter VII covers conclusions and implications of the study findings, and gives areas for further research. The report also has twelve appendices, which supplement the text.

1.10 Conclusion

In this Chapter, the foundations for the research were laid. The research problem was introduced and the study objectives and hypotheses stated. Then, the study was justified, scope explained, limitations and assumptions given, and the study report outlined. On these foundations, the report can proceed with a detailed description of the study.
Chapter II

LITERATURE REVIEW

2.1 Introduction
Chapter I discussed the problem of excessive fluctuations and slow growth of construction output in Kenya and set the research path followed in investigating the problem. This chapter presents the related literature reviewed and uncovers the knowledge gap in the literature. The chapter is organized around five major topics, namely: construction output in Kenya, determinants of construction demand, methods of predicting construction demand, systems views on fluctuations and growth of output, and application of system dynamics to construction industry problems. Eventually, it will be shown that no records of prior research work on time series modeling or system dynamics modeling of construction activity in Kenya were found in the literature reviewed.

2.2 The Construction Industry of Kenya

Kenya is a developing country in East Africa, bordering the Indian Ocean, between Somalia and Tanzania. The country has a population of about 37 Million people and occupies an area of 582,650 square kilometres (CIA 2007). It obtained independence from the UK in 1963, after about 70 years of British colonial rule (Ochieng’ & Maxon 1992). Kenya has a GDP (purchasing power parity), of US Dollar 40.77 Billion, a GDP growth rate of 5.5% and a GDP per capita (purchasing power parity) of US Dollar 1200 [2006 estimates] (CIA 2007).

As stated previously, Kenya’s economy was mainly agricultural – with agriculture contributing over 50% of the GDP and providing employment of over 80% of the working population (Mbaya 1984) - up to early this decade. Today, though agriculture employs 75% of the country’s labour force, its contribution to the GDP is 16.3%, and is lower than contributions of industry or services, which are 18.8% and 65%, respectively.

The construction industry of Kenya provides the physical infrastructure necessary for the country’s economy, in way of buildings and civil engineering structures of various standards, as recorded in the World Fact Book (CIA 2007) - it consists of 225 airports, 15 of which have paved runways. Its railways and roadways are 2,778 kilometres and 177,765 kilometres respectively, but with only 8,933 kilometres of the roads being paved.

The technology of building in Kenya is mainly reinforced concrete in urban areas, and mainly timber-and-earth in rural areas. For the country as a whole, building technology is currently a mixture of indigenous and non-indigenous technologies. The indigenous technologies are those that were used in various communities of Kenya before the introduction of foreign building technologies by European settlers, in the 19th and early 20th centuries. Grass thatch, un-treated timber posts and mud are some of the indigenous construction materials, while cement, steel, dressed stone, treated timber, glass, metal sheets, plastics, paints and iron mongery are some of the non-indigenous building materials. Floor areas and heights of buildings are quite diverse, with more high-rise buildings in the urban areas than in the rural areas. As Knight Frank (1998) points out “high rise development in the 10 – 30 floor range has a 30 year history” in the city of Nairobi, Kenya.
Construction output in Kenya today is about Kshs 123,148 Million (US Dollar 1895 Million; official exchange rate) (Republic of Kenya 2005). As stated before, research on the construction industry of Kenya as a whole has been less than research on the industry’s sub-entities – such as the projects, the contractors and the labour force. Consequently, in refereed fora, literature on construction activity in Kenya is rather limited. All the same, much may be gleaned from anecdotal evidence – such as the local technical magazines and daily newspapers. That anecdotal evidence is included in the documentary data in Appendix C, and is addressed in the analysis of data.

2.3 Fluctuations in Construction Output

Construction output fluctuations, which in their more extreme form are called construction cycles (Hillebrandt 2000), appear to have been accepted by the majority of writers as a stubborn but inevitable phenomenon. They result from fluctuations in construction demand. Although a change in construction demand does not cause an immediate change in construction output, construction industry players generally view fluctuations in construction demand and fluctuations in construction output as one and the same thing. Hillebrandt (2000: 27) points out that “there seems no prospect of eliminating the fluctuations in construction output ….. the industry would do well to assume that it has to exist with fluctuations in demand.” Desperation is implied in this statement, and it underscores the need for a continual and closer scrutiny of construction output fluctuations wherever they occur.

Business cycles in the economy cause cycles in construction demand, which in turn lead to cycles in construction output. Briscoe (1991), Hillerbradt (1985) and Raftery (1992) explain construction output cycles as the construction industry’s response to business cycles in the national economy. Construction cycles are Kuznets cycles, whose period averages 15 – 25 years; this period is about twice as long as the period of major business cycles in the economy, whose period averages 8 – 10 years (Samuelson 1976). Investigating the process by which business activity in the economy translates into construction demand is therefore likely to reveal leverage points for managing the demand, and by implication, the output cycles.

Excessive fluctuations in construction activity bring about uncertainty in construction business and consequently harm the construction industry. For example, Ofori, Hindle & Hugo (1996; 217) observed that cyclical fluctuations in construction activity made the construction industry of South Africa lose “a large number of experienced, highly skilled professional and technical personnel who are unlikely to return to construction.” Due to fluctuations, construction firms have to adjust workforce levels in line with the available work at various points in the workload cycle. When the construction workload begins to increase, firms gradually take on more manpower. But when workload declines these workers are laid off. Therefore, the need for stability in construction activity can not be over-emphasized.

Recommendations for reducing cyclical fluctuations in construction activity are frequently directed to governments urging them to increase public investment, in order to ensure continual construction demand. However, this approach has not delivered best long-term results even where it has been pursued diligently. Ofori (1988) described how government intervention and investment in the construction industry of Singapore performed from 1960 to 1986, showing that demand management is not a panacea to fluctuations. He pointed
out that poor timing of government interventions and the likelihood of oversupply of constructed space in the long-run are two major challenges that demand management normally encounters. Solutions to construction activity cycles are therefore not necessarily ‘out there’ in the economy or the government; they might lie within the construction industry itself.

Unanticipated falls in demand for products or services of an organization can be avoided by expanding the market of the organization. For example, this policy strategy was suggested in Ofori’s (1984) study of construction industries of Ghana and Tanzania, and can be paraphrased as follows:-

(1) Co-operation of the participants in the construction industry, towards safeguarding their collective future;
(2) Development of a mechanism for ensuring that changes in construction activity are orderly and painless, matching the rate at which new projects are started with the availability of inputs and advising employers accordingly;
(3) Arrangement of manpower exchange programmes between industries of different countries, involving the development of links amongst the relevant institutions; and
(4) Encouragement - by governments or by professional/business associations - of construction firms with export capability to compete for international projects in the neighbouring countries.

However, there is no evidence - from the literature reviewed in this study - as to whether these ideas were ever tried in Ghana or Tanzania to which they were directed.

In Kenya, changes in economic conditions and government expenditure are generally considered to be the main cause of construction demand cycles. As described in Section 1.1 of Chapter I, the proportion of construction output to GDP in Kenya declined from about 6.5% in the 1980s to 4% in 2001. This fall is generally attributed to decline in public sector investment in construction and to harsh economic conditions prevailing in the country during in the 1980s and 90s. For example, Mitullah & Wachira (2003) and Wells (2001) point out that under Structural Adjustment Programmes which began in the late 1980s, Kenya government expenditure was heavily curtailed as part of the austerity measures required by donors, investment in buildings particularly reduced, and as a result the public sector client in the construction industry was significantly reduced. As explained previously, similar views are held in many other countries, as observed by Briscoe (1991), Hillerbradt (2000) and Raftery (1992). This theory of demand cycles explains why models for predicting construction demand or construction output are mainly based on economic factors, as described in Section 2.4.

In understanding variations in construction activity, two major challenges are encountered, namely: the multiplicity of socio-economic factors that may influence construction demand, and the complexity of the construction industry itself. The following two Sub-sections briefly describe the determinants of construction demand and the detail complexity of the construction industry.
2.3.1 *Determinants of Construction Demand*

From construction economics theory (Briscoe 1991, Hillerbradt 2000 and Raftery 1992), twenty specific factors likely to influence construction demand in any economy can be gleaned. In alphabetical order, the factors are as follows:

1. Availability of credit
2. Condition of the existing stock of built facilities
3. Economic conditions – economic growth & development
4. Exchange rates
5. Government action – policy & expenditure
6. Household disposable income
7. Household formation rate
8. Interest rates
9. Inflation
10. Money supply
11. Peoples tastes & preferences for housing, entertainment etc
12. Planning regulations
13. Political climate – conflict, governance, security etc
14. Population (size, structure and geographical distribution)
15. Prices – tender prices, property prices & import prices
16. Output
17. Taxation
18. Technology
19. Unemployment
20. Weather conditions.

These factors are highly interrelated and the significance of each one of them varies from one construction sector to another. For example, political priorities and government expenditure are likely to be more significant in social-type construction than in commercial or industrial construction, while economic growth and price level are likely to be more significant in industrial and private residential construction (Akintoye & Skitmore 1991, Hillerbradt 2000).

Although the construction economic theory is mainly developed in the UK, research observations made in other countries indicate that the 20 factors listed above adequately represent the generic determinants of construction demand and, by implication, construction output worldwide. Examples of the observations made outside the UK are: Killingsworth (1990), Malizia (1991) and Samuelson (1976) for the US; Bee-Hua (1996) for Singapore; Cole (1998), Flaherty & Lombardo (2000) for Australia; Ofori *et al* (1996) for South Africa; Murigu (2005) for Kenya; and Fox *et al* (1999) for other countries. These scholars, however, point out that the nature of influence of a factor to construction demand may vary significantly from one country to another. All the same, there seems to be consensus amongst all the writers in this field that government action and interest rates are very significant in most of the developed and developing countries.
A country’s economy and its construction investment are interdependent; their causal relationship is bi-directional. Construction investment may be growth-dependent or growth-initiating. Where the construction investment is growth dependent, GDP may be considered the independent variable but where the investment is growth initiating, GDP is the dependent variable. Figure 2.1 illustrates the logic of these relationships, as implied in Briscoe (1991) and Hillerbradt (2000). It suggests that both relationships may exist simultaneously in the same economy.

The fact that determinants of construction demand are generally leading indicators makes them usable in a demand forecasting model, since their levels can be observed way before the demand itself. As Killingsworth (1990) observes, there is normally a time lag between the identification of the need for a built facility and the use of the facility, due to the time required for design, bidding and construction. While this attribute of the determinants is an advantage for the forecasting model, it is a limitation to its accuracy; the model may not sufficiently take account of long-term implications of lags in construction supply.

![Figure 2.1 Causal relationships between construction investment and economy](image)


In Kenya, there are about ten major determinants of construction demand in the economy. These determinants can be inferred from Murigu’s (2005) study of the variables considered in the decision to invest in commercial real estate in the country. Normally, a decision to invest translates into demand for construction services after the developer has committed himself to invest and has initiated the project design and implementation. Murigu (2005) conceptualized the issues considered in the investment decision in terms of 30 factors and rated the...
importance of each one of them on a 5-point horizontal numeric scale, as shown on Table 2.1. The table shows that all the factors (except ‘other factors’) were observed to be important in the decision to invest because their mean ratings of importance are greater than 2.00, which is statistically greater than the lower extreme (0 & 1.00) of the horizontal numeric scale. The lower extreme indicates “not important at all.”

The 30 factors on Table 2.1 seem to have been obtained by splitting the generic factors listed in paragraph 1 of this Sub-section, into details that would be considered in a feasibility appraisal at the micro-economic level of an individual project. Grouping all the mainly micro-economic factors together as project specific factors gives a total of 11 factors that may be considered determinants of construction demand at the sectoral and national levels in Kenya. The 11 factors are shown on Table 2.2 in a descending order of their mean ratings of importance.

Table 2.1 Determinants of the Decision to Invest in Commercial Building in Kenya (Project Level)

<table>
<thead>
<tr>
<th>Factor considered</th>
<th>Mean ranking of importance (on a 5-point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Expected income</td>
<td>4.3067</td>
</tr>
<tr>
<td>2. Expected rate of return</td>
<td>3.5467</td>
</tr>
<tr>
<td>3. Scope of building</td>
<td>3.5000</td>
</tr>
<tr>
<td>4. Payback period</td>
<td>3.3800</td>
</tr>
<tr>
<td>5. Demand for commercial space</td>
<td>3.3733</td>
</tr>
<tr>
<td>6. Size of land</td>
<td>3.3667</td>
</tr>
<tr>
<td>7. Cost of land</td>
<td>3.2867</td>
</tr>
<tr>
<td>8. Cost of construction</td>
<td>3.1867</td>
</tr>
<tr>
<td>10. Cost of finance</td>
<td>3.1600</td>
</tr>
<tr>
<td>11. Social/psychological satisfaction expected from the investment</td>
<td>3.1400</td>
</tr>
<tr>
<td>12. Services and infrastructure</td>
<td>3.0933</td>
</tr>
<tr>
<td>13. Supply of commercial space</td>
<td>3.0667</td>
</tr>
<tr>
<td>14. Location of site</td>
<td>3.0200</td>
</tr>
<tr>
<td>15. Security &amp; regularity of income</td>
<td>2.9400</td>
</tr>
<tr>
<td>16. Distance from the city centre</td>
<td>2.8133</td>
</tr>
<tr>
<td>17. Level of security</td>
<td>2.7200</td>
</tr>
<tr>
<td>18. Marketability &amp; liquidity of capital</td>
<td>2.6267</td>
</tr>
<tr>
<td>19. Rate of inflation</td>
<td>2.6200</td>
</tr>
<tr>
<td>20. Rate of the National Economic Growth</td>
<td>2.5867</td>
</tr>
<tr>
<td>21. Nature of property ownership</td>
<td>2.4933</td>
</tr>
<tr>
<td>22. Investor's willingness to bear risks</td>
<td>2.4800</td>
</tr>
<tr>
<td>23. Level of taxation in the property market</td>
<td>2.3800</td>
</tr>
<tr>
<td>24. Likelihood of the investment enhancing the investor's image in the community</td>
<td>2.3600</td>
</tr>
<tr>
<td>25. Quality of the physical environment</td>
<td>2.2867</td>
</tr>
<tr>
<td>26. Cost of managing the property</td>
<td>2.1867</td>
</tr>
<tr>
<td>27. Political climate</td>
<td>2.1600</td>
</tr>
<tr>
<td>28. Government controls</td>
<td>2.1133</td>
</tr>
<tr>
<td>29. Independence (freedom from worry, harassment etc) expected from the project</td>
<td>2.1067</td>
</tr>
<tr>
<td>30. Other factors</td>
<td>1.0667</td>
</tr>
</tbody>
</table>

Source: Murigu (2005: 213)
Table 2.2 Determinants of Investment in Commercial Building in Kenya (Country Level)

<table>
<thead>
<tr>
<th>Factor considered</th>
<th>Mean ranking of importance (on a 5-point scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Demand for commercial space</td>
<td>3.3733</td>
</tr>
<tr>
<td>2. Prices – cost of land &amp; cost of construction</td>
<td>3.2367</td>
</tr>
<tr>
<td>3. Cost of finance</td>
<td>3.1600</td>
</tr>
<tr>
<td>4. Supply of commercial space</td>
<td>3.0667</td>
</tr>
<tr>
<td>5. Project specific (micro-economic) factors</td>
<td>2.8226</td>
</tr>
<tr>
<td>6. Level of security</td>
<td>2.7200</td>
</tr>
<tr>
<td>7. Rate of inflation</td>
<td>2.6200</td>
</tr>
<tr>
<td>8. Government action (controls &amp; expenditure)</td>
<td>2.6033</td>
</tr>
<tr>
<td>9. Rate of the National Economic Growth</td>
<td>2.5867</td>
</tr>
<tr>
<td>10. Level of taxation in the property market</td>
<td>2.3800</td>
</tr>
<tr>
<td>11. Political climate</td>
<td>2.1600</td>
</tr>
</tbody>
</table>

Source: Derived from interpretation of Murigu (2005; 213)

On Table 2.2, cost of land and cost of construction are grouped together as prices, while government controls and services & infrastructure (past government expenditure) are grouped together as government action. The project specific (micro-economic factors) group carries the rest of the 18 factors as shown on Table 2.1. The ranking of the group is the average of the rankings of the 18 factors in it. No factor observed in Murigu’s (2005) study may be considered alien to the list of generic factors shown in paragraph 1 of this Sub-section.

2.3.2 Complexity of the Construction Industry

The construction industry is a complex socio-economic organization; it has a great diversity of role players, processes and outputs. Mbaya (1984) gives an integrated view of the construction industry of Kenya, which is presented in Figure 2.2.

“The construction industry in Kenya like in many other countries is one of the most complex sectors.... [It] may be assumed to consist of sub sectors, each sub-sector consisting of numerous projects, and each project involving different stages of activities from project conception to completion. The basic process – conception to completion – is regarded as the INPUT-OUTPUT. The input resources of material, labour, plant, finance, information and institutional resources result in outputs of various built products. This process takes place within the extended production system represented by total construction process in the entire national economy” Mbaya, J. S. (1984: 41)

Since the model is an adoption from Ganesan 1984 – i.e. from studies done elsewhere - it is a fair representation of the detail complexity of many construction industries.

In the model, the sub-sectors of the construction industry are conceptualized in terms of the end-use of the facility, which creates different real estate sub-markets, where demand originates from and supply ultimately goes. A great variety of participants is expressly or implicitly included in the model. The national economy is also included as the supra-system of which the industry is a part.
Figure 2.2 An Integrated View of Construction Industry and the Construction Process; Mbaya (1984: 42); adapted from Ganesan (1984)
It is this complexity of the industry together which the many determinants of construction demand, which are likely to have rendered demand forecasting models developed so far, rather inaccurate. In respect of econometric models for forecasting demand for industrial buildings, Hillebradnt (2000: 59) observes that “none of these various methods has been found to give results which, when applied to periods in the past for which the outcome is known, inspire confidence in their use as the only methods of forecasting” industrial construction output. Perhaps, the econometric models do not include an adequate number of explanatory variables or do not adequately take account of the complexity of the construction industry.

2.4 Methods of Predicting Construction Output
Frequently, forecasts of construction output are ‘proxied’ by forecasts of construction demand. While several methods specifically developed for predicting construction demand were found in the literature reviewed, only one method developed specifically for predicting construction output was found. All the same, construction economists do not consider this an issue since construction demand is a leading indicator of construction output. A basic assumption in this view appears to be that construction supply can always be somehow managed once construction demand is accurately forecasted.

The methods of predicting construction demand may be classified into six categories on the basis of their complexity. In a roughly ascending order of complexity, the categories are:

1. Qualitative methods
2. Simple time series models
3. ARIMA regression models
4. Simple regression models
5. Multiple regression models
6. Artificial neural network models

While category 1 is mainly judgemental, categories 2 – 6 are mainly quantitative. The methods differ in accuracy and their application differs from one construction sub-sector to another; one method may be more realistic in one sub-sector than in another. Qualitative methods and simple time series analyses are the most commonly used methods.

2.4.1 Qualitative Methods
Qualitative methods are primarily based on expert intuition coupled with some arithmetic calculations. Hillebradnt (2000) describes how the qualitative methods are applied in various sub-sectors of the construction industry. In forecasting demand for new housing the methods are applied as follows:-

(i) To build up the total needs (needs assessment of a population), for new housing and then to decide over what period the need will be satisfied;
(ii) To consider directly the factors which affect economic demand and forecast them to arrive at total housing demand;
(iii) To look at past trends in house building and its determinants and project them forward.
In practice, almost all forecasts of housing demand are a function of these three methods. The last method is the most useful when it is a reasonable assumption that there are no great changes in the underlying factors determining demand and supply, or when the period is so long that fluctuations around a trend are unimportant. The factors that are considered in such a forecast include incomes, supply of credit or savings, interest rates, unemployment and house prices. In forecasting industrial and commercial building activity, forecasters combine qualitative methods with econometric analysis. For industrial building, Hillerbradt (2000) and Killingworth (1990) observed that use of either of the methods alone does not guarantee accurate predictions.

Prediction of demand for social-type construction (some which includes public housing) is mainly based on welfare economics and is done by cost benefit analysis. To estimate the social-type demands likely to be put to the construction industry, a needs assessment is normally done together with a consideration of the resources likely to be available; this is an area where political decisions and priorities play a great part (Hillebrandt 2000). The proportion of the assessed need that translates into effective demand for construction depends on government investment expenditure.

In Kenya, it is qualitative methods that are generally used in forecasting construction demand in all the sub-sectors. Murigu (2005) observed the qualitative methods to be most commonly used in investment appraisal of construction development in the country. In her study, she observed that methods used to take account of the numerous determinants of investment decisions were mainly qualitative; she observed the most popular method of viability appraisal to be the payback method followed by the simple rate of return method.

Qualitative methods - of demand prediction and/or investment appraisal - are more popular in Europe and areas of European influence than they are in America. According to Barham (1991), in Europe and areas of European influence, development appraisal in a majority of cases consists of not much more than the financial calculation, the data and design decisions being based on, primarily the developers subjective approach and some sparse local investigation; however, in the American sphere of influence, such studies tend to be based much more on statistical analysis of the local market with predictions of demand being used to support the appraisal.

This pervasive use of qualitative methods implies that construction demand is not formally taken account of in the investment decision. While expert intuition is indispensable, a notable problem with the qualitative methods is risk. As Lima (1991) points out, the methods normally provoke decision making at a risk level that is significantly high. Continued application of qualitative methods in construction activity prediction does not therefore give any hope of ever managing construction cycles imaginatively.

2.4.2 Simple Time Series Models
This category includes extrapolation, averaging, smoothing, decomposition and trigonometric functions of time series. They are non-causal forecasting models and generally aim to model the basic parameters - amplitude, period and trend – of the time series. Flaherty & Lombardo (2000) is an example of studies where these models have been applied. The simple non-causal models investigated in this study are: single exponential smoothing,
Brown’s double exponential smoothing, Holt’s exponential smoothing, Winter’s exponential smoothing, classical decomposition, linear multiple regression trend, with seasonal dummy variables, and trigonometric seasonal forecasting

Application of these methods has a significant degree of uncertainty, particularly in long-term forecasting. It is, perhaps, in view of this uncertainty that MacFarlane (2000) made the following remarkable conclusion regarding cycle methodologies: “Questions of cycle shape … pose major difficulties for property cycle researchers. The main problem is the lack of historic data. With cycles of the order of 10 –15 years, there are few locations in the world for which reliable data is available for more than 2 cycles. Further, there is a very real question of the relevance and applicability of data from many years ago to the current set of property and economic circumstances and conditions. Further, if each cycle is unique ….. then there will be minimal forecasting accuracy over time. For this reason, long-term forecasting using cycle methodologies may prove to be of limited value.”

However, shortage of data is not necessarily the underlying problem of demand forecasting models. In his critique of current prediction models, Malizia (1991) points out that “although better data are always helpful, the more fundamental problem lies in the realm of theory; … models are not properly specified for the purpose of … forecasting.” He challenges researchers to do more comprehensive and more realistic model specification. Perhaps, a paradigm change in the model conceptualization plus inclusion of more explanatory variables – such as government policies and values, political climate, and innovation initiatives – is likely to improve performance of prediction models.

2.4.3 ARIMA Regression Models

In this category construction demand is conceptualized as a self projecting time series variable. Demand levels are regressed on their past levels and stochastic error terms. Like simple time series models, ARIMA (auto-regressive moving average) models are non-causal, but they are more rigorous and accurate. In Notman et al (1998) and Flaherty & Lombardo (2000) ARIMA regression is used to model construction activity in the UK and in Australia, respectively. The rationale of ARIMA modeling in construction activity is that there are likely to be some potentially causal relationships between current performance and past performance. The objective in the modeling is to identify the stochastic process that describes the data best and that is invariant with respect to time.

Establishing a good ARIMA model of a variable implies that the underlying phenomena generating the variable have not changed in any significant way over the length of the time series. Regarding ARIMA modeling of the UK construction output from 1955 to 1995, Notman et al (1998) observe that despite volatility and a boom-bust cycles in the construction output, the underlying process had been constant over the 40 years. They add that the 1990s recession in construction activity of the UK was not some extra-ordinary phenomenon; it was just part of the underlying stochastic process that had characterized the industry behaviour since the 1950s. There was no upward or downward trend in the construction output data. ARIMA regression therefore not only gives a
prediction of the expected future levels of activity, but it also gives an evaluation of the effect of past policy interventions or economic changes on the behaviour of the construction industry.

The level of accuracy of ARIMA models is comparable to that of causal (simple or multiple regression) models. However, ARIMA models are most well suited for short-term forecasting while causal models are most well suited for long-term forecasting (Gujarati 1995, Kendal & Ord 1993). A simple rule-of-thumb for forecasting with an ARIMA \((p, d, q)\) model is that the forecast should not extend beyond \(p + q\) periods (Notman \textit{et al} 1998), where \(p\) is the number of autoregressive terms, \(q\) is the number of moving average terms and \(d\) is the number the time series has to be differenced to attain stationarity.

### 2.4.4 Simple Regression Models

In these models construction output is expressed as a function of one variable, usually an economic indicator, after establishing the lags between the two variables. An example of studies where these models have been applied in the construction industry is Flaherty & Lombardo (2000). They regressed housing starts in Australia on lagged GDP and observed that the housing starts were influenced by the GDP (absolute) as far back as 12 quarters (3 years). Their coefficient of determination (Adjusted \(R^2\) values) is 0.675, which implies that their model had a relatively low explanatory power. Perhaps, the variability in construction activity can not be adequately explained by one economic variable.

### 2.4.5 Multiple Regression Models

In these models construction output is expressed as a function of many variables, the number of explanatory variables ranging from as few as two to as many as ten. In the literature reviewed, five multiple regression models were encountered. Multiple regression has been used to model construction activity in the UK (Akintoye & Skitmore 1991 & 1994), in the US (Killingsworth 1990 & Malizia 1990) and in Singapore (Bee-Hua 1996). Table 2.3 shows the explanatory variables used in those regressions. While Akintoye & Skitmore (1991 & 1994), Killingsworth (1990) and Malizia (1990) used five explanatory variables, Bee-Hua (1996) used thirteen of them. Her regression model was developed for comparison with a neural network model developed using the same data. The results of this regression analysis are reviewed together with those of neural network analysis in Section 2.4.6 below.

Explanatory powers (coefficients of determination) of the models shown on Table 2.3 vary significantly. In Akintoye & Skitmore’s (1991) model the coefficient of determination (\(R^2\) value) was observed to be 0.92 (on average, for 5 sub-sectoral regression models), meaning that 92% of the variability in construction output could be explained by the five determinant factors together.
Table 2.3 Explanatory Variables in Regression Modeling

<table>
<thead>
<tr>
<th>Modeler &amp; Year</th>
<th>Sector of construction activity</th>
<th>Explanatory variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akintoye &amp; Skitmore (1991)</td>
<td>All sub-sectors; UK</td>
<td>GNP, real interest rates, unemployment, price level, and seasonality (weather conditions)</td>
</tr>
<tr>
<td>Akintoye &amp; Skitmore 1994</td>
<td>Private sector housing, commercial &amp; industrial construction; UK</td>
<td>GNP, real interest rates, unemployment, price level and profitability</td>
</tr>
<tr>
<td>Killingsworth (1990)</td>
<td>Industrial construction; USA</td>
<td>Population, surplus capacity, plant &amp; equipment, interest rates, Sales and economic shocks</td>
</tr>
<tr>
<td>Malizia (1990)</td>
<td>Commercial construction; USA</td>
<td>Economic growth (regional location &amp; industry mix) and economic development (diversity, output, innovation potential, resilience &amp; centrality)</td>
</tr>
<tr>
<td>Bee-Hua (1996)</td>
<td>Private &amp; Public residential construction; Singapore</td>
<td>National income per capita, general demand for construction, size of population, rate of household formation, interest rate, property price, levels of supply of residential property, GDP, unemployment/employment, inflation rate, construction cost, mortgage credit availability/supply &amp; household personal savings.</td>
</tr>
</tbody>
</table>


As for the Akintoye & Skitmore’s (1994) model, Killingsworth’s (1990) model and Malizia’s (1990) model, the R² values, and therefore the explanatory powers, were significantly lower. In this category of demand prediction models, it is therefore Akintoye & Skitmore’s (1991) model which is likely to give most accurate results.

2.4.6 Neural Network Models

Neural network models are a category of prediction models that have been gradually gaining application in the construction industry since the 1990s. Neural network models are algorithms for cognitive tasks, such as learning and optimization, which are in a loose sense based on concepts derived from research into the nature of the brain (Muller, Reinhardt & Strickland 1995). An artificial neural network (ANN) model is made up of a complex network of artificial neurons (processing units) which receive input information, process it and output the results to other neurons (Bee-Hua 1996). Developing an ANN model entails devising network architecture, training the system such that the input data on explanatory variables produces about the same output of the dependent variable as the actual one observed in the field, and using holdout data that was not used in the modeling process to test the prediction accuracy of the model (Lin et al 1995).

An example of a study where this method was applied in the construction industry is Bee-Hua’s (1996) modeling of construction investment in Singapore. She developed an ANN model for construction investment, compared its forecasting accuracy with that of a multiple regression model developed using the same data using their Mean Absolute Percentage Error, and showed that the forecasting error of the ANN model was about one fifth of that of the multiple regression model.

The accuracy of the ANN model is comparable to that of the ARIMA model described in Section 2.4.3. Neural networks perform better than conventional methods for time series with short memory but for series with long memory, neural networks and the traditional Box-Jenkins model produce comparable results (Muller et al 1995).
The neural network model does not give accurate long-term prediction (Lin et al 1995). While the ANN and the ARIMA models are better and may replace each other for short-term forecasting, neither of them has the accuracy and explanatory power that the multiple regression model has for medium to long-term forecasting.

2.5 A Systems View of Fluctuations in Output

Fluctuation of output is a classical problem in Systems literature. However, the systems view of fluctuations is quite different from the views explained in Sections 2.2 and 2.3, which mainly attribute the fluctuations to external factors. In the systems thinking, the main causes of fluctuations in the output of an organization (i.e. a system) are considered to be the interactions within the organization, but not influences from outside the organization. Problems of the organization are not blamed on outside circumstances – the competitors, the press, the markets, the economy or the government. “Systems thinking shows that there is no outside; that you and the cause of your problems are part of a single system” (Senge, 1990: 67). For example, Forrester (1991) and Kummerow (1999), adopting systems thinking, observed the phenomenon of cycles in industrial activity to be a ‘managerial’ failure rather than unavoidable circumstances of the activity. Systems thinking would therefore not attribute fluctuations in construction output to ‘outside factors’ – business cycles, changes in government expenditure, etc – but it would attribute the fluctuations to the ineffectiveness of the industry’s ‘management’.

The view that excessive fluctuations or stunted growth of construction activity are internal problems of the construction industry is not naïve. Systems thinking attributes the behaviour of a system to the feedback control structure of the system itself. This view does not mean ignoring effects of external factors such as business cycles and changes in government policies; it does mean that the way the system responds to these supposedly external factors depends on the dynamic structure of the system itself. For that reason, a system’s dynamic structure can be imaginatively designed in such a way that the “external” factors will eventually not adversely affect the performance of the system. This argument is amplified in system dynamics literature, for example in Senge (1990). At first sight, the argument may appear to go against conventional wisdom but it does not necessarily do so. It actually gives the conventional wisdom greater insight and more often than not challenges it to view an organization’s problem from a wider perspective.

2.5.1 The Systems View

A good start point in explaining how systems thinking would be applicable to the construction industry is a technical definition of a 'system'. A system is simply “a collection of parts organized for a purpose” (Coyle 1996: 5). According to Schoderbek, Schoderbek & Kefalas (1980:12), a system is “a set of objects together with relationships between the objects and between their attributes, connected or related to each other and to their environment in such a manner as to form an entirety or whole.” Both definitions are basically the same. All the same, Coyle’s (1996) definition sounds more pragmatic and is therefore adopted in this study.

Viewing an organization as a system assists in solving problems in the organization, from a broader perspective; the problem solving adopts a broad look at the organization rather than an overly obsessive scrutiny of the particular problem in question. This holistic view is considered to be most realistic for the solution of present-day organizational problems because of their increasing complexity (Forrester 1969, Schoderbek, Schoderbek &
Kefalas 1980). The systems approach contrasts with the analytical method, whereby an entity is examined primarily from the viewpoint of its constituent elements or components. All the same, the systems thinking supplements rather than replaces the analytical thinking (Schoderbek, Schoderbek & Kefalas 1980). A systems view of construction activity can therefore be coupled with the analytical (unsystemslike) views that have hitherto been embraced.

In adopting systems thinking to problem-solving, various systems approaches are used depending on the nature of the system in which the problem occurs. From Schoderbek, Schoderbek & Kefalas (1980), the various systems approaches, may be summarized as follows:

1. General systems theory – framework for viewing complex phenomena as wholes with all their interrelated and interacting parts, which was formulated by an interdisciplinary team of scientists in the 1950s.

2. Cybernetics – the science of control and communication in the animal and the machine; it uses information feedback loops as the means of system control.

3. System dynamics - the science of feedback behaviour in multiple-loop nonlinear social systems; it can be seen to be an extension of the cybernetic approach to social systems, albeit at a higher resolution level.

4. Systems analysis – a systematic examination of a problem of economic choice in which each step of the analysis is made as explicit as possible; it involves problem formulation, search of relevant data, building a model and exploring its consequences, and deriving conclusions.

5. Systems engineering – invention, design and integration of the entire assembly of equipment, as distinct from the invention and design of the parts; the end item is viewed from the total view of the system. System engineering often employs principles of cybernetics, systems analysis and operations research.

6. Operations research – application of quantitative techniques to decision-making regarding organizational operations; it comprises linear and dynamic programming, decision trees, queuing theory, transportation method, network analysis and simulation models.

Choice of a systems framework depends on the complexity of the system in question. For systems that are probabilistic (with many states of nature) and fairly complex such as inventory levels and sales, operations research may suffice. However, for systems that are probabilistic and exceedingly complex such as human beings, corporations, industries and economies, cybernetics and system dynamics are most suitable. Between the two extremes are systems of somewhat intermediate complexity such as management information systems and development projects where systems analysis and systems engineering are the most suitable approaches (Schoderbek, Schoderbek & Kefalas 1980).
Of these systems approaches, system dynamics appears to be the one most suited to viewing socio-economic systems of the size and complexity comparable to that of a construction industry. Two classical examples of system dynamics studies of corporations that experienced excessive fluctuations in activity are Wonder Tech (a 1960s US electronics company) and People Express (a 1980s US Airline), which are amplified in Senge (1990). Both of the corporations rose and fell contrary to expectations. Senge (1990) describes how system dynamics modeling has been used to show how these corporations could perhaps have avoided collapse. Additionally, the potentials of system dynamics were demonstrated by Forrester (1969) in his study of the growth processes of urban areas in the US and by Kummerow (1999) in his study of changes in office markets in Australia. For that reason, review of the relevant systems literature in this study focuses on system dynamics.

2.5.2 System Dynamics Principles

In system dynamics (SD), a system is conceptualized as being controlled by a process of information, action and consequences (i.e. results of action), in order to maintain its purpose. In the system, “information produces actions which have consequences, generating further information and actions, and so on” (Coyle 1996: 5). This continual sequence is what is technically referred to as feedback in the system and exerts control on the system. An SD study of an organization’s problem, therefore aims to capture this feedback control process, thereby modeling the organization as a feedback control system.

A fundamental principle of SD is the idea of proportional control, whereby control action is proportional to the discrepancy between the current and the target states of the system, in view of the purpose of the system. SD modeling is therefore “application of the attitude of mind of a control engineer, to the improvement of dynamic behaviour” in systems (Coyle 1996: 5). It involves interpreting a real life system into computer simulation models that allow one to see how the structure and decision-making policies in the system create its behaviour.

A basic motive of SD modeling is “to improve a situation by suggesting how people can act upon the system. The perspective is often similar to that of a corporate executive who has some degree of control, including the possibility of changing system design, if the system misbehaves” (Kummerow 1999: 236). However, these principles apply, not only to ‘managed’ entities - such as projects, firms and corporations – but also to ‘non-managed’ entities – such as markets, industries and economies – where an individual does not manage them as a corporation is managed. Such systems are “designed and managed collectively. Aggregate decisions by multiple individuals and institutions determine the system outcomes.” (Kummerow 1999: 246).

Although every system may have specific attributes, SD studies have revealed certain attributes that are common to all complex systems. From Coyle (1996), Forrester (1969 & 1991) and Schoderbek, Schoderbek & Kefalas (1980), fundamental principles of systems - from the standpoint of SD - can be summarized as follows:

(1) Systems are seen as feedback processes having a specific and orderly structure. From the structure of the particular system arises its dynamic behaviour.
(2) Simple systems consist of one level variable on the feedback loop. Walking, warming ones hands beside a stove, picking things up and driving a car may be approximated as simple systems. Complex systems have many level variables and a network of feedback loops. Corporations, cities, economies and governments are complex systems.

(3) A complex system behaves in many ways quite the opposite of the simple systems from which experience has been gained. Most of intuitive responses have been developed in the context of simple systems, where the intuitive lesson that cause and effect are closely related in time and space has been grasped. However, in complex systems, cause and effect are often not closely related in either time or space because of the multiplicity of the interacting feedback loops.

(4) Complex systems are counterintuitive. That is, they give indications that suggest corrective action which will often be ineffective or even adverse in its results. They have a tendency to present apparent causes that are in fact coincident symptoms. Conditioned by training in simple systems, people apply the same intuition to complex systems and are led into error. The outcome lies between ineffective and detrimental.

(5) SD modeling helps to unify decision makers’ knowledge of a complex system, enhances their mental perception models of the problem in question and reveals the few policy areas which are leverage points for the system improvement. A general characteristic of systems is high resistance to policy changes. Perhaps as many as 98% of the policies in a system have little effect on its behaviour because of the ability of the system to compensate for changes in most policies.

Following the guidelines given in Section 2.5.1, a construction industry is a very complex system. Perhaps, construction output fluctuations in Kenya are a manifestation of some of the counterintuitive behaviour of the industry.

A remarkable strength of SD modeling is that it takes account of the delays in the flow of matter and information through the system. Delays are simply hold-downs that inhibit instant flow of material or information through a system. Insights from SD models “often have to do with delayed and counterintuitive effects of feedbacks. Delays mean current information may provide misleading signals” (Kummerow 1999: 236). In Kenya, for example, an average size building project takes between 1 and 2 years to complete. Considering construction times for all the projects in the industry at a given time, the industry’s system delays are therefore likely to have a significant influence on its dynamic behaviour.

2.5.3 System Dynamics Process
A system dynamics (SD) study adopts the case study research design; it aims to do an in-depth elucidation of one entity – the system in focus. The SD modeling process involves conceptualization and quantification of the phenomena underlying the problem behaviour. Although, the SD process is somewhat iterative, it has distinct phases. According to Coyle (1996), Forrester (1991) and Pidd (1988) the process entails the following stages:
(1) Identification of the problem;
(2) Development of a dynamic hypothesis explaining the cause of the problem – drawing influence diagrams, either as causal-loop diagrams or level-rate diagrams;
(3) Qualitative analysis of the problem – examining what the participants in the system feel is the problem with the system and establishing whether any bright ideas on the system can be borrowed from the modeler’s previous experience with similar systems;
(4) Building a computer simulation model of the system at the root of the problem – drawing detailed influence diagram(s) using computer code and formulating necessary difference equations;
(5) Testing the model to be certain that it reproduces the behaviour observed in the real world;
(6) Devising and testing in the model, alternative policies that alleviate the problem; and
(7) Implementing the solution recommended.

The process is similar to the case study process of an analytical (i.e. unsystemslike) approach to problem investigation. However, the details - conceptualization and quantification of the variables - are a complete paradigm shift from the analytical approach. If applied to an industry, the SD modeling procedures are likely to capture more variables than those that have hitherto been captured in econometric modeling. SD modeling of construction activity is therefore expected to add significantly to the insight regression modeling has so far given regarding the construction activity cycles.

An SD study need not cover all the seven stages listed above. “The problem is sometimes solved at stage 3 [qualitative analysis], and there is no need to go on to the other stages,” (Coyle 1996: 11) except, of course, the last one – i.e. the implementation of the solution recommended by the qualitative analysis.

At the qualitative analysis stage, great insight may gained by a comparing the pattern of the problem behaviour with generic patterns of similar systems, technically known as system archetypes. From Braun (2002) and Senge (1990), eleven system archetypes are explained as follows: -

1. **Balancing Process with a Delay**: A person, group, or organization acting towards a goal adjusts their behaviour in response to delayed feedback. If they are not conscious of the delay, they end up taking more corrective action than needed, or (sometimes) just giving up because they cannot see that any progress is being made.

2. **Shifting the Burden**: A problem symptom can be resolved either by using a symptomatic solution or applying a fundamental solution. Once a symptomatic solution is used, it alleviates the problem symptom and reduces pressure to implement a fundamental solution, a side effect that undermines fundamental solutions.

3. **Eroding Goals**: A gap between a goal and an actual condition can be resolved in two ways: by taking corrective action to achieve the goal, or by lowering the goal. When there is a gap between a goal and a
condition, the goal is lowered to close the gap. Over time, lowering the goal will deteriorate performance.

4. **Escalation**: This archetype occurs when one party’s actions are perceived by another party to be a threat, and the second party responds in a similar manner, further increasing the threat. The two balancing loops will create a reinforcing figure-8 effect, resulting in threatening actions by both parties that grow exponentially over time.

5. **Success to the Successful**: If one person or group (A) is given more resources than another equally capable group (B), A has a higher likelihood of succeeding. A’s initial success justifies devoting more resources to A, further widening the performance gap between the two groups over time.

6. **Tragedy of the Commons**: This archetype identifies the causal connections between individual actions and the collective results (in a closed system). If the total usage of a common resource becomes too great for the system to support, the commons will become overloaded or depleted and everyone will experience diminished benefits.

7. **Fixes that Fail**: A quick-fix solution can have unintended consequences that exacerbate the problem. The problem symptom will diminish for a short while and then return to its previous level, or become even worse over time.

8. **Limits to Growth**: A reinforcing process of accelerating growth (or expansion) will encounter a balancing process as the limit of that system is approached. Continuing efforts will produce diminishing returns as one approaches the limits.

9. **Growth and Under-Investment**: This applies when growth approaches a limit that can be overcome if capacity investments are made. If a system is stretched beyond its limit, it will compensate by lowering performance standards, which reduces the perceived need for investment. It also leads to lower performance, which further justifies underinvestment over time.

10. **Accidental Adversaries**: When teams or parties in a working relationship misinterpret the actions of each other because of misunderstandings, unrealistic expectations or performance problems, suspicion and mistrust erode the relationship. If mental models fueling the deteriorating relationship are not challenged, all parties may lose the benefits of their synergy.

11. **Attractiveness Principle**: The result sought by a firm and which is the target of a growing action may be subject to multiple slowing actions, each of which represent an opportunity and an opportunity cost to managers. Insight into the interdependencies between the slowing actions is a critical insight into deciding how scarce resources should be utilized to reduce or remove the slowing actions.
Three of the archetypes listed above appear to be most relevant to the problem of construction output fluctuations and stunted growth. The three archetypes are: balancing process with a delay, limits to growth and growth and underinvestment. Table 2.4 gives brief descriptions of the archetypes and examples of situations in which such archetype may apply.

<table>
<thead>
<tr>
<th>System Archetype</th>
<th>Dynamic Theory</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balancing Process with Delay</td>
<td>A person, group, or organization acting towards a goal adjusts their behaviour in response to delayed feedback. If they are not conscious of the delay, they end up taking more corrective action than needed, or (sometimes) just giving up because they cannot see that any progress is being made.</td>
<td>Real estate developers keep building new properties until the market has gone soft – but by then, there are already enough additional properties still under construction to guarantee a glut.</td>
</tr>
<tr>
<td>Limits to Growth</td>
<td>A reinforcing process of accelerating growth (or expansion) will encounter a balancing process as the limit of that system is approached. Continuing efforts will produce diminishing returns as one approaches the limits.</td>
<td>A new start up that grows rapidly until it reaches a size that requires more professional management skills and formal organization.</td>
</tr>
<tr>
<td>Growth and Underinvestment</td>
<td>Applies when growth approaches a limit that can be overcome if capacity investments are made. If a system is stretched beyond its limit, it will compensate by lowering performance standards, which reduces the perceived need for investment. It also leads to lower performance, which further justifies underinvestment over time.</td>
<td>People or firms with grand visions who never realistically assess the time and effort they must put in to achieve their visions.</td>
</tr>
</tbody>
</table>

Source: Compiled from Braun (2002) & Senge (1990)

The archetype examples on Table 2.4 include occurrences that are not alien to construction projects, firms or industries, implying that some insight into the behaviour of the construction industry as a whole (or its parts) can be gained from examining the relevant system archetypes. For more detailed explanation of the other archetypes, the references may be consulted.

### 2.6 Applications of System Dynamics

System dynamics is a widely applied systems approach. Since its inception at the Massachusetts Institute of Technology in the 1950s, SD modeling has been “used to simulate a droplet of rocket fuel, species extinctions, predator/prey systems, inventory control, transportation systems, manufacturing processes, military battles, disease contagion, urban growth and development, Earth’s carrying capacity for humans, etc” (Kummerow 1999: 236). However, application of SD modeling is more popular in other industries than in the construction industry. Ogunlana, Lim & Saeed (1998) observe that SD modeling has been applied in addressing managerial, research and development problems in other industries than it has been applied in the construction industry. A lot can therefore be borrowed from where policy recommendations from SD studies have been tested and found working.

In the construction industry, SD modeling is more frequently used at the micro-economic level of the industry than it is used at the macro-economic level of the industry. In the literature reviewed, there were more examples
of SD modeling applications to construction projects and firms than examples of SD modeling applications to construction markets and industries.


Examples of studies where SD modeling has been applied in investigating construction markets or industries are: Bajracharya, Ogunlana & Bach (2000), Kummerow (1999) and Turk & Weijnen (2002). Turk & Weijnen (2002) used SD modeling to examine the performance of infrastructure markets, while Kummerow (1999) used it to investigate office space markets. Bajracharya, Ogunlana & Bach (2000) used SD modeling to explore organizational infrastructure for training workforce in the Nepalese construction sector. They observed, through simulation experiments, that the public sector there “needs a pro-active management effort, along with a value reformation policy to reverse the adverse direction of dominating vicious cycles, while the private sector needs to equip itself with proactive culture and entrepreneurial values supported by favourable government policies providing spacious domain for the companies to play their role” (Bajracharya, Ogunlana & Bach, 2000: 91). This observation has a characteristic most observations from SD learning have, namely, a persuasive insight into the dynamic shortcomings of existing system structures and seemingly counterintuitive recommendations which appear to go against existing beliefs.

No evidence was found in the literature reviewed of any construction industry where policy recommendations from SD modeling had specifically been adopted and the results evaluated. However, such evidence was found in respect of the power industry of the United States. Ford (1996) gave a rigorous analysis of the evolution of the US energy sector, from its birth in the 1880’s to the 1990’s, showing how dynamic reasoning had been applied in the energy policies and how spectacular the outcomes were in the long-run. An interesting measure that the power suppliers had to take at one point in time, in order to manage consumer demand, was to encourage their consumers to conserve power. “Indeed, it is probably hard for any manager to appreciate why a private company would encourage its customers to use less of its product” (Ford 1996: 70). This point suggests that ‘rationalization’ of the use of the existing stock of constructed is a practical strategy for managing construction demand, particularly when there is an economic boom and there is excessive workload in the construction industry. However, such strategy would sound rather counterintuitive.

Despite the apparently counterintuitive character of policy recommendations derived from system dynamics studies, the policy ideas have been tested and found working, though not mainly in construction industries. Ford (1996:80) pointed out that “system dynamics practitioners have accumulated an impressive record of application in the electric power industry. System dynamics has given us a unique capability to ‘see the feedback’ at work in the power system…. [And to] to all system dynamicists … If you ‘see the feedback’ at work in your own field,
system dynamics will give you the opportunity to contribute in a unique manner.” This implies that if one were to clearly ‘see the feedback’ at work in construction output fluctuations, SD modeling would give one that ‘opportunity to contribute in a unique manner’.

A challenge that one has to face in applying SD modeling to construction activity is the concept of inventorying construction output. In structuring feedback control systems, principles of inventory management are frequently used to minimize (or eliminate) fluctuations in the system’s delivery rates; a ‘desired inventory’ level is set by the system’s management, all production is geared towards correcting the discrepancy between that ‘desired inventory’ and the actual inventory, and deliveries to the consumers are strictly made from the actual inventory. In Coyle (1996) and Pidd (1988) the use of inventory in feedback control structures is illustrated. However, in the construction industry, the idea of inventorying output is not as practicable as in the manufacturing industry. Raftery (1992: 42) points out that “unlike many other industries, the product [of construction industry] is sold before it is made. This has the implication that, with the exception of private sector housing, there is no need for firms to carry an inventory of finished products.” Perhaps, the difficulty of inventorying constructed space is the reason for the limited use of system dynamics in investigating construction activity at industry level.

Despite the difficulty of inventorying finished constructed facilities, the concept of inventorying is applicable to the construction industry’s production, albeit in a modified way. Turk & Weijnen (2002) suggest that reserve production capacity can be used to give a control facility in infrastructure markets, similar to the one given by inventory in product markets. Therefore, the concept of reserve capacity may be usable in minimizing fluctuations in construction output. This idea was adopted in this study, and is illustrated later.

2.7 Conclusion and Literature Gap

In conclusion, some research work has previously been done in developing time series regression models and system dynamics models of construction activities in other countries but not in Kenya. The review of literature has shown that research work has previously been done in developing time series regression models for predicting construction demand/output in the UK, the US, Australia and Singapore. It has also shown that system dynamics models have been used for understanding construction activity in Australia, Nepal and the US.

Any country observed to have excessive fluctuations in construction activity qualifies for a systems study of the problem of fluctuations. Going by the World Bank’s (1984) study discussed in Section 1.1.2 of Chapter I, sixteen countries are eligible, namely: Brazil, Columbia, Ethiopia, Federal Republic of Germany, Ghana, Italy, Japan, Kenya, Liberia, Malaysia, Peru, Sri Lanka, Sweden, UK, USA and Zambia. In that study, construction outputs of these countries were observed to vary more than their Gross Domestic Products. From this list, Kenya was selected for this study mainly on the basis of practical considerations; it was the country where the researcher had had the longest industry experience. This prior experience was certain to facilitate conceptualization of the dynamic complexity of the industry.

In the literature reviewed, no records of prior research work - on econometric or system dynamics modeling of construction activity in Kenya – were found. The predominant methods used for demand prediction and ‘systems
learning’ in the construction industry of Kenya are the intuitive ones, described in Section 2.3.1. As Forrester (1991) points out, these intuitive methods are generally defied by complex systems, of which a construction industry is a good example. It is for that reason that this study attempts to develop a more effective tool for understanding the broad behaviour of the construction industry of Kenya.

The next Chapter describes the research strategy adopted, and the methods used to provide and analyze the data.
Chapter III

METHODOLOGY

3.1 Introduction

Chapter II identified the gap in the literature related to fluctuations and growth of construction activity in Kenya. This chapter describes the methodology used to collect the data and to analyze them, to provide assurance that appropriate research procedures were followed. The chapter is organized around five major topics, namely: research design, study period, data collection, variables in the study, and data analysis.

3.2 Research Design

This study adopted a case study design coupled with a longitudinal element, and combined quantitative and qualitative research strategies. The two research strategies were employed to complement each other in covering aspects of the investigation which would not be sufficiently covered by either of the strategies if it were used alone. As explained in Bryman (2004), Hammersley (1992) and Silverman (2000), quantitative and qualitative research strategies can be effectively combined to compliment each other. In this study, one of the aspects to bring out was description of the construction industry participants’ subjective views of the industry, as well as the researcher’s own interpretation of these views. The other aspect to bring out was description of the historical levels of various variables in the construction industry and its environment, and replication of the historical behaviour to establish a laboratory for experimenting with various policy suggestions aimed to improve performance of the construction industry of Kenya. For those reasons, data collection and analysis in this study involved both quantification and words.

The case is the construction industry of Kenya, which was chosen as an exemplifying case for the phenomenon of construction output cycles in the construction industry worldwide. From the literature reviewed, it was observed that the problem of instability in construction activity is found in many countries. The longitudinal element in the case study is brought in by: (i) the need to analyze archival data – i.e. historical time series analysis, (ii) the need to replicate the observed historical behaviour – i.e. system dynamics simulation, and (iii) the need to project the behaviour to a reasonably distant future, in order to find out the expected behaviour of the construction industry of Kenya in the very long term. These needs were dictated by the research question – what causes excessive fluctuations and stunted growth of construction output in Kenya? – explained in Section 1.3 of Chapter I.

The fact that the construction industry is a complex socio-economic organization renders it amenable to system dynamics modeling. According to Kummerow (1999: 236), SD models offer two advantages: (i) it is relatively easy to incorporate qualitative mental and written information as well as quantitative data; and (ii) simulations can be used where data are inadequate to support statistical methods or where change in processes makes historical data misleading. In this study, the construction industry is therefore conceptualized as a feedback control system, in order to replicate the behaviour of the construction activity.
In systems parlance, a system’s line of behaviour is specified by the time-variance of its stocks and flows (Schoderbek, Schoderbek & Kefalas 1980). Stocks are accumulations of the quantities in the system at various stages of its activity process, while flows are the rates of change in the accumulations (Coyle 1996, Forrester 1968, Schoderbek, Schoderbek & Kefalas 1980, Pidd 1988). Examples of stocks found in the construction industry’s production process are the number of construction firms, the amount of construction work in progress and the quantity of buildings completed. Since the ultimate goal of the construction industry is to produce constructed facilities, the annual output of these facilities is the strongest indicator of the behaviour of the construction industry system.

As stated in Section 1.3 of Chapter I, the aim of the study is to develop a mathematical simulation model of construction output in Kenya. The outcome of the study is a model for learning implications of various policy alternatives on the behaviour and evolution of the construction industry of Kenya. The model takes into account both qualitative and quantitative data, which were collected by documentary research supplemented by interviews of key participants in the construction industry of Kenya.

The unit of analysis in the study is the construction industry of Kenya in a given year; one data point is therefore the year in question, starting from year 1964. Annual data on various variables in the construction industry and its environment were collected and analysed.

### 3.3 Study Period

The nature of the existing construction industry was investigated to establish the construction industry system boundary and attributes of its production process, which may influence the industry’s feedback control structure.

In order to describe the historical behaviour of the industry, historical data were investigated.

In this study, choice of the longest time period that could practically be covered was considered better than choice of any options of shorter periods, because finding out the long-term behaviour of a socio-economic system, such as an industry, needs scrutiny of the longest time period practicable. The period for which the relevant historical data were available was 1964 to 2003. This was therefore the historical period covered in the study.

Using a system dynamics model developed from the data collected, simulations of construction activity in Kenya were run up to year 2050, showing the expected behaviour of the construction industry even beyond year 2030, which is currently the focus year of Kenya’s national development vision – Kenya Vision 2030 (Republic of Kenya 2007).

### 3.4 Data Collection

The data were collected by documentary search and interviewing, between 20th January 2006 and 31st December 2006. The documents examined and found to contain material describing various aspects of a system view of the construction industry of Kenya were about 30 in number, and are listed in Appendix A. Semi-structured
questionnaires were used in the interviewing, in which ten respondents participated. Appendix A also gives a brief description of the interviewees who participated.

Interviewing was aimed at supplementing data from the documentary sources and, consequently, selection of the interview participants was based on the data gaps established in the documentary search. About 75% of the documentary search was completed before the interview questionnaires were prepared and potential interviewees identified. The interviews involved government officials, property development consultants, construction professionals and scholars, and were conducted by the researcher in person, using five different categories of interview questions shown in Appendix B.

The data collection tool for the qualitative data was a pre-structured case outline, whereby field notes (from documents and interviews) were coded and entered in the appropriate thematic category as the fieldwork proceeded. Both qualitative and quantitative data were obtained. The qualitative data comprise the relevant clauses, sentences and paragraphs copied from the documents and transcriptions of the statements made by interviewees. The pre-structured case outline is shown in Appendix C, together with the qualitative data collected.

Quantitative data were mainly obtained from the Central Bureau of Statistics (CBS) of Kenya and the Ministry of Roads and Public Works. The CBS provided data on construction output and GDP while the Ministry provided data on contractors and construction professionals.

The data collection tools for the historical time series data were data sheets containing a list of the variables in the study and covering the study period. The time series variables were (i) indicators of construction activity in the whole of the industry and its sub-sectors – construction output, Gross Fixed Capital Formation & cement consumption; and (ii) indicators of economic performance of the country – Gross National Product (absolute, per capita & growth rate), interest rates, inflation and unemployment.

In the government publications – Economic Surveys, Statistical Abstracts, etc - data are normally not presented in the form and detail required in this study. A special request was made to the CBS to provide the available annual data to as much detail as practicable. The data provided comprises 24 time series variables spanning between 1964 and 2003, as detailed in Appendix D.

In processing their data, the CBS had used the 1963 version of the System of National Accounts (SNA 1963), for all economic data up to year 2003. This accounting system is different from the 1993 version (SNA 1993) used for processing the data after 2003. SNA93 includes more variables in the computation of the economic indicators. For example, a comparison of GDP levels (at current prices) based on both systems from 1996 to 2003 showed that SNA93 gave GDP figures which were 15% higher on average over this period. However, SNA 93 data is not available for research study until CBS completes update of the SNA63 data. This updating is to be done back to 1982 and the updating process is in progress. For that reason, only historical data up to 2003 is analyzed in this study.
The intended start point of the historical data analysis was 1963 - the year of Kenya’s political independence. This is because various attributes of the construction industry’s environment in Kenya before independence are likely to have been significantly different from its attributes after the independence. However, the actual start point of the analysis was shifted to 1964 because that is the year from which the available construction output data start.

In this study report, evidence for deductions made from the qualitative data in Appendix C is cross-referenced as ACRRef …… [reference numbers stated]. Cross-references to all the other Appendices are stated in full.

3.5 Variables in the Study

There are four basic variables in this study, namely: construction output, contractors, system delays and the environment of the construction industry. From these basic variables, the simulation model variables - levels, rates, auxiliaries and constants - were created. This section describes the basic variables; the simulation model variables are amplified in Section 5.5.

3.5.1 Construction Output

Construction output refers to the quantity of constructed facilities. The most practical method of quantifying constructed facilities is to express them in money values, unless it is the very money values which are under study (Hillebrandt 2000). To remove the effect of inflation on output figures of different years, the output values are normally deflated to a base year (see, for example, Akintoye & Skitmore 1991, Nortman et al 1998 and Wells 2001). This was the measurement criterion adopted in this study for construction output. The construction output was therefore measured in Millions of Kenya Shillings (Kshs Millions) at constant (1982) prices.

The construction output was proxied by the Gross Fixed Capital Formation contributed by the construction industry (construction GFCF). This was done because in the historical construction data of Kenya, the construction GFCF is more comprehensive than the construction output data. It covers a longer period (1964 – 2003) than construction output (1975 – 2003). Moreover, construction output and construction GFCF are approximately equal, as explained in the Sources & Methods used for the National Accounts of Kenya (Republic of Kenya 1977). In that document, the statistical procedures used in estimating construction output and construction GFCF are elaborated. In brief, construction output refers to the value of production by construction service providers (particularly contractors) while construction GFCF refers to the capital expenditure incurred - by consumers of construction services – on construction investments. The former is estimated through production accounts while the later is estimated through expenditure accounts. The slight difference between the two comes because the value of repairs and replacements is more accurately captured in the construction GFCF than in the construction output. Additionally, the output is based on producer prices while the GFCF is based on consumer prices.

Although the above-explained slight differences between construction GFCF and construction output occasionally imply considerable differences between their recorded values, their profiles are similar in Kenya.
Pre-analysis of the quantitative data collected in this study showed that the time series of construction output and construction GFCF in Kenya are fairly well synchronized in their trends and fluctuations, although their values are rather different. Figure 3.1 shows that the two variables have approximately equal *amplitudes and frequencies of oscillations* in the period 1975 to 2003, for which the construction output data are available. Pre-analysis of the data also showed that the coefficient of correlation between construction output and construction GFCF in Kenya was 0.60 at lag 0, and was statistically significant, in the period 1975 to 2003. For these reasons, construction GFCF is a realistic surrogate for construction output in Kenya.

![Figure 3.1 Construction GFCF and Construction Output (at Constant 1982 Prices); 1975 to 2003](image)

In Kenya, the total construction output comes from six owner-user sub-sectors, namely: private residential, private non-residential, public residential, public non-residential, private other construction and public other construction. The ‘other’ construction work normally refers to civil engineering works (ACRef 4.22) and mainly constitutes road works. Outputs from the six sub-sectors are summed up to give the total construction output. For deflating construction output from their current price levels to constant price levels, “separate cost indices are calculated for residential buildings, non-residential buildings and civil engineering projects, [and are published] annually in the Statistical Abstract. The indices take into account labour costs, the costs of inputs and the depreciation of plant and machinery. … The value of output at constant prices is derived by deflating the components of the value of output – residential building, non-residential building and road construction – by the appropriate cost index, namely, the Building Cost Index, the Non-Residential Building Cost Index and the Civil
Engineering Cost Index. For the other construction, the deflator is the weighted average of the Non-Residential Building Cost Index and the Civil Engineering Cost Index” (Republic of Kenya 1977: 56)

Pursuant to these statistical procedures the sub-sectoral construction outputs (at current prices) were separately deflated (or inflated, if occurring before 1982) to their 1982 price level and the deflated (or inflated) sub-sectoral figures were then summed up to give the total construction output for construction industry as a whole. Appendix F shows the overall price level adjustment to 1982 level, for the sub-sectoral and total outputs. It shows that output figures at 2003 price level need to be deflated by 85% to bring them to their 1982 price level. It also shows that output figures at 2007 price level need to be deflated by 92% to bring them to their 1982 price level. This implies that it is Kshs 12.80 Million worth of constructed space at 2007 prices that is equivalent to Kshs 1 Million worth of constructed space at 1982 prices. In other words, the cost value of constructed space in Kenya in year 2007 is about thirteen times its cost value in the year 1982. Similar comparisons can be made for every year from 1964 to 2003, as shown in Appendix F. This use of construction output levels at constant prices was meant to take account of all effects of price changes in construction materials and technology over the study period, thereby making the monetary measure of constructed space sufficiently robust. This measurement concept is therefore reliable.

The private residential output comprises a monetary sector and a non-monetary (or traditional) sector. Examples of non-monetary sector construction are hut building by rural households for their own use and construction work by self-help schemes. The procedures for collecting the construction output data are amplified in the CBS methods report - Sources & Methods used for the National Accounts of Kenya (Republic of Kenya 1977) - and appear to be adequate for capturing rural construction activity. However, the procedures appear not to be adequate for capturing urban informal construction activity. “The estimates of private expenditure on residential and non-residential building are derived from the value of reported completions of private buildings and of extensions to them. This information is supplied by all the municipalities” (Republic of Kenya 1977: 91). Since informal sector construction - which takes place in private building (residential and residential/commercial) - is normally not regulated by local authorities or reported to them, it is unlikely to have been captured in the data collection processes of the Central Bureau of Statistics of Kenya.

Poor capture of informal sector construction output has been observed in previous research. For example, Wells (2001) observed this deficiency, but pointed out that the “informal construction sector ‘continued to create more additional jobs than the modern sector,’” implying that not all informal construction activity has been escaping statistical recording. Perhaps, informal sector activity was not significant in 1977 when the CBS methods report was prepared, and improvements might eventually have been made in the data collection process to capture informal construction activity more adequately. All the same, the informal construction activity might have remained unrecorded over a significant portion of the period 1964 to 2003. Because informal sector construction has a very active presence in Kenya today (Mitullah & Wachira 2003), description of the construction industry of Kenya would give a picture that is significantly less than a full one if it were to completely leave out the informal sector contribution to the overall total construction output. For that reason, the researcher considered it
necessary to make adjustments in the observed construction output figures to sufficiently guarantee inclusion of informal sector activity in this study.

Adjustment for informal sector construction output was done using a multiplier computed from the ratio of cement consumption index and private building activity index. Computation of the multiplier is detailed in Appendix E. The multiplier concept was borrowed from Wells (2001: 269) suggestion that the scale and extent of unrecorded building activity in Kenya “could be gauged from the data on cement consumption.” Her reasoning here was that the index of cement consumption should be approximately equal to the index of building activity, since “cement is not used to any great extent in road construction” (Wells 2001: 273). Therefore, any significant difference occurring between these indices should be attributed to unrecorded private sector building activity, since public sector building is unlikely to escape recording. That idea was adopted in this study to compute the multiplier described above. Then, private sector building activity was upped by the multiplier, as shown in Appendix E. Since indices of cement consumption from 1964 to 1983 are generally lower than those of the private building activity, no adjustment was applied to the private building output from 1964 to 1983. This indicates that the adjustment is not entirely accurate, though it is a plausible way out in absence of better options.

In describing the overall behaviour of the construction industry over the study period, the adjusted figures of construction output were used - for Section 4.3.1 of Chapter VI. However, in investigating the system archetypes in the industry, developing time series regression models, and developing the system dynamics model, only the monetary construction output was used – for Section 4.3.2 of Chapter IV to Section 6.3.2 of Chapter VI. The informal and non-monetary sector outputs were omitted from the time series regression and the system dynamics modeling processes. This omission was done because the construction process and, by implication, the feedback control structure of the formal construction sector are quite different from those of the informal and the non-monetary construction sectors. The non-monetary building activity is similar to informal sector building activity, in that it is mainly executed by the building owner himself or herself, sometimes aided by minimal professional consultancy.

### 3.5.2 Contractors

Contractors are business establishments that execute construction works. They are also referred to as construction firms or contracting firms. In Kenya, formal construction work for both the private and the public clients is mainly executed by private contractors. Activities of a construction project, besides the physical execution of construction works, which generally take place before and during site construction execution, may be collectively termed as ‘project planning, design and control’. They are normally undertaken by other private firms, except in design & build procurement, whereby the contractor serves the design function as well the construction function. These other private firms are the construction industry consultants and comprise project managers, architects, engineers, quantity surveyors, etc. The Ministry of Roads and Public Works is the main construction consultant for the government.
If the construction industry were to be conceptualized as one large corporation, construction firms would collectively constitute the ‘production department’ of this corporation, since it is their production activity that generates the ultimate physical output of the construction industry. Being the ones contractually and functionally responsible for the physical execution of construction works, contractors are bound to be a critical capacity item of a construction industry. In Kenya, concerns of construction industry participants over the dynamics of contractors were observed to be more frequent than those over the dynamics of consultants (see for example, ACRef 1.1, 1.9, 1.13, 1.23, 4.1 to 4.4, 4.33, 4.34, 6.3 & 6.6). This suggests that the contractors have hitherto been the most crucial and, consequently, the most keenly observed capacity item in the construction industry of Kenya. It appears that the contractors are more susceptible to variance in construction workload in the economy of Kenya than the consultants are.

For the reason given above, the number of contractors in the construction industry was used in this study, as the surrogate for the size of the industry’s production department. It is a major constituent of the industry’s capacity. Capacity of a construction industry is “the maximum output which is attainable by the industry, within the limits of conditions considered acceptable at the time” (Hillebrandt 2000: 191). Capacity is therefore a function of the size of the industry’s production department (i.e. number of contractors fully employed plus those that are idle) and its average contractor output (Output/Contractor/Year), among other factors. Estimation of the contractors for whole of the study period is explained in Section 1.7 of Chapter I and Section 4.3.5 of Chapter IV.

In this study, it was conceptualized that the number of contractors required to handle workload in the industry is determined by the contractors’ average annual output and a completion target that depends on the time it would take the industry to complete all the outstanding works, if there were no further additions to the workload. This time is approximated to be the construction period of an average size project, as explained in Section 3.5.3 below. The completion target is generally not expressly stated; it is mainly implied by technical constraints in the production process at a given time. Following this concept, the contractors in the construction industry of Kenya are enumerated as if they were of equal potential every year. However, contractors in an industry are normally of different sizes and potentials. Since the system dynamics modeling in this study is for the construction industry as a whole, this difference in contractor size does not obscure fluctuations in the overall average number of contractors well engaged in the industry every year. As stated before, the contractor estimates are of contractors who were considered to have been fully engaged in the formal construction industry every year. One contractor refers to an average size construction firm together with its management, manpower, machinery and materials, which are necessary to execute a construction project. Therefore, all sub-contractors and suppliers of construction materials, components, plant and equipment are indirectly but fully represented in this concept.

Use of contractors to represent the construction industry’s capacity does not down-play the influence of the other industry players in the construction industry’s production process. Influences of private consultants, public consultants (particularly, the Ministry of Roads and Public Works) and development control authorities (Ministry of Local Government and all its local authorities), are included in the system model in the form of the system delays, which are occasioned by their involvement in the construction process.
3.5.3 System Delays

System delays are the hold-downs that inhibit instant flow of production or information through a system. Examples of system delays in the construction process are the time to complete design, time to obtain physical planning approval, tendering time, contract period and the defects liability period. Generally, system delays are technically inevitable because time is necessary for output (matter or information) of various sub-systems to be realized in the production process of the system. This notwithstanding, delays render a system rather sluggish in responding to control actions applied to it. Coyle (1996) identifies three types of delays: (i) time to find out; (ii) time to decide what to do; (iii) time to remedy discrepancies from desired states. “The time it takes before the system reacts to discrepancies from desired states (information flows), and the speed and strength of the responses (physical adjustments) determine the dynamic behaviour of the system” (Kummerow 1999: 236).

Because of delays and many non-linear relationships amongst variables in a system, the perceived behaviour of the system is, more often than not, significantly different from the real behaviour of the same. Paich and Sterman (1993: 1449, 1456) showed that “decision-making is poor where decisions have delayed, indirect, non-linear, and multiple feedback effects. … In situations of high dynamic complexity, people’s mental models are grossly simplified compared to reality.” MBA students at the Massachusetts Institute of Technology were presented with a simple two feedback loop model posing pricing production and inventory control problems similar to those faced by construction business decision-makers. The students showed a tendency towards “conservative demand forecasts which ensures actual capacity will be grossly inadequate during the boom phase, causing high backlogs, long delivery delays and market share erosion” (Paich and Sterman 1993: 1452). They “then failed to cut capacity fast enough in the ensuing bust. In repeated trials, although some learning took place, subjects never succeeded in matching the performance of a simple decision rule.” (Kummerow 1999: 237).

Naturally, there exists a time lag between the day unsatisfied demand for constructed space occurs in the property market and the day the space is delivered by the construction industry. In this study, this time lag was conceptualized in terms of three major system delays, namely: time for design, time for planning approval and time to complete outstanding construction work. Time for design is the duration required for feasibility study, pre-contract design and documentation, while time for planning approval is the duration local authorities (City & Municipal Councils) take to approve proposed construction projects. Although tendering may have to wait till Planning approval is obtained, it is normally part and parcel of project documentation, and therefore, tendering time is included in the time for design.

Generally, post-contract design activities – such as project co-ordination and control, quality control and cost management – take place in parallel with site construction activity, and do not portray their system delays as originating from the design function. These activities may influence the time to complete outstanding construction workload, which comprises the contract period, mobilization period for contractors and extensions of construction time in accordance with the conditions of contract. For that reason, system delays arising from post-contract design activities were considered to be accurately accounted for in the Time to Complete
Outstanding workload – a system delay amplified in Section 5.4 of Chapter V. To keep the system model relatively simple, delay effects of the defects liability period of the construction contract was not included in the modeling.

3.5.4 Environment of Construction Industry

In the environment of a construction industry system there are social, economic and political factors that influence the activity of the industry. Construction demand has variously been regressed on these ‘environmental’ factors in econometric modeling as described in Section 2.4.5 of Chapter II. In Kenya, the ‘environmental’ variables whose data are available for the whole of the study period – 1964 to 2003 are three, namely: Gross National Product (GNP), unemployment rate and inflation rate. While GNP is an indicator of the economic performance of a country, unemployment rate and inflation rate are indicators of the political and social conditions in the country. As Lipset & Schneider (1987) explain, misery index – the sum of the unemployment rate and the inflation rate – is the indicator of public (consumer & investor) confidence towards the government of a country.

(i) Gross National Product

Gross National Product is a money measure of goods and services produced in an economy in a year (Samuelson et al 1992). It is a sum of local and foreign expenditure. GNP is obtained by adding GDP to net factor incomes from outside the country.

\[
\text{GDP} = C + I + G + X - M
\]

Where, \(C\) is personal consumption expenditure, \(I\) is private investment expenditure, \(G\) is government expenditure (on consumption & investment), \(X\) is exports, and \(M\) is imports (Samuelson et al 1992).

Demand for construction work (i.e. for capital investment in real estate) is motivated by the demand for consumer goods in the economy, which need the constructed space for their production. Raftery (1992: 37) explains that “the demand for most buildings is ‘derived’ demand, that is, it depends on the demand for goods and services which can be produced from the building or for the utility offered by the building.” This demand for consumer goods in the economy is normally represented by the GNP (absolute, growth rate & per capita) of the country. A period of economic prosperity tends to raise consumer demand for goods and services, which in turn triggers off the demand for construction space (Briscoe 1991, Hillebrandt 2000 & Raftery 1992).

GNP is frequently used in regression modeling of construction activity. Examples of previous research studies where GNP was used are Akintoye & Skitmore (1991 & 1994) and Bee-Hua (1996), which are discussed in Section 2.4.5 of Chapter II. GNP is so frequently used to explain construction activity because it is a good proxy for the expected sales growth in an economy and, by implication, a major determinant of investment in construction work (Akintoye & Skitmore 1991).
(ii) Misery Index

As stated before, the misery index is the sum of unemployment rate and inflation rate. Although the index is mainly an economic indicator, Lipset & Schneider (1987) observed it to change in the same pattern as the public distrust (confidence gap) in the government and its major institutions. It is therefore, a plausible surrogate for political climate. Since a country’s public comprises both consumers and investors, this surrogate represents both consumer and investor confidence in the country. Construction activity is expected to be inversely proportional to misery index because increase in the index is likely to decrease investor morale and, consequently, decrease in construction demand.

Unemployment and inflation also have their separate influences on construction activity. A rise in unemployment and/or inflation normally causes a fall in construction demand (Briscoe 1992, Hillebrandt 2000 and Raftery 1992). Unemployment is the percentage of active labour force unable to obtain the type of work or the remuneration which they think is reasonable, or which their education has led them to expect (International Labour Office 1973). Jobs are the essential bridge between economic growth and people’s lives. Unemployment arises when some members of the working population, who are actively seeking jobs, are not able to find them (International Labour Office 1983). In Kenya, the percentage of the population aged 15 years and over – including the unpaid family workers - is considered to be active in the labour force, ready to take part in the production of goods and services (UNDP 1999).

GNP and unemployment jointly represent the two key components of economic demand – i.e. ability and willingness to pay for goods or services. While GNP may be considered to be the main indicator of a population’s ability to pay for constructed space, it is unemployment (i.e. its inverse) which may be considered the proxy for the population’s willingness to pay for the constructed space. In addition to causing a fall in incomes, increased unemployment may raise the level of financial uncertainty among potential investors in construction, causing them to defer or abandon investments and eventually causing a fall in construction demand. In a regression model of construction demand, GNP and unemployment should therefore adequately explain the variability of the demand.

Inflation tends to erode a population’s ability to pay for goods or services. Inflation rate is measured by changes in the retail prices and indicates the general increase in consumer price level. It tends to raise the cost of construction and is therefore inversely related to the purchasing power of a population. Increased inflation implies reduced purchasing power and consequently, reduced demand for constructed space.

In the literature reviewed, none of the past regression analyses of construction demand/output used misery index, as shown in Section 2.4.5 of Chapter II. For example, Akintoye & Skitmore (1991 & 1994) and Bee-Hua (1996) used unemployment and inflation – either on its own or as a constituent of real interest rate. However, misery index (unemployment plus inflation) has been used in regression analysis in other fields. For example, using regression analysis Clark, Green & Robertson (2004) investigate whether misery index is a good predictor of lottery sales in the US states of Texas, Missouri and Louisiana. Therefore, where inflation and unemployment are used as predictor variables in a regression model, it is realistic to use the two variables either separately or
jointly as misery index. In this study, choice was made to use misery index (unemployment plus inflation) as opposed to using unemployment and inflation separately, in pursuit of the regression analysis principle of parsimony (Chaterjee 1977); when fewer explanatory variables are used, fewer degrees of freedom are consumed.

3.6 Data Analysis

The data were analyzed using qualitative and quantitative methods, aided by three software packages, namely: Ms-Excel 2003, EViews 5 and Powersim Studio 2005 (Service Release 4). The systemic nature of the construction industry was analyzed by textual exposition, while its historical behaviour was analyzed by time series analysis of its annual outputs from 1964 to 2003. On the basis of the qualitative and historical time series analyses, a system dynamics model of the industry’s output was developed.

3.6.1 Qualitative Analysis

Qualitative analysis was used to address objective 1 and 2 stated in Section 1.3 of Chapter I. It involved textual exposition aided by graphical analysis of the construction output time series. The system boundary of the construction industry was drawn, then system archetypes responsible for the problem of excessive fluctuations and slow growth of construction output explored.

The system boundary between the construction industry and its environment was “drawn” by describing what constitutes the inside and the outside of the construction industry system, as evidenced by the qualitative data collected. According to Forrester (1969: 15), “the specific system boundary is most easily defined in terms of the interacting components that are to be included within the system.” That concept was adopted in this study. Therefore, an entity was considered to lie within the construction industry system boundary if (i) the entity is most essential in the construction process; and, (ii) the control of the entity falls within the jurisdiction of the decision-makers in the construction industry. Any other entity that may have influence on the construction industry but does not posses these two characteristics was considered to lie outside the dynamic system boundary.

From the view point of the general systems theory, the system boundary of a construction industry is ‘open’ since the industry freely interacts with its environment (Schoderbek, Schoderbek & Kefalas 1980). However, from the view point of the system dynamics approach to systems, the boundary is ‘closed’ because it encloses the interactions that give the industry its characteristic behaviour (Forrester, 1968 & 1969). The two viewpoints do not conflict; they supplement each other. “The closed boundary does not mean that the system is unaffected by outside occurrences. But it does say that those outside occurrences can be viewed as random happenings that impinge on the system and do not themselves give the system its intrinsic growth and stability characteristics” (Forrester 1969: 12).

The principle of a closed dynamic boundary is useful when a modeler is conceptualizing the forces at work in the system. Although some forces may come directly from the environment, the influences at work in the system mainly lie within the system boundary. Forrester (1969: 18) explains that “the environment can affect the system, but the system does not significantly affect the environment. In terms of loop structure, there are no
loops essential to [the system dynamics] study that run from the system to the environment and back to the system.” This principle helps to conceptualize the influences at work in the focal system most accurately. In this study, the ‘closed dynamic boundary’ principle was used to differentiate between variables dictated by the environment of the construction industry of Kenya and the variables determined by the industry itself.

The historical behaviour of the construction industry system was described using line graphs of the construction output over the 40 year period – 1964 to 2003. Profiles of the line graphs were used as the indicators of the nature of system archetypes that were operating in the construction industry of Kenya.

Deductions from the qualitative analysis results are made in the light of the literature reviewed and covered the following areas: (i) systemic processes of the construction industry; (ii) interactions of the industry with its environment; (iii) levels of construction output from 1964 to 2003; and (iv) underlying system archetypes responsible for industry’s output fluctuations and stunted growth.

3.6.2 Time Series Analysis

More rigorous time series analysis was performed to address objective 3 stated in Section 1.3 - and to test the econometric hypothesis stated in Section 1.4 - of Chapter I. The analysis was done following procedures detailed in Gujarati (1995) and Kendall & Ord (1993), using the E-Views 5 software for econometric analysis. It involved: (i) stationarity tests of construction output, GNP and misery index; (ii) ARIMA regression of construction output; and (iii) multiple regression of construction output on GNP and misery index.

Stationarity tests were necessary preliminaries to the regression analyses because “empirical work on time series data assumes that the underlying time series is stationary” (Gujarati 2003: 792). Regressing a non-stationary time series on another non-stationary time series risks the problem of spurious regression results, whereby the researcher obtains a very high coefficient of determination (R² value) indicating a significant relationship, even though there is actually no meaningful relationship between the two variables (Gujarati 2003). A time series is said to be stationary if its mean and variance are constant over time, and the value of covariance between two time periods depends only on the lag between the periods, but not on the actual time at which the covariance is computed (Gujarati 2003, Kendall & Ord 1993). For that reason, line graphs were drawn to obtain preliminary visual impressions of the stationarity status of the time series data, and then unit root tests of stationarity were done on the data using the Augmented Dickey-Fuller test. Where a variable was found to be non-stationary, it was differenced to attain stationarity, before being used in the ARIMA or multiple regression analyses.

As a self-projecting variable, construction output (or annual construction completion rate [CCR]), in a given year is influenced by construction output in the previous year(s) and stochastic error terms. The output at time t (CCRₜ) was therefore modeled as an ARIMA (autoregressive integrated moving average) process (i.e. in terms of its own level at the previous times and its stochastic error terms) as follows:

\[
\text{CCR}_t = \theta + \alpha_1 \text{CCR}_{t-1} + \alpha_2 \text{CCR}_{t-2} + \ldots + \alpha_p \text{CCR}_{t-p} + \beta_0 t + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \ldots + \beta_q u_{t-q} \]

[2]
Where, $\theta$ represents a constant term, $p$ is the number of autoregressive terms, $q$ is the number of moving average terms, $u_t$ is an unautocorrelated random error term with zero mean and constant variance ($\sigma^2$). Here level of output (CCR) at time $t$ depends on its level in the previous $p$ time periods, and on a moving average of the current and past $q$ error terms.

As an explained variable, annual construction output is influenced by many variables as explained in Section 2.3.1 of Chapter II. However, only two of the explanatory variables had their data available for this study, as stated before. The two variables are GNP (Kshs Millions) and misery index (i.e. unemployment rate + Inflation rate, %). Therefore, construction output at time $t$ (CCR$_t$) was expressed as a function of these variables, as follows:

$$ CCR_t = \alpha + \sum \beta_{ji} X_{j,t-i} + \epsilon_t $$

Where, $\alpha$ and $\beta_i$ are parameters ($\beta_{ji} \neq 0$), $X_{j,t-i}$ represents selected lags of the two explanatory variables. $\epsilon_t$ is a random error term, with a mean of zero and variance of $\sigma^2$. The explanatory variables are described in Section 3.5.4 before.

The accuracy of the ARIMA and the multiple regression models were evaluated using their $R^2$ values and their mean absolute percentage error (MAPE).

### 3.6.3 System Dynamics Analysis

On the basis of the qualitative and quantitative analyses described in Section 3.6.1 before, the construction industry of Kenya was then conceptualized as a feedback control system. This conceptualization started by identifying components of the dynamic complexity ingrained in the industry. Then, a system dynamics model of the construction industry was built up, encapsulating the research problem in the feedback control structure. This analysis was performed to address objective 4 and 5 stated in Section 1.3 - and to test the dynamic hypothesis stated in Section 1.4 - of Chapter I.

The system dynamics modelling was not adopted because of poor results of time series analyses carried out to address objective 3. Even if best results of the time series analyses were obtainable, system dynamics modelling would still be the better method to address the research question in this study. According to Kummerow (1999) and Ogunlana, Lim & Saeed (1998) system dynamics modeling is the method of choice where a system: (i) comprises multiple interdependent components, multiple feedback processes and non-linear relationships; (ii) is highly dynamic; and (iii) involves both “hard” and “soft” data. A construction industry has those system characteristics. Therefore, from the very onset, system dynamics modelling was the most suitable approach to the problem of fluctuations and slow growth of construction activity in Kenya. It would have addressed the problem sufficiently. However, the researcher considered it necessary to also show how conventional time series analyses would perform in the case of the construction industry of Kenya. As explained before, the conventional time series analyses – ARIMA and multiple regressions - are the modelling approaches most frequently used in
previous studies in this field. Based on the results of this study, comparison of the time series methods and the system dynamics method is given in Section 7.3.

In this study, the dynamic hypothesis is presented using a level-rate diagram. According to Coyle (1996), influence diagramming in system dynamics may be done using causal-loop diagrams or level-rate diagrams. Both level-rate diagramming and causal-loop diagramming serve the same purpose – i.e. to show diagrammatically the influences at work in the system. Additionally, Powersim Studio, the system dynamics program used in the study, does not have a function for causal loop diagramming. It only uses level-rate diagramming, which is sufficient. The dynamic hypothesis is shown diagrammatically in Figure 3.2, where construction output (‘quantity’ of constructed space completed per year) is the construction completion rate.

![DIagram](image_url)

**Figure 3.2 Dynamic Influences on Construction Output**

*Note:* Concept based on construction process described in Section 5.2 of Chapter V.

Figure 3.2 uses the analogy of water flowing in a plumbing system of pipes and tanks, to show the influences at work in the construction industry system. The water flows in the pipes (double arrows) to increase or decrease the water levels in the tanks (boxes). Figure 3.2 shows the major influences at work in the construction industry system, at a fairly high level of abstraction, in a bid to amplify the dynamic hypothesis. The symbols in the diagram are the standard symbols used in system dynamics modeling, specifically using the Powersim Studio 2005 (Service Release 4) software package for system dynamics simulation.

The symbol meanings are as follows:

- **Box** – level (stock); it is accumulation (or integration) of the flows that cause the level to change.
- **Circle & valve** – flow rate
- **Double arrows** – flow; the flow is controlled by the flow rate.
- **Circle** - auxiliary; a variable that combines or reformulates information in the system.
• Diamond – constant; a factor that remains constant over the time period of the simulation.
• Single arrow – information links.
• Cloud – source or sink of the feedback control structure; indicates infinity and marks the boundary of the model.

The dynamic relationship amongst the variables shown in the Figure 3.2 can be expressed as follows:

(i) \( \text{WAR}_t = \frac{1}{DT} (\text{DCS}_t - \text{SCS}_{t-1}) \) \[4\]

Where, work addition rate (WAR) is the rate at which construction workload at a given time (t), ‘moves’ from design stage into construction stage, \( \text{DCS}_t - \text{SCS}_{t-1} \) is the discrepancy between the overall demand for constructed space (DCS) in the economy (an exogenous variable to the construction industry system) and the existing stock of constructed space (SCS) in the real estate industry at the time, and design time (DT) is a system delay (i.e. average time architects require to complete design, get planning approval and tender the work) in the construction process.

(ii) \( \text{CCR}_t = \frac{1}{CT} \cdot \text{OCW}_t \) \[5\]

Where, construction completion rate (CCRt) is the annual construction output at a given time (t), \( \text{OCW}_t \) is outstanding construction work at that time, and construction time (CT) is a system delay (i.e. average time contractors require to mobilize their resources and execute construction work). The construction time is inversely proportional to the average contractor output (Output/Contractor/Year) and the number of contractors.

If the number of contractors required for timely execution of the outstanding construction work - at a given level of average contractor output in the industry - is always available in the system, then CCRt can also be expressed as a function of the number of contractors, as follows:

\[ \text{CCR}_t = \frac{1}{CT} \cdot \text{OCW}_t = C_t \cdot \text{ACO}_t \] \[6\]

Where, \( C_t \) is the number of contractors at time (t) and \( \text{ACO}_t \) is the average contractor output at the time.

(iii) \( \text{OCW}_t = \text{OCW}_{t-1} + \text{WAR}_t - \text{CCR}_t \) \[7\]

This means that the outstanding construction work at a given time (t) is depleted by the construction completion rate at that time and increased by the work addition rate at the time.

(iv) \( \text{SCS}_t = \text{SCS}_{t-1} + \Delta t \cdot \text{CCR}_t \) \[8\]
Where, the *stock of constructed space* (SCS,) in the real estate industry at time (t) and \( \Delta t \) the time over which construction completion has been taking place.

The system dynamics structure illustrated in Figure 3.2 was the basic systems concept used in this study. However, the level-rate diagram was elaborated to incorporate more system variables as shown in Figure 5.2 of Chapter V and Figure 6.6 of Chapter VI.

In this study, three precautions were taken to ensure validity of the study findings. Firstly, all the variables in the study and the relationships amongst the variables were clearly defined, using *reliable measurement criteria* for the variables and *pragmatic interpretation of relationships* amongst them, based on the literature reviewed and the qualitative data collected. Such precautions should ensure construct validity and internal validity, which are key measures of the validity of research as explained, for example, in Bryman (2004). Secondly, *correctness of model construction* was ensured by strictly adhering to Lai & Wahba’s (2001) checklist of model correctness in the process of building the system dynamics model. Finally, the overall model validity was tested using behaviour replication tests, parameter values tests and extreme conditions tests, as explained in Shreckengost (2001).

The validation exercise of the system dynamics model involved: (i) comparing the simulated values of construction completion rate (i.e. annual construction output) with the actual values of the construction output in the historical time series data; (ii) comparing the *simulated numbers* of contractors with *arithmetically estimated numbers* of the contractors; and (iii) exploring the model behaviour with extreme values of its parameters, thereby identifying parameter values that are not acceptable in the model for reasons that represent *the way the actual system works*.

Using the validated model, various scenarios of the system parameters were experimented with and the sensitivity of the system dynamics model to parameter changes tested. Then, possible structural changes in the system dynamics model of the *existing system structure* of the construction industry of Kenya were explored, to find out fundamental changes that could bring in stability and growth of construction output. These structural changes produced a system dynamics model of an *improved system structure* of the construction industry of Kenya. Expected influences of parameter and structural changes were the criteria for appraising policy suggestions made by construction industry participants in Kenya, for the purpose of solving the problem of excessive fluctuations and stunted growth in the industry’s output.

Finally, the likely future behaviour of construction activity in Kenya was projected to year 2050, using the model of the existing construction industry. This projection was compared with a similar projection done using the improved model, and implications of the projections explained.
3.7 Ethical Considerations

All necessary precautions were taken to ensure that this study was conducted in an ethical manner. Four ethical considerations were made as follows. Firstly, RMIT human research ethics conditions were satisfied and ethics approval obtained before interviews were conducted in the field. Additionally, ethical procedures were strictly followed in the fieldwork. A plain language statement of invitation was sent to potential interviewees, and those who agreed to participate signed a consent form. These two documents are shown in Appendix L.

Secondly, this research was officially authorized by Kenyan authorities, and a research permit granted. This authorization is also shown in Appendix L.

Thirdly, all transcriptions of statements made by interviewees are what the interviewees actually said. The interview questionnaires are stored securely in the School of Property Construction and Project Management, RMIT University. Moreover, records of documentary data are exactly what the documents expressly say. The data source documents are listed in Appendix A, and are obtainable from various libraries in Kenya.

Finally, the researcher verified that all the references given in this study do actually say what the study report says they do.

3.8 Feedback from the Construction Industry of Kenya

Comments on the findings of this study were sought from construction industry participants in Kenya, after the first draft of the study report was ready. A comprehensive summary of the draft report was prepared and send to eight key construction industry participants in Kenya, to seek their views on the results of the study. Four of the participants, one of which was an expert in systems thinking, responded.

The construction industry participants generally observed that the study findings represented the profile of construction activity in Kenya, particularly for the period 1964 – 2003, for which the findings were verifiable from recorded statistics of construction output in the country. However, they pointed out various concerns regarding the variables in the SD model and the implications of the assumptions made in the modelling, and gave insightful ideas that were incorporated in the subsequent versions of the research report.

Another remarkable observation of the construction industry participants was that the solutions recommended by this study for addressing the research problem, are rather counter intuitive. This observation was one confirmation that the study was actually a real SD study. According to Forrester (1969 & 1991), SD studies have a tendency to bring out recommendations that at first sight appear counter-intuitive to the system’s management, but are eventually found to be the real solutions to the research problem in the long run. Therefore, the SD modeling work done in this study was realistic.

3.9 Conclusion

This study adopted a case study design and a multi-strategy approach, choice of which was dictated by the research question. In this Chapter, the research design, data collection and analysis procedures, variables in the study and ethical considerations made in the study were elaborated.
In brief, appropriate methodological procedures were followed in the study, and they provided a strong foundation for valid observations. The next three chapters – Chapter IV, V and VI - present the results of the data analysis.
Chapter IV

SYSTEM BOUNDARY AND BEHAVIOUR

4.1 Introduction
In Chapter III, the research methodology used in this study was discussed. This chapter presents the results of the data analysis addressing objectives 1, 2 and 3 stated in Section 1.3 of Chapter I. The data analyzed for this chapter are the qualitative data presented in Appendix C and the quantitative data presented in Appendix D. As stated before, evidence for deductions made from the qualitative data in Appendix C is cross-referenced as ACRef ……. [reference numbers stated], while cross-references to all the other Appendices are stated in full. The chapter comprises three major topics, namely: system boundary of the construction industry of Kenya, system behaviour of the construction industry, and time series regression of the construction output.

It will be shown that the underlying causes of excessive fluctuations and stunted growth of construction output in Kenya are two system archetypes operating in the construction industry, namely: balancing process with a delay and limits to growth. Chapter VII will discuss the findings presented in this chapter, within the context of the literature reviewed.

4.2 System Boundary
The essence of the construction industry is to produce constructed physical facilities whose purpose is to provide space where other activities may take place (ACRef 4.10, 4.13 & 4.14). The basic resources required for the industry’s operation are: land, labour, technology, materials, plant & equipment, utilities, information and time (ACRef 2.10). The production process for a construction project involves: project planning, design, approval of drawings, tendering and construction. Many industry participants are involved in the process of a single project, rendering the production process very management-intensive. In the process, there is so much back and forth flow of information amongst the project participants that the process becomes a complex web of functional and contractual interactions. At the industry level, there are projects at various stages of the process at any given time.

As explained in Section 3.6.1 of Chapter III, two principles that may guide in drawing the construction industry’s system boundary are: (i) the essentiality of an entity in the construction process; and (ii) the controllability of the entity by decision-makers in the construction industry. Following these principles, entities inside the system are those that are most essential in the construction process and whose control falls within the jurisdiction of the decision-makers in the industry. Any other entity that may have any influence on the industry but does not possess these two characteristics may be placed outside the system.

Since the Ministry of Roads and Public Works is the government body assigned the responsibility and authority of formulating and implementing policy for the country’s construction industry (ACRef 1.3 & 1.12), it is the top decision-maker of the industry. The Ministry and the industry participants under its jurisdiction were therefore considered to fall within the system boundary. Another government ministry which appears to operate on almost
the same level of responsibility and authority as the Ministry of Roads and Public Works is the Ministry of Local Government, particularly in control of private developments in urban areas. City and municipal councils are the entities which approve drawings for proposed construction projects and check the quality of the built facilities, particularly in urban areas (ACRef 1.29, 6.11 & 6.12). The councils were observed to be so essential in the construction process that they were considered to practically fall inside the system boundary, although they do not functionally fall under the Ministry of Works.

Therefore, the industry participants approximated to fall within the system boundary were: legislators (on development control and standards of materials & workmanship), consultants (public & private sectors) and contractors (including the associated sub-contractors and suppliers of materials & machinery) (ACRef 1.1, 1.5, 1.6, 1.8, 1.9, 1.25). Since demand for construction services is a phenomenon that is normally not within the control of the construction industry, entities that generate demand for construction services were considered not to fall inside the system boundary. Entities considered to lie outside the boundary - in the industry’s environment – were developers (public & private), policy makers (on land, physical planning & development planning), the general public, politicians, other government ministries & departments, the economy as a whole, other countries and Bretton Woods institutions (ACRef 3.2 to 3.4, 3.8).

The system boundary of the construction industry of Kenya is shown in Figure 4.1. The industry interacts freely with its environment; it is an open system. For that reason, the boundary is shown as a dashed line. Figure 4.1 also shows the location of the other entities in the supra-system, relative to the boundary line. It shows that four major entities were considered to fall inside the system boundary, while eight major entities were considered to fall outside the boundary. The Ministry of Roads and Public Works doubles up as a legislator to the private sector – contractors and consultants - and a consultant to the public sector.

As explained in Section 3.6.1 of Chapter III, the construction industry system boundary is ‘open,’ from the viewpoint of the general systems theory, but ‘closed’ from viewpoint of the particularized system dynamics theory. The boundary is ‘open’ since the industry freely interacts with its environment, but it is also ‘closed’ because it encloses the fundamental interactions that give the industry system its characteristic behaviour.
4.2.1 Inside the System

The Ministry of Roads and Public Works is the government consultant for all public construction projects. Although construction (and sometimes design) works for public projects are executed by the private sector, the work is channelled to the private sector through the Ministry of Roads and Public Works. The Ministry influences construction activity in the private sector by regulation of contractors (keeping a register of contractors) and consultants (mainly through the Board of Registration of Architects & Quantity Surveyors) (ACRef 1.3, 1.13, 1.24 & 1.29). Additionally, the Ministry of Roads and Public Works has the function of formulating and implementing policy for the country’s construction industry (ACRef 1.3 & 1.12). It can therefore be concluded that this Ministry is the ‘manager’ or the ‘leader’ of the construction industry. However, a number of interviewees were of the view that the construction industry as a whole has ‘no manager’ whatsoever. The general feeling of the interviewees was that the organizational effectiveness of the construction industry was quite low (ACRef 1.21, 1.20, 1.23, 1.30 & 4.11).
The Ministry of Local Government (City/Municipal/County Councils) regulates the activity of the private sector by checking proposed projects and control of the developments in accordance with the Building Code and Planning regulations ((ACRef 1.29, 6.11 & 6.12). Practices of contractors and professionals are further regulated by their respective professional institutions or umbrella bodies. The main umbrella body for contractors is KABSEC (Kenya Association of Building & Civil Engineering Contractors), while the main professional bodies are: Architectural Association of Kenya, Institute of Engineers of Kenya and Institute of Quantity Surveyors of Kenya (ACRef 1.13, 1.17 & 1.23).

In year 2006, numbers of contractors and professionals were estimated as follows: (i) contractors - 2500 No; (ii) registered engineers - 2000 No; (iii) registered architects - 1090 No; and (iv) registered quantity surveyors - 560 No. Appendix D gives a summary of contractors of various categories in the Ministry of Works Register of Contractors, as at 15th July 2006. The classes of contractors are based on the contractors’ production potentials and specializations. As pointed out in Section 7.6 of Chapter VII the criteria of contractor classification in Kenya is questionable and is therefore an area for further research.

Feedback in the construction industry of Kenya was observed to be rather poor (ACRef 2.6 to 2.8, 2.12 & 2.14). Feedback, in this context, refers to the *back-and-forth flow of information* amongst the industry participants for input into further production processes. It does not refer to the *sequence of information-action-consequence* which constitutes feedback control in systems, and which naturally goes on undeterred by people’s unawareness or awareness, as explained in Section 2.5.2 of Chapter II. The information considered necessary to flow in the industry includes performance of past projects, contractors’ experience and workload and research findings. The construction industry participants in Kenya point out that the feedback process is quite slow and that production decisions are not sufficiently informed by the feedback process in the industry.

### 4.2.2 Outside the System

Entities outside the system boundary of the construction industry of Kenya, falling in the industry’s environment, were categorized as follows: -

1. Physical planners and legislators such as the Ministry of Lands;
2. Developers and consumers (individual & institutional) of constructed space, including all other government ministries (ACRef 2.2, 2.3, & 3.10);
3. Country’s economy – fiscal & monetary policy, donor funding, growth & development, investor confidence, profit expectations etc (ACRef 3.1, 3.2, 3.4, 3.6, 3.7 & 3.11);
4. Politics – governance, public & investor confidence in the government, etc (ACRef 4.39);
5. Other countries – competitors for resources and markets for services; examples: Uganda, Tanzania, Malawi, Botswana, Ghana, South Africa, Namibia, USA & Australia (ACRef 3.9).
Influences of these entities on the construction industry are generally viewed as exogenous variables to the construction process. The environment provides demand for construction services, provides input resources and absorbs the output of the construction process (ACRef 3.14, 3.16, 3.17, 3.20, 320 & 3.21). Specific factors of the Kenyan construction industry’s environment, which influence production activity in the industry, were enumerated as follows:

1. Gross National Product – absolute, growth & per capita;
2. Technological developments;
3. Social pressures;
4. Political instability
5. Interest rates;
6. Credit facilities;
7. Construction prices;
8. Inflation;
9. Physical planning;
10. Population growth;
11. Government – privatization policy and expenditure on buildings & infrastructure;
12. Exchange rates;

These factors are generally the same as the generic determinants of construction demand that are observed in construction economics theory, as explained in Section 2.3 of Chapter II. The combined effect of all the ‘environmental’ factors on the construction industry as a whole is the level of demand for constructed space stimulated by the factors, jointly or individually, in the property industry. The state of the environment determines the amount of constructed space demanded from the real estate industry (ACRef 3.10, 3.11, 3.14, 3.18, 3.19, 4.18 to 4.20, & 4.25). The constructed space demand results in construction service demand if the existing stock of constructed facilities in the property industry is not adequate to meet the constructed space demand. This phenomenon is pursued further in Section 5.3 of Chapter V.

Environmental pollution is a significant output of the construction industry (ACRef 3.22). In Kenya, costs of pollution are said to be increasing (ACRef 3.23). The national Environmental Management Authority (NEMA) of Kenya is currently undertaking elaborate research aimed at developing appropriate environmental management tools. Environmental pressure groups have continuously suggested that polluter fines should be up to 10% of company turnover or even higher, and that polluters be required to restore natural habitats they have damaged to pristine conditions and replace lost flora and fauna. A likely outcome of such measures is rise in total development costs; environmental costs will have to be incorporated, not only in feasibility appraisals but also in contractors’ tenders (ACRef 3.23).

4.2.3 Problems of the Construction Industry

As stated before, construction industry participants in Kenya generally observed the industry’s performance to be sub-optimal and explained aspects of this performance in various ways. Table 4.1 summarizes the
participants’ performance judgment in terms of 10 major problem categories. Each problem category is stated together with a brief explanation which the industry participants give for it, as evidenced by the documentary and interview data presented in Appendix C. The problems touch on both the government – particularly the ministries of Roads & Public Works and Local Government – and the private sector (professionals and contractors).

### Table 4.1 Industry Problems and their Explanations

<table>
<thead>
<tr>
<th>Problem</th>
<th>Explanation</th>
</tr>
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| 1 Low construction demand in the formal sector | • Source of construction demand is limited to Kenya (ACRef 6.4);  
• Shortage of market information for investment decision making (ACRef 4.44). |
| 2 High construction demand in the informal sector | • The nature of most building works is informal (ACRef 6.11.11);  
• Inefficiency in the Local Authorities’ development control (ACRef 1.29 & 6.11.6). |
| 3 Fluctuations in construction demand | • Unexpected changes in government expenditure policies (ACRef 4.35);  
• Business cycles in the national economy (ACRef 4.34);  
• Politics - uncertainty from change to multi-party politics and national elections (ACRef 4.39). |
| 4 Project delays and cost overruns | • Poor project planning, control & coordination (ACRef 2.6 & 6.11.3);  
• Poor institutional & regulatory frameworks (ACRef 1.29, 4.23, 6.11.6 & 6.11.7);  
• Inefficiency of procurement systems (ACRef 6.11.2). |
| 5 Construction policies and targets not commensurate with the construction industry capacity | • Poor flow of information between policy makers and the lower levels of the industry participants (ACRef 2.8 & 2.9). |
| 6 Absence of a coherent set of policies and national goals for the construction industry | • The industry is poorly managed (ACRef 1.21, 1.22, 4.23, 6.11.7 & 6.11.16). |
| 7 Failure to keep high calibre manpower in the industry | • Skilled manpower is attracted to more lucrative jobs outside the industry (ACRef 3.9, 4.38). |
| 8 High costs of construction | • Unnecessarily high standards for construction materials (ACRef 6.6). |
| 9 Unsustainable use of natural resources; environmental degradation | • Failure to account for environmental effects in feasibility appraisal; polluters are not fined (ACRef 3.23). |
| 10 Low research activity in the construction industry | • Lack of government funding for Research & Development (ACRef 6.11.9);  
• Market research in construction & real estate sectors is poorly done (ACRef 4.41, 6.16 to 6.19). |

**Note:** Table compiled from the documentary & interview data shown in Appendix C

Some of the problems originate from the construction industry itself while others originate from the industry’s environment. People normally judge effectiveness of an organization using parameters which they feel constitute the organization’s goals (Schoderbek, Schoderbek & Kefalas 1980). Therefore, these ten problems highlight areas which organizational design of the industry should pay great attention to. The construction industry participants suggested various policy changes for solving the problem of excessive fluctuations and stunted growth in construction output in Kenya. In Section 6.4 of Chapter VI, these policy suggestions are presented and appraised in the light of insights gained from a system dynamics model of the construction industry.
4.3 System Behaviour

As stated in Section 3.2 of Chapter III, the behaviour of a system is normally described in terms of the time-variance of its levels or rates. In this Section, the behaviour of the construction industry of Kenya is described using the time-variance of its annual output levels from 1964 to 2003. Annual construction output is the rate at which the stock of constructed space is increased every year. It is also the level of the production capacity of the industry, particularly when there are no resources lying idle in the industry. The overall behaviour of the construction industry as a whole – formal sector plus informal sector construction activity – is described first, and then the formal (or monetary) construction activity focused on.

4.3.1 Overall Total Construction Output

The overall total construction output is the sum of the recorded construction output and the informal sector construction output which is estimated as explained in Section 3.5.1 of Chapter III. While the recorded total construction output was rather stunted in growth, the overall total construction output was not, as shown on Figure 4.2. In this Figure, adjusted TCO, unadjusted TCO, monetary TCO refer to overall total construction output, recorded total construction output and total monetary construction output, respectively.

![Figure 4.2 Total Construction Output in Kenya; 1964 to 2003](image)

*Note*: the figure shows time-variance of construction output levels at constant (1982 prices); the effect of inflation is removed.

The recorded total construction output exhibits an upward trend with a reducing gradient while the overall total construction output exhibits a continual upward trend. Figure 4.2 also shows that the profile of the monetary total construction output closely resembles that of the unadjusted TCO, although the monetary TCO is lower. This is because the monetary construction output was obtained by deducting the traditional (non-monetary) private sector building from the recorded construction output.
Inclusion of informal sector output in the construction output figures added significantly to the overall total construction output figures. Its addition to private building output ranged from 1.65% (in 1984) to 168.95% (in 2003), while its addition to the total construction output ranges from 1.07% (in 1984) to 61.65% (in 2003), as shown in Appendix E. This implies that informal sector construction in Kenya is so huge that it should not just be left unregulated. If an informal sector must remain in the construction industry of Kenya, then it needs to be managed more imaginatively for the sake of the manpower engaged in the sector and the owners or users of the informal constructed facilities.

However, the overall total construction output portrays the construction industry of Kenya as having been generally vibrant in activity since independence. This picture appears to be more optimistic than the picture implied in the industry participants’ feelings. The industry participants considered construction activity in Kenya to have hit an all-time-low at various times, particularly in the 1990s (ACRef 4.34); the building sector was particularly rather dormant in 1990s, despite the vibrancy of construction activity which would be inferred from the overall construction output figures. This discrepancy is expected since informal sector and non-monetary sector construction activities do not normally give work to established consultants or contractors engaged in formal construction business.

The total monetary construction output was generally greater than the total non-monetary construction output (inclusive of the informal sector construction output). Appendix E shows that the percentage of monetary construction output was about 75% (on average) of the overall total construction output over the period 1964 to 2003. This suggests that construction industry policy in Kenya would be relatively more realistic if it were to streamline the formal sector first, and then incorporate the informal sector. For that reason, this study focused on the monetary construction sector. It used the monetary (i.e. formal) construction output data to investigate the system archetypes operating in the construction industry of Kenya, and to develop regression and system dynamics models of the industry’s construction.

In this study, it was considered unrealistic to combine formal and informal sector construction activities in a system dynamics model of construction activity in Kenya because the construction process, and by implication, the feedback control structure of the monetary construction sector are quite different from those of the informal construction and the non-monetary construction sectors. For example, the non-monetary (traditional) and informal sector construction processes do not involve physical planning approval or regulation by local authorities (Mitullah & Wachira 2003, Wells 2001), which are key factors considered in conceptualizing system delays in this study.

Therefore, all the results of data analyses presented from Section 4.3.2 onwards focus on the monetary construction output in Kenya. The term ‘formal’ is used in place of ‘monetary’, because the concept of construction output in the study was the physical quantity of the output rather than the cost value of the output; the monetary value was only used as a surrogate for the quantity of constructed space.
4.3.2 Relative Volume of Formal Construction Output

The relative volume of formal construction output in Kenya had a downward trend for ¾ of the study period. Figure 4.3 shows the relative volume of construction output (i.e. relative to the Gross Domestic Product [GDP]) in Kenya from 1964 to 2003. It shows that from 1971 to 2003, the trend of the relative volume was generally downward. As explained in Sections 1.1.1 and 1.2.2 of Chapter I, the trend of the relative volume of construction output in a country should evolve as the country develops from being a less developed country (LDC), through being a newly industrialized country (NIC), and into being an advanced industrialized country (AIC). The trend shown in Figure 4.3 is therefore not the one expected of output from a growing construction industry, particularly in a developing country.

![Figure 4.3](Image)

**Figure 4.3 Relative Volume of Construction Output in Kenya; 1964 to 2003**

*Note:* the figure shows time-variance of the relative volume of construction output (i.e. construction output ÷ GDP); the decreasing trend implies that GDP levels grew at a faster rate than construction output levels.

This downward trend of the relative volume of construction output in Kenya implies that in the study period, the construction market in the country remained smaller than the size necessary for continual growth and development of the construction industry. A limiting effect of the market size started operating in the industry as early as 1970. This suggests that policy interventions aimed to improve growth and development of the construction industry of Kenya need to be more revolutionary than any of the policy interventions applied to the industry since 1970.

4.3.3 Variance of Formal Construction Output

Total formal construction output fluctuated very widely between 1964 and 2003. From 1972 onwards, the output dropped by about 35% on average and rose by about 75% on average, with about 9 to 10 years between troughs or peaks. The amplitude - difference between peaks and troughs - of the cycles was about Kshs 2,675 Million on average. Figure 4.4 shows the annual total construction output from 1964 to 2003. It also shows a trendline of
the output, which has a decreasing gradient, indicating that during that period, the industry generally grew but at a decreasing rate.

It appears that the construction activity was never stable at any time between 1964 and 2003; it was either rising or falling. After Kenya’s independence in 1963, the construction output generally grew steadily up to 1972, but dropped rather sharply in 1973, perhaps because of the global oil shocks of the early 1970s. The output then grew steadily in the following nine years, reaching its maximum - rate of about Kshs 7,000 Million per Year - in 1981. From that year, the annual output oscillated erratically and excessively, about a fairly constant level - of about Kshs 6,000 Million per Year, with amplitude of about Kshs 2,750 Million on average.

Construction industry participants in Kenya have experienced the consequences of this excessive fluctuation in construction activity. When a drastic fall in construction activity occurs, the construction industry loses its production capacity; manpower moves to other industries in the country and abroad and many construction firms run bankrupt (ACRef 4.38). During recovery, the shortage of contractors leads to increase in tender prices and sometimes poor quality work (ACRef 4.37). Therefore, need for stability of construction activity in Kenya cannot be overemphasized.

The fluctuations are normally explained as natural and inevitable responses of the industry to the political climate and business cycles in the economy, which are major constituents of the industry’s environment (ACRef 4.34 to 4.36), and are commonly understood to lie outside the control of the industry. From that view point, the fall of construction activity in 1984 was interpreted to be a consequence of the 1982 attempted \textit{coup d’état}, while that of 1994 was interpreted to be a consequence of political uncertainty caused by ethnic clashes of 1992 and disturbances preceding the first multi-party election in 1992. These interpretations are understandable, after
all construction demand, and by implication output, could not have thrived in conditions of political uncertainty or economic stagnation. However, the interpretations imply helplessness on the part of the industry’s policy maker, contractor and consultant. The industry participants ‘understand’ that ‘what ails the industry is out there and nothing much can be done about it. …’

It appears that the structure of the construction industry makes the industry so vulnerable to the vagaries of its environment that the industry participants naturally consider the ‘enemy to be out there’; they do not recognize influence of the industry’s own feedback structure on its behaviour. However, from a systems viewpoint, there is no ‘out there’ to blame for systems’ behaviour. As Senge (1990: 20) explains, “out there’ and ‘in here’ are usually part of a single system.” Therefore, despite the fact that swings in the economy or political uncertainty are expected to adversely affect construction activity, there are measures that the construction industry itself could have taken to minimize, if not to eliminate, the adverse effects of these swings, as explained hereinafter.

Comparing the output graph in Figure 4.4 with generic output graphs of complex systems amplified in Braun (2002) and Senge (1990), reveals that there were two major system archetypes operating in the construction industry of Kenya between 1964 and 2003. The fact that the construction output exhibits excessive fluctuations indicates that a balancing process with a delay was one major system archetype operating in the construction industry in that period. Additionally, the fact that the construction output exhibits a reducing rate of growth indicates that limits to growth was another major system archetype operating in the industry in the same period. None of the other nine system archetypes - explained in Section 2.5.3 of Chapter II – explains the systemic behaviour of the construction industry of Kenya as the balancing process with a delay and the limits to growth archetypes do.

The balancing process with a delay is a system archetype that explains instability in many socio-economic systems. The theory of this archetype is briefly explained in Section 2.5.3 of Chapter II. In paraphrase, an organization’s corrective action - in response to, for example, changes in its environment - can end up being more than needed, if the organization is not conscious of the delays in the system’s feedback structure. This causes oscillation in the results of the action.

In Kenya, construction work for both public and private clients is executed by the private sector contractor. When changes in the market for construction services occur, the private sector aggressively responds accordingly, to vary its capacity - paying little or no cognizance of the influence of information and technical delays in the construction industry’s production system. This aggressive response of the construction industry to changes in construction demand appears to be the fundamental cause of fluctuations. According to Senge (1990: 379), “in a sluggish system, aggressiveness produces instability. Either be patient or make the system more responsive.” This observation suggests that a possible approach to minimizing fluctuations in construction activity is to regulate the private sector response to construction demand – a really challenging thing to do, since private sector response to construction demand has hitherto been an unregulated action.

The limits to growth archetype explains stunted growth in output of many socio-economic systems. As Figure 4.4 shows, the gradient of the construction output trend line had a constantly decreasing rate of change over a
whole 40 years (1964 to 2003), indicating that the industry’s *active production capacity* was stunted in growth over this period. For a period of 22 years – from 1981 to 2003 – the maximum output figure was about Kshs 7,350 Million in 1997, which was not significantly different from the figure of Kshs 7,000 Million in 1981. The theory of the limits to growth archetype is also briefly explained in Section 2.5.3 of Chapter II. In paraphrase, a reinforcing process of accelerating growth in a system eventually encounters a balancing process as the limit of that system is approached; continued efforts to increase growth in the system produce diminishing returns as system’s limits are approached. A limiting factor may come from within the system or from its environment.

For the construction industry of Kenya, the growth limiting factor appears to have been originating from the industry’s environment because *a considerable amount of the industry’s production capacity was frequently idle* in the period 1964 to 2003. This idle capacity was the rationale for defining one system dynamics model variable in this study, termed as Contractor Redundancy Percentage, as the amplified in Section 4.3.5 of Chapter IV. A factor that appears to have been the major limiting factor to the growth of the construction industry of Kenya is construction demand in the country (ACRef 4.34, 4.35 & 6.4). This observation suggests that infrastructure and housing development goals in Kenya were generally not well achieved in the period 1964 to 2003. As explained in Section 1.2.2 of Chapter I, Kenya’s needs for constructed facilities, which are documented in the country’s long-term development plans, strongly indicate that the volume of output expected from the construction industry continually increased since independence in 1963. If as much workload as implied in the national development plans were injected into the economy of Kenya, construction demand would not have been a limiting factor to growth of the output.

More government investment could have brought in more construction demand, thereby removing the limiting effect of construction demand. However, such government action would not necessarily have brought stability of the construction industry. For example, Ofori (1988) observed that after a long period of massive government investment in property development in Singapore, construction demand eventually fell drastically and many contractors were rendered redundant. Therefore, increasing government investment is not a leverage point for instilling stability into a construction industry; leverage points are more likely to be found in promoting the industry’s ability to operate in a stagnant or contracting economy. Additionally, as Ofori (1984) argues, emphasis should be put on *what the industry itself can do*, since experience has shown that it is naïve to expect governments to shield the industry from the effects of unfavourable economic conditions. The solution therefore, remains with the industry; it is not ‘out there.’

Construction demand comes from the construction industry’s environment, and is implied by the country’s economic conditions, whose major indicator is the Gross National Product (GNP). However, while the construction output rose and fell the absolute GNP had a generally rising trend, as analysis of data in Appendix D showed. It is the GNP growth rate and the construction output growth rate which appear to have been somewhat synchronized. Line graphs of these rates are shown in Figure 4.5. There is a remarkable pattern in the growth rates, when they are viewed jointly.
Figure 4.5 GNP and Formal Construction Output Growth Rates in Kenya; 1964 to 2003

*Note:* The relationship illustrated here is the joint pattern of the oscillations exhibited by the two graphs; it is not their correlation coefficient.

As Figure 4.5 shows, the growth rates are not in phase; one leads the other. Crests and troughs of the GNP growth rate lead those of the TCO growth rate by 1 to 3 years. For example, the GNP rate crest of 1966 was followed by the TCO growth crest of 1967, while the 1971 GNP growth crest was followed by the 1974 TCO growth crest. Although the GNP and TCO crests appear to have coincided in 1971 and 1985, note that the TCO growth crests were responding to earlier (1969 & 1983) GNP growth crests. The lag structure portrayed in Figure 4.5 implies that the time required for *unsatisfied demand for constructed space in the economy* to start translating into construction output, ranged from 1 – 3 years over the study period. That was the time required to appraise development feasibility, complete design, obtain planning approval, tender and mobilize construction activity. Thereafter, the unsatisfied demand translated into construction workload in the industry.
Another observation from Figure 4.5 is that the TCO growth rate fluctuates more that the GNP growth rate; the TCO growth amplitudes are larger than those of the preceding GNP growth. This agrees with the World Bank (1984) observation that construction output varied more than GDP in Kenya.

In the light of the foregoing, the construction industry of Kenya needs to consider prescriptive actions which are fairly independent of government expenditure and which the construction industry itself can do. A possible solution to the limiting factor of demand is to purposefully expand the industry’s source of demand beyond the economy of Kenya, thereby weakening the impact of the economy on the industry. As Braun (2002) and Senge (1990) explain, the prescriptive action for handling a limits to growth scenario is to focus on removing the limit or weakening its effect rather than to continue driving the reinforcing process of growth. Where the limit comes from the environment “expansionistic thinking is a key competency” (Braun 2002:3) for handling the limits to growth problem. Such thinking is implied in a suggestion given in 1985 to “help Kenya’s construction industry get out of the doldrums” (ACRef 6.4). However, there is no evidence whether that thinking was pursued or not.

4.3.4 Sectoral Construction Output

In the construction industry of Kenya, the six client-use sub-sectors which constitute the industry can be grouped into two fairly distinct categories of the construction supply process, namely: building construction activity and civil engineering construction activity. Building projects are executed by general building contractors while civil engineering projects are executed by civil engineering contractors. There appears to be no significant difference between execution of residential and non-residential building works. For that reason, analysis of sectoral contributions to the total construction output focused on these two major sectors.

Three major observations were made on the analysis of sectoral contributions to the total formal construction output. Firstly, the formal building construction output (BCO) and the civil engineering construction output (CECO) fluctuated very widely, in the period 1964 to 2003, just as the total formal construction output described in Section 4.3.3. However, while the BCO had growth and decay, CECO had continual growth, as shown in Figure 4.6. From 1989, the CECO increased while the BCO decreased, leading to the stunted overall growth of the industry as a whole. The growth limiting factor (i.e. construction demand) appears to have impacted more on the building construction than on the civil engineering construction. This seems to have occurred particularly in the 1990s when the government changed its role in housing, from being mainly a developer to being mainly an enabler to the private sector developer (ACRef 3.14 & 3.18). In this policy scenario, the percentage of public housing construction output to the overall total construction output (i.e. output adjusted for informal sector activity) fell from 7% in 1990 to 2% in 2003.
Secondly, construction industry consultants in Kenya feel that the government’s client role in the industry has gradually fallen from its level of 60% in the 1980s and before, to about 20% today (ACRef 1.4, 1.21 & 4.12), implying that the private sector client role today is 80%, but not the 35% observable from the recorded statistics. This feeling was strongly supported by the results of the quantitative data analysis, particularly in respect of the building sector. The percentage of public building output to the overall total construction output has remained below 20% since 1991; as at 2003 the public building output was 13% of the overall total construction output, as detailed in Appendix G.

Finally, government’s client role in the construction industry of Kenya remains quite high in the formal construction activity. The public sector construction output rose rather steadily from 37% in 1964 to 84% in 1992 but fell to 70% in 2003, as shown in Appendix G. Growth in public construction output was mainly in the civil engineering construction. The percentage of CECO remained about 50% in the 1960s and the greater part of the 1970s, fell to its lowest of 38% in 1979, and then rose steadily to about 70% in 2003. Therefore, formal construction activity in Kenya remains vulnerable to changes in the government’s capital expenditure, although that vulnerability is more in the civil engineering construction activity than in the building construction activity.
4.3.5 Estimating Average Contractor Output and Contractors

The numbers of contractors in the Ministry of Works Register of Contractors in various construction trades in 2006 are shown in Appendix D. In that Register, building contractors constitute about 80% while civil engineering contractors constitute about 10% of the number. The remaining 10% contains specialist contractors — in mechanical and electrical installations — who are normally sub-contractors to the main building or civil engineering contractors. Data on the numbers of contractors in previous years were not available to as much detail as given in Appendix D for year 2006. All the same, from the qualitative data in Appendix C, it is evident that the total number of contractors rose from a relatively small figure in 1964 to about 5000 in the 1980s, then fell to about 1500 in 2005 (ACRef 1.5, 1.13, 1.23). This observation was the basis used in this study to estimate the average contractor output (ACO [Output/Contractor/Year]) and the number of contractors in Kenya, from 1964 to 2003.

From the documentary data (ACRef 1.5, 1.13 and 1.23), figures for the total numbers of contractors involved in formal construction activity in Kenya could be realistically inferred for the years 1981, 1988 and 2003 as being approximately 5000, 3000 and 1500, respectively. Given the number of contractors and the annual construction output, ACO was simply computed as a quotient of the construction output and the number of contractors for the years 1981, 1988 and 2003, as shown on Table 4.2. Using curve interpolation and linear extrapolation functions in Powersim Studio (a system simulation software), the ACO for 1964 was estimated, and from it the number of contractors in 1964 also approximated.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Monetary Construction Output; (Kshs M at 1982 Prices)</th>
<th>Number of Contractors</th>
<th>Average Contractor Output; Overall (Kshs M/Contractor/Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>1,767.60</td>
<td>1768</td>
<td>1.00</td>
</tr>
<tr>
<td>1981</td>
<td>7,001.22</td>
<td>5000</td>
<td>1.40</td>
</tr>
<tr>
<td>1988</td>
<td>6,354.20</td>
<td>3000</td>
<td>2.12</td>
</tr>
<tr>
<td>2003</td>
<td>6,908.24</td>
<td>1500</td>
<td>4.61</td>
</tr>
</tbody>
</table>

In adopting this estimating method, it was assumed that the ACO grew as a smooth curve from 1964 to 2003. Assumption of the curve pattern of ACO growth appeared to be more plausible than assumption of a linear pattern of ACO growth, because curve interpolation was observed to link up the known points of the ACO more accurately than linear interpolation did.

From these three data points — 1981, 1988 and 2003 - the ACO for the other 37 years were estimated using curve interpolation and linear extrapolation functions in Powersim Studio, and the expected numbers of busy contractors also calculated by simple arithmetic. The estimates of ACO and contractors for the whole period –
1964 to 2003 – are show in Appendix G. This time series of estimated contractors is one set of the reference data used to validate the system dynamics model developed in Chapter V.

The numbers of contractors shown in Appendix G are estimates for contractors who could be considered to have been fully engaged in the formal construction activity every year, at a given level of the ACO from 1964 to 2003. It is from these estimates that the percentage of contractors getting redundant in the industry every year - due to shortage of work in the formal sector - was also estimated as explained in Section 5.5 of Chapter V.

4.4 Time Series Regression of Construction Output

This section presents the results of ARIMA regression and the multiple regression of construction output. In the multiple regression analysis, construction output was regressed on Gross National Product (GNP) and misery index. As stated before, GNP and misery index were the two explanatory variables whose data were obtainable in Kenya for the whole period of this study. The construction output used in the regression was the total formal construction output from 1964 to 2003. In the regression modeling the sample data used were for the period 1964 to 2000; data for 2000 to 2003 were held out and used to test the ‘out of sample’ forecasting accuracy of the models. The level of significance (α level) used to test the regression coefficients was 0.05. Construction output and GNP time series were observed to be non-stationary in level, but their first differences were stationary. Misery index series was stationary in level.

4.4.1 Stationarity Tests

Construction output and GNP exhibit upward trends while misery index appears not to have any trend, as shown in Figures 4.7, 4.8 and 4.9. Therefore, while Construction output and GNP are definitely non-stationary in level, misery index is likely to be stationary in level.

![Figure 4.7 Graph of Construction Output](image-url)
To confirm the preliminary deductions based on the graphical analyses above, unit root tests were carried out on the variables, and two conclusions made. Firstly, the first differences of Construction Output and GNP are stationary time series. Augmented Dickey-Fuller (ADF) tests show that the first differences do not have unit roots, as shown on Table 4.3 and 4.4. This implies that construction output and GNP are both random walks (i.e. integrated of order 1).
Table 4.3 ADF Test of Stationarity of the First Difference of Construction Output

Null Hypothesis: 1\textsuperscript{st} difference of Construction Output has a unit root

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-6.442849</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.615588
- 5% level: -2.941145
- 10% level: -2.609066

Table 4.4 ADF Test of Stationarity of the First Difference of GNP

Null Hypothesis: 1\textsuperscript{st} difference of GNP has a unit root

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.759127</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.632900
- 5% level: -2.948404
- 10% level: -2.612874

The p-values on Tables 4.3 and 4.4 are less than $\alpha$ (= 0.05) and for that reason the null hypotheses – that the 1\textsuperscript{st} differences have unit roots – were rejected. The first differences of construction output and those of GNP were therefore considered to be stationary series.

Secondly, misery index is stationary in level. The ADF test of Misery index level shows that the series does not have a unit root, as illustrated on Table 4.5. The p-values on Tables 4.5 is less than $\alpha$ (= 0.05) and for that reason the null hypothesis – that the level of misery index has a unit root – was rejected. The variable was therefore considered to be stationary in level.
Table 4.5 ADF Test of Stationarity of Misery Index

Null Hypothesis: Misery Index has a unit root

<table>
<thead>
<tr>
<th></th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-3.134547</td>
<td>0.0323</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.615588
- 5% level: -2.941145
- 10% level: -2.609066

Stationary time series data of construction output, GNP and misery index were then used for ARIMA and multiple regression analyses as follows.

4.4.2 ARIMA Regression

The stochastic process of Construction Output was observed to be neither a predominantly autoregressive (AR) process nor was it a predominantly moving average (MA) process. In a correlogram of the first difference of construction output, patterns of autocorrelations (AC) and partial autocorrelation functions (PACF) did not clearly resemble either of the theoretical patterns for identification explained, for example, in Gujarati (2003: 845). That correlogram is shown in Figure 4.10, and suggested that the underlying stochastic process of the Construction Output time series was a mix of AR and MA processes.

<table>
<thead>
<tr>
<th>Autocorrelation</th>
<th>Partial Correlation</th>
<th>AC</th>
<th>PAC</th>
<th>Q-Stat</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.071</td>
<td>0.2108</td>
<td>0.646</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>-0.184 -0.190</td>
<td>1.6722</td>
<td>0.433</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.020 -0.051</td>
<td>1.6904</td>
<td>0.639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>-0.100 -0.147</td>
<td>2.1446</td>
<td>0.709</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>-0.177 -0.226</td>
<td>3.0162</td>
<td>0.906</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>-0.122 -0.247</td>
<td>4.3376</td>
<td>0.631</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.110 -0.057</td>
<td>4.9432</td>
<td>0.667</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>-0.080 -0.243</td>
<td>5.2713</td>
<td>0.728</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.071 -0.079</td>
<td>5.6329</td>
<td>0.786</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.226 0.069</td>
<td>0.4126</td>
<td>0.569</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0.053 0.033</td>
<td>8.5759</td>
<td>0.661</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>-0.108 -0.070</td>
<td>9.2644</td>
<td>0.580</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>-0.070 -0.073</td>
<td>9.5676</td>
<td>0.729</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>0.133 0.143</td>
<td>10.693</td>
<td>0.710</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0.145 -0.032</td>
<td>12.099</td>
<td>0.672</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>-0.089 -0.020</td>
<td>12.660</td>
<td>0.696</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.10 Correlogram of the first difference of Construction Output

On the basis of the observations made on the correlogram in Figure 4.10, regressions of various AR and MA combinations were run and their explanatory powers tested. In the end, it was the ARIMA (1, 1, 1) model that showed best results. Therefore, the ARIMA process that most comprehensively describes variability of Construction Output in Kenya between 1964 and 2003 is the ARIMA (1, 1, 1) process, which means that the
process has 1 autoregressive term and 1 moving average term, and that construction output level data are integrated of order 1. The ARIMA (1, 1, 1) is shown on Table 4.6 below.

**Table 4.6 ARIMA Model of Construction Output**

Dependent Variable: Difference of Construction Output

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>69.96422</td>
<td>17.37347</td>
<td>4.027072</td>
<td>0.0003</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.525011</td>
<td>0.148351</td>
<td>3.538971</td>
<td>0.0013</td>
</tr>
<tr>
<td>MA(1)</td>
<td>-0.997067</td>
<td>0.077380</td>
<td>-12.88526</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared: 0.264109
Adjusted R-squared: 0.218115
F-statistic: 5.742340
Prob(F-statistic): 0.007396
Durbin-Watson stat: 1.836826

Although the R² value of the ARIMA model is rather low, the regression coefficients are statistically significant and the Durbin-Watson (DW) statistic indicates that there are no serial correlations in the residuals. However, the fact that the constant term is significant means that there is the *variability of construction output unexplained* by the ARMA (1, 1) process remains significant. The p-value of the F-statistic is less than \( \alpha = 0.05 \), meaning that all the regression coefficients of the AR and MA terms are jointly statistically significant.

From the regression results on Table 4.6, construction output in Kenya can therefore be given by the following ARIMA expression:

\[
dCO_t = 69.96 + 0.53*dCO_{t-1} - u_{t-1} \tag{9}
\]

Where, \( dCO_t = CO_t - CO_{t-1} \) (the first difference of Construction Output) and \( u_{t-1} = dCO_{t-1} - dCO_{t-2} = (CO_{t-1} - CO_{t-2}) - (CO_{t-2} - CO_{t-3}) = CO_{t-1} - 2CO_{t-2} + CO_{t-3} \).

The ARIMA equation above can be expressed in terms of the levels of construction output as follows:

\[
dCO_t = 69.96 + 0.53*dCO_{t-1} - u_{t-1} \text{ can be expanded to } CO_t - CO_{t-1} = 69.96 + 0.53*(CO_{t-1} - CO_{t-2}) - (CO_{t-1} - 2CO_{t-2} + CO_{t-3}).
\]

Opening up the brackets and putting like terms together results in:

\[
CO_t = 69.96 + 0.53CO_{t-1} + 1.47CO_{t-2} - CO_{t-3} \tag{10}
\]

This equation means that the level of construction output in a given year is influenced by its levels in each of the previous three years.
However, the forecasting accuracy of this model is not impressive. The Mean Absolute Percentage Error (MAPE) is 40%, as shown in Appendix I (g). This error level and the low $R^2$ (0.26) value imply that the ARIMA model developed in this study does not comprehensively explain variance of construction output in Kenya in the period 1964 to 2003. Consequently, construction output forecasts based on this ARIMA model would not be sufficiently accurate.

### 4.4.3 Multiple Regression of Construction Output

As described in Section 4.4.1, both construction output and GNP were observed to be random walks. However, the two variables are not synchronized in level as shown in Figure 4.11. Their trends and profiles are not the same. Both variables have a rising trend but GNP has a higher and apparently constant gradient. Construction output has a lower and decreasing gradient as described in Section 4.3.3 before. For this reason, it was concluded that the two series are not co-integrated.

![Figure 4.11 Graphs of Construction Output and GNP](image)

Misery index was found to be stationary in level as shown in Section 4.4.1, and is therefore obviously not co-integrated with construction output which was observed to be non-stationary in level. For these reasons, a co-integrating regression amongst the three variables was considered to be unrealistic. As a result, multiple regression of construction output on the two explanatory variables had to be done using only stationary time series - i.e. the first difference of construction output (dCO), the first difference of GNP (dGNP) and the level of misery index (MI).

Cross correlations between dCO and dGNP were observed to be highest at lags 0, 2, 3 & 4, while cross correlations between dCO and MI were found to be highest at lags 0 & 1. This was evident from the cross correlograms shown in Figures 4.12 and 4.13 below. In each of the figures, the bar graph and cross-correlation...
values indicate the strength of relationship up to lag 16. Lags where cross correlations were highest were the variables expected to give the highest coefficient of determination ($R^2$) of the dCO.

<table>
<thead>
<tr>
<th>DFCO, DFGNP(-i)</th>
<th>DFCO, DFGNP(+i)</th>
<th>i</th>
<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.3041</td>
<td>0.3041</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>0.2735</td>
<td>0.0813</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>-0.0711</td>
<td>-0.2056</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.1776</td>
<td>-0.2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>-0.4535</td>
<td>-0.2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>-0.1171</td>
<td>-0.1262</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>-0.1765</td>
<td>0.0449</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>-0.0434</td>
<td>0.0195</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>0.2068</td>
<td>0.1165</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>-0.0333</td>
<td>0.3134</td>
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<td></td>
<td></td>
<td>10</td>
<td>0.0296</td>
<td>-0.0271</td>
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<tr>
<td></td>
<td></td>
<td>11</td>
<td>-0.0445</td>
<td>0.2369</td>
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<td></td>
<td></td>
<td>12</td>
<td>-0.0669</td>
<td>-0.1614</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>0.0077</td>
<td>-0.0912</td>
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<td></td>
<td></td>
<td>14</td>
<td>0.0270</td>
<td>0.0694</td>
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<tr>
<td></td>
<td></td>
<td>15</td>
<td>-0.0157</td>
<td>-0.0862</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>-0.0331</td>
<td>-0.0183</td>
</tr>
</tbody>
</table>

Figure 4.12 Cross Correlogram of the Difference of Construction Output and the Difference of GNP

<table>
<thead>
<tr>
<th>DFCO, MI(-i)</th>
<th>DFCO, MI(+i)</th>
<th>i</th>
<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>-0.3511</td>
<td>-0.3511</td>
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<tr>
<td></td>
<td></td>
<td>1</td>
<td>-0.3233</td>
<td>-0.1690</td>
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<tr>
<td></td>
<td></td>
<td>2</td>
<td>-0.0103</td>
<td>-0.1028</td>
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<tr>
<td></td>
<td></td>
<td>3</td>
<td>0.1170</td>
<td>0.0003</td>
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<td></td>
<td></td>
<td>4</td>
<td>0.1367</td>
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<td></td>
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<td>5</td>
<td>-0.0212</td>
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<td></td>
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<td></td>
<td>7</td>
<td>0.0638</td>
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<td>0.0598</td>
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<td></td>
<td></td>
<td>9</td>
<td>-0.1262</td>
<td>-0.2308</td>
</tr>
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<td></td>
<td>10</td>
<td>-0.0159</td>
<td>-0.2630</td>
</tr>
<tr>
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<td></td>
<td>11</td>
<td>0.0516</td>
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<td></td>
<td></td>
<td>14</td>
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<td>0.0498</td>
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<td></td>
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<td>0.0191</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>0.0959</td>
<td>-0.0010</td>
</tr>
</tbody>
</table>

Figure 4.13 Cross Correlogram of the Difference of Construction Output and Level of Misery Index

Regression of dCO on the above significant dGNP and MI lags gave a model which had three lagged variables of GNP and one lagged variable of Misery Index. The regression results are shown on Table 4.7. Although the coefficient of dGNP (-2) is not statistically significant (i.e. p-value > α), this variable was maintained in the model because its omission was observed to raise the Durbin-Watson statistic - from 2.299 to 2.412 - thereby increasing the risk of serial correlations in the regression residuals.
Table 4.7 Multiple Regression Model of Construction Output
Dependent Variable: Difference of Construction Output

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>380.3446</td>
<td>374.4972</td>
<td>1.015614</td>
<td>0.3185</td>
</tr>
<tr>
<td>D(GNP)</td>
<td>0.135110</td>
<td>0.041844</td>
<td>3.228881</td>
<td>0.0032</td>
</tr>
<tr>
<td>D(GNP(-2))</td>
<td>-0.061328</td>
<td>0.041926</td>
<td>-1.462787</td>
<td>0.1547</td>
</tr>
<tr>
<td>D(GNP(-3))</td>
<td>0.087465</td>
<td>0.040035</td>
<td>2.184732</td>
<td>0.0374</td>
</tr>
<tr>
<td>MI(-1)</td>
<td>-36.87759</td>
<td>13.90943</td>
<td>-2.651266</td>
<td>0.0130</td>
</tr>
</tbody>
</table>

R-squared 0.374574
Adjusted R-squared 0.285228
F-statistic 4.192379
Prob(F-statistic) 0.008748
Durbin-Watson stat 2.298485

From the regression results shown on Table 4.7, construction output can be given by the following equation:

\[ dCO_t = 380.34 + 0.14 \times dGNP_t - 0.06 \times dGNP_{t-2} + 0.09 \times dGNP_{t-3} - 36.88 \times MI_{t-1} \]  \[\text{[11]}\]

Where, \( dCO_t = CO_t - CO_{t-1} \) (the first difference of Construction Output).

The regression equation above can be expressed in terms of the levels of the variables, as follows:

\[ dCO_t = 380.34 + 0.14 \times GNP_t - 0.06 \times GNP_{t-2} + 0.09 \times GNP_{t-3} - 36.88 \times MI_{t-1} \]

can be expanded to

\[ CO_t - CO_{t-1} = 380.34 + 0.14 \times (GNP_t - GNP_{t-1}) - 0.06 \times (GNP_{t-2} - GNP_{t-3}) + 0.09 \times (GNP_{t-3} - GNP_{t-4}) - 36.88 \times MI_{t-1} \]

Opening up the brackets and putting like terms together results in:

\[ CO_t = 380.34 + CO_{t-1} + 0.14 \times GNP_t - 0.14 \times GNP_{t-1} - 0.06 \times GNP_{t-2} + 0.15 \times GNP_{t-3} - 0.09 \times GNP_{t-4} - 36.88 \times MI_{t-1} \]  \[\text{[12]}\]

This equation means that the level of construction output in a given year depends on: (i) construction output level in the previous one year; (ii) GNP levels in the current year and in each of the previous four years; and (iii) misery index (unemployment + inflation rates) in the previous one year.

The regression coefficients of GNP_t and GNP_{t-3} are positive, implying that GNP in the current year and GNP three years back tend to increase construction output in the current year. This finding is in line with the economic theory explained in Section 2.3.1 of Chapter II and the conceptual framework explained in Section 3.5.4 of Chapter III. However, the regression coefficients of GNP_{t-2} and GNP_{t-4} are negative suggesting that GNP
two years back and GNP four years back tend to decrease construction output in the current year. This observation is not in line with the economic theory explained in Section 2.3.1 of Chapter II or the conceptual framework explained in Section 3.5.4 of Chapter III. Perhaps, the relatively short length of the time series used in the regression is the cause of this anomaly.

The regression coefficient of \( M_{t-1} \) is positive, implying that misery index in the in the previous one year tends to decrease construction output in the current year. This finding is in line with the economic theory explained in Section 2.3.1 of Chapter II and the conceptual framework explained in Section 3.5.4 of Chapter III. Misery index is therefore a leading indicator of construction activity in an economy.

The \( R^2 \) value (0.37) of this multiple regression model is greater than that of the ARIMA model developed in Section 4.4.2 before. Additionally, the forecasting accuracy of the multiple regression model is also better than that of the ARIMA model; its Mean Absolute Percentage Error (MAPE) is 13%, as detailed in Appendix I (j), which is significantly lower than the 40% MAPE of the ARIMA model. On that basis, it can be concluded that in Kenya, modeling annual construction output as a dependent variable explained by other variables is more realistic than modeling the output as a self-projecting variable.

4.5 Conclusion

In brief, three major observations have been made in this chapter. Firstly, entities that constitute the construction industry of Kenya are: legislators, consultants and contractors. Therefore, the main influences at work in the construction industry’s system behaviour are the links amongst these three major entities. Other entities that have influence on the construction industry fall in the industry’s environment, and comprise: developers, policy makers, the general public, politicians, government, the economy as a whole, other countries and Bretton Woods institutions. From a systems point of view, the magnitude of the environmental influence on the construction industry depends on the structure of the links amongst the three major entities in the industry.

Secondly, in the construction industry of Kenya, the underlying system archetype responsible for excessive fluctuations in construction output is a balancing process with a delay, while the archetype responsible for stunted growth in construction output is a limits to growth archetype. Generic prescriptive actions for these archetypes are to imaginatively regulate the system’s response to change in its environment, and to remove the limit or reduce the impact of the limit. These general prescriptions are quite challenging but appear to be realistic for the construction industry of Kenya.

Finally, construction output in Kenya is significantly influenced by its own past levels, past levels of misery index, and past levels of GNP – to as far back as four years. However, the ARIMA and multiple regression models developed in this Chapter have relatively low explanatory power; they do not give sufficiently accurate predictions of the construction output. These time series models are therefore not suitable for comprehensive understanding of the behaviour of the construction industry of Kenya.
For the purpose of developing a system dynamics model of construction output, identification of the underlying system archetypes is the most insightful of three observations explained in this chapter. The next chapter presents a system dynamics model developed for the construction industry of Kenya, to replicate the problem of excessive fluctuations and stunted growth in the industry’s output.
Chapter V

SYSTEM DYNAMICS MODELING

5.1 Introduction

In Chapter IV, the generic system archetypes operating in the construction industry of Kenya from 1964 to 2003 were identified, and the time-variance of construction output, contractors and average contractor output discussed. This chapter presents development of a system dynamics model of construction output, which is based on: (i) construction process at industry level in Kenya, and (ii) features of the two system archetypes operating in the construction industry. The chapter presents quantification of the construction industry as a feedback control system. It discusses results of the data analyses performed to address objective 4 stated in Section 1.3 of Chapter I, amplifying the model variables, model building and model validation.

The system dynamics model of the existing structure of the construction industry system of Kenya was formulated, conceptualizing the problem of construction activity fluctuations and stunted growth in terms of nineteen system variables. As explained in Section 1.6 of Chapter I, the model was particularly for the total (i.e. building plus civil engineering) construction output. The construction industry as a whole was conceptualized as one large corporation, whose annual production is the construction output captured in national statistics every year. Only formal construction output was used in the modelling process because formal construction activity was observed to have produced a larger volume of output than informal (plus traditional construction) activity, in the period 1964 to 2003, as explained in Section 4.3.1 of Chapter IV. Conceptualization of the model variables was generally based on deductions made in the qualitative data analysis, in Sections 4.2 and 4.3 of Chapter IV. However, more ideas were added in the formulation of the model structure, in order to replicate a real life construction industry as closely as practicable. The model variables and their units of measurement were derived from the four basic variables described in Sections 3.5.1 to 3.5.4 of Chapter III.

The modeling process took the following steps: (i) review of construction process in Kenya; (ii) estimation of demand for constructed facilities in the economy of the country; (iii) articulation of the existing feedback control structure - using level-rate diagrams and difference equations; (iv) functional definition of the model variables; and (v) simulation runs. After several simulation runs to ensure the soundness of the model construction, validity of the model was tested using behaviour replication tests, parameter tests and extreme conditions test.

It will be shown that the system dynamics model developed in this study is valid for the purpose of understanding influences of various policy interventions on the behaviour of the construction industry of Kenya. Chapter VII will discuss the insights gained from the reference mode of this model, in the light of the literature reviewed.
5.2 **Construction Process in Kenya**

The construction process at industry level is quite complex; very many activities and participants are involved in the production process of constructed facilities (ACRef 2.1 to 2.14). However, not all the activities (or players) in the production process significantly influence the dynamic behaviour of the industry.

The dynamic behaviour of the construction industry is determined by the *dynamic complexity* of the industry, which involves fewer entities than the *detail complexity* of the industry. Senge (1990) points out that these two types of complexity exist together in a complex system, and that the dynamic behaviour of the system is determined by the dynamic complexity of the system but not by the detail complexity of the same. While detail complexity is indicated by the number of actors and activities in the system, dynamic complexity is indicated by the *number of levels in the feedback control structure of the system* (Forrester 1969, Senge 1990). In a construction industry’s production process, the number of system levels is much smaller than the number of actors and activities in the process. Therefore, despite the multiplicity of activities in the construction process at industry level in Kenya, the number of activities in the production process, which are responsible for the dynamic behaviour of the industry, is rather small.

In this study, the dynamic complexity of the construction industry was conceptualized in terms of *five components* in the production process, namely: (i) demand for constructed space in the country’s economy; (ii) design for the constructed space; (iii) approval for the design; (iv) construction work-in-progress; and (v) stock of constructed space completed. The five components are shown in Figure 5.1. They are fairly distinct occurrences in the construction process, and the arrows indicate the flow of matter and information in the process. From the five components of dynamic complexity, four *level variables* are conceptualized as explained in later.

For one project, the occurrences in Figure 5.1 are fairly sequential but when the industry is considered as a whole, the occurrences are simultaneous. The construction process for civil engineering projects is basically the same as that of building projects. However, the detail complexity of a civil engineering project is different from that of a building project. Generally, a building project has more ‘nitty gritty’ and, by implication team interactions, than a road project of the same size. While components 2, 3 and 4 fall inside the construction industry’s system boundary, components 1 and 5 fall outside the boundary, as explained in Sections 4.2.1 and 4.2.2 of Chapter IV.

The feasibility study (market research or environmental scanning) is done by the property market to establish the unsatisfied demand for constructed space in the economy. As Hillebrandt (2000: 45) pointed out, demand for “new housing will depend on the demand for all housing and the stock of housing.” Also, Raftery (1992:36) remarked that “the demand for built space will only be translated into construction business if there is not already an appropriate building in the right location.” This implies that the existing stock of constructed space generally informs the decision to invest in property development, though not necessarily by way of a sophisticated feasibility appraisal. The construction process therefore, makes a circular sequence of *information-action-consequences*, whereby the information produces actions which have consequences, generating further
information and actions, and so on. This sequence exerts control on the system, as explained in Section 2.5.2, and renders the construction process amenable to system dynamics modeling.

The main physical item flowing in the construction process is constructed space. Constructed space is the item ordered from the construction industry and ultimately supplied to the space consumer. In this study, the unit of measurement for constructed space was the Construction Output Unit (COU), which is the same as the unit of measurement for construction output, used in Section 4.3 of Chapter IV. One COU is equivalent to constructed space estimated at Kshs 1 Million (at Constant 1982 Prices). Use of COU was meant to give the impression of physical output - as opposed to the impression of monetary output – and to aid in checking dimensional consistency of the system dynamics model variables in a neat way.

The COU represents only values of the constructed facilities. It does not include value of the land on which the structures stand. As amplified in Section 3.5.1 of Chapter III, the construction output unit is at constant 1982 Prices, meaning that the effect of price inflation is taken account of in the unit. COU (Kshs Million, at Constant 1982 Prices) is therefore a robust measure of constructed space.
5.3 Estimating Demand for Constructed Space

Demand for Constructed Space (DCS) in the economy determines the rate of production required of the construction industry. From Hillebrandt’s (2000: 45) and Raftery’s (1992: 36) observations stated above, it can be inferred that the unsatisfied (i.e. effective) demand is a difference between the overall demand in the economy and the stock of constructed space in the property industry of the economy. Considering the duration required to put up constructed facilities, construction output observed in a given year is only a fraction of the total workload in the construction industry. Additionally, this workload is only a fraction of the DCS in the economy as a whole.

Since the construction process essentially starts from the DCS in the economy, as shown in Figure 5.1, following the construction process in reverse – starting from the observed annual construction output (the annual change in the Stock of Constructed Space) all the way back to the demand for space in the economy – should give a backcast of DCS. In the construction industry of Kenya, there are three major ‘stopovers’ that one would find along this reverse route. These are the major delays in the construction industry system, namely: time to complete outstanding construction work, time for planning approval and time for design.

A backcasting method was developed in this study and named workload differencing and summation method. The method transforms observed values of annual construction output into values of annual construction demand in the economy as a whole. It was developed by following the construction process in reverse order and taking into account the three major delays, mentioned above. The following explains how the method was developed:

(a) Annual workload in a construction industry was viewed in three perspectives: workload at start of the year, workload during the year, and workload at the end of the year. Since construction activity normally continues throughout the year, the picture given by each of the three perspectives depends on the construction completion rate (CCR) in the industry. CCR over one year is the same as the annual construction output for the year, which is normally recorded at the end of the year. It represents work executed during the year, and was therefore used to estimate annual levels of workload in the construction industry.

Outstanding construction work (OCW) at the end of a year equals OCW at the start of the following year. In Kenya, the average time required to complete outstanding construction work in the industry was observed to be an average of about 3 years (ACRef 4.8, 5.4, 5.5 & 5.7). Therefore, the outstanding construction work at the start of each year is approximately 3 times the output observed for the year.

\[
\text{CCR}_{t \text{ End}} = \frac{1}{3} \text{OCW}_{t \text{ Start}} \tag{13}
\]

\[
\text{OCW}_{t \text{ Start}} = 3 \text{CCR}_{t \text{ End}}
\]

Using this equation, levels of OCW for successive years were computed as shown in the third and fourth columns of Table 5.1.
(b) OCW at the end of a year equals the OCW at the start of the following year. The net change in the OCW in
the course of the year is the difference between workload at the end of the year and workload at the start of the
year.

\[ \Delta \text{OCW}_t \text{During} = \text{OCW}_t \text{End} - \text{OCW}_t \text{Start} \]  

Where, \( \text{OCW}_{t \text{End}} = \text{OCW}_{t+1 \text{Start}} \)

Therefore, given levels of OCW at start of successive years, the net change in the OCW in the course of the year
was estimated as shown in the fifth column of Table 5.1.

(c) Outstanding construction work by year end is the balance of outstanding workload, after addition by
planning approval rate (PAR) and reduction by the construction completion rate (CCR). As stated above, CCR
represents output of construction activity taking place in the course of the year, though it is normally recorded at
the end of the year. \( \text{CCR}_t \text{End} \) is the same as \( \text{CCR}_t \text{During} \) because annual construction output is the average rate
of construction completion for the whole year. PAR increases the level of OCW while CCR depletes it. Therefore,
PAR is the sum of change in OCW and CCR, as shown below:

\[ \text{OCW}_t \text{End} = \text{OCW}_t \text{Start} + \text{PAR}_t \text{During} - \text{CCR}_t \text{During} \]  

\[ \text{PAR}_t \text{During} = \{\text{OCW}_t \text{End} - \text{OCW}_t \text{Start}\} + \text{CCR}_t \text{During} = \Delta \text{OCW}_t \text{During} + \text{CCR}_t \text{During} \]  

Given changes in OCW and CCR values for successive years, PAR was estimated as shown in the sixth column
of Table 5.1.

(d) In Kenya, it takes about 2 years on average, for proposed construction work to go through design and
planning approval, as explained in Section 5.4.3. In one project, design activity and planning approval activity
are generally done in series. Assuming that each of them takes about a year, work at the planning approval stage
in a given year is the work at the design stage in the previous year, since design leads planning approval.

\[ \text{Design completion rate (DCR}_t) = \text{PAR}_{t+1} \]  

\[ \text{DCR}_{t+1} = \text{PAR}_t \]  

Therefore, given values of PAR in successive years, DCR was estimated as shown in the seventh column of
Table 5.1.
Table 5.1 Process of Estimating Historical Demand for Constructed Space

<table>
<thead>
<tr>
<th>Year</th>
<th>OCW at Yr Start</th>
<th>CCR + OCW by Year End</th>
<th>Net Change in OCW During the Year</th>
<th>PAR During the Year</th>
<th>DCR During the Year</th>
<th>Stock of CS at Year End</th>
<th>Demand for CS at Year Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>5,302.81</td>
<td>2,090.29</td>
<td>1,767.60</td>
<td>60,000.00</td>
<td>63,104.77</td>
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</tr>
<tr>
<td>1964</td>
<td>6,855.10</td>
<td>2,090.29</td>
<td>4,616.91</td>
<td>66,384.52</td>
<td>63,642.77</td>
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<td></td>
</tr>
<tr>
<td>1965</td>
<td>6,855.10</td>
<td>4,616.91</td>
<td>2,285.03</td>
<td>68,590.14</td>
<td>65,927.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>9,186.98</td>
<td>2,285.03</td>
<td>3,062.33</td>
<td>9,186.98</td>
<td>4,947.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td>11,072.03</td>
<td>3,062.33</td>
<td>3,690.68</td>
<td>11,072.03</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: (i) To facilitate estimation of the PAR for 2003, the OCW at start of 2004 was estimated by extrapolation; (ii) In order to bring a UDCS (and DCR) of 3,104.77 COU at the very beginning of the simulation, the DCS value must include the CCR for 1964 (1767.60 COU) to offset its effect on the SCS.
(e) *Unsatisfied demand for constructed space* (UDCS) enters the construction industry system through architectural or engineering design of structures. Therefore, work in the process of design in a given year indicates the UDCS in that year, while the work in the process of planning approval represents the UDCS in the previous year.

\[
\text{UDCS}_t + \text{SCS}_t = \text{DCS}_t
\]  \[18\]

Where, SCS is the stock of constructed space in the property industry and DCS is the demand for constructed space in the economy as a whole. Note that UDCS$_t = \text{DCR}_t = \text{PAR}_{t+1}$ as shown in (d) above.

(f) SCS at the end of a given year is the cumulative total of all annual construction outputs (CCR) of the previous years, up to and including that particular year.

\[
\text{SCS}_{\text{End}} = \sum_{t=0}^{t} \text{CCR}
\]  \[19\]

SCS at the end of a year is equal to SCS at the start of the following year. In this equation, it is assumed that the construction demolition rate is zero, which is realistic because in Kenya, building obsolescence and/or demolition has so far been somewhat negligible. Therefore, SCS as at the end of 1963 (start of 1964) was the sum of all annual construction outputs up to 1963.

Since SCS is a *level variable*, any initial value specified for it does not influence the profile of the simulated time series; it only defines the starting point of the SCS time series. For that reason, the value of SCS was ‘arbitrarily’ chosen for this study. It was approximated at a quarter of all the construction output from 1963 to 2003, which is about 60,000 COU (Kshs Millions at Constant 1982 Prices). An exact initial value for SCS was quite difficult to assign since data on the existing stock of real estate developments in Kenya as at 1963 was not obtainable in this study. The choice of a quarter was based on the fact that during the pre-independence era in Kenya, economic conditions and government policy were not conducive to rapid development of property in the country (Maxon 1992, Obudho & Obudho 1992). It is therefore unlikely that SCS in 1963 was significantly different from 60,000 COU.

(g) DCS is given by:

\[
\text{DCS}_{\text{Start}} = \text{SCS}_{\text{Start}} + \text{DCR}_{\text{During}}
\]  \[20\]

This is the equation used to estimate DCS as shown in the last column of Table 5.1.

As shown in step (e) above, UDCS$_t + \text{SCS}_t = \text{DCS}_t$ and therefore UDCS$_t = \text{DCS}_t - \text{SCS}_t$. The initial value (60,000 COU) of SCS is included in the DCS. The initial value should therefore not affect the profile of the simulated construction output (construction completion rate [CCR]) time series because the difference between DCS and SCS, which is the source of dynamic behaviour in the model, includes this initial value in both
variables. The difference of the variables (i.e. UDCS) ensures that the effect of the initial value is cancelled from the very start of the simulation.

Since construction output statistics do not normally include values of the land occupied by the constructed facilities, DCS does not include value of land. Following this *workload differencing and summation method*, DCS values from 1964 to 2003 were estimated, using the annual construction output data collected. The estimated values of DCS from 1964 to 2003 are presented in Appendix H. The created DCS time series and the actual annual construction output time series were then used jointly to build up the reference mode of the system dynamics model of the existing structure of the construction industry of Kenya, as explained in Section 5.5.

### 5.4 Model Variables

A system dynamics model of the existing structure of construction industry of Kenya was conceptualized in terms of nineteen variables of a system dynamics model. The model variables, comprise: 4 levels, 6 auxiliaries, 4 constants and 5 rates. Technical meanings of these variables in system dynamics are briefly explained in Section 3.6.3 of Chapter III. In this Section, the variables are defined and their relationships explained. The build-up of the system dynamics model is described in the next Section, and the model diagrammatically shown in Figure 5.2.

#### 5.4.1 Levels

The level variables in the model are: Stock of Constructed Space (SCS), Outstanding Planning Approvals (OPA), Outstanding Construction Work (OCW) and Contractors (C).

(i) **Stock of Constructed Space (SCS)**

SCS is the quantity of constructed structures – buildings, infrastructure, etc – measured in Construction Output Units (COU), defined earlier. It is increased annually by additional construction output – i.e. the Construction Completion Rate in Figure 5.2. The difference between overall Demand for Constructed Space in the country and the Stock of Constructed Space is the unsatisfied demand which needs the services of the construction industry. As explained in Section 5.3, an initial value of SCS was taken as 60,000 COU to represent the quantity of SCS in Kenya as at the end of 1963.

(ii) **Outstanding Planning Approvals (OPA)**

OPA is the construction design work that has already been completed by consultants and is awaiting *physical planning approval* by local authorities. Currently, planning approval by local authorities is required for private sector projects only. All the same, OPA is a relevant variable for both private and public construction works. In a public construction project, OPA represents construction design work that has already been completed by private consultants or the Ministry of Works, and is awaiting *budgetary approval* by the Ministry of Planning and National Development. OPA is increased by the Design Completion Rate - addition of workload from activities of private consultants and the Ministry of Roads and Public Works - and depleted by the Planning Approval Rate - completion of the physical or budgetary planning approvals.
(iii) **Outstanding Construction Work (OCW)**

OCW is the workload in the process of execution by the contractors in the industry. It is increased by addition of workload from activities of Local Authorities (physical planning) and the Ministry of Planning and National Development (budgetary planning for public projects). In the model, OCW is increased by completions of the approvals (Planning Approval Rate) and depleted by completion of the works (Construction Completion Rate).

(iv) **Contractors (C)**

This variable was used as a surrogate for the construction industry’s production capacity, as explained in Section 3.5.2. It is the total number of general building and civil engineering contractors, and includes the associated management, manpower and machinery required for an effective contractor business. It was observed that the number of contractors fell from about 6000 - when construction demand was very high in the 1980s – to about 1000 – when the demand was very low in the 1990s and 2000s (ACRef 1.5, 1.13, 1.23). In the model, contractors are increased by the Contractor Entry Rate and depleted by the Contractor Redundancy Rate, defined in Section 5.4.4. An estimate of the number of contractors from 1964 to 2003 was computed as described in Section 4.3.5 of Chapter IV.

### 5.4.2 Auxiliaries

The auxiliary variables are: Demand for Constructed Space (DCS), Unsatisfied Demand for Constructed Space (UDCS), Practical Completion Target (PCT), Required Contractors (RC), Average Contractor Output (ACO) and Contractor Redundancy Percentage (CRP).

(i) **Demand for Constructed Space (DCS)**

This is the demand for constructed facilities by the individuals, firms and government in the economy as a whole, and is therefore an exogenous variable to the construction activity. Like the Stock of Constructed Space DCS is measured in COU. It represents the total quantity of demand for the existing and the yet-to-be developed constructed space. The method used for estimating DCS is explained in Section 5.3.

(ii) **Unsatisfied Demand for Constructed Space (UDCS)**

UDCS is the difference between Demand for Constructed Space and Stock of Constructed Space, and its units are therefore COU. It represents the unsatisfied market in the property industry and normally results in demand for new construction.

(iii) **Practical Completion Target (PCT)**

PCT is the proportion of the Outstanding Construction Work which can practically be completed in one year. It is obtained by dividing the Outstanding Construction Work by the Time to Complete Outstanding Work, and is therefore measured in COU/yr. In the existing structure of the construction industry of Kenya, the annual production targets are not preset by the industry’s ‘management’; they are naturally set by the industry’s own feedback control criteria. From the fluctuations of construction activity – described in Section 4.3.3 of Chapter IV – it was inferred that the product completion ‘target’ mainly depends on the Outstanding Construction Workload in the production process. The higher the Outstanding Construction Workload the higher the target.
Required Contractors (RC)

RC is the number of contractors required to complete the Practical Completion Target, at a given level of the Average Contractor Output. It is obtained by dividing the Practical Completion Target (COU/yr) by the Average Contractor Output (COU/C/yr), described below. This variable is different from the level variable Contractors explained before, because there is normally a delay between the time to notice shortage (or excess) of contractors and the time to adjust for the shortage (or excess). While RC represents the ‘ideal’ number of contractors at a given level of Average Contractor Output, Contractors refers to the actual number of contractors in the system whether the adjustment has taken place or not.

Average Contractor Output (ACO).

ACO is the average construction output per contractor per year and is measured in COU/C/yr. The overall ACO (i.e. for building and civil engineering sectors) increased from about 1 COU/C/yr in 1964 to about 5 COU/C/yr in 2003, as described in Section 4.3.5. Estimated ACO values from 1964 to 2003 are presented in Appendix G.

Contractor Redundancy Percentage (CRP).

CRP is the percentage of contractors in a given year, who remain idle in the industry or leave the industry particularly because of being out work. This normally happens when construction demand falls. CRP is estimated by differencing the time series for the number of contractors, described in Section 4.2.5. Its values are shown in Appendix G. CRP is a very oscillatory variable; its values range from 0% to above 60%. It is synchronized with the Contractor Entry Rate, (CER, described in Section 5.4.4) such that the minimum CRP is Zero, which occurs when there is no idle capacity in the industry.

5.4.3 Constants

The constant variables are: Time for Design (TD), Time for Planning Approval (TPA), Time to Complete Outstanding Construction Work (TCO) and Time to Attract Contractors (TAC). These constants are all system delays and their general implications are described in Section 3.5.3. The stated values of the constants are those that apply to the existing construction industry structure, which is the reference mode in this modeling. Estimating constants always has uncertainty; they are at best ‘guestimated’ initially. Then, sensitivity of the model to the parameters is tested, thereby revealing the risk of error associated with the ‘guestimate’. The specific definitions of the constants are as follows.

Time for Design (TD)

TD is the time required for feasibility study, pre-contract design, documentation and tendering. TD and TPA are rather difficult to dissociate. Though the action of planning approval is normally subsequent to the action of design, the documentary data collected shows that the two delays have almost always been lumped together. As observed in Section 4.3.3 of Chapter IV, the time lag between the construction output growth and GDP growth in Kenya is about 1 – 3 years. This implies that the time required for the unsatisfied demand (for constructed space in the economy) to start translating into construction output, is about 1½ years on average. It is within this time that design is completed and planning approval obtained.
It takes the local authorities about 1 year (on average) to approve drawings for proposed projects (ACRef 5.8). For that reason, an estimate of 1 year for both TD and TPA was considered plausible. All the same, TD is generally not considered a significant hold-down in the construction process in Kenya, particularly at the pre-construction stage of a project. Its delay attribute normally becomes more apparent during the construction period. For example, delays in receiving architects’/engineers’ drawings (or instructions) are grounds for extension of contract period in the conditions of the construction contract.

(ii) Time for Planning Approval (TPA)
TPA is the time local authorities (City & Municipal Councils) take to approve proposed construction projects. For most large new buildings (and certainly all of those in the public sector), plans are drawn up by architects and formally approved by the local planning authority, before the project is put out to tender (Wells 2001). This time was estimated at 1 year, as explained above. The proposed private sector developments normally go through the local authorities, but the proposed public projects, particularly executed through the Ministry of Roads and Public Works, do not go through the local authorities. The Ministry of Roads and Public Works undertakes the development control function, for the public projects.

In the approval of public projects, a system delay that may even be greater than the local authority approval delay found in approval of private projects is the time required for budgetary approval and allocation, as evidenced by the documentary data. To give an indication of this delay, below is an excerpt from Appendix C (see ACRef 5.5).

“On paper, there are established procedures to be followed in project funding. According to these procedures, the Treasury should not consider proposals for new buildings or construction projects for inclusion in annual estimates unless all preliminary information about project need, site selection, etc have been undertaken and the MOPW has provided preliminary estimates of costs for the works involved. To make this effected [sic], there are procedures for programme review and forward budgets ensure that needed projects are identified early enough and financial requirements are foreseen at least three years in advance.” Nguyo (1988: 131).

TPA in public projects can therefore be up to 3 years, or perhaps more, on average. All the same, this is a very unpredictable delay (ACRef 5.4, 5.5 & 5.14). In order to keep the modeling simple, TPA was taken as 1 year on average. Since this is a constant, any value can suffice as long as it is considered in estimating the DCS - Demand for Constructed Space - as well. This is because DCS is the main input variable necessary to create the reference mode of the model.

(iii) Time to Complete Outstanding Construction Work (TCO)
TCO represents the average time a contractor takes to complete a construction project awarded to him. It represents the duration that clients have to wait for their orders to be delivered, using conventional construction technology – reinforced concrete & load-bearing masonry walling - which is the one used in the mainstream
construction industry of Kenya. If there were no further addition of workload into the industry, all outstanding construction works in the industry would be completed within this period.

TCO represents the contract period – agreed at the contract award time – plus all necessary extensions of construction time plus unwarranted time overruns. A recent research study on construction periods of private building projects in Kenya observed their average construction period to be about 1¼ years (ACRef 5.9 to 5.11). No records of a similar study for civil engineering construction projects were found in the documentary data collected. All the same, the order of this construction period was inferred from Wachira’s (1993) analysis of delays in public construction projects (ACRef 5.6 & 5.7), and the typical contract periods for road works reported in the Ujenzi Magazine of the Ministry of Roads and Public Works (ACRef 5.14). The contract periods (excluding contractual extensions of time and unwarranted time overruns) were on average 1.87 years for the road works projects. Allowing for the 182% average time overrun which Wachira (1993) observed for public projects (ACRef 5.7), the average completion time for these works came to 5¼ years.

For that reason, the average TCO - for building and civil engineering projects together – was approximated at 3 years. Again, just as said regarding TPA above, any value of TCO can suffice as long as it is considered in estimating the DCS - demand for constructed space - as well.

(iv) Time to Attract Contractors (TAC)

TAC is the time required to attract new contractors into the industry or allow existing contractors to increase their capacity, in response to increased construction demand. It is the time required to clear any contractor capacity deficit occurring in the industry. TAC includes the duration required for information on construction business opportunities to flow to businessmen plus the duration new entrants need to establish themselves.

Considering that feedback in the construction industry was observed to be rather inefficient (ACRef 2.6 to 2.9, 2.12 & 2.15), TAC could be as long 5 years, or more. However, since the construction market of Kenya is not limited to the local contractors, it is unlikely that a feasible construction development project would lack a contractor for more than one year. A significant number of Class A contractors in Kenya are foreign firms (ACRef 1.1 & 1.9).

Shortage of contractors was not observed to have been a serious impediment to real estate development in Kenya (ACRef 4.1). For that reason, TAC was taken to be 1 year, to represent the logistical difficulty that a deficit in capacity would bring to the system.

Unlike TD, TPA and TCO, TAC was not included in estimating DCS, in order to keep the estimating process relatively simple. A challenge one would encounter in taking account of this variable in a DCS estimate is to also take account of the Contractor Redundancy Percentage which has the opposite but accompanying influence in the model.
5.4.4 Rates

The rate variables are: Design Completion Rate (DCR), Planning Approval Rate (PAR), Contractor Entry Rate (CER), Contractor Redundancy Rate (CRR) and Construction Completion Rate (CCR).

(i) Design Completion Rate (DCR)

DCR is the rate at which workload resulting from the Unsatisfied Demand for Constructed Space (UDCS) is completed by architects and engineers and added to the backlog of physical planning approvals (for private projects) or backlog of budgetary approvals (for public projects). It depends on the speed at which project planning, design and documentation are handled. It is therefore a quotient of the UDCS and TD, measured in COU/yr.

(ii) Planning Approval Rate (PAR)

PAR is the speed at which workload resulting from the domain of planning approval is added to the domain of contractors for them to execute. It is a quotient of the Outstanding Planning Approvals and the Time for Planning Approval, and is therefore measured in COU/yr. The effectiveness of the planning regulations and the efficiency of the planning departments are some of the factors that could influence this rate.

(iii) Contractor Entry Rate (CER)

CER is the rate at which new contractors – or additional capacity of existing contractors - enter the construction industry. Computation of this variable is done as follows:

\[
CER = \frac{RC - C}{TAC} - CRR
\]  

[21]

Where, RC is Required Contractors; C is Contractors, TAC is Time to Adjust Contractors and CRR is the Contractor Redundancy Rate (explained below). CER is therefore measured in Contractors/year.

(iv) Contractor Redundancy Rate (CRR)

CRR is the rate at which contractors are rendered redundant in the industry, particularly due to fall in construction demand. They either remain idle in the industry or depart from it to seek better opportunities elsewhere, in the construction industry’s environment. CRR is a function of the Contractor Redundancy Percentage and the number of Contractors, and its units of measurement are therefore Contractors/year.

(v) Construction Completion Rate (CCR)

CCR is the quantity of output of constructed space produced per year. It is a product of the number of Contractors and the Average Contractor Output. Its units of measurement are therefore COU/yr.

CCR is equivalent to the annual construction output recorded in national statistics every year. It is a rate variable in this model, depleting the OCW level to increase the SCS level. However, in describing the capacity of the construction industry itself, this variable was used as the indicator of the level of the industry’s production
capacity, as applied in Sections 4.3.2 and 4.3.3 of Chapter IV. The actual time series data of formal construction output are presented in Appendix E.

CCR is the variable equivalent to the ‘problem variable’ in this study – i.e. construction output which fluctuates excessively and grows very slowly. The objective of the reference mode of the model developed was to produce CCR values that were as close to the real construction output values as possible, thereby replicating the fluctuations as well as the trends of the output. So the created DCS time series was entered into the model and taken through the process of stocks and flows in the model, generating CCR along the way and ultimately increasing the Stock of Constructed Space. The generated CCR time series was then compared with the actual construction output time series to evaluate the validity of the model, as described in Section 5.6.

5.5 Model Building

The system dynamics model comprises two major sub-systems, namely: construction output sub-system and contractor sub-system, as shown in Figure 5.2 which is a level-rate diagram of the model. It is an amplification of the dynamic hypothesis explained in Section 3.6.3 of Chapter III (see Figure 3.2).

In Figure 5.2, the single arrows indicate information links in the construction industry system, while the double arrows indicate physical flows - of the constructed space and contractors - in the system. Meanings of all the symbols used in Figure 5.2 are explained in Section 3.6.3 of Chapter III. The information links and space flows are related by difference equations specified for all the model variables, in Powersim Studio code. Functional definitions of all the variables are shown in Appendix K. In the model, the Unsatisfied Demand for Constructed Space adds construction workload to contractors through consultants’ design activity and planning approval activity; the Outstanding Construction Work then determines the number of contractors and comes out of the production process as constructed space, after a delay of some years, to add to the stock of constructed space.
Figure 5.2 System Dynamics Model of the Construction Industry of Kenya
In creating the reference mode of the model, the variables were functionally defined as follows: 

(a) Demand for Constructed Space (DCS) is the input variable at the very beginning of the system. The estimated historical time series of DCS was entered into the model using a step function, specified as shown in Appendix K. DCS could be defined as a polynomial function but that would have ‘hidden’ some of the variations that may appear small in the DCS but have significant effects on the Unsatisfied Demand for Constructed Space. DCS values ranged from 62,090 COU in 1964 to 275,122 COU in 2003, as detailed in Appendix H. Figure 5.3 shows the graph of the estimated DCS time series, together with its estimated trend line, a second order polynomial function. X represents the number of years from 1964.

\[ y = 59.543x^2 + 3020.4x + 62090 \]

\[ R^2 = 0.9977 \]

Figure 5.3 Demand for Constructed Space Estimated from Construction Output Data

(b) The stock of Constructed Space (SCS) was initialized at 60,000 COU while the Outstanding Planning Approval (OPA) was initialized at 2,090 COU, which were computed as described in Section 5.3. Though the initial value of SCS – i.e. SCS at the end of 1963 was an ‘arbitrary’ figure of 60,000 COU - any figure can work since the figure has to be included in the DSC, thereby offsetting its effect on the Unsatisfied Demand for Constructed Space which is the effective construction demand.

(c) The Outstanding Construction Workload (OCW) was formulated as a reservoir so that it would never be depleted below zero. This was meant to avoid the possibility of a negative Construction Completion Rate which would start depleting the Stock of Constructed Space. Such a thing had not been observed in the real system. The initial value of OCW (i.e. OCW as at the start of 1964) was estimated at 5,303 COU, as described in Section 5.3.
(d) The expected values for the Time for Design (TD), the Time for Planning Approval (TPA) and the Time to Attract Contractors (TAC) were taken to be 1 year each, while the expected value for the Time to Complete Outstanding Work (TCO) was taken to be 3 years.

(e) The Average Contractor Output (ACO) was entered in the model as graphical function of time (number of years from 1964). It is a smooth curve whose trendline can be expressed as a third order polynomial, as shown in Figure 5.4. The coefficient of determination ($R^2$ values = 0.9989) of the polynomial expression is almost 1, meaning that it represents ACO quite well. In the polynomial, $X$ represents the number of years from 1964.

$$y = 2E-05x^3 + 0.0021x^2 - 0.0219x + 1$$

$R^2 = 0.9989$

![Figure 5.4 Average Contractor Output; COU/Contractor/Year](image)

(f) The Contractor Redundancy Percentage (CRP) was also entered in the model as graphical function of time and was a very oscillatory time series. CRP was estimated from percentage changes in the number of contractors in the construction industry, as explained in Section 4.3.5 of Chapter IV. The percentage changes are shown in Figure 5.5. A negative percentage implies a fall in the number of engaged contractors and therefore a rise in the number of idle contractors. A positive percentage implies a discrepancy between the Required Contractors and the Contractors in the system. For that reason, in defining CRP in the model, only the negative values in Figure 5.5 were entered in the graphical function because they were the ones that implied contractor redundancy. Positive values which implied contractor shortage were taken care of by the Contractor Entry Rate in the model.
The time step was ¼ of a year, while the integration method was the second order Runge-Kutta method. This is a standard integration method in Powersim Studio, which does two flow calculations in the time step. Therefore, in the simulation, states of levels and rates were updated every quarter of the year, using two flow calculations in the quarter, thereby ensuring sufficient accuracy in the value estimates.

Using the variable definitions in (a) to (g) above, simulations were run from 1964 to 2003. The simulation results were then compared with the actual construction output data collected from the field and also with the number of contractors arithmetically estimated as explained in Section 4.3.5 of Chapter IV.

5.6 Model Correctness and Validation

This system dynamics model was soundly constructed. Its overall correctness was ensured by clearly defining every variable and precisely harmonizing its units of measurement with relationships implied by the variables linked to it, consistently following Lai and Wahba’s (2001) checklist of model correctness. The checklist of model correctness was satisfied as follows:

1. **Units check**: Powersim has a built-in units feature that checks all equations for consistency in units to make sure the left and right sides of an equation have the same units. This feature helped to ensure that valid dimensions, constants and equations were used in this study.

2. **Naming variables**: Naming of variables was kept clear and consistent. As described before, every variable name clearly explains what the variable represents.
3. **No constants embedded in equations**: It is often tempting to simplify equations by using numeric constants embedded in equations. One must not do so! A good model shows all constants explicitly as individual variables. This allows constants to be recognized and changed easily in future simulations, without changing any equations in the model. In this study, no numeric constants are embedded in the difference equations, as shown in Appendix K.

4. **Choose appropriately small time steps**: The time step chosen should be about one-eighth the value of the smallest time constant in the model in order to increase the frequency at which the model equations are solved, improving the approximations of continuous time. In this study, the smallest time constant is 1 year; this principle was satisfied by choice of a time step of \( \frac{1}{4} \) of a year and use of the second order Runge-Kutta method, as explained before.

5. **Stock values can be changed only by flows**: The only model elements with direct connections to stocks are flows. No constants or auxiliary variables should directly enter the stock equation, except for the initial values of the stock. In this study, the links between levels and rates adhere to this principle, as shown in Figure 5.2.

6. **Every flow should be connected to a stock**: A flow only increases or decreases a stock; it cannot be used as a source of information in a model as it cannot be measured. A flow unattached to a stock serves no purpose in the model, as it does not affect anything. In this study, the links between levels and rates adhere to this principle, as shown in Figure 5.2.

7. **Stocks should not be linked to stocks**: A stock is the integral of a flow. To show information transfer between two stocks, one should connect the first stock to the flow of the second stock. In this study, links between levels are made through the rate variables, as shown in Figure 5.2.

8. **No Use of IF THEN ELSE, MIN/MAX and other logic statements**: Almost no real-life situations behave according to IF THEN ELSE or MIN/MAX statements. Change is almost always gradual and not sudden like such functions suggest. One must use table functions to avoid discontinuities introduced by such statements. In this study, no IF THEN ELSE or MIN/MAX statements were used; table functions were used as described in Section 6.3.2 later.

9. **Use of Initial Values**: When initial values are used in a model, they should be clearly specified and connected to the model. In this study, initial values for all level variables are clearly stated as shown in Appendix K.

10. **Curving connectors**: This issue deals with aesthetics. The connectors that link one variable to another should be curved as a model with curved connectors looks nicer, and the feedback loops are easier to trace. In this study, all connectors are curved, as shown in Figures 3.1, 5.2 and 6.6.
In the light of the foregoing, the system dynamics model shown in Figure 5.2 is believed to be soundly constructed. It is neat, with no criss-crossing information links or vague variable names, but comprehensively captures the dynamic complexity of the construction industry of Kenya in an apparently simple level rate diagram.

The system dynamics model is valid for the intended purpose – to understand influences of various policy interventions on the behaviour of the construction industry of Kenya. The methods used to ensure validity of the model were: behaviour replication tests, parameter tests and extreme conditions tests. In system dynamics, choice of methods for testing a model’s validity – i.e. usefulness - depends on the purpose of the model. Shreckengost (2001) gives methods of testing the validity of a model, as follows: model parameter test, boundary adequacy test, extreme conditions test, anomalous behaviour test, behaviour replication test, behaviour sensitivity test and family member test. Of these validation methods, three are applicable to this model, namely: behaviour replication tests, parameter tests and extreme conditions tests. They were therefore the validity tests applied in this model to show its fitness for purpose and the level of confidence which the model users may have in it.

The model replicates the behaviour of construction output in Kenya very well. Fluctuations and growth exhibited by the simulated construction activity were observed to be of the same scale as those found in the actual construction activity. However, the simulated activity values were not equal to the actual activity values. Annual construction output and number of contractors were the variables used to show how well the model behaviour replicates the actual system behaviour. Simulated Construction Completion Rate (CCR) was compared with the actual construction output, and the simulated number of contractors compared with the numbers calculated arithmetically, as explained in Section 4.3.5 of Chapter IV.

The simulated CCR is quite close to the actual construction output, particularly in the amplitude of fluctuations and in the trend, as shown in Figure 5.6, only that the parameter values of the simulated and the actual system data are not equal for a number of the data points. All the same, the simulated CCR graph is quite close to the actual construction output graph. The simulated number of contractors behaves in the same way as the simulated CCR, as shown in Figure 5.7. The simulated Contractors exhibit fluctuations of the same order as that of the arithmetically estimated number of Contractors and a trend of the same direction as that of the arithmetically estimated number of Contractors.

One explanation for the differences between the simulated and ‘actual’ values – of the Construction Completion Rate and the Contractors - is the absence of the contractor entry delay from the estimation of the Demand for Constructed Space, for reasons given in Section 5.4.3 (see Time to Attract Contractors). If this delay were included in the DCS estimate, it is likely that the actual and estimated variable values would be approximately equal.
Figure 5.6 Comparisons of Actual and Simulated Construction Completion Rates

Figure 5.7 Comparisons of Estimated and Simulated Contractors

The model is robust to extreme parameter values except where a value tends to make the level of OCW (a reservoir) drop below zero. As stated before, this would be an ‘illegal’ action in the model because it would mean a negative CCR which would start ‘destroying’ the existing stock of constructed facilities. For that reason, some parameter values were not acceptable in the model. The limitations of parameter values are as follows: -
(a) Time for Design (TD) – Values less than 0.80 years are not acceptable. All other values even up to 5 years are suitable; they produce CCR whose oscillation and trend are similar to those of the reference mode CCR. However, the further away a TD value is from the expected value – of 1 year – the greater the deviation of the resultant CCR from the reference mode CCR.

(b) Time for Planning Approval (TPA) – There is no lower limit; values as low as the time step (0.25 years) are acceptable, but values above 2.4 years are not acceptable. The expected value is 1 year.

(c) Time to Complete Outstanding Work (TCO) – All values above 2.4 years are acceptable. The expected value is 3 years.

(d) Time to Attract Contractors (TAC) – There is no lower limit; values as low as the time step (0.25 years) are acceptable, but values above 4 years are not acceptable. The expected value is 1 year.

In conclusion, although the model does not excel in the parameter values test it is valid. The slight difference between the actual and simulated parameter values does not render the model invalid considering the purpose of the study – to understand influences of various policy interventions on the behaviour of the construction industry of Kenya. As Coyle (1996: 11) points out, the emphasis of system dynamics modeling is “exploring the [broad] behaviour of the system rather than predicting precise details.” Since the model replicates the construction output behaviour - fluctuations and trends – reasonably well, it is quite suitable for a systems learning of the construction industry of Kenya.

The simulated CCR shown in Figure 5.6 was therefore the reference mode CCR. Effects of possible changes in the system parameters or the system structure were assessed by comparing the resulting CCR with the simulated CCR shown in Figure 5.6.

5.7 Inference from the Reference Mode

The reference mode of the system dynamics model developed represents the existing construction industry of Kenya. The resultant values of variables are therefore those that are expected to have occurred in the industry from 1964 to 2003. From the reference mode five major inferences were made regarding: (i) the force behind construction activity fluctuations; (ii) uncertainty of the force causing fluctuations; (iii) effect of ‘distance’ from the force, on the rate variables (iv) influence of the average contractor output; and (v) variability of contractor redundancy.

5.7.1 Force behind Fluctuations

Unsatisfied Demand for Constructed Space (UDCS) is the force driving construction activity. This observation may appear to simply support Hillebrandt’s (2000) and Raftery’s (1992) observations - that construction activity does not occur when there is no unsatisfied demand for constructed facilities in the economy. However, comparison of the UDCS oscillation with oscillations of the other model variables tells the story in a relatively more compelling way. UDCS is more uncertain than Demand for Constructed Space (DCS) or Stock of
Constructed Space (SCS), which are its determinants. DCS and SCS vary at different rates; their difference (UDCS) should therefore have a higher coefficient of variation (standard deviation ÷ mean) than that of either of the two variables.

DCS and SCS exhibit increasing trends (means) and various gradients, as shown in Figure 5.8. However, their difference which is UDCS oscillates about an apparently constant level and at a higher frequency. As Figure 5.8 shows, the magnitude of UDCS variation appears rather small when the series is viewed together with the DCS and SCS series. However, this magnitude is quite high compared to that of the rate variables in the construction output sub-system, as shown in Figures 5.9 and 5.10. This large oscillation of the UDCS which is at the very beginning of the system’s production process is the origin of fluctuations, which the construction industry policy maker needs to pay greater attention to.

5.7.2 Uncertainty of the Force behind Fluctuations

The force underlying construction activity fluctuations – proxied by UDCS - is so uncertain that it is unlikely to be ‘captured’ by time series regression modeling of the activity. Fluctuations of the UDCS are far and way more vigorous (i.e. of greater frequency and amplitude) than those of the Construction Completion Rate (CCR) - the surrogate for annual construction output. The CCR graph is smoother and of lower amplitude than the UDCS graph, as shown on Figure 5.9. Variance of the UDCS is of a scale which is significantly higher than that of the variance exhibited by the CCR. These variables do not therefore have a long-term equilibrium. Consequently, inferring the behaviour of UDCS (the underlying force) from the observed behaviour of construction output (represented by CCR in the system dynamics model) would be a gross simplification.

As shown in Figure 5.2, the ‘distance’ – in time and space - between UDCS and CCR along the production process is so long that prediction of CCR that does not take account of this distance in a realistic way is unlikely to be accurate. Regression modeling does not take account of such ‘distances’ accurately, despite its stationarity and lag identification procedures. This appears to be one reason why the time series regression models developed in this study and similar regression models developed in previous studies may not give a comprehensive picture of the behaviour of construction activity.
Figure 5.8 Demand for Constructed Space, Stock of Constructed Space and Unsatisfied Demand for Constructed Space
Figure 5.9 Construction Completion Rate and Unsatisfied Demand for Constructed Space
5.7.3 Effect of ‘Distance’ on Production Rates

The oscillation - frequency and amplitude - of a production rate variable is inversely proportional to the ‘distance’ of the variable from the UDCS, along the construction supply chain. Design Completion Rate (DCR) resembles UDCS and is more oscillatory than the Planning Approval Rate (PAR) or the Construction Completion Rate (CCR), as shown in Figure 5.10. System levels in the production process seem to have the effect of reducing oscillation of subsequent rate variables; the greater the number of levels preceding a rate, the lower the oscillation of the variable. This suggests that an extra level variable introduced anywhere before the Outstanding Constructor Work (OCW) will eventually reduce oscillation in the CCR.

One way of introducing an additional level variable in the system is to queue proposed developments, thereby introducing a level variable between the Planning Approval Rate and the Outstanding Construction work. However, that approach would not only be counterintuitive but would also be risky. As Kummerow (1999) points out, an institution to facilitate such queuing could have the unintended effect of making cycles worse; it could also be corrupted. In Kenya, the institution would particularly not be popular since it would be interfering with developers’ business freedoms (ACRef 4.39 to 4.44).
Figure 5.10 Design Completion Rate, Planning Approval Rate and Construction Completion Rate
Despite being a higher risk and counter-intuitive the queuing of proposed development projects appears to be quite feasible. An imaginative policy for project queuing would particularly remove developments that are not feasible from the system, thereby reducing the backlog of planning approvals. This would significantly decrease the Time for Planning Approval without necessarily increasing workforce in the local authorities. The following excerpt from the documentary data (ACRef 4.8) indicates that a significant proportion of the backlog of planning approvals with the local authorities is for financially non-feasible projects.

“On the whole, only about a third of approved building plans ever get used. In the 1980 – 84 period, plans worth £260 Million were approved, but work worth only £104 got completed. This poor rate of completions is attributed to the failure of many developers to arrange for adequate financing, as well as to increasing costs which often lead to abandonment of projects” Industrial Review (1985): “The Construction Industry”, October 4, 1985.

Perhaps, a policy whereby only planning applications for projects formally appraised to be feasible are accepted could significantly minimize the Outstanding Planning Approvals. In this case, the onus would be on property developers and their consultants to provide a formal and thorough feasibility appraisal report, together with the project drawings, to the planning authorities. Such policy would motivate the developers to do more thorough feasibility study and appraisal of their proposed projects, thereby fostering more comprehensive project planning. That should ultimately improve the organizational effectiveness of the construction industry as a whole.

5.7.4 Influence of the Average Contractor Output

Although the Outstanding Construction Work (OCW) oscillates less than the Outstanding Planning Approvals (OPA), it is of generally higher magnitude. The maximum value of OCW is over 25,000 COU while that of OPA is about 10,000 COU, as shown in Figure 5.11. The consequence of the OCW oscillation is the oscillation in the number of Contractors (C) and, by implication the Required Contractors (RC). However, while OCW exhibits a generally upward trend, RC and C exhibit rise and fall, as shown in Figure 5.12. This implies that increasing workload in the industry required a reducing number of contractors - an expected occurrence given that the Average Contractor Output (ACO) increased exponentially from 1 COU/C/year in 1964 to about 5 COU/C/year in 2003. The number of Required Contractors (RC) is given by:

\[ RC = \frac{PCT}{ACP} \]  \hspace{1cm} [22]

Where, PCT (Practical Completion Target) is directly proportional to OCW.

Consequently, increase in ACO leads to decrease in RC and C. A positive discrepancy between RC and C implies shortage of contractors, which is filled in by the Contractor Entry Rate (CER) that has a minimum value of zero C/yr in 1972 and a maximum value 2,381 C/yr in 1974, as shown in Figure 5.12.
Figure 5.11 Outstanding Planning Approvals and Outstanding Construction Work

Note: Both OPA and OCW oscillate excessively because they depend on UDCS which is extremely oscillatory as shown in Figure 5.9. However, OPA has generally lower levels than OCW.
Figure 5.12 Required Contractors, Contractors and Contractor Entry Rate
5.7.5 Contractor Redundancy Percentage

The Contractor Redundancy Percentage (CRP) is a very erratic auxiliary. CRP values are synchronized with the Contractor Entry Rate (CER) such that there is no negative value of CER. A negative CER would mean that the CER and the CRP (Contractor Redundancy Rate) are serving the same function in the model – the function of indicating the number of contractors rendered idle by fall in construction workload. The percentage differences of contractors shown in Figure 4.8 are the guide used in approximating the CRP values shown in Figure 5.13. From 1964 to 1970, it is assumed that CRP was practically zero, since construction industry output showed continual growth over that period, as described in Section 4.3.3. It is from 1973 that CRP enters the system. It exhibits the pattern shown in Figure 5.13. Note that the actual and simulated values of CCR and Contractors in Figures 5.6 & 5.7 are approximately equal until 1972, when CRP enters the scene.

At first sight the CRP graph appears to have no pattern at all. But a closer look reveals that the graph does have a pattern comprising four profiles of rise-and-fall, each of them covering a period of about 10 years. The peak values of the profiles are somewhat different. CRP rises drastically from the assumed value of 0% in 1970 to a maximum of 73% in 1973 and falls to 2.5% in 1974. In the following ten years, and thereafter, CRP rises to peak values of about 40% and minimum values of about 3%. The implications of CRP on the Contractor Redundancy Rate (CRR) are shown in Figure 5.14, which also includes the CER to illustrate how the three variables work jointly to ensure that only the necessary number of contractors remain in the system.

Between 1964 and 2003, construction industry capacity in Kenya repeatedly lay idle, as evidenced by the large oscillations of CRR shown in Figure 5.14. The value of CRR is highest – 1,585 C/yr – for the year 1973, and has an overall average of about 400 C/year. The fact that the industry’s capacity is made redundant to this scale is of great concern to the businessman – contractor or consultant - in the construction industry of Kenya. It is unlikely that any rational businessman would enter the industry and invest adequately in production capacity, while understanding that sooner or later s/he will have to run bankrupt and/or leave the industry. In view of the adverse effects of continual redundancy in production capacity – such as bankruptcy, high manpower attrition, poor skills/professional development, inadequate investment in production capacity, wasted capital investment, etc, – the need for innovative planning of the construction industry, for the collective good of all the industry participants, can not be overemphasized.
Figure 5.13 Contractor Redundancy Percentage
Figure 5.14 Contractor Redundancy Rate and Contractor Entry Rate
5.8 Conclusion

In this chapter, a system dynamics model of construction activity in Kenya has been developed. The model is believed to be soundly constructed and valid. It is therefore suitable for understanding influences of various policy interventions on the behaviour of the construction industry of Kenya.

The reference mode of the model represents the existing feedback control structure in the construction industry. Simulations from the reference mode reveal that Unsatisfied Demand for Constructed Space (UDCS) in the economy of Kenya is the underlying force behind construction output fluctuations and growth trends. Action of system archetypes operating in the construction industry of Kenya can be sufficiently explained in terms of the time-variance of the UDCS. Therefore, the UDCS feedback loop is the main area which policy design for the construction industry of Kenya should focus on.

The next Chapter presents policy testing and design by simulation, using the system dynamics model developed. It explores parameter and structural changes in the construction industry system, which could minimize fluctuations and foster growth of construction output in Kenya.
Chapter VI

POLICY DESIGN AND BEHAVIOUR PROJECTIONS

6.1 Introduction

In Chapter V, a system dynamics model of construction output was developed and major observations made from its reference mode which represents the existing system structure of the construction industry of Kenya. This chapter presents the experimentation that was carried out using the system dynamics model developed, to address objective 5 stated in Section 1.3 of Chapter I. It was an exploration of possible changes in the parameters and the feedback structure of the existing construction industry system of Kenya, which could help to minimize fluctuations and foster continual growth of construction output.

The chapter is organized around four major topics, namely: sensitivity analysis of the system dynamics model, structural changes in the model, appraisal of policy changes suggested by construction industry participants in Kenya, and the future of construction activity in Kenya. It will be shown that regulation of response of the construction industry to changes in demand, coupled with expansion of the industry’s market beyond the economy of Kenya, are the measures that could minimize fluctuations and foster continual growth of construction activity in the country.

6.2 Sensitivity Analysis of the Model

This section describes the sensitivity of the system dynamics model developed in Chapter V, to changes in values of policy parameters (i.e. constant variables in the model). There are four policy parameters in the system dynamics model, namely: Time for Design (TD), Time for Planning Approval (TPA), Time to Complete Outstanding Work (TCO) and Time to Attract Contractors (TAC).

Systemic behaviour of the existing construction industry of Kenya was described in Section 5.6 and 5.7 of Chapter V. The probability of obtaining this behaviour remains quite high even with different policy parameters, as evidenced by analysis of the sensitivity of Construction Completion Rate (CCR) to various values of the four model variables listed above. It was observed that similar fluctuations and trends in construction activity were exhibited by various values of a constant, as long as the values were within the range dictated by the reservoir nature of the Outstanding Construction Work (OCW), explained in Section 5.5 of Chapter V. The valid ranges of the policy parameters are summarized on Table 6.1 below.

Parameter values outside the ranges shown on Table 6.1 violate the reservoir nature of OCW (see Figure 5.2) and this therefore renders them invalid for the system simulation. For that reason, truncated normal probability distribution – i.e. normal distribution with defined lower and upper limits – is the most suitable distribution to adopt in this sensitivity analysis. Out five different probability distributions used in sensitivity analysis in Powersim Studio, it is only the truncated normal probability distribution that allows for restricting limits of the parameter values. Therefore, the parameter values were entered into the analysis task as truncated normal probability distributions, with defined lower and upper limits, and a standard deviation of 10% of the expected value. The expected value is the value used in the reference mode. Values of the independent auxiliaries –
Demand for Constructed Space, Average Contractor Output and Contractor Redundancy Percentage were those used in the reference mode.

### Table 6.1 Valid Ranges of Policy Parameters

<table>
<thead>
<tr>
<th>Policy Parameter</th>
<th>Minimum</th>
<th>Expected Value</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Time for Design (TD),</td>
<td>0.80</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>2 Time for Planning Approval</td>
<td>0.25</td>
<td>1.00</td>
<td>2.40</td>
</tr>
<tr>
<td>3 Time to Complete Outstanding Work (TCO)</td>
<td>2.40</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>4 Time to Attract Contractors (TAC)</td>
<td>0.25</td>
<td>1.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

**Note:** Summary of parameter limits discussed in Section 5.6 of Chapter V.

The sensitivity of CCR was assessed for each constant separately, using the Latin Hypercube sampling method. This is a sophisticated sampling method which is tenfold better than its alternative – the Monte Carlo sampling method – as explained in Powersim Studio 2005. Using this sampling method, 40 sample value sets were generated for each constant, and then the assessment task simulated CCR values for all the samples and gave the specified percentiles of the CCR values. The results of the sensitivity analysis are illustrated graphically in Figures 6.1 to 6.4. The 10 percentile graph represents CCR values simulated from parameter values that are above the 10\(^{th}\) percentile of the parameter, while the 90 percentilograph represents CCR values simulated from parameter values that are below the 90\(^{th}\) percentile of the parameter. The probability an effect variable (in this case CCR) lies between the 10\(^{th}\) percentile and the 90\(^{th}\) percentile is 0.90, while the sensitivity of the variable to changes in the variable is indicated by the width of the gap between the percentiles. A larger gap indicates higher sensitivity.

The highest sensitivity of CCR is to TCO, followed by sensitivity to TD, as shown in Figures 6.1 and 6.2. The degree of sensitivity is proportional to the gap between the graph of the 10 percentile and that of the 90 percentile. As Figures 6.1 and 6.2 show, CCR is quite sensitive to TCO and TD for the gaps between the 10 and 90 percentile graphs are fairly wide. If the sensitivity were insignificant, the three percentile graphs would almost be on each other. Sensitivities of CCR to TPA and TAC are relatively lower; the gaps between their 10 and 90 percentile graphs are narrower as shown in Figures 6.3 and 6.4. These differences in CCR sensitivity imply that policies directed to changing TCO or TD are likely to influence construction activity more significantly than policies directed to changing TPA or TAC.
Figure 6.1 Sensitivity of Construction Completion Rate to Time to Complete Outstanding Work
Figure 6.2 Sensitivity of Construction Completion Rate to Time for Design
Figure 6.3 Sensitivity of Construction Completion Rate to Time for Planning Approval
Figure 6.4 Sensitivity of Construction Completion Rate to Time to Attract Contractors
The parameter values can be reduced to minima of about 2½ years, 10 months, 3 months and 3 months for TCO, TD, TPA and TAC respectively, only that the reduction could not be done to all the four variables simultaneously. The limiting factor was the Demand for Constructed Space (DCS) whose values were maintained as in the reference mode. As stated before, the sensitivity of CCR was assessed for each constant separately, assuming the expected (reference mode) values of the other three constants. It was observed that changing values of a constant did not change the systemic influence of the constant. The systemic influence - trends and fluctuations (frequencies and amplitudes) - remained the same as observed in the reference mode. As Figures 6.1 to 6.4 show, the pattern of CCR is generally the same for each set of percentile graphs. This indicates that construction activity fluctuations would be generally unresponsive to policies that may aim to change the four parameters with a view to reducing the fluctuations.

Reduction of a constant to its lowest value means that values of each of the other three constants must be kept equal to their expected value or greater. For example, reducing TD to 0.80 years does not allow TCO in the model to go below 3 years. Since TCO is the parameter showing the largest potential absolute reduction (about 7 months) reducing it to its lowest value of 2.4 years gives a good indication of the effect of the parameter changes on fluctuations and trends of construction activity. Comparison of the current CCR – i.e. CCR given by the minimum value of TCO - and the reference mode CCR is shown in Figure 6.5. It shows that the current CCR has a greater amplitude of oscillation than the reference mode. However, their frequencies of oscillation appear to be equal. Additionally, the upward trend of the current CCR has an increasing gradient as opposed to the upward trend of the reference mode CCR, which has a decreasing gradient.

From this sensitivity analysis, it can be concluded that there is no likelihood of improving fluctuations of construction activity in Kenya, by changing policy parameters in the existing system structure. This concept is used in appraisal of policy changes suggested by industry participants in Kenya, as described in Section 6.4. The other concept used in this appraisal is the change of the system structure itself. This concept is explored in the next Section.
Figure 6.5 Current and Reference Mode Construction Completion Rates

Notes: Reference is the CCR of the reference mode, where TCO is 3 years. Current is the CCR of current simulation run, where TCO is 2.4 years. Though the amplitude of the current is larger their frequencies are the same.
6.3 Structural Changes in the Model

This section describes possible structural changes in the system dynamics model developed in Chapter V, which could have helped minimize fluctuations and foster growth in construction activity in Kenya between 1964 and 2003. Structural changes implied re-design of the construction industry system model, thereby altering a number of the model variables and changing various relationships in the model of the existing structure. Simulation results of the changed model were then compared with those of the reference model to evaluate the nature of the resulting fluctuations and growth trends in construction output.

As explained in Section 4.3.3, prescriptive actions for handling the system archetypes operating in the construction industry of Kenya were observed to be regulation of response of the industry to changes in construction demand, and expansion of the system’s source of demand. Application of these actions requires changes in the system dynamics structure of the construction industry, as follows:

1. Regulation of the industry’s response to demand amounts to change of approach to Unsatisfied Demand for Constructed Space (UDCS) which is the underlying force behind fluctuations (as explained in Section 5.7.1). In this study, regulation of response to demand was achieved by altering the information links within the system – that is, information links operating after the UDCS in the level-rate diagram shown in Figure 5.2.

2. Expansion of the industry’s source of demand entails incorporation of Construction Demand from Outside Kenya, into the system’s structure. In this study, incorporation of Demand from Outside Kenya was achieved by adding an information link from the industry’s environment beyond the economy of Kenya into the UDCS - that is, an information link operating before the UDCS in the level-rate diagram shown in Figure 5.2. The boundary of the construction industry system, as drawn in section 4.2 of Chapter IV, was not altered.

These changes bring new variables and relationships to the systems dynamics model of the existing feedback control structure. The additional variables are mainly auxiliaries, whose systemic function is to combine and reformulate information in a system, meaning that the improvement is not in the nature of information in the industry but in the way the information is treated by the industry. The added model variables comprise five auxiliaries and three constants, making a total of 27 variables in the improved model, as shown in Figure 6.6.

6.3.1 Additional Auxiliaries

The additional auxiliaries are: Planned Completion Target (PCT), Reserve Capacity (RC), Fraction of Average Contractor Output (FACO), Multiplier for Time to Complete Outstanding Work (MTCO) and Construction Demand Outside Kenya (CDO). Time to Complete Outstanding Work (TCO) is also a new variable in the model of the improved structure, although it was also included in the existing structure model. This is because the definition of TCO in the improved structure model is different.
Figure 6.6 Improved System Dynamics Model of the Construction Industry of Kenya
In the improved model, TCO is an auxiliary defined by a table function – as opposed to being a constant. Also, Practical Completion Target, which was a function of the OCW in the original model, is replaced with a Required Completion Target, which is determined by Planned Completion Target and Reserve Capacity.

(i) **Planned Completion Target (PCT)**

PCT is a projection of feasible target construction output per year which needs to be set by policy well in advance to guide organized production and growth of the industry. It is a purposeful policy input which may be based on existing historical data or any other acceptable method of goal setting.

It is expected that study of construction output data of, say 40 years preceding 1964 would have revealed output trends and fluctuations similar to those revealed by the construction output data used in this study. This expectation assumes that system interactions in the industry of Kenya have not changed in a significant way in the last about 100 years. Whether this is true or not, it is a fact that history repeats itself. Therefore, insight from the 1964 – 2003 construction output data should help set realistic output goals for the years to come.

A realistic goal would have been to increase construction output gradually from its level of 1,768 COU/yr in 1964 to 7,342 COU/yr - the maximum figure observed in the study period - by 2003. The planned annual production rate could be expressed as a polynomial function derived from assigning output for the years in increasing order, as shown in Figure 6.7 below. The trend line represents PCT and is similar to the trend line presented in the description of the industry’s historical behaviour illustrated in Figure 4.4. In the polynomial equation, X is the number of years from 1964.

\[
y = 0.0778x^3 - 7.6385x^2 + 318.28x + 1768
\]

\[
R^2 = 0.9857
\]

![Figure 6.7 Planned Completion Target; (COU/Year)](image_url)
Entering the polynomial expression above into the improved system dynamics model requires that the equation be reformulated to take account of the time-step in the model, as follows:

\[ Y = 0.0012156X^3 - 0.4774062X^2 + 79.57X + 1768 \]  

Where, \( X \) represents the period number (i.e. \((\text{time} - \text{start time})/\text{time step}\)). In the model the time step is \( \frac{1}{4} \) of a year.

PCT is therefore pre-determined, and then continually adjusted using Reserve Capacity in such a way that inevitable oscillations in the Unsatisfied Demand for Constructed Space (UDCS) do not cause instability in the system at all.

In the simulation run, the Average Contractor Output was kept at the same level as in the original model i.e. growing exponentially from about 1 COU/Contractor/year in 1964 to 5 COU/Contractor/year in 2003. However, the Contractor Redundancy Percentage was re-defined as a minimum - a constant value of 5% - since drastic changes in the industry’s capacity would not be desirable in a stable construction industry.

(ii) Reserve Capacity (RC)

RC is the additional output per year, which is required to adjust the pre-set PCT to take account of unforeseen changes in the UDCS that may render the PCT rather impractical. RC is given by:

\[ RC = \frac{UDCS}{TARC} \]  

Where, TARC is the Time to Adjust Reserve Capacity, defined hereinafter. The units of measurement of RC are therefore COU/yr just like the PCT.

The function of RC in the model is to quicken response of the contractor sub-system to market changes, making the sub-system attract additional contractors into the system before the excessive work implied in the overshoot of UDCS goes through design and planning approval. Consequently, fewer contractors leave the system and more are attracted just in time to meet demand.

RC represents contractors available to absorb inevitable short-term oscillations of the UDCS, thereby preventing these oscillations from affecting the annual construction output. It makes the construction activity relatively more stable. Measures that may make application of RC in the system dynamics structure effective are:

(a) Timely market research for the construction industry and effective dissemination of the research findings;
(b) Comprehensive recruitment of construction manpower and incentives to encourage contractors acquire appropriate construction plant and equipment, for continual build-up of production capacity and increase in the average contractor productivity;

(c) Deployment of a significant amount of the construction capacity of Kenya to the market in the neighbouring countries, in such a way that the ‘exported’ capacity is easily returnable to Kenya in case of need. For example, a policy where 60% of the construction capacity is engaged in Kenya and 40% of the capacity is engaged in the market outside Kenya may be formulated. Additionally, 3 – 5% of the construction capacity may be purposefully kept ‘idle’ to absorb short term unanticipated rises in construction demand.

(iii) **Required Completion Target (RCT)**

RCT is the Planned Completion Target (PCT) adjusted for unforeseen changes in the UDCS. It is a sum of the PCT and RC defined above. RCT in the improved model replaces the Practical Completion Target in the original model, which was determined by the Outstanding Construction Work. In the policy design, that relationship is replaced by having a pre-determined Planned Completion Target, as explained before. That way, impulses of UDCS have less impact on the annual construction output – Construction Completion Rate (CCR) in the model.

RCT determines the number of Required Contractors and the actual number of Contractors in the system, subject to the Average Contractor Output (ACO) and delays in the contractor sub-system, particularly the Time to Attract Contractors (TAC). Because of this delay, there is bound to be discrepancy between the Required Contractors and actual Contractors most of the time. Consequently, the actual CCR is generally lower than the RCT.

In the improved model, CCR remains a product of Contractors and the Average Contractor Output, just as it was in the original model. The information from RCT to CCR does not change the underlying influences because CCR is defined as follows:

\[
\text{CCR} = \text{RCT} - \text{ACO}*(\text{RC} - \text{C})
\]

But \(\text{ACO} \times \text{RC} = \text{RCT}\), since \(\text{RC} = \frac{\text{RCT}}{\text{ACP}}\)

Therefore,

\[
\text{CCR} = \text{RCT} - \text{RCT} + \text{ACO} \times \text{C}
\]

\[
\text{CCR} = \text{ACO} \times \text{C}
\]

This emphasizes that ultimately, it is the Contractors in the system, who would actually be working to produce the annual construction output but not the target pre-set by the construction industry planner.
(iv) **Fraction of Average Contractor Output (FACO)**

FACO is a quotient of ACO and a constant ACO set by policy (i.e. the Normal Average Contractor Output defined below). It is unitless since ACO and NACO have the same units. FACO is an indicator of the overall increase in the speed of production in the industry, which implies reduction in the time required to Complete Outstanding Work. It was therefore used as the explanatory variable in a table function of the Time to Complete Outstanding Work.

(v) **Multiplier for Time to Complete Outstanding Work (MTCO)**

MTCO is the factor by which a constant value of TCO set by policy (i.e. the Normal Time to Complete Outstanding work defined below) is multiplied to give the expected TCO in a given year. MTCO is conceptualized as a table function of FACO. Its values in the function are based on perception of the expected changes in the speed of construction between 1964 and 2003, which is rather subjective.

In this study, it was assumed that TCO decreased gradually from about 6 years in 1964 to about 2½ years in 2003. Since TCO is an effect variable in the model, at least not influencing CCR, any reasonable assumption can suffice. The concept here is simply that TCO in 2003 was definitely lower than TCO in 1964, assuming that advances in construction techniques in Kenya, between 1964 and 2003, were not insignificant.

(vi) **Construction Demand from Outside Kenya (CDO)**

CDO is demand for construction services, which could come from outside Kenya if the construction industry of the country were to venture successfully into the construction market in the African region and beyond. It is postulated that Demand for Constructed Space (DCS) would have been less of a limit to construction output growth after 1981, if the construction industry of Kenya had significantly expanded its market base beyond the country’s boundaries.

In this model, expansion of the construction market is for both contracting and design services. Additionally, CDO is conceptualized as an exogenous variable like DCS, but net of the effect of existing stock of constructed space in the external market. CDO is therefore the unsatisfied demand for constructed space required by the property industries outside Kenya. This outside market is quite large. For example, reconstruction of neighbouring war torn countries such as Sudan, Ethiopia, Somalia and Rwanda offers a great demand for construction services. Additionally, the relatively more stable neighbouring countries - such as Botswana and Seychelles – also offer great opportunities for construction business in Africa. Therefore, the total unsatisfied construction demand in the neighbouring counties is expected to be many times larger than the UDCS in Kenya, at any time.

Currently, there are Kenyan contractors and professionals engaged in the construction market outside Kenya (ACRef 3.9). However, this engagement has hitherto not been facilitated or coordinated at industry level. The amount of CDO available to Kenya should therefore mainly depend on the ability of the Kenyan construction industry to enter the market.
In the model, CDO enters the overall Unsatisfied Demand for Constructed Space (UDCS) directly, as shown in Figure 6.6. This entry necessitates renaming of the space stock and demand variable in the improved model; SCS becomes Stock of Constructed space by Kenya while DCS becomes Demand for Constructed Space in Kenya. Their functional definitions remain the same as they were in the original model.

6.3.2 Additional Constants

The additional constants are: Time to Adjust Reserve Capacity (TARC), Normal Average Contractor Output (NACO) and Normal Time to Complete Outstanding Work (NTCO).

(i) Time to Adjust Reserve Capacity (TARC)

TARC is time set by the construction industry planner, for correcting projected deficit in the required production capacity. Its function is simply to determine the fraction of UDCS that needs to be added to the Planned Completion Target to get the Required Completion Target.

Acceptable values of TARC are those that do not increase CCR so drastically as to deplete OCW (a reservoir) below zero. Parameter tests showed that 10 years was a realistic value of TARC, implying a Reserve Capacity value of about 0.1*UDCS (COU/yr). Reserve Capacity values greater than about 0.15*UDCS (COU/yr) i.e. TARC < 8 years were not acceptable, particularly when Construction Demand from Outside Kenya (CDO) was kept zero, in a bid to show the effect of less aggressive response to demand changes in the system.

(ii) Normal Average Contractor Output (NACO)

NACO is the estimated maximum ACO expected in the construction industry during planning period. A normal is a constant in a system dynamics model, which is set by policy; it helps to formulate a table function of a non-linear relationship which may have no known algebraic expression (Martin 2001). It aids the process of conversion of information by auxiliary variables, guarding against confusion of units of measurements of the variables in a table function. The value of NACO is 5 COU/Contractor/year.

(iii) Normal Time to Complete Outstanding Work (NTCO)

NTCO is the estimated maximum TCO expected in the construction industry during planning period. It is used to define TCO as a table function of ACO. An increase in ACO is likely to cause a decrease in TCO, implying increased efficiency of delivery of constructed space by the industry. In this study, NTCO was ‘arbitrarily’ defined as 6 years, which was considered to be the TCO in the early 1960s. Additionally, MTCO was conceptualized to have reduced from about 1 in 1964 to 0.35 in 2003, causing TCO to reduce from 6 years in 1964 to about 2 years in 2003. Since TCO does not influence PCT or CCR in the improved model, any plausible assumption of NTCO can work.

On simulation of the Construction Completion Rate and Contractors, these structural changes were observed to reduce fluctuations significantly, as shown in Figure 6.8. To show the effect of the structural changes on fluctuations, the Kenyan Demand for Constructed Space (DCS) in the improved model, was kept equal to the DCS in the original model. Construction Demand from Outside Kenya (CDO) is kept zero. As Figure 6.8
shows, fluctuations in the current CCR (improved model CCR) are significantly less than the fluctuations in the reference mode CCR. The CCR rises rather smoothly, albeit at a reducing gradient, from its lowest value of 2255 COU/yr in 1964 to its highest value of 6973 COU/yr in 2003. Although the Reserve Capacity oscillates as vigorously as the UDCS, its oscillatory effect on CCR is small, as shown in Figure 6.9. Because the Reserve Capacity is generally positive throughout the period, the Required Completion Target remains greater than the Planned Completion target and the Construction completion rate.
Figure 6.8 Improved Construction Completion Rate; Effect of Internal Structural Changes

Notes: Reference graph is for CCR from the model of the existing structure. Current graph is for CCR from the model of improved structure. The Current CCR graph is more stable; it has smaller oscillations.
Figure 6.9 Effect of Reserve Capacity
The effect of structural changes on variations of Contractors is also significant. Oscillation in the number of Contractors is lower in the improved model than in the original one, as shown in Figure 6.10. In the improved model, the level of Contractors rises to a maximum of 4454 in 1977 and falls to a minimum of 1513 in 2003, a drop of 2941 contractors. This is obviously lower than the drop of 4236 contractors in the original model, where the level of Contractors rises to a maximum of 5736 in 1977 and falls to a minimum of 1500 in 2003, as shown in Figure 5.12 of Chapter V.

As stated before, the CCR increases smoothly but at a decreasing gradient implying that the limiting effect of DCS remains in the system, despite the internal structural changes. Expansion of the construction industry market could have minimized the limiting effect of the DCS. For example, the Construction Demand from Outside Kenya (CDO) could be increased steadily from 1981, the year when continual growth of construction output appears to have stopped. The expected effect of this market expansion on the CCR is shown in Figure 6.11. The CDO is increased at a rate of 2500 COU/year from 1981 (the 17th year from the Start, 1964), rising to above 50,000 COU/year by 2003, as shown in Figure 6.12. This entry of CDO increases the gradient of CCR, implying continual growth in the construction output.
Figure 6.10 Improved Variations in Contractors; Effect of Internal Structural Changes

Notes: Reference graph is for Contractors from the model of the existing structure. Current graph is for Contractors from the model of improved structure. The Current Contractors graph is more stable; it has smaller oscillations.
Figure 6.11 Improved Construction Completion Rate; Effect of Market Expansion

Notes: Reference graph is for CCR from the model of the existing structure. Current graph is for CCR from the model of improved structure. The Current CCR grows more steadily and has significantly smaller oscillations.
Figure 6.12 Construction Demand from Outside Kenya; Effect of Market Expansion
The effect of market expansion on variations of Contractors is also significant. Oscillation in the number of Contractors is lower in the expanded market model market, as shown in Figure 6.13. The level of Contractors rises to a maximum of 4454 in 1992 and falls to a minimum of 1992 in 2003, a drop of 2462 contractors, which is significantly lower than the drop of 2941 contractors in the un-expanded market model, as shown in Figure 6.10.

In conclusion, change of the industry’s response to the UDCS coupled with expansion of the industry’s market base can minimize fluctuations and increase growth of construction activity in Kenya. This concept is used to appraise policy changes suggested by industry participants in Kenya, as explained in Section 6.4 later.

Although the stabilizing influence of the improved model structure is quite impressive, there are two attributes of the improved model which would pose major challenges to the model applicants. Firstly, the Design Completion and Planning Approval Rates in the model of the improved structure are as oscillatory as in the model of the existing structure. This suggests that the design and planning sub-system should maintain capacity of such level and flexibility necessary to meet the oscillatory demand.

Secondly, the Outstanding Construction Work (OCW) in the model of the improved structure increases to levels which are higher than levels reached in the model of the existing structure. The maximum value of OCW in the model of the existing structure is about 25,000 COU. After applying the internal structural changes, the OCW increases to a maximum of over 50,000 COU in the late 1980s and falls back to about 5,000 COU in 2003, as shown in Figure 6.14. After expanding the market OCW increases continually to levels above 300,000 COU, as shown in Figure 6.15. While a high OCW value implies that the industry is quite vibrant, it may have the unintended implication that the industry’s production speed is rather low. That is likely to erode customer confidence. Perhaps, an efficient public relations function in the industry could help maintain the customer confidence high despite this implied sluggishness. Additionally, market expansion should be coupled with advancement in technology to ensure faster delivery of constructed space, and by implication higher growth rate of the average contractor output.
Figure 6.13 Improved Variations in Contractors; Effect of Market Expansion

Notes: Reference graph is for Contractors from the model of the existing structure. Current graph is for Contractors from the model of improved structure. The Current Contractors graph is more stable; it has oscillations that are even smaller than those of the Current Contractors graph in Figure 6.10.
Figure 6.14 Outstanding Construction Work; Effect of Internal Structural Changes

Notes: Reference graph is for OCW from the model of the existing structure. Current graph is for OCW from the model of improved structure. The Current OCW increases rises to a maximum and falls to a minimum after the internal structural changes.
Figure 6.15 Outstanding Construction Work; Effect of Market Expansion

Notes: Reference graph is for OCW from the model of the existing structure. Current graph is for OCW from the model of the improved structure. The Current OCW increases continually after the market expansion, necessitating increase in the rate of change of the average contractor output for the industry to deliver.
6.4 Appraisal of Suggested Policy Changes

The policy changes suggested by participants in the construction industry of Kenya are unlikely to solve the problem of fluctuations in construction output. Table 6.2 presents the problem categories described in Section 4.2.3 of Chapter IV. It shows respective policy suggestions given by the industry participants, and gives the expected effect of the suggestions on the system dynamics model of the existing system structure. The Table shows that the policy changes suggested mainly constitute parameter changes in the system dynamics model of the existing system structure. As observed in Section 6.2, changing policy parameters in the existing system structure, cannot improve fluctuations of construction activity in Kenya.

Most of the suggested policy changes tend to provide more information in the system and/or make the flow of the information more efficient in the system, thereby reducing the system delays – Time to Design, Time for Planning Approval and Time to Complete Outstanding construction work. Policies that would make fundamental changes in the system structure are those that tend to change the way the information is used in the industry. Participants in the construction industry of Kenya gave only one such policy suggestion which is expansion of the construction industry’s market to neighbouring countries.

Fluctuations in construction demand – and by implication construction output – in Kenya are generally considered to arise from factors outside the industry, and to be inevitable. As Table 6.2 shows, there are many explanations for the fluctuations but no specific policy suggestion to address them. Queuing proposed property developments to minimize excessive fluctuations in construction output was considered an impractical intervention in Kenya (ACRef 4.39 to 4.44). One reason given for that view was that such queuing would introduce monopolies in the property markets and would also interfere with developers’ freedom of judgment (ACRef 4.39 & 4.40). Therefore, to the construction industry participant in Kenya, the problem of fluctuations in construction activity in the country has no practical policy solution.

Although a central body to manage the construction industry was proposed, it was pointed out that the body should only be an advisory body but not a regulatory body (ACRef 1.19). As shown on Table 6.2, this central body is suggested for the purpose of setting the construction industry’s goals and policies at national level. In Section 6.3, it was shown that regulation of response of the construction to changes in construction demand is a leverage point in the system dynamics structure of the industry. However, such regulation would seem to be a counterintuitive strategy to the construction participant in Kenya.

As stated before, the only policy suggestion that implies a structural change in the system dynamics model of the existing system structure was the suggestion to expand the construction industry’s market to neighbouring countries. Venturing into markets beyond the economy of Kenya could obviate the limiting power of the country’s economy, and guarantee demand for construction services (provided by Kenya), even when the economy of Kenya is down.
<table>
<thead>
<tr>
<th>Problem (a)</th>
<th>Explanations given by Construction Industry Participants in Kenya (b)</th>
<th>Policy Changes Suggested by the Construction Industry Participants (c)</th>
<th>Appraisal: Effects the Policy Suggestions on the System Dynamics Model of the Existing Structure (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low construction demand in the formal sector</td>
<td>• Source of construction demand is limited to Kenya (ACRef 6.4); • Shortage of market information for investment decision making (ACRef 4.44).</td>
<td>Expand market to neighbouring countries (ACRef 6.4) &amp; Better market research in real estate (ACRef 6.16 – 6.19)</td>
<td>Structural change – system boundary expansion; Parameter change – Time to Design decreases</td>
</tr>
<tr>
<td>2* High construction demand in the informal sector</td>
<td>• The nature of most building works is informal (ACRef 6.11.11); • Inefficiency in the Local Authorities’ development control (ACRef 1.29 &amp; 6.11.6).</td>
<td>Improve development control at City Hall (ACRef 6.13)</td>
<td>***********************************************</td>
</tr>
<tr>
<td>3 Fluctuations in construction demand</td>
<td>• Unexpected changes in government expenditure policies (ACRef 4.35); • Business cycles in the national economy (ACRef 4.34); • Politics - uncertainty from change to multi-party politics and national elections (ACRef 4.39).</td>
<td>Speed up approval of drawings by City Hall (ACRef 5.12) &amp; better procurement systems (ACRef 6.11.2)</td>
<td>Parameter changes – Time for Planning Approval &amp; Time to Complete Outstanding work decrease</td>
</tr>
<tr>
<td>4 Project delays and cost overruns</td>
<td>• Poor project planning, control &amp; coordination (ACRef 2.6 &amp; 6.11.3); • Poor institutional &amp; regulatory frameworks (ACRef 1.29, 4.23, 6.11.6 &amp; 6.11.7); • Inefficiency of procurement systems (ACRef 6.11.2).</td>
<td>Improve flow of information (ACRef 2.13); Avail more resources for development targets (ACRef 1.30)</td>
<td>Parameter changes – Time for Planning Approval &amp; Time to Complete Outstanding work decrease</td>
</tr>
<tr>
<td>5 Construction policies and targets not commensurate with the construction industry capacity</td>
<td>• Poor flow of information between policy makers and the lower levels of the industry participants (ACRef 2.8 &amp; 2.9).</td>
<td>A central advisory body (ACRef 1.18 – 1.22) &amp; Policy for whole industry (ACRef 2.14)</td>
<td></td>
</tr>
<tr>
<td>6 Absence of a coherent set of policies and national goals for the construction industry</td>
<td>• The industry is poorly managed (ACRef 1.21, 1.22, 4.23, 6.11.7 &amp; 6.11.16).</td>
<td>A central advisory body (ACRef 1.18 – 1.22) &amp; Policy for whole industry (ACRef 2.14)</td>
<td></td>
</tr>
<tr>
<td>7 Failure to keep high calibre manpower in the industry</td>
<td>• Skilled manpower is attracted to more lucrative jobs outside the industry (ACRef 3.9, 4.38).</td>
<td>Polluters to be fined &amp; to restore damaged habitats (ACRef 3.24)</td>
<td>***********************************************</td>
</tr>
<tr>
<td>8 High costs of construction</td>
<td>• Unnecessarily high standards specifications in the building code for construction materials (ACRef 6.6).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9* Unsustainable use of natural resources; environmental degradation</td>
<td>• Failure to account for environmental effects in feasibility appraisal; polluters are not fined (ACRef 3.23).</td>
<td></td>
<td>***********************************************</td>
</tr>
<tr>
<td>10 Low research activity in the construction industry</td>
<td>• Lack of government funding for Research &amp; Development (ACRef 6.11.9); • Market research in construction &amp; real estate sectors is poorly done (ACRef 4.41, 6.16 to 6.19).</td>
<td>Better market research in real estate (ACRef 6.16 – 6.19)</td>
<td>Parameter change – Time to Design decreases</td>
</tr>
</tbody>
</table>
As observed in Section 6.3, this expansionist strategy implies a structural change in the system dynamics model of the existing system structure, and results in continual growth of construction output and production capacity of the construction industry. Successful application of this strategy in Kenya would mean that the construction industry’s production capacity is never rendered redundant by drastic falls in construction demand in the country.

On Table 6.2, two of the problems raised by the construction industry participants lie outside the boundary of the system dynamics model. The two ‘outside’ problems are: high construction demand in the informal sector, and unsustainable use of natural resources. Their suggested policy solutions do not therefore cause any change in the parameters or the structure of the system dynamics model. Therefore, the system dynamics model developed in this study can be used to understand 8 out of the 10 major problem areas of the construction industry of Kenya.

6.5 Future of Construction Activity in Kenya

This section describes projections of the expected future behaviour of construction activity in Kenya, using the system dynamics model of the existing structure of the construction industry system, and also using the model of the improved structure of the industry system. Projections of the activity were simulated up to year 2050, showing the expected activity about 20 years before and after year 2030 which is currently the focus year of Kenya’s long-term development plan – Kenya Vision 2030 (Republic of Kenya 2007).

6.5.1 Projections from the Model of Existing System Structure

The system dynamics model developed in Chapter V was used to project construction output to year 2050. To facilitate this projection, Demand for Constructed Space (DCS) and Contractor Redundancy Percentage (CRP) were functionally defined as follows:

(a) Demand for Constructed Space – DCS was defined as a step function from 1963 to 2003, retaining the existing behaviour described before. From 2004 to 2050, DCS should ideally have been defined as a step function. However, this was not practical; one step function over the whole period – 1964 to 2050 - produced too many steps to be acceptable in Powersim. For that reason, beyond year 2003, the DCS was functionally defined in terms of two ramp functions and three step functions as shown in Appendix K. This definition brought the total DCS to 762,224 COU which was the figure estimated from a polynomial function of DCS derived from the DCS values in the original model. As explained before, defining DCS as a polynomial over the whole period (1964 to 2050) would not have been wrong but it would tend to smoothen the DCS curve, thereby ‘hiding’ some variations that might be significant to the UDCS (Unsatisfied Demand for Constructed Space). Figure 6.16 shows the resultant graphs of DCS - together with SCS and UDCS - from 1963 to 2050, after running the simulation. The DCS and SCS series trend upwards and are very close to each other, as expected in the un-expanded market model.
(b) Contractor Redundancy Percentage – CRP was defined as a graph function that repeated every forty years, the form shown in Figure 5.13 of Chapter V. It was postulated that in the existing system structure, CRP should drop to about 0% in year 2005 and then fluctuate vigorously in the following 43 years, the same way it was observed to have done between 1970 and 2003. Figure 6.17 shows the graph of CRP from 1963 to 2050.

The Average Contractor Output was postulated to grow exponentially from its value of about 5.0 COU/Contractor/year in 2003 to a value of about 14.5 COU/Contractor/year in 2050. Additionally, the delays – Time for Design, Time for Planning Approval and Time to Complete Outstanding Work, were assumed to remain 1 year, 1 year and 3 years respectively. Though these are simplifying assumptions, changes in these parameter values are unlikely to change the oscillations and trends in the activity as observed in Section 6.2.
Figure 6.16 Demand for Constructed Space in Kenya; 1963 to 2050
Figure 6.17 Contractor Redundancy Percentage in the Existing Structure; 1963 to 2050
Projection using the model of the existing structure showed that future construction output in Kenya would be characterized by excessive fluctuations and slow growth, as it had been in the period 1964 to 2003. This projection is shown in Figure 6.18. The amplitudes of fluctuations in construction output in the period 2004 to 2050 are large, just as they are in the period 1963 to 2003. The DCS ramp function – defined in Appendix K - makes the 2004-to-2050 amplitudes of CCR appear to be relatively larger but they may not necessarily be larger in the real system. The point is that the fluctuations will remain as excessive as they have always been if the existing system structure of the construction industry of Kenya is maintained. CCR has a maximum value of 17,620 COU/year in year 2015 and a minimum value of 2813 in year 2021.

The projection also showed that in the period 2003 to 2050, growth in construction output would remain slow, as illustrated in Figure 6.18. This is evidenced by the gradient of the CCR trend-line, which keeps decreasing all the way to year 2050. Therefore, in the existing system structure of the industry there is no hope of significant and permanent growth in the industry’s capacity in the foreseeable future.

Also, projection of Contractors using the model of existing structure showed excessive fluctuations in the number of contractors, as shown in Figure 6.19. In the 2004-to-2050 period, the level of Contractors rises to a maximum of 2547 in year 2015 and falls to a minimum of 348 in year 2021. In absolute terms, this fall is 2199 Contractors and is less than the fall (4236 Contractors) in the 1963-to-2003 period. However, in percentage terms the future fall is greater than the past fall; it is 86% while the past fall was 74%.

It can be concluded that fluctuations and slow growth of construction output will remain inevitable in the construction industry of Kenya, if the existing feedback control structure of the industry is not changed in a fundamental way.
Figure 6.18 Construction Completion Rate in the Existing Structure; 1963 to 2050

Notes: Current graph is for CCR simulated using the existing structure model, beyond year 2003. It is simulated over a period of 87 years, from 1963 to 2050. In this case, the Current CCR simulation and the Reference CCR simulation are the same.
Figure 6.19 Contractors in the Existing Structure; 1963 to 2050

Notes: Current graph is for Contractors simulated using the existing structure model, beyond year 2003. It is simulated over a period of 87 years, from 1963 to 2050. In this case, the Current simulation of Contractors and the Reference simulation of Contractors are the same.
6.5.2 Projections from the Improved System Structure

The improved model built up in Section 6.2 is used to project construction output to year 2050. The Demand for Constructed Space in Kenya and the Average Contractor Output are functionally defined as in the existing structure, in Section 6.4.1 before. The Contractor Redundancy Percentage is kept at a constant 5% and the Time to Adjust Reserve Capacity is 10 years.

As explained in Section 6.2, two major improvements in the model are the Planned Completion Target (PCT) and the Construction Demand from Outside Kenya (CDO), and are functionally defined as follows:

(a) Planned Completion Target – PCT is defined as polynomial function, just as in Section 6.2. However, the polynomial has an inflexion beyond year 2005, its gradient becoming steeper and growing more rapidly as shown in Appendix J. This implies a plan to purposefully increase the construction output exponentially in the 2003-to-2050 period. Otherwise, another definition of PCT can still work, only that it may not clear the Unsatisfied Demand for Constructed Space as fast as the third-order polynomial.

(b) Construction Demand from Outside Kenya – CDO is defined as a ramp function, growing at a rate of 2500 COU/year, from 1981 to 2050.

The projected Construction Completion Rate (CCR) exhibits relatively less oscillation and faster growth, as shown in Figure 6.20. The amplitude of its oscillation is smaller, while the gradient of its trend-line does not exhibit a decreasing tendency. This continual growth of CCR is caused in by the CDO, which grows to a value of over 150,000 COU/year. Additionally, CDO enables the Stock of Constructed Space (by Kenya) to rise above the DCS (in Kenya) without violating the reservoir nature of the Outstanding Construction Work.

Projection of Contractors also shows improvement in the degree of fluctuation, as shown in Figure 6.21. In the 2004-to-2050 period, the level of Contractors remains between about 2000 and 1300, implying that the improvement in the model in makes the contractor sub-system more stable.

The projected behaviour of the other model variables in the improved structure is shown in Appendix J. It can be concluded that forward planning of the construction output, inclusion of reserve production capacity in the structure and expansion of the market are some of the fundamental changes in the feedback structure of the construction industry of Kenya, which can significantly minimize fluctuations and increase growth in the construction output in the very long run.
Figure 6.20 Construction Completion Rate in the Improved Structure; 1963 to 2050

Notes: The Reference graph is for CCR simulated using the existing structure model, while the Current graph is for CCR simulated using the improved structure model. Fluctuations of CCR in the Current simulation are significantly smaller.
Figure 6.21 Contractors in the Improved Structure; 1963 to 2050

Notes: The Reference graph is for Contractors simulated using the existing structure model, while the Current graph is for Contractors simulated using the improved structure model. Fluctuations of Contractors in the Current simulation are significantly smaller.
6.5.3 Estimates for Year 2030

For year 2030, values of key variables estimated using the existing structure model appear to be not significantly different from the values estimated using the improved structure model. As shown on Table 6.3, estimates of the Construction Completion Rates and those of the Contractors are approximately equal.

Table 6.3 Estimates for Year 2030

<table>
<thead>
<tr>
<th>Model Variable</th>
<th>Projection from Existing Structure Model</th>
<th>Projection from Improved Structure Model</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>a Construction Completion Rate</td>
<td>11,611</td>
<td>13,255</td>
<td>COU/yr</td>
</tr>
<tr>
<td>b Contractors</td>
<td>1184</td>
<td>1352</td>
<td>Number</td>
</tr>
<tr>
<td>c Average Contractor Output</td>
<td>9.81</td>
<td>9.81</td>
<td>COU/Contractor/yr</td>
</tr>
<tr>
<td>d Practical Completion target</td>
<td>13,497</td>
<td></td>
<td>COU/yr</td>
</tr>
<tr>
<td>e Planned Completion target</td>
<td>11,869</td>
<td></td>
<td>COU/yr</td>
</tr>
<tr>
<td>f Required Completion Target</td>
<td>14,387</td>
<td></td>
<td>COU/yr</td>
</tr>
</tbody>
</table>

Source: Data Analysis (2007)

This apparent equality in value estimates implies that the construction industry’s production targets in some of the years in future may be achieved using either the existing system structure or the improved system structure.

However, establishing a stable path (i.e. path with minimum oscillations and continual growth of activity) to these targets remains the great challenge. Oscillations of the time series – Construction Completion Rates, Contractors and Completion Targets – projected using the existing structure model are significantly different from the oscillations of the time series projected using the improved structure model, as shown in Sections 6.4.2. Therefore, it is advisable to improve the existing feedback control structure of the construction industry of Kenya, to ensure a stable development path of the industry towards year 2030, and beyond.

6.6 Conclusion

In conclusion, three major observations can be made from the data analysis and results presented in this chapter. Firstly, the system dynamics model developed in Chapter V is fairly sensitive to changes in the policy parameters in it. However, there is no chance of improving fluctuations of construction activity in Kenya, by changing the policy parameters in the existing system structure.

Secondly, excessive fluctuations and stunted growth of construction output can be significantly improved by structural changes in the existing system structure. These structural changes aim to regulate response of the industry to changes in construction demand, and to expand the system’s source of demand. The changes are: (i) setting long-term targets of annual construction output in the industry as a whole; (ii) incorporating reserve capacity in the production process; and (iii) expanding the system structure to capture a larger construction market.
Thirdly, most of the policy changes suggested by participants in the construction industry of Kenya constitute parameter changes in the existing system structure. Consequently, the policy suggestions are not effective for addressing the problem of excessive fluctuations in construction activity in the country.

The next chapter discusses the findings presented in this chapter - and also those findings presented in Chapters IV and V - in the context of the literature reviewed in Chapter II. Then, it gives implications of the findings to the construction industry of Kenya, and also to construction economics and management theory.
Chapter VII

CONCLUSIONS AND IMPLICATIONS

7.1 Introduction

The problem addressed in this research was introduced in Chapter I, and the path followed to investigate the problem explained. Review of related literature was discussed in Chapter II, discussing construction output fluctuations and systems views about the fluctuations. Then, the methods used in the collection and analysis of data were presented in Chapter III to provide assurance that appropriate research procedures were followed in this study.

At the end of Chapter II, a gap in the literature related to fluctuations and/or growth of construction activity, particularly in the construction industry of Kenya, was pointed out. Chapters IV, V and VI have presented the study findings, showing how each of the five objectives set in Chapter I were addressed in the data analysis and interpretation. System archetypes operating in the construction industry of Kenya were identified, time series regression models developed and system dynamics models developed, each of them giving remarkable insight into the behaviour of the construction industry of Kenya.

This next Chapter discusses the study findings in the context of this research and prior research discussed in the literature review. On the basis of the study findings, the Chapter gives conclusions about the study aim and objectives, discusses implications of the findings for theory and for policy in the construction industry of Kenya, and gives areas for further research. It will be shown that this study makes a distinct contribution to the body of knowledge of construction economics and management.

7.2 Conclusions about the Research Aim and Objectives

All the objectives of the study were achieved and, consequently, the aim of the study also achieved. The study aim was to develop a system dynamics model of construction output in Kenya, for the purpose of understanding influences of various policy interventions on the behaviour of the construction industry in the country, while the specific objectives were to: -

1. Define the construction industry system boundary;
2. Describe the historical behaviour of the construction industry system;
3. Develop time series models of construction output;
4. Build a system dynamics model of the construction output problem - of excessive fluctuations and slow growth – in the existing system structure of the construction industry; and
5. Explore possible changes to the system structure of the construction industry and to the system dynamics model, which could minimize fluctuations and foster growth in construction output.

Objectives 1, 2 and 3 are addressed in Chapter IV, objective 4 addressed in Chapters V, and objective 5 addressed in Chapter VI. The following are the conclusions made in respect of each objective.
7.2.1 Construction Industry System Boundary

This objective is addressed in Section 4.2 of Chapter IV. Four major conclusions were made. Firstly, in the
construction industry of Kenya, legislators (on development control and standards of materials & workmanship),
consultants (public & private sectors) and contractors (including the associated sub-contractors and suppliers of
materials & machinery) are the entities that fall within the construction industry’s system boundary. Therefore,
the main influences at work in the construction industry’s system behaviour are the links between these three
major entities.

Secondly, outside the boundary - in the industry’s environment - lie developers (public & private), policy makers
(on land, physical planning & development planning), the general public, politicians, other government
ministries & departments, the economy as a whole, other countries and Bretton Woods institutions. From the
systems point of view of an organization’s output, which is amplified in Sections 2.5 and 2.6 of Chapter II, the
magnitude of the environmental factor influences on the construction industry depends on the structure of the
links amongst the three major entities inside the industry’s system boundary. This structure of links is
encapsulated in the existing system structure of the construction industry of Kenya.

Thirdly, feedback in the construction industry of Kenya is rather poor. Feedback, in this context, refers to the
back-and-forth flow of information amongst the industry participants for input into further production processes.
It does not refer to the sequence of information-action-consequence which constitutes feedback control in
systems, and which naturally goes on undeterred by people’s unawareness or awareness, as explained in Section
2.5.2 of Chapter II. While this observation on feedback implies that participants in the construction industry of
Kenya do not purposefully or imaginatively benefit by the existing feedback mechanism, systems theory would
point out that there naturally exists an underlying and effective feedback process in the structure of the industry.
This form of feedback does not feature in the data collected and seems to be rather hidden from the industry
participants’ eye. The natural feedback process of the industry is a defining attribute of all socio-economic
organizations. It influences the organization’s sub-entities through natural adjustments effected by the
relationships amongst them in the medium-term or the long-term, resulting in the growth/decay and evolution of
the organization. If not well understood and imaginatively changed, this structure may render the system
unresponsive to policy interventions.

Finally, interactions amongst the entities within the industry’s system boundary are fundamental to the
construction process at the industry level, and their main output is constructed space which is added to the
existing stock of the space in the real estate industry. Interactions amongst entities in the environment mainly
influence the nature of demand for construction services, which is a basic input in the production process of the
construction industry. The ‘environmental’ factors that influence construction demand in Kenya are generally
the same as the determinants of construction demand identified in the literature review, in Section 2.3.1 of
Chapter II.
7.2.2 Historical Behaviour of the Construction Industry

This objective is addressed in Section 4.3 of Chapter IV. Two major conclusions were made. Firstly, *the relative volume of construction output in Kenya has a downward trend* for the greater part of the country’s post independence era. According to Bon (1992), this behaviour is unexpected of a developing country making progress. In this study, this observation was a preliminary pointer to presence of a systemic limiting factor in the construction industry of Kenya.

Secondly, fluctuations and trends of the absolute values of construction output in Kenya in the period 1964 to 2003 exhibits behaviour which resembles two of the major system archetypes explained in Braun (2002) and Senge (1990). The two archetypes are: *a balancing process with a delay* and *limits to growth*. Therefore, in the construction industry of Kenya, the underlying system archetype responsible for excessive fluctuations in construction output is the *balancing process with a delay*, while the underlying system archetype responsible for stunted growth in construction output is the *limits to growth*. Generic prescriptive actions for these system archetypes are *to imaginatively regulate* the system’s response to change in its environment, and *to remove the limit or reduce the impact of the limit*, respectively. The possibility of adopting these prescriptions in the construction industry of Kenya is explored in objective 5, which is addressed in Chapter IV.

7.2.3 Time Series Models of Construction Output

This objective is addressed in Section 4.4 of Chapter IV, where ARIMA and multiple regression models of annual construction output in Kenya are developed. In brief, construction output in Kenya is significantly influenced by *its own past levels*, past levels of *misery index*, and past levels of *Gross National Product – to as far back as four years*. However, the time series regression models developed in this study exhibit relatively lower explanatory power than time series models developed prior research.

As discussed in Sections 2.4 of Chapter II, examples of past multiple regression modeling studies of construction activity are Akintoye & Skitmore (1991 & 1994), Bee-Hua (1996), Flaherty & Lombardo (2000), Killingsworth (1990) and Malizia (1990). Examples of ARIMA regression modeling studies of construction activity are Flaherty & Lombardo (2000) and Notman *et al* (1998). Coefficients of determination ($R^2$ values) observed in the time series models developed in these past studies are significantly greater than the $R^2$ values observed this study.

There are two reasons for this difference. Firstly, there were more data available in the past regression studies than in this study. For example, Notman *et al* (1998) used *quarterly* construction output data of the UK from 1955 to 1995, while the data available for this study was annual construction output of Kenya from 1964 to 2003. Additionally, relatively more data on the explanatory variables were available in the multiple regression models. In Akintoye & Skitmore (1991 & 1994), for example, five explanatory variables were used in the regression modeling. In contrast, only two explanatory variables had their data available for regression modeling in this study.
Secondly, almost all the past multiple regression studies mentioned above used non-stationary time series in their modeling. In contrast, this study used only stationary time series because it was observed that the variables were not jointly co-integrated. Strictly speaking, time series regression requires that all the variables involved are stationary except where the variables are jointly co-integrated (Gujarati 2003, Kendall & Ord 1993). Otherwise, the variables should either be stationary in their levels or be made stationary by an appropriate transformation, such as differencing. All the same, some researchers choose to regress time series variables in their levels - even if some of the series are nonstationary – in which case, the regression results are significantly influenced by the nonstationarity of the data (Gujarati 2003).

Regressing nonstationary time series appears to have been the choice made by Akintoye & Skitmore (1991) and Bee-Hua (1996), where construction output levels (or their logarithms) were regressed on levels (or logarithms) of explanatory variables. Of the previous multiple regression studies mentioned above, $R^2$ values were highest in Akintoye & Skitmore’s (1991) study; they were greater than 0.90 (on average) for models of five different construction sub-sectors. It is likely that these results were spurious. Another attribute of Akintoye & Skitmore’s (1991) study is that its study period – 1974 to 1988 - was relatively short, and may not have sufficiently captured the long-term relationships amongst the variables in the study. Although the study used quarterly data, variability of construction output within a short period may not capture the long run behaviour of the output. As shown in Section 4.3.2 and 4.3.3 of Chapter IV, a completely different picture would have been observed in this study, if data from 1989 to 2003 – a 15 year period – were to be analyzed, even if the data were quarterly.

7.2.4 A System Dynamics Model of Construction Output in the Existing System Structure

The whole of Chapter V is devoted to addressing this objective. A system dynamics model of construction output in Kenya is developed on the basis of the construction process at industry level in the country and features of the two system archetypes operating in the construction industry, as observed in the preceding data analysis. The system dynamics model encapsulates the problem of excessive fluctuations and stunted growth in the output of the existing system structure of the construction industry of Kenya, in terms of nineteen model variables, comprising: 4 levels, 6 auxiliaries 4 constants, and 5 rates – as Shown in Figure 5.2 of Chapter V. It is soundly constructed and valid, and is therefore suitable for understanding influences of various policy interventions on the behaviour of the construction industry of Kenya.

Simulations from the system dynamics model support the systems view of fluctuations in output of an organization. They confirm that the fluctuations and growth trends of construction output in Kenya actually originate from the feedback control structure of the existing construction industry system, as argued in systems thinking (for example, in Braun 2002 and Senge 1990). The reference mode of the system dynamics model represents the existing system structure of the construction industry of Kenya. Simulated values of the model variables are therefore those that are expected to have occurred in the industry from 1964 to 2003.

The reference reveals that the force driving construction activity fluctuations is the Unsatisfied Demand for Constructed Space (UDCS). This observation agrees with Hillebrandt’s (2000) and Raftery’s (1992) observations - that construction activity does not occur when there is no unsatisfied demand for constructed
facilities in the economy. Additionally, comparison of the UDCS oscillation with oscillations of the other model variables indicates that UDCS is significantly more uncertain than Demand for Constructed Space (DCS) or Stock of Constructed Space (SCS), which are its determinants, as described in Section 5.7.1. The variation of DCS gives insight into the way the two system archetypes – balancing process with a delay and limits to growth – actually operate in the construction industry of Kenya. This insight was used to explore possible structural changes in the system dynamics model of the existing structure of the construction industry of Kenya, as amplified in Section 6.3 of Chapter VI.

7.2.5 A System Dynamics Model of Construction Output in an Improved System Structure

This objective is addressed in Chapter VI, where possible parameter and structural changes in the system dynamics model of the existing construction industry system of Kenya are explored. The exploration produces a system dynamics model of construction output in an improved structure of the construction industry system of Kenya. Then, construction activity in Kenya is projected to year 2050 to find out the expected future behaviour of the construction industry of Kenya. Four major conclusions are made from this exercise.

Firstly, the system dynamics model of the existing construction industry system of Kenya is fairly sensitive to changes in the policy parameters in the model. Changes in parameter values may produce fairly different values of the effect variable which, in this study, is the Construction Completion Rate. However, changes in policy parameters do not change the amplitude or frequency of oscillation in the construction activity. For that reason, there is no chance of improving fluctuations of construction activity in Kenya, by changing the policy parameters in the existing system structure. This result agrees with the counterintuitive principle of complex systems, as pointed out by Coyle (1996), Forrester (1969 & 1991) and Schoderbek, Schoderbek & Kefalas (1980).

Secondly, fluctuations and stunted growth of construction output can significantly be improved by structural changes in the existing system structure, which aimed to regulate response of the industry to changes in construction demand, and to expand the system’s source of demand. By so doing, these changes incorporate the prescriptive actions for the system archetypes operating in the construction industry of Kenya, as explained in Section 6.3. The structural changes necessary in the system dynamics model of the existing system structure are: (i) setting long-term targets of annual construction output in the industry as a whole; (ii) incorporating reserve capacity in the production process; and (iii) expanding the system structure to capture a larger construction market. Incorporation of such concepts in an industry implies that response of the construction industry to changes in construction demand should be imaginatively regulated within the long-term output targets set. Introducing regulation of response to changes in construction demand appears to be a rather counterintuitive measure and is likely to be quite challenging. All the same, it agrees with Kummerow’s (1999) concept of queuing proposed development projects to regulate the supply of constructed space. An equally counterintuitive concept encountered in the literature review is found in Ford (1996), whereby private power suppliers in the US managed demand by encouraging their consumers to use less power.
Thirdly, most of the policy changes suggested by participants in the construction industry of Kenya constitute parameter changes in the existing system structure, which are rather ineffective as explained above. For that reason, most of the policy suggestions are not effective for solving the problem of excessive fluctuations in construction activity in the country. All the same, one policy suggestion from the construction industry participants in Kenya, which constitutes a structural change in the system dynamics structure of the existing industry system, is the suggestion to expand the construction industry’s market to neighbouring countries. The policy suggestions are appraised in Section 6.4, in the light of the inferences made from the exploration of parameter and structural changes in the system dynamics model. The system dynamics model helps to assess the expected influence of policy changes in respect of eight out of the ten major problems of the construction industry of Kenya described in Section 4.2.3 of Chapter IV.

7.3 Conclusions about the Research Problem

It can be concluded that the research problem – excessive fluctuations and stunted growth of construction output in Kenya – investigated in this study is fundamentally caused by the structure of the existing construction industry system, which is characterized by (i) absence of regulation of response of the construction industry to changes in construction demand, and (ii) dependency of the construction industry on the Kenyan construction market. For that reason, policy measures aimed to address this problem will be effective if and only if they constitute fundamental changes in the feedback control structure of the construction industry.

At its lowest level of abstraction the construction industry of Kenya comprises many construction projects at various stages of their development. In one construction project, participants are brought together by the contractual and factual obligations specified in the construction contract. The main agreement is normally between a client and a contractor, but the rest of the participants come in by virtue of their responsibilities to either of the two. The main link between all the participants is the money paid or received in exchange for goods or services received or rendered (ACRef 1.27). Links between projects (and project teams) are their competition for resources, practical training of manpower for the industry and contribution to the overall outlook of the industry as a whole. Therefore, policy formulation to minimize fluctuations of construction activity and foster continual growth of the activity should fundamentally alter the links between projects and the links between participants in one project. For that reason, effective management is necessary for the construction industry as a whole, as well as for every individual project in the industry; the construction industry should be a managed system the way a corporation is.

The research hypotheses of this study were tested and neither of them was rejected. From these hypotheses tests it can be concluded that in the construction industry of Kenya, construction output is influenced by: (i) its own past levels; (ii) factors in the construction industry’s environment, which include the Gross National Product and misery index (i.e. unemployment rate + Inflation rate, %); and (iii) the system structure of the industry, which is illustrated diagrammatically in Figure 5.2 of Chapter V. Additionally, there are three remarkable insights obtained from this study, regarding the research problem, namely: (i) the variability Unsatisfied Demand for Constructed Space (UDCS) is significantly greater than the variability of construction output, (ii) historical levels of construction demand can be estimated by a workload differencing and summation method. and (iii)
system dynamics modeling gives more comprehensive understanding of construction activity than time series regression modeling.

Firstly, the force underlying construction activity fluctuations – proxied by the UDCS - is so uncertain that it is unlikely to be ‘captured’ by regression modeling which is the method mainly used in previous research to study construction activity. Fluctuations of the UDCS are far and away more vigorous - i.e. of significantly greater frequency and amplitude - than those of the Construction Completion Rate (CCR) which is the surrogate for annual construction output in the system dynamics model. Consequently, inferring the behaviour of UDCS (the underlying force) from the observed behaviour of construction output (represented by CCR in the system dynamics model) would be a gross simplification. But that is the practice implied in the majority of regression models of construction activity, whereby construction demand is proxied by construction output. As illustrated in Figure 5.2, the ‘distance’ – in time and space - between UDCS and CCR along the production process is so long that prediction of CCR that does not take account of this distance in a realistic way is unlikely to be accurate. Regression modeling does not take account of such ‘distances’ accurately, despite its stationarity and lag identification procedures. This appears to be a major reason why the time series regression models developed in this study and many similar regression models developed in previous studies have low explanatory powers (R² values) or give unrealistic representations of the variability of construction activity.

Secondly, in the conceptualization of the system dynamics model, a key exogenous variable that needs to be functionally defined is Demand for Constructed Space (DCS) in the economy of Kenya as a whole. A method for estimating historical values of DCS was developed for this study, as explained in Section 5.3 of Chapter V. The method is named *workload differencing and summation* method, and it transforms observed values of annual construction output into values of annual construction demand in the economy as a whole.

Thirdly, the system dynamics model (SD) developed in this study provides greater insight into the construction industry of Kenya, than the time series (ARIMA and multiple regression) models developed in the study. Four advantages of SD modeling are evidenced by the results of this study, as follows: -

1. The concept of incorporating system delays in the SD modeling takes account of the “distance” amongst variables in the construction process, in a more comprehensive way than the concept of identifying the lag structure of the variables in time series regression modeling. As a result, the process of the construction industry’s production activity is more elaborately brought out in the SD model. Consequently, the SD models explain greater variability in construction output than the time series models.

2. The construction data available in Kenya is more sufficient for SD modeling than it is for the time series modeling. The SD modeling incorporates both qualitative and quantitative data, an attribute which facilitates incorporation of 26 variables in the SD model. However, the time series modeling requires quantifiable data which were available for 3 variables only (construction output and 2 explanatory variables). This data limitation makes the coefficients of determination (R² values) of the
regression models relatively low. Additionally, even if there were more explanatory variables for regression modeling, the multiple regression analysis would be greatly limited by the length of the time series (sample size). According to Gujarati (2003: 853), estimating that many regression coefficients “will consume a lot of degrees of freedom, with all the problems associated with that.”

(3) The SD models offer more versatile tools for experimentation with various policy changes suggested for the construction industry of Kenya, as demonstrated in Sections 6.2 to 6.4, of Chapter IV. This is because there are more variables in the SD models than in the time series models, as explained above. Therefore, the system dynamics model can help policy analysts see influences of changes in variables which are apparently ‘far apart’ in distance and time. Additionally, the variable relationships conceptualized in the SD models are ‘circular’, as opposed to the ‘linear’ relationships conceptualized in the time series models. In the SD models, construction output influences and is influenced by 25 other variables. However, in the regression models, the construction output is a dependent variable influenced by its own past values and also by other explanatory variables. Influence of construction output on these variables is not taken account of in the time series models found in the literature reviewed. For that reason, many more ‘what if’ tests can be performed with the SD models than with the time series regression models.

(4) The SD models have a longer forecast horizon than the time series models. As demonstrated in Sections 6.5.1 to 6.5.3, the SD models can simulate construction activity in Kenya even up to year 2050. This would alert the industry’s policy maker of the expected system behaviour well in advance, and should aid long range planning. However, forecast horizons of time series models are quite short. For example, the forecast horizon of the ARIMA (1, 1, 1) model developed in Section 4.4.2 of Chapter IV is only 2 years i.e. p + q periods, according to Notman et al (1998). The ARIMA model is therefore not suitable for understanding long-term implications of policy interventions.

Despite the above-described advantages of SD modeling, one of their attributes is that they are not precise in forecasting. All the same, this is not a serious weakness because precision is not the objective of SD models; accuracy – i.e. realistic replication of the problem behaviour and fitness for the intended purpose - is the main objective. According to Coyle (1996: 11) the emphasis of SD modeling is “exploring the behaviour of the system rather than predicting precise details.” Where precise forecasts are necessary, SD models may be coupled with time series models for correction of forecast error (for example in Pidd 1988).

A time series model that may support the SD model developed in this study is a regression model of the Demand for Constructed Space in the economy of Kenya. Demand for Constructed Space (DCS) is the variable that is situated ‘closer’ to the construction industry’s environment than Construction Completion Rate (CCR), as shown Figure 5.2 of Chapter V. It is therefore more realistic to conceptualize DCS as an intervening variable between ‘environmental’ factors and CCR than to conceptualize CCR as a function of the ‘environmental’ factors. This is an area for further research as explained in Section 7.6.
In the light of the conclusions made about the research objectives and the research problem, it is evident that this study makes a distinct contribution to the body of construction economics knowledge in three aspects, namely: (i) the study performs time series and system dynamics modeling of construction output in Kenya, which were observed not to have been done in any of the previous research studies encountered in the literature review; (ii) the study performs system dynamics modeling of construction output at industry level, which is not a commonly adopted approach to investigating problems in the construction industry worldwide, as indicated by the literature reviewed; and (iii) the study develops a transformation method for estimating historical construction demand in the construction market, based on interpretation of the system delays in the construction process at industry level. According to Perry (2002: 81), stretching a body of knowledge, albeit slightly, by “using a relatively new methodology in a field, using a methodology in a country where it has not been used before, or making a synthesis or interpretation that has not been made before” constitutes a distinct contribution to knowledge. Therefore, this study has actually made a distinct contribution to knowledge of facts about the construction industry of Kenya, and of theory in construction economics and management generally.

7.4 Implications for Theory

In brief, the development of a system dynamics model of construction output implies that experimental economics and management can be used to learn the behaviour and evolution of a construction industry. The system dynamics model is a laboratory where various policy suggestions can be experimented with - to gain sufficient insight into the expected response of the construction industry - before the policies are actually applied to the industry. Such a laboratory should be a great decision tool for policy makers in the construction industry.

Observations made in this study have three major implications for theory in construction economics and management, and for theory in property management. Firstly, the observation that there is need for regulation of response of the construction industry to changes in construction demand implies that the industry as a whole needs to be managed the way a business corporation is managed. Generally, a construction industry is not viewed as a ‘managed system’ the way a corporation is viewed, and according to Kummerow (1999), the industry is therefore managed collectively and simultaneously by all the players in it. This leads to the prisoner’s dilemma, whereby bright individual strategies result in collective folly. Efficient construction management at project (and firm level) should be supported by efficient construction management at industry level, in order to increase the organizational efficiency of the construction industry as a whole.

Secondly, adoption of systems thinking in the construction industry is likely to significantly influence the property industry which is the source of demand for constructed space and also the consumer of constructed space. In system dynamics terms, the property industry is the source and the sink of the system structure of the construction industry. Regulation of the industry’s response to outcomes from the source implies that the flow of output going to the sink is also regulated. This influences the rate at which the stock of constructed space is added into the property industry. Consequently, the property industry as whole and individual property developers in it may have to make do with a number of apparently counterintuitive regulatory measures, such as Kummerow’s (1999) queuing of proposed development projects to regulate supply of constructed space.
Finally, adoption of systems thinking in construction economics and management mainly involves change in the way the information available is used in the construction industry. While need for more comprehensive records of construction activity is not in dispute, systems thinking is not limited to recorded data. A system’s decision criteria depend on data that exists in the system whether the data is recorded or not. The challenge of the construction industry ‘manager’ is to imaginatively changes the information links in the system in order to purposefully drive the industry towards clearly defined and mutually beneficial long-term targets.

7.5 Implications for Policy

As stated before, poor regulation of construction activity at industry level and limited market of the construction industry are the underlying causes of excessive fluctuations and stunted growth of construction output in Kenya. For that reason, recommendations for addressing this research problem are system ideas that have been tested and found working for similar problems in other complex systems. All the same, the system ideas here are tailored to the specific characteristics of the construction industry of Kenya, and emphasize what the construction industry itself can do, without needing the government to shield it from effects of unfavourable political, social or economic conditions in the country.

Generally, it is innovative collaboration between policy makers, consultants and contractors in the construction industry of Kenya that will bring stability and continual growth of the industry’s output, and by implication, production capacity. Effectiveness of the construction industry can be increased by the Ministry of Roads & Public Works, Ministry of Local Government, consultants and contractors jointly establishing a regulatory framework to (i) constantly avoid overshoot and collapse in the industry’s activity, and (ii) to continually develop, employ and retain the production capacity of the construction industry.

A realistic starting point in the application of regulatory and expansionist ideas of systems thinking is to establish a strong central body to plan and control all the matters of the construction development process spread over various government ministries. The essence of a central body is to make the construction industry a “managed system”, consequently avoiding its collective and simultaneous management by diverse individuals or institutions. As Kummerow (1999) observed, such collective and simultaneous management leads to the prisoner’s dilemma, whereby bright individual strategies result in collective folly. Therefore, the construction industry system needs to be consistently steered by management towards defined long-term goals in order to remain stable.

The idea of a central statutory body to manage construction industry has been echoed in various fora. For example, in 2006, the International Symposium on Construction in Developing Economies advocated establishment of construction industry development boards (CIDB) in developing countries, for the purpose of developing and regulating construction activity in the countries (Serpell 2007). Singapore and South Africa are some of the countries that have established CIDB’s (Fuk-Jin & Ogunlana 2006, Ofori, Hugo & Hindle 1996, Republic of South Africa 2000); Kenya can borrow a leaf from there. The managerial role of a well established CIDB cannot be overemphasized. According to Fuk-Jin & Ogunlana (2006), a CIDB should provide managerial services that directly benefit the companies registered under it and eventually improve industry’s organizational
efficiency in drastic ways. Therefore, establishing a CIDB is a realistic way to convert a construction industry from being an unmanaged system to being a managed system whose feedback control structure can be purposefully designed for continual growth and stability.

In Kenya, a central body to manage the construction industry has also been recommended in previous studies. For example, in Mutiso’s (1998) Report, a Planning and Building Authority was recommended mainly for controlling the quality of constructed facilities in Kenya. However, there is no evidence that that recommendation was ever implemented. From a systems point of view, there are many indications that the construction industry of Kenya remains an unmanaged system, as described before. This study recommends a central body to \textit{plan and regulate the construction process at the macro-level} of the industry. The responsibility of the central body should ideally include the micro-level quality control strategies recommended in Mutiso’s (1998) Report.

On the basis of the findings of this study, possible measures that the central body can take to address the problem of fluctuations and stunted growth of construction output in Kenya are to: (1) set annual targets of construction output in the industry as a whole; (2) regulate activity of the private sector within the set targets; (3) expand the market of the construction industry; and (4) minimize the supply lag of constructed space. Table 7.1 gives a summary of the findings that make the basis of these recommendations. It also shows the Sections in the text where the findings are presented. The recommendations are amplified in Sections 7.5.1 to 7.5.4 below.

7.5.1 Setting annual targets of construction output

In order to avoid excessive overshoot and collapse of construction activity the central body can set the annual construction completion targets in the country as a whole, in the very long-run, say in the next 40 – 50 years. Setting of the production targets should be based on (i) the total construction demand implied in the long-term development plans of Kenya (such as Kenya Vision 2030 [Republic of Kenya 2007]); (ii) construction demand outside Kenya, which the construction industry should purpose to serve as explained in 7.5.3, and (iii) expected future levels of private construction demand in Kenya, which can be inferred from the trends observed in this study.

A possible approach to setting the production targets could be to assess the long-term growth potential of the construction industry – considering the three factors above - and then define a feasible trend for this growth to follow. That would be similar to the concept used in this study to define the Practical Completion Rate for the period 2003-to-2050. The purpose is to have clearly defined construction output targets \textit{set by industry policy well in advance} to guide consistent production and growth of the industry.
<table>
<thead>
<tr>
<th>Finding</th>
<th>Section</th>
<th>Recommendation</th>
</tr>
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<tr>
<td>1 There lacks clearly defined production goals at industry level, in the existing feedback control structure of the construction industry of Kenya. Consequently, the completion ‘targets’ of construction activity are determined by the outstanding construction workload. For that reason, inclusion of <em>a planned completion target</em> in the improved system dynamics model of the construction industry constitutes a fundamental change in the industry’s feedback control structure.</td>
<td>Section 5.4 (v), Section 6.3.1 (i) and Figures 6.8.</td>
<td>Set annual targets of construction output in the industry as a whole.</td>
</tr>
<tr>
<td>2 The private sector responds to the Unsatisfied Demand for Constructed Space in an uncoordinated manner. Consequently, the sector’s corrective action in response to demand changes fails to sufficiently take account of system delays in the production process at industry level. For that reason, inclusion of <em>reserve capacity</em> in the improved system dynamics model of the construction industry constitutes a fundamental change in the industry’s feedback control structure.</td>
<td>Section 5.7.1 &amp; 5.7.2, Section 6.3.1(ii) and Figure 6.9.</td>
<td>Regulate activity of the private sector within the set targets.</td>
</tr>
<tr>
<td>3 Dependency of the construction industry of Kenya on the construction demand from the country is a limiting factor to the growth of the industry. For that reason, inclusion of <em>construction demand from outside Kenya</em>, in the improved system dynamics model of the construction industry constitutes a fundamental change in the industry’s feedback control structure.</td>
<td>Section 4.3.3, Section 6.3.1(vi), and Figure 6.11.</td>
<td>Expand the market of the construction industry.</td>
</tr>
<tr>
<td>4 Fluctuations of construction output in Kenya are rather insensitive to parameter changes in the feedback control structure of the construction industry. Consequently, reducing system delays - Time to Design, Time for Planning Approval and Time to Complete Outstanding workload – does not constitute fundamental changes in the feedback control structure, for the purpose of minimizing output fluctuations. All the same, reduction of the system delays implies increase in the Average Contractor Output, which may <em>increase the quantity of annual construction output and production capacity of the industry.</em></td>
<td>Section 5.4.3, Section 6.2, Figure 6.1 to 6.4, and Table 6.2.</td>
<td>Minimize the supply lag of constructed space.</td>
</tr>
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7.5.2 Regulating activity of the private sector

Efficient regulation of the construction industry is necessary for its activity to proceed as per the long-term growth and stability targets of the industry. The central body should therefore regulate the response of the construction industry - particularly the private sector contractors and consultants - to changes in construction demand. A possible tool for this regulation is sufficient reserve production capacity in the industry. The reserve capacity constitutes consultants and contractors available to absorb inevitable short-term oscillations of the Unsatisfied Demand for Constructed Space, thereby preventing these oscillations from affecting the annual construction output, and making construction activity relatively more stable.

However, reserve capacity is a tricky tool to use because reserve capacity, is expensive to maintain. It requires continual build-up and retention of the production capacity of the industry and an effective flow of market information through the construction industry. Active and reserve production capacities should therefore be imaginatively managed to ensure overall feasibility of the tool to the construction industry as a whole.

7.5.3 Expansion of the construction market

In order to overcome the limiting effect of the Kenyan construction demand, the central body can market all Class A construction firms in Kenya, to the Eastern & Central African region as a whole and assist the firms expand their operations into the neighbouring countries – Uganda, Tanzania, Rwanda, Sudan, Ethiopia, Botswana and Seychelles - thereby reducing dependency on the Kenyan construction demand. Should an abrupt deficit occur in the construction workforce in Kenya, the Kenyan workforce spread over the region should be relatively easier to bring back to the country, at least in the short run, since the workforce would be employed by Kenyan firms. That expansion will therefore make the industry less vulnerable to vagaries of its environment.

7.5.4 Minimization of the space supply lag

Space supply lag refers to the duration between occurrence of demand for constructed space in the property market and delivery of the required space to the market. In order to minimize this lag the central body can: (i) do accurate market surveys and disseminate the findings to the real estate industry, to facilitate prompt feasibility appraisals of real estate investments and timely decisions to invest in real estate; and (ii) establish overall industry measures to minimize individual project delays, for example: comprehensive physical development plans, efficient development control by Local Authorities, effective recruitment of contractors, and efficient procurement systems.

These measures should minimize the three major system delays in the construction industry, namely: Time to Design, Time for Planning Approval and Time to Complete Outstanding work. They should make the construction industry more efficient, thereby increasing the Average Contractor Output and the reputation of the industry in the regional market. However, the measures do not constitute fundamental changes in the system structure of the construction industry of Kenya. They are therefore not as effective as the three measures explained in Sections 7.5.1 to 7.5.3 above.
7.6 Further Research

This study adopted a case study design. There is need for a survey research to generalize the findings to other construction industries. In the course of the study, it was observed that the following areas, which particularly relate to the construction industry of Kenya, need further research:

(i) **Annual Completion Targets**: Developing criteria for setting the annual targets of construction output requires further investigation. The Planned Completion Target (PCT) is a key variable in the system dynamics model developed in this study. A major challenge in setting the PCT is to synchronize the projected industry capacity with construction output levels implied in long-term national development plans. The construction completion targets implied in the property development goals in these plans should therefore be estimated and synchronized with the expected levels of the construction industry’s production capacity in the very long run.

(ii) **Reserve Production Capacity**: Developing criteria for availing and maintaining the reserve production capacity in an economical way requires further study. Reserve capacity is expensive to maintain. It may imply idle capacity always remaining in the construction industry system. Innovative ways of maintaining the reserve capacity at minimum cost should be established.

(iii) **Construction market research**: Expansion of the construction industry market beyond Kenya requires investigation of the construction business opportunities in the African continent and beyond. The logistics of partnering between the government and the private sector need to be established, in order to make the expansion exercise feasible. Venturing into the outside market needs to be well balanced with serving the Kenyan market adequately, to ensure that the national development goals of Kenya are not compromised in the pursuit of stability and growth of its construction industry.

(iv) **Inventorying the constructed space**: Developing procurement methods that promote speculative building in all the building sub-sectors such that building space can be inventoried and sold just in time to meet demand. This should reduce space supply lag and make construction activity relatively more stable.

(v) **Regression model of Demand for Constructed Space (DCS)**: A multiple regression model of DCS should be established, for forecasting DCS in terms of various explanatory variables in the environment of the construction industry. This model could be used together with the system dynamics model developed in this study, for monitoring activity of the construction industry. In the system dynamics model, projections of DCS can be done by extrapolation for long term planning (say, for next 50 years), followed by adjustments of prediction error every 5 years, using forecasts from a regression model of DCS. Additionally, a system dynamics study of the economy of Kenya (the supra-system of the construction industry of Kenya) is necessary to establish how factors in the environment of the construction industry interact to produce DCS in the economy as a whole.

(vi) **Contractor recruitment and co-ordination**: Although there are contractor organizations in Kenya, the operation of the contractors at industry level is rather haphazard. Additionally, the criteria of registration of contractors by the Ministry of Roads and Public Works appear to be somewhat ineffective. Anecdotal evidence
shows that some contractors registered as class A do not have the requisite capacity to execute large projects. Contractor recruitment and co-ordination therefore requires investigation and streamlining to create a contractor sub-system that is amenable to regulation of response to construction demand and to orderly expansion into the international market.

(vii) **System dynamics models of sectoral construction outputs in Kenya**: System dynamics modeling should be applied to study of the building and civil engineering sectors separately, taking account of differences in the detail complexities of the two sectors. Also, use of SD modeling to understand the non-monetary and informal construction activity should be explored. These studies should establish areas of leverage for various policy interventions in the sectors, which can improve the organizational performance of the construction industry of Kenya as a whole.

(viii) **Policy experiments with construction demand originating from Public Private Partnerships**: Construction demand originating from private public partnerships (PPP) in Kenya should be incorporated in the system dynamics model developed in this study, and its influence on the growth and stability of the construction activity investigated. PPPs have only just started in Kenya and not much can now be said regarding their performance in the country. There is therefore need to establish whether the PPPs bring about parameter changes or structural changes in the feedback control structure of the construction industry.

### 7.7 Conclusion

The literature reviewed suggests that systems thinking can be effectively used to understand the problem of excessive fluctuations and slow growth in the construction industry of Kenya. This research developed a system dynamics model of construction output in Kenya. It showed that the system dynamics model gives remarkable insight into the behaviour of construction industry, as the literature suggests, and set a foundation for further research about system dynamics modeling in the construction industry worldwide.
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Appendix A: Documents and Interviewees
The following is the list of the documents examined and the nature of persons interviewed in the data collection process. The documents total 37No. They are theses, articles, etc found to somewhat describe the systems view of the construction industry and are listed in alphabetical order. The earliest of them is dated 1980, while the latest is dated 2005. The Interviews were conducted between April and May 2006.

1. **Documents Examined**


Appendix A


Appendix A

Documents and Interviewees


2. Interviewees

The following is a brief description of the interviewees who participated in this study.

Interviewee No. 1: Land Economist & Property Consultant; Interview Date, 29th March 2006

Interviewee No. 2: Land Economics Scholar & Researcher; Interview Date, 5th April 2006

Interviewee No. 3: Land Economics Scholar & Researcher; Interview Date, 5th April 2006

Interviewee No. 4: Construction Economics Scholar & Researcher; Interview Date, 5th April 2006

Interviewee No. 5: Land Economist & Property Consultant; Interview Date, 6th April 2006

Interviewee No. 6: Land Economics Scholar & Researcher; Interview Date, 6th April 2006

Interviewee No. 7: Construction Economist & Applicant of Systems Theory in Research; Interview Date, 13th April 2006

Interviewee No. 8: Architect & Senior Government Official; Ministry of Roads & Public Works; Interview Date, 19th April 2006

Interviewee No. 9: Surveyor & Senior Government Official; Ministry of Lands; Interview Date, 20th April 2006

Interviewee No. 10: Construction Economist & Applicant of Systems Theory in Research; Interview Date, 5th May 2006
Appendix B: Interview Questions
The interview questions are semi-structured; they were simply meant to prompt discussion with the interviewee.

(a) Ministry of Roads & Public Works
1. What is the vision of the construction industry in Kenya?
2. What policy documents lay down how the vision is to be achieved?
3. How do government ministries place their requests to the government for constructed facilities?
4. Describe how the government decides whether or not to execute the requested developments.
5. What percentage of the requested developments gets the government approval?
6. How are estimates of development expenditure on construction at the Ministry computed?
7. What is the physical scope of works implied in the Development Estimates?
8. Do the development estimates for the Ministry of Roads & Public Works include all projected construction expenditure on public projects in all the other ministries?
9. How does the Ministry influence construction activity in the private sector?
10. Suggest ways by which the difference between the demand for and supply of constructed facilities in Kenya can be minimized.
11. Tender price indices from 1955 to 2005
12. Progress of the District Focus for Rural Development Strategy
13. Practicality of central body to do overall planning, control & coordination of the construction industry for private & public sectors.

(b) Ministry of Lands
1. What is the vision of the national physical planning in Kenya?
2. What percentage of the rural & urban land is planned/surveyed/registered?
3. Influence of the existing land policy & physical plan on real estate development
4. Procedure for availing land for proposed public developments

(c) Real Estate Developers & Property Consultants
1. How do you identify demand for constructed facilities in Kenya?
2. How do you estimate and take account of the demand in your investment appraisal?
3. What criteria do you use to decide whether to construct or not to construct new facilities?
4. What is the weakest link in the supply of constructed facilities in Kenya?

5. Which of the following resources do you consider to be a limiting factor in real estate development in Kenya: land, information, materials, manpower, plant & equipment, power, transport, finance, etc?

6. Briefly describe the trends you expect outputs of residential building, commercial building & road construction to show in the next five years in Kenya.

7. What is the rate of growth/decay in demand for each of the three categories of constructed facilities in (5) above?

8. Give your opinion on the reasons for fluctuations in construction activity in Kenya and ways in which the fluctuations can be minimized.

9. Give your suggestions for minimizing the duration between the time construction demand presents itself in the market and the time it is noticed.

10. Give your suggestions for minimizing the difference between the demand for and supply of constructed facilities in Kenya?

11. Practicality of queuing proposed projects at City Council (& other local authorities) to control supply & avoid fluctuations.

12. Practicality of a central body to do overall planning, control & coordination of the construction industry for private & public sectors.

13. Existing levels of demand for various facilities – recent market surveys and/or data bases of developers & property consultants.

14. Real estate development capacity & its growth rate in Kenya

15. Inventory of the existing stock of constructed facilities, e.g. lengths of roads, commercial space, housing etc.

16. Equilibrium level of construction output i.e. where annual construction supply is equal to annual construction demand, allowing for existing stock, growth rates in demand and growth rates in supply capacity.

17. Market research firms in the construction industry in Kenya & popularity of their service.

18. Accuracy and comprehensiveness of the market data, as basis for decision-making.

(d) Scholars & Researchers - Generally

1. What is your current (or most recent) research in the construction/real estate industry in Kenya?
2. Which of the following resources do you consider to be a limiting factor in real estate development in Kenya: land, information, materials, manpower, plant & equipment, power, transport, finance, etc?

3. Briefly describe the trends you expect outputs of residential building, commercial building & road construction to show in the next five years in Kenya.

4. What is the rate of growth/decay in demand for each of the three categories of constructed facilities in (5) above?

5. Give your opinion on the reasons for fluctuations in construction activity in Kenya and ways in which the fluctuations can be minimized.

6. What is the weakest link in the supply of constructed facilities in Kenya?

7. Give your suggestions for minimizing the duration between the time construction demand presents itself in the market and the time it is noticed.

8. Give your suggestions for minimizing the difference between the demand for and supply of constructed facilities in Kenya?

9. Which of the following systems approaches have you ever applied in your research/design project: general systems theory, cybernetics, system dynamics, systems analysis, systems engineering, operations research?

10. What were your objectives & observations in applying (6) above?

11. Demand/supply decisions that are mainly based on expert intuition & experience [heuristics].


13. Practicality of queuing proposed projects at City Council (& other local Authorities) to control supply & avoid fluctuations.

14. Practicality of a central body to do overall planning, control & coordination of the construction industry for private & public sector.

15. Contracting capacity & its growth rate in Kenya.


17. Equilibrium level of construction output i.e. where annual construction supply is equal to annual construction demand, allowing for existing stock, growth rates in demand and growth rates in supply capacity.

18. Market research firms in the construction industry in Kenya & popularity of their service.

19. Accuracy and comprehensiveness of the market data, as basis for decision-making.
(e) Applicants of Systems Theory in Research

1. What are the performance objectives of the construction industry in Kenya as a whole - output targets, product/service quality, production efficiency, etc?

2. Who “manages” the industry towards achieving the performance objectives in (1) above?

3. What phenomena influence performance of the construction industry, causing performance improvement (or decline) or keeping the performance at the same level in the long run?

4. How is feedback (i.e. performance evaluation & corrective action) structured at industry level?

5. If you feel that the feedback structure in (4) above needs to be improved, suggest ways in which this can be done?

6. What is best (realistic & comprehensive) way of viewing the construction industry sub-systems in Kenya?

7. What are your views on this research study generally?
Appendix C: Qualitative Data
<table>
<thead>
<tr>
<th>System Aspect</th>
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<th>Description of System Aspect</th>
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<tbody>
<tr>
<td>(I) Sub-Systems</td>
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<td></td>
</tr>
<tr>
<td>(a) Entities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Mathu K. (1980) “Designers must come over” Build Kenya April 1980&lt;br&gt;Page 29: The contracting side of the construction industry in Kenya has a three tier pattern. Large, sophisticated and often foreign contractors dominate the lucrative highly organized large civil engineering and building projects; well organized mainly local firms concentrating on the smaller civil engineering and commercial developments in the main towns; the third group is composed of emergent contractors and jobbers mainly African - who execute small building projects and maintenance jobs while being almost entirely excluded from the civil engineering element. The top category of large contractors has no geographical specialization and controls 60% of value of contract awarded. The middle one is largely in main urban centres and about 30% and the bottom one controls about 10%</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>Mbaya, J. S. (1984)&lt;br&gt;Page 4: The complexity of clients' demand, together with increasing complexity of building process and the environment has forced specialization in the building industry. The professions associated with construction are distinct as separate skills of architects, quantity surveyors, structural/mechanical/electrical engineers, planners, etc. The organizations associated with supply of buildings have also emerged as main-builders, specialist sub-contractors, suppliers, plant hirers, etc working with the main contractor. Any project even the very small one will involve a large number of contributors. For all these differentiated professions, firms or skills involved, there is need for inter-organizational co-ordination and integration.</td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>Nguyo D M A (1988)&lt;br&gt;The Ministry of Public Works is the government ministry with responsibility for policy formulation for the country’s construction industry. It is also supposed to disseminate construction information to the industry.</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>The public sector contributes about 50% of the construction demand, a significant quantity for a single client.</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>The government building development programme utilizes the private professional consultants whenever its specialized skills are lacking in number or quality. Building production is done through the private contracting industry. There are about 3000 registered contractors who undertake various types of work under different category levels.</td>
<td></td>
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</tbody>
</table>

**Note:** In Chapters III to VII of this study report, evidence for deductions made from the qualitative data in Appendix C is cross-referenced as ACRef …… [reference numbers stated], while cross-references to all the other Appendices are stated in full.
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<tr>
<td>(a) Entities (Cont’d)</td>
<td></td>
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</table>
Page 2: The property market is strongly influenced by major institutional interests, principally insurance companies and pension funds. Asset weightings are as high as 25% or more. However, investment trading is generally low and the market tends to lack liquidity. |
| 1.8 | Page 7: The planning system in Kenya is similar to the UK model, although in Nairobi, there is only one tier of Government - the City Commission. Whilst City Plans are prepared, the operations of the planning process are based on participation rather than regulation. Detailed zoning systems are in place but these can and do respond to commercial and/or political pressure. The current City Plan for Nairobi dates back to 1972 and, despite revisions, now requires complete overhaul to take account of profound changes in the commercial and social landscape. |
| 1.9 | Page 8: The contractor sector is well developed but dominated by Asian interests. |
Page 5: To date, the Institute has a membership of about 150 No. members of different classes. |
Page 11: On the whole, I (QS Gichuiri) would say that the QS profession has grown in numbers from only three indigenous professionals in 1972, to over 500 as of today. |
Functions of the Ministry of Roads and Public Works: Roads Development Policy; Public Works Policy; Development, Standardization and Maintenance of Roads; Materials Testing and Advice on Usage; Public Works Planning and Policy Development; Standardization and Maintenance of Plant and equipment; Vehicles, Plant and equipment; Kenya Roads Board; Development and Maintenance of Public Buildings; Maintenance of Inventory of Government Property; Provision of Mechanical and Electrical Services; Supplies Branch; Co-ordination of Procurement of Common-user Items by Government Ministries; Kenya Building Research Centre; Registration of Engineers, Architects and Surveyors; Registration of Contractors and Material Suppliers; Registration of Civil, Building and Electromechanical Contractors; Kenya Institute of Highways and Building Technology; Maintenance of Airstrips; Maintenance of Security Roads; Other Public Works” |

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<td>(a) Entities (Cont’d)</td>
<td>Role players- individuals &amp; organizations - in the industry</td>
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</table>

#### Table: Role Players - Individuals & Organizations - in the Industry

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<tr>
<th>Reference No.</th>
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<tr>
<td>1.13 Ministry of Roads &amp; Public Works Contractors Registration Bureau; March 2006</td>
<td>In 2004, there were about 7000 contractors in the Ministry of Works Register of Contractors. Allowing for attrition over the years, the highest active number of contractors at one time is approximated at 5000 - 6000 No. The Ministry deregistered all of them and requested fresh applications in order to update its records. As at 15th July 2005, 1346 contractors had reapplied and re-registered. The re-registration process is ongoing.</td>
</tr>
<tr>
<td>1.14</td>
<td>There are professional bodies such as the Architectural Association of Kenya (AAK), Institute of Engineers of Kenya (IEK) &amp; Institute of Quantity Surveyors of Kenya (IQSK). Registration of professionals is done by the Board of Registration of Architects &amp; Quantity Surveyors (BORAQS).</td>
</tr>
<tr>
<td>1.15</td>
<td>A professional body for construction project management is now in the process of registration. The registration is facilitated by the IQSK. The body is named the Institution of Construction Project Managers of Kenya (ICPMK) and is aimed at regulating the practice of construction project management in the country. Although there exists a project management (general) body in Kenya, there is now no formal regulation of construction project management in the country.</td>
</tr>
<tr>
<td>1.16 Engineers Registration Board; March 2006</td>
<td>In 2004, there were 2289 Engineers registered with the Engineers Registration Board. But 918 of them were de-registered, leaving 1371 No. Registered Engineers in the Board’s list. Adding 182No. Registered Consulting Engineers brings the number of currently active Engineers (of various disciplines) to 1553 No. Allowing for Engineers who may still be active, despite de-registration, the number of active engineers in the construction industry may be estimated at 2000No. Their distribution is roughly as follows: Civil/structural, 80%; Electrical 9%; Mechanical, 7%; and Agricultural, 5%.</td>
</tr>
<tr>
<td>1.17 Board of Registration of Architects &amp; Quantity Surveyors (BORAQS); March 2006</td>
<td>There are about 560 Quantity Surveyors and 1090 Architects registered with BORAQS</td>
</tr>
<tr>
<td>1.18 Interviewee No. 1: Land Economist &amp; Property Consultant; 29th March 2006</td>
<td>A central body - an independent Commission, drawing all stakeholders, even contractors - to oversee and coordinate development process (land acquisition, occupancy, etc.) has been proposed in various government Sessional Papers &amp; draft policies - Draft National Land Policy, Housing Policy 2004, Draft Housing Act, Physical Planning Act 1996 and the Environmental Management Act. However, the Acts/Policies sometimes conflict.</td>
</tr>
</tbody>
</table>

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## System Aspect | Reference No. | Description of System Aspect
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### (1) Sub-Systems
| (a) Entities (Cont’d) | Interviewee No. 3: Land Economics Scholar & Researcher; 5\textsuperscript{th} April 2006 | A central coordinating body (like NEMA) is practical; it should be a public advisory body but not a body to exert control. The body could be for planning and guiding investment, based on an investment policy. An investor would go to this body first before going to City Hall, to confirm that the investment meets the national demand.
| | Interviewee No. 4: Construction Economics Scholar & Researcher; 5\textsuperscript{th} April 2006 | A central coordinating body (Board) like in South Africa is practical and should be encouraged. The construction industry is currently haphazard and uncoordinated in operation.
| | Interviewee No. 7: Construction Economist & Applicant of Systems Theory in Research; 13\textsuperscript{th} April 2006 | The industry has no “manager”. The private sector has been left to market forces. Yet, 40\% of all other industries depend on construction (infrastructure); for manufacturing, 20\% of the industry depends on construction industry. This has resulted in uncontrolled, uncoordinated and contradictory developments. Example – increase in housing in Kilimani but with no sufficient infrastructure. The government does not seem to show interest in the private sector, yet today the sector contributes about 80\% of construction activity. Not even a chapter in the National Development Plan is devoted to the construction industry despite its importance as an input in every other sector.
| | Interviewee No. 10: Construction Economist & Applicant of Systems Theory in Research; 5\textsuperscript{th} May 2006 | The construction industry has no centralized management for the greater (national) vision.
| | Ministry of Roads & Public Works; Contractors Registration Bureau; February 2007 | The Current Register of Contractors (dated 15\textsuperscript{th} July 2006) comprises 1799 registered contractors. The registration process is going on. It is expected that about 500 – 700 more contractors will be added in the next Edition of the Contractors’ Register, which is likely to be ready in March or April 07. Appendix D shows the number of contractors registered in various trades.

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### Appendix C  Qualitative Data Collected

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<tr>
<td>(b) Sub-system bonds</td>
<td></td>
<td>Links between the inputs, processes, outputs in one sub-system, and links between all the sub-systems; mechanisms and lines of communication and production.</td>
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<tbody>
<tr>
<td>1.24</td>
<td>Mbaya, J. S. (1984)</td>
<td>Page 7: Government influences professional practice in construction industry through the Board of Registration of Architects &amp; Quantity Surveyors and through other legislative mechanisms to the extent that practice and procedure applicable for government projects can be considered to be widespread. Some of the documents that contain the control legislation are: Cap 525 of Laws of Kenya, AAK Constitution &amp; By-Laws &amp; the Conditions of Engagement &amp; Scales of Fees for Professional Services for Building Works.</td>
</tr>
<tr>
<td>1.25</td>
<td>Nguyo D M A (1988)</td>
<td>Page 20: The success of the construction process depends upon the way in which the architect, engineer, QS, contractor, subcontractors and the client work together.</td>
</tr>
<tr>
<td>1.26</td>
<td>Nguyo D M A (1988)</td>
<td>To realize integration, given the fragmented organizational structure of the project implementation process in public projects it is necessary to maintain all the interconnections with an efficient flow of information. In an industry as fragmented as construction, information provides the necessary linkages between participants.</td>
</tr>
<tr>
<td>1.27</td>
<td>IQSK (2000)</td>
<td>Participants in construction are brought together by the contractual and factual obligations specified in a construction contract. The agreement is between a client and a contractor but the rest of the participants come in by virtue of their responsibilities to either of the two. The link between all the participants is the finance paid or received in exchange for goods or services received or rendered.</td>
</tr>
<tr>
<td>1.28</td>
<td>IQSK (2000)</td>
<td>“Memorandum by the Council Members of IQSK Presented to the Minister for Roads &amp; Public Works, Hon. Eng. Andrew Kiptoon, on 5th April 2000” The Quantity Surveyor, Journal of the Institute of Quantity Surveyors of Kenya [IQSK], Nairobi, Tumaini Agencies Page 8: He noted that professionals in the building and construction industry in Kenya have been compromised and are no longer applying what they learned at the University and other institutions. For instance, Architects have take shortcuts in designs and do not give detailed drawing as required by their professional training. Quantity surveyors have also their sins of omissions and commissions. He observed that the Government in Kenya has not been employing and retaining the best brains in the professions unlike the developed countries like USA, UK, Japan and European countries. Subsequently, the Government has been lacking the best policy formulators, executors and implementers of Government projects. The Government should look at this issue very critically if it has to retain quality professionals.</td>
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<tr>
<td>(b) Sub-system bonds (Cont’d)</td>
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<td>Links between the inputs, processes, outputs in one sub-system, and links between all the sub-systems; mechanisms and lines of communication and production.</td>
</tr>
</tbody>
</table>
|                | 1.29         | **Interviewee No. 8: Architect & Senior Government Official; Ministry of Roads & Public Works; 19th April 2006**  
MOW influences construction activity in the private sector by regulation of contractors and consultants. The City Council regulates the activity of the private sector by ‘approval/rejection’ of drawings. But the City Council is understaffed; it has only 25% of the necessary staff. |
|                | 1.30         | **Interviewee No. 10: Construction Economist & Applicant of Systems Theory in Research; 5th May 2006**  
The prime movers of construction industry are “entrepreneurs” (who are profit driven) but not policy. Our development plans are not backed by the implied/requisite resources.                                                                                                                                 |
| (2) Processes  |              | Processes followed & basic resources required in the industry operations                                                                                                                                                                                                                                                                                     |
|                | 2.1          | **Mbaya, J. S. (1984)**  
Page 6: The construction process basically follows the stages of client’s decision to build, appointment of consultants, designing, application of planning permission, design realization (billing, working organization, tendering, planning & programme), construction & completion. |
|                | 2.2          | **Nguyo D M A (1988)**  
Page 1: In Kenya, initiation and placement of demand for construction products is done by either the private or the public sector, depending on the nature or use of the individual facility.                                                                                                                  |
|                | 2.3          | The initiation of the building process is a brief submitted by government ministries and departments to the Ministry of Public Works. Finances for building developments are controlled by the Ministry of Finance. The latter approves expenditure when advised by the implementing ministry (MOPW). The MOPW consults with the client ministries or departments before it advises the Ministry of Finance. |
|                | 2.4          | Land on which the intended buildings are to be erected is controlled by the Ministry of Lands and Housing. Before such land is allocated, Physical Planning authorities are consulted.                                                                                                                    |

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### System Aspect | Reference No. | Description of System Aspect
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(2) Processes (Cont’d) | | 

| | | 
|---|---|---
| 2.5 | **Nguyu D M A (1988) (Cont’d)** | Construction process: project initiation to completion. Phases: (i) Feasibility study & site selection (ii) Design (iii) Tendering (iv) Construction (v) Property management after completion |
| 2.6 | Page 137: Communication between the Treasury, clients, the MOPW and within the MOPW itself is very poor. The result was that in the majority of cases, the amount provided for projects had no relationship with the amount required, as the latter changed frequently and those changes were not communicated quickly. |
| 2.7 | Page 182: Though the attributes/aspects of the construction industry hereinbefore underline the need for efficient communication, communication is one of the major problems of the industry yet to be solved. Poor communication within the industry has repercussions in the total economy since its relationship with the national economy necessitates integration with overall planning. This is because commitment of its resources to various sub-sectors and the role to be played by private and public sectors are determined at the national policy level. The appropriateness of policy will depend on how far the industry is understood by those in charge of making the policy. |
| 2.8 | The feedback required includes performance of past projects, contractors' experience & workload & research findings. This feedback remains poor. The industry's information system is very poor. The KBRC (Kenya Building Research Centre) does not give building information necessary to clients or public or MOPW. It is ineffective, due to lack of resources (qualified staff & funding), lack of political support (no interest in it by those concerned) and poor link to client organizations & MOPW departments. |
| 2.9 | The MOPW role in information dissemination to the industry was inadequate. It is necessary to enhance information flow (communication) regarding market information & feedback. |
| 2.10 | **Mugenda A. G. (1990) “the Changing Face of the Construction Industry in Kenya” Construction Review Jan/Feb 1990** | Page 7: Construction also involves other resources, which though difficult to monetarise, are important but scarce in developing countries. Such resources include time, skills, technology and knowledge. In construction, inputs are human labour, temporary and permanent materials, plant and equipment, utilities, technology and time. Throughputs include the administration and coordination of all the inputs by the contractor on one hand and the consultants on the other. |

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### Processes (Cont’d)

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<tbody>
<tr>
<td>(2) Processes (Cont’d)</td>
<td></td>
<td>Processes followed &amp; basic resources required in the industry operations</td>
</tr>
<tr>
<td></td>
<td>2.13</td>
<td>Interviewee No. 7: Construction Economist &amp; Applicant of Systems Theory in Research; 13th April 2006</td>
</tr>
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<td>Interviewee No. 10: Construction Economist &amp; Applicant of Systems Theory in Research; 5th May 2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>There is no feedback. We are simply “firefighting”; the industry has no policy but has regulations which are not followed; City Hall is not efficient. To establish feedback there is need for policy formulation for the whole industry, implementation plan &amp; action, and evaluation &amp; report.</td>
</tr>
<tr>
<td>(3) Environment</td>
<td></td>
<td>Variables/entities ‘outside’ the construction industry</td>
</tr>
<tr>
<td>(a) Environmental factors</td>
<td></td>
<td>Mbaya, J. S. (1984)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Page 1: The construction industry’s clients also exist under complex conditions which have been forced on them by circumstances arising from technological developments, uncertain economic conditions, social pressures, political instability, etc. These conditions make them place increasing demands upon the industry in general and construction team in particular, in terms of project performance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kithinji N. B. (1988)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Page 1: In most developing countries, Kenya included, construction activity is financed through foreign borrowing.</td>
</tr>
</tbody>
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## System Aspect Reference No. Description of System Aspect

### (3) Environment

(a) Environmental factors (Cont’d) | Variables/entities ‘outside’ the construction industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual GDP Growth (%)</th>
<th>Annual Population Growth (%)</th>
<th>Per Capita GDP (US$)</th>
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<tbody>
<tr>
<td>1995</td>
<td>5.2</td>
<td>3.1</td>
<td>275</td>
</tr>
<tr>
<td>1996</td>
<td>5.2</td>
<td>3.0</td>
<td>281</td>
</tr>
<tr>
<td>1997</td>
<td>5.8</td>
<td>2.9</td>
<td>289</td>
</tr>
<tr>
<td>1998</td>
<td>5.8</td>
<td>2.8</td>
<td>298</td>
</tr>
<tr>
<td>1999</td>
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<td>2019</td>
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<td>2020</td>
<td>10.6</td>
<td>1.5</td>
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Page 5: Until the early 1990s, Kenya's economy was strictly controlled and regulated. Whilst such protectionist policies had hitherto served to dampen some of the worst excesses of African economic volatility, by the early 1990s it had become apparent that a variety of structures and controls were actually retarding the overall economy. Starting from 1993, a widespread programme was introduced which saw price controls lifted, import licensing relaxed, exchange controls abolished and a variety of investment incentive and new enterprise packages introduced. This has resulted in better economic growth and more outward facing, international trade market. The Nairobi real estate market has been a direct beneficiary as a result of the city's growing regional, perhaps wider, dominance of a more freely trading environment. |
|             | 3.5 | Page 7: Increasingly, there is a presumption against detailed physical planning which is viewed as a limiting constraint on economic growth and progress. In addition, the enforcement powers of Local Authorities are restricted. With planning authorities handling only around 30% of actual development in Nairobi, the Kenyan system is based on encouragement and guidance. |
Page xvii: After experiencing moderately high growth rates during the 1960s and 1970s, Kenya's economic performance during the last two decades has been far below its potential. As a result, per capita income in constant 1982 prices declined from US$ 271 in 1990 to US$ 239 in 2002. The number of people openly unemployed currently stands at over 2 million or 14.6% of the labour force. |
Page 4: One of the key factors that have distorted interest rates in Kenya is high country risk fed by a perception of low credibility of government policies; this lowers investor confidence and interest rate premiums are loaded on to Kenya's interest rates. |
|             | 3.8 | Page 8: The recent resumption of IMF loan programme to Kenya is bound to improve investor confidence and thereby lower country risk premium. This development will have the impact of lowering the rates. |

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<td>Page 8: Export of professional services to neighbouring countries has not been duly recognized nor any assistance rendered by the Kenya Government. There seems to be no official and deliberate campaign to encourage Kenyan professionals in the building and construction industry to venture out to the neighbouring countries and earn money, which can be repatriated to assist the national economy. Individual quantity surveyors have moved to be employed or established offices in Botswana, South Africa, Malawi, Tanzania, Uganda, Ghana, Namibia and other African countries. Others have migrated to Australia and USA. The minister agreed that there are no official records or a strategy to encourage this export of professional service. He noted the issue is also applicable to other professionals like engineers and architects.</td>
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</table>

| Page 10: During the 1974 -1978 National Development Plan period, 25,000 housing units were produced compared with 50,000 that were required. The comparable supply & demand figures for the 1997 – 2001 period are 112,000 and 560,000 respectively. In the next decade, the average annual urban housing demand is estimated at 150,000 units, but only 30,000 to 50,000 units is expected to be produced, if the factors that constrain housing production are not addressed. In addition, an estimated 300,000 housing units will require to be improved annually in the rural areas. |

| 3.11 | The housing deficit derives from the low level of investment in the sector by both public agencies and the formal private sector, with housing produced by both sectors representing only an estimated 20% of the total number of new urban households. During the Economic Recovery Period, the Government undertakes to facilitate various actors in the Sector to meet housing demand estimated at 150,000 housing units annually. |

| 3.12 | Page 3: It is estimated that the current production of new housing in urban areas is only 20,000 – 30,000 units annually, giving a deficit of over 120,000 units per annum. This shortfall in housing has been met through proliferation of squatter and informal settlements and overcrowding. |

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| | | Page 2: The Kenyan economy has been growing steadily in the past two years after several decades of low growth rates. The year 2004 and the first nine months of the year 2005 have recorded impressive growth rates on the strength of favourable macroeconomic environment, increased consumption (both locally and abroad) and positive remarks by IMF and World Bank. The low interest rates and stable shilling exchange rate have supported increased credit to the private sector thus supporting consumer demand and investment. The planned investments in infrastructure, the emerging opportunities in the reconstruction efforts in Southern Sudan and the strategic location of the country within the East and Central Africa will support the high growth rate. However, the slow rehabilitation of infrastructure, the high cost and instability of power supply and rising inflation may hinder the attainment of the above growth targets.
| | | Page 21: Construction process imports ideas, energy, materials, information etc from the environment, then transform them into its output which is finished buildings, roads, bridges, etc. The whole process of designing and constructing a building can be analyzed as an “open adaptive system” which must respond to its environment. However, in practice, the process is to a certain extent protected from its environment by construction of rules, procedures, codes of practices and conventions which have been granted validity by public authorities, professional institutions and other bodies. For example, in Kenya the construction process is protected from its environment by such practices as use of Standard Methods of Measurement, Standard form of Contract, Standard Specification for materials & workmanship, price control regulations, import restrictions, building materials price fluctuation formulae lists, etc.

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<tr>
<td>(b) Effect of environment (Cont’d)</td>
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</table>
Page 120: Most African countries rely on imported building materials and energy used in construction. For instance, the import content in Kenya’s construction industry is as high as 37% (Syagga, 1998: 84). |
|                        | 3.18          | Page 121: Also, high interest rates of up to 30% have to a large extent dampened economic growth and also negatively impacted on the property market. With these high interest rates, it has meant that the returns on cash can exceed those on property by a substantial margin. |
|                        | 3.19          | Page 131: It is increasingly being accepted that governments through innovative enabling policies can create leverage through which the private sector, the local governments and the non-governmental organizations can actively participate in the supply of housing for both the middle and the low income earners. |
| (c) Effect of the industry |               |                                                                                             |
Page 40: A building project is an open system. It imports from the environment inputs of materials, skills, information and energy and passes its products of built facilities, wastes, acquired skills, incurred debts and information to the environment. |
Page 4: The construction industry is a major contributor to the national income of the country and is normally the first one to be affected when the economy is not doing well and the last one to rise when the economy picks. For a long time, construction industry has been in the doldrums, which has affected the many professionals and many others who depend on it, considering that it has both backward and forward linkages. |

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<tr>
<td>(c) Effect of the industry</td>
<td>3.22</td>
<td>Influence of the construction industry on the environment</td>
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<td></td>
<td>3.23</td>
<td>Page 12: The construction industry poses a significant threat to any environment. This threat is as a result of consumption and wastage of enormous amounts of materials during the process. Extraction, transfer, placement and misplacement of the various materials partly describe the process of construction. Construction materials include, among others: perlite, cement, gypsum, limestone, granite, basalt, sandstone, marble, slate, limestone, dimension stone, sand &amp; gravel, as well as lumber and steel. Construction companies are responsible for more pollution incidents than any other industrial sector. In other sectors, incidents are decreasing. In construction, they increased globally by 30% between 1996 and 1999 according to UNEP statistics.</td>
</tr>
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<td></td>
<td>3.24</td>
<td>Page 18: Mining, harvesting, and processing of construction materials can disturb remote landscapes and ecosystems, while buildings themselves alter the landscape and what can live on it.</td>
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</table>

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### Systems Aspect

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<tr>
<td><strong>(i) Enablers</strong></td>
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<tr>
<td></td>
<td>Factors that tend to encourage or constrain contracting effectiveness</td>
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</table>
| 4.1                     | **Interviewee No. 2: Land Economics Scholar & Researcher; 5th April 2006**  
Contracting capacity is not an impediment to real estate development in Kenya. |
| 4.2                     | **Interviewee No. 4: Construction Economics Scholar & Researcher; 5th April 2006**  
Contracting capacity is sufficient in building projects, most of which have been generally simple. However, the capacity is limited with regard to civil engineering works and perhaps very complex buildings; few Kenyan contractors are in Category A in the Ministry of Works listing. Major road works, for example, are not done by Kenyan contractors. |
| 4.3                     | **Interviewee No. 6: Land Economics Scholar & Researcher; 6th April 2006**  
Contracting capacity is limited. Materials are now a problem; for example, Bamburi is not able to supply enough cement. |
| 4.4                     | **Interviewee No. 7: Construction Economist & Applicant of Systems Theory in Research; 13th April 2006**  
Contracting capacity seems to be a problem for public projects but not for private projects. Contractors seem not to be interested in public projects. In the tender for renovation of Parliament Buildings, for example, only 12 contractors expressed interest and of those, only 2 were acceptable. Perhaps, contractors have lost confidence with the government. |
| **(ii) Estimating methods** | Methods (used in estimating construction output/workload/activity) & surrogates used to represent it |
| 4.5                     | **Central Bureau of Statistics (1977) Sources and Methods Used for the National Accounts of Kenya; Nairobi, Government Printer**  
The methods used in the collection and processing of construction industry data – for Statistical Abstracts & Economic Reviews – are fully described. Generally, data on the expenditure incurred in paying for construction work in the formal sector appear to be sufficiently captured. It is presented as the Gross Fixed Capital Formation contributed by various sectors of the construction industry. |
| 4.6                     | In processing the National Statistics from 1963 to 2003, the CBS used the 1963 System of National Accounts (SNA 63). But for the statistics of 2004 and after, the CBS has used the 1993 System of National Accounts (SNA 93). CBS is in the process of updating the 1996 – 2003 Statistics to present them in terms of SNA93. |

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<td>(ii) Estimating methods</td>
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| **4.7** | **Industrial Review (1985: ..) The Construction Industry October 4, 1985**  
Page 5: There is a wide and apparently growing disparity between building approvals and completions. Since approved plans are early indicators of the future situation, there is optimism about the future of the building and construction sector based on an increase in approvals in 1984 and the first quarter of 1985.  
| **4.8** | On the whole, only about a third of approved building plans ever get used. In the 1980 – 84 period, plans worth £260 Million were approved, but work worth only £104 got completed. This poor rate of completions is attributed to the failure of many developers to arrange for adequate financing, as well as to increasing costs which often lead to abandonment of projects.  
Page 5: Indicators of the country’s building activity - domestic cement consumption, drawings approved by City Council(s), index of reported (private & public) building work done in the main towns, index of government expenditure on roads and number of people employed in the sector.  
The levels of construction output from 1963 to 2003, obtained from these documents, are tabulated in Appendix D.  
| **4.11** | **Mbaya, J. S. (1984)**  
**Page 1:** The construction industry performs very poorly in satisfying its client in supply - cost overruns & time overruns and low/poor functional quality.  
| **4.12** | **Page 7:** The government as a client accounts for well over 60% of construction work in the nation and can therefore be regarded as a fair representative of the construction industry practice.  

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Qualitative Data Collected

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<tbody>
<tr>
<td>(4) Construction Output</td>
<td>Estimates of constructed space production levels: observed or projected</td>
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<tr>
<td>(iii) Estimates</td>
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<td>4.13</td>
<td><strong>Nguyo D M A (1988)</strong> Products – constructed physical facilities, whose purpose is to provide space where other activities may take place. Characteristics of the products – produced &amp; operated on a specified site, bulky &amp; expensive, complex, and linked to its environment tho’ infrastructure etc.</td>
</tr>
<tr>
<td>4.14</td>
<td>Page 147: The MOPW had a rolling Annual Works Programme (AWP), which included various types of projects as follows: office buildings for use by the central government, laboratories, training institutions, government staff housing, hospital development and social &amp; cultural projects</td>
</tr>
<tr>
<td>4.15</td>
<td><strong>Knight Frank (1998) Kenya Property Report London, Knight Frank Research May 1998</strong> Page 2: OFFICE - The office market has been the most active real estate sector over the past ten years. In the current upward cycle, annual completion rates in Nairobi have risen from around 50,000 sq m in 1992 to 100,000 sq m+ in 1997 and 1998. Despite this, vacancy rates have been close to zero. CBD supply is however, now likely to rise. Current development activity is concentrated in Nairobi CBD, Westlands and The Hill. An analysis of supply and demand suggests that the CBD may experience a degree of oversupply (although lack of prime space will mean that new developments will not remain vacant for long), whilst the suburban markets will experience under supply. Rental growth, off a forthcoming suburban benchmark of Kshs 500 – 550 per sq m per month (Us$ 8.40 – 9.20), will be strongest out-of-town and will continue to stimulate development activity.</td>
</tr>
<tr>
<td>4.16</td>
<td>Page 3: RESIDENTIAL - The provision of reasonable standard residential accommodation for the majority of Kenya’s population arguably represents the country’s biggest challenge. Lack of funding and poor infrastructure, compounded by the loss of foreign aid, has hindered the upgrading of Kenya’s residential stock. Growth projections which point towards 255,500 new homes each year in rural areas over the next five years and 123,200 per year in urban locations only serve to make the challenge still greater.</td>
</tr>
<tr>
<td>4.17</td>
<td>Page 7: Whilst difficult to measure accurately, non-residential development levels in Nairobi have been steadily rising over the past 3-4 years. Commercial development planning consents and informal construction currently sum to around 130,000 sq m per annum. The purpose build market in Kenya is limited, making the majority of construction speculative.</td>
</tr>
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### (iii) Estimates (Cont’d)

#### 4.18

Page 9: Over the period 1990 – 97, average annual office completion levels are estimated to have been 76,400 sq m. Overall, approximately 611,000 sq m of new office space has been developed in Nairobi thus far in this decade. Although difficult to measure precisely, there were approximately 112,775 sq m of office development either under active construction or at the site preparation stage in the three principle Nairobi submarkets (CBD Westlands, & The Hill) as at January 1998.

#### 4.19

In addition, to the space under active development, there are also currently some 85 – 90,000 sq m of office space with planning consent across the three main markets. Active projects combined with planning permissions produce a total potential supply level of approximately 200,000 sq m. This is broadly equivalent to two years supply based on recent annual completion rates, although it should be noted that this supply measure contains delayed and stalled projects which will clearly influence the precise part ten of supply over time.

#### 4.20

Page 4: Of the estimated 1.44 million sq ft (134,000 sq m) of new build that was released onto the Nairobi office market by large scale developments in 1999, 54% was in the CBD, 26% in Westlands and 19% on the Hill.

#### 4.21

Page 76: Output is physical infrastructure, which comprises: transport support system (roads, railways, marine transport - port facilities & container depots - air transport and pipeline transport and buildings & construction - private & public buildings and other construction

- construction of Juá Kali sheds & necessary infrastructure, construction of piers along fishing grounds around major lakes;
- construction and repair of fish ponds & hatcheries, design;
- construction & rehabilitation of fishery jetties, Malindi Sea Wall Jetty Phase II, dry docks & ship-ways;
- construction of dykes and canals for soil conservation and flood control (especially in Nyando & Busia districts); and
- Fencing for protection and identification of public lands and for control of human & wildlife conflicts.

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<tr>
<td>4.24</td>
<td>Page xii: The Ministry’s mission Statement is “to facilitate provision and maintenance of quality infrastructure mainly in roads, buildings and other public works so as to promote and sustain socio-economic development”</td>
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<tr>
<td>4.25</td>
<td>Page xiii: The Ministry’s Vision is “to achieve and sustain excellence in roads, buildings and other public works, to support social economic needs and aspirations”.</td>
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<tr>
<td>4.26</td>
<td>Page 34 to 116 presents the proposed implementation strategy of the Strategic Plan, detailing the Key Result Areas and specific service delivery targets to be met in order to realize the Ministry’s Vision by 2009.</td>
</tr>
<tr>
<td>4.28</td>
<td>Page 127: Between 1982 and 1992, approximately 148 new commercial buildings were constructed in the city of Nairobi, offering about 7.4 million square feet of space (Swazuri et al 1992: 9).</td>
</tr>
<tr>
<td>4.29</td>
<td>Page 136: In Kenya, the share of new construction of industrial buildings is smaller compared to both residential and commercial properties. They include warehouses and factory buildings. Generally, many developers favour warehousing to factories because of the greater flexibility of use, the wider range of first class tenants such as airlines, import and export companies and the slower rate of physical deterioration. Factory buildings on the other hand are mainly owner occupied.</td>
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<td>4.30</td>
<td><strong>Interviewee No. 7: Construction Economist &amp; Applicant of Systems Theory in Research; 13th April 2006</strong></td>
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<td>Construction industry objectives are normally stated in descriptive non-measurable terms, such as:</td>
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<tr>
<td></td>
<td>• to provide adequate business infrastructure and good social services;</td>
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<td></td>
<td>• to generate more employment</td>
</tr>
<tr>
<td></td>
<td>The standard is not specified.</td>
</tr>
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<td>4.31</td>
<td><strong>Interviewee No. 8: Architect &amp; Senior Government Official; Ministry of Roads &amp; Public Works; 19th April 2006</strong></td>
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<td></td>
<td>The production efficiency is not addressed empirically. Performance is generally measured using surrogates - consumption of cement, approvals of drawings by City Council &amp; reported completions. These are not too good, though better than nothing. Some of the factors influencing performance are cost of money, business performance of other industries (derived demand) and government policy [if the target 150,000 houses per year were to be implemented, there would be a lot of activity]. ... There are no measurements for the industry's efficiency. All the same, from a casual observation the industry's efficiency has been quite low. One of the indicators is the standard of the roads (transport &amp; communication systems), which are generally poor.</td>
</tr>
<tr>
<td>4.32</td>
<td><strong>Interviewee No. 10: Construction Economist &amp; Applicant of Systems Theory in Research; 5th May 2006</strong></td>
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<td>The physical scope of works targeted for execution in the public sector in a given year may not be implied in the current Development Estimates because some of the figures include ongoing works and works not yet &quot;proposed&quot;.</td>
</tr>
<tr>
<td>4.33</td>
<td><strong>Interviewee No. 10: Construction Economist &amp; Applicant of Systems Theory in Research; 5th May 2006</strong></td>
</tr>
<tr>
<td></td>
<td>Construction industry objectives at the industry level are generally the same as objectives at the individual project level, i.e. to deliver project at specified budget, time and quality. However, at the industry level one needs to add efficiency and self-sufficiency as objectives, tying all the objectives to the national economy.</td>
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<table>
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<tr>
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<th>Description of System Aspect</th>
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<tbody>
<tr>
<td>(4) Construction Output</td>
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</tr>
<tr>
<td>(iv) Fluctuations</td>
<td>Industry participants’ understanding of activity cycles in the industry</td>
</tr>
</tbody>
</table>

<table>
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</thead>
<tbody>
<tr>
<td>Page 5: Explanation of the 1990 – 94 Slump. The slump in the industry was caused by the dismal economic performance of the country, due to: -</td>
</tr>
<tr>
<td>1. Dramatic political reforms resulting from the ushering in of the multi-party system which was accompanied by economic uncertainty;</td>
</tr>
<tr>
<td>2. Ethnic clashes which dampened the output of the affected regions;</td>
</tr>
<tr>
<td>3. Weather affecting agricultural regions;</td>
</tr>
<tr>
<td>4. Uncertainty in the financial markets;</td>
</tr>
<tr>
<td>5. Weakening in the industrial sector that led to negative impact on export;</td>
</tr>
<tr>
<td>6. Withholding of foreign aid by donor countries leading to foreign exchange crisis</td>
</tr>
<tr>
<td>All these factors led to a marked decrease in the ability/willingness of the private sector to invest and hence the negative 9.3% change in real gross fixed capital formation. The effect of these factors was further compounded by inflation.</td>
</tr>
<tr>
<td>7. Inflation rose to 27.5% in 1992. It was fanned by, among other things, (i) a 35% rate of growth of aggregate money supply; (ii) Depreciation of the Shilling, leading to high cost of imports (1US$ = 63.38 Kshs); (iii) Shortage of essential food stuffs due to bad weather and price decontrol; (iv) higher demand for upward wage adjustments as a defense mechanism against expected declines in real incomes; and (v) strong rise in consumer demand caused by expenses incurred during the campaign period.</td>
</tr>
<tr>
<td>8. Government expenditure – the government expenditure on building and other construction has been on a downward trend as indicated by the index on expenditure on roads and reported public building work completed.</td>
</tr>
<tr>
<td>9. Interest rates – the building and construction industry heavily depends on borrowed finances. This means that it is seriously affected by interest rates offered in the banking sector. These interest rates have been very high, rising from 19% in 1990 to 29% in 1991 and 30% in 1992. In economic terms, this has further declined the construction industry because it implies that the returns from the investment must be over 30% in order to make the investment viable. E. to enable the investor pay the cost of finance and also have profit for himself. Given the state of the general economy, it is difficult to imagine which construction investment can bring this kind of return.</td>
</tr>
</tbody>
</table>

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<tr>
<td><strong>(iv) Fluctuations</strong> (Cont’d)</td>
</tr>
<tr>
<td>Page 6: Governments have various measures of controlling (reducing) construction demand: -</td>
</tr>
<tr>
<td>• Credit squeeze;</td>
</tr>
<tr>
<td>• Interest rates increase;</td>
</tr>
<tr>
<td>• Reducing government’s own capital expenditure;</td>
</tr>
<tr>
<td>• Taxation.</td>
</tr>
<tr>
<td>The converse is applied in increasing demand. This is demand management.</td>
</tr>
<tr>
<td><strong>4.36</strong> A government applies such policies because she is aware that some aspects of the industry can cause many problems e.g. fluctuating demand. If there is fluctuating demand, this will lead to: -</td>
</tr>
<tr>
<td>• Unemployment and reduced earnings;</td>
</tr>
<tr>
<td>• A loss of skilled workers and reduced recruitment and training;</td>
</tr>
<tr>
<td>• Wasted capacity in building materials industries;</td>
</tr>
<tr>
<td>• Reduction of contractors’ margin below commercial level;</td>
</tr>
<tr>
<td>• Increased bankruptcies and liquidation.</td>
</tr>
<tr>
<td><strong>4.37</strong> If there is excess demand, this will produce: -</td>
</tr>
<tr>
<td>• Labour shortage;</td>
</tr>
<tr>
<td>• Work done over-hastily or delayed;</td>
</tr>
<tr>
<td>• Materials shortages which can not be met, as in other industries, by imports;</td>
</tr>
<tr>
<td>• Inflationary price increases in excess of cost increases;</td>
</tr>
<tr>
<td>• A loss of competition leading to inefficiency.</td>
</tr>
<tr>
<td><strong>4.38</strong> On the other hand, if there is fluctuating demand, this leads to: -</td>
</tr>
<tr>
<td>• Low investment;</td>
</tr>
<tr>
<td>• Greater reliance on inefficient peak load plants;</td>
</tr>
<tr>
<td>• Discouragement of technical development and innovation;</td>
</tr>
<tr>
<td>• Inadequate training;</td>
</tr>
<tr>
<td>• Impermanence of work teams;</td>
</tr>
<tr>
<td>• Lack of stable career structure</td>
</tr>
</tbody>
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### Systems Aspect | Description of System Aspect
--- | ---
(4) Construction Output |  
(iv) Fluctuations (Cont'd) | Industry participants' understanding of activity cycles in the industry

| Interviewee No. 1: Land Economist & Property Consultant; 29th March 2006 | Fluctuations in construction activity in Kenya are caused by politics & elections. Towards the election year, activity dips, climbs sharply in the 2nd year, reaches max. in 3rd year and drops sharply to a minimum in the election year. This is based on the uncertainty of the election outcome; it has been like this since the advent of multiparty politics in Kenya. Fluctuations can be minimized by de-linking politics from decision-making; a government where ministers are not necessarily politicians. Queuing proposed projects at City Hall (& other local authorities) to [control supply and] avoid fluctuations is not practical. We are in a free market economy; this would amount to monopoly. Let City Hall do control of land, safety standards, etc.

| Interviewee No. 2: Land Economics Scholar & Researcher; 5th April 2006 | Oversupply occurs because demand may be depleted while developers are still in the process of supply; decisions already made, construction process can't stop when demand is depleted. Promptness in demand identification and satisfaction can be enhanced by improving information flow. Queuing proposed projects at City Hall (& other local authorities) to [control supply and] avoid fluctuations may not work because it would be interfering with investors' freedom of judgment and advice.

| Interviewee No. 3: Land Economics Scholar & Researcher; 5th April 2006 | Promptness in demand identification and satisfaction can be enhanced by active and regular market surveys and information dissemination to the people. This should also include analysis of property life cycles. Queuing proposed projects at City Hall (& other local authorities) to [control supply and] avoid fluctuations may not work; the best is to simply advise and let the people decide. ... Fluctuations in demand are caused by political uncertainty; signs of uncertainty make investors adopt a wait and see attitude, which makes the construction industry stagnate. Poor performance in the stock market may cause more people to go to real estate development, resulting in a boom, as it was observed in Kenya in the 1980s.

| Interviewee No. 4: Construction Economics Scholar & Researcher; 5th April 2006 | Fluctuations in construction activity in Kenya are responses to economic growth; economic growth spurs real estate development and in turn spurred by it. ... Promptness in demand identification and satisfaction can be enhanced by developing & sharpening prediction tools in order to see demand immediately it comes. Promptness in demand satisfaction may also be enhanced by designing buildings which are flexible (can be altered as per demand) [i.e. flexibility in adaptation of existing space to fit in new demand. ... Queuing proposed projects at City Hall is ultra vires the City council concern and is not practical. 

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<tr>
<th>Interviewee No. 5: Land Economist &amp; Property Consultant; 6&lt;sup&gt;th&lt;/sup&gt; April 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluctuations in construction activity are responses to the economy and politics. They can be minimized by: stability in the government involvement in social housing &amp; infrastructure provision, clear long-term policy on financing (banking regulations) and general stability in the macro-economic management of the country. ... Promptness in demand identification and satisfaction may be enhanced by (1) information i.e. having a national bureau to direct people where demand is and give information, like in the UK and South Africa; (2) Streamlining (drastic change in) City Council – computerization, more skilled manpower and elimination of corruption.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interviewee No. 6: Land Economics Scholar &amp; Researcher; 6&lt;sup&gt;th&lt;/sup&gt; April 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluctuations in construction activity are caused by lack of perfect information; investors rush to develop without professional advice because they wish to own property. The desire to own property is very compelling – property is tangible, illiquid, gives social status &amp; security, and is more well known as an investment compared to stocks. ... Promptness in demand identification and satisfaction may be enhanced by providing perfect information and by the government providing social housing. ... Queuing proposed projects at City Hall to control supply may not be practical with our corruption status; people will just pay their way. City Council is not efficient enough to do this.</td>
</tr>
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<table>
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<tr>
<th>(5) Delays</th>
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<tr>
<td>Hold-downs which prevent most efficient flow of production &amp; information through the system</td>
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</table>

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<tr>
<th>Nguyo D M A (1988)</th>
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</thead>
<tbody>
<tr>
<td>The cost overruns are caused by delays during policy formulation, design and/or implementation.</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Nguyo D M A (1988)</th>
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</thead>
<tbody>
<tr>
<td>There are 3 types of delays; the first one is associated with programme assembly process and the second arises during collective decision process. The third one is called purposive delay. Examples of delays: clients searching for a good service provider (professionals &amp; contractors) – meetings, discussions, etc; time for service providers to decide/commit their resources to supply &amp; terms of service provision.</td>
</tr>
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<th>Hold-downs which prevent most efficient flow of production &amp; information through the system</th>
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</table>

### 5.3

**Nguyo D M A (1988) (Cont’d)**

Delay is a product of numerous and diverse causes:

- **(i)** Nature of substantive tasks – this involves the problem of moving from the general conception to the detailed specifics. It also requires specification of how to come from the present to the future. The more difficult the task, the longer the people take to perform it.

- **(ii)** Potential providers take time in responding due to the phenomenon alternating slack and overload which makes operating appear uncoordinated and inefficient. Any organizational unit faced by random arrivals of its workload obligations will develop a backlog unless it has a great deal of slack resources. But even without the queuing problems, delay may still occur because numerous units have to be consulted and the cumulative delaying effect may be significant.

- **(iii)** Even with affirmative promise to provide, time still elapses before delivery, for instance while waiting for a new accounting period or expenditure cycle.

- **(iv)** The need to deal with providers serially and not simultaneously is another source of delay. In bureaucratic memo-routing, approval by one official is often contingent on clearance by other officials. This can be solved by project management.

- **(v)** Purposive delay, which results from effective resistance or obstruction by some parties. Such parties exploit others preference for greater haste as leverage to gain better terms. They may hold up clearances in order to demonstrate their power to command deference.

### 5.4

Methods of notifying the MOPW that particular projects were required differed with different client organizations. The approaches are:

- **(i)** Letters & phone calls to the MOPW, then the Architect follows up to develop a brief with the client personnel. The problem with this approach is lack of appreciation by some client officials, of the role they should play in the brief formulation; consequently a lot time and effort are wasted.

- **(ii)** Client organizations identify own projects required, obtain approved site from the Commissioner of Lands or District Commissioner and submitted the project requirements to the MOPW. This submission was preceded by forward budget sessions a year or two before. During such sessions the MOPW participated in giving professional advice and cost estimate.

- **(iii)** Submission as in (ii) above but with no financial projections. The design participants planned for and designed projects assuming they would be funded within a year, only to realize later that no such funds were forthcoming.

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### (5) Delays (Cont’d)

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<tbody>
<tr>
<td>Nguyo D M A (1988) (Cont’d)</td>
</tr>
<tr>
<td>Nguyo D M A (1988: 131): On paper, there are established procedures to be followed in project funding. According to these procedures, the Treasury should not consider proposals for new buildings or construction projects for inclusion in annual estimates unless all preliminary information about project need, site selection, etc. have been undertaken and the MOPW has provided preliminary estimates of costs for the works involved. To make this effected there are procedures for programme review and forward budget ensure that needed projects are identified early enough and financial requirements are foreseen at least three years in advance.</td>
</tr>
<tr>
<td>Nguyo D M A (1988: 125)</td>
</tr>
<tr>
<td>The MOPW came to know of intended projects when funds were allocated in the Development Estimates. Since such funds were allocated for spending during specific financial years, this kind of allocation was spent in formulation of brief, planning and designing. Another limitation was that the allocations were done on the basis of what clients had asked for and due to inadequacy of knowledge on building matters there was little relationship, if any, between the amount provided and the scope of work provided.</td>
</tr>
</tbody>
</table>

| Page 5: Public Sector construction projects are poor in terms of cost performance and are especially pathetic in time performance. The quality objective has not been specifically measured, and quality assurance is left to the design team who are authorized to condemn work which they deem unfit. It can be safely assumed that the quality performance is satisfactory. |

| Page 8: A medium to large sized office building in Nairobi will usually take two years to construct, sometimes longer. |

#### 5.5

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</thead>
<tbody>
<tr>
<td>The contract agreement offers situations where the cost and time of a project can be varied in order to give the client the best use and value for his money. However, the situation in the sector seems to indicate that variation to time and cost is a norm rather than an exception. In my research I considered 90 projects randomly selected from records of all projects finalized between 1980 and 1990. Of these 90 odd projects, 17% were delivered within stipulated cost, while 4% were delivered on time. Cost overruns range from 0 to 187.6% with an average cost overrun of 27.92% and time overrun ranges from 10 to 1056%, with an average of 182.12%. This is a very disheartening performance.</td>
</tr>
</tbody>
</table>

| Page 8: A medium to large sized office building in Nairobi will usually take two years to construct, sometimes longer. |

#### 5.6

#### 5.7

#### 5.8

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</tbody>
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<thead>
<tr>
<th>5.9</th>
<th><strong>Peter TK (2000)</strong></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Page 73: Actual construction time of building projects: mean - 66.90 weeks; minimum - 1800 weeks; maximum - 252 weeks.</td>
</tr>
</tbody>
</table>

| 5.10 | Page 74: Actual construction cost of building projects: mean - Kshs 71.34 Million; minimum - Kshs 2.64 Million; Maximum - Kshs 575.68 Million (at December 1997 prices). |

| 5.11 | Page 91: The relationship between the actual construction time (T) [in weeks] and its actual construction cost (C) [in Kshs Million, at December 1997 prices] can be represented by the following function: |
|      | \[ T = 21.2593 + 0.9045C + 0.0011C^2 \quad [R^2 = 0.74] \] |

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### 5.12

**Interviewee No. 5: Land Economist & Property Consultant; 6th April 2006**

The weakest link in the supply of constructed facilities in Kenya is the Nairobi City Council; it takes an average of one year to approve drawings for proposed projects.

### 5.13

**Interviewee No. 8: Architect & Senior Government Official; Ministry of Roads & Public Works; 19th April 2006**

Generally, client ministries place their requests (briefs) of constructed facilities with the Ministry of Works (MOW), which designs and gives estimates. The client ministry negotiates financial allocation with Treasury, then MOW implements (design, documentation & supervision). The priority ranking of proposed projects is determined by the Ministry of Economic Planning & National Development.

### 5.14


<table>
<thead>
<tr>
<th>Project Name</th>
<th>Total Length (KM)</th>
<th>Nature of Works</th>
<th>Contract Sum Kshs Million</th>
<th>Date of Award</th>
<th>Projected Completion Date</th>
<th>Contract Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitui - Kagonde</td>
<td>45</td>
<td>New Construction</td>
<td>1,020.00</td>
<td>April 2005</td>
<td>June 2007</td>
<td>2 1/2 Yrs</td>
</tr>
<tr>
<td>Ruiri-Isiolo-Muriri</td>
<td>52</td>
<td>New Construction</td>
<td>938.69</td>
<td>Dec 2004</td>
<td>December 2007</td>
<td>2 Yr 8 months</td>
</tr>
<tr>
<td>Ndori -Owimbi</td>
<td>22</td>
<td>New Construction</td>
<td>693.00</td>
<td>Dec 2004</td>
<td>June 2006</td>
<td>1 1/2</td>
</tr>
<tr>
<td>Bunala-Busonga - Nabelenge-Port Victoria</td>
<td>34</td>
<td>New Construction</td>
<td>904.99</td>
<td>Dec 2004</td>
<td>December 2006</td>
<td>2</td>
</tr>
</tbody>
</table>

The average contract period for five projects is 1.87 Yrs.

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### Pet Theories

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</tr>
</thead>
<tbody>
<tr>
<td>(6) Pet Theories</td>
<td>What the Industry participants feel/think is the problem with the industry</td>
</tr>
</tbody>
</table>

<table>
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<tr>
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<tbody>
<tr>
<td>Page 31: Problems in the construction industry - The overall problems of the industry in Kenya are not different from those found even in more advanced economies particularly the western countries. Some of these are: -</td>
<td></td>
</tr>
<tr>
<td>• The ever increasing cost of building materials;</td>
<td></td>
</tr>
<tr>
<td>• The heavy impact of transport costs for building materials especially with the now-familiar oil prices escalation;</td>
<td></td>
</tr>
<tr>
<td>• The pathetically wasteful separation of design and production process in the industry;</td>
<td></td>
</tr>
<tr>
<td>• Credit situations which do not recognize the particular needs of a high-geared cashflow process;</td>
<td></td>
</tr>
<tr>
<td>• Lack of sufficient numbers of skilled tradesmen;</td>
<td></td>
</tr>
<tr>
<td>• Lack of enough work, especially in periods when the economy is not performing well;</td>
<td></td>
</tr>
<tr>
<td>• The harmful effects of yearly fiscal and monetary policy in dealing with an industry whose goods can take years to produce.</td>
<td></td>
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</tbody>
</table>

| 6.2 Several problems are characteristic in Kenya and these include: - |
|---|---|
| • The fragmented nature of the construction industry i.e. the industry has no way of releasing excess capacity to be found in some fields and some geographical areas to other fields with inadequate capacity in other regions. As a result urgent projects are left undone or done very expensively in Moyale while capable contractors are unemployed in Nairobi or Mombasa. In this situation it is also difficult to reap the benefits of economies of scale. |
| • A lack of adequate manufacturing base. This results in prolonged contract periods while waiting for imported building materials and components and of course consequently, increased costs; |
| • A particularly inefficient way of training technicians. Fortunately, in one or two institutes of technology, trainees are attached to construction firms for meaningful periods; |
| • Low credit finance capability; |
| • Inadequate high level expertise necessitating importation of this expertise. |

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<tbody>
<tr>
<td><strong>6.3</strong></td>
<td>Industrial Review (1985: ... The Construction Industry October 4, 1985</td>
</tr>
</tbody>
</table>

Page 3: Economic planners and decision makers in Kenya are blamed by some economists and contractors interviewed by Industrial Review for not according the sector high priority. These people think that better planning for and programming of construction demand in the country could have reduced the current disparity between construction work and demand. Such planning, they think, would spur activity in the industry. A look at policy documents such as the National Development Plan will attest, however, that those who make plans for the building and construction industry in Kenya do establish goals for the construction sector in terms of macro-economic indicators such as contribution to the GDP, to the gross fixed capital formation and to employment. Planners also list major public construction projects that should be undertaken during the plan period and set targets for increased production of construction materials such as cement.

**6.4** To help Kenya’s construction industry get out of the doldrums, some suggest that Kenya explore the construction requirements of neighbouring countries. The National Construction Corporation or another government agency, they say, could assist the industry by identifying the construction requirements of neighbouring countries and formulating appropriate policies that would encourage export of construction activity. Such initiatives would make use of the excess capacity in Kenya’s construction industry.

**6.5** One of the government’s declared policies in respect of the construction and building industry is the import substitution of construction materials. But many contractors interviewed by Industrial Review think little effort is being made to achieve this objective. Some contractors and economists believe the government should make surveys and assessment of local materials that could be used in the construction industry. Studies to evaluate, test and upgrade indigenous materials are needed. Without such initiatives, critics will continue to fault decision makers for paying lip-service to objectives they themselves have set.

**6.6** Others suggest that the state in its role as regulator of construction activity make adjustments in building codes, standards and regulations so that these reflect the conditions and available resources in Kenya. One contractor, for example, argued that the government ought to lower building standards and codes because construction costs have plummeted in the last three years. Many developers, in fact, find it uneconomical these days to begin new projects.

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<tr>
<td><strong>6.7</strong> Industrial Review (1985: ..) The Construction Industry October 4, 1985 (Cont’d)</td>
<td>Page 6: Despite spirited efforts by the National Construction Corporation [NCC] (established in 1972 to help indigenous contractors by provision of technical &amp; financial assistance; 90% of the construction business in the country was in the hands of non-African, mostly Asian, contractors) the situation has changed little. Africana have yet to make a significant break into the industry. Many of the reasons given for this state of affairs are uncomplimentary to African contractors. Addressing a delegation from the Kenya Association of Building and Civil Engineering in May this year, President Moi said that African contractors were failing because they did not live up to their profession’s ethics and code of conduct. More often however, African contractors are accused of lacking sufficient management skills to organize successfully the commissioning of big projects.</td>
</tr>
<tr>
<td><strong>6.8</strong></td>
<td>African contractors often contest this argument, saying that there is sufficient evidence that they can perform just as well as their Asian counterparts. In their view, the most serious obstacle to their growth is lack of concern by major employers which include the ministry of works, planning and physical development, local authorities and parastatal organizations.</td>
</tr>
<tr>
<td><strong>6.9</strong></td>
<td>When Africans began to venture seriously into the construction business, they were hampered by inadequate working capital – a situation made worse by an absence of credit. They also had endless problems with such important tasks as estimating and tendering, contract formulation, project planning, work supervision and book-keeping. Finding credit is still a problem for African contractors, since there are hardly any sources of finance for them other than those offered by the NCC, which by themselves, are inadequate. While African contractors contend that they have to overcome their managerial problems, they are also convinced that their plight would be less dire if the government were more practical in pursuing its stated objective of giving Africans a bigger share of the market.</td>
</tr>
</tbody>
</table>

*Note:* In Chapters III to VII of this study report, evidence for deductions made from the qualitative data in Appendix C is cross-referenced as ACRef …… [reference numbers stated], while cross-references to all the other Appendices are stated in full.
<table>
<thead>
<tr>
<th>Systems Aspect</th>
<th>Description of System Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6.11</strong></td>
<td><strong>What the Industry participants feel/think is the problem with the industry</strong></td>
</tr>
<tr>
<td>6. Pet Theories (Cont’d)</td>
<td>Kenya Institute of Public Policy Research &amp; Analysis [KIPRA] (2004) “Construction Industry Performance Improvement Study” Minutes of KIPRA Breakfast Meeting, Held at the Grand Regency Hotel, Nairobi on 29th April 2004 (Cont’d) Summary of the main issues in the construction industry, raised in the Meeting: - 1. High costs of construction; 2. Inefficient procurement system; 3. Uncoordinated nature of construction works (public) from conception to delivery; 4. Long time taken to complete construction works; 5. Poor building standards - need to harmonize them; 6. Poor institutional, legal and regulatory framework; 7. Poor governance in the construction industry/absence of proper management of projects; 8. Lack of capacity in training in the industry; 9. Lack of proper funding on R &amp; D; 10. Lack of ethics and integrity in the industry; 11. Informal nature of most building and construction works; 12. Public Private Partnerships needed in the construction industry; 13. WTO issues particularly General Agreements on Trade in Services (GATS) and in particular Trade Related Intellectual Property Rights (TRIPS); 14. Poor remuneration of construction workers; 15. Data - poor quality data (e.g. data from municipalities) or absence (parameters for pricing [indices?]) 16. Bad management of the industry</td>
</tr>
<tr>
<td><strong>6.12</strong></td>
<td>Murigu, J. M. (2005) An Analysis of the Decision-making Criteria for Investing in Commercial Real Estate in Kenya, Unpublished Ph.D. Thesis, University of Nairobi. Page 146: Difficulties in abiding by the set down requirements have often been given by property developers as one reason causing them to undertake developments without approval (Musau, 1990). The developers complain of the cost and the time it takes for their plans to be approved. One has to follow up applications, “paper chase”, from one office to the next, including sometimes pervasive corruption, making the process costly. Consequently, there have been numerous cases of blatant disregard of planning regulations, resulting in mushrooming of unplanned settlements, misuse of road reserves, and serious strain on services and infrastructure.</td>
</tr>
</tbody>
</table>

*Note:* In Chapters III to VII of this study report, evidence for deductions made from the qualitative data in Appendix C is cross-referenced as ACRef …… [reference numbers stated], while cross-references to all the other Appendices are stated in full.
Systems Aspect | Description of System Aspect
--- | ---
(6) Pet Theories (Cont’d) | What the Industry participants feel/think is the problem with the industry


The enforcement powers of local authorities are, therefore, restricted with the planning authorities handling on average 30% of actual development in the city of Nairobi, as shown on the Table below.

| Table: Level of Planning Approval in Commercial Developments (000 square metres) |
|---|---|---|---|---|
| Approved by Council | 18 | 20 | 30 | 42 |
| Unapproved by the Council | 32 | 55 | 80 | 88 |
| Total | 50 | 75 | 110 | 130 |
| % of Unapproved | 36 | 27 | 27 | 32 |

Constructed from Fig. 4.2

This scenario has enabled large tracks of unplanned and unregulated developments to emerge around the major towns and cities, especially Nairobi.

| 6.14 | Page 148: It is this state of affairs that resulted in the Architectural Association of Kenya condemning inefficiencies in all the councils in the country (Karirah, 1998: 102). The Association emphasized that the councils had contributed to the construction of unapproved buildings due to ineffective administration and infighting. Furthermore, the coordinating role of council’s planning and development control within the city of Nairobi, is not well established and organized. Therefore, the role of the building inspectorate team is weak, meaning that the inspectors do not follow up on-site developments to ensure that the buildings are in accordance with the approved plans. Also, although the code requires the council to give a reply within 30 days of receipt of a duly completed application form and other particulars, studies have established that it takes over a year to have any communication from the council (Musau, 1990). |
### Systems Aspect

<table>
<thead>
<tr>
<th>Description of System Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(6) Pet Theories (Cont’d)</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What the Industry participants feel/think is the problem with the industry</th>
</tr>
</thead>
</table>


6.16 Page 6: Globalization is taking the world by storm and as professionals, you must rise to the occasion by keeping abreast with what is new in your areas of jurisdiction and also exploring what other options can be offered. Recent trends throughout the world are moving towards the use of alternative non-traditional procurement methods aimed at improving the traditional “design-tender-construct” method. Clients are seeking ways of raising the standards of performance of the industry. The environmental impact of developments and project management are also priority areas that need to be addressed. New developments in information & communication technologies (ICT) are greatly influencing many industries and construction industry is no exception. The industry must embrace new ways by using latest and economical technologies to be internationally competitive.

**Interviewee No. 1: Land Economist & Property Consultant; 29th March 2006**

Sometimes market research is done by property consultants for distribution to clients, but it is not scientific or accurate. There are no market research firms because the service is not paid for.

**Interviewee No. 2: Land Economics Scholar & Researcher; 5th April 2006**

Many real estate investment decisions are based on intuition; people invest when they feel it is the right time. Market research is normally done by most serious investors - HFCK, National Housing, etc. There is no specific market research firm in Kenya focusing on the construction industry or real estate. Demand forecasting is lacking.

6.18 The government is not supporting research. There are no market research firms in the construction/property industry in Kenya. Their services are not considered necessary. People do feasibility study for an individual project. There is nothing done at the macro-level. A market research outfit is required. A practical approach would be to research & publish, people buy.

6.19 Interviewee No. 5: Land Economist & Property Consultant; 6th April 2006

There is a huge demand for market research service. The service currently given by property consultants (valuers & quantity surveyors) is not comprehensive.

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**Note:** In Chapters III to VII of this study report, evidence for deductions made from the qualitative data in Appendix C is cross-referenced as ACRef ……. [reference numbers stated], while cross-references to all the other Appendices are stated in full.
Appendix D: Quantitative Data
## (a) List of Variables

<table>
<thead>
<tr>
<th>Item</th>
<th>Variable</th>
<th>Units</th>
<th>Data available</th>
<th>Length of series</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 a</td>
<td>Private residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>2 b</td>
<td>Public residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>3 c</td>
<td>Private non-residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>4 d</td>
<td>Public non-residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>5 e</td>
<td>Private other construction work</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>6 f</td>
<td>Public other construction work</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td>Construction output (at current prices)</td>
<td>Kshs Millions</td>
<td>1975 - 2003</td>
<td>29</td>
</tr>
<tr>
<td>8</td>
<td>Cement consumption (local)</td>
<td>000 tonnes</td>
<td>1960 - 2003</td>
<td>44</td>
</tr>
<tr>
<td>9</td>
<td>Unemployment</td>
<td>%</td>
<td>1964 - 2005</td>
<td>42</td>
</tr>
<tr>
<td>10</td>
<td>Inflation rate</td>
<td>%</td>
<td>1961 - 2005</td>
<td>45</td>
</tr>
<tr>
<td>11</td>
<td>Average interest rate for 91-day Treasury Bills</td>
<td>%</td>
<td>1973 - 2004</td>
<td>32</td>
</tr>
<tr>
<td>12</td>
<td>Average interest rate for Commercial bank loans &amp; advances (maximum)</td>
<td>%</td>
<td>1973 - 2004</td>
<td>32</td>
</tr>
<tr>
<td>13</td>
<td>Total Government expenditure</td>
<td>Kshs Millions</td>
<td>1954/55 - 2003/04</td>
<td>50</td>
</tr>
<tr>
<td>14</td>
<td>Capital Government expenditure</td>
<td>Kshs Millions</td>
<td>1954/55 - 2003/04</td>
<td>50</td>
</tr>
<tr>
<td>15</td>
<td>GDP Absolute [at Factor Cost] (at constant 1982 Prices)</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>16</td>
<td>GDP Growth rate</td>
<td>%</td>
<td>1964 - 2003</td>
<td>38</td>
</tr>
<tr>
<td>17</td>
<td>GDP per Capita</td>
<td>Kshs</td>
<td>1964 - 2003</td>
<td>39</td>
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<tr>
<td>18</td>
<td>GNP Absolute (at constant 1982 Prices)</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>19</td>
<td>GNP Growth rate</td>
<td>%</td>
<td>1964 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>20</td>
<td>Foreign Exchange Price</td>
<td>Kshs per US$</td>
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<td>21</td>
<td>Building price index (resource based)</td>
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<td>22</td>
<td>Civil engineering price index (resource based)</td>
<td>1972 - 2004</td>
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<td></td>
</tr>
<tr>
<td>23</td>
<td>Population size</td>
<td>Millions</td>
<td>1962 - 2003</td>
<td>33</td>
</tr>
<tr>
<td>24</td>
<td>Election dates; 10 No.</td>
<td>1963 - 2002</td>
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</table>
## (b) Codes of Variables

<table>
<thead>
<tr>
<th>Item</th>
<th>Code</th>
<th>Variable on Sheet 3</th>
<th>Units</th>
<th>Data available upto 2003</th>
<th>Length of series upto 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a</td>
<td>PRR Private residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>b</td>
<td>PUR Public residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>c</td>
<td>PRNR Private non-residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>d</td>
<td>PUNR Public non-residential building</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>e</td>
<td>PROC Private other construction work</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>f</td>
<td>PUOC Public other construction work</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>TGC Total Gross Fixed Capital Formation (by construction) (at constant 1982 prices)</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>CO Total Construction Output (at constant 1982 prices)</td>
<td>Kshs Millions</td>
<td>1975 - 2003</td>
<td>29</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>CEM Cement consumption (in the country)</td>
<td>000 tonnes</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>UNEMP Unemployment</td>
<td>%</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>INFL Inflation</td>
<td>%</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>MI Misery Index (inflation rate + unemployment)</td>
<td>%</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>RIRTB Real interest rate TB (Average interest rate for 91-day Treasury Bills minus inflation rate)</td>
<td>1973 - 2003</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>RIRCLA Real interest rate CLA (Average interest rate for Commercial bank loans &amp; advances [maximum] minus inflation rate)</td>
<td>%</td>
<td>1973 - 2003</td>
<td>31</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>CEP Capital Government expenditure percentage</td>
<td>%</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>GDPA GDP Absolute (at Factor Cost) (at constant 1982 Prices)</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>GDPR GDP Growth rate</td>
<td>%</td>
<td>1964 - 2003</td>
<td>38</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>GDPC GDP per Capita</td>
<td>Kshs</td>
<td>1965 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>GNPA GNP Absolute (at constant 1982 Prices)</td>
<td>Kshs Millions</td>
<td>1964 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>GNPR GNP Growth rate</td>
<td>%</td>
<td>1964 - 2003</td>
<td>39</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>EXR Exchange Rate; value of Kshs = reciprocal of Forex price in Kshs per US$</td>
<td>US$ per Kshs</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>BPI Building price index (resource based)</td>
<td>1973 - 2003</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>CEPI Civil engineering price index (resource based)</td>
<td>1972 - 2003</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>TCPI Total construction price index (resource based)</td>
<td>1972 - 2003</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>POP Population size</td>
<td>Millions</td>
<td>1964 - 2003</td>
<td>40</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>TECYR Time on Election Cycle; scale 0 - 5</td>
<td>Year</td>
<td>1963 - 2002</td>
<td>40</td>
</tr>
</tbody>
</table>
### Construction GFCF (Kshs M) [at Constant 1982 Prices]

<table>
<thead>
<tr>
<th>Year</th>
<th>PRR</th>
<th>PUR</th>
<th>PRNR</th>
<th>PUNR</th>
<th>PROC</th>
<th>PUOC</th>
<th>TGC</th>
<th>TCO</th>
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</thead>
<tbody>
<tr>
<td>1964</td>
<td>874.64</td>
<td>82.43</td>
<td>394.58</td>
<td>185.12</td>
<td>502.51</td>
<td>392.17</td>
<td>2,431.46</td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>891.94</td>
<td>102.21</td>
<td>323.95</td>
<td>251.01</td>
<td>550.46</td>
<td>647.42</td>
<td>2,587.16</td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>935.94</td>
<td>107.71</td>
<td>281.32</td>
<td>332.58</td>
<td>611.51</td>
<td>696.57</td>
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</tr>
<tr>
<td>1967</td>
<td>1,129.85</td>
<td>204.43</td>
<td>427.47</td>
<td>487.57</td>
<td>645.48</td>
<td>929.13</td>
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<tr>
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<td>1,269.13</td>
<td>317.63</td>
<td>579.70</td>
<td>670.82</td>
<td>1,117.23</td>
<td>4,538.23</td>
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</tr>
<tr>
<td>1969</td>
<td>1,393.26</td>
<td>293.45</td>
<td>759.94</td>
<td>946.78</td>
<td>629.91</td>
<td>1,063.66</td>
<td>4,637.01</td>
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<tr>
<td>1970</td>
<td>1,535.72</td>
<td>297.85</td>
<td>661.29</td>
<td>490.51</td>
<td>455.80</td>
<td>1,306.49</td>
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<td>663.88</td>
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<td>1972</td>
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<td>434.89</td>
<td>356.80</td>
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<td>3,836.05</td>
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</tbody>
</table>

### Values of Variables

Note: Construction GFCF was used in Appendices E to I, as the proxy for Construction Output because the Construction Output series was too short for the analysis.

(c) **Quantitative Data Collected**

### Appendix D

- **Construction GFCF (Khs M) [at Constant 1982 Prices]**
- **Note:** Construction GFCF was used in Appendices E to I, as the proxy for Construction Output because the Construction Output series was too short for the analysis.
### Values of Variables (Cont'd)

<table>
<thead>
<tr>
<th>Year</th>
<th>MI</th>
<th>UNEMP</th>
<th>INFL</th>
<th>TECYR</th>
<th>CEP</th>
<th>POP</th>
<th>EXR</th>
<th>BPI</th>
<th>CEPI</th>
<th>TCPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964</td>
<td>6.10</td>
<td>4.00</td>
<td>2.10</td>
<td>1.00</td>
<td>18.79</td>
<td>9.30</td>
<td>0.1400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>7.60</td>
<td>4.10</td>
<td>3.50</td>
<td>2.00</td>
<td>20.50</td>
<td>9.62</td>
<td>0.1400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>6.80</td>
<td>4.20</td>
<td>2.60</td>
<td>3.00</td>
<td>22.66</td>
<td>9.95</td>
<td>0.1400</td>
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</tr>
<tr>
<td>1967</td>
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<td>2.60</td>
<td>1.00</td>
<td>24.77</td>
<td>10.28</td>
<td>0.1400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968</td>
<td>7.10</td>
<td>4.70</td>
<td>2.40</td>
<td>2.00</td>
<td>27.10</td>
<td>10.61</td>
<td>0.1400</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>6.50</td>
<td>4.90</td>
<td>1.60</td>
<td>3.00</td>
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<td>1970</td>
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<td>1.00</td>
<td>32.02</td>
<td>11.38</td>
<td>0.1400</td>
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<td></td>
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</tr>
<tr>
<td>1971</td>
<td>8.90</td>
<td>5.20</td>
<td>3.70</td>
<td>2.00</td>
<td>33.21</td>
<td>11.82</td>
<td>0.1400</td>
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</tr>
<tr>
<td>1972</td>
<td>10.60</td>
<td>5.40</td>
<td>5.40</td>
<td>3.00</td>
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(d) Numbers of Contractors Registered with the Ministry of Roads & Public Works as at 15 July 2006

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NOTE: The list in the Contractors’ Register shows a total of 1799 contractors. However, some of the contractors are registered in two trade categories, thereby increasing the effective contracting capacity by 337No. (i.e. 19%)
Appendix E: Adjustments for Informal & Non-Monetary Output
### Adjustment for Informal Sector and Non-Monetary Building Output

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<th>Year</th>
<th>Civil Engineering Construction Output (Kshs M at 1982 Prices)</th>
<th>Private Building Output (Kshs M at 1982 Prices)</th>
<th>Total Monetary Construction Output (Kshs M at 1982 Prices)</th>
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### Notes:
1. Recorded data (at constant 1982 prices) are in columns a, b, l, k and p; the other columns are generated from there.
2. Cement consumption is for cement used in Kenya; it excludes cement exported from Kenya.
3. Column e shows both the multiplier for building output and the addition to the private sector building. The % addition is ( e - 1)%.
4. The % of Monetary Construction Output to the Overall Total Construction Output ranges from about 60% to 90%, with an average of about 75% over the period 1964 - 2003.

### Average of Monetary CO2; 1964 to 2003

73%
Appendix E Adjustment for Informal Sector and Non-Monetary Building Output Apdx E/2

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- Adjusted TCO
- Unadjusted TCO
- Monetary TCO
Appendix F: Indices of Construction Output
### Appendix F

#### Indices of Construction Output

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**Note:** From the Logarithmic trendline, the 2007 index for the total construction output is estimated at 0.0782.
Appendix G: Sectoral Contributions to Construction Output
<table>
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<tr>
<th>Year</th>
<th>Total Formal Construction Output</th>
<th>Formal Building Output</th>
<th>Civil Engineering Output</th>
<th>Percentage of Civil Engineering Output</th>
<th>Formal Contractors Output</th>
<th>Percentage of Public Sector to Construction</th>
<th>Average Contractor Output</th>
<th>Contribution</th>
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<tr>
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<td>872.92</td>
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</table>
Appendix G

Sectoral Contributions to Construction Output

Year

Unadjusted
PRR
PRNR

1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

874.64
891.94
993.94
1,129.85
1,269.13
1,393.26
1,535.72
1,774.75
1,807.15
835.04
1,631.41
1,692.29
1,380.08
1,501.55
2,077.97
2,310.40
1,960.07
2,136.71
2,037.40
1,681.00
1,811.40
1,659.20
1,964.00
1,953.20
1,627.20
1,802.40
1,424.20
1,334.20
1,149.82
741.04
719.62
665.80
695.20
728.00
694.02
670.04
643.93
647.15
696.72
714.56

394.58
323.95
281.32
427.47
579.70
759.94
661.29
666.17
734.36
414.74
714.10
510.63
682.13
629.12
548.23
795.51
762.92
979.91
585.80
713.40
529.60
860.00
759.40
775.00
946.80
1,119.00
477.00
497.80
342.02
151.88
133.60
129.20
149.60
173.20
180.24
249.60
239.76
307.50
398.83
406.61

Note:

Adjusted
PRR + PRNR
1,269.22
1,215.88
1,275.27
1,557.32
1,848.82
2,153.20
2,197.01
2,440.91
2,541.52
1,249.78
2,345.51
2,202.92
2,062.21
2,130.67
2,626.20
3,105.91
2,722.99
3,116.63
2,623.20
2,394.40
2,401.40
2,845.45
3,178.38
4,022.66
3,858.23
4,532.67
5,385.53
5,095.97
5,049.90
4,039.38
3,877.66
4,810.93
5,246.85
5,135.73
4,842.10
5,018.28
4,819.97
4,919.35
5,476.33
5,723.43

PUR

PUNR

82.43
102.21
107.71
204.43
317.63
293.45
297.85
478.10
378.08
216.94
297.86
309.02
262.98
368.32
363.25
503.06
680.46
601.05
471.80
332.00
409.60
267.40
410.80
413.20
356.00
482.20
804.40
590.20
328.66
383.20
428.00
352.40
352.80
315.20
255.10
265.74
261.30
222.94
223.21
249.69

185.12
251.01
332.58
487.37
631.70
496.78
490.51
663.08
750.93
434.89
743.75
795.33
635.35
885.44
965.21
1,197.98
1,365.94
1,297.68
1,174.20
880.80
915.60
876.20
910.60
890.80
1,691.20
1,404.20
1,581.60
1,577.80
1,084.52
1,075.40
990.80
1,639.60
1,439.40
1,647.34
1,495.80
1,356.08
1,200.50
1,128.60
1,273.15
1,353.23

BUILDING
1,536.77
1,569.11
1,715.56
2,249.12
2,798.16
2,943.44
2,985.37
3,582.09
3,670.53
1,901.61
3,387.11
3,307.27
2,960.54
3,384.43
3,954.66
4,806.94
4,769.38
5,015.35
4,269.20
3,607.20
3,726.60
3,989.05
4,499.78
5,326.66
5,905.43
6,419.07
7,771.53
7,263.97
6,463.08
5,497.98
5,296.46
6,802.93
7,039.05
7,098.27
6,593.00
6,640.10
6,281.77
6,270.89
6,972.69
7,326.35

PROC

PUOC

502.51
550.64
611.51
645.48
622.83
629.91
455.80
560.55
462.88
358.80
325.02
248.33
159.77
198.11
225.20
215.57
274.37
257.98
217.00
376.60
271.40
222.00
326.60
190.20
169.40
264.80
417.80
334.80
212.90
826.80
826.76
836.60
1,577.20
1,610.40
1,656.70
1,716.92
1,521.75
1,610.10
1,459.67
1,490.77

392.17
467.42
696.57
929.13
1,117.24
1,063.66
1,306.49
1,934.65
2,365.59
1,575.65
2,200.69
2,228.18
2,316.97
2,359.25
2,376.70
2,011.93
2,462.55
2,885.03
2,763.20
1,993.40
1,708.80
2,208.80
2,247.60
2,182.40
2,631.00
2,510.60
3,155.60
3,400.80
4,037.82
3,258.52
2,132.20
3,016.20
3,157.00
3,449.20
3,222.82
3,246.34
3,447.49
3,464.90
3,242.54
3,250.56

CIVIL
894.69
1,018.06
1,308.07
1,574.61
1,740.07
1,693.57
1,762.29
2,495.20
2,828.47
1,934.45
2,525.71
2,476.51
2,476.74
2,557.36
2,601.90
2,227.51
2,736.92
3,143.00
2,980.20
2,370.00
1,980.20
2,430.80
2,574.20
2,372.60
2,800.40
2,775.40
3,573.40
3,735.60
4,250.72
4,085.32
2,958.96
3,852.80
4,734.20
5,059.60
4,879.52
4,963.26
4,969.24
5,075.00
4,702.21
4,741.33

Adjusted TCO
2,431.46
2,587.16
3,023.63
3,823.73
4,538.23
4,637.01
4,747.66
6,077.29
6,499.00
3,836.05
5,912.83
5,783.78
5,437.28
5,941.79
6,556.55
7,034.45
7,506.30
8,158.36
7,249.40
5,977.20
5,706.80
6,419.85
7,073.98
7,699.26
8,705.83
9,194.47
11,344.93
10,999.57
10,713.80
9,583.30
8,255.42
10,655.73
11,773.25
12,157.87
11,472.52
11,603.36
11,251.01
11,345.89
11,674.90
12,067.68

Apdx G/2

Total Pubic
27.13%
31.72%
37.60%
42.39%
45.54%
39.98%
44.12%
50.61%
53.77%
58.07%
54.84%
57.62%
59.13%
60.81%
56.51%
52.78%
60.07%
58.64%
60.82%
53.64%
53.16%
52.22%
50.45%
45.28%
53.74%
47.82%
48.85%
50.63%
50.88%
49.22%
43.01%
47.00%
42.04%
44.51%
43.35%
41.95%
43.63%
42.45%
40.59%
40.22%

Total Building
63.20%
60.65%
56.74%
58.82%
61.66%
63.48%
62.88%
58.94%
56.48%
49.57%
57.28%
57.18%
54.45%
56.96%
60.32%
68.33%
63.54%
61.48%
58.89%
60.35%
65.30%
62.14%
63.61%
69.18%
67.83%
69.81%
68.50%
66.04%
60.32%
57.37%
64.16%
63.84%
59.79%
58.38%
57.47%
57.23%
55.83%
55.27%
59.72%
60.71%

Public Building
11.00%
13.65%
14.56%
18.09%
20.92%
17.04%
16.61%
18.78%
17.37%
16.99%
17.62%
19.09%
16.52%
21.10%
20.26%
24.18%
27.26%
23.27%
22.71%
20.29%
23.22%
17.81%
18.68%
16.94%
23.52%
20.52%
21.03%
19.71%
13.19%
15.22%
17.19%
18.69%
15.22%
16.14%
15.26%
13.98%
12.99%
11.91%
12.82%
13.28%

(1) For the Variable Codes, see Appendix D.
(2) All percentages on this page are of the overall total construction output (i.e. Construction output inclusive of the informal sector adjustment).

Total Civil
36.80%
39.35%
43.26%
41.18%
38.34%
36.52%
37.12%
41.06%
43.52%
50.43%
42.72%
42.82%
45.55%
43.04%
39.68%
31.67%
36.46%
38.52%
41.11%
39.65%
34.70%
37.86%
36.39%
30.82%
32.17%
30.19%
31.50%
33.96%
39.68%
42.63%
35.84%
36.16%
40.21%
41.62%
42.53%
42.77%
44.17%
44.73%
40.28%
39.29%

Public Hsg
3.39%
3.95%
3.56%
5.35%
7.00%
6.33%
6.27%
7.87%
5.82%
5.66%
5.04%
5.34%
4.84%
6.20%
5.54%
7.15%
9.07%
7.37%
6.51%
5.55%
7.18%
4.17%
5.81%
5.37%
4.09%
5.24%
7.09%
5.37%
3.07%
4.00%
5.18%
3.31%
3.00%
2.59%
2.22%
2.29%
2.32%
1.96%
1.91%
2.07%

Private Building
52.20%
47.00%
42.18%
40.73%
40.74%
46.44%
46.28%
40.16%
39.11%
32.58%
39.67%
38.09%
37.93%
35.86%
40.05%
44.15%
36.28%
38.20%
36.19%
40.06%
42.08%
44.32%
44.93%
52.25%
44.32%
49.30%
47.47%
46.33%
47.13%
42.15%
46.97%
45.15%
44.57%
42.24%
42.21%
43.25%
42.84%
43.36%
46.91%
47.43%


Appendix H: Estimates of Demand for Constructed Space
### Total Demand for Constructed Space

<table>
<thead>
<tr>
<th>Year</th>
<th>Monetary CCR</th>
<th>OCW</th>
<th>PAR</th>
<th>DCR</th>
<th>Stock of CS</th>
<th>Demand for CS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>33.3% OCW</td>
<td>2,090.29</td>
<td>3,104.77</td>
<td>61,357.60</td>
<td>63,167.77</td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>5,625.50</td>
<td>3,104.77</td>
<td>4,616.91</td>
<td>63,642.77</td>
<td>66,384.52</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>4,815.98</td>
<td>4,347.37</td>
<td>4,347.37</td>
<td>59,527.30</td>
<td>68,595.14</td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td>3,960.68</td>
<td>3,964.20</td>
<td>4,159.41</td>
<td>72,880.00</td>
<td>73,149.54</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>3,807.71</td>
<td>7,801.58</td>
<td>7,801.58</td>
<td>76,402.65</td>
<td>80,482.38</td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td>5,205.66</td>
<td>3,527.80</td>
<td>3,527.80</td>
<td>83,370.35</td>
<td>82,990.45</td>
<td></td>
</tr>
<tr>
<td>1974</td>
<td>4,984.07</td>
<td>4,984.07</td>
<td>4,984.07</td>
<td>88,345.46</td>
<td>89,217.26</td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>4,825.37</td>
<td>4,825.37</td>
<td>4,825.37</td>
<td>94,310.57</td>
<td>95,232.32</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>4,436.96</td>
<td>4,436.96</td>
<td>4,436.96</td>
<td>100,375.68</td>
<td>101,308.54</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>4,057.56</td>
<td>4,057.56</td>
<td>4,057.56</td>
<td>106,439.79</td>
<td>108,330.34</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>3,669.15</td>
<td>3,669.15</td>
<td>3,669.15</td>
<td>112,503.90</td>
<td>114,362.76</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>3,280.74</td>
<td>3,280.74</td>
<td>3,280.74</td>
<td>118,568.01</td>
<td>120,380.82</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>2,892.33</td>
<td>2,892.33</td>
<td>2,892.33</td>
<td>124,632.12</td>
<td>126,380.82</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>2,503.92</td>
<td>2,503.92</td>
<td>2,503.92</td>
<td>130,696.23</td>
<td>132,380.82</td>
<td></td>
</tr>
<tr>
<td>1991</td>
<td>2,115.51</td>
<td>2,115.51</td>
<td>2,115.51</td>
<td>136,760.34</td>
<td>138,380.82</td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td>1,727.10</td>
<td>1,727.10</td>
<td>1,727.10</td>
<td>142,824.45</td>
<td>144,380.82</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>1,338.69</td>
<td>1,338.69</td>
<td>1,338.69</td>
<td>148,888.56</td>
<td>150,380.82</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>950.28</td>
<td>950.28</td>
<td>950.28</td>
<td>154,952.67</td>
<td>156,380.82</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>561.86</td>
<td>561.86</td>
<td>561.86</td>
<td>160,016.78</td>
<td>161,380.82</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>172.45</td>
<td>172.45</td>
<td>172.45</td>
<td>166,080.89</td>
<td>167,380.82</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>73.04</td>
<td>73.04</td>
<td>73.04</td>
<td>172,144.99</td>
<td>173,380.82</td>
<td></td>
</tr>
</tbody>
</table>

### Overall Increase in Demand

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>317,033.91</td>
</tr>
</tbody>
</table>

### Annual Demand Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>33.33% OCW</td>
</tr>
</tbody>
</table>

### CCR is 33.33% of OCW at Start

### Demand for Constructed Space

\[ y = 59.543x^2 + 3020.4x + 62090 \]

\[ R^2 = 0.9977 \]
Appendix I: Regression of Construction Output
Figure AI 1 Graph of Construction Output

Observation: Construction output has an upward trend; it is non-stationary in level
Table AI 1 ADF Test of Stationarity of the First Difference of Construction Output

Null Hypothesis: D(CO) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic based on SIC, MAXLAG=9)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-6.442849</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.615588
- 5% level: -2.941145
- 10% level: -2.609066


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(CO,2)
Method: Least Squares
Date: 06/15/07   Time: 04:27
Sample (adjusted): 1966 2003   Included observations: 38 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(CO(-1))</td>
<td>-1.071099</td>
<td>0.166246</td>
<td>-6.442849</td>
<td>0.0000</td>
</tr>
<tr>
<td>C</td>
<td>141.7640</td>
<td>127.6624</td>
<td>1.110461</td>
<td>0.2742</td>
</tr>
</tbody>
</table>

R-squared 0.535546   Mean dependent var 1.439438
Adjusted R-squared 0.522644  S.D. dependent var 1122.327
S.E. of regression 775.4265  Akaike info criterion 16.19590
Sum squared resid 21646305  Schwarz criterion 16.28209
Log likelihood -305.7221  F-statistic 41.51031
Durbin-Watson stat 2.022427  Prob(F-statistic) 0.000000

*Observation: The first difference of construction output is stationary.*
Appendix 1: Regression of Construction Output

(b) Stationarity of GNP

Observation: GNP has an upward trend; it is non-stationary in level
### Table AI 2 ADF Test of Stationarity of the first difference of GNP

Null Hypothesis: D(GNP) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic based on SIC, MAXLAG = 9)

<table>
<thead>
<tr>
<th></th>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-4.759127</td>
<td>0.0005</td>
</tr>
<tr>
<td>Test critical values:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% level</td>
<td>-3.632900</td>
<td></td>
</tr>
<tr>
<td>5% level</td>
<td>-2.948404</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
<td>-2.612874</td>
<td></td>
</tr>
</tbody>
</table>


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GNP,2)
Method: Least Squares
Date: 06/15/07  Time: 04:33
Sample (adjusted): 1969 2003
Included observations: 35 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D(GNP(-1))</td>
<td>-1.505948</td>
<td>0.316434</td>
<td>-4.759127</td>
<td>0.0000</td>
</tr>
<tr>
<td>D(GNP(-1),2)</td>
<td>0.505742</td>
<td>0.256834</td>
<td>1.969139</td>
<td>0.0582</td>
</tr>
<tr>
<td>D(GNP(-2),2)</td>
<td>0.689145</td>
<td>0.224631</td>
<td>3.067900</td>
<td>0.0045</td>
</tr>
<tr>
<td>D(GNP(-3),2)</td>
<td>0.347971</td>
<td>0.167956</td>
<td>2.071806</td>
<td>0.0470</td>
</tr>
<tr>
<td>C</td>
<td>4029.131</td>
<td>978.0222</td>
<td>4.119673</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

R-squared 0.590082  Mean dependent var 3.274787
Adjusted R-squared 0.535427  S.D. dependent var 4212.338
S.E. of regression 2871.113  Akaike info criterion 18.89435
Sum squared resid 2.47E+08  Schwarz criterion 19.11654
Log likelihood -325.6511  F-statistic 10.79636
Durbin-Watson stat 2.132528  Prob(F-statistic) 0.000015
Observation: The first difference of GNP is stationary.

(c) Stationarity of Misery Index

Observation: Misery index is likely to be stationary in level, since it appears to have no trend.
Table AI 3 ADF Test of Stationarity of Misery Index

Null Hypothesis: MI has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic based on SIC, MAXLAG=9)

<table>
<thead>
<tr>
<th>t-Statistic</th>
<th>Prob.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Augmented Dickey-Fuller test statistic</td>
<td>-3.134547</td>
</tr>
</tbody>
</table>

Test critical values:
- 1% level: -3.615588
- 5% level: -2.941145
- 10% level: -2.609066


Augmented Dickey-Fuller Test Equation
Dependent Variable: D(MI)
Method: Least Squares
Date: 06/15/07 Time: 04:38
Sample (adjusted): 1966 2003
Included observations: 38 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI(-1)</td>
<td>-0.416139</td>
<td>0.132759</td>
<td>-3.134547</td>
<td>0.0035</td>
</tr>
<tr>
<td>D(MI(-1))</td>
<td>0.198578</td>
<td>0.164023</td>
<td>1.210666</td>
<td>0.2341</td>
</tr>
<tr>
<td>C</td>
<td>8.004509</td>
<td>2.673145</td>
<td>2.994417</td>
<td>0.0050</td>
</tr>
</tbody>
</table>

R-squared 0.219202 Mean dependent var 0.389890
Adjusted R-squared 0.174585 S.D. dependent var 7.562597
S.E. of regression 6.870796 Akaike info criterion 6.768094
Sum squared resid 1652.274 Schwarz criterion 6.897377
Log likelihood -125.5938 F-statistic 4.912977
Durbin-Watson stat 1.850531 Prob(F-statistic) 0.013165
Appendix I Regression of Construction Output

Observation: The ADF test confirms that misery index is stationary in level.

(d) ARIMA Regression of Construction Output (CO)

<table>
<thead>
<tr>
<th>Auto correlation</th>
<th>Partial Correlation</th>
<th>AC</th>
<th>PAC</th>
<th>Q-Stat</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-0.071</td>
<td>-0.071</td>
<td>0.210</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-0.184</td>
<td>-0.190</td>
<td>1.872</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>-0.030</td>
<td>-0.051</td>
<td>1.089</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0.100</td>
<td>-0.147</td>
<td>2.144</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>-0.177</td>
<td>-0.228</td>
<td>3.016</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1</td>
<td>-0.122</td>
<td>-0.247</td>
<td>4.337</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1</td>
<td>-0.110</td>
<td>-0.227</td>
<td>4.943</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>1</td>
<td>-0.080</td>
<td>-0.243</td>
<td>5.273</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>1</td>
<td>0.071</td>
<td>-0.079</td>
<td>5.373</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>1</td>
<td>0.226</td>
<td>0.689</td>
<td>8.412</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>1</td>
<td>0.553</td>
<td>0.633</td>
<td>8.529</td>
</tr>
<tr>
<td>12</td>
<td>1</td>
<td>1</td>
<td>1.194</td>
<td>0.679</td>
<td>9.264</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>1</td>
<td>1.069</td>
<td>0.673</td>
<td>9.567</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>1</td>
<td>0.133</td>
<td>0.143</td>
<td>10.090</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>1</td>
<td>-0.145</td>
<td>-0.032</td>
<td>12.090</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>1</td>
<td>-0.039</td>
<td>-0.020</td>
<td>12.050</td>
</tr>
</tbody>
</table>

Figure AI 4 Correlogram of the first difference of Construction Output

Observation: AC & PACF patterns in the correlogram do not show clearly whether the stochastic process of construction output is mainly an AR or mainly an MA process. They suggest that the process is a mix of AR and MA processes.
### (e) ARMA (1, 1) Regression of the First Difference of Construction Output

Table AI 4 ARIMA (1, 1, 1) Regression Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>69.96422</td>
<td>17.37347</td>
<td>4.027072</td>
<td>0.0003</td>
</tr>
<tr>
<td>AR(1)</td>
<td>0.525011</td>
<td>0.148351</td>
<td>3.538971</td>
<td>0.0013</td>
</tr>
<tr>
<td>MA(1)</td>
<td>-0.997067</td>
<td>0.077380</td>
<td>-12.88526</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

- R-squared: 0.264109
- Adjusted R-squared: 0.218115
- S.E. of regression: 706.3504
- Sum squared resid: 15965787
- Log likelihood: -277.6985
- Durbin-Watson stat: 1.836826

Inverted AR Roots: 0.53
Inverted MA Roots: 1.00
Appendix I Regression of Construction Output

(f) ARIMA Fitted Values and Residuals

Figure A1.5 ARIMA Fitted Values and Residuals of Construction Output
(g) Forecast Accuracy of ARIMA model

(1) Accuracy in the sample data used in modelling

Forecast: COF
Actual: CO
Forecast sample: 1964 2000
Adjusted sample: 1966 2000
Included observations: 35

Root Mean Squared Error  2413.918
Mean Absolute Error      2263.335
Mean Abs. Percent Error  40.46354
Theil Inequality Coefficient 0.273154
  Bias Proportion          0.879129
  Variance Proportion     0.053963
  Covariance Proportion   0.066908

Figure AI 6 Error Analysis of ARIMA Forecast of Construction Output; in the Sample Data
Appendix I Regression of Construction Output

(2) Accuracy in the hold-out data

Figure AI 7 Error Analysis of ARIMA Forecast Construction Output; Hold-out Data

Observation: The MAPE (1.09%) in the hold-out data is lower than the MAPE (40.46%) in the sample data used in the regression, as shown in Figure AI6. However, the later is a more realistic measure of the error because construction output fluctuations in the years 2001 to 2003 were significantly lower than those of the years 1964 to 2000.
(h) Multiple Regression of Construction Output (CO)

Cross Correlogram of DFCO and DFGNP

Date: 06/15/07  Time: 05:06
Sample: 1964-2003
Included observations: 39
Correlations are asymptotically consistent approximations

<table>
<thead>
<tr>
<th>DFCO, DFGNP(-i)</th>
<th>DFCO, DFGNP(+i)</th>
<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.3041</td>
<td>0.2641</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>0.0711</td>
<td>0.2655</td>
</tr>
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<td>4</td>
<td>0.0636</td>
<td>0.2000</td>
<td>6</td>
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<tr>
<td>2</td>
<td>0.0534</td>
<td>0.0449</td>
<td>7</td>
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<td>0.3134</td>
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<tr>
<td>0</td>
<td>0.0157</td>
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<td>16</td>
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Cross Correlogram of DFCO and MI

Date: 06/15/07  Time: 05:10
Sample: 1964-2003
Included observations: 39
Correlations are asymptotically consistent approximations

<table>
<thead>
<tr>
<th>DFCO, MI(-i)</th>
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<th>lag</th>
<th>lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.3511</td>
<td>-0.3511</td>
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</tr>
<tr>
<td>4</td>
<td>2</td>
<td>0.0103</td>
<td>0.1028</td>
</tr>
<tr>
<td>2</td>
<td>0.1367</td>
<td>0.0558</td>
<td>4</td>
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<td>2</td>
<td>0.0523</td>
<td>0.0433</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
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<td>0.0588</td>
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<td>1</td>
<td>12</td>
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<td>1</td>
<td>12</td>
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<td>0.0260</td>
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<td>0</td>
<td>14</td>
<td>0.0623</td>
<td>0.0488</td>
</tr>
<tr>
<td>0</td>
<td>0.0569</td>
<td>0.0110</td>
<td></td>
</tr>
</tbody>
</table>

Figure AI 8 Cross Correlograms of the first difference of Construction Output and (i) first difference of GNP, and (ii) level of Misery Index.
### Table AI 5 Multiple Regression Model

Dependent Variable: D(CO)
Method: Least Squares
Date: 06/15/07  Time: 05:25
Sample (adjusted): 1968 2000
Included observations: 33 after adjustments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>380.3446</td>
<td>374.4972</td>
<td>1.015614</td>
<td>0.3185</td>
</tr>
<tr>
<td>D(GNP)</td>
<td>0.135110</td>
<td>0.041844</td>
<td>3.228881</td>
<td>0.0032</td>
</tr>
<tr>
<td>D(GNP(-2))</td>
<td>-0.061328</td>
<td>0.041926</td>
<td>-1.462787</td>
<td>0.1547</td>
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<tr>
<td>D(GNP(-3))</td>
<td>0.087465</td>
<td>0.040035</td>
<td>2.184732</td>
<td>0.0374</td>
</tr>
<tr>
<td>MI(-1)</td>
<td>-36.87759</td>
<td>13.90943</td>
<td>-2.651266</td>
<td>0.0130</td>
</tr>
</tbody>
</table>

R-squared          0.374574  Mean dependent var 112.6922
Adjusted R-squared 0.285228  S.D. dependent var 813.7926
S.E. of regression  688.0144  Akaike info criterion 16.04422
Sum squared resid   13254187  Schwarz criterion 16.27097
Log likelihood      -259.7297  F-statistic 4.192379
Durbin-Watson stat  2.298485  Prob(F-statistic) 0.008748

(I) Fitted Values and Residuals of the Multiple Regression Model
Figure AI 9 Multiple Regression Model Fitted Values and Residuals of the first difference Construction Output
(j) **Forecast Accuracy of the Multiple Regression Model**

### (1) Accuracy in the sample data used in modelling

![Graph showing error analysis of multiple regression model forecast of construction output in the sample data.](image)

- **Forecast:** COF
- **Actual:** CO
- **Forecast sample:** 1964-2000
- **Adjusted sample:** 1968-2000
- **Included observations:** 33

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Root Mean Squared Error</td>
<td>851.3078</td>
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<tr>
<td>Mean Absolute Error</td>
<td>699.0551</td>
</tr>
<tr>
<td>Mean Abs. Percent Error</td>
<td>13.46759</td>
</tr>
<tr>
<td>Theil Inequality Coefficient</td>
<td>0.071867</td>
</tr>
<tr>
<td>Bias Proportion</td>
<td>0.246886</td>
</tr>
<tr>
<td>Variance Proportion</td>
<td>0.001065</td>
</tr>
<tr>
<td>Covariance Proportion</td>
<td>0.752050</td>
</tr>
</tbody>
</table>

**Figure Al 10** Error Analysis of Multiple Regression Model Forecast of Construction Output; in the Sample Data

### (2) Accuracy in the hold-out data
Observation: As observed in the case of ARIMA forecasts, in the Multiple Regression Model forecasts, the MAPE (4.90%) in the hold-out data is lower than the MAPE (13.47%) in the sample data used in the regression, as shown in Figure AI 10. All the same, the later figure is a more realistic measure of the error because construction output fluctuations in the years 2001 to 2003 were significantly lower than those of the years 1964 to 2000.
Appendix J: Projections from the Improved Structure Model
Appendix J Projections from the Improved Structure Model

(a) Completion Targets, Rate and Reserve Capacity

<table>
<thead>
<tr>
<th>Year</th>
<th>Reserve Capacity</th>
<th>Required Completion Target</th>
<th>Planned Completion Target</th>
<th>Construction Completion Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Jan 1965</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 1981</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 1989</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 1997</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 2013</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1 Jan 2021</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 2029</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Jan 2037</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1 Jan 2045</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
(b) Demand, Stock & Unsatisfied Demand

[Graph showing projections for Demand for Constructed Space in Kenya, Stock of Constructed Space by Kenya, and Unsatisfied Demand for Constructed Space from 1 Jan 1965 to 1 Jan 2045.]
Appendix J Projections from the Improved Structure Model

(c) Demand from Outside Kenya & total Unsatisfied Demand

- Construction Demand Outside Kenya
- Unsatisfied Demand for Constructed Space
(f) Multiplier for Time to Complete Outstanding Work
Appendix J: Projections from the Improved Structure Model

(g) Average Contractor Productivity

Average Contractor Productivity vs. Time

COU/(yr*C)

1 Jan 1965  1 Jan 1973  1 Jan 1981  1 Jan 1989  1 Jan 1997  1 Jan 2005  1 Jan 2013  1 Jan 2021  1 Jan 2029  1 Jan 2037  1 Jan 2045
Appendix J Projections from the Improved Structure Model

(h) Contractor Entry and Redundancy Rates

Contractor Redundancy Rate
Contractor Entry Rate

C/yr
0 500 1,000 1,500 2,000
1 Jan 1965 1 Jan 1973 1 Jan 1981 1 Jan 1989 1 Jan 1997 1 Jan 2005 1 Jan 2013 1 Jan 2021 1 Jan 2029 1 Jan 2037 1 Jan 2045

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Appendix K: Functional Definitions of Model Variables
This Appendix gives definitions in Powersim Studio code, of model variables of the System Dynamics model of the construction industry of Kenya, shown in Figures 5.2 and 6.6 of the main text.

(a) Levels

1. Stock of Constructed Space
   Initial Value: 60000\text{COU}
   Flows: \(\Delta t\)\*Construction Completion Rate

2. Outstanding Planning Approvals
   Initial Value: 2090.29\text{COU}
   Flows: \(\Delta t\)\*Design Completion Rate - \(\Delta t\)\*Planning Approval Rate

3. Outstanding Construction Work
   Initial Value: 5302.81\text{COU}
   Flows: \(\Delta t\)\*Planning Approval Rate - \(\Delta t\)\*Construction Completion Rate

4. Contractors
   Initial Value: Required Contractors at start
   Flows: \(\Delta t\)\*Contractor Entry Rate - \(\Delta t\)\*Contractor Redundancy Rate

(b) Auxiliaries

1. Demand for Constructed Space (DCS)

   (i) Polynomial
   \text{POLY(\text{(TIME-STARTTIME)}/\text{STIME},62090\text{COU},3020.4\text{COU},59.543\text{COU})}

   \text{NB: the polynomial function is } Y = 62090 + 3020.4X + 59.543X^2, \text{ where } Y \text{ is DCS and } X \text{ is number of years from 1964.}
(ii) DCS Values for the Reference Mode, 1964 to 2003; Steps Only

\[ \begin{align*}
61767.6 & \cdot \text{COU} & + \text{STEP}(3104.77 \cdot \text{COU}, \text{STARTTIME} + 0 \cdot \text{yr}) & + \text{STEP}(3279.75 \cdot \text{COU}, \text{STARTTIME} + 1 \cdot \text{yr}) \\
& + \text{STEP}(2205.62 \cdot \text{COU}, \text{STARTTIME} + 2 \cdot \text{yr}) & + \text{STEP}(1301.85 \cdot \text{COU}, \text{STARTTIME} + 3 \cdot \text{yr}) & + \text{STEP}(3257.54 \cdot \text{COU}, \text{STARTTIME} + 4 \cdot \text{yr}) \\
& + \text{STEP}(7332.84 \cdot \text{COU}, \text{STARTTIME} + 5 \cdot \text{yr}) & + \text{STEP}(2508.07 \cdot \text{COU}, \text{STARTTIME} + 6 \cdot \text{yr}) & + \text{STEP}(-3946.61 \cdot \text{COU}, \text{STARTTIME} + 7 \cdot \text{yr}) \\
& + \text{STEP}(14840.46 \cdot \text{COU}, \text{STARTTIME} + 8 \cdot \text{yr}) & + \text{STEP}(1839.02 \cdot \text{COU}, \text{STARTTIME} + 9 \cdot \text{yr}) & + \text{STEP}(2489.44 \cdot \text{COU}, \text{STARTTIME} + 10 \cdot \text{yr}) \\
& + \text{STEP}(7128.22 \cdot \text{COU}, \text{STARTTIME} + 11 \cdot \text{yr}) & + \text{STEP}(5434.26 \cdot \text{COU}, \text{STARTTIME} + 12 \cdot \text{yr}) & + \text{STEP}(4711.62 \cdot \text{COU}, \text{STARTTIME} + 13 \cdot \text{yr}) \\
& + \text{STEP}(5780.29 \cdot \text{COU}, \text{STARTTIME} + 14 \cdot \text{yr}) & + \text{STEP}(5992.66 \cdot \text{COU}, \text{STARTTIME} + 15 \cdot \text{yr}) & + \text{STEP}(2162.44 \cdot \text{COU}, \text{STARTTIME} + 16 \cdot \text{yr}) \\
& + \text{STEP}(3961.67 \cdot \text{COU}, \text{STARTTIME} + 17 \cdot \text{yr}) & + \text{STEP}(8420.42 \cdot \text{COU}, \text{STARTTIME} + 18 \cdot \text{yr}) & + \text{STEP}(8912.60 \cdot \text{COU}, \text{STARTTIME} + 19 \cdot \text{yr}) \\
& + \text{STEP}(5110.40 \cdot \text{COU}, \text{STARTTIME} + 20 \cdot \text{yr}) & + \text{STEP}(2736.60 \cdot \text{COU}, \text{STARTTIME} + 21 \cdot \text{yr}) & + \text{STEP}(8521.60 \cdot \text{COU}, \text{STARTTIME} + 22 \cdot \text{yr}) \\
& + \text{STEP}(3819.60 \cdot \text{COU}, \text{STARTTIME} + 23 \cdot \text{yr}) & + \text{STEP}(6149.80 \cdot \text{COU}, \text{STARTTIME} + 24 \cdot \text{yr}) & + \text{STEP}(5744.40 \cdot \text{COU}, \text{STARTTIME} + 25 \cdot \text{yr}) \\
& + \text{STEP}(4934.04 \cdot \text{COU}, \text{STARTTIME} + 26 \cdot \text{yr}) & + \text{STEP}(6097.24 \cdot \text{COU}, \text{STARTTIME} + 27 \cdot \text{yr}) & + \text{STEP}(4618.64 \cdot \text{COU}, \text{STARTTIME} + 28 \cdot \text{yr}) \\
& + \text{STEP}(12958.24 \cdot \text{COU}, \text{STARTTIME} + 29 \cdot \text{yr}) & + \text{STEP}(5190.20 \cdot \text{COU}, \text{STARTTIME} + 30 \cdot \text{yr}) & + \text{STEP}(4955.98 \cdot \text{COU}, \text{STARTTIME} + 31 \cdot \text{yr}) \\
& + \text{STEP}(3753.46 \cdot \text{COU}, \text{STARTTIME} + 32 \cdot \text{yr}) & + \text{STEP}(7629.28 \cdot \text{COU}, \text{STARTTIME} + 33 \cdot \text{yr}) & + \text{STEP}(6849.09 \cdot \text{COU}, \text{STARTTIME} + 34 \cdot \text{yr}) \\
& + \text{STEP}(7434.33 \cdot \text{COU}, \text{STARTTIME} + 35 \cdot \text{yr}) & + \text{STEP}(6528.38 \cdot \text{COU}, \text{STARTTIME} + 36 \cdot \text{yr}) & + \text{STEP}(7460.83 \cdot \text{COU}, \text{STARTTIME} + 37 \cdot \text{yr}) \\
& + \text{STEP}(7004.68 \cdot \text{COU}, \text{STARTTIME} + 38 \cdot \text{yr}) & + \text{STEP}(6908.24 \cdot \text{COU}, \text{STARTTIME} + 39 \cdot \text{yr})
\end{align*}\]

**NB:** In order to bring a UDCS (\& DCR) of 3,104.77 COU at the very beginning of the simulation, the DCS value must include the CCR for 1964 (1767.60 COU) to offset its effect on the SCS.
Appendix K  Functional Definitions of Model Variables

(iii) DCS Values for the Reference Mode, 1964 to 2050; Steps from Year 0 to Year 39 (1964 to 2003) + Ramp at Year 40 + Steps at Years 47, 54 & 68 + Ramp at Year 75

\[
61767.60\text{COU} + \text{STEP}(3104.77\text{COU},\text{STARTTIME} + 0\text{yr}) + \text{STEP}(3279.75\text{COU},\text{STARTTIME} + 1\text{yr}) + \text{STEP}(2205.62\text{COU},\text{STARTTIME} + 2\text{yr}) + \text{STEP}(1301.85\text{COU},\text{STARTTIME} + 3\text{yr}) + \text{STEP}(3257.54\text{COU},\text{STARTTIME} + 4\text{yr}) + \text{STEP}(7312.84\text{COU},\text{STARTTIME} + 5\text{yr}) + \text{STEP}(2508.07\text{COU},\text{STARTTIME} + 6\text{yr}) + \text{STEP}(-3946.61\text{COU},\text{STARTTIME} + 7\text{yr}) + \text{STEP}(14840.46\text{COU},\text{STARTTIME} + 8\text{yr}) + \text{STEP}(1301.85\text{COU},\text{STARTTIME} + 9\text{yr}) + \text{STEP}(3257.54\text{COU},\text{STARTTIME} + 10\text{yr}) + \text{STEP}(7312.84\text{COU},\text{STARTTIME} + 11\text{yr}) + \text{STEP}(2508.07\text{COU},\text{STARTTIME} + 12\text{yr}) + \text{STEP}(-3946.61\text{COU},\text{STARTTIME} + 13\text{yr}) + \text{STEP}(14840.46\text{COU},\text{STARTTIME} + 14\text{yr}) + \text{STEP}(1301.85\text{COU},\text{STARTTIME} + 15\text{yr}) + \text{STEP}(3257.54\text{COU},\text{STARTTIME} + 16\text{yr}) + \text{STEP}(7312.84\text{COU},\text{STARTTIME} + 17\text{yr}) + \text{STEP}(2508.07\text{COU},\text{STARTTIME} + 18\text{yr}) + \text{STEP}(-3946.61\text{COU},\text{STARTTIME} + 19\text{yr}) + \text{STEP}(14840.46\text{COU},\text{STARTTIME} + 20\text{yr}) + \text{STEP}(2736.60\text{COU},\text{STARTTIME} + 21\text{yr}) + \text{STEP}(8521.60\text{COU},\text{STARTTIME} + 22\text{yr}) + \text{STEP}(6149.80\text{COU},\text{STARTTIME} + 23\text{yr}) + \text{STEP}(5744.40\text{COU},\text{STARTTIME} + 24\text{yr}) + \text{STEP}(4618.04\text{COU},\text{STARTTIME} + 25\text{yr}) + \text{STEP}(6190.20\text{COU},\text{STARTTIME} + 26\text{yr}) + \text{STEP}(4955.98\text{COU},\text{STARTTIME} + 27\text{yr}) + \text{STEP}(4955.98\text{COU},\text{STARTTIME} + 28\text{yr}) + \text{STEP}(6190.20\text{COU},\text{STARTTIME} + 29\text{yr}) + \text{STEP}(12958.24\text{COU},\text{STARTTIME} + 30\text{yr}) + \text{STEP}(7629.28\text{COU},\text{STARTTIME} + 31\text{yr}) + \text{STEP}(6849.09\text{COU},\text{STARTTIME} + 32\text{yr}) + \text{STEP}(6849.09\text{COU},\text{STARTTIME} + 33\text{yr}) + \text{STEP}(14840.46\text{COU},\text{STARTTIME} + 34\text{yr}) + \text{STEP}(7629.28\text{COU},\text{STARTTIME} + 35\text{yr}) + \text{STEP}(6528.38\text{COU},\text{STARTTIME} + 36\text{yr}) + \text{STEP}(7460.83\text{COU},\text{STARTTIME} + 37\text{yr}) + \text{STEP}(6849.09\text{COU},\text{STARTTIME} + 38\text{yr}) + \text{STEP}(6908.24\text{COU},\text{STARTTIME} + 39\text{yr}) + \text{RAMP}(8350\text{COU/yr},\text{STARTTIME} + 40\text{yr}) + \text{STEP}(10450\text{COU},\text{STARTTIME} + 47\text{yr}) + \text{STEP}(12500\text{COU},\text{STARTTIME} + 54\text{yr}) + \text{STEP}(15335\text{COU},\text{STARTTIME} + 68\text{yr}) + \text{RAMP}(4550\text{COU/yr},\text{STARTTIME} + 75\text{yr})] + \text{RAMP}(8350\text{COU/yr},\text{STARTTIME} + 75\text{yr})
\]

NB: DCS total up to Year 86 (2050) is 762,224.42 COU, calculated from the polynomial function in (a) above; average gradient is 8,863.075 COU/Yr

2. Unsatisfied Demand for Constructed Space
'Demand for Constructed Space' - 'Stock of Constructed Space'

3. Practical Completion Target
'Outstanding Construction Work'/'Time to Complete Outstanding Work'

4. Required Contractors
'Practical Completion Target'/'Average Contractor Output'

5. Average Contractor Output
GRAPHICURVE((TIME - STARTTIME)/Timestep,0,80,(1.00, 1.60, 4.80)<COU/C/yr>)
6. Contractor Redundancy Percentage
   (i) Up to Year 2003

   GRAPH(((TIME - STARTTIME)/TIMESTEP,24,4,0, 15, 25, 73.3, 2.5, 5.29, 11.69, 12, 18, 20, 21, 26.5, 30, 35.92, 16.78, 2, 3, 10.46, 11, 12.5, 13.5, 15.5, 17, 20.5, 32.46, 0, 2.5, 10.25, 25, 19, 16, 15, 13, 10)\%/yr)\)

   (ii) CRP up to Year 2050

   GRAPH(((TIME - STARTTIME)/TIMESTEP,24,4,0, 15, 25, 73.3, 2.5, 5.29, 11.69, 12, 18, 20, 21, 26.5, 30, 35.92, 16.78, 2, 3, 10.46, 11, 12.5, 13.5, 15.5, 17, 20.5, 32.46, 0, 2.5, 10.25, 25, 19, 16, 15, 13, 10, 8, 6, 4, 0, 15, 25, 73.3, 2.5, 5.29, 11.69, 12, 18, 20, 21, 26.5, 30, 35.92, 16.78, 2, 3, 10.46, 11, 12.5, 13.5, 15.5, 17, 20.5, 32.46, 0, 2.5, 10.25, 25, 19, 16, 15, 13, 10, 8, 6, 5, 2, 1, 6, 12, 18, 25, 35, 65)\%/yr)\)

7. Planned Completion Target
   POLY((TIME-STARTTIME)/TIMESTEP,1768<<COU/yr>>,79.57<<COU/yr>>,0.4774062<<COU/yr>>,0.0012156<<COU/yr>>)

8. Reserve Capacity
   'Unsatisfied Demand for Constructed Space'/'Time to Adjust Reserve Capacity'

9. Required Completion Target
   'Planned Completion Target' + 'Reserve Capacity'

10. Fraction of Average Contractor Output
    'Average Contractor Output'/'Normal Average Contractor Output'

11. Multiplier for Time to Complete Outstanding Work
    GRAPH('Fraction of Average Contractor Productivity',0.1,0.2, {0.9, 0.7, 0.6, 0.5, 0.4, 0.35, 0.33, 0.31, 0.29, 0.27, 0.25, 0.23, 0.21, 0.19, 0.17, 0.13, 0.11, 0.10, 0.10, 0.10})

12. Construction Demand from Outside Kenya
    RAMP(2500 <<COU/yr>>,STARTTIME + 17 <<yr>>)

---

Appendix K  Functional Definitions of Model Variables
(c) Constants

1. Time for Design \(1\text{yr}\)
2. Time for Planning Approval \(1\text{yr}\)
3. Time to Complete Outstanding Work \(3\text{yr}\)
4. Time to Attract Contractors \(1\text{yr}\)
5. Time to Adjust Reserve Capacity \(10\text{yr}\)
6. Normal Average Contractor Output \(5\text{COU/C/yr}\)
7. Normal Time to Complete Outstanding Work \(6\text{yr}\)

(d) Rates

1. Design Completion Rate
   \('Unsatisfied Demand for Constructed Space'/'Time for Design'\)

2. Planning Approval Rate
   \('Outstanding Planning Approvals'/'Time for Planning Approval'\)

3. Contractor Entry Rate
   \((('Required Contractors'-Contractors)/'Time to Attract Contractors')- 'Contractor Redundancy Rate'\)

4. Contractor Redundancy Rate
   \(Contractors\times 'Contractor Redundancy Percentage'\)

5. Construction Completion Rate
   (i) \(Contractors\times 'Average Contractor Output'\)

   (ii) \('Required Completion Target' - ('Required Contractors'- Contractors)'\times 'Average Contractor Output'\)
Appendix L: Ethics Considerations
Appendix L  Ethical Considerations  Apdx L/A

(a) Plain Language Statement Approved by RMIT Human Research Ethics Committee

School of Property, Construction & Project Management
Building 8, Level 8, City Campus, 360 Swanston Street, GPO Box 2476V, Melbourne, 3001, Victoria, AUSTRALIA.

Date: ____________________________

Mr/Mrs/Ms/Dr/Prof. ____________________________

Invitation to Participate in a Research Project

Project title: Modelling Construction Output in Kenya: System Dynamics & Time Series Analyses

Dear ______________________________________

My name is Titus Mbiti, a student undertaking a research study in construction as part of a Doctor of Philosophy degree in Building and Construction Economics. You are invited to participate in this research project. This information sheet describes the project in plain English. Please read this sheet carefully and be confident that you understand its contents before deciding whether to participate. I am undertaking this research study under the supervision of Dr Nick Blismas and Prof. Ron Wakefield of RMIT University. The project has been approved by the RMIT Human Research Ethics Committee, Australia and the Ministry of Education, Kenya.

You have been selected to participate in this study, from the list of developers/experts/contractors in the Construction Review/IQSK Magazine (December 2005 edition) because you are an expert/investor/businessman in the construction industry of Kenya and you have a long period of experience. This research aims to investigate how business activity in the construction industry changes with time and how various parts of the industry contribute to this change in the long run. The data for the study is obtained from documented sources and from interviews of the industry participants. About twenty five respondents are expected to participate in the study.

If you agree to participate, you will be required to attend a 30 – 45 minute interview on the process of decision-making in your consultancy/business field and on measures of stabilising business activity in the construction industry. The interview will be conducted at your place of work or at a mutually convenient place of your choice. Your participation has no risks associated with it but it will be a great contribution to advancement of knowledge in Construction. The information you give will be kept anonymous. Any information that you provide can be disclosed only if (1) it is to protect you or others from harm, (2) a court order is produced, or (3) you provide the researchers with written permission”.

As a participant, you have the right to withdraw your participation at any time, without prejudice; have any unprocessed data withdrawn and destroyed, provided it can be reliably identified, and provided that so doing does not increase risk for you; have any questions answered at any time.

A report of the project outcomes will be provided to the Ministry of Education in Kenya and RMIT University in Australia. The data will be stored securely in the School of Property, Construction & Project Management for at least five years and then destroyed in accordance with the RMIT procedures for destruction of records.

If you are willing to be interviewed, please complete and return the attached Consent Form. Please contact me directly or my supervisors at RMIT, if you require any further information.

Yours faithfully,

Mr Titus K. P. Mbiti
Student, Doctor of Philosophy – Building & Construction Economics
tkivaap@yahoo.com
+254 734 836266

Dr Nick Blismas
(PhD, Bsc, MCIOB);
Supervisor
nick.blismas@rmit.edu.au
+61 3 9925 5056

Professor Ron Wakefield
PhD, School Head;
Supervisor
ron.wakefield@rmit.edu.au
+61 3 9925 3448

Any complaints about your participation in this project may be directed to the Executive Officer, RMIT Human Research Ethics Committee, Research & Innovation, RMIT, GPO Box 2476V, Melbourne, 3001. The telephone number is (03) 9925 2251. Details of the complaints procedure are available from the above address.
Appendix L  Ethical Considerations

(b) RMIT HREC Form 2b - Consent Form

Prescribed Consent Form for Persons Participating in Research Projects Involving Interviews, Questionnaires or Disclosure of Personal Information

Portfolio
School of Property Construction and Project Management
Name of participant:

Project Title:

Modelling Construction Output in Kenya: System Dynamics & Time Series Analyses

Name(s) of investigators: (1) Titus Kivaa P. M. Phone: +254 734 836266 +254 726 817949
(2) Nick Blismas Phone: +61 3 9925 5056

1. I have received a statement explaining the interview/questionnaire involved in this project.
2. I consent to participate in the above project, the particulars of which - including details of the interviews or questionnaires - have been explained to me.
3. I authorise the investigator or his or her assistant to interview me or administer a questionnaire.
4. I acknowledge that:
   (a) Having read the Plain Language Statement, I agree to the general purpose, methods and demands of the study.
   (b) I have been informed that I am free to withdraw from the project at any time and to withdraw any unprocessed data previously supplied.
   (c) The project is for the purpose of research and/or teaching. It may not be of direct benefit to me.
   (d) The privacy of the personal information I provide will be safeguarded and only disclosed where I have consented to the disclosure or as required by law.
   (e) The security of the research data is assured during and after completion of the study. The data collected during the study may be published, and the project outcomes will be provided to the Ministry of Education in Kenya and RMIT University in Australia. Any information which will identify me will not be used.

Participant’s Consent

Participant: ___________________________________________ Date: __________________________

(Signature)

Witness: ___________________________________________ Date: __________________________

(Signature)

Where participant is under 18 years of age:

I consent to the participation of ___________________________________________ in the above project.

Signature: (1) ___________________________________________ (2) ___________________________________________ Date: __________________________

(Signatures of parents or guardians)

Witness: ___________________________________________ Date: __________________________

(Witness to signature)

Participants should be given a photocopy of this consent form after it has been signed.

Any complaints about your participation in this project may be directed to the Executive Officer, RMIT Human Research Ethics Committee, Research & Innovation, RMIT, GPO Box 2476V, Melbourne, 3001. The telephone number is (03) 9925 2251. Details of the complaints procedure are available from the above address.
MINISTRY OF EDUCATION, SCIENCE & TECHNOLOGY

Telegrams: EDUCATION™, Nairobi

Fax No.
Telephone: 318581
When replying please quote

MOEST 13/001/35C554/2

16th November 2005

Titos Mhiti
School of Property Construction &
Project Management
Melbourne VIC 3000
AUSTRALIA

Dear Sir,

RESEARCH AUTHORIZATION

Following your application for authority to carry out research on “Modelling Construction output in Kenya System Dynamics and Time series Analysis”, This is to inform you that you have been authorized to conduct research in construction firms in Nairobi for a period ending 31st December 2006.

You are advised to report to report to the Provincial Commissioner, The Provincial Director of Education, and the Chief Executive Officers of the Construction firms you will visit before embarking on your research project.

Upon completion of your research, you are expected to submit two copies of your research report to this office.

Yours faithfully,

M.O. ONDIEKI
FOR: PERMANENT SECRETARY

cc. The Provincial Commissioner
Nairobi
The Provincial Director of Education
Nairobi
The Chief Executive Officers construction firms
Nairobi.