# Organisational and industrial practice in the steel industry: A sociology of science study

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## Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

**Signature:** B K Sedumedi **Date:** 12 March 2004

## Abstract

The study investigated the nature of a steel production process in South Africa. The Iron and Steel Corporation of South Africa (Iscor) was analysed within various theoretical approaches within the sociology of science and technology.

Iscor follows the production processes that are based on a particular paradigm practiced throughout the world by steel-making organisations. The study aims to unlock this paradigm by using specific theoretical (ANT, SCOT and SSR) and disciplinary (MOT) approaches. Each approach provides a unique analytical dimension to the study: the influence of various human and non-human actors, the influence of social pressures, the historical evolution of the current practices and the management of risk.

The study explores how Iscor adheres to mainstream scientific work. Hence there is a focus on endogeneous approaches – "processes of technological change and their outcomes are part of what has to be explained and understood" (Rip et al, 1995). It is also noted that the technologies are derived from practical experiences and processes of scientific research.

There is an ongoing attempt to formulate an understanding between technical and social content of steel-making processes because automated plant machinery continue to replace manual labour. Finally, the study investigates how dominant steel-making technologies within Iscor's Vanderbijlpark (VP) and Saldanah Bay (SB) plants have evolved to achieve a position of stability.

## Opsomming

Die studie het oorsake van die staal produksie proses in Suid Afrika geondersoek. Die Yster en Staal Korperasie van Suid Afrika (Yskor) was geanaliseer binne die verskillende teoretiese benaderings in die sosiologie van wetenskap en tegnologie.

Yskor volg 'n produksie wat gebaseer is op 'n spesifieke paradigm wat deur alle staal vervaardigde organisasie wereld wyd gepraktiseer word. Die studie beoog om hierdie paradigm te ontbloot, deur spesifieke teoretiese (ANT, SCOT and SSR) en disiplinere (MOT) benaderings te gebruik. Elk van hierdie benaderings sal 'n unieke analiese demensie voortbring aan die studie: die invloed van verskillende menslike en nie-menslike aspekte, die invloed van sosiale druk, die geskiedkundige evolusie van die huidige praktyke en die bestuur van risikos.

Die studie ondersoek hoe Yskor riglyne volg in die wetenskaplike veld. Al te mits is daar 'n mikpunt op endogeniese benadering – "tegnologiese prosese verandering en die resultate wat deel vorm van hoe die proses verduidelik word en verstandbaar moet wees" (Rip et al, 1995). Dis is dus duidelik dat die tegnologie verkry word deur praktiese ondervinding en wetenskappe navorsing prosese.

Daar is voortdurend pogings om die verwantskap tussen tegniese en die sosiale inhoud van die staal vervaardigings prosese te formuleer, deurdat auto-matiese mashienerie all deurgans oorneem van werkers. Laastens die studie ondersoek hoe die dominante staal vervaardigde tegnologie binne in Yskor Vanderbijlpark (VP) en Saldanha Baai (SB) verander het om 'n stabiele stands poort te verkry.

## Acknowledgements

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# Chapter 1
# Introduction

## 1.1 Objective of the study

This is a case study of the processes of steel making at Iron and Steel Corporation (Iscor). The study explored how the science of manufacturing and the related practices at Iscor are consistent with the current theories in the field of science and technology studies and innovation management. In addition, the study aimed to develop an understanding of how the eventuality of a dominant steel making process is influenced by both technical and social factors. Insights were thus sought from the following theories: Actor Network Theory (ANT), Social Construction of Technology (SCOT) and the Structure of Scientific Revolutions (SSR), and the discipline of the Management of Technology (MOT).

The objective of the study was to contribute to knowledge within the field of science and technology in three ways:

(a) To develop an understanding of how ANT, SCOT, SSR and MOT explain the steel making products and processes;

(b) To detail how various scientific and non-scientific actors within Iscor influence the steel making process; and

(c) To apply insights gained from the theoretical framework to the case study.

We attempted to explain why steel making is not only a technical outcome but also a socio-technical outcome. A process of "inductive falsification" was followed to develop an analysis of how of technical detail has been left out of the final process rather than how much social detail was introduced (Popper, 1966). The discipline of MOT and each applied theory i.e. ANT, SCOT and SSR, introduced unique analytical tools to the study as explained in Chapter 2 to support this notion.

## 1.2 Rationale of the study

According to the Engineering News of 28 September 2001, much has been written in South Africa about the development of new production techniques for designing materials, particularly the manufacturing organisations. Most approaches exclude an analysis of how the current materials are produced especially the primary metallic material, namely steel.

According to the article, two schools were emerging within the current understanding of materials development: either the improving of the existing materials processes or a design of completely new materials processes that are futuristic in outlook. This implies adhering to the existing production techniques or introducing new production methods, respectively.

The steel industry has always used alloying as a tool to produce good quality steel. The basic knowledge in this field is derived from the metallurgical, chemical and physical sciences. Various role players were identified in the production process and their role explained in interactions between them and the instruments of production. The interactions assisted in understanding how the various Iscor actors associate with particular social and technical networks (Latour, 1987).

The philosophy of technology has recently been challenged because of its “lack” of relevance to empirical studies. Hence the ANT is chosen as an approach in the discipline of philosophy of technology within the “mild” approach of SCOT (Brey, 1999).

### 1.3 The problem statement

Iscor is the largest producer of steel in South Africa accounting for about 68% of the market. The object of our analysis is the steel-making process at the Iscor VP plant. The use of flat steel products has a wide range of applications including social applications. Some of the flat steel products produced at the VP plant are: hot rolled sheets, hot rolled steel plates, hot rolled steel strips, cold rolled steel strips, electrolytically galvanised steel sheets, colour coated steel sheets and electrolytic steel plates. The SB plant produces hot-rolled thin gauge coils.

The study assumed that ANT, SCOT, SSR, and MOT could serve as tools to explain the social and market conditions of steel-making in South Africa. Thus there was an attempt to understand whether certain principles of the metallurgical sciences are influenced by social interests and market conditions. However it was realised that in this approach the use of ANT, SCOT, SSR and MOT as analytical tools is also a limiting factor to the study. The specific factors that we focused on in the case study are the following:

1. The understanding of the basic scientific principles used at Iscor;
2. The management of technology at Iscor VP plant;

3. The extent of rationality within Iscor;
4. The distribution of knowledge within the organisation; and
5. The extent of the application of metallurgical sciences.

The study also sought to investigate how a particular practice of the steel-making process emerged to be dominant. Therefore the following could be identified as dimensions that would inform the outcomes of our study:

1. The manner in which science particularly metallurgy is represented at Iscor;
2. How the current steel-making production methods evolved from the past;
3. How innovation finds expression at both plant and management levels;
4. How globalisation especially the development of new products affects Iscor; and
5. A brief risk analysis of the steel making process.

The study also made an attempt to highlight other important research questions relating to configuration of production processes (Chapter 5). Furthermore, Chapter 3 looks at the research methodology employed in the study, and Chapter 4 discusses the results using insights from the identified theoretical approaches.

# Chapter 2
# Literature Review

## 2.1 Overview

Our review of the scholarship covers four areas: the philosophy of science and technology, paradigm analysis, innovation studies and technology management.

The structure of knowledge within Iscor is a point of departure, particularly the understanding of the practice of metallurgical sciences. Importantly, the focus of the study is to understand the environmental factors (UNESCO, 2001) in analysing the transformation processes from science to projects that are workable.

The approach adopted attempts to describe the interface and/or distance between Iscor's empirical descriptions i.e. scientific principles based on metallurgical science, and social expectations and prescriptions experienced by different interest groups.

The unique approaches of philosophy of science and paradigm analysis have been vehemently criticised by some scholars for lacking an empirical basis. It is not surprising that various methods of social construction of technology (SCOT) are being investigated to afford an empirical basis of the sociology and philosophy of science (Stalder, 1997 and Bijker, 1995). There is abundant scholarship for our retrospective investigation on Iscor, although more work still needs to be done to clarify certain observations made.

## 2.2 Description of conceptual framework

Our review of the literature will focus on three theoretical approaches that are relevant to our study: Social Construction of Technology (SCOT), Actor-Network Theory (ANT), the Theory of the Structure of Scientific Revolutions (SSR); as well as the discipline of Management of Technology (MOT).

In each case we will cover the following aspects of the theory:

- The key aspects of each theoretical approach;
- The debates within the theoretical approach;
- The dominant thinking within the theoretical approach; and

- Possible challenges and opportunities faced by each theoretical approach.

In all the theoretical approaches, dominant variants were considered as a subject of analysis particularly where there is available and established scholarship. However, other useful approaches were taken into consideration when making and concluding on observations made about the unit of analysis.

### 2.2.1 Social Construction of Technology (SCOT)

*The key aspects of SCOT*

SCOT is primarily concerned with how knowledge, particularly technology, is produced. According to this approach, many of the social and cultural effects of a new technology are determined during the development stage of technology. This is done through various processes of social negotiation and interpretation. SCOT disputes "the existence and conditioning of an internal logic in yielding technological knowledge or scientific knowledge" (Brey, 1999).

Therefore certain questions coming from scientific activity have to be found outside of science. These questions give rise to how science is perceived by various interest groups e. g. those who are regarded as scientists and those who are social players. Traditional practice of science has only considered views, opinions and perceptions as solely expressed by scientists. SCOT interrogates this view by including how science is influenced by other social activity and social actors and vice versa. Importantly, the practice of science is also regarded as a social activity (Latour, 1987). Hence SCOT advocates a constructivist approach to science and technology as compared to the standard view espoused by scientists (Bijker, 1995).

*The debates within SCOT*

The current understanding of SCOT is a development of the mid-eighties by scholars like Latour, Callon, Hughes, Pinch and Bijker. There are different approaches to SCOT although with a semblance to one another. These are the weak, mild and strong approaches of SCOT. The weak approach explains that science is not essentially influenced by social factors. According to this approach, science is primarily dependent on its method, which is not wholly influenced by social factors. This is referred to as the "technology determinism" approach. Bijker and Pinch adhere to this view. Bijker is more direct with his conception of SCOT (Bijker, 1995:1):

> *Some of the implications of these standard images are positive and comforting. Thus, for example, does scientific knowledge appear as a prominent candidate for solving all kinds of problems. In the domain of political thought, this naturally leads to 'technocracy' – like proposals. Also, it seems technology is good in itself and independent of context. Of course it can be applied negatively, but then the users are to be blamed, not the technology.*

The strong approach is also referred to as the "social determinism" approach. It is premised on the fact that science is primarily influenced by social factors. Technology is regarded as a genuine social construction. According to this approach, experimentation is simply an isolation of the technical variables from the social variables (Woolgar, 1988). This results in a physical enclosure like a laboratory, which provides experimental outcomes because there was "predictive success" (Knorr-Cetina, 1994). The perception of an exclusive environment led Woolgar to conceptualise technological change as being explained by social practices like the processes of negotiation, and interpretation. Collins and Woolgar adhere to this approach.

The mild approach is a moderate approach which is also referred to as the "social shaping" approach (MacKenzie and Wajcman, 1985). It analyses how social factors shape technology, and retains the conventional distinctions of what is social and natural, and between social and technical. Technological properties and effects are defined relative to a social context. Such properties and effects are to a large extent also regarded as social properties and social effects. The mild approach is very close to ANT discussed in 2.2.2 because in both instance a principle of "methodological symmetry is followed" (Bijker and Pinch, 1987). MacKenzie and Wajcman adhere to this view.

*The dominant thinking within SCOT*

SCOT views technological development as a contingent process, involving heterogeneous factors. It follows that technological change cannot be analysed as following a fixed, unidirectional path. Technological change can be explained by referring to technological controversies and disagreements involving different actors or relevant social groups (Latour, 1987). Therefore, mainstream thinking within

SCOT has led to social constructivist approaches that are broadly the "social shaping" approaches (MacKenzie and Wajcman, 1985) and the Actor-Network Theory or constructivism (Latour, 1987).

The "social shaping" and constructivism approaches typically employ the principle of "methodological symmetry" or "methodological relativism" (Pinch and Bijker, 1987). The principle of symmetry implies that the observer or analyst remains impartial to the true properties of the object of analysis viz. Technology. The analyst does not evaluate any of the knowledge claims by different actors. SCOT has always grappled with the distinction between reality and representation (Woolgar, 1988). This implies making a distinction between how science works i.e. reality and how it is experienced and perceived i.e. representation. Katherine Hayles has thus qualified SCOT by referring to it as "constrained constructivism" because there are always limiting factors or constraints on how scientific activity finally assumes social representation or construction. By implication, the representation of science or "the process of its construction" remains a subject of ideology.

*Challenges and opportunities to SCOT*

Bijker (1995) makes a distinction between the "standard" and "constructivist" images of technology. According to Bijker, relevant social groups are a point of departure for analysing technology and its outputs. He continues by saying "*technical artefacts are described through the eyes of the members of relevant social groups. The interactions within and among relevant social groups can give different meanings to the same*". There is thus "*interpretative flexibility that shows neither an artefact's identity, nor its technical success or failure, are intrinsic properties of the artefact but subject to social variables*" (Bijker, 1995:2). This is a deviation from the standard image of science, which views science as being value-free, objective and grounded by experts. It is agreeable with the fact that science is not a product of consensus by experts but an objective enquiry for the truth.

Similarly, the working of technology is an intrinsic property of the technical machines and properties. Therefore, according to Bijker, SCOT is based on the following critical factors:

- Interpretative flexibility of the technological products: SCOT asserts that social variables have to be considered as an intrinsic property, which is a radical departure from the historically known image and method of science;

- Multi-dimensional development of the technological products: Technological products should not be purely facilitated and experienced as scientific products but should be accommodative of social interventions;
- Involvement of relevant social groups or actors: During technological development, all affected and interested social groups should be allowed to give inputs on how the final product and/or processes should look like and/or operate, respectively;
- Understanding of "technological frames": During technological development it is critical for all stakeholders to realise that there are limits to their capacity in terms of understanding the particular subject matter and taking care of their interests;
- Utility of technological products: It is important to know how widespread will be the social use of technological products particularly whether a product will offer a problem to a long-standing social problem;
- Form and processes of stabilisation of technological products: It is important for practitioners in the scientific community to understand the appropriate methods of disclosing the operations of a product for social acceptance; and
- Increased tolerances of developing future technological products: Experts will have to accommodate more social variables in order to make a product more user-friendly and interactive. This would imply that more interdisciplinary teams have to be employed to influence the production processes, both technically and socially.

The existing scholarship on SCOT reflects on the utility of technical processes, thus fusing opportunities and challenges to an extent. This utility has been a subject of organisational and technical control. The control is achieved by introducing limitations to participation by specific interest groups from society. Increasing the social groups has offered more opportunities in the past, especially in the market. This has affected the product design in attempting to reconcile divergent social interests.

### *2.2.2 Actor-Network Theory (ANT)*

*The key aspects of ANT*

Actor-Network Theory is a variant of the SCOT approaches. It has its roots in the mid-eighties through scholars like Bruno Latour, Michel Callon and John Law amongst others. ANT emerged as an independent theory when the science of meaning-making or semiotics was fused with SCOT:

**SCOT + Semiotics = ANT**...(Lemke, 1997)

Approaches to semiotics were drawn from the works of Charles Peirce's (1878) "*How to Make our Ideas Clear*", F Saussure's (1915) "*Course in General Linguistics*" and Roland Barthe's (1964) "*Elements of Semiology*". All the works emphasise the emergence of a "system of relations" that facilitates the coming into being of an "eco-social organisation". Bruno Latour commented on this emerging organisation and made the following observation about science and society (Latour, 1987:175):

> *...Our travel through techno-science should then be full not of microbes, radioactive substances, fuel cells and drugs, but of wicked generals, devious multi-nationals, eager consumers, exploited women, hungry kids and distorted ideologies. Have we come all this way and escaped the Charybdis of "science" only to be wrecked by the Scylla of "society"?*

Latour refers to "all the elements tied to the scientific contents" as "techno-science", and "science and technology" to designate as "what is kept of techno-science once the trials of responsibility have been settled". According to Latour, it is an optical illusion that science and technology is not only a subset that takes precedence because of its seemingly enlarged esoteric content. The challenge is thus to understand and explain the processes that lead to the eventuality of techno-science.

*The debates about ANT*

The main criticism of ANT comes from outside the field of social studies of science. Scholars and physicists like Sokal and Bricmont have been the leading critiques of ANT. Their criticism of ANT stems from the fact that they cannot comprehend how ANT can redefine the practice of disciplines like physics, biology and chemistry. According to them, the practice of scientific disciplines does not depend on external social contexts but the underlying scientific principles. Obviously they do not associate the formulation of scientific principles with any given context. Hence they accuse ANT of philosophical relativism unparalleled in the history of scientific thinking (Sokal and Bricmont, 2001). Sokal et al (2001) furthermore argue that ANT, as a theoretical approach does not have cognitive coherence or an independent cognitive status.

Sokal and Bricmont assert that the propagators of ANT like Latour and Callon are inconsistent when applying scientific principles. They argue that sociologists and philosophers of science choose to apply different rules of the scientific method to the natural sciences as compared to the social sciences or the humanities. This criticism of ANT seems to be based on a notion of a Strong Programme within the SCOT approach. The Strong Programme is explained as the strong approach of SCOT as explained by Brey in 1999. Sokal and Bricmont interprete ANT as suggesting social factors determine the outcome of scientific discourse.

*The dominant thinking of ANT*

ANT approaches the work of scientists as a simultaneous reconstruction of social contexts of which they form part – laboratories link the social and natural contexts upon which they act. Instruments or *"inscription devices"* are seen as a practical extension of the social world (Latour, 1987:68). Therefore, it is important to locate the *"black boxes"* within an experimental setting. In the process of opening the *"black boxes",* no distinction is made between subjects and objects (Latour, 1987:1-3). Both are actors i.e. people and non-humans i.e. machines.

Human and non-human are not necessarily treated symmetrically but are defined relationally. This approach negates the positivist view of actors as existing in themselves prior to any participation in eco-social and semiotic networks of interactions (Lemke, 1997).

Callon describes ANT as follows (Callon, 1998:1):

> *...Actor-Network Theory is based on no stable theory of the actor, in other words, it assumes the radical indeterminacy of the actor For example, neither the actor's size nor its psychological make-up nor motivations behind its actions are pre-determined ... This hypothesis ... has, as we all know, opened the social sciences to non-humans.*

Hence, actors are non-local with variable forms and competencies. The indeterminacy of the actors justifies their association to be referred to as a network. Thus John Law explains ANT as "a *sociology of translation concerned with the mechanics of power*" (Law, 1992:1). He questions why certain interactions amongst actors become "*macro-social*", i.e. "*...how it is that they seem to generate the effects such as power, fame, size, scope or organisation with which we are familiar*" (Law,

1992:1). The attainment of a macro-social status seems to be similar to Latour's approach of the "*black box*" derived from cybernetics (Latour, 1987). Hence, the existence of the macro-social status or "black box" characterises a stable pattern out of a heterogeneous network. Law
continues by saying:

> *...But the general case, and the one pressed by actor-network theory, is this. If human beings form a social network, it is not because they interact with other human beings. It is because they interact with human beings and endless other materials too ... Actor-Network Theory says, then, that order is an effect generated by heterogeneous means* (Law, 1992:3).

Accordingly, what counts as a person is an effect generated by a network of heterogeneous, interacting materials. Furthermore, we can deduce that an actor is "*a patterned network of heterogeneous relations, or an effect produced by such a network*" (Latour, 1996:1). The latter factor seems to justify the use of the hyphen between the words "Actor" and "Network" in referring to the Actor-Network Theory.

*The challenges of ANT*

ANT is recognised as an independent theoretical approach with its own cognitive coherence. However, the key challenges of ANT are the identification of actors in a given context and the understanding of a network in a given environment. These challenges exist because actors and networks are not static i.e. they are *immutable mobiles* (Latour, 1987:227). Furthermore the notion of a network depends on the existence of both human and non-human actors that influence and are influenced by a dynamic environment.

The emergence of ANT as a formidable theory cannot be internalised by some of the science disciplines. However, it can be used to provide specific inputs of an analytical nature to disciplines such as management, bio-ethics, physics and engineering amongst others. It seems logical to view ANT in this context because ANT is a theoretical approach at a meta-scientific level.

### *2.2.3 The Structure of Scientific Revolutions (SSR)*

*The key aspects of SSR*

Paradigm analysis has its roots in the work of Thomas Kuhn (1962) in the "*The Structure of Scientific Revolutions*". SSR is a theory that is usually accommodated within the discipline of social studies of science. SSR is premised on how historical epochs originate and take shape in the sciences. Kuhn postulates a similarity between political and scientific revolutions in terms of new or non-accumulated knowledge.

According to Kuhn "*scientific revolutions are inaugurated by a growing sense, again often restricted to a narrow sub-division of the scientific community, that an existing paradigm has ceased to function adequately in the exploration of an aspect of nature to which that paradigm itself had previously led the way*" (Kuhn, 1962:92). The latter statement captures how the new knowledge structure comes into being through the establishment of paradigms. Therefore the establishment of a paradigm is a function of a well-defined structure of non-accumulated knowledge that explains a certain aspect of nature (Kuhn, 1962). Some scholars view this as only a flow of intellectual steps and part of "*the craft of experimental science*" (de Solla Price, 1984).

According to SSR paradigms provide the necessary intellectual basis that provides the necessary sociological conditions for scientific work in a similar field. However, there is disagreement of what causes a change of paradigm. Derek de Solla Price considers a paradigm change to be caused by "*technological change*" rather than Kuhn's "*intellectual crisis*" . A paradigm change is thus a "*response to a crisis*".

The study has qualified technology as "science-derived technology" to justify for a paradigm analysis. A response to a crisis in the Iscor context could mean an emerging technological discontinuity due to a new innovation as in the SB plant. De Solla Price's approach will be more reliable than Kuhn's as no relevant scientific theory is being questioned for inconsistencies. Hence in the Iscor context there is no intellectual crisis to refer to by using Kuhn's approach.

If de Solla Price's approach is correct, a response to a crisis implies the occurrence or potential occurrence of a technological change. On the other hand, Kuhn's "intellectual crisis" would wrongly imply that there is a new scientific understanding to the metallurgical, physical and chemical sciences. Thus in this study SSR is used interchangeably with "Paradigm Analysis" to emphasise on the notion of paradigm. This is irrespective of it being a scientific paradigm i.e. Kuhn's approach, or technological paradigm i.e. de Solla Price's approach. A response to a crisis or an emerging challenge refers to making a determination whether there is a paradigmatic change. This would either be a scientific paradigm, or a technological paradigm as in this case study. The two technological practices at the VP and SB plants are compared to arrive at a determination of whether there is an emerging technological change.

*The debates within SSR*

Many of the debates about SSR had their origins in the following statement by Kuhn:

> *The transition from a paradigm in crisis to a new one from which a new tradition of normal science can emerge is far from a cumulative process, one achieved by an articulation or extension of the old paradigm. Rather it is a reconstruction of the field from new fundamentals, a reconstruction that changes some of the field's most elementary theoretical generalisations as well as many of its paradigm methods and applications* (Kuhn, 1962: 84-85).

According to Derek de Solla Price, Kuhn's approach to paradigm change could be interpreted as being positivist due to its focus on theoretical generalisations rather than the processes that are involved including the instruments used. Theoretical generalisations exist because there is or lack of accumulated knowledge. Hence Kuhn's approach could be labelled the "intellectual crisis approach" and Derek de Solla Price's the "technological crisis" approach. However, Sokal and Bricmont seem to be comfortable with Kuhn since they think that SSR has an empirical basis given the debates that surfaced during the development of the telescope in the sixteenth century.

Kuhn concedes that scientists can *"agree on the identification of a paradigm without agreeing on, or even attempting to produce, a full interpretation or rationalisation of it"* (Kuhn, 1962: 44). He further substantiates this statement by stating that *"...Lack of a standard interpretation … agreed reduction to rules will not prevent a paradigm from guiding research. ...Indeed, the existence of a paradigm need not even imply that any full set of rules exists"* (Kuhn, 1962:44). It could also be concluded that the emergence of a paradigm is not necessarily equivalent to standardisation.

*The dominant thinking within SSR*

The main conclusion that the theory of scientific revolutions draws is that the non-accumulation of knowledge is the critical determining factor for a paradigm shift to occur. If knowledge non-accumulation occurs within a paradigm, anomalies or *counter-instances* begin to emerge. Currently, there is "*no fully general answer*" that can explain the worthiness of scrutinising an anomaly. Hence in a paradigm, theories are accepted on the authority of experts and/or texts, not necessarily because of evidence. Emphasis is usually on the learning of the paradigm not because there is substantial evidence but because it is current scientific practice. Thus if there is a failure, the scientist will be discredited and not the theory espoused by the scientist within a paradigm.

There is no question of the value of Kuhn's theory paradigmatic revolutions, and its contribution to the interpretation by philosophy of science of experimentation as a vehicle of testing theories (de Solla Price, 1984). Adaptation to a paradigm is also a "consequence of pragmatism" that is "a justifiable, praiseworthy act in certain circumstances". Thus society has to agree on a path that would make complex matters generally bearable. In this context it can be concluded that a paradigm is a manifestation of adapting to the complexities of the real world (Rorty, 1982).

*Opportunities of SSR*

SSR has great potential as a meta-scientific analytical tool. This is the case because SSR seems to be a useful instrument in disciplines like Engineering, Research Methodology, Management of Technology and Policy Studies. SSR can provide information on how knowledge trajectories are formed. For example, researchers could evaluate how knowledge has historically been codified into instruments, products and processes. Therefore the information could be used to create awareness amongst the scientific disciplines, particularly on their particular stage of development.

## 2.3 The discipline of Management of Technology (MOT)

*The key aspects of MOT*

The Management of Technology developed into a discipline due to two aspects in the development of technology or technological products or technological enterprises (Rip, 1995) i.e. Product Creation Process (PCP) and Societal Embedding Creation Process (SECP).

Product Creation Process (PCP)

Iscor is continuously involved in creating products that are largely dependent on alloying and process design. The new products are a product of a contingent process. Hence the customers would be demonstrated the *"demonstrable monstrosities"* (Rip, 1995) or initial products conceived from a contingent process. Then the products could be considered ready to be embedded into society.

Societal Embedding Creation Process (SECP)

SECP is a process that attempts to balance out the necessity of products from their acceptance in society. An organisation like Iscor has to identify all stakeholders looking at the variables such as legislative requirements, environmental concerns and likely social responses. The introduction of the product could be possible if done gradually through a *"social niche"* (Rip, 1995).

*The dominant thinking within MOT*

The discipline of MOT has received widespread attention by organisations especially in the 1980s. Drejer has cited a number of reasons that could be attributed to the emergence of MOT:

- Changes or perceived changes in a business;
- Political and social environments of firms;
- Growth of research and development (R & D) spending in absolute terms and as a percentage of the Gross National Product (GNP); and
- Concern of managers with core competencies as a source of competitive advantage.

MOT seems to be a departure from viewing technology as an object i.e. objectivist view technology to accommodate societal factors in organisations. It is recognition of the human elements of technology together with its continuous and natural development. Perhaps the following could be postulated:

**SCOT + Technology Objectivism = MOT**

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The above postulate is an observation motivated by how social influences (SCOT) and the perceived technical value of technology (Technology Objectivism) could as a result lead to MOT. It is a conclusion based on the inevitability of social factors in applying a new or old technology. Furthermore, the postulate could be developed into a theoretical model that can clarify the various theoretical components of MOT. Henceforth, further research questions can be followed up.

MOT was known in the 1970s under labels such as Strategic Management, Engineering Management, Innovation Management and R & D Management (Ulhoi, 1992). However, MOT schools currently in existence are the following: Research & Development Management, Innovation Management, Technology Planning and Strategic MOT as to be discussed in the coming sections. The latter are variations of MOT approaches. MOT postulates that the recognised transformation of technological products is "*socio-technical*" rather than "*technical*" (Rip, 1998).

The function of MOT is seen to be the integration of business concerns and technology (Bhalla, 1987). Furthermore, various meanings of "technology" are employed in the above mentioned MOT approaches:

- *Allusive definitions*: technology is viewed as a key factor of success;
- *Extensive definitions*: technology is extended to all areas of expertise existing in an organisation such that it becomes difficult to differentiate between what is technology and what is not; and
- *Specific definitions*: technology is placed between science and the commercial products or process derived from the application of scientific knowledge (Kemp, 1993).

The above-mentioned definitions of technology suggest that a profit motive or commercial concerns in management approaches are primary, as it is true with most industrial organisations. It is not surprising and a given that industrial organisations enforce or encourage standards on technological products as a management tool (Utterback and Abernathy, 1975). Hence technology could still be viewed as a tool or system or value from a management perspective.

*The challenges and debates within MOT*

MOT has become a subject for disintegration because a large number of disciplines are involved in MOT. These disciplines work on various MOT approaches to change its content and theoretical base by focusing on their particular cognition (Drejer, 1996). Therefore MOT has come to encompass disciplines such as engineering, industrial sociology, philosophy of technology, business management, human resources and innovation studies. The question is whether MOT could assume one dominant theoretical perspective.

MOT has increased in complexity over time. It is continuously posing challenges to organisational strategy and management. Consequently, MOT facilitates the analysis of technology at a meta-level rather than just being a tool because it has to be adaptable to the various interfacing disciplines that are likely to lead to its disintegration. MOT seems to be the function of the complex view of technology and organisational dynamics. Hence, MOT has been viewed by some scholars as part of management theory and organisational theory because of the notion of rationality attached to management and technology. The challenges to MOT are primarily to keep pace with human diversity and societal demands.

Research work on MOT could increase the levels of "normative contributions" (Utterback and Abernathy, 1975). This is the case because of the continuing disintegration of MOT due to the influence of various fields such that experiments will not be value-free and/or content-free. In the present era a mix of the innovation and R & D management seem to dominate current thinking on MOT (Utterback and Abernathy, 1975). Current thinking on MOT contends that choices made at one level are necessarily reflected at other levels. Hence, cognisance is taken of how the organisation is aligned to the industry in general. It becomes possible to monitor whether there is a "dominant design" emerging or interference with the dominant design. This implies that organisations have to identify how to attain stability (i.e. a management process) in terms of product manufacture in their complex operational environment as explained under 2.2.1 – 2.2.3.

## 2.4 Deliberations on conceptual framework of study

### *2.4.1 Actor Network Theory*

The Actor-Network Theory (ANT) was identified as a variant of approaches of the social construction of technology (SCOT) within the philosophy of technology. (Brey, 1999). This approach helps us in that the philosophy of technology is investigated within the social studies of science, particularly in the post-Kuhn era (Woolgar, 1988). ANT is here not only seen to be located within the approaches of the sociology of knowledge.

Reference was used to some concepts of the sociology of science. ANT forms part of the theoretical frameworks to interpret the heterogeneity and scale of activity of players and/or actors in a given context. Actors could be both human and non-human (Latour, 1987 and Stalder, 1997).

According to Law, ANT is in brief *radical semiosis*. (Law, 1999) It makes the process of making meaning to various organisational activities possible. Iscor clearly uses the science of metallurgy as its basic science and formative context for its core production processes. The structure of knowledge within Iscor is concentrated on expanding on this science or scientific technology, and technologies derived from it. Therefore incremental learning i.e. basic learning and second order learning i.e. learning via routines. Laws (1992) places different emphasis on different elements of the organisation in relation to the levels of personnel training in metallurgy.

Incremental learning within the context of ANT refers to new knowledge acquired without impacting on the existing production and metallurgical processes. This implies not interfering with the production of flat steel products at the Vanderbijlpark (VP) plant although there is a new technological approach being employed at the Saldanah Bay (SB) plant. Consequently, incremental learning does not temper with organisational routines. Hence, both the human and non-human actors remain in a position of relative order and/or stability in relations. Some scholars refer to this aspect as a situation of steady state (Drejer, 1996).

Second-order learning is the identification of best practice of both human and non-human actors for a possible socio-technical action (Latour, 1987, Laws, 1992 and Rip, 1998). The Saldanah Bay plant attempts to offer Iscor this opportunity. Organisational routines are challenged and tempered through the different use of materials i.e. by non-human actors and behaviour of employees i.e. the human actors.

The established organisational routines, which embody the "black-box" (Latour, 1987 and Stalder, 1997), could usher in a discontinuity (Rip, 1997) depending on the following: scale of developing relations amongst human actors, and between human and non-human actors, and the extent and scale of heterogeneity of actors (Lemke, 2000).

The extent of interactions between the human and non-human actors are largely mediated by technologies employed, particularly those linked with the production process. Thus an attempt to quantify the philosophy of technology to determine its ontological status (Ihde, 1983) is pursued through ANT.

Clearly, the outcomes cannot be attributed to only the rational approaches within Iscor as in purposive rational activities (Habermas, 1968) or mechanisms to adapt to a variety of complexities (Rorty, 1982). Hence, the literature seems to suggest that science as represented by metallurgy in this context is not accommodative to deal with all complexities within Iscor. (Rorty, 1982)

According to Horowitz, "the correctness of the sciences is but a small part of truth". In general this correctness does not unite all relevant stakeholders completely. Science as it is at practised at Iscor, analyses the stakeholders as unique, but as only isolated and independent intellectual beings. It only unites actors in the subject that it is understood in the particular i.e. science, but not in totality or real terms i.e. science practice within Iscor (Horowitz, 1961).

Based on this, the critical question then is whether the metallurgical sciences are representative of what is happening at Iscor. The location and relevance of Iscor can be analysed from how empirical descriptions are arrived at to the identification of associated social prescriptions. Empirical descriptions relate to the basic scientific principles on which Iscor's knowledge or technology is based. The social prescriptions are all the factors that can go beyond rational approaches of knowledge production (Habermas, 1968). Hence, current scholarship suggests an encompassing approach of both rational and "irrational" approaches to provide Iscor with an organisational identity it requires.

The distinctive and contrasting production processes at Iscor's Vanderbijlpark (VP) and Saldanah Bay (SB) plants are an interesting development in the socio-technical analysis of Iscor. The SB plant uses a new state-of the-art production technique called the Corex-Midrex process whilst the VP plant uses the conventional method. Other actors playing a role at the SB plant are the Industrial Development Corporation (IDC), which has a shareholdership at SB and which could be surrendered in due course. The collaboration could be seen as a means to enhance innovation.

The investigation at Iscor helped to define a particular environmental context (paradigm lock) (UNESCO, 2001), which identified the necessary factors of transition from the identified theoretical approaches and discipline to the actual Iscor practice. ANT, SCOT and SSR are useful approaches under the circumstances to analyse the reality about Iscor using the existing relations between human and non-human actors. The internal working of science, particularly the production of knowledge to yield new production processes, needs to be questioned further.

According to Ant actors are considered to have relative indeterminacy (Callon, 1998) whereby there is no stability. The strengths of ANT are associated with the role attributed to the relational context between humans and non-humans. The non-humans are traditionally ignored in approaches of social network theories, and humans too in the definition of networks in a technical sense as in the information and communication technologies (Latour, 1992). The non-humans are the machinery and the associated production techniques and processes. The production processes are the metallurgical processes as defined by the basic science of metallurgy.

ANT is thus a positive break from the conventional approaches of social science as it opens the social sciences to non-humans like machines, theories and disciplines (Callon, 1998). It facilitates movement beyond multi-culturalism to define and accommodate the notion of multi-naturalism. Any existing environment defines the nature of relations between various actors and their intermediaries (Latour, 2001). It is documented and worth noting that human actors, at one time or another in their careers, are directly or indirectly affected by changes in their jobs or work environments (Champion, 1975).

Therefore, plans for adjusting changes that affect the number and levels of existing jobs are many. A preliminary listing of some of the more popular plans would include the following: attrition, early notification of change, training for new assignment and positions, worker seniority rules, employee consideration, transferrals and relocating at company expense, shift work, shorter workdays, and the use of temporary employees (Champion, 1975).

Thus ANT neither refers to social networks nor technical networks but captures the notion of an actor as an “immutable mobile” (Latour, 1987). Most approaches adopt multi-level analysis in describing an actor. Lemke clarifies this point by asserting that the notion of actor is non-localised and is at various characteristic scales of space and time. Hence, an approach of heterogeneous actor is adopted as compared to homogeneous actor. The existence of a notion of heterogeneity is a necessary and sufficient condition for a system to organise itself (Lemke, 1997).

Consequently, the integration of new technologies into the normal Iscor activities to achieve the "black box" could be approached as follows:

- The use of diffusion models of widely adopted technologies like the Corex-Midrex method; and
- The evolutionary economic development models that measure cost efficiencies, information flow, market barriers and critical mass (Bijker, 1995)

However, existing scholarship is still based on simple models. Hence, currently there are inquiries going on about complex models by scholars like Bijker. Lemke alludes to the emphasis for a more complex analysis and empirical studies. His approach is to develop a "repertory of means for representing how processes on different characteristics temporal as well as spatial scales are intimately relevant to one another" (Lemke, 1997).

The current study has attempted to illustrate that ANT, SCOT and SSR as meta-theories are a break from the more orthodox currents of social theory. ANT and SCOT have particularly been accused of being relativist theories (Sokal and Bricmont, 2001) because the notion of an actor is associated with an agent that either enrols into action or is enrolled when it has no initiative. Sokal et al are comfortable with the flexibility of ANT with respect to its methodological approach but not the cognition of the scientific disciplines under investigation.

### *2.4.2 Paradigm Analysis*

The relevance of a paradigm analysis is necessitated by how the structure of knowledge is developed in relation to advances of modern society. It is important to note that 86% of steel trade accords amongst the Organisation of Economic Co-operation and Development (OECD) countries. Furthermore, 81% of steel production lies with the OECD countries. Hence South Africa and Iscor are negligible players in the world steel market (OECD, 2000).

There are always conditions encouraging a paradigm to emerge. In the current era the capacity to break from accumulated knowledge (Kuhn, 1962) is necessitated by the texture of the emerging knowledge societies and the politics of globalisation (Stehr, 2000). In most organisations, an attempt to move to new technologies is facilitated by the organisational strategy of mergers and acquisitions, and joint ventures (Kang and Johansson, 2001).

The difference of the industrial structure of the steel industry from the petroleum and automobile industries is a point to highlight compared to the regulations governing these industries globally. Joint ventures pre-suppose that there will be co-marketing, co-manufacturing and co-production techniques. Co-production techniques include research and development, evaluation, and logistical support.

The Midrex-Corex production process currently in use at the SB plant confirms the existence of technological discontinuities. The discontinuities determine the prevailing socio-technical transformations within Iscor with its associated technological regime (Rip, 1998 and Bijker, 1995). These transformations define the landscape within which transformations occur. An example is the difference in the continuity of processes of casting and rolling at the SB and VP plants.

Paradigm analysis proceeds from an understanding of the theoretical frameworks in which scientific activity occurs. Defining a paradigm pre-supposes that theories exhibit a structure from which it is based (Kuhn, 1962 and Chalmers, 1999). A structure like the Steel and Engineering Industries Federation of South Africa (SEIFSA) has to be accommodated when defining the theoretical framework and maintenance of standards. This would assist in identifying and controlling deviations like radical innovations from the normal practice of metallurgy.

Within an industry, concepts do not always acquire their meaning by way of definitions. Historians of science reject definitions as a fundamental way of establishing meanings because concepts can only be defined in terms of other concepts, the meanings of which are given (Chalmers, 1999). For example, the concept of a recrystallisation temperature in physical metallurgy is a useful example in this instance. The processes of cold- or hot-rolling have particular explanations specific to the structure of knowledge within the metals industry, and the metallurgical sciences in particular.

Recrystallisation temperature would refer to the thresh-hold temperature at which steel will reform into crystals during heat treatment (Avner, 1974). Very rarely do experts in the metallurgical field regard cold- and hot-rolling as some form of heat treatment procedure. Another essential feature of perceiving theories as knowledge structures is in the revolutionary character of scientific progress.

According to Kuhn, scientific progress can be schematically summarised as follows:
*Pre-science-----normal science-----crisis-----revolution-----new normal science-----new crisis--------normal science*

A paradigm is thus made up of the general theoretical assumptions, laws and their techniques for their application that members of the community of metallurgists adopt. Knowledge workers within a paradigm practise normal science. A paradigm signifies a structured activity adhered to by a scientific community. A state of crisis in a scientific activity ushers in a revolution such as is possible within the metallurgical science as practised at the SB plant. Kuhn and Chalmer's scholarly works need to verify whether we can be lead to adopting a more concrete picture like the following:
*Research & Development product(s) (pre-science)---VP plant (Normal science)---Rising production costs (crisis)---SB plant (new normal science)---(new crisis**?**)---(new normal science**?**)* (Chalmers, 1999)

The new crisis and the new normal science phases seem to be subjects of a prospective study. Hence, a discontinuous change could constitute a scientific revolution that facilitates an emergence of a new paradigm. This sets standards for legitimate work within science or scientific technology. A paradigm supports normal science and distinguishes it from non-science and other irrational activity (Kuhn, 1962).

The realisation of a paradigm implies the identification with a coherent cognitive approach (Weingart, 1996). There are standard practices and facilities associated within the practice of science and industrial activity at Iscor and other metallurgical industries. The activities in industry include spectrometric analysis of chemical samples, physical testing facility, metallographic analysis units, gauge measuring methods at plant level after rolling processes, remelt processes and chemical laboratories.

Fundamental laws and theoretical assumptions are entrenched in a paradigm as described by its scientific activities and units mentioned above (Rosnow, 1981). The portrayal of activities within a paradigm is of a theoretical and experimental nature because the nature of a paradigm is sufficiently imprecise and open-ended. The basic scientific metallurgical approaches determine the lack of disagreements over fundamentals. However, it is not always possible to perform esoteric or purely scientific work necessary to understand nature in depth given the practice of science at Iscor. Aspects that show deviations from fundamentals are seen as anomalies rather than falsifications (Chalmers, 1999). It is always possible that some works within a paradigm violate the specific characterisation of the paradigm. Although there is no complete and explicit characterisation because individual scientists acquire knowledge of a paradigm through scientific education of that paradigm. The same can be said of the knowledge structure within an organisation like Iscor, which also produce industrial practitioners.

Iscor's knowledge structure is enmeshed in a paradigm through scientific metallurgical management education acquired by its scientists and senior managers. The scientists refer to those who are in the production of pre-science materials, which is in essence the core business of Iscor, i.e. the production of iron and steel, and the manufacturing of flat metal structures. Observations and experiments are dependent on theory because a paradigm guides the search and gives interpretation of observable phenomena. Variables defining a paradigm are almost fixed in comparison to existing theories within a paradigm (Gibbons et al, 1994).

Therefore the introduction of an unsolved anomaly can be a source of crisis that can lead to a scientific revolution (Kuhn, 1962). The standardised knowledge within a paradigm becomes tacit knowledge in normal scientific activity (Polanyi, 1973 cited in Chalmers, 1999). If there is then persistence of anomalies including the qualitative challenges they pose, it could lead to a paradigm crisis. Anomalies could arise from the research methodologies in metallurgy, new approaches in environmental sciences and perceptions about innovation studies.

The fixed variable-dependence of a paradigm is worth noting. Consequently, it would suggest that this variable dependence emphasises that paradigms are social constructs independent of any detail of content within the established scientific knowledge. Hence, the old methods at the VP plant are used instead of adopting the SB production techniques although the costs of production at the SB plant are much lower than at the VP plant. Perhaps a conclusion can be made that it is philosophy rather than science that comes closest to being adequately characterised in terms of constant criticisms of fundamentals (Chalmers, 1999).

There is no rational compulsion for a scientific community to drop one paradigm in favour of a new one. It cannot be demonstrated that there is a purely logical argument in changing paradigms. Scientists are often faced with a task of making judgements given a number of factors at play when they decide on a new product. Hence, they are forced to prioritise although they are value-laden individuals. Some factors considered include things such as simplicity, changing social needs and the ability of new products and/or processes to solve new problems.

ANT has illustrated that the concept of a "black box" is associated with attaining indifference in the manner in which science is practised (Stalder, 1997) such that every scientific activity is regarded as a given or normal. The study illustrated that there is convergence or overlap between the concept of a "black box" and the existence of a scientific or technological paradigm. Future studies could clarify how this convergence relates to transitions in knowledge production and methods of experimentation.

### *2.4.3 Management of Technology (MOT)*

#### *2.4.3.1 Overview*

The central question in the management of technology is whether there are general patterns for all of technology in terms of its organisational capturing (Rip, 1995). Technical change happens largely outside the organisation and is influenced by the threats and opportunities in its environment. Hence, management deals with directing and influencing technical change for the better. This understanding is mostly retrospective and cannot always be extrapolated into the future.

The business, political and social environment of firms is always changing, particularly in relation to the concern with core competencies as a source of competitive advantage. This informs perceptions on MOT that are based on different assumptions regarding, among others, the idea of rationality (Drejer, 1996). This leads to MOT to be divided into four schools: the research and development (R & D) management school, innovation management school, technology planning school, and strategic management of technology (Drejer, 1996).

R & D management is defined as the co-ordination of different actors in order to optimise the organisational technological performance against that of its competitors. It is a "black box" in organisations and is often not considered a top management responsibility. Corporate leadership places money and resources and reaps benefits from increased technological performance (Bhalla, 1987). It has been suggested that R & D have to be managed according to the combination of the following elements: people, ideas, funds and culture (Jain and Triandis, 1990).

Innovation management concentrates on the changes that occur or could occur in the prevailing technological paradigm. It places focus on the discontinuities of technological development i.e. on radical innovations. During a discontinuity stage, entry barriers into industrial participation are very low. Hence, the flooding of the market by new entries is a management issue (Dosi, 1988 cited by Drejer, 1996). The result is to focus on the entire innovation process from invention to commercialisation. This is particularly true when the technology life cycle is short. Briefly, invention and innovation are related in the following way:

*Innovation = Conception + Invention + Exploitation* (Drucker, 1985)

The technology planning school emphasises that the predictability and simplicity of technological change can no longer be taken for granted. This school takes the approach of developing analytical tools like technology portfolio analysis (Bhalla, 1987) and other management tools. Hence, it is a reaction to an environment that is no longer perceived to be simple and stable. Technology planning is facilitated by increased competition as product life cycles decrease, sustained progress as time is shortened between discovery and application, and a crisis situation caused by introduction of entirely new technological systems.

The strategic management school is based on the shortcomings of the above-mentioned MOT approaches. Some of the shortcomings of the traditional approaches are the relatively low rate of technology absorption, high rate of implementation failure and poor handling of the consequences of new technology. These shortcomings reveal that technology and MOT have yet to reach the top management agenda. Consequently, the strategic implications of technological changes are not appreciated in strategic management, which are much too often focused on business issues. Furthermore, the understanding between business and technology is still lacking, as implementation of new technologies cannot be separated from organisational changes (Bhalla, 1987 and Drejer, 1996).

The current theory of MOT is under threat in the context of challenges facing MOT. The following are the main challenges: assumed uncertainty and simplicity, perceptions of the external environment in which the organisation is to survive and manage technology, defining and locating MOT within the broader management theory and the questionable rationality of MOT managers and processes.

Furthermore, these challenges can be summarised as follows: a new view of strategy, a new view of management and new organisational views (Drejer, 1996). The challenges are a realisation that organisations have to be in a continuous adaptation mode in respect of their external environment. Several disciplines drive the formulation of the current theory on MOT. These disciplines are also functions within organisations that define the rationale of MOT. MOT is based on the theoretical principle of co-evolution studies. Co-evolution studies suggest processes of how technology and society evolve alongside each other. A range of variables rather than a single element as compared to some innovation approaches (Rip and Kemp, 1998) necessitates MOT.

Modern MOT takes a highly rational outlook and emphasises technology planning as the most important technique in managing technology. Most researchers seem to agree that modern industrial organisations are transforming to have a new outlook characterised by networking, teams and process view, among others. This approach would force organisations to recognise technology management as a critical component of corporate strategy.

However, the diversity of MOT can facilitate readiness for action within organisations such as Iscor as diversity can be used as a proactive tool. In modern times, the formulation of new organisations goes along with new management approaches. The challenge is how to incorporate MOT and technology into the new management approaches associated with the formulation of new organisations. The unbundling of Iscor to focus on essential business units can be seen as a new organisational formulation.

Iscor refers to itself as a resource organisation rather than a steel and iron engineering organisation. It has other non-core interests like its 50% shareholdership in Macsteel, which is its marketing company. An obvious approach of incorporating Iscor's general organisational management into MOT is to regard technology as a social construction (Knorr-Cetina, 1984, Stalder, 1997 and Brey, 1999), particularly as explained by SCOT and ANT above.

MOT largely deals with the dynamics of technological changes and subsequent outcomes. Being multidisciplinary in approach, MOT does not make allowance for the invention of a classical organisation that is steeply structured as compared to a flat organisation. The steepness and/or flatness of organisations refer to hierarchical tolerances within the organisation in co-existence with its external environment.

Perhaps MOT's contribution in organisational development is influenced by an existing paradigm, especially as represented by the core competencies of an organisation. The drive to assume a new innovating organisation is like a "deductive falsification" (Popper, 1966) process where preferred processes are chosen because of the failure of the other processes. Furthermore, it is clear that organisational activities such as experimentation are not value-free and/or context-free.

MOT can influence the organisational culture. This could create some problems on how findings are arrived within Iscor, particularly the research and development practioners. MOT can also be facilitated and enhanced by proper classification of technologies existing within an organisation e.g. materials technology and information technology at Iscor. Usually, the dominant classification has been that of differentiating between simple and unassembled tools on the one hand, and complex assembled machines (Marx, 1887 and Rip & Kemp, 1998).

*2.4.3.2 The Innovation Approach*

Organisations introduce new technologies or technological products to be better players in the market. This process of invention up to the introduction into the market i.e. innovation requires careful management of product and all related processes involved. This is particularly true for radical innovations. Knowledge and technical capabilities have had a tremendous acceleration over time.

Modern science has been a growth industry since taking off in the seventeenth century (Ziman, 1994). This growth has occurred within a context of social development. It led to the innovation approach as an aspect of technology management to be described within a context of the product creation process (PCP) and societal embedding creation process (SECP) (Rip et al, 1997).

The practice of research has created a complex situation in the innovation approach to a company like Iscor. Nowadays it is acceptable to refer to innovation management as a variant of the discipline of MOT (Drejer, 1996). According to the MOT scholarship, it can be said that MOT defines the cognitive parameters of innovation management. Hence within endogenous theories, the innovation approach seems to depend on the dynamics of technological development and its outcomes. Within Iscor, the innovation approach was not readily identifiable due to a lack of distinct and identifiable inputs from management and workers into the business processes.

The development of the steel industry can be traced back to the second kondratiev cycle in technological development i.e. e. approximately between 1750 and 1850 for it to be a dominant industrial material (Rip and Kemp, 1998). Technologies employed were universal and any new innovation was bound to receive attention from all world steel producers. The history of the industry orientates Iscor to also underplay the importance of innovation because of the global interchangeable support and sharing of ideas.

The innovation approach is primarily concerned with the business objectives of the organisation with the help of the regulatory environment. The wider society plays a peripheral role in matters of science-based technology. However, challenges are faced when products are introduced into society. For example, the unbundling process at Iscor involves the separation of the steel-making business and the mining operations. The move had to receive regulatory approval from the South African Revenue Service (SARS).

The co-existence of curiosity-driven research and use-directed invention usually emerge as two modes of scientific activity, and this scientific activity evolves into a technological innovation. It is not always possible to separate science from other highly technical activities that contribute to the overall process of R & D. Some of these technical activities associated with the steel industry are performance specification, design engineering, prototype testing, and pre-competitive and competitive trials. Hence innovation management implies managing a process from "occasional patronage to a commercial contract" (Ziman, 1994).

Part of the economic benefits of a new technology comes from process improvements introduced after the process has been commercially established (Christensen and Rosenbloom, 1993). Most firms have succeeded in exploiting a series of incremental technological innovations built upon their established organisational and technological capabilities. Studies of innovation explore factors influencing the rate and direction of technological change by distinguishing between the following: radical changes, which are innovations launching new directions in technology, and incremental changes that make innovations along established paths (Christensen and Rosenbloom, 1993).

Innovations can be classified according to the degree to which innovations reinforce or diminish the value of a firm in two respects i.e. by componentry and architecture. Hence, apart from the incremental and radical innovations described above, there is modular innovation that denotes the introduction of new component technology inserted within an unchanged product and/or process architecture; and architectural innovation, which alters the ways that components work together (Drejer, 1996).

Innovation management has to capture how a technological paradigm is constituted in terms of the architecture of a given set of core technologies. In steel-making some of these technologies are: foundry technology, metallography, spectometry, rolling, forging, extruding, and physical testing techniques like impact and fatigue tests.

The critical role of innovation management occurs in the early stages of the emergence of a new technological paradigm. This occurs because there are no existing dominant designs as there are diverse technical approaches and fluidity in designing products (Christensen and Rosenbloom, 1993). Normal modes of innovation are followed upon the establishment of a dominant design. Innovation studies propose that the focus of incumbent firms' innovative efforts will shift from product to process innovations, which seems to coincide with a move from the product creation process (PCP) to the societal embedding creation process (SECP), respectively (Rip, 1997). The shift is not a mechanical shift as in linear models of technological development, but it is non-linear and not necessarily related to the life cycle of the product.

Innovating organisations vary widely in terms of scale and degree of novelty. This implies that a product could offer new possibilities than is apparent. New production options can thus be identified and could lead to developing new strategic concepts. The same principle is applicable in the service sector although being tangible (Rip and Kemp, 1998). This principle of developing new strategic concepts about products has led the National Innovation Fund (NIF) sponsored by the Department of Science and Technology formerly the Department of Arts, Culture, Science and Technology (DACST) to recognise both tangible and intangible products for a positive social impact (S & T White Paper, 1996) e.g. customer satisfaction.

An established high volume product like steel has well understood product characteristics and standardised recognition. Production technologies are efficient, equipment intensive and specialised, and competition is on a basis of price. What constitutes a product innovation by a small unit is often the process equipment adopted by a large unit (Drejer, 1996). Hence, innovation management could have a gradual, cumulative effect on production. It recognises the competitive structure and dynamics of an industry (Utterback and Suarez, 1993). In this context, there is a need to recognise if there is an emergence of a dominant design such that standardisation is enforced. A dominant design assumes the form of a new product or set of features derived from individual technological innovations introduced independently in prior product variants.

Forecasting about a new product design is greatly facilitated by innovation processes that look at new product or process design, from historical and future perspectives. These are the exploratory and normative approaches to product or process design for an improved commercial gain (Abernathy and Utterback, 1978 cited in Drejer, 1996). Hence, trend analysis and scenario mapping are useful approaches for innovation management within the context of forecasting. Innovation is mostly managed as part of the core business process in organisations, particularly associated with renewal.

Innovation management can be approached as a generic activity associated with survival and growth of an organisation. This implies and pre-supposes the existence of a knowledge base within an organisation. Innovation helps organisations to usually come to a self-realisation of their scale, nature, and degree of novelty within them. These in turn will identify context variables within which the organisation operates i.e. whether it is a sector, small firm, a national system or life cycle (Ulrich & Wieland, 1980 and Rip & Kemp, 1998) of technology and industry.

The innovation management approach is in agreement with Marx's analysis of development of machination in society (Marx, 1887) and Habermas' approach of purposive rational action (Habermas, 1968). However, it needs to be noted that industialisation thrives under technological improvements, and may expand without them where it may grow under retrogressive forms of technology (Blumer, 1990) particularly as has been experienced in developing and underdeveloped nations.

## 2.5 Summary

### *2.5.1 Overview*

The literature offers a range of insights in approaching the research problem. Several observations were made in our literature review of ANT, SCOT, paradigm analysis, and management of technology (MOT). The observed variables, typologies and networks within the unit of analysis i.e. metallurgical science practice at Iscor, were compared with the theoretical framework i.e. ANT, SCOT and SSR, and the discipline of MOT. However, the literature review has identified certain limitations and emergent points.

The limitations identified are: the nature of the study being exploratory, there are no precedent studies of this nature in some respects, and the orientation of Iscor limits information mostly to technical matters. Therefore the scholarship provided the following: a need to match the existence of paradigms to the concept of a "black box", simplifying the design issues to facilitate industrial production, and how the societal demands influences and shapes metallurgical sciences and product development.

Our review of the literature has helped to pose particular methodological questions that have to be answered in analysing our case study. Some of the important questions are raised in section 3.2 to inform the research design. The questions further informed the thematic discussion of the findings. The following insights were gained through the review of the literature:

### *2.5.2 The manner in which stakeholders observe and interpret science*

ANT helps us to understand the extent of differences between various human actors and their relationships to the non-human actors. There is a focus on explaining how human actors are non-uniform and heterogeneous in character. These characteristics served as a basis to explain how a network is attained based on the property of translation.

Both human and non-human actors are exposed to various networks within and external to their organisation. The configuration of different machines/non-human actors confirms their network status as they align into complex processes with the human actors. Therefore the existence of a network would confirm a stable situation (black box), which either becomes an overall organisational routine or routines limited to sections of the organisation or both.

### *2.5.3 The manner of knowledge production*

The SCOT revealed that knowledge forms like science are understood differently at various levels within an organisation. Organisations involved in the practice of science do not necessarily recognise science as a social activity. This is because different interest groups are differentiated in terms of their status in an organisation, and the power to define what is science is restricted to the experts.

Organisations form networks on the basis of their formative/founding principles. A particular stratum e.g. top management would always have the power to define the content of the founding principles e.g. the practice of metallurgical science to produce steel, of an organisation. The level of skills of non-experts is found to influence the overall quality of a scientific product. Therefore the practice of science has social influences particularly when taking into account the outlook of an end product of science.

### *2.5.4 A change of paradigm*

Our analysis of paradigmatic changes made it clear that there could be two major factors facilitating a paradigm change. These are either the existence of an intellectual crisis or a significant technological change. Kuhn's study of major scientific revolutions led him to adopt the intellectual crisis as a key factor, whilst to de Solla Price's focus on manufacturing organisations made him conclude that technological changes are paramount.

No study has yet been conducted to determine whether the two factors could act jointly i.e. a paradigm change being caused by both the intellectual crisis and technological change. In case studies, the de Solla Price's approach is highly likely to influence a paradigm change because the unit of analysis is a closed system operating within a known major scientific paradigm e.g. atomic theory. Hence there would be no need for a challenge to the paradigm by intellectual means because there is a stable scientific paradigm.

### *2.5.5 Disciplinary influences to technology management*

The discipline of MOT is often viewed as a "disintegrating" discipline because of it being influenced by other disciplines. Disciplines such as philosophy, engineering, physics and economics have always influenced how MOT is represented. Hence it was sometimes referred to as R & D management or innovation management or engineering management or strategic technology development (Drejer, 1996).

A key research question is whether there can be a situation or case whereby all these definitions could be integrated into one single definition of MOT. As for our case study, it is highly likely that innovation management and engineering/production management would guide how MOT is conducted. The applicability of the useful tools of MOT i.e. technology risk analysis and technology assessment was not predictable given the non-generalisibility of a case study.

### *2.5.6 The overall approach to the notion of transformation*

Most of the notions captured in the literature review referred to various forms of transformations. Some of these are: technical to socio-technical/collaboration methods, mode1 to mode 2 knowledge production, localised/traditional to globalised/diversified product identities, standard to constructivist technology approaches, mono-naturalism to multi-culturism of human's orientation to acquire knowledge.

The notions of transformation in the review of literature suggest that the understanding of "relatively" natural phenomena (referred to as "objects" or "science" by Woolgar) require some sufficient and necessary conditions to be understood and accepted by society. Therefore this approach argues that these natural phenomena should have a social representation or form or model. It now raises another research question that could be outside the scope of this study i.e. what are necessary factors for science to have a socially acceptable representation.

### *2.5.7 Remarks*

The literature review attempted to clarify the research question better. It further facilitated the relation of the case study to the theoretical approaches and discipline chosen. Insights from the literature review helped in informing the methodological approach followed. Therefore it was easy to compare the observations at Iscor with generalisations of the literature review.

There is recognition that it was assumed that the technology being referred to in the case study is the science-derived technology. It was however not a subject of interrogation to clarify about the effects of the non-science-derived technology, or the contribution of non-science-derived-technology in raising particular research questions within the metallurgical sciences at Iscor.

# Chapter 3
# Methodology

## 3.1 Overview

This chapter explains how the case study was conducted and results arrived at. The key concepts defining the study are the theories discussed under the Literature Review i.e. ANT, SCOT, SSR and MOT together with the scientific practices at Iscor VP plant. Hence the chapter will cover the following topics:

- Description and choice of design;
- Data collection methodologies; and
- Shortcomings and sources of error.

The key notions and variables that were examined are the following:

- Representation of science at Iscor as analysed by ANT and SCOT;
- History of science at Iscor as analysed by the SSR;
- Globalisation aspects as assessed by ANT, SCOT, SSR and MOT;
- Expression of innovation as analysed by MOT,
- Resource management as measured by MOT; and
- Risk analysis as measured by MOT.

Three kinds of data and analysis have been followed:

- Attribute data (survey research): this involved gathering data through semi-interviews from Iscor VP plant management and subsequent variable analysis;
- Ideational data (ethnographic research): this involved observing interactions at the VP plant level between human and non-human actors, using methods of typological analysis and observations of a standard nature; and
- Relational data (documentary research): this is the primary approach used for gathering textual data of steel at Iscor and South Africa's steel industry using methods of network analysis, as supported by our theories (Scott, 2000).

The methodology followed is typical of case studies in that it is flexible. It focuses on real differences and does not reinvent different settings in consistent theoretical terms. ANT, SCOT, SSR and MOT provide a suitable theoretical framework for representing an assembly of people, skills, techniques, and resources. The theories are not conceived as singular positions but as a multiple sets of approaches. They are best suited to mapping the ideal operations of a steel plant and the actual practices metallurgy by management, employees, and production processes at Iscor.

Other background factors such as evolving policy questions and current theoretical debates in the field were used in strengthening the analysis. These assisted in making an informed assessment of our frame of reference and the location of this study in the technical and social contexts.

Deviations or divergences from reality can also be detected if the study is mirrored against the factors mentioned in the latter paragraph. The study has to detect levels of consistency with the dominant thinking in the industrial practice of the Iscor VP plant. Thus ANT, SCOT, SSR and MOT will better position the relevance of the study to the current trends in South Africa and the rest of the world.

Our unit of analysis i.e. the practice of metallurgical science at Iscor has been analysed against this non-homogeneous setting defined by the identified theories. There will thus be an attempt to look at various aspects within our unit of analysis so that issues of non-uniformity or non-homogeneity are fully explored in terms of policy approaches and debates within the field.

An attempt is also made to extrapolate findings with established industrial and technological practices within the steel industry, notably by the OECD countries. All possible verification procedures in this primarily ethnographic research are followed appropriately to ensure that the study achieves its objectives.

### 3.2 Research design

The management of Iscor considers the company to be a resource management organisation that has three strategic priorities: achievement of operational excellence, attainment of market optimisation and the consolidation of the industry. None of the priorities make direct reference to how the metallurgical sciences are conducted. The nature of the investigation can be regarded as studying an existing philosophical and model-building programme viz. the practice of metallurgy at Iscor. The case study is indeed an exploratory study as can be noticed from the literature review, which bases its analysis, by both school of thought, and theme or construct. As this is a qualitative study, the study has been based on an assumption that the social reality at Iscor has been historically constituted, and various stakeholders have participated in shaping the practice of metallurgical sciences at Iscor.

Sources of data used are qualitative and participatory methods i.e. participant observation and semi-structured interviews in a form of presentations attended and discussions. There were numerous field inspections of the Iscor VP plant as a representative field site, accompanied with semi-structured interviews with engineers at various sites of the plant.

Textual data have been compiled for the whole of Iscor from its publications and media releases, South African Bureau of Standards (SABS) research design articles and attendance of Design Institute seminar, and the scholarship review. Numerical data have been derived from existing data and other observed aspects at the VP plant level like the process chart and data sheets of sub-plant capacities. The following methods and sources of gathering data were used:

*Semi-structured interviews*

Semi-interviews were conducted with engineers at the quality testing laboratory, the basic oxygen furnace (BOF), the casting site and the rolling plant. I gained an impression of how Iscor's technical team viewed various components of the production process. Emphasis from the various sites differed on the following: technical relevance, economic sustenance, environmental concerns and safety, and metallurgical knowledge of non-technical staff.

*Observations*

During the four visits at Iscor on 02 August 2001, 06 September 2001, 04 October 2001 and 03 October 2002, a considerable amount of time was spent observing the process flow from the iron making plant to the steel making plant. The observations, particularly at the steel making plant were compared with the existing textual data from Iscor, the literature on metallurgical sciences and MOT, and the theories followed in this study. Also observed were levels of automation and innovation together with the competency of both the technical and non-technical staff.

*Documents*

The theories explained under the Literature Review were tested with textual evidence about Iscor and other steel industries like LNM and BHP Billiton. The following served as textual data beside the literature of metallurgical science covered in the Literature Review: Iscor Annual Reports (1999/2000, 2000/2001), Iscor 2001 slide presentation, Iscor 1953 Silver Jubilee Report (1928-1953), Iscor 2001 Video i.e. The Story of Steel video, SABS Design Institute Seminar Papers 2001 and News clippings as under Reference.

The following are key questions that would inform the findings of our study:

1. Relevant aspects of metallurgy at BOF, casting and rolling sites;
2. Levels of automation to complement the basic science of metallurgy;
3. The understanding of metallurgy by management and employees;
4. Community and employee participation/contribution to metallurgy;
5. Optimisation factors to the products of metallurgy;
6. Levels of innovation at Iscor;
7. Effects of the basic science on the environment;
8. The role of various historical epochs to metallurgy;
9. The frequency of conducting technology assessments; and
10. Effects of globalisation on science at Iscor.

### 3.3 Limitations and sources of error

Generally, shortcomings within our methodology stem from a lack of studies that are discipline-based. There is no cognitive coherence existing in the field. Case studies differ from studies on formal theory construction in that there is a limited risk of developing over-abstract formulations that are very far from reality such that no empirical validation is possible. Similarly, standardisation errors are associated with the assumptions specifying the model and the quality of the empirical data against which the model will be fitted. The objective of the study is clearly to minimise this possibility through the application of the identified theories. The study would not achieve much by following a single theoretical approach. Hence, an approach of meta-theoretical debates could be appropriate in strengthening the objectives of the study to avoid charges of irrelevance.

There is a risk of interpretative bias as the sources of both textual information and observations made cut across different historical epochs. Hence, problems may arise in informing and clarifying the context of the study. Both the methods of observations, semi-structured interviews and textual data have a low degree of variability in terms of control, except if the data analysis is secondary and statistical. Measurement errors could arise when there is bias from the observer and/or interviewer. The challenge is to counter the effects of lack of control groups and randomisation of subjects i.e. there is potential lack of rigorous control with the investigation. It thus follows that the results obtained cannot necessarily be generalised because the measurement methods adopted are non-standard.

### 3.4 Data Profiles

*Relational data*

The current investigation is premised on the existing scholarship in the field of sociology, philosophy, and history of science in understanding the practice of metallurgical science in steel making. Hence, the primary sources of the investigation were textual data, which fitted well with the ANT, SCOT, SSR and MOT. However, there is also an effort to explain the current technological processes at Iscor in terms of Kuhn's theory of paradigms.

The study also used documents Iscor as it is *but* a frame of reference to articulate the objectives of the study. Therefore, we relied on Iscor documents like the Jubilee Report, Annual Reports, Process Reports, and the literature of metallurgy and steel-making. Each theme or notion captured in the review of scholarship was checked for consistency against the particular documents of Iscor and steel-making.

A substantiation of the consistency check entailed an investigation into the history of steel in South Africa and how actors within the industrial process of steel-making relate to each other. This is done in terms of technologies used and the objectives of the practice, in particular the business practice of steel making. Consequently, the relational data captured through documents was the dominant investigative method used. However, this method was complimented by other methodological approaches.

*Ideational data*

Observations were made when visiting various production-sites at the Iscor Vanderbijlpark plant. Sites were visited three times between July and 04 October

2001. A deeper appreciation of the important steel making processes was done i.e. the basic oxygen furnace (BOF), casting and rolling processes. This also included the iron-making process, remelting process of scrap metal at the electric arc furnace, and the physical and chemical testing laboratories.

I sought to gain an impression about the following: the working conditions at various production-sites, levels of automation, technologies used, production from the first scientific principles and the interaction of human and non-human actors. Hence, various variables were identified, and a typological analysis done to provide the best illustration of both the technological and business processes.

This ethnographic research focuses on the unit of analysis as discussed above in capturing relational data. I made an attempt to understand whether the production practices at Iscor VP plant are a comparable feature of similar industries. The primary data such as the textual data made it possible, which in part covered the general aspects of the study. Hence, the typological analysis given in some sections is facilitated by the thematic nature of the investigation.

The method of analysis is independent of the method of capturing data or data collection methods. This implies the collection methods of the relational and ideational data could in some instances overlap although having different methodological bases. The latter factor cannot be ignored because it helps with a detailed analysis between the human and non-human actors, or between labourers/engineers/managers and machines. Ideational data complement well with the relational data.

*Attribute data*

The attribute data were collected through discussions at the production-sites with engineers at the BOF, casting and rolling sites. Several questions dealing with the technical aspects of the production process were asked. Interestingly, most responses could not ignore the social factors of production. These include the experience that employees had in relation to productivity levels, access of labourers to decision-making processes and the delegation of authority. This method was less objective than the collection of ideational data. It is so because the interpretative flexibility of the study based on this data was influenced by the inputs of engineers. Consequently, this can be regarded as the most interactive of the data collection methods. The findings from the other data types were also compared against the attribute data.

The manner of using the attribute data can also be regarded as a personification of non-human actors. This personification could simply be interpreted as pre-empting the social variables at play during and after the process of production. Since the attribute data are explained through a variable analysis, some findings also overlap with those derived from the analysis of ideational data i.e. observations. Attribute data tend to form a basis of juxtaposing technical and social variables. Furthermore, it helps answer the question: How technical is technical? In addition: How social is social? Moreover, How technical is social? Furthermore, How social is technical? Engineers at the important steel-making production sites have particular impressions about the particular processes that they have to technically account for. However, their impressions about the entire steel-making process differed with respect to the human and business factors.

# Chapter 4
# Findings

## 4.1 Results

### *4.1.1 Background*

We used the ten key questions informing the acquisition of our data identified in section 3.3 as a basis for a thematic discussion of results. These would also serve as an analysis of the data obtained under this chapter.

The presentation of results followed closely on the themes captured in the literature review. The thematic approach is also as per methods of data collection used and the subsequent analyses. This approach was chosen because the analyses of the research are influenced by all the identified themes from the literature review.

The documentary evidence, observations and discussions held supported the findings presented. Most of the evidence leading to the conclusions was obtained from the attribute and ideational data, and consequently from the variable and typological analyses respectively. The themes covered by our analysis are the following:

(1) Representation of Science;
(2) History of metallurgical science at Iscor;
(3) Expression of Innovation;
(4) Globalisation Aspects;
(5) Resource Management; and
(6) Risk Analysis.

The themes listed above emerged from an analysis of the data as represented by the ten key questions stated in section 3.3. By clustering our data in this manner, it became easier to assess whether the theories that were discussed in our literature review explain the observations made in the case study adequately or not.

The events of 11 September 2001 in the USA revealed to metallurgists the limited social endurance of primary structural steel. Although it melted at 600 C as expected, it primarily led to the collapse of the twin towers. Does this call for a rethink in the design of future materials as a function of social adaptability such as the resistance to social actions like terror acts? Does this prove that the technical characteristic features of a product and processes are but a limiting factor in arriving at its comprehensive understanding?

In 1889 the Eiffel tower was built and stood at 3200m and 7000 t of steel was used. Nowadays, it is known that 2000 t of steel can do the job of building the Eiffel tower. It shows that there has clearly been progress in the science of steel making and the related technologies associated with it particularly materials design and alloying (Bolbrinker, 1992).

Both materials design and alloying are a function of the development of specific products and/or processes for human consumption and industrial production. The final design is only attained through social acceptance in terms of the diversity and orientation of both human and non-human actors. Iscor caters for this diversity and orientation through its Technology Management section which is part of the Materials Science Division.

It is known that 70% of produced steels worldwide are upgraded in downstream processes of secondary metallurgy or post-treatment processes. Iscor flat steel products at the VP plant have the rolling process as the secondary metallurgical process. This plant applies alloying primarily as a requirement that is specific to its various customers. The VP plant tends to focus on standardised and similar flat steel coils, sheets and plates produced for known and existing clients. Hence, downstream beneficiation is not a major consideration because clients customise their own product outlooks. Therefore Iscor VP and SB plants consider their processes and products as geared towards a primarily functional value, rather than an aesthetic value and orientation.

Four visits at the VP plant sufficed to reveal certain observations about iron-making and steel making. Importantly, processes of interest within steel-making included the basic oxygen furnace (BOF) process encompassing the desulphurisation procedure, the casting site and the rolling plant. The business distinctiveness of these processes could have contributed to the motivation for the unbundling of Iscor into the mining and steel-making businesses.

Interestingly as compared to the VP plant, the SB plant has fused the casting and rolling processes into a single process referred to as the Corex-Midrex process.

The modernisation at the SB plant did not guarantee the capture of a sizeable market share. There are also important considerations in the "agonistic field"/market such as the social and environmental factors, and better quality of steel (Latour & Woolgar, 1986). It is worth noting that the SB plant was initially a joint venture between Iscor and the IDC.

The categorisation of what is primary and secondary metallurgy becomes blurred as the Corex-Midrex process at the SB plant fuses the two procedures that are traditionally separate into a continuous process. Hence, the intent of producing standardised flat steel products of a functional nature cannot only be explained in purely scientific terms. Business considerations are also critical in shaping the eventual configurations of processes leading to process and product developments.

The explanations given by engineers, observations made, and textual and statistical data consulted point to steel making being a stable activity. Stability is interpreted in terms of the nature of products produced and not in terms of the configuration of processes. This agrees with Drejer in that when product stability is attained, most innovations are incremental and process-related (Drejer, 1996). Basic scientific principles of chemistry and metallurgy are thus objectified by the attained stability.

However, there seems to be a methodological problem in arriving at an accurate representation that relates to metallurgical processes. Representation is undoubtedly an "ideological" phenomenon that has to be resolved within the "agonistic field" i.e. the environment external to the principles metallurgical science. It is an effort to conform to a paradigm and for Iscor to become a more prosperous organisation. The uniform relations from both the human and non-human actors are dependent on the configuration of processes. It would thus not be surprising if in future iron-making and steel-making become two distinct business entities.

Furthermore, it is arguable whether in future the various processes of steel making can also be identified as separate distinct processes in a business sense. If it would be possible other factors need to be taken into consideration: transportation costs and logistics, availability of scrap metal, environmental considerations, and the continuous evolution of existing traditional processes of secondary metallurgy like rolling.

## 4.2 Thematic discussion of results

### *4.2.1 Representation of Science*

We base our discussion on the premise that the nature of science practised at Iscor has changed over time (see section 4.2.2). This variation can be explained from a technical and a business sense, either individually or as a combination. The ANT and SCOT offered a guide to understanding the practice of metallurgy at Iscor. Practices at Iscor seemed to have been responsive to various historical changes and have influenced the organisational structure and its hierarchical set-up. This is more than a methodological observation, but also a readily identifiable reality at Iscor. The following is an observation of a science typology at Iscor:

**Figure 1: Typology of observed representation of science at Iscor**

| **Layer vs Variation** | **Technical considerations** | **Business considerations** |
|---|---|---|
| *Top Management* | Secondary | Primary |
| *Engineers* | Primary | Secondary |
| *Labourers* | None | Primary |
| R & D Practitioners | Primary | None |

*4.2.1.1 Approach about non-human actors*

This approach takes science to differ from other activities because of its complex character. Science is conceived as an object and a coherent method. The recognition of non-human actors like plant machines informs the definitions within metallurgical science with respect to steel-making. The literature review explored the notion of actors under ANT in understanding the role of non-human actors.

Variations in knowledge are associated with differences in class background, religious affiliation, social context, social groups, culture and race. The apparent stability in the body of knowledge of metallurgy is the result of processes of defining and negotiating its paradigm, and not the condition in the nature of the science. Science is thought of as being closed to other forms of knowledge. Hence, in our case as shown in Figure 1, our interest groups were categorised in terms of their status within Iscor and attributes towards the practice of metallurgical science.

The existence of scientific ideas pre-supposes the existence of a scientific group or class. Scientific ideas exist because their origins can be traced within society. Hence, at Iscor status and group membership seem to stand out as the most identifiable categorisation of interest groups as per observation. Most engineers and metallurgical technicians are found at plant level, focused on particular procedures to improve the production process. Their primary focus is not necessarily on how the products finally find reception in the external environment.

The social reality of science is a given since different interest groups within Iscor participate at various levels in the practice of metallurgy. There is an isomorphism or parallelism between the science of metallurgy and Iscor's interest groups. The levels of understanding of metallurgy by the interest groups are also a reflection of their participation in the business matters of the organisation. There is no proof of the severing of ties between social organisation and intellectual activity at Iscor (Latour, 1993).

The practice of science at Iscor does not provide any proof of divergence because the organisation already defines how each interest group will participate in the steel-making process. Therefore, the network notion of cross-influences and non-uniformity of actors towards non-actors is strengthened by observations at Iscor. There could be agreement of science being knowledge of a special status if its understanding is aligned to different levels of specific practices by interest groups.

Nowadays greater specialisation and differentiation demands increased social organisation and control. Scientists cannot work in isolation without recognising that they belong to a complex socio-technical network. Scientists' relationships with one another at Iscor are defined by what counts as scientific in steel-making. There is an increase of social isolation of scientists from academia, as they have to respond to the demands of producing good quality of steel cost-effectively whilst being considerate of social acceptance of technological products (as per documents, observations, discussions held and presentations made during visits).

The nature of science has been affected by a change from amateur science of the seventeenth century to how it is currently practised. There is an increased awareness of science being a social practice. Here "social" tends to emphasise those circumstances and effects that lie external to the intellectual activity of the scientist. This factor is relevant at Iscor because engineers are also trained as production managers. The non-technical elements are continuously introduced to inform the quality and levels of production.

Activities like making observations, improving and marshalling evidence have been social. This perspective is neglected to a large extent in favour of the institutional or structural sense in which scientific action is social. Thus, the central concern is how science organises and regulates itself. It is recognised that there was a lot of concentration on relationships between scientists. This was at the expense of ways in which different kinds of knowledge is produced and accredited for assimilation in production processes.

The network and constructivist approach to science treats both scientists and non-scientists equally/symmetrically in as far as the content of science is concerned. Engineers and R & D practitioners as representative of a scientific group at Iscor, indicate insignificance in their relationship. It is so because Iscor's science of steel-making defines that for them as routines and procedures.

There are identifiable constraints in the conception of science with respect to non-human actors:

(1) Persistence that science is special and distinct from other forms of knowledge;

(2) Persistence of what could be referred to as the standard view of science;

(3) Persistence of a notion of knowledge being an individualistic and isolated intellectual activity; and

(4) Persistence to unwillingly be steadfast on efforts of a critical attack on science.

Therefore it can be concluded that non-human actors like plant equipments and processes are dependent on human intervention for defining the steel-making processes.

*4.2.1.2 Approach to human actors*

The approach to human actors emanates from variations in definitions of science that take the position that society determines the practice of science. It is a challenge to the approach of non-human actors. Emphasis on the human factor stems from the fact that there is constant re-negotiation and re-classification in specifying how science has to be practised.

According to this approach, there is no such a thing as "the scientific method". Definitions of science stem from disciplinary practices of scientific participants. Figure 1 illustrates that R & D practitioners are scientists with a focus to resolve a particular scientific problem in production and to conduct a study of how certain scientific activities can be improved.

Top management is not only concerned with how tacit knowledge can be enhanced for better scientific practice within Iscor. They are primarily concerned with the organisational profitability and its market positioning. On the other hand, engineers are only concerned with the business success of the organisation as far as the efficiency and cost-effectiveness of production is concerned.

The labourers don't have the capacity to comprehend the scientific foundations nor the founding principles of Iscor. It is fair to regard them as having some understanding about the business success particularly as it regards productivity. Most of the Iscor workers are organised under the National Union of Metalworkers of South Africa (NUMSA) that holds regular education workshops around issues of industrial production and worker rights within the metal industry in South Africa.

Once more, the distinction between human and non-human actors was not restricted to methodological observations. The emphasis on the human actors tended to adopt a relativist approach to the phenomena it studies. The phenomena include how the interest groups influence their participation in the production process. There is ambivalence with research in as far as the actor emphasis is concerned because it is closer to mode 2 of knowledge production. Mode 2 of knowledge production implies a context-based and multi-disciplinary approach to knowledge production. This approach risks a lack of cognitive coherence as in multi-disciplinary approaches. The actor emphasis cannot be discipline based because of the various social and technical networks available to the actors.

The Iscor VP plant has an in-house environmental management team which monitors and implements procedures for environmental compliance. Their efforts seem non-existent and ineffective because of the observed dust and other emissions. Hence from the 2002 Annual Report, Iscor is still striving for ISO 14001 certification. This further confirmed that a pure business approach was primary with top management, sometimes neglecting their corporate social responsibility with the nearby communities. The class legal case accusing Iscor of underground water contamination proves the point.

Other stakeholders usually blame scientific activity that it is not concerned with intellectual work outside its domain. The challenge of management is to aggressively confront this demarcation in its decision-making processes. It can be pointed out that metal making as an industrial activity has internalised its business and scientific activity such that any externally induced changes have to be gradual. Representation of science at Iscor can be described as an activity that is focused on managing steel as a resource.

Therefore Iscor provides proof of Woolgar's fundamental dualism and supposed distinction between "representation" i.e. resource management and "object" i.e. metallurgical science. Iscor's foundation is based on the practice of the metallurgical sciences whilst it regards itself as a resource management organisation. The challenge is still to provide a clear distinction between the relationship between the practice of metallurgical sciences, and statements made about the results of the investigation or management of the resources.

There is an issue of methodological inadequacy that management have to recognise. The marketing of steel could be under-communicated due to a lack of recognition of salient elements associated with steel-making (Iscor Annual Report, 2000). For example data sheets used by Iscor are only a description of technical attributes of a specific range of "standard products".

### *4.2.2 History of metallurgical science at Iscor*

Knowledge in the steel-making industry is of an accumulated or cumulative nature (Kuhn, 1962). It is true if the history of steel-making in South Africa and Iscor in particular is investigated. There are clear analytical discrepancies and historical inadequacies that need further clarity for a more acceptable historical context.

*4.2.2.1 History of steel-making in South Africa*

Sir Theophilus Shepstone observed in the late eighteenth century that South African native iron was chemically pure. Some samples, particularly from the Zulu people, were taken to Britain for observation. Indigeneous people used clay for furnace material and charcoal from trees as a charge material. The resultant outcomes of the British observations are still unclear especially lessons learnt on the indigenous furnace development (Iscor Jubilee Report, 1953).

According to the British colonialists, industrialisation was tantamount and equivalent to the expansion of the colonial power. Industrialisation is not necessarily a function of technological development and/or contemporary modelling of political systems. The British colonial power first recognised the importance of an iron industry in South Africa by building a steel works in Natal.

Hence, the resources in Natal were examined in 1853. It is not surprising that in 1882 the first prospectus for a company to mine ore and smelt iron appeared in Natal, viz. that of the South African Coal and Iron Company. No company was formed from this effort. However, the first production of pig iron by "European methods" occurred in 1901 or 1902 by Mr Samuel Light Green.

A number of entrepreneurs came into the picture like Sammy Marks and Cornelis Frederick Delfos. Most approaches came from the German model - particularly the Gutehoffnungshűtte Report in 1924. Hence, on the 5$^{th}$ of June 1928 the South African Iron and Steel Corporation Limited was founded. There is no indication of a technological paradigm shift from the indigeneous production by charcoal including the non-allowance of iron to be molten.

There are currently four business activities at the VP plant: iron-making, steel-making, production of uncoated products, and production of coated products.

*4.2.2.2 Modern Steel-making*

*Iron-making*: it requires coal, iron ore (magnetite or haematite), dolomite and lime (for slag forming) and sinter products (fine elements to concentrate iron). All these components are fed into the blast furnace (blast because it uses blast gases) to heat and melt the iron ore. Coke provides the energy needed to raise the temperature to the melting point of iron (Annexure 1).

*Steel-making:* the molten iron is transported to the steel making plant where sulphur (S) is removed. The concentration of other chemical elements like manganese (Mn) is reduced. The iron melt is taken to the BOF where carbon (C), Mn, phosphorus (P) and S are further reduced under high pressure of oxygen ($O_2$) (Annexure 1).

The steel is then put into continuous cast moulds to produce slabs with a thickness of 240mm. Molten steel is also supplied from the electric arc furnace, which mainly uses scrap metal as its source of molten steel. Other additives are also added, and thereafter cast as the steel originally from the blast furnace (Annexure 1). Earlier entrepreneurs in South Africa before the existence of the steel industry were more inclined to follow this method of remelting scrap metal.

*Uncoated products:* here slabs are cooled, and thereafter reheated and hot-rolled to produce steel coils or plates (Annexure 1).

*Coated products*: Steel coils are either dispatched or cooled and further processed by cold-rolling them to supply material for tin plates, colour products and galvanised steel (Annexure 1).

On the hand, the SB plant uses continuous casting that automatically feeds the molten steel into the hot-rolling mills. This is in contrast to forming slabs, which need to be cooled and reheated before being hot-rolled i.e. the Corex-Midrex process. There are clear benefits for using the Corex-Midrex process. The obvious benefits are in saving power through the elimination of preheating before hot-rolling, removing logistics nightmare of storing slabs, and reducing the transportation costs of moving the slabs from their storage to the roughing mill (as per observations and discussions held).

Our treatment of the "technological discontinuity" and the "new technology" is approached within the current scientific and technological paradigm. Hence, reference can be made to an emergent discontinuity in the secondary metallurgy of hot-rolling. This is due to the new Corex-Midrex currently in use at the SB plant. There is thus no intent to suggest an emergent paradigm because the nature and structure of knowledge is derived from the previous body of knowledge, that is, knowledge is accumulated in this instance.

Hence, the "technological discontinuity" will have nothing to do with the existing scientific practice, particularly when comparing the VP and SB plants. The dominant factors characterising the "new crisis" are the cost-effectiveness and efficiency of production, which seem to agree with de Solla Price's observations in 1984. Cost-effectiveness will have to address issues of the increasing scarcity of coking coal, savings in electricity power and transport costs. Efficiency will address matters relating to adherence to environmental regulations, safety standards, production of excellent steel quality, increased productivity and employee development.

The "new technology" refers to the emerging production methods reflected by the differences in the production methods of the hot-rolling process. The way the mills are configured is not a salient point since they both use the same mechanism of back-up rolls and working rolls. Corex technology was developed jointly by Voest-Alpine Industrieanlagenbau (VAI) of Austria and Germany, and introduced in South Africa in 1985 by Korf Engineering of Germany. However, the process was not initially intended for rolling as it was used at the Pretoria Iscor plant.

Therefore, the "new normal scientific technology" can be taken as the Corex-Midrex process in this context. Hence, Kuhn's intellectual crisis as a source of a paradigmatic crisis is challenged. The complete picture as expressed in the scholarship review would be as follows (Chalmers, 1999):
*R & D product(s) (pre-science)-----VP plant (normal scientific technology)-----Rising production costs (challenge)-----SB plant (new technology/Corex-Midrex technology)-----lack of coking coal (new challenge)-----Corex-Midrex process (new normal scientific technology)*

The following are among the benefits realised by Iscor by adopting the Corex-Midrex process as per observation:

- Lower capital costs as compared to those for the traditional coke oven – blast furnace route;

- Usage of low grade coals, of which there are abundant supplies in South Africa and throughout the world;
- Very low pollution levels which make it easier for environmentally friendly processes; and
- Decreased dependence on the availability of cold scrap in the steel-making operations.

In 1990 Iscor was the fourteenth (14) largest steel producer in the world from about eighty (80) steel producing companies, and currently contributes 77% of total production in South Africa (according to the BOF process engineer). Iscor is thus in a monopolous relationship within the steel industry in South Africa. It would thus not be far-fetched to make conclusions of the steel industry in South Africa by basing that on certain fundamental observations at Iscor. Furthermore, the history of Iscor and the South African steel industry can broadly be divided into the following historical epochs:

- 1928 – 1942: Iscor existed for entrepreneurial and strategic purposes to avail the necessary raw material primarily for internal national consumption;
- 1942 – 1989: Iscor was in a process of disentangling itself from the World War II effort when the VP plant was set up to help with the production of the necessary raw materials, the coming into power by the National Party (NP) in 1948, and its commercialisation from 1989; and
- 1989 – now: Iscor's commercialisation route accompanied by its current process of unbundling into the mining and steel-making concerns, network forming with organisations like the LNM group, and its categorisation as a resource management company.

All these epochs do not necessarily reflect on any scientific and/or technological changes. Perhaps the Iscor 1989 changes were pre-empting the political changes of 1990. The adaptation of the production process at the SB plant has elements of a socio-technical process since it takes care of environmental factors, internal productivity level trends and global cost-saving measures that need to be followed. Iscor's commercialisation effort needs to be seen in the context of its diversification into the economic sector of resources. Firstly, this implies seeking opportunities in other organisations within the resources sector. It is not surprising that Iscor is now the fourth largest producer of steel due to its co-operation with LNM. Secondly, it was expected that the steel-making (Iscor) and iron-making (Kumba Resources) businesses would be separated.

### *4.2.3 Expression of Innovation*

*4.2.3.1 Internal factors*

It has already been mentioned that innovation in the steel industry is focused on the design of processes. It is incremental in nature and is particularly observed as it relates to how various processes are configured and integrated into a single design. Industrial design was first defined during the Industrial Revolution (Drejer, 1996).

There is no evidence of Iscor putting much emphasis on innovation. Although, there is a technology management function under the Materials Science Department responsible for organisational innovation. The top management strategy seems to be reliant on acquiring technology elsewhere for direct implementation (as per observations and discussions). The BOF engineer stated that "the processes of steel-making are uniform and standard, and the only innovation that could be introduced was in employee training and reducing transportation costs". The SB plant processes were regarded as being very an innovative because the transportation costs and other operational costs would be drastically lessened

The seven rolling mills currently in use at the VP plant are manufactured by Mitsubishi. The same is also true with the designers of the Corex-Midrex process at the SB plant as mentioned above. It would follow that innovation in the steel industry entails appropriate configuration of processes. These configurations tend to merge processes either into automated and/or continuous processes.

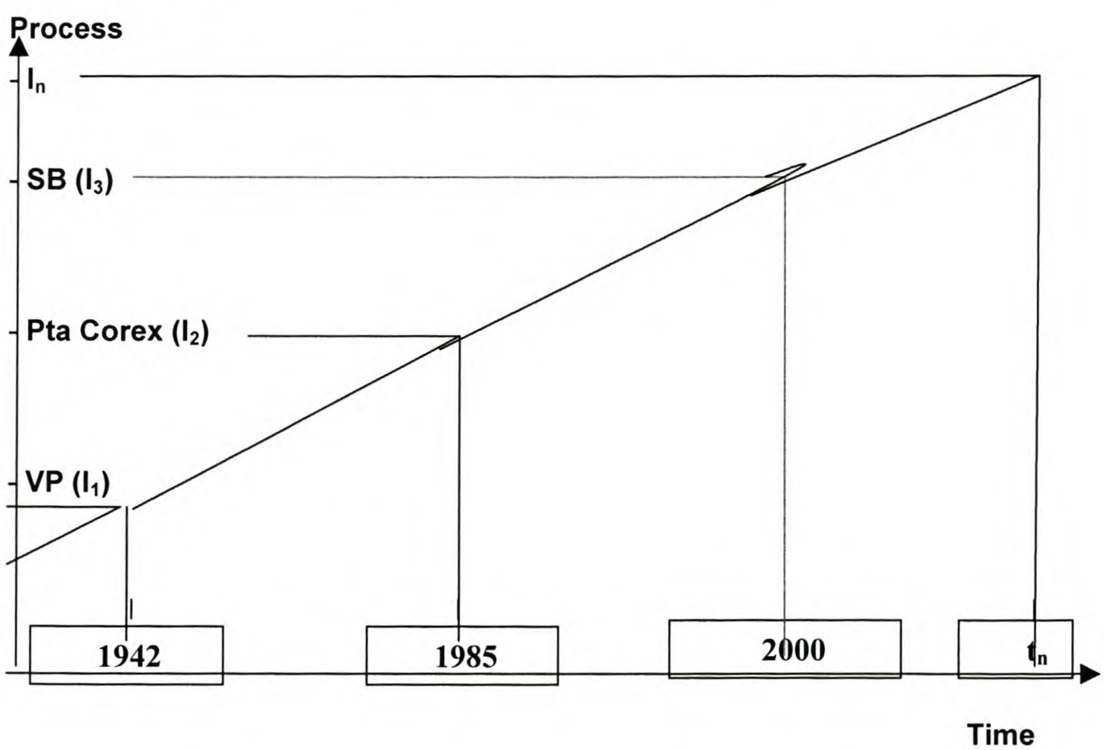
Innovation should improve the quality of the product as it previously happened from ingot casting to continuous casting (Bolbrink, 1992). Furthermore, the innovation should save costs related to availability of materials, power and transportation. By observation, the dream of any innovator in steel-making would be to have a single automated process from iron-making to steel-making.

Simply shown:

*Iron-making (Blast furnace)* → *Steel-making (BOF)* → *Post-treatment* such that all the processes like the blast furnace process, BOF process, and the post-treatment (secondary metallurgy) like rolling are included in a single giant process. This would be a confirmation that the practice of innovation closes the gap between inventor and the marketer who must sell the product at a price the market will bear. Therefore, innovations currently being introduced could be regarded as negligible as compared to the ideal production process required. Importantly, it cannot be proved that the current innovations are incrementally linked to the eventual ideal process illustrated in the sketch below (Figure 2).

By observation, it is also most probable that the efforts are disjointed because innovations are context based and sometimes value-laden. If efforts were not disjointed we would possibly experience the ideal picture at a projected time $t_n$. The picture described above can be illustrated graphically as follows:

**Figure 2: Possible observed process to attaining ideal innovation stage in the South African context**




An assumption obviously made in this illustration is that each successive innovation is better in most aspects than the previous one; and the innovation process units have the same interval between each innovation. Hence, at time $t_n$ we should have the ideal innovation $I_n$ as per illustration. Alternately,

$I_1 (t_1) + I_2 (t_2) + I_3 (t_3) + \ldots + I_{n-1} (t_{n-1}) = I_n (t_n)$

The review of the literature has, however, shown that innovation is asymmetrical, non-linear and not path-dependent. It could be possible to attain this ideal innovative process in steel-making because of the following as in Figure 2:

- Processes of steel production are generally standard and similar globally;
- All industry players have equal access to any new information of steel-making as contained in textual as well as statistical data;
- Steel-making is still regularised by the interest of governments with the help of industry associations like Steel and Engineering Industrial Federation of South Africa (SEIFSA) and the South African Iron and Steel Institute (SAISI); and
- Most steel-making organisations experience similar challenges of how to best optimise their industrial processes to improve on production.

Hence, there will always be collaboration amongst the various producers of steel. Innovations within the steel industry tend to enhance the functional value of the product although being process-related. Hence, there is much concentration by steel producers to increase levels of production to be regarded as big players within the industry. The Iscor-LNM Group collaborative venture needs to be seen in the context of increasing production levels at Iscor.

*4.2.3.2 Organisational Dynamics*

By observations and the documents consulted, acquisition of innovative products at Iscor seems to depend on the following:

- Market feedback;
- Performance of competitors;
- New technology;
- Market trends;
- Economical environment; and
- Supplier care.

This would suggest that industrial organisations are not only focusing on keeping up with technology and their competitors. They are also actively striving to create new social and technical processes through innovation. Product and process developers always think that they can improve their innovations and that they are still to achieve for their efforts.

In the steel industry, innovations are not necessarily geared to enhance client service but to save costs. Customer needs at flat steel products are taken care of by alloying procedures and rolling of slabs into the customer-specific gauges. The gauge obtained after casting is 240mm and can be reduced to 1,5mm at the VP plant after rolling (as per engineer's explanation at the rolling site).

The impression gained from observations and asking engineers questions is that the steel industry in general is not necessarily concerned with the long term upgrading of innovation programmes and projects. Innovation becomes an imposed phenomenon primarily due to shortages in raw materials. This creates a need for new technology and/or new technological configurations.

Distinctly identifiable processes of steel-making are a causal link between the existing procedures and the envisaged processes. This could be the primary reason why the steel industry is extremely fluid. It is worth noting that there are two major technologies currently in use in the steel industry i.e. materials technology and information technology. The complexity in the manner that these technologies are configured makes the stand-alone inventors obsolete. Innovation involving complex technologies is the work of an organisation and industry networks, and not a single person or product or process. Management views innovation as a component that facilitates self-learning. Network learning seems to be the new approach at Iscor particularly considering their strategic equity partnership with the British-based LNM group. The LNM group is the number four steel producer in the world producing about 21 million tonnes per annum.

Iscor would welcome an international partner to enhance access to international markets and improve its levels of production. By the end of June 2001, Iscor would have produced 3,5 million tonnes of flat steel products, 1,6 million tonnes of profile products and 365 000 tonnes of speciality steels (Iscor Report, 2000). Clearly, innovation is driven by the primary considerations of co-production and co-marketing, especially when choosing partnerships.

The appropriate investors should be able to reduce the dependence on German steel imports. According to the Minister of Trade and Industry, Mr Alec Erwin, any foreign investor eyeing a stake at Iscor must commit to improve the local steel quality to levels acceptable to the country's car manufacturers. However, this will be possible by the successful unbundling of Iscor into the mining group, Kumba Resources and the steel-making entity, Iscor.

Hence, innovation at Iscor accommodates both internal and external factors to the organisation. Although observations and textual data point to more focus being on the external factors due to the fluctuations in the world steel markets particularly considering the dumping levy Iscor would possibly pay in the United States of America (USA).

Internal factors are of a steady state nature, and predictable to a large extent. In contrast, the external factors are largely unpredictable and require Iscor to be engaged in an aggressive second order learning i.e. learning beyond the formative context of the organisation of only understanding metallurgical science.

### *4.2.4 Globalisation Aspects*

#### *4.2.4.1 Industrialisation*

The 11 September 2001 American occurrences plunged the prices of steel and related commodities. It served as an example of how steel as the most used material can mediate how various national economies position themselves. Globalisation effects were investigated from the point of view of industrialisation.

Worldwide trends inform us that in the 1980s most mergers and acquisitions occurred between different business concerns e.g. mining and automobile sectors. In the 1990s these processes occurred within the same sectors. Examples are the petroleum and automobile industries. The steel industry has historically been tied to the mining industry due to the provision of raw materials particularly iron ore (Hang and Johansson, 2001).

Steel industries globally and in South Africa were founded out of a strategic concern. The Cold War period and the pre- and post- World War II era exacerbated this orientation of the industry. It is an orientation that was not considerate to economic growth, technological development and social change.

The focus was to develop strategic materials for governments to position themselves.

Globalisation facilitated the eradication of a false dichotomy between scientific creativity and utility i.e. the Jeffersonian research versus the Newtonian view of public science. Baconian research i.e. industrial research as in Iscor is carried out in a more tightly managed and disciplined environment. This is so because knowledge to solve an identified problem is presumed to be substantially easy to attain because of the established body of knowledge of the disciplines followed by Iscor employees.

Industrialisation as perceived within Iscor is rightly not necessarily a function of the national economic growth; but what is important is to keep the order book in a satisfactory position. The modernisation of processes does not imply the introduction of the state-of-the-art designs, but a major consideration is to increase production cost-effectively.

Hence, global competitiveness pushes Iscor to adopt an evolutionary and gradual process of industrialisation through network-forming as with the LNM group. This in turn influences the productivity levels geared at meeting the demand-side expectations especially of the automobile sector like BMW, Nissan and Daimler-Chrysler (Iscor Annual Report, 2000).

*4.2.4.2 New Product Development*

The creation of new identities is one of the characteristic features of globalisation. This would include the newly identified roles of steel. One way of looking at this aspect is to examine how technical aspects of production have assumed a certain degree of the social elements. In short, processes or some elements of processes have transformed from being technical to being socio-technical.

The automation of most processes at Iscor reduces exposure to danger and increases safety. By definition, designing involves a consideration of social variables. It can be said that processes at Iscor have elements of being socio-technical in as far as they address business processes internally, including employee interests.

Externally, it is not an effort that goes beyond satisfying the clients. The amount of emissions, dust released and underwater pollution remains a health hazard to the local communities, and there is a great danger of workers at the coke batteries due to the low level of automation as most of the work is done manually (as per observation during site visits and various media reports of November 2001).

The determining and limiting factor of a transition to a fully-fledged socio-technical set-up seems to be a function of Iscor's market share and national policy making. Iscor's clients have never complained of negative effects of the production process, and neither have communities decisively mobilised themselves to address this question. This is enough motivation for Iscor to appraise its decision-making processes, and communities would then be in a position to relate some of the products they consume to their process of production.

New product developments have always separated the production processes and the conception of those products as consumed. The extent to which this distance can be closed would define a new product identity in the global context. This seems to be the argumentation of the anti-globalisation movement, which is also consistent with the ANT and SCOT as there is a need to recognise mechanisms of mediation and intermediary-forming both nationally and internationally (Law, 1992).

### *4.2.5 Resource Management*

#### *4.2.5.1 Overview*

Iscor regards itself as a resource management organisation that merely happens to be in the steel-making business. It is an interesting situation and interpretation because there is an underlying meaning of detachment from its formative context. This context being that of an entrepreneurial organisation pursuing the science and technology of industrial steel-making for domestic, social and industrial use.

The observation is that Iscor is trying to move from a reductionist approach in analysing its business within the global context (Stehr, 2000). It is as Mark Twain stated that "people whose only tool is a hammer, everything look like a nail". The notion of a resource management organisation pre-supposes an organisation that has identified its limitations in terms of business rhetoric, technology base and its global competitiveness. Therefore, a resource-orientation enhances the organisation to transcend a one-dimensional outlook to be multi-dimensional.

Multi-dimensionalism suggests an organisation that is learning or going beyond its formative context. This second order learning puts emphasis on interrogating and positively exploiting organisational routines, capturing of tacit knowledge, enhancing intuition, and probing how people make judgements.

Thus, this is a shift from over-reliance on transmitting explicit knowledge as compared to tacit knowledge. Explicit knowledge in this context is the science of metallurgy, creation of databases and configuring of processes. This knowledge cannot be implemented as codified and/or rationally as it would best require dialogue and interactive problem-solving.

It is observed that interactive problem-solving at Iscor is still restricted to its formative context i.e. the one-dimensional outlook of scientific activity is still dominant. The dominance of the one-dimensional outlook is made possible by factors such as: the steep and hierarchical organisational structure; a decentralised to almost non-existent innovation function; low level skills base; ideological orientation of organisation; top-down management and organisational culture; and entrenched social, physical and material networks unrelated to the production process. Therefore, the resultant situation is a serious lack of awareness of shortcomings the business is facing.

*4.2.5.2 The Actor-Network Approach (ANT)*

The constructivism and generalised symmetry approach to the approach of the social construction of technology i.e. the Actor-Network Theory in this investigation, enhances our understanding of Iscor in terms of: knowledge base, translation of available skills into organisational deliverables and sustenance of positive outcomes. Hence, the notion of a resource organisation enhances and enables a mediating organisation that is at the centre of all the networks created by both human and non-human actors (Latour, 1987). Iscor is still to create a situation where both technical and non-technical employees easily follow the meaning-making processes of steel-making. The resource notion is still in a codified form and requires breaking up and unpacking. All the activities being mediated will be understood in relation to the central mediation.

Currently, the mediated activities are perceived to be from individual organisational functions like the blast furnace and BOF processes, scrap metal recycling, casting and rolling processes. Consequently, this silo mentality tends to demarcate scientific creativity from utilitarian activities as if there was ever an "anthropological Great Divide" (Latour, 1993). Management meetings seem to be the only activity that acts as an intermediary between various and diverse organisational structures like Human Resource and Materials Science. Furthermore, there is a definite confusion observed from explanations received between innovation management and technology management. According to the quality assurance engineer, technology management is seen or interpreted as an activity of observing current practices in order to make new technological acquisitions. Innovation management on the other hand is seen as limited to machines i.e. limited to the non-human actors. The implication is that skills development is just provided to fulfil immediate tasks and challenges.

A positive development is the organisation of plant tours for members of the public and clients. The primary reasoning of orientating clients is to let them appreciate the time duration to produce some of their products like steel coils. The automated processes demonstrate how human actors in interaction with information technology facilitate materials technology and subsequent production of steel of a specific quality. Primary functions performed by human and non-human actors are transportation of materials, configuration of material, observation of standards and compatible use of a supporting technology like information technology.

*4.2.5.3 Creation of Order from Disorder: Attainment of stable products*

The value-add of steel-making stems from the physical chemistry of iron (Fe) up to the post-treatment of steel, which is commonly referred to as secondary metallurgy. Briefly, this could be shown as follows:

***Fe*** ⟶ ***Post-treatment product of steel-making***

The process above is non-linear and based on a deterministic scientific activity, which is essentially path-dependent as compared to a statistical activity. If 70% of steels produced are upgraded in downstream processes of secondary metallurgy like rolling, the challenges of management to achieve and sustain profitability will be focused on process technologies. These process technologies imply acquiring the state-of-the-art plant equipment.

The disorder-to-order sequence by Latour seems to be defined in this context through well-established multi-dimensional processes in a steady state set-up (Ziman, 1994). However, if irrationality by various actors is considered, the content will begin to look differently as Latour proposed.

Acquisition of modern technologies is a function of possible commercial benefits to the organisation. Aspects such as skills levels, organisational structure and the social impact of such a technology become critical. This approach surpasses the plausibility of the scientific argument but accommodates the superimposition of social factors as in the notion of construction.

Hence, the stabilisation of a process occurs when reality is the consequence of "a set of operations rather than the modalities qualifying a given statement" (Latour and Woolgar, 1986). This is the contrast between the agonistic and nature, or between science and scientific activity, or between Fe-understanding and the post-treatment product of steel.

The notion of agonistic explains contingencies to make decisions. It is so because there is incorporation of social characteristics such as business partnerships, disputes and market forces, and "epistemological aspects such as proof, fact and validity" (Latour, 1993). Consequently, the realisation of the stable re-alignment of variables and elements within the Iscor's process design and new product development is not only accompanied by the emergence of a "black box" or "macro-social status", but also by the creation of "order" from "disorder".

The dispute of what counts as a scientific proof about the origins and nature of inclusions, intermetallics and defects in steel indicates disorderliness (Avner, 1974). It is the resolution of disorderliness to orderliness that would focus on "phenomenotechnique", which are the principles involved in accumulating a laboratory (Latour, 1993). This calls for a closer focus or scrutiny between "material" equipment and "intellectual" components of laboratory activity, or interactions between human and non-human actors (Lehrer, 1997).

The SB plant should be interpreted as an outcome (i.e. a "materialisation" or "reification"), which was time-dependent on the technological progress at the VP plant. By implication, if the products and processes at the SB plant are perceived to be “credible” or socially acceptable, that will create an understanding of notions such as the cost of investment (economics), and proof and validity (epistemology). This equation of economics-epistemology notion surfaces through budgetary increases for successful and recognised incremental innovations within the steel industry.

The aspect of circumstances has generally been regarded as irrelevant to the practice of science. The historicity of science (Habermas, 1968) emphasises the apparent “escape of science from circumstances”, and is possible through localised and specific practices.

Consequently, the approach to conduct basic science investigations into the chemical behaviour of Fe will most probably depend on the secondary metallurgical process to be further pursued (as per observation). Thus, the metallurgically-explained longitudinal forces acting on steel slabs during rolling and multi-dimensional forces on some profiled products could warrant varying analytical outlooks on the physical chemistry of Fe (as per observation).

The amplification or growth of knowledge is a function of available information. Hence, order is attained through methodological approaches that validate dominant processes because they differ from what is expected. Such technological processes contain more information that requires further exploitation to yield order/stability. In the MOT discipline, we know that order/stability is achieved when there is a dominant technological design or product or process. Any deviations from a stable pattern could be interpreted as the real origin of technological discontinuities emanating from “information differentials” (Latour and Woolgar, 1986).

### *4.2.6 Technological Risk Analysis*

*4.2.6.1 Iscor’s constructed risk*

This aspect covers risk analysis based on a selection of technical and environmental dangers. The ANT was used to identify various perspectives that have a potential of influencing approaches to risk reduction and risk management.

The advanced perspectives are explained in terms of variables within the unit of analysis in order to appropriately deal with feasible social goals. Hence, a safe working environment of workers is critical, and the environmental impact in terms of the consumers and the ecology.

In our study, the aspect of risk cannot entirely be separated from the notion of technology assessment. Technology assessment is pre-occupied with approaches of how to take risks. Rather the pre-occupation was concerned with creating a balance between dangers and benefits associated with these process technologies. The analysis of danger in terms of the theoretical framework was important to our study. The distance from danger is a function of power of decision-making and value systems.

Risk involves a development of an alternative scenario that is a subject of fierce contestation, sometimes leading to violent objections and/or robust debates. It is also true that there are two levels of addressing the social discourses or contests around the essence of risk and its management. These contests are at the levels of ideas, and institutions or social groups. If we consider a concentric model of actors, the centrists will view their social commitment as more to do with engaging with the market and there will be self-regulation on safety and environmental factors. Those at the boundary like workers see themselves as influencing the distribution of power from the centre in order for decisions to be more legitimate.

Hence, those who are at the periphery argue that they have the ability and social commitment to make interventions when it comes to powers of definition i.e. emphasis on the human actors. The suggestions for cost saving measures by engineers at the hot mills "are not always taken seriously and followed by the organisation" as per discussion with the engineer at the rolling plant.

*4.2.6.2 Technology Assessment*

*Democratic function*

Public participation in technology assessment is a matter that draws from two aspects viz. consensus forming and the assurance of values of society. Iscor seems to be affected by the existing blur between science and technology, which in turn impact on democratic participation. The manner of the evolution of science seems to contradict the existence of a democratic tradition within science, thus discouraging participation/pluralism within Iscor (Bijker, 1995).

Technology assessment is a reflection of the blur between the exclusivity of science and the required openness required as a result of the impact of technological products. There is a long held tradition that consensus is incompatible with science. Hence, the allowance of consensus as in technology assessment practices seems to define the social content of technological outputs.

The notion of democracy within science poses a challenge to the scientific method. Science has historically been a closed field only open to its practitioners. However, the current challenge has to do with how technology impacts on the values of society like the steel products and the environmental challenges it poses. Technology assessment offers the public an option of not only deciding on technological products but on whether the current values should be eroded or not.

Scientists and experts have interpreted the assessment of technology as the invalidation of the scientific method. Hence the evolution of the scientific method is seen to be under threat from its Greek origins. The institutionalisation of science and the scientific method never recognised or pre-empted the emergent democratic traditions because they were in their infancy.

The role of technocrats and experts cannot be dismissed in technology assessment. They are an important constituent part in technology assessment as they introduce the technical dimension. They find themselves at loggerheads with society because whilst clinging to the traditions of the scientific method, society has values to take care of. Scientists and experts are clearly not experts in the area of values and ethics.

Technology assessment cannot be dismissed as though it is not a management function. Whilst the technocratic tendencies can be removed in technology assessment, the approach of using technological products responsibly is a management function. Management cannot only be associated or be a function of those exposed to the scientific method as Figure 1 illustrated. If this is the view of management then other stakeholders have a role to play in the central function of management.

Technology policy decision-making bears testimony to the centrality of the management function. Clearly, public participation does not have to be seen as the erosion of the scientific method but recognition that other stakeholders are entitled to decide on the values of society e.g. how the emissions at Iscor can be reduced to a tolerable level for environmental safety.

*Limits of technology assessment (TA)*

Technology assessment (TA) faces other challenges from a philosophical outlook. There is recognition that various stakeholders within society have specific roles to play. Members of the scientific community are best suited to be practitioners at what is their enterprise. Technology assessment is yet to identify the broader philosophical concerns particularly on the history of philosophy because of the fluid stakeholdership of technology assessment.

Hence, TA has been seen as consisting of a number of steps geared at winning public acceptance. TA has been understood differently and coined into other terms and sometimes these taken as necessary steps. Higher technological insight has not always succeeded in facilitating acceptance because expectations around TA were exaggerated. The exaggeration led to TA being misunderstood rather than developing an understanding of complexities involved in reaching social acceptance.

Technology assessment is not necessarily a practice of science. The required objectivity of science cannot always be applicable in this instance. The forecasting consequences and side effects of technologies cannot amount to desirability of those consequences and side effects. Hence, it is not always possible to have a calculated risk analysis because it does not necessarily lead to the social acceptance of production methods and products.

Forecasting in a narrow sense has to encompass a statement of expectation and the preferred expectations must be justified. On a wider scale, the approach to forecasting has involved the use of trend analysis and the use of experts. The forecasts are most likely inexact because there is no law-like proposition involved. Identifying a trend from a given body of data commonly uses methods of extrapolating. Iscor frequently uses expert agreement and scenario framing to improve its market position and not to engage in TA activities. Perhaps it is because TA is largely underdeveloped as a practice in South Africa.

There is currently still a lack of a system that can facilitate looking at all interdependencies within technology assessment. All the actors at Iscor are still striving to perfect the definition of the business and the kinds of solutions they arrive at have to be independent of time. Hence, there is still a need to come with a substantive background theory so that forecasts will be relevant in the future. Forecasting currently leads to a dead end.

The current non-reliability of technology assessment seems to be entangled within the unresolved questions and/or non-development of a philosophy of history. This will seemingly lead to the reduction of relying on science and technology. It thus seems that the social content of technological products is coming to the fore in a more pronounced way. However, society has internalised the technical content of most technological products together with related values and norms. It would thus be interesting to note how the epoch of Modern Age of Enlightenment will eventually perfect approaches to technology assessment.

## 4.3 Concluding Interpretations

Five concluding interpretations were made from our study:

### *4.3.1 Technical to Socio-technical transformations*

The study succeeded in illustrating that there would be a tendency for Iscor to transform from the traditional technical approaches to socio-technical/collaborative aspects of technological production. The following aspects motivating for transformation were identified as per observation at the VP site:

- More involvement of non-scientific staff in the production process;
- Change in the methods of how Iscor gathers its knowledge to be usable information;
- Change in the method of how Iscor approaches the market and optimises its market share; and
- Change in the method of how products and processes are conceived.

The unit of analysis has constantly responded to pressures associated with the Iscor's founding scientific principles and the subsequent secondary learning mechanisms. This implies that besides the known and obvious organisational strengths, there is a need to inculcate approaches of best practice.

The study further shows that top management being responsible for planning the production processes is part of networks that define the business orientation/agonistic field of Iscor.

#### *4.3.2 Mono-natural to Multi-natural transformations*

There is an approach that goes beyond the single view of nature i.e. the interpretation of nature being independent of social aspects. Hence, products are seen as embodying a particular technical value that is far removed from the human actors. Mono-naturalism implies a uniformity and linearity in the approaches of industrial production (Latour, 2001).

Multi-naturalism emphasises the non-linearity of processes accompanied by diversified methods of industrial production (Latour, 2001). The study showed that Iscor's accumulation of scrap metal was beneficial considering the shortages in coking coal for the blast furnace process for iron-making and later steel-making. The aspect of naturalism further explained the transformation from conventional and closed experimentation to collaborative or socio-technical experimentation (Latour, 2001).

#### *4.3.3 Creation of new identities*

The notion of globalisation is not only accompanied by new social identities. Technological products also assume new identities through industrial processes like mergers and acquisitions. This is particularly true in the current era where mergers and acquisitions occur between industries in the same sector. It is highly unlikely that an unbundled steel-making Iscor will enter into co-marketing and co-production agreements with a mining company. This is so because its partner in the unbundled process i.e. Kumba Resources, could take care of the mining business.

Therefore, the creation of new identities is also accompanied by the differentiation of products and processes. This further leads to a specialisation of product profiles that are dependent on market demand. The differentiation of products into plates, sheets and other coils of a reduced gauge from the hot mills is determined by external influences like the clients' needs and the nature of the competition.

#### *4.3.4 Lack of rationality*

We have illustrated from our unit of analysis how different interest groups influence decisions (Figure 1) before a position can be arrived at. Most of these decision-making processes are not solely influenced by the technical factors/purposive rational approaches as seen from the literature review (Habermas, 1968). Politicians like the Minister of Trade and Industry have made interventions about the role of the steel industry in the automobile industry. He emphasised on the continuous improvement of the quality of steel to avoid importing from Germany.

Most processes that lead to the culmination of steel-making occur primarily because of an interaction amongst industry players, and between the steel-makers and customers. Thus, Iscor hosts groups of customers regularly for them to appreciate processes involved to yield steel coils. The two examples of how Iscor tabs into the social and economic environments are: influence and sometimes pressure by networks on management, and pre-planned family visits every second month. The latter are not necessarily orientated at improving the understanding of metallurgical sciences by the clients or visitors.

#### *4.3.5 Innovation being context-dependent*

Iscor has learnt a lot from the operations of the eighty-six (86) or so steel-making companies worldwide about the industrial approach to best practice. Most lessons were acquired in terms of business management and production processes. The continuing collaboration between Iscor and the LNM group confirms Iscor's motive to increase the production levels.

According to the engineer at the BOF process, Iscor could be amongst the top five steel companies (without the LNM collaboration) in the world if it was not of transportation costs. The use of the Saldanha harbour has been beneficial in this regard. Hence, shareholder value could be enhanced if there can be an expansion of the domestic market and production of good quality steel.

# Chapter 5
# Conclusion

## 5.1 Anomalies in the data

The study clearly succeeded in meeting its objectives i.e.:

(a) To collate various and closely related social theories covering processes on product development;

(b) To develop a mechanism for product development;

(c) To apply the insights from the theoretical framework to the case study; and

(d) To identify and analyse technological options derived from (a), (b) and (c).

However, the identified theories are not always consistent with the unit of analysis from the case study. Most of the inconsistencies are caused by the existence of gaps in explaining the occurrence or non-occurrence of certain aspects in the "black box" defined in the literature review. The ANT and SSR do not always accommodate these inconsistencies when a stable production process exists. Examples of the inconsistencies are: the overlooking of technological gaps, and paying of less attention to the training needs of the non-technical staff members. According to Bijker, a constructivist conception of technology encompasses both the open/pluralist and direct participation models of organisational control of technology (Bijker, 1995).

The specific socio-technical form in which stability is attained may vary between technologies employed in different sites of the production processes. Hence, a generalised typological and variable analysis could be misleading. It is so because typologies and variables at play, say at the BOF process, would differ remarkably with those at the casting process, which in turn differ with those at the rolling process. The SB plant could provide a better generalisation because rolling occurs automatically and continuously from casting. It can thus be said the more processes are integrated, the better are the chances to yield a good generalisation. Although, it is easier to identify areas of best practice at the VP plant as compared to the SB plant. This is because at the VP plant there are more human actors that are involved in production, and there is recognition of various localised processes. Scientific rationality is less pronounced because of the lower level of automation than at the SB plant.

The inclusion of more non-human actors like technology development could improve the decision-making processes to implement better production methods to increase the tonnages. It is thus not surprising that Iscor is not immune from retrenching workers upon investing or acquiring new technologies. Management regards this approach as making the enterprise more competitive and investor friendly.

However, an investment in technology or a new innovation is a function of the existing and required skills. The identification of the required skills is in turn dependent on the organisational strategic objectives such as centres/locations of best practice i.e. identifying the existing tacit knowledge and improvement of the market positioning.

Some of the anomalies that the study could readily identify are the following:

- The identification of a new technological discontinuity within Iscor could be very fluid/differentiated if all the individual processes of steel-making are taken into consideration;
- The understanding of a new technology could be superfluous considering various modular and architectural innovations that are consistently introduced to improve the production processes;
- It is not clear whether management embodies the collaborative socio-technical approach that a modern business organisation requires;
- There is clearly non-uniformity in socio-technical transformations within various sites of production and mostly dependent on the skills base of the human actors. This non-uniformity has wrongly been referred to as relativism by some scholars but it's simply a reflection of heterogeneity of the human actors which also impacts on their relationships with the non-human actors;
- There is an anomaly in this case study in accommodating Kuhn's "intellectual crisis" approach in explaining the development of a new paradigm; although de Solla Price's approach of "technological change" seems consistent with the case study; and
- Furthermore, it can be stated that second-order learning is not a general phenomenon but localised to particular relationships between the human and non-human actors. It is not obvious to identify this phenomenon in an organisation that has entrenched routines like Iscor.

The obvious fact is that the manner in which interest groups relate to metallurgy was found to be non-uniform, uneven and unpredictable. This is so because each organisational section or business unit has its own specific objectives not necessarily integrated to the whole process. There seem to be extreme lack of awareness of process integration at the micro-level. Management does not necessarily have the power of definition or authoritative know-how on various technical functions and processes. The engineers and R & D experts play the role of defining the scientific principles of the production process effectively.

## 5.2 Significance of findings

### *5.2.1 Model formulation*

The formulation of models as in the configuration of steel processes is aimed at solving complex mathematical and scientific problems related to production. Our case study has shown that models are geared to address the social aspects of industrial production (Annexure 1) because they are a simplification of a complex process. Models in steel-making are a valuable aid in assessing the effects of changing various parameters that impact on the quality and design of the final product.

Results obtained allow the final design to be determined by specified sets of characteristics. These characteristics could be captured by equations that can be used to extrapolate other aspects of steel-making at a plant level. This was the case when there was transformation from ingot casting to continuous casting. Hence, models have to be consistent with the mathematical and scientific formulations, and societal interventions (Hibberd & Massey, 1982).
Societal interventions primarily would come from customers and communities represented by municipalities. These interventions arise as a result of service satisfaction and environmental factors. Ideally, models have to be accommodative of the social and technical variables of production and the subsequent consumption of the products (Hibberd and Massey, 1982). The current model used is an international standard that is not necessarily accommodative of the employees and communities because of the safety and hygienic factors.

It's already stated that the social relevance of a product and process are usually captured through physical models. In this instance, there is an attraction by most organisations to employ dimensional analysis. The dimensional analysis informs about the kind of tolerances that are likely to be acceptable to society (Farias and Robertson, 1982). It is thus true that this requires an enormous experimental task such that there is development of correlations between mathematical and physical modelling on the one hand and social needs on the other hand.

The casting of liquid steel into slabs instead of billets illustrated the eventuality of process design to meet the requirements of clients (Iscor Group Review, 2000). Furthermore, the process at the SB plant introduces other requirements through the production of the ultra-thin gauge steel coils. This could be interpreted with an aim at maintaining the customers satisfied and not necessarily happy (Business Objectives of Iscor, 2000).

The actual needs of society seem to shape the manner of how the processes are designed. It was mentioned in the Introduction that steel in South Africa is primarily used for the construction and packaging functions. The design of processes including the mathematical and physical modelling is dependent on societal pressures/needs and interventions. Broadly, it is the overall effect of the market demand/agnostic field.

However at the scientific and technological levels, modelling aims to avoid the formation of steel imperfections and impurities/inclusions in the final product. This implies that there is also a need to create models of imperfections such as buldging in continuous casting using the bending and shearing beam theory (Farias and Robertson, 1982).

The adoption of process models would seem to agree with the approach of paradigm analysis as adopted in the literature review. However, the study added another approach of how scientific validity could be verified, viz. capturing the tacit knowledge of experts who are continuously involved in purely scientific experimentation.

## 5.3 Recommendations

Recommendations can be looked at through two important aspects: policy options and future studies.

### *5.3.1 Policy Options*

*5.3.1.1 National objectives*

Identification of important sectors of social relevance has always been a priority of most science and technology policies and systems throughout the world, South Africa included. There has been a shift in interpreting what is called strategic science, and this movement is characterised by worldwide shifts from vision-orientated science to mission-orientated science.

In this context, South Africa finds itself in between the two practices such that the distinction is blurry particularly in post-1994 era. This is a cause of concern for a company like Iscor in terms of its long term planning because the policy environment should be stable. It is thus natural that the re-engineering processes do not exceed five-year cycles. It is not clear at this stage whether the organisation would be comfortable with the mission approach or the vision approach or some hybrid approach.

Furthermore, it is unclear whether Iscor's programmes address the concern of government for South Africa to decrease its reliance on German's steel import. The government is motivated by a strategic goal of reducing the unemployment rate. It is not obvious that Iscor has the same pressing objectives as articulated by the science and technology policy priorities of South Africa particularly the move towards strategic science.

*5.3.1.2 Independent Advisory Body on Innovation*

The South African parliament has approved a legislation recognising the National Advisory Council on Innovation (NACI) as an independent body. This was done in October 2001 through the NACI Act to ensure "objectivity" and appropriate socio-economic focus of NACI. This move seemed to place a high premium on innovation.

However, it is critical to understand how independent innovations could be relative to the already set national goals. Is there an identifiable grey area to justify referring to this newly re-constituted body as independent? How will it relate to the other already running and "independent" programmes such as the IDC's Special Programme for Industrial Innovation (SPII), and NRF's Technology for Human Resource and Industry Programmes (THRIPS), and the National Innovation Fund?

The independence of science and technology has not convinced many scholars whether it facilitates its objectivity. This is so because its objectivity is not always seen as being "congruent" or equivalent to the creation of an enabling environment for social and economic progress (Marais, 2000).

Scholarship still has to identify the necessary and sufficient variables to attain congruence and its limitations in this regard. This could lead to a better understanding of the evolution of the following: mode 1 to mode 2 of knowledge production, mono- to multi-naturalism transformations, and the technical to the socio-technical or collaborative experimentation.

It could also be clarified whether strategic science can possibly have cognitive coherence and be testable in being defined as a knowledge form with an independent intellectual domain of its own. The only prominent advantage of an independent innovation body lies in its proposed function of technology assessment. The advantage lies in the fact that most parts of South Africa are underdeveloped and delivery planning has so far been ad hoc without the inputs of consumers, including for Iscor's products.

### 5.3.2 *Future research*

#### *5.3.2.1 Co-evolution Studies*

Society is currently grappling with the notions of the Product Creation Processes (PCP) and the Societal Embedding Creation Processes (SECP) as proposed by Rip. This is particularly true for those interested in the social studies of science. There is knowledge of how the practice of science influences how society behaves or adapts to changes in science and technology and vice versa.

The South African case as in Iscor indicates ideological orientation of how technology interacts with society. It is a vivid case where the public views technologies especially the new ones suspiciously. The suspicion is based on a mistrust of the dominant social and economic order, although a new one is evolving in South Africa. These perceptions and realities need to be overcome in order to ascertain the embedding of technologies in society, particularly as experienced by the historically disadvantaged people.

It seems that Iscor would need a broader stakeholdership than it has in order to properly define its technology management function. Hence, there is a need to have inputs from a diversity of role players. However, the challenge is whether it would be possible to sustain such interactions without a common, long term and visionary approach. The creation of technological trajectories could help in sustaining the interactions with the stakeholders.

Although, it is known that the National Party government of South Africa attempted with some success to position the country as an important stakeholder with the leading edge technologies i.e. space technology, nuclear technology, information technology and materials technology. Later there was tremendous interest with biotechnology and information technology. South Africa could nonetheless not map out technological trajectories for all these technologies except recently in 2002 with the biotechnology strategy.

Scholarship should still develop a "general" model of technological trajectories such that the national priorities are catered for by the long-term socio-technical landscapes. Long term in this instance includes accommodating the exceeding of several life cycles of dominant and most prevalent technological products and processes. It is quite clear that the extent of science and technology development can be understood as a function of aspects such as political and economic development. However, there is a need of a "general" model no matter how diffuse it can be. This is similar to the conceptualisaton and implementation of the idea of the United Nation Organisation (UNO), with its diffuse and loose organisational character.

The South African situation is most susceptible to government intervention, but also to modulate the ongoing technological dynamics to get closer to the desired objectives. There will be less of technology management approaches and policy debates as dominant technological patterns emerge as in the steel industry. These patterns have not necessarily meant an existence of co-evolution between industry structures and broader societal developments. Currently, South Africa would best rely on cases from elsewhere to assess the distance between the basis of scientific technological activity and its intended uses. In other words, there should be a frame of reference that would explain any divergence between technology niches and market niches.

*5.3.2.2 Rational Consensus Approach*

According to Lehrer and Wagner, there has always been "a need to arrive at some explication or explanation of some central or fundamental conception". These explanations are social factors that are in essence a factor of consensus or agreement. This could be an indication to design a technological process that could be scientifically sound and address the tangible outcomes of the efforts. Models have been developed along algorithmic and philosophical approaches to explain this phenomenon. Hence, a methodology followed was used from the point of view of axioms in the fields of politics and ethics, can extended to science and technology. This method can be accused of being relativistic by being more applicable to certain disciplines under particular contexts.

However, there is still a need for scholarship to develop thematic approaches that would not be discipline-bound. It would encourage the derivation of motivations of explaining knowledge forms that are based on context and the generally identifiable variables within society. However, these motivations are based on assumptions that certain things or phenomena are a given reality. Some scholars like Lehrer refer to this notion as "a principle of reason" which define rational consensus.

The approach of rational consensus encourages functional differentiation because there are obvious applications as in politics and ethics. The less obvious applications are in the fields of science and language. Therefore, scholarship that has supported this approach has neglected a general thematic approach that can be developed to coincide with collaborative approaches.

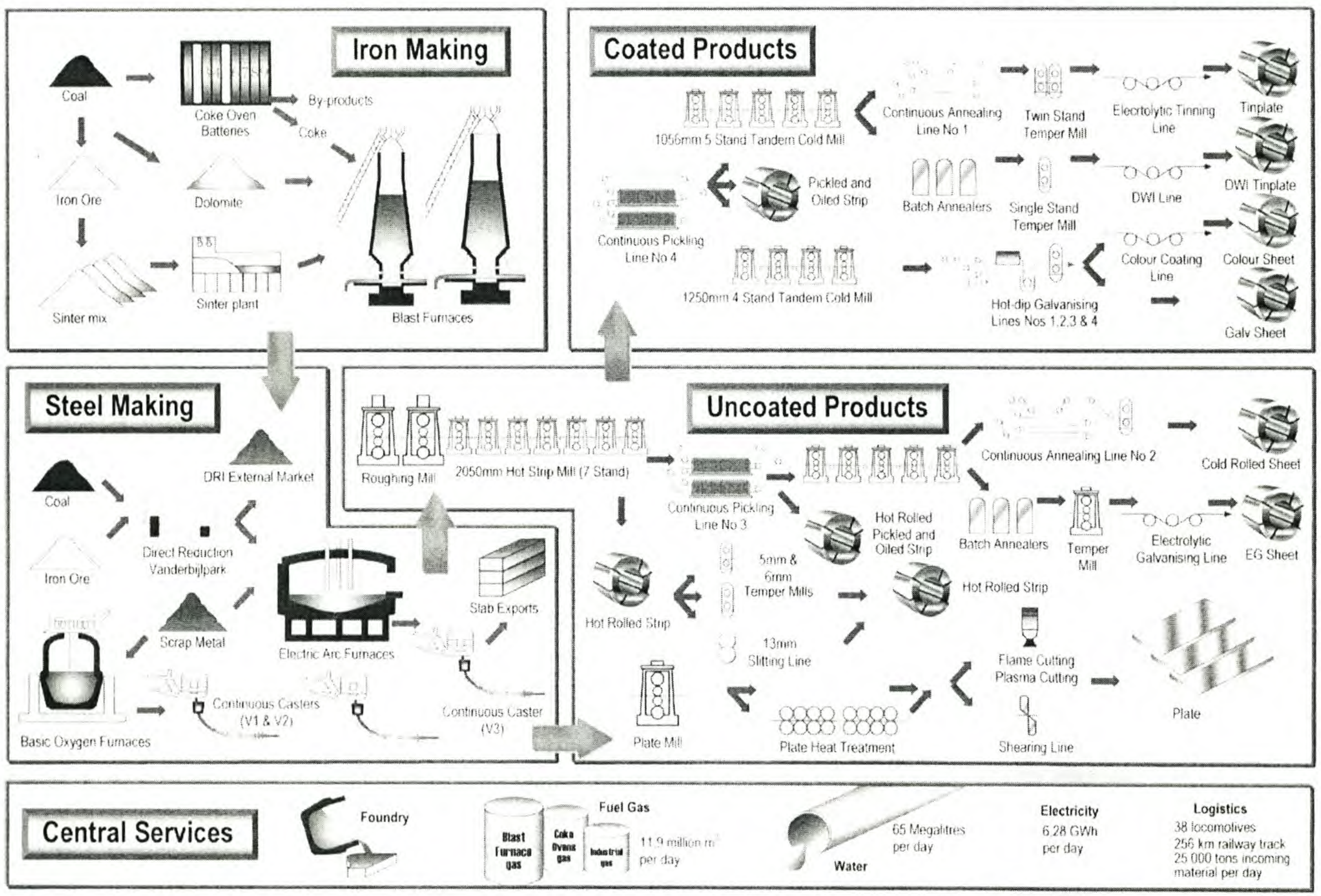
Finally, the latter factor is critical for Iscor where functions are still interpreted with a silo mentality. The development of human resources is regarded as independent from technology management together with its technological acquisitions (Iscor Report, 2000). Epistemologists seem to be correct when asserting, "the normative concerns within society do not always reconcile with the available empirical evidence" (Barnes, 1982).

Annexure 1

Flat Steel Products

# Process flow

ISCOR flat steel



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**Site Visits:**

Four site visits were undertaken at the Iscor Vanderbijlpark Plant to interact with the engineers and marketers and to further understand Iscor's production processes on the following dates: 02 August 2001; 06 September 2001; 04 October 2001 and 03 October 2002.

**Discussions:**

Discussions were held with metallurgical engineers at the following places within the Iscor Vanderbijlpark (VP) plant: quality testing, basic oxygen furnace (BOF), the casting and rolling sites.