

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

**The Quality Story  
A Framework for Problem Solving**

by

**N.P.WEBER**

**Submitted towards fulfilment of the requirements for the  
degree of**

**MASTERS IN INDUSTRIAL ADMINISTRATION**

at the

**UNIVERSITY OF CAPE TOWN**

**TUTOR : PROF TOM RYAN**

**August 2001**

## FOREWORD

Having spent all of my working life at Nissan, I have seen the company and the automotive industry go through many changes. Datsun and Nissan as it was called in the 70's was a solely South African owned company enjoying a high degree of consumer confidence and operating in an environment that was not very discerning with regards to quality and costs. This soon changed, and by the 80's, after the introduction of a few not so successful models, consumer confidence, together with market share, dropped and the company found itself in severe financial difficulties. Having barely survived and after numerous owner changes, the company found itself operating in a highly competitive market with regards to quality, cost and delivery. Customers had become extremely critical and too many local manufacturers with far too many models on offer supplied the very limited South African market. If this was not enough, imported models became a reality with the government reducing import duties in an effort to force the local manufacturers to become 'world competitive'. In this light, Nissan as it was now known, by 1995 was 50% owned and by mid 1999, fully owned by Nissan Japan. During the transition from South African to Japanese ownership, the introduction of the Japanese management system in the form of the Nissan Plant Management System became a non-negotiable necessity. The system itself is very effective in that it focuses the company from the CEO to the lowest level of management on common goals and objectives. It also requires continuous monitoring of performance against the targets set together with frequent reviews to realign the plan with the changing environment.

The NPMS ( as it is affectionately known) is a very powerful tool for management in that for the first time everyone is aware of how the company is performing and not just in broad terms, but by specific data displayed openly on a chart on the wall for everyone to see. The system however has one very large weak link in the South African context in that it relies very heavily on the management of the shop floor. It's foundation is built on the understanding that the operator is diligent, disciplined and has pride in what he does. With this as a given, the foreman, around whom the shop floor management system rotates, is free to maintain and improve on the production process. In South Africa unfortunately, we have lost the ability (or maybe we never had it) to

communicate with and control the operator. It is the operator after all who decides through his efforts, the quality, delivery and ultimately the cost of the manufactured product. All management's plans and efforts will amount to nothing if we do not control and standardised the production process. Delivery and built in quality must be a given so that management (starting with the foreman) can concentrate all their efforts on continuous improvement activities. All service departments, and most importantly engineering, must focus their activities towards assisting production in achieving their goals.

With this in mind, my personal objective over the last few years has been to move the engineering activities closer to production. This required quite a serious mind set change as, over the years, many service departments have become compartmentalised and seem to think that production's problems were not their problems. They seemed to go about their business with the misperception that they could survive as separate business entities and did not acknowledge that failure by production would mean failure of the whole company. Fortunately, this situation is rapidly improving and the results are clearly seen by the major improvements made in delivery, quality and most importantly, cost.

Engineering is a very powerful tool to assist production in understanding and solving many of the problems that are encountered daily. Engineers have the background, time and resources to investigate the true cause of problems and to implement the necessary changes or improvements to put the process back on track. This however is not always the case with engineers often going for the 'quick fix' and addressing the symptoms rather than honing in on the root cause of the problem. This invariably results in the problem reappearing once the process has returned to its previously unsatisfactory, yet stable state resulting in much frustration for management, production and the engineer.

Hence my desire to put together this thesis that would hopefully give the engineer a good understanding of his role as problem solver in the organisation, management and more importantly, within the Japanese management system. The framework for problem resolution or Quality Story together with the quality tools detailed give a simple yet very logical step by step process for effective problem resolution. As simple as it may at first appear, it requires much practise before it is mastered due to our western desire to dive straight in and to implement countermeasures before fully understanding the actual problem. This framework

requires much time and effort to be spent on the understanding and full analysis of the current situation in which the problem resides before any efforts are made at improving the situation. This does not preclude the implementation of a 'quick fix' to stabilise production while the investigation is taking place provided, once the true cause is known, the necessary countermeasures are taken to remove the problem.

Although this thesis is focused on engineers within a Japanese management environment as problem solvers, the techniques described can be just as effectively used by any person faced with a problem in any environment.

Nissan, as a company, has moved into a new phase with the advent of the merger with Renault and the implementation of the Nissan Revival Plan under the guidance of Carlos Ghosn whereby Nissan will revert back to a profitable company world-wide by 2001. This involves a policy of 'globalisation' whereby, each of the Nissan plants around the world will compare performance of quality, cost and delivery against very strict world class targets. Performance objectives will be benchmarked against the best plant in the world in each category and failure to achieve could result in the demise of the company. In this light, it is now more important than ever that every member of the team become more adept at problem solving so as to be able to achieve the very high levels of performance required.

A final word of thanks to Professor Tom Ryan of UCT who has been my mentor in becoming a system thinker and teaching me to take a more scientific approach to management as well as to all my Japanese colleagues who, over the years, have taken great pain and personal sacrifice in teaching me to think logically and understand the Japanese management way.

**Nick Weber**

# TABLE OF CONTENTS

	<b>PAGE</b>
<b>Abstract</b>	<b>i</b>
<b>Introduction</b>	<b>iv</b>
<b>Chapter 1.0</b>	
<b>A SYSTEMS VIEW OF ORGANISATION</b>	<b>01</b>
1.1 Systems Thinking	02
1.2 Cybernetics	04
1.3 Basic Laws of Systems	06
1.4 Roles of Models	06
1.5 Viable Systems Model (VSM)	07
1.5.1 System One	
1.5.2 System Two	
1.5.3 System Three	
1.5.4 System Four	
1.5.5 System Five	
1.6 Conclusion	12
<b>Chapter 2.0</b>	
<b>THE NATURE OF PROBLEMS</b>	<b>13</b>
2.1 Characteristics of Problem Situations	17
2.1.1 Complexity	
2.1.2 Dynamics	
2.1.3 Intransparence	
2.1.4 Ignorance and Mistaken Hypotheses	
2.1.5 Goal Setting	
2.2 Problems Relating to Quality	20
2.3 The Learning Organisation	21
2.4 Systems Failures	23
2.4.1 Categorising Failure	
2.4.2 Forecasting and Preventing Failure	
2.4.3 Failure Avoidance	
2.5 Basins of Stability	28
2.6 Conclusion	29

## Chapter 3.0

<b>FRAMEWORK FOR PROBLEMS SOLUTION</b>	<b>30</b>
3.1 System Dynamic Modelling (SDM)	31
3.2 Strategic Assumption Surfacing and Testing (SAST)	33
3.2.1 Group Formation	
3.2.2 Assumption Surfacing	
3.2.3 Dialectical Debate	
3.2.4 Synthesis	
3.3 Soft Systems Methodology	38
3.3.1 Stage one	
3.3.2 Stage two	
3.3.3 Stage three	
3.3.4 Stage four	
3.3.5 Stage five	
3.3.6 Stage six	
3.3.7 Stage seven	
3.4 Heuristics	45
3.4.1 Unbounded rationality	
3.4.2 Optimisation under constraints	
3.4.3 Bounded rationality	
3.4.4 Fast and frugal heuristics	
3.4.5 Principles for the use of heuristics	
3.5 Conclusion	55

## Chapter 4.0

<b>STANDARDISED APPROACH TO SHOP FLOOR MANAGEMENT</b>	<b>59</b>
4.1 Nissan Plant Management System	61
4.2 Policy Management (Hoshin Kanri)	63
4.3 Shop Floor Management (Genba Kanri)	66
4.3.1 Basic Philosophy of GK	
4.3.2 Foreman Training for GK	
4.3.3 Practice and Implementation of GK	
4.3.4 3 'S' Activities	
4.3.5 Standardisation	
4.3.6 Role of Manager in GK	
4.4 Synchronised Production (Douki Seisan)	72
4.5 Conclusion	78

## Chapter 5.0

<b>THE QUALITY STORY</b>	<b>80</b>
5.1 Step One (Selecting a Theme)	81
5.2 Step Two (Understanding the current Situation)	82
5.3 Step Three (Creating a plan of action)	84
5.4 Step Four (Analysing the Factors)	84
5.5 Step Five (Developing and Implementing Countermeasures)	85
5.6 Step Six (Confirming Effectiveness)	86
5.7 Standardisation and establishing control	86
5.8 QC Story and the PDCA cycle	88
5.9 Conclusion	90

## Chapter 6.0

<b>THE SEVEN QC TOOLS</b>	<b>91</b>
6.1 The Seven QC Tools	94
6.1.1 Pareto Diagram	
6.1.2 Cause and Effect Diagram	
6.1.3 Graphs	
6.1.4 Check Sheets	
6.1.5 Histograms	
6.1.6 Scatter Diagrams	
6.1.7 Control Charts	
6.1.8 Stratification	
6.2 Seven Management and Planning Tools	112
6.2.1 Interrelationship Digraph	
6.2.2 Affinity Diagram	
6.2.3 Tree Diagram	
6.2.4 Matrix Diagram	
6.2.5 Matrix Data Analysis	
6.2.6 Process Decision Program Chart (PDPC)	
6.2.7 Activity Network Diagram	
6.3 The QC Story and Quality Tools	128
6.4 Conclusion	128

## Chapter 7.0

<b>PRACTICAL APPLICATION OF QUALITY STORY</b>	<b>130</b>
7.1 Step One (Selecting a Theme)	130
7.2 Step Two (Understanding the current situation)	130
7.3 Step Three (Creating a Plan of Action)	133
7.4 Step Four (Analysing the Factors)	134

7.5	Step Five (Developing and Implementing Countermeasures)	137
7.6	Step Six (Confirming Effectiveness)	137
7.7	Standardisation and establishing control	138

## Chapter 8.0

<b>REFLECTION</b>	<b>139</b>
-------------------	------------

<b>REFERENCES</b>	<b>143</b>
-------------------	------------

<b><u>LIST OF FIGURES</u></b>	<b>PAGE</b>
-------------------------------	-------------

01	Formal Systems Model Indicating the Relationship between the system, wider System and the Environment	3
02	Viable Systems Model	8
03	The Meta System	10
04	Jackson's Extended Version of Jackson and Key's grid of problem contexts	15
05	Assumption Rating Chart	37
06	Diagrammatic Representation of the Soft Sytem Methodology indicating the seven stages of Implementation	45
07	Visions of Rationality	49
08	Nissan Plant Management System Map	62
09	Structure of Genba Kanri, Shop Floor Management	66
10	Diagrammatic Representation of GK activities	69
11	Alignment of the QC Story Problem Solving Procedure and Shewart's PDCA cycle	89
12	Flow chart for PC Board Assembly	93
13	Pareto Diagram for 'Problems in QC Circle Activities'	95
14	Cause and Effect Diagram for Manufacturing Problem	97

15	Run Chart for Percentage Defects Produced per day	99
16	Broken Line Graph for Parts Defect Ratio	100
17	Bar Chart of Vehicle Straight Through Ratio	101
18	Pie Chart of Vehicle Defects	101
19	Band Graph of Capital Expenditure per annum	102
20	Check Sheet for Defects in Assembly Process	103
21	Histogram for Melting Point of Fuses	105
22	Scatter Diagram for Weld Diameter and Strength	107
23	Control Chart for External Diameter Dimensions (x and R chart)	109
24	Stratification of Plant Injuries	111
25	Interrelationship Diagram for missed delivery dates	113
26	Affinity Diagram for "What is the future of QA"	116
27	Tree Diagram for Reducing Data Entry Complexity	118
28	Matrix Diagram for Countermeasures to Eliminate Claims Against Products	120
29	Matrix Data Analysis for the Reduction of Data Entry Complexity	123
30	Process Decision Program Chart (PDPC)	125
31	Activity Network Diagram	127
32	Application of Quality Tools in QC Story Framework	128

**LIST OF TABLES**

**PAGE**

A. Skills Evaluation and Training Standard	68
B. Step Up Activity for Douki-Seisan	77
C. Quality Story Problem Solving Procedure	87

## ABSTRACT

This thesis is aimed at engineers as problem solvers operating within an automotive environment that is governed by Japanese management practises. The reason for this specific focus is that the engineer in this environment plays a particularly important role in the establishment and maintenance of production with regards to quality, cost and delivery performance. It is therefore imperative that the engineer fully understands the Japanese management system and the role that he has to play. Although specifically focused, there is no reason why this practise can not be used by problem solvers operating in any environment, as the principles remain the same.

The first section of this thesis is dedicated to the understanding of the organisation, systems thinking and the laws that govern systems. Management Cybernetics is introduced as a system used to deal with the effective management of complex organisations. The problem solver will be faced with a large degree of information and variety and through the law of Requisite Variety, will understand the need to filter out and only consider that which is relevant to the problem. Stafford Beer's Viable Systems Model is used to illustrate the different levels of the organisation and their roles internally as well as their interface to the external environment. In this way, the problem solver or engineer can understand his or her role within the organisation and the interface between the different levels when dealing with problems.

The next logical step is to understand the nature of the problem situation itself and to this end, the next section introduces the classification of problems. The categories depend on the complexity of the system in which they reside, whether they are mechanical or systemic and on the relationship between the participants. Jackson's extended grid is used to illustrate the different categories in terms of Unitary, Pluralist and Coercive depending on the degree of co-operation between the people involved in the problem resolution.

In order to become an effective problem solver, it is necessary to understand the nature of failure and to learn from the experience. A definition of failure in systems terminology is 'the production of undesirable outputs of the system'. The understanding of how and why failures occurred in the past can help to influence and avoid them happening in the future. One way to reduce the incidence of

failure is to make use of failure avoidance in the form of a Failure Mode and Effect Analysis (FMEA). If not eliminating the failure, this reliability approach can reduce the impact if the failure has at least been anticipated and planned for. The problem solver next needs to understand the tools or methodologies that are available to him to assist with problem resolution. The first methodology in Chapter 3 is Systems Dynamic Modelling which relies heavily on structure and is used to predict the outcome of a system under varying conditions. In contrast to Systems Dynamics, Strategic Assumption Surfacing and Testing concentrates on the relationship between the many participants bringing the political and human aspects of the organisation to the fore. The source of this methodology is from the works of R.O.Mason and I.I.Mitroff and with much of the philosophy based on the thinking of Churchman in his book 'The Systems Approach.' The next methodology described in this chapter is the Soft System Methodology developed by P.B.Checkland and is based on the belief that problems do not exist independent of the people involved. In this way, problems can be best understood and solved by the sweeping-in of all the different perceptions of the people involved to find solutions that all are committed to make work. The last section of this chapter is dedicated to Herbert Simon's vision of heuristics which leads the problem solver to make use of bounded rationality. The image of 'Laplacean demons' possessing super human intelligence is used to illustrate the shortcomings of unbounded rationality due to the massive demand on time, knowledge and computational resources. The greatest weakness of unbounded rationality is that it does not describe the way real people think. Principles such as a 'stopping rule' and 'satisficing' are introduced to limit the time spent on searching for information. Fast and frugal heuristics are introduced as employing minimum time, knowledge and computation to make adaptive choices in real life situations.

As mentioned previously, it is necessary for the problem solver to understand the basics of Japanese management practises and to this end, Chapter 4.0 describes the most important of these practises in detail. Nissan has been used as an example for the Japanese management practises in the form of the Nissan Plant Management System (NPMS). Underlying this system is standardisation and globalisation to enable comparison of performance and benchmarking with other plants world wide.

Having a good understanding of the philosophy behind Japanese management practises, it is now possible to understand the need for a standardised problem solving technique. Chapter 5.0 describes just that under the name of 'The Quality Story'. Rather than a problem solving methodology, this is a rigid framework for how to proceed in problem resolution. This step by step framework leads the problem solver through a very logical thought process of first understanding and then improving on the problem situation. The setting of a target for improvement in the initial stages is fundamental to understanding what the desired state should be. 'No journey is complete until the end is reached and therefore, it is necessary to know where the end is before embarking on the journey.' Only when the defined target is achieved, can the problem be considered completed. If the target is not clearly stated up front then, on many occasions, during the problem resolution process, the target is 'watered-down' in line with the actual achievement. In so doing, the original, desired state will never be achieved. Effective use of available data is essential for problem resolution and to this end, the next section, Chapter 6.0, has been dedicated to the detailing of the seven old and seven new quality tools. Unrefined data is of no use to the problem solver and will not help to lead him towards understanding and solving the real problem. Selected data can also be misleading and can sometimes be used to support individuals personal or political viewpoints. It is therefore essential that the problem solver collects his own data and establishes his own understanding of the current situation to ensure a balanced and unbiased view. The tools detailed in this section can be used throughout the different stages of the framework to make best use of data for understanding, analysis and planning. The use of data throughout the process enables the results of problem resolution to be measured and defined in terms of the objectives set out in the initial stages of the analysis. The practical application of the Quality Story detailed in Chapter 7.0 serves to illustrate just how effective this methodology is for problem solving as well as continual quality improvement making best use of the quality tools. As mentioned previously, the Quality Story is rigid with regards to the thought process that must be applied, but not with regards to the format that is used. Consequently, each Quality Story will look different depending on the amount of data and analysis that is required in each stage of the process.

## INTRODUCTION

Engineers in a mass production environment are called upon on a daily basis to solve a multitude of problems varying from deterioration in the quality level of the product to conditions resulting in the required production volume not being met. The only thing the engineer knows for sure on the outset to addressing a problem is that, if the problem was not there previously and it is there now, then something has changed.

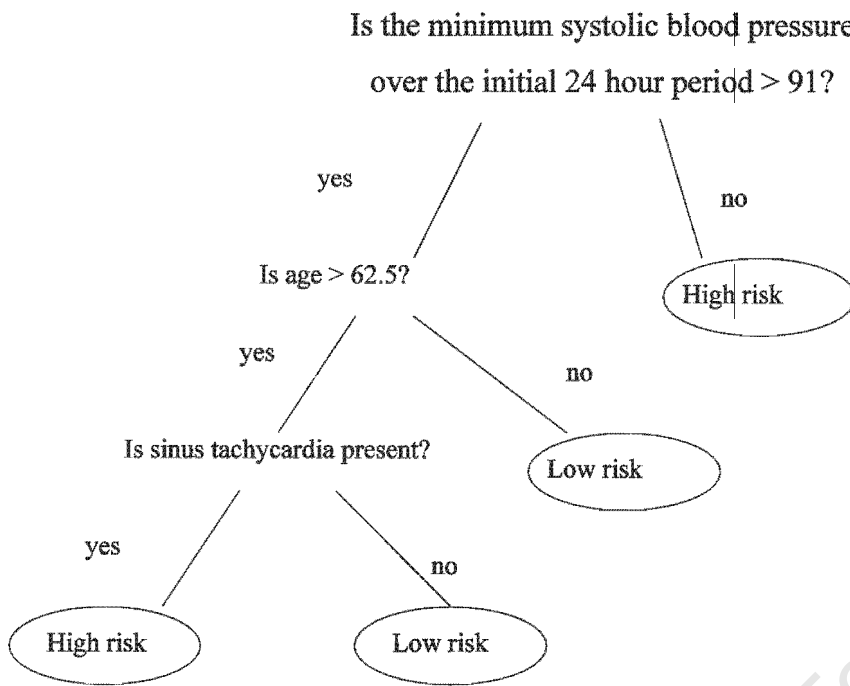
Change is particularly prevalent in the automotive industry where quality levels and productivity improvements are a daily occurrence and new products are introduced on a regular basis. Due to the highly competitive nature of the industry, failure to continually improve quality and reduce costs would result in a loss of market share and ultimately in a loss of profitability. One of the cornerstones of Japanese management philosophy is the strive towards continual improvement through a process known as *Kaizen*. Engineers play an important role in the promotion of the Kaizen activity to improve both quality and delivery through the improvement of the process as well as reducing cost through the elimination of waste.

The engineer as problem solver is working with limited time, knowledge and resources and needs to find solutions that are both relevant and effective. He needs to decide on an appropriate problem solving methodology that will be suitable for the situation. A balance must be made between trial and error solutions based on his knowledge and previous experience and full analytical methodologies that require much time in computing all the possible alternatives. Fundamental to the successful solution of problem situations is the initial formulation of the problem and the understanding that the first impression of the cause of the problem may not be correct. Much time and effort can be wasted in the addressing of the symptoms rather than understanding and solving the root cause of the problem. By addressing the symptoms, a short term improvement can normally be seen but, given time, the problem will more often than not reappear.

Further complicating problem resolution is the realisation that problems do not exist in isolation of the organisation in which they are found. The organisation is, in itself, a complex system of interactions between people and machines, the elements of which are not always easy to understand. The existence of the problem may be as a result of the social/political interaction between different departments at that particular point in time. Problems can also take on more importance or magnitude at different times depending on certain individuals or elements that require the problem to exist. This can explain why previously minor problems can, all of a sudden, be elevated to a level that they become potential 'line stoppers'.

Engineers are often faced with problems on the production lines that requires them to make fast and appropriate decisions to prevent long and costly line stoppages. The luxury of having time to consider all possibilities and calculate all probable outcomes is not available, therefore, the engineer must fall back on to his experience and make a decision based on the limited information that is available. Having implemented the countermeasure to overcome the immediate concern, the engineer must follow up with a quick evaluation that confirms his initial understanding of the problem and, if necessary, reinforce and justify the decision that was taken.

The engineer's situation on a production line can be likened to a doctor treating a patient for a heart attack. The doctor's immediate concern is whether or not to treat the victim as a high or low risk patient. If the patient is at a high risk, then his life is threatened and he should be afforded the most expensive care and even possibly surgery. Even though this initial decision could cost the life of the patient if the wrong decision is taken, the doctor must decide using only the information that is readily available. The correct and safer method to decide would be based on all information obtained from an extensive range of tests but time does not allow and instead, the decision is taken based on only three variables. The following simple decision tree indicates a method used to determine the patients risk profile and makes use of only three variables:



**A simple decision tree for classifying heart attack patients into high and low risk.**

This decision process is simple in that it ignores a vast majority of information that could be obtained and ignores quantitative information by using only yes and no answers to the questions. The strategy is a step by step process leading to the final decision and could end after the first question and does not add or weight the values of the three determinates. This process is a fast and frugal strategy in that it does not involve any extensive computations and only searches for some of the available information.

The engineer's situation, although not life threatening, is similar in that problems must be solved under the threat of possible line stoppages and producing sub standard products, when time and information are both limited.

What is required is a step by step framework that can be used to lead the engineer through a logical process when faced with day by day problems.

Use must be made of the available information and the process must be frugal in that time and resources to gather and compute extensive information are not available. The process must also be standard in its application to support the Japanese management requirement for standardisation and must support the use of analytical problem solving methodologies when the problem is of a more complex nature.

## CHAPTER 1.0

### A SYSTEMS VIEW OF ORGANISATION

*In order to implement management interventions with the intention of improving a problematic situation, it is first necessary to understand what governs the elements of the organisation and enables them to operate and produce the required outputs. Pre-systems thinking was dominated by a mechanistic viewpoint which believed that organisations could be reduced to the elements making up the whole and that by independently optimising the performance of the elements, the organisation could be made to perform. This reductionistic thinking implied that the organisation was equal to the sum of all its parts. Systems thinking on the other hand recognises that organisations are complex systems the whole of which is greater than the sum of its parts and should be treated as entities whose identity and integrity should be respected. They have emergent properties peculiar to themselves which could not be derived from their parts and are open rather than closed to their environment. The system does the work of transforming inputs into outputs and the processes within the system are characterised by feedback either directly from one element to another or indirectly via a series of connected elements, to influence the element that initiated the behaviour.*

*An organisation is able to sustain an identity by maintaining itself in a dynamic state of homeostasis in the face of and using its changeable environment. A system that maintains an identity and stable transformation processes over time, in changing circumstances, is said to be exhibiting some form of control. Systems occur in hierarchies and may therefore be considered as a sub-system of a wider system.*

*Cybernetics on the other hand is defined as “the science of effective organisation” (Stafford Beer, 1979) and provides tools and a method of analysing the extreme complexity that organisations experience. The Viable Systems Model (VSM) was developed out of a cybernetic background and can be used to diagnose faults in any organisational system or to design new systems.*

## 1.1 SYSTEMS THINKING

(System Approach to Failures, The Open University, 1993)

A system is a transformation process that converts a set of inputs into a set of outputs and consists of a number of subsystems that themselves have all the qualities and characteristics of a system. Conversely, taking the hierarchical nature of systems, each system will exist and operate within a wider system.

The wider system will:

- set the objectives or define the purpose of the system
- strongly influence the decision taker within the system
- monitor, or measure the performance of the system
- provide the resources to allow the system to function.

External to the wider system is the environment in which it operates and which affects it and which the system can attempt to influence. Whereas both the system and the wider system have boundaries, the environment, by its nature, has no boundary.

Each system must contain the following subsystems:

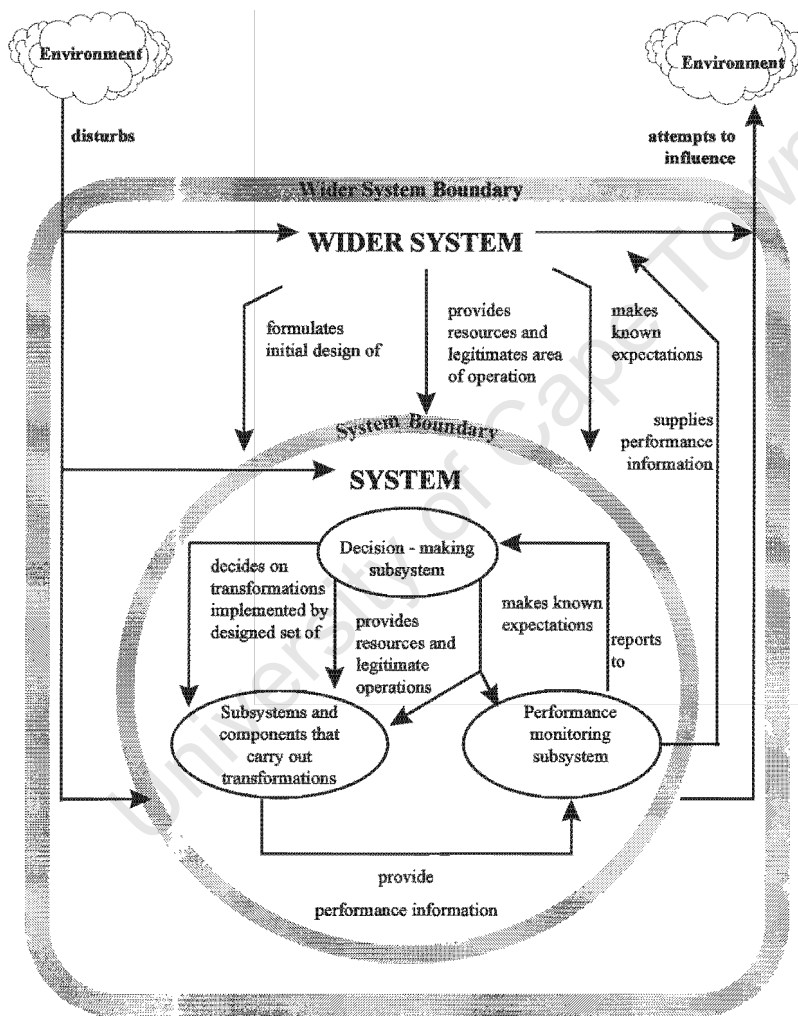
- a decision making subsystem
- a performance monitoring subsystem
- subsystems which carry out the specific tasks of the particular system and thus effect its transformation.

Refer to FIGURE 01 for a diagrammatic representation of a formal systems model indicating the relationship between the different systems and the environment.

When a system fails to produce the anticipated output, one or more of the following situations may exist:

- (1) Deficiencies in the apparent organisational structure, such as a lack of a performance measuring subsystem or a control/decision taking system.
- (2) No clear statement of purpose supplied in a comprehensible form from the wider system.
- (3) Performance of one or more of the subsystems deficient.
- (4) Ineffective means of communication between the subsystems.

- (5) A subsystem inadequately designed.
- (6) Insufficient consideration given to the influence of the environment and sufficient resources to cope with foreseeable environmental disturbances not built into the organisation.
- (7) Imbalance exists between the resources applied to the basic transformation processes and the related monitoring and control processes leading at one extreme to quality problems and at the other to cost or quantity problems.



**FIGURE 01:** Formal systems model indicating the relationship between the system, wider system and the environment.

(Model taken from *THE OPEN UNIVERSITY, Systems Paradigms, Studying Systems Failures, 1993*).

## 1.2 CYBERNETICS

(Clemson, 1984)

The generally accepted father of Cybernetics, Norbert Wiener defined it as “The science of effective communication and control in man and machine”.

Stafford Beer defines it as “The science of effective organisation”. In this context, Beer is thinking of systems having the following characteristics:-

- **COMPLEX:-** more relevant detail than the observer can possibly cope with.
- **DYNAMIC:-** changing in behaviour or structure or both
- **PROBABLISTIC:-** elements whose behaviour is at least partly random.
- **INTEGRAL:-** act in some important sense as a unity.
- **OPEN:-** embedded in an environment which affects them and which they affect.

Management Cybernetics is therefore applied science used to deal with the effective management of complex organisation.

The key notion in Cybernetics is that of circular causality generally referred to as feedback. The second fundamental is that the whole is more than the sum of the parts, that the characteristics of the system are due to the interaction among the parts.

Cybernetics provides a method of analysing extreme complexity resulting from the interaction of the following four determinants:

- The number of elements comprising the system
- The interactions among these elements
- The attributes of the specified elements of the system
- The degree of organisation in the system.

Systems that are too complex are handled by being considered as black boxes and in order to cope with these black boxes, it is necessary to gain some knowledge of system behaviour even if it is never understood what causes that behaviour.

Stability within an organisation is brought about by the existence of mechanisms that exert self regulation on the system. Wiener (1948) established that the way to ensure self regulation is through the negative feedback mechanism. The feedback

control system is a closed loop structure that operates by the continuous feedback of information about the output of the system. This output is then compared with predetermined goals and, if the system is not achieving its goal, the margin of error (the negative feedback) becomes the basis for adjustment to the system to bring it closer to its goal. In order for this system to work, the following four elements are required:

- A desired goal, which is conveyed to the comparator from outside the system
- A sensor ( a means of sensing the current state of the system)
- A comparator which compares the current state and the desired outcome
- An activator ( a decision making element that responds to any discrepancies discovered by the comparator in such a way as to bring the system back towards its goal ).

Feedback control systems may not be sufficient to regulate organisations, it may be necessary to employ strategic control based on feedforward information that attempts to predict disturbances before they actually affect the organisation.

The ability of an organisation to respond to unexpected occurrences to which it is continually confronted determines whether or not it will be successful.

The complexity of a system is defined as the number of possible states it is capable of exhibiting. It is a measure of the complexity of the system and is a subjective concept depending on the observer. However, organisations and their environments are systems that possess massive variety. According to Ashby's law of requisite variety, only variety can destroy variety. Therefore, in order to control a system, the regulator must have as much variety available as the system itself exhibits. It is possible to reduce the variety a system is confronted with through variety reduction or to increase the variety of the regulator through variety amplification. This process of balancing varieties is known as " variety engineering" (Beer, 1979).

Managers must learn how to use variety reducers to filter out the vast complexity of operational and environmental variety and capture only that which is of relevance to the organisation.

### **1.3 BASIC LAWS OF SYSTEMS**

Three basic laws of systems apply to Cybernetics and are of particular interest to management:-

#### Self Organising Systems:

Complex systems organise themselves. The characteristic structural and behavioural patterns in a complex system are primarily a result of the interaction amongst the system parts. Every self organising system has a region of stability separated by thresholds of instability.

#### Feedback:

The output of a complex system is dominated by the feedback and (within wide limits) the input is irrelevant. All outputs that are important to the system will have associated feedback loops.

#### The Law of Requisite Variety:

Given a system and some regulator of that system, the amount of regulation attainable is absolutely limited by the variety of the regulator. Most of the regulation of complex systems is achieved through the interaction of the parts (i.e. one part acts to regulate some other part).

Every manager finds himself confronted with a situation that is more complex than himself. Therefore, by the law of requisite variety, the Manager is always faced with a situation in which it is not theoretically possible to achieve complete regulation. Therefore, the Manager enters a situation with certain knowledge that his regulation over the situation will be partial and incomplete. Managers, through regulation, select the outcomes they require out of those that are possible.

### **1.4 ROLES OF MODELS**

Managers are faced with trying to change the behaviour of situations. The managers actions are based on a framework that includes at least four elements:

- Some image of preferred state
- Some image of the current state of the system
- Some image of how the system works
- A belief based on the previous three images that the situation can be improved by a given method of managing.

## **1.5 VIABLE SYSTEMS MODEL (VSM)**

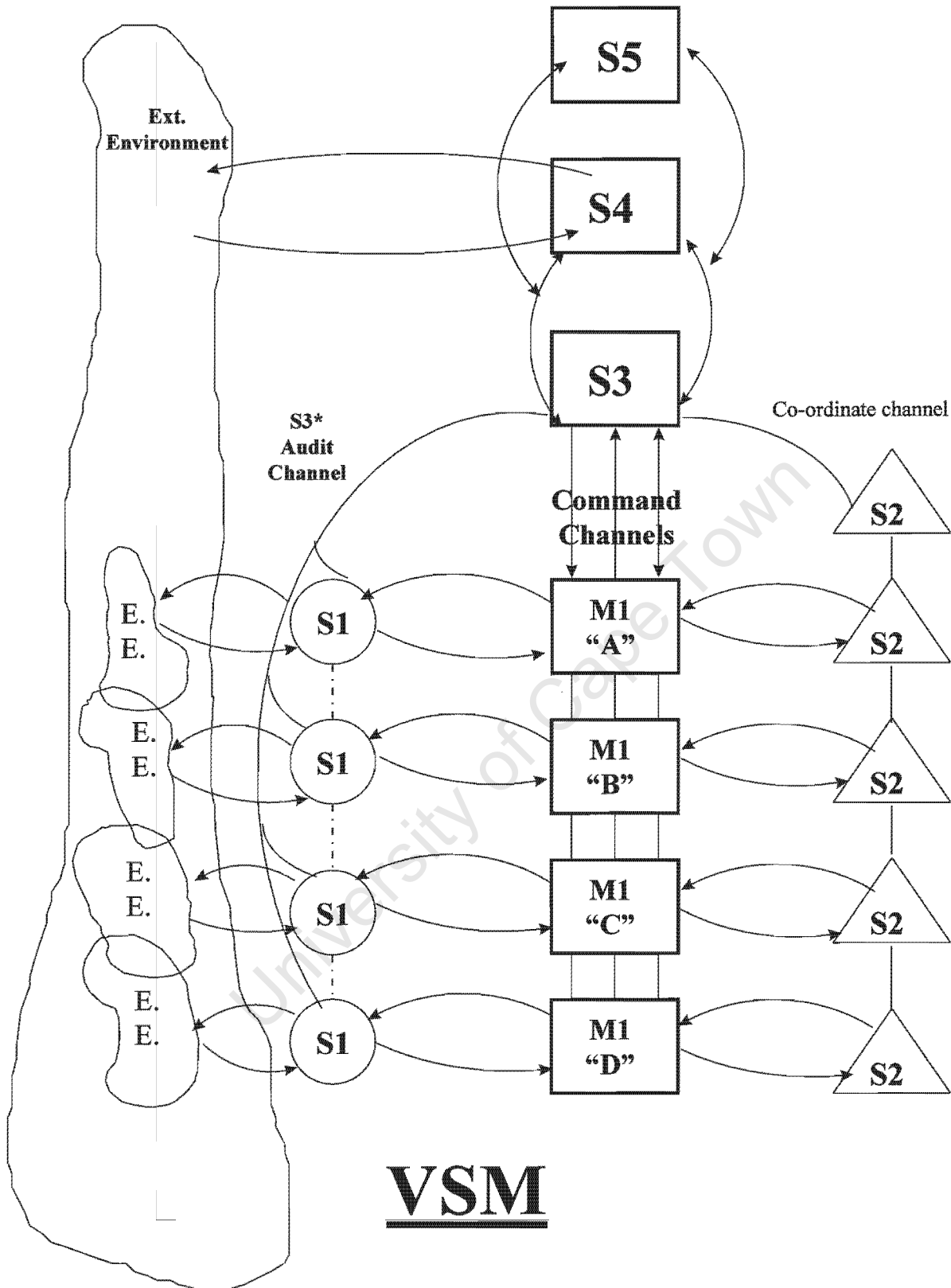
The Viable System Model is Stafford Beers design for effective formal organisation based explicitly upon the principles of Cybernetics (Beer, 1979). The model facilitates consideration of what is and is not possible within formal organisations and provides guidance in creating efficient structures. Refer FIGURE 02 for a typical diagrammatic representation of a Viable Systems Model. The VSM specifies five broad functions that must be carried out in any organisation that manages to both maintain internal stability and adapt to the changing environment. These functions are designated systems one through to system five.

### **1.5.1 SYSTEM ONE**

An organisation typically consists of a number of operational units each influenced by its own environment and requiring management and control. Each of these operational units interact and influence each other and collectively (excluding the environment) constitutes an organisational entity referred to as System One.

The System One functions are also termed the “value added” operations as they produce the output of the organisation.

The survival and effectiveness of each operational unit is the primary concern of the management of each unit who are charged with making that unit work well. However, the survival and effectiveness of the larger organisation may require that the unit be decreased in size or even abolished altogether. Such choices are necessarily the responsibility of management other than the units own. Thus we see the need for a higher level of management referred to as the meta system to System One and consisting of Systems Two to Five. In Cybernetic terms, the meta-system must maintain the homeostasis of the organisation to make sure that all the critical variables are maintained within their normal limits so that the overall organisation can continue to function effectively.



**NB:** The model re-occurs only in S1. The reason is that S1 is viable

**FIGURE 02: VIABLE SYSTEMS MODEL**

### **1.5.2 SYSTEM TWO**

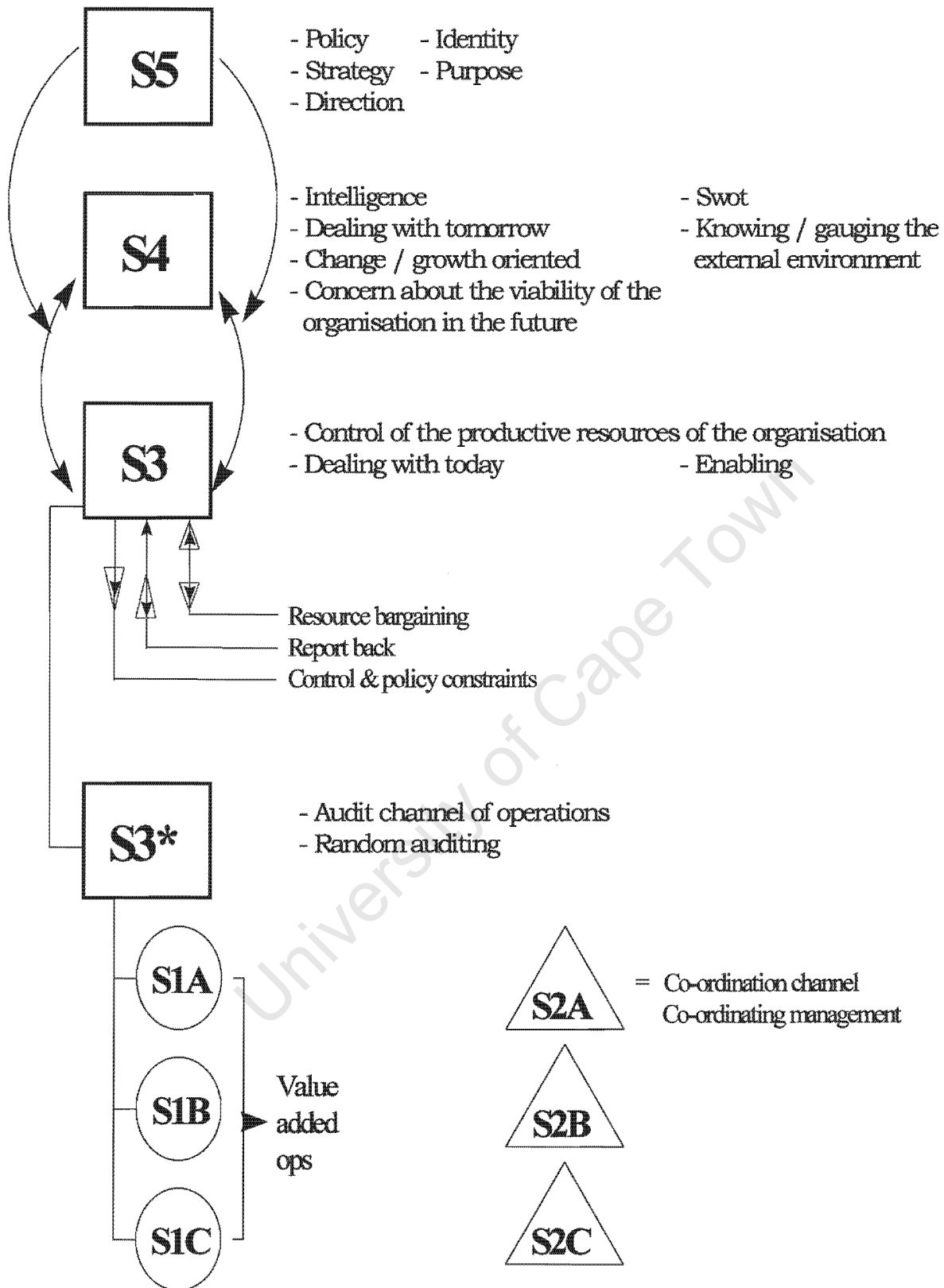
System Two's function is to prevent the various operational units from affecting each other through inadequate co-ordination. This function should not have the right to tell anybody what to do except in so far as particular activities need to be regulated to avoid oscillations. In this sense, System Two should be a servant to the operational elements and should not be another boss. However, being located within the meta system, it has the power of System Three behind it. (Refer FIGURE 03 for a pictorial view of the Meta System).

### **1.5.3 SYSTEM THREE**

System Three is charged with maintaining the internal homeostasis of the organisation and must ensure that the various operational units are in fact producing what they should. System Three therefore has the whole power that comes from control of the productive resources of the organisation. Its responsibility is for the internal environment and the "now" situation.

System Three uses S2 as a command channel for giving orders to the management of System One. It also has an audit channel designated as S3\* for in-depth investigation into any of the operational units as and when required.

Due to the vast complexity of the operational elements, System Three finds itself faced with the major task of controlling the huge variety of operations. The way this is handled is by treating each operational element as a black box and only monitoring the critical outputs of each box. In this way, System Three can ignore the internal workings of each unit so long as the outputs are reasonable. To this end, the critical outputs of each operation must be identified and monitored. System Three must ensure that the internal operational elements are able to secure the resources (people, machine, raw material and money) required to function.



**FIGURE 03: THE META SYSTEM**

#### **1.5.4 SYSTEM FOUR**

System Four is charged with the external environment and the future in contrast with System Three which deals with the internal environment and the present.

The first function of System Four is to create an explicit model of the organisation and define what the organisation does and how it does it. The second function is to model the organisation environment by establishing which aspects of the environment are actually critical, which aspects the organisation can affect and which aspects actually affects it.

The third function of System Four is to deal with the future by developing an explicit model of the future desired situation.

In other words, the functions of System Four are:-

- a) Providing a focus for the organisations explicit self knowledge.
- b) Providing a focus for the organisations explicit knowledge of its problematic environment.
- c) Creating the organisations desired future.

#### **1.5.5 SYSTEM FIVE**

The function of System Five is to maintain a creative tension between System Three focusing on maintaining the status quo and System Four committed to all sorts of improvements for the future. In maintaining the balance between stability and change, it is essential that the whole organisation has a shared view of identity. As System Five's principle role is strategy, policy and identity, it's responsibility lies mainly with the board of directors or CEO.

Failure to maintain a clear organisation's identity results in System Five collapsing down to System Three with directors controlling production and dealing with today issues rather than the future.

This phenomenon results in the following three problems;

1. Directors carrying out internal warfare (politics) with each other.
2. Total neglect of the System Four role of the external and the future.
3. Causes serious problems for the System One operational units trying to achieve the intended mission.

Most successful organisations exhibit a very clear and explicit corporate identity that fits the operation at that point in time. Thus the balance between today and tomorrow (System Three and Four) is crucial to the survival of the organisation.

Notice from the VSM (refer FIGURE 02) that only System Four and the System One operational units have direct connections to the external environment. This further illustrates that the System Three function is focused on the internal environment and System Five is concerned with the integration of the whole organisation.

## **1.6 CONCLUSION**

The purpose of this section was to illustrate to the engineer or problem solver the complexity of the organisation in which he is functioning. Each problem situation should be seen in the light of where it appears in the organisation and why the problem exists at all. In this way, problem situations take on a whole new perspective and more appropriate and effective solutions can be found. The next section deals with the nature of problems and their different classification depending upon whether they are simple or complex and on the relationship between the participants involved.

## CHAPTER 2.0

### THE NATURE OF PROBLEMS

*Problems can be categorised depending on their degree of complexity, whether they are mechanical or systemic, the complexity of the system in which they reside and the relationship between the participants involved in the problem situation. Even simple, mechanical problems can become complicated once the personalities or political aspirations of the different people involved come into play. Jackson's grid is used to show the different classifications of problems from unitary, where the participants are fully co-operative, to coercive, where one participant must exert his will over the others to achieve a resolution. An initial reference is made to hard as well as soft system methodologies for the solving of the different types of problems.*

*The characteristics of problem situations like complexity, intransparence, internal dynamics and incomplete or incorrect understanding of the system are basic to all intricate situations in which problem solvers are called upon to plan and act carefully.*

*Jung made the following statement about learning: 'The psychotherapist learns little or nothing from his successes. They mainly confirm him in his mistakes, while his failures on the other hand, are priceless experiences in that they not only open up the way to a deeper truth, but force him to change his views and methods.' Learning is a vital part in the development of individuals and as such, Senge's five disciplines for the creation of a learning environment is a necessary addition to this chapter. It is crucial that individuals understand why failures occur and learn from theirs and others mistakes. Only through these experiences will they become better and more effective problem solvers.*

Before attempting to solve a problem situation, it is necessary to have a good understanding of the nature of a problem situation and all the factors that can effect the problem. Problems do not exist in isolation to the systems that are effected and any intervention or improvement will have an effect on other elements of that and other systems. Even simple mechanistic problems can

become complex once the human element of the different participants is taken into account. If the participants associated with the problem context are in general agreement on objectives, share common interests, have compatible values and beliefs and all participate in the decision making process, then the problem will be less difficult to solve than if their objectives conflict. On the other hand, if there is little or no common interest between the participants, then the problem will be more difficult to solve and will more than likely result in the need to exert power or dominance by one of the participants to force through a solution.

Other than the participants involved in the problem situation, the other determinate is the complexity of the system in which the problem resides, and can be categorised from simple through to complex, depending on the characteristics it contains.

Simple systems exhibit the following characteristics:

- small number of elements
- few interactions between the elements
- attributes of the elements are predetermined
- interaction between the elements is highly organised
- well defined laws govern behaviour
- system does not evolve over time
- sub-systems do not pursue their own goals
- the system is unaffected by behavioural influences
- the system is largely closed to the environment

Complex systems on the other hand exhibit the following characteristics:

- large number of elements
- many interactions between the elements
- attributes of the elements are not predetermined
- interaction between the elements is loosely organised
- they are probabilistic in their behaviour
- the system evolves over time
- sub-systems are purposeful and generate their own goals
- the system is subject to behavioural influences

- the system is largely open to the environment.

It is not to say that large systems are by necessity complex and small systems are simple but should rather be classified in terms of the characteristics which they possess.

By the nature of the problem, whether it is mechanical or systemic, and by the complexity of the system in which it resides, together with the nature of the interaction of the participants, it is possible to classify the problem situation into one of the following three categories:

Unitary- where the participants have a common interest and work together to come to an acceptable solution to the problem

Pluralist- where the participants have different interests and objectives but a genuine compromise can be reached which will be acceptable to all.

Coercive- where no common interest exists between the participants and the only way a solution can be found is through the exertion of power or the domination of one participant over the others.

This classification implies that all the participants of any problem situation must be able to be placed into one of the three categories and by applying the split between systemic and mechanistic, it is possible to classify all problems into one of six different classifications as depicted in figure 04.

		PARTICIPANTS		
		UNITARY	PLURALIST	COERCIVE
M E C H A N I C S Y L S T E M S Y S T E M I C	Mechanical			
	Systemic			

**FIGURE 04:** Jackson's Extended Version of Jackson and Key's grid of problem contexts.

The terms unitary, pluralist and coercive are used to describe the relationship between the participants of the problem situation.

Having established the grid of six different problem classifications, the temptation is to try and place all problem situations into one of these categories and implies that six different problem methodologies would be required to handle each of the six different categories.

This is not entirely true since, in the real world, problems will not readily fit into the different categories, and the use of different methodologies is far from arbitrary. It is very much left to the discretion of the problem solver as to the preference of which method will be used. Support for the classification of problems from the variables of systems and participants can be found in the works of Ackoff and Habermas on the basis that organisations are sociotechnical systems.

Hard type methodologies seem to be better suited for tackling mechanical, unitary type problems in that these problems are more of a mechanical nature with easy to establish objectives for the system in which they reside. It is then possible to represent the system in a quantitative model that simulates the performance under differing operational conditions.

On the other hand, methodologies based on cybernetic principles seem better suited for systemic, unitary type problems where a view on organisations as systems is required to best understand the operational needs.

Soft system thinking methods like “strategic assumption surfacing and testing” proposed by Mason and Mitroff (1981) and Ackoff’s approach to “interactive planning and responsive decision system” could be used for pluralistic, mechanical and systemic problems. Coercive problems however are far more difficult to handle and require methods such as Ulrich’s critical systems heuristics, which pays special attention to the need for coercion, in order to tackle the very complex situations that can be encountered in these problem situations. It is not to say that these methodologies should be used as indicated, but, the problem solver should be aware of each of the different methods together with their different strengths and weaknesses as well as the underlying assumptions on which they are based, before deciding which one to use.

## **2.1 CHARACTERISTICS OF PROBLEM SITUATIONS**

Planning and decision making processes can go wrong if not enough attention is given to the possible side effects of countermeasures and their long term repercussions. Some analysts claim that humans have a strong tendency to visualise when forming hypotheses about the world and events that take place within it and that the mind therefore has a great difficulty grasping problems that can not be visualised. There is no thinking without emotion. People get angry when they can not solve a problem and that anger influences their thinking. This situation can be improved however if people understand the demands that problem solving places on them and the errors that are prone to be made when they attempt to meet them.

### **2.1.1 COMPLEXITY**

In order to solve problems effectively, the complexity of the many features and the influences between them must be kept in mind. The more variables and the greater their interdependence, the greater is that systems complexity. Great complexity places high demands on the problem solver capacity to gather information, integrate findings and design effective actions. Links between variables means that many features have to be dealt with simultaneously and it is impossible to undertake only one action in a complex system. Interrelationship between the variables guarantees that any action that affects or is meant to affect only one part will also affect other parts of the system.

### **2.1.2 DYNAMICS**

The dynamics inherent in systems make it important to understand developmental tendencies. Systems are not standing still waiting for someone to make changes therefore it is not possible to gather all the information before taking action. Often solutions must be implemented based on limited, incomplete knowledge because time pressures force action before complete information can be gathered and a comprehensive plan put in place. Problem solvers can not study a system at one point in time but must instead try to determine where the whole system is heading over time.

### **2.1.3 INTRANSPARENCE**

Intransparence injects another element of uncertainty into planning and decision making in that what is needed to be seen may not be visible. Planners and decision makers may have no direct access or indeed no access at all to the information about the situation they must address. They must make decisions affecting a system whose momentary features they can only see partially or possibly not at all.

### **2.1.4 IGNORANCE AND MISTAKEN HYPOTHESES**

In order to operate within a complex and dynamic system, it is necessary to know not only what its current status is but also what its status will be, or could be in the future and how actions taken will influence the situation. To achieve this, structural knowledge of how the variables within the system are related and how they influence one another must be known. This assumption created within the problem solvers mind about the reciprocal influences between the variables is called that individual's 'reality model' of the situation. A reality model can be explicit and always available to the individual in a conscious form, or it can be implicit with the individual himself unaware that he is operating on a certain set of assumptions and unable to articulate what those assumptions are. Implicit knowledge is common and is referred to as 'intuition.'

An individual's reality model can be right or wrong, complete or incomplete and as a rule, it will be both incomplete and wrong. Decision makers and problem solvers must keep this probability in mind that their own perception or reality model of the situation may be flawed. People are most inclined to insist that they are right when they are wrong and when they are beset by uncertainty and may even prefer their incorrect hypotheses to correct ones. The ability to make allowances for incomplete and incorrect information and hypotheses is an important requirement for dealing with complex situations.

The following analogy taken from Dietrich Dorner's book 'The Logic of Failure' (Dorner, 1989) best describes the task awaiting a decision maker dealing with a complex situation:

‘A decision maker in a complex situation can be likened to a chess player whose set has many more than the normal number of pieces, perhaps many dozen. Furthermore, these chessmen are all linked to each other by rubber bands, so that the player can not move just one figure alone. Also, his men and his opponent’s men can move on their own and in accordance with rules the player does not fully understand or about which he has mistaken assumptions. To top things off, some of his own and his opponent’s men are surrounded by a fog that obscures their identity.’

### **2.1.5 GOAL SETTING**

Without goals, it would not be necessary to do anything! When dealing with problems in complex systems, few things are as important as setting useful and meaningful goals. Goals can come in many forms, they may be positive or negative, general or specific, clear or unclear, simple or multiple and implicit or explicit.

A positive goal is where something needs to be achieved whereas a negative goal is when the desire is to remove some unwanted condition. Generally a positive goal is defined very precisely whereas a negative is not so specific.

A general goal is one that is defined by one or two criterion whilst a specific goal is defined by many and is described and conceptualised very precisely. A general goal has a clear criterion while an unclear goal is one that has no clear criterion and it is difficult to decide with certainty whether the goal has been achieved. An example of an unclear goal would be ‘Improve Quality’. This goal indicates that the actual desired state is not known and that the condition should be different to some degree from the current state.

Pursuing multiple goals means that many factors have to be attended to and several criteria must be satisfied when action is implemented. The interrelationship between variables within a system brings with it an interrelationship among goals. Goals, like the variables, may be positively, negatively linked or not linked at all. If two goals are positively linked, it implies that by satisfying one, the other will automatically be satisfied. This is not the case in negatively linked goals in that the satisfying of the one will fail to satisfy the other.

Explicit goals are those that people are aware of and working towards achieving whilst, unknown to them, there may be other implicit goals that they may be unknowingly pursuing. Implicit goals may be dangerous because they go unnoticed at the early stages of the planning process and emerge only after goals to which they are linked are pursued. More often than not, implicit goals are negatively linked to other goals and have a detrimental effect on the outcome.

## **2.2 PROBLEMS RELATING TO QUALITY**

In theory it should be possible to avoid quality problems by adopting procedures and processes that guarantee success. Such an approach would not be feasible since even if it were practical, a complete zero defect process would require limitless resources. A more logical approach is the setting of appropriate quality standards and an integrated quality system capable of measuring performance and employing some form of problem solving mechanism. Many of these systems are based either on the teachings of the so-called quality gurus like Crosby's zero defect and Deming's 14 points or on one of the many international customer quality standards like ISO 9000, Q101 and VDA6, or some combination of the two. No matter what system is used, some mechanism for tackling quality problems must exist. These problem solving mechanisms can vary greatly from Crosby's use of quality circles or similar teams to Juran's employment of an improvement programme which makes use of problem solving specialists. The problem solving mechanism can provide an umbrella under which many problems can be tackled making use of problem solving methods such as brainstorming, Pareto analysis, cause and effect diagrams to name but a few (refer Chapter 6.0 The Seven QC Tools).

One of the basic principles behind many of the problem solving mechanisms is that participants are free to operate on problems that they select themselves as being of greatest concern to themselves and their customers. This principle is adopted so as to secure full commitment to the problem solving process.

One problem to this approach is that it leads to solutions being found to easily definable, lower level problems whilst higher level, higher consequence problems are neglected.

There is not much difference between a quality problem and a failure as they are both concerned with performance and any non-conformance to specification or standard can be considered as a failure. It is normally the scale of the problem that causes observers to distinguish between a quality problem and a failure.

For example, a weld defect coming off an automotive assembly line is not much different and shares many features with the weld problem that led to the collapse of the Alexander L. Keilland oil rig in the North Sea in 1980. The former however would be treated as a quality problem and the latter as a failure.

### **2.3 THE LEARNING ORGANISATION**

Successful organisations respond to differing circumstances in much the same way as humans display adaptability and learning when faced with a challenging environment in which, failure to adapt would almost certainly result in extinction.

It is also true that modern complex organisations can not rely on the vision and ideas of one grand strategist, but must rather draw experience from all levels of the organisation. What is important is that an organisation increases its ability to learn and in so doing, adapts in response to its changing environment.

Senge (1990) identified five disciplines, or bodies of theory and technique, which when brought together create the capacity to learn.

1) *Systems Thinking*- which integrates the other four disciplines.

For Senge this is concerned with seeing developing patterns rather than snapshots. 'At the heart of the learning organisation is a shift of mind- from seeing ourselves as separate from the world to being connected to the world, from seeing problems caused by someone or something 'out there' to seeing how our own actions create the problems we experience.'

2) *Personal Mastery*- a personal commitment to lifelong learning by individuals in the organisation. Mastery is seen in the craft sense of constantly striving to improve on the personal skills which the individual has acquired.

3) *Mental Models*- Senge argues that there are deeply ingrained assumptions and images which influence the way individuals perceive the world and actions that are taken. These mental models are different from the 'espoused theories' in that they are based on observed behaviour. In Senge's view these models need to be brought into the open so that they can be subjected to scrutiny.

- 4) *Building Shared Vision*- Senge posits that if organisations are to be successful everyone must pull in the same direction towards the same vision of the future and that they must do so because they want to, not because they are told to. 'You don't get people to buy into a vision, you get them to enrol.' The commitment to learning is a part of that vision.
- 5) *Team Learning*- the team rather than the individual is the key learning unit transforming conversational and collective thinking skills so that groups of people can reliably develop intelligence and ability greater than the sum of individual members talents. Primarily this is because a team is regarded as a microcosm of a whole organisation, but it may also be influenced by the knowledge that there was already a body of established management creation of successful teams.

An organisation to be successful must be aware of the environment in which it is operating and have the ability to monitor its progress across a broad band of measures and performance indicators. Failure must be recognised and analysed appropriately with the opportunity to learn from the experience. In situations where the causes and the consequences of the failure were systemic, redesign may be indicated and the findings can be fed into a process for generating an agenda for change. This will not be achieved unless individuals are free to share their experience without fear of recrimination. In an ideal world, all the information about any failure situation would be available, but in practise, understanding is like all knowledge in that it is tentative, provisional and incomplete and limited by lack of time and shortage of creative imagination.

Failure is an emotive subject that causes people to hide things, even trivialities, but in studying past failures, one does at the very least, have the benefit of hindsight.

## 2.4 SYSTEMS FAILURES

Learning from failure is a crucial element in the development of individuals and is adequately demonstrated in the following statement (Ackoff, 1994):

“When one does something right, one only confirms what is already known: how to do it. A mistake is an indicator of a gap in one’s knowledge. Learning takes place when a mistake is identified, its producers are identified and it is corrected.” The word ‘mistake’ in this statement can be substituted with ‘failure’, as it is true that real learning comes, not through success, but through understanding of failure. Learning by individuals from their own experiences can be extended to learning from situations in which they played no part and, in which they have no direct experience. In other words, it is possible, and very important, for individuals to learn from the failures of others.

In order to become an effective problem solver, it is necessary to understand the nature of failure and to learn from the experience.

Failure is defined as a shortfall between performance and expectation and depends on the goals of the parties concerned. Different parties involved in the resolution of a problematic situation may have different objectives and may view the outcome as a failure while others may see it as a success. Whether a particular solution is deemed to be a success or not is dependent on the viewpoint of the participants involved and is a comparison between the ideal or expected condition and the outcome of the action. In order therefore to determine whether an outcome is a success or failure, it is necessary to predict or forecast in advance the expected outcome for future comparison.

Understanding failure, as defined by Bignell and Fortune in their book ‘Understanding Systems Failures’ (Bignell, Fortune, 1989), starts with a failure that is regarded as significant by an observer. The failure is seen as a disappointing shortfall in output performance, emanating from a system or systems. Failures arise from a host of contributory factors, each an aspect of system behaviour.

The activity of understanding the failure requires the elimination of these factors, tracing them back, assessing the importance of each as a contributor.

Understanding is comprehension of the case; it is the achievement of a mental

grasp of the information that is already to hand, followed by a search for fresh information. The whole picture comes together with the intention in our minds of making the story more intelligible, first to ourselves and hopefully also to others. Understanding deals in reasons, grounds, motives and consequences. It tries to make sense out of complexity and seeks to put consideration of the whole on a par with or above the separate study of individual parts.

Understanding is best achieved by making use of a systemic approach as failure is never due to a single cause, and in so doing, seeking out the systems in the situation and uncovering the true cause of the failure. The systems approach ensures that the failure is thoroughly examined in a rigorous way by focusing attention on the causes rather than the symptoms of the failure. By understanding the causes of failure, it is possible to use this knowledge to predict or prevent potential failures in the future.

One of the most useful ways of describing failures in systems terminology is as 'the production of undesirable outputs of the system.' There are two ways to measure the performance of a system by using the systems outputs:

- 1) Compare the inputs with the outputs and measure the systems efficiency
- 2) Compare the outputs with the objectives or goals of the system and measure its effectiveness.

As well as providing information about the performance, these measures should also be used in efforts to control the behaviour of the system.

The systems approach also encourages analyst to look at all of the outputs of the whole system, both desirable and undesirable and to search for the reasons why outputs that should be there are not. In this way, a broad examination of the failure as well as the context in which it occurred is carried out.

#### **2.4.1 CATEGORISING FAILURE**

Failures can be categorised into one of four types, namely;

### **TYPE 1- Objectives not met**

In a type 1 failure, the objectives of the designers, sponsors, or users are not fully met. These are the failures that surround us every day and include for example, inventions that never worked properly and companies that go out of business.

### **TYPE 2- Undesirable side effects**

In these failures, the original objectives are met but there are also consequences or side effects that are judged to be inappropriate or undesirable. An example of this type of failure would be the drug thalidomide that seemed beneficial but later proved to have devastating side effects.

These first two categories of failure are not mutually exclusive in that a failure may fail to achieve the required expectations and also have undesirable side effects. A good example of this could be the Concorde project which failed to meet cost objectives and turned out to be so noisy that it was banned from some airports.

### **TYPE 3- Designed failures**

Failure in itself does not necessarily imply that something has gone wrong for something's are designed to fail at a particular time or under particular circumstances. Such failures are normally integral parts of safety devices and as such are present to protect the rest of the system in the event of failure.

An example of this type of failure is a fuse within an electrical circuit. Something has gone wrong, but the fuse has achieved the design objective.

### **TYPE 4- Inappropriate objectives**

This type of failure occurs when the objectives that were set are met without undesirable consequences or side effects but by the time they were achieved, there was no longer any merit or satisfaction in achieving them. Examples of these failures are products designed for a market that no longer exists or to meet legal or safety standards that no longer apply. Such failures satisfy their own pre-set criteria but, with the benefit of hindsight, are no longer appropriate.

The distinction between a type 1 failure and a type 4 hinges on whether the objective setting was carried out correctly or not in the first place. In defining a

type 1 failure, the objectives are clearly taken as given and a judgement made solely on the extent to which they have been met. The type 4 definition however leaves open the question of whether or not the original objectives were flawed. The categorisation therefore relies very heavily on the view taken of the original objectives which in turn is very dependent on the viewpoint of the observer. Almost all judgements about failure are subjective and are coloured by personal perception, circumstances and expectations of the participants involved.

#### **2.4.2 FORECASTING AND PREVENTING FAILURE**

Understanding how and why failures happened in the past can help to influence and perhaps avoid them happening in the future.

After a failure has occurred, a repair could be carried out to adjust the outcome to one that is more in line with the original expectations. A repair of this nature would provide no assurance that a similar failure could not occur again under a similar set of circumstances. In order to gain this assurance, a remedy rather than a repair should be carried out. A clear distinction between the concepts of a repair and remedy is necessary in that the aim of the remedy is to not only repair any damage, but also to prevent future failures. Unfortunately, more often than not, repairs rather than remedies follow failures. Prevention of failures can be grouped into three main areas, namely;

- 1) Preventing the same or similar failure occurring again in the situation that was examined.
- 2) Preventing the same or similar failure in similar systems
- 3) Preventing failures that might happen but which have not done so yet either because the combination of events that would be necessary has not yet occurred or because the system does not exist yet.

The benefits of comparing situations that are very alike are often realised but the opportunity to apply the lessons learnt from one failure to possible failures in similar situations is often lost.

Realistically, it is not possible to avoid all failure, therefore, the best line of defence is to concentrate on those areas in which failure is the least acceptable.

The most that can be achieved is to forecast potential failure in those areas where

we have some authority or influence and to use the understanding of failure in the designing of change.

### **2.4.3 FAILURE AVOIDANCE**

One way of reducing the potential for failure is to design plant and processes in such a way that when something goes wrong, it does not have a devastating impact or at least it had been anticipated and planned for. This reliability approach to failure is performed by making use of a system called Failure Mode and Effect Analyses (FMEA). An FMEA is performed at the design stage of a project and its purpose is to answer the question: 'What could possibly go wrong with the system as a whole as a result of the failure of a single part?' It is not concerned with the overall reliability of the whole system but rather with individual components and the ways in which they might fail.

The steps taken to carry out an FMEA are as follows:

(Taken from Learning from Failure, The Systems Approach. Fortune and Peter, 1995)

1) Definition of the system.

Precise boundary of the analysis is defined together with the mission or purpose of the system under consideration. Inputs from and outputs to other parts of the system and relationships with the environment are also specified.

2) Description of system operation.

Behaviour of the system when it is operating properly and what happens to all the various inputs and outputs when one or more components fail or the inputs change are described.

3) Description of the environmental conditions.

The physical environment in which the system will operate is described.

4) Listing of failure modes.

A mode of failure is the description of how a component behaves after it has failed. All significant modes, including both random and degradation failures must be evaluated.

5) Analysis of failure mechanisms

At least one failure mechanism must be identified for each mode of failure.

6) Analysis of failure effects.

The interaction of the failed component with the rest of the system is described.

7) Failure detection.

The mechanisms within the system that reveal the occurrence of the failure modes are identified. For components that may fail without causing the system as a whole to cease operation, periodic tests may be necessary.

8) Compensation for failure.

The provisions of mechanisms to compensate for the failure mode at the level being analysed are noted.

The FMEA starts with the potential for failure and then considers the many aspects of design to overcome or compensate in the event of failure.

Other planning techniques contain an element that tries to take into account the potential for failure based on the probability of failure and builds in the need for additional redundancy components. In this way, duplicate systems are incorporated into the design so that failure of one system will not cause the whole system to collapse.

The hallmark of a learning approach are reflective investigation and involves questioning whether a situation has the signs of a potential failure followed by action based upon that reflection. It does not provide a set of solutions but is instead a process for considering the lessons to be drawn from experience.

## 2.5 BASINS OF STABILITY

All systems have a natural state in which they feel comfortable and if undisturbed, will operate. To move the system from this natural state will require an intervention or external influence but if this influence is removed, the system will immediately return to its original steady state. To lift the system to another level will require to move it past some 'boundary' to a higher level where it will achieve a new 'improved' steady state.

This phenomenon is referred to by Dr. Barry Clemson in his book 'Cybernetics, a new management tool' (Clemson, 1984) as a basic rule of cybernetics in that all complex systems have basins of stability separated by thresholds of instability.

This is of particular importance in problem resolution in that if changes made to improve a problem are not kept firmly in place, the system will very quickly revert back to its previously problematic state.

## 2.6 CONCLUSION

By now, the problem solver has a good understanding of the complexity and nature of the organisation in which he is operating as well as an insight into the different categories of problems he could encounter. Great care must be exercised when attempting to solve problem situations as, what may at first appear to be the problem, may not be the problem at all. Remember, problems are rarely, if ever, solved but are changed or moved in time to create other problem situations!

An important aspect of problem solving is the setting of goals early in the process against which, the performance of the solution can be measured. The balance between resources and results is important as a complete zero defect process would require the use of unlimited resources.

Understanding failure is necessary so that individuals and organisations can learn from the experience. This learning potential is essential for an organisation in order to enable adaptation in response to its changing environment. In order to ensure that this learning can take place, individuals must feel free to express their thoughts and experiences without fear of recrimination.

One way of reducing failure is through the use of a system called 'failure mode and effects analysis'. Through the use of this reliability approach, it is possible to predict the potential for failure and, in the event of its occurrence, lessen the impact through planning.

The next section will give the problem solver an introduction into the different types of methodologies that are available for the resolution of problem situations.

## CHAPTER 3.0

### FRAMEWORK FOR PROBLEM SOLUTION

*The previous chapters made it clear to the reader that a good understanding of the problem situation as well as the organisation is necessary before attempting to establish an intervention to improve on the current situation. This implies that in order to successfully resolve problem situations requires that consideration is given to both people as well as the system involved.*

*This chapter describes three methodologies, each different from each other, yet each able to be used to solve problems in different situations.*

*The first is Systems Dynamic Modelling which is a hard methodology that relies heavily on structure with little, if any, consideration given to the people involved.*

*The second methodology is Strategic Assumption Surfacing and Testing which concentrates on the relationship between the different participants. In this way, the political and human aspects of the organisation are brought to the fore while structure slides into the background.*

*The third methodology is Soft Systems Methodology and, as the name implies, is a soft methodology. This methodology is based on the belief that problems do not exist independent of the people involved. In problem resolution, it makes use of many different perspectives in order to find solutions that are appropriate and acceptable to all concerned.*

*The final section of this chapter is dedicated to 'Heuristics' in contrast to the previously mentioned methodologies in that it takes into account the limitations of the human mind. Problem solvers in real world situations have only a finite amount of time, knowledge, attention or money to spend on a particular problem. Bounded rationality makes use of a 'stopping rule' to limit the time spent on researching information and consequently leads to more practical methods of decision making.*

### **3.1 SYSTEM DYNAMIC MODELLING (SDM)**

This system is based on the assumption that all situations can be considered as existing mainly in terms of elements and flows whereby the flows depict the relationship between the elements. It requires that a model of the system is constructed consisting of all the influential elements together with their respective interacting loops and particularly the feedback loops, all of which are contained within a boundary. The inputs and outputs to the system which cross over the boundary are very much restricted in a systems dynamic (SD) model.

Although there may be many elements and interconnecting loops, the model is considered as being simple and unitary in that the interactions are deterministic and do not evolve over time.

The model is also considered to be closed to the environment in that all influential factors are contained within the boundaries. The model has some purpose and is analysed on the sequence of cause and effect created by the transformation process of converting inputs into outputs.

The systems dynamic view places emphasis on structure and the processes within that structure. It considers that behaviour is principally caused by the structure and is therefore, a theory of the structure of systems and dynamic behaviour. Structure does not only relate to physical aspects of the plant and production processes but also refers to politics and traditions both tangible and intangible that dominate decision making.

This theory assumes that analysis of a situation can be undertaken from an external objective viewpoint and that the structure and dynamic processes can be recreated in systems diagrams and mathematical models. In building this model, it is possible to understand and to some extent, predict the outcome of the system in reality. The system consists of many multi-causal feedback loops that exist between the different elements and the output of one element constitutes the input of the next. Hence, by making use of a computer to run the complex mathematical representation of the system and by varying the inputs, it is possible to predict the outcome of the phenomenon of change. In this way, it is possible to determine the effect of change in the structure and to test out or simulate future ideas and plans and predict the possible outcomes.

The systems dynamic model relies heavily on structure and is used to predict and to some extent, control the outcome of a system under varying conditions.

Structure in this context is seen to have the following four significant characteristics, namely:

- Order

A key issue in the development of the model is the number of levels that are used to represent the structure. The number of levels determines the order of the system and may exceed one hundred in a very complex model.

- Direction of feedback

Feedback is when the behaviour of one element may directly or indirectly effect the behaviour of another element by way of their relationship. These feedback loops may be either negative or positive in that, negative is an inhibiting or controlling influence and positive is augmenting by either creating growth or decline. Positive and negative are depicted as the direction of the feedback and are fundamental in the analysis of structure.

- Non-linearity

Non-linear systems influenced by positive feedback produce exponential growth or decline from the base point unlike linear systems where such feedback is not necessarily detrimental.

- Loop multiplicity

Managerial, economic and social models will comprise multiple feedback loop systems consisting of both positive and negative directions that leads to difficulty in identifying key variables and predicting outcomes. In order to run these complex models, it is necessary to make use of a computer simulation programme.

As mentioned earlier, the purpose of this type of model simulation is to predict the possible outcomes from different scenarios of both structure and differing disturbing stimuli. The quality of the prediction will depend on the accuracy and complexity of the model which in turn will be reliant on the analytical modelling methodology employed. In this way, management is able to understand the different effects of changes to the system and can then concentrate its attention on introducing controlling policies. Control can be implementing new structural changes or decision policies in order to achieve the predicted desirable states.

Other than the different elements and their respective positive and negative feedback loops, the model will also contain levels and rates whereby, the levels refer to the quantity of goods and the rate is a flow which contributes to the change in quantity per unit of time. Once the appropriate mathematical representation of the system has been formulated, a software package like DYNAMO or STELLA will be required to run the very complex simulations.

### **3.2 STRATEGIC ASSUMPTION SURFACING AND TESTING (SAST)**

In contrast to dynamic modelling, strategic assumption surfacing and testing is a wholly different approach to problem solving in that it does not focus on structure but rather on the relationship between the participants involved in the problem context. In this way, the political and human aspects of the organisation are brought to the fore while the issue of structure slides into the background. This methodology looks very much at the culture of the organisation and is suited for ill-structured problem situations where differences of opinion prevent decisive action to be taken.

The source of this methodology comes from the work of R.O. Mason and I.I. Mitroff and is based on the assumption that once the issues of pluralism have been overcome, the traditional hard system type methodologies can be used to complete the job of solving the problem situation.

Much of the philosophy behind SAST is based on the thinking of Churchman in his book 'The Systems Approach' (Churchman, 1968) in which he recognises that subjectivity must be embraced in systems thinking and that the only way to come close to grasping the whole system is to sweep in as many different perspectives as possible. Each individual's world view or *Weltanschauung* is terribly restricted and is also likely to be highly resistant to change. World views can not be seriously challenged by presenting them with new facts which will simply be interpreted according to the individual's already fixed presuppositions. In order to be objective, a prevailing world view (thesis) should be confronted by another world view based entirely on different assumptions (anti-thesis) in order to bring about a richer appreciation of the situation expressing elements of both positions while going beyond them (synthesis).

There are no experts in system designing and in order to be successful, systems designers must be willing and able to expose the restrictive nature of their own world views by opening themselves up to the opinions of others.

Objectivity, after all can only rest upon debate among many different perspectives and a system analysis requires the participation of many stakeholders in the design process.

SAST is used with masses of highly interdependent problems and is based on four arguments about the nature of problems.

Firstly, it is argued that normal management methods of problem solving are suited for solving simple, well structured problems and not complex problems involving the interrelationship between many different parties. As such, management is not able to use these methods to solve their most important problems.

Second, organisations do not like to challenge the accepted, current way of doing things. Policy opinions that differ from the accepted norm are not considered.

One aim of SAST is to ensure that alternate policies are considered.

Third, data alone will not ensure that an organisation changes its policy as the data can be interpreted within the current way of thinking. An organisation only begins to learn once it accepts that its most cherished assumptions can be challenged by reasonable counter-assumptions.

Lastly, it must be accepted that tension will develop between the different groups but all must be committed to the process. Organisations are arenas of conflict between different groups each expressing alternate world views which will have to be managed and SAST attempts to surface these conflicts as a means of achieving a genuine synthesis.

SAST incorporates four clear principles in its methodology, namely:

- Adversarial- based on the belief that judgements about ill-structured problems are best made after consideration of opposing perspectives.
- Participative- seeks to involve participants from different levels of the organisation to gather the knowledge and resources required to solve complex problems and to implement solutions.

- Integrative- on the assumption that the differences thrown up by the adversarial and participative processes must eventually be brought together again in a higher order synthesis.
- Managerial mind supporting- believing that managers exposed to different assumptions will better understand the organisation, its policies and problems.

Each of the principles are employed in all of the four major stages of the methodology.

- group formation
- assumption surfacing
- dialectical debate
- synthesis

### **3.2.1 GROUP FORMATION**

The purpose of this stage is to structure groups to facilitate the productive operations in the later stages of the methodology and should include as many individuals as possible who have a potential bearing on the definition of the problem and its proposed solution. It is imperative that each individual is encouraged to express his perception of the problem and that as many perceptions as can be found are included. The individuals are divided into small groups on the basis of one or more of the following criteria:

- advocates of particular strategies
- vested or common interest
- personality types
- managers from different functional areas
- time orientation (short or long term)
- any other criteria that may lead to a coherent group activity

The aim of establishing groups should be to maximise similarity of perspective within the groups while maximising different perspectives between the groups. Each groups perspective should be challenged by at least one other group.

### 3.2.2 ASSUMPTION SURFACING

Each group must develop a preferred solution or strategy based on their own perspective of the situation and in so doing, uncover and understand the key assumptions on which its solution rests. Three techniques are used in this process.

Firstly, *stakeholder analysis* which asks each group to identify the key individuals, parties or groups who have a stake in and on which the success or failure of their strategy would depend if it were to be adopted.

Typical questions that should be addressed are

- who is affected by the strategy?
- who has an interest in it?
- who can affect its adoption, execution or implementation?
- who cares about it?

The second technique is *assumption specification* whereby, the group lists all assumptions made about each of the stakeholders identified in believing that its preferred strategy will succeed. These are the assumptions on which the success of their strategy or solution depends.

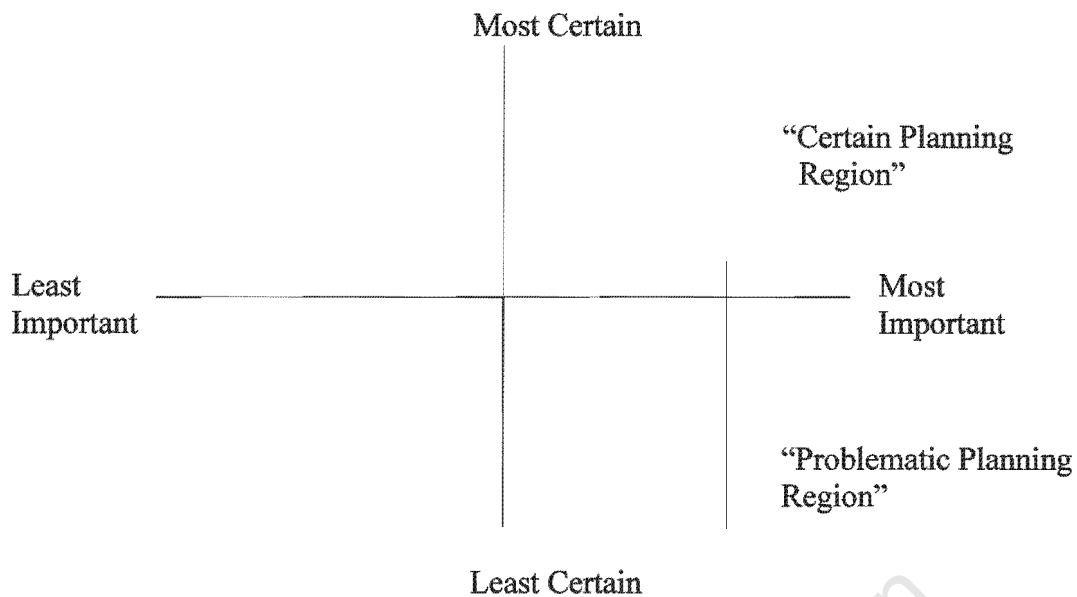
The third and final technique is *assumption rating* where each group rates each of the assumptions with respect to the following two criteria:

- How important is this assumption in terms of its influence on the success or failure of the strategy?
- How certain are we that the assumption is justified?

The results are recorded on a chart as shown in figure 05.

The results falling on the extreme left are of little significance and should be disregarded however, those falling in the top right quadrant (certain planning region) are important and those in the bottom right quadrant (problematic planning region) are most critical and require the most attention.

Each group should now list the most significant assumptions on which its preferred strategy depends.



**Figure 05: Assumption Rating Chart.**

### 3.2.3 DIALECTICAL DEBATE

Each group now presents its preferred strategy to the rest of the groups clearly identifying the most significant assumptions it has made. During presentation, only questions relating to information may be asked and the purpose is that each group understands the strategies and underlying assumptions of each and every other group.

Once completed, open dialectical debate is permitted between the groups with each group displaying its list of key assumptions and guided by questions such as:

- How are the assumptions of the groups different?
- Which stakeholders feature most strongly in giving rise to the significant assumptions made by each group?
- Are assumptions rated differently by the groups?
- What assumptions of the other groups does each group find the most troubling?

After the debate has progressed for a period, each group is allowed to reconsider and, make changes if it desires, to its assumptions. This process of assumption modification should be allowed to continue for as long as progress is being made.

### 3.2.4 SYNTHESIS

The aim of this stage is to achieve a compromise on assumptions from which a new higher level of strategy or solution can be derived. A list of agreed assumptions is drawn up and debate continues on the negotiation and modification of the others until the list of agreed assumptions is sufficiently long enough for a strategy to be worked out. This new strategy should bridge the gap between the old strategies and go beyond them as well and the assumptions on which it was based can be evaluated as it is put into effect.

If no synthesis can be achieved, points of disagreement must be noted and research undertaken to resolve the differences. Meanwhile, any agreed, common strategy put into effect can be more fully evaluated

The advantages of this methodology is that many different, diverse perspectives are swept into the planning and implementation of new strategies. However, it is doubtful that in a truly coercive situation, whether it will be possible to achieve the adversarial and participative debate necessary for the proper application of SAST as it is dependant upon the participants being willing to lay bare their assumptions.

SAST does have its uses when applied to simple pluralist problem situations where it can assist in structuring the bringing together of different world views.

### 3.3 SOFT SYSTEMS METHODOLOGY

(Soft Systems Analysis, The Open University, 1984)

The soft systems approach is based on the following key ideas:

- (1) Problems do not exist independent of the human beings involved with them, but are rather constructs of the concerned mind and are defined by the perceptions of the individuals who are troubled or intrigued by them.
- (2) People see problems differently based on their beliefs and values which are influenced and shaped according to their own personal experiences. These experiences or World Views are referred to as *Weltanschauung* (German for World View) and differ from individual to individual and can be illustrated in the following anecdote:

A newspaper report in the 1950's recorded the following exchange between Lord Robens, the then Chairman of the National Coal Board, and a miner, with regards to a concern that so many miners were working four shifts instead of the regulation five.

Lord Robens: "Tell me, why do you regularly work four shifts instead of the regulation five?"

Miner: "I'll tell you why I regularly work four shifts, it's because I can't quite manage on the money I earn in three." (Checkland, 1981)

What this story illustrates is that the Chairman sees mining as a system for maximizing manpower and machinery utilization towards making a profit whereas, for the miner, it was a system which provided income in return for going down a hole in the ground; an unpleasant and dangerous task, which he wished to minimize as much as possible. Both Weltanschauung of the same situation totally different, yet both valid.

- (3) A problem is a perceived discrepancy between an actual state and a desired state. This implies that the actual state and the desired state of affairs are known. With the existence of conflicting Weltanschauungen (plural '-en'), people disagree about the description of the actual state as well as the desired state of affairs.

A second difficulty is that problems do not exist in isolation. Russel Ackoff, the American systems analyst suggested that every problem interacts with other problems and is therefore, part of a set of interrelated problems. He further suggested that solutions to most problems produce other problems. (Ackoff, 1974).

This theory suggests that problems are never solved, merely moved in time.

- (4) A central belief of the soft system approach is that improvements in complex problem situations are most likely found through the sharing of perceptions and through persuasion and debate. In this regard, soft system analyst see their role as therapeutic rather than expert, and engage in assisting the people involved in the problem situation to find solutions to which they will be committed.

- (5) The final principle of soft system analysis is its abandonment of the idea that the analyst can be divorced or detached from the problem situation. In this regard, much of the analysis is what is known as 'action research' in that the analyst is attempting not only to understand the situation but also to help change it for the better.

Refer to FIGURE 06 at the end of this section for a pictorial representation of the different stages of the Soft System Methodology. For clarity, reference should be made to this figure during the reading of the remainder of this chapter.

Soft system methodology was developed by Professor P. B. Checkland and is fully described in his book 'Systems Thinking, Systems Practice' (Checkland, 1981). The methodology is a process of inquiry with a number of distinct stages, passage through which is usually iterative rather than linear.

### **3.3.1 STAGE ONE: The Problem Situation Unstructured**

This stage requires a full understanding of the problem situation in as open a way as possible without trying to precast it into a particular mode. This requires the identification of the different role players affected by the system. Role players will include owners, system actors and system clients, all of whom may, and probably will, have different perspectives on the situation. The 'sweeping-in' of these different perspectives is necessary to obtain a balanced view of the system and what is problematic about it. The analyst should not try to prejudge this unstructured situation or 'mess' but should rather understand that it is a complex system of interrelated problems.

### **3.3.2 STAGE TWO: Rich Pictures**

This stage is concerned with getting from finding out about a problem situation to taking action to improve it. An efficient, economical and illuminating method of summarising and representing all the information gained in all its complexity is to draw a cartoon-like representation called a rich picture. This picture will contain both hard and soft information like structure and reporting channels as well as subjective view points.

The following guidelines can help when compiling a rich picture:

- (1) First look for the elements of structure. These elements change relatively slowly over time and are relatively stable.
- (2) Next look for elements of process. These are the elements which are in a state of change- the activities which go on within the structure.
- (3) Look for the ways in which the structure and processes interact. This will give an indication of the climate of the situation. Over time processes can change within a structure that no longer is appropriate.
- (4) Do not try to represent the situation in terms of systems as the assumption that the system exists could be part of the problem situation. Thinking in systems can channel the thought process towards how to make the system perform better rather than question whether the function is necessary.
- (5) Rich Pictures should include soft subjective information as well as hard factual data about the situation.
- (6) Due consideration must be given to the social roles between the role players as this will give an indication as to the accepted behaviour.
- (7) Enrich the picture with appropriate text and foot notes. The analyst as an individual with his/her own values and perceptions will have an effect on the situation.
- (8) The two main important aspects to look for in the Rich Picture are the Primary Tasks and the Issues of the problem situation. The primary tasks are those activities for which the organization was created to perform.

Normally, these activities are necessary for the organization to survive. The aspect of Issues are matters of concern or are the subject to dispute and more often than not, the issues are unstated.

Having identified the Primary Tasks and Issues completes the requirement for stage two. Moving to stage three requires the crossing of the border between the 'real world' and the 'abstract world' into the systems world (refer FIGURE 06).

### **3.3.3 STAGE THREE; Relevant Systems and their Root Definitions**

Having studied the Rich Picture, the next step in the methodology is to identify the Relevant Systems. These are the systems that are relevant to the situation in

that, when studied they will yield insight into the situation. In this way, these systems are relevant to the process of improving the situation.

It is not possible at this stage to know for sure that the system chosen is in fact 'relevant', however, on discussion with the role players, if the ideas for change are rejected then it can be accepted that the system was in fact irrelevant. As explained previously, all stages of the methodology including this one are iterative, therefore, the analyst should go back and take another relevant system. A relevant system is not a system that anyone is going to design and implement in the real world, in fact, it is an entirely abstract idea. Once the relevant system has been chosen, the next step is to describe the system by means of a Root Definition. This is a precise verbal description of the essence of the process implied by the relevant system. Not necessarily only one sentence, but the root definition should be kept as brief as possible. In order to confirm that the root definition is complete in its description of the system, the CATWOE checklist should be applied. The letters form a mnemonic which stand for the various aspects that should be contained in the definition as follows:

- C- customers of the system (victims or beneficiaries)
- A- actors.(role players involved in the carrying out of the essential activities)
- T- transformation process (transforms inputs into outputs)
- W- Weltanschauung (world view)
- O- owners (who have power over the system to cause it to cease to exist)
- E- environmental constraints.

With the exception of T, all of the other letters should be, but not necessarily have to be, included in the definition. All root definitions must include the transformation process. The purpose of CATWOE is to force the analyst to question the definition to ensure that it is complete.

### **3.3.4 STAGE FOUR: Conceptual Models**

The Conceptual Model is an activity model of the relevant system indicating activities or processes which logically must go on if the system is the one described in the root definition. This model is not a picture of some real world system which someone is going to try and build in the future, it is a purely

abstract model. The activities detailed in the model must be described by means of a noun and a verb (they are activities after all ).The main or primary activities should be arranged in a logical sequence with their secondary activities clustered around them.

In building the model, no real world considerations are allowed to be introduced as this model is a representation of the relevant system in the systems world. Due to the relationship between Root Definitions and Conceptual Models, it is logical to think of them as linked pairs. As all the stages of the methodology are iterative (including this one) other pairs will be constructed later in the analysis.

In order to ensure that the model is complete and adequate, it is necessary to compare it with the formal systems model (refer FIGURE 01). In comparing with the formal systems model, it forces the analyst to ask questions of the model to ensure that all the requirements of an efficient and effective system are present.

### **3.3.5 STAGE FIVE: Comparison of Conceptual Model with Rich Picture**

This stage requires the comparison of the now highly developed Relevant System to the Rich Picture of the real world situation. In order to do this, it is necessary to cross over the border between the abstract system world back into the real world situation. When comparing the model with the real world situation, certain significant differences may become apparent, in particular, certain activities that the model requires may not happen in reality. From these differences a list of agenda items is drawn up for discussion with the role players at a later stage. The purpose of this stage is the drawing up of this list of agenda items to be used in a debate with the actors in the problem situation. The items on the agenda should address the issue of ‘what’ activities are missing rather than ‘how’ activities should be carried out. When carrying out the comparison, new issues may come to light that can cause the analyst to go back and fill in more information on the rich picture. In extreme cases, it may necessitate the need to change the relevant system due to the analyst’s improved understanding of the situation.

### **3.3.6 STAGE SIX: Debate with Role Players**

The debate on the list of agenda items is held with the role players including clients, problem-owners, problem-solvers and any other interested parties. All proposals put up for discussion must be both systematically desirable and

culturally acceptable. In order to be systemically desirable, the proposal must make sense in system terms and not violate nor contradict the systems thinking that has gone into the formulation of the relevant system. Culturally feasible implies that it is acceptable to the particular set of actors involved. Both of these criteria are important and only changes that satisfy both should be considered for implementation.

For changes to work, it is important that the people involved are convinced that these changes will bring about meaningful improvement. To this end, it may happen that none of the proposed changes are accepted by the role players and therefore no changes can be made. In this case, it may be more prudent to do nothing than to take action for the sake of it. If none of the role players agree with the proposed changes then it is fair to assume that the relevant system is in fact irrelevant to the problem situation. As mentioned earlier, the process is iterative and therefore, the analyst must return and select another relevant system.

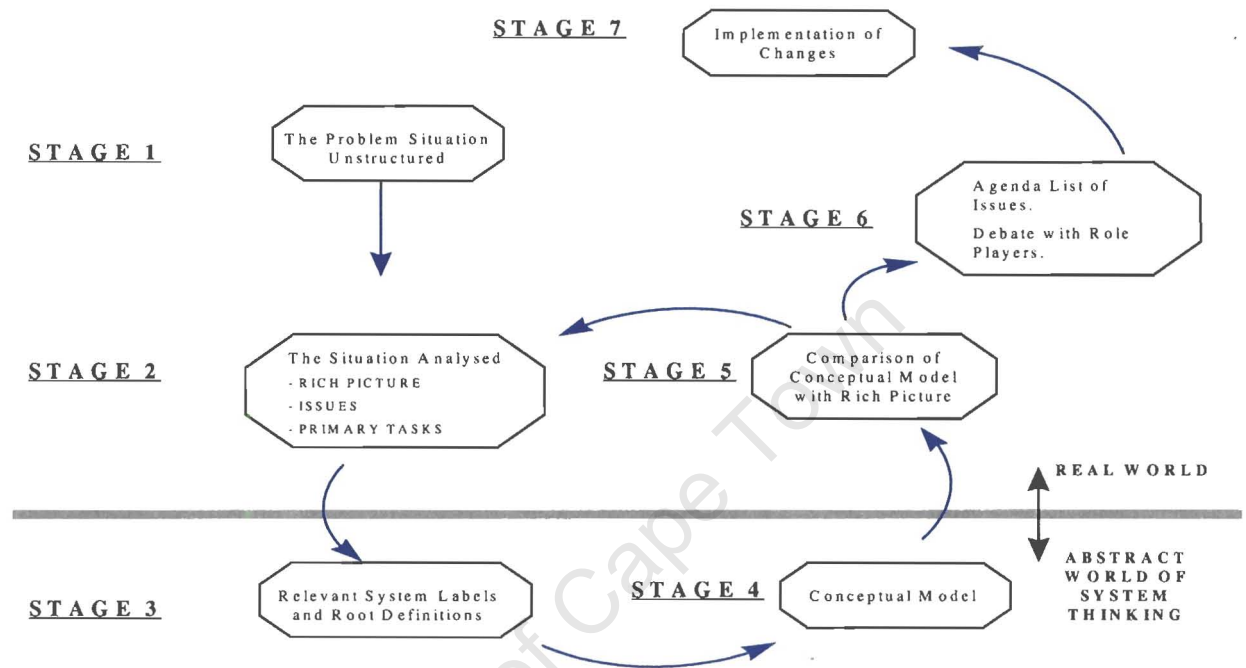
### **3.3.7 STAGE SEVEN: Implementation**

Soft System Methodology is based on the rationale that changes will not happen and make meaningful improvement unless the people directly involved are persuaded of their merit. This implies that people are rational and amenable to logical argument and persuasion. More often than not, this is not the case and in fact, people are more likely to react to emotion than to logical argument. To quote a cliché, "The only thing that is common about common sense is the fact that it is not common at all".

However, when changes can be made, they can be expected to be in one of the following categories:

- (1) Changes in structure- changes in organisational groupings, departments, reporting structures, line of command, lines of functional responsibility, or even physical layout.
- (2) Changes in procedure- alterations in the dynamic elements of the system (processes or activities which go on within it). Changes of this type really amount to different ways of doing the same things.
- (3) Changes in policy- goals and strategies of the human activity systems being investigated.
- (4) Changes in attitude.

Changes of the first three types are relatively easy to implement however, changes in attitudes can prove to be a little more difficult. Through the methodology, people are encouraged to look at their situation differently and by this new understanding gained, it is possible to influence the required changes in attitude.



**FIGURE 06:** Diagrammatic Representation of the Soft Systems Methodology indicating the seven stages of implementation. (Adapted from THE OPEN UNIVERSITY, *Soft Systems Analysis: An Introductory Guide*, 1984.)

### 3.4 HEURISTICS

‘The work of managers, of scientists, of engineers, of lawyers, the work that steers the course of society and its economic and governmental organisations, is largely work of making decisions and solving problems’ (Simon, 1986).

The term ‘heuristics’ is of Greek origin and means ‘serving to find out or discover’. From its introduction into English in the early 1800 up until about 1970, heuristics referred to useful, even indispensable cognitive processes for solving problems that cannot be handled by logic and probability theory alone. After 1970, a second meaning of heuristics emerged in the fields of psychology and decision making research which defined it as a limited decision making method that people often misapply to situations where logic and probability

theory should have been applied. Heuristics used in this text relates to the previously used definition emphasising their beneficial role in guiding search and creating precise computational models useful for problem solving in real world situations.

Funke and Frensch define complex problem solving as follows: 'Complex problem solving occurs to overcome barriers between a given state and a desired goal state by means of behavioural and/or cognitive, multi-step activities (Funke, Frensch, 1995). The given state, goal state and barriers between are complex, change dynamically during problem solving and are intransparent. The exact properties of the given state, goal state and barriers are unknown to the solver at the outset. Complex problem solving implies the efficient interaction between a solver and the situational requirements of the task and involves a solvers cognitive, emotional, personal and social abilities and knowledge'. This definition implies that in order to solve these problems, a solver has to be able to anticipate what will happen over time and has to consider side effects of potential actions. Also of note is the focus on the distance between the task and the solver, rather than a focus on the nature of the task itself. That is, a complex problem is said to exist only if there is a 'gap' between task and solver, or a 'barrier' between the state given in the actual situation and the goal state in the head of the problem solver. This 'gap definition' implies that the same task may constitute a problem for one solver but not for another, whereas 'task' oriented definitions assume that a given task constitutes a problem for all solvers.

People make inferences about their world with limited time, knowledge and computational power. In contrast, many problem solving methodologies view the problem solver as a supernatural being possessing demonic powers of reason, boundless knowledge and all of eternity with which to make decisions. Such models or methodologies based on visions of rationality often conflict with reality but are useful for comparison to help clarify our own vision of ecological rationality.

This rationality is the adaptive behaviour resulting from the fit between the mind's mechanisms and the structure of the environment in which it operates. Mental functions are assumed to be computations performed on probabilities and utilities and therefore, prescribe sound reasoning, judgement and decision making. This concept is referred to by Gigerenzer and Todd in their book 'Simple

Heuristics That Make Us Smart' as the 'Probabilistic Revolution' and has led to many elegant theories as well as many horny problems (Gigerenzer, Todd, 1999). The moment one moves beyond simple constraint settings to real world situations, the time, knowledge and computational capacity that probabilistic models demand becomes unfeasible.

In this book, Gigerenzer and Todd push for a second revolution that provides a different vision of how the mind deals with the uncertain world. They proposed replacing the image of an omniscient mind computing intricate probabilities with that of a bounded mind reaching into an adaptive toolbox filled with fast and frugal heuristics. Their premise is that much of human reasoning and decision making can be modelled by such heuristics making inferences with limited time and knowledge. These heuristics do not involve high levels of computation nor compute quantitative probabilities but are rather models of bounded rationality. The 'father' of bounded rationality, Herbert Simon in his work 'Decision Making and Problem Solving' (Simon, 1986), distinguishes between the empirical research on problem solving and decision making from the prescriptive approaches derived from the theory of subjective expected utility (SEU) in that the former gives attention to the limits on human rationality. These limits are imposed by the complexity of the world in which we live, the incompleteness and inadequacy of human knowledge, the inconsistencies of individual preference and belief, the conflicts of value between different people and the inadequacy of the computations that can be realistically carried out. The real world of human decisions is not a perfect world and to bring it within the scope of human thinking powers, problem formulations must be drastically simplified even to the point of leaving out much or most of what is potentially relevant. The descriptive theory of problem solving and decision making is centrally concerned with how problems are cut down to size and how approximate, heuristic techniques are applied to handle the complexity that cannot be handled exactly. One of the accomplishments of this theory of problem solving has been to provide an explanation for the phenomena of intuition and judgement frequently seen in the behaviour of experts. The store of expert knowledge is indexed by the recognition of cues that the problem situation exhibits and combined with some basic inferential capabilities, accounts for the ability of experts to find satisfactory solutions to difficult problems almost instantaneously. The expert makes use of

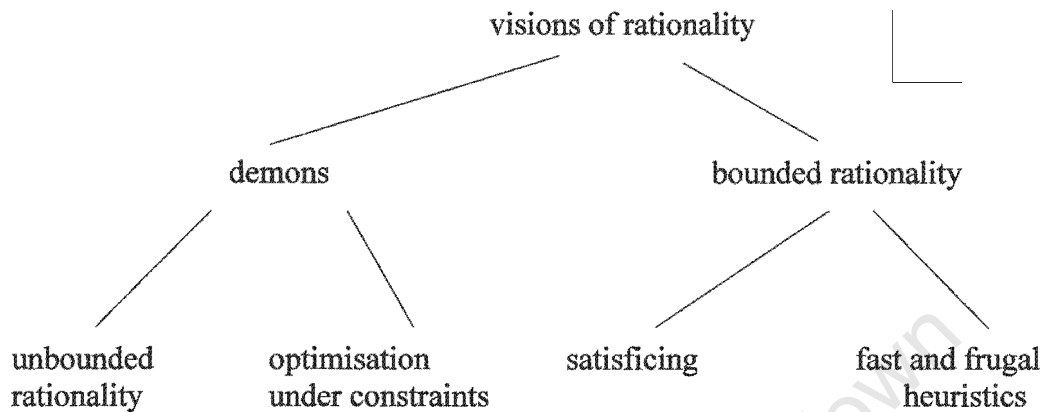
intuition and judgement based on his understanding of the problem and calls on his large store of previous experience. When this fails to provide a suitable solution, the expert falls back on the slower process of analysis and inference. The very first steps in the problem solving process are the least understood. The way a problem is identified and presented goes a long way towards facilitating an appropriate solution. The task of prioritising and setting an agenda is of utmost importance because both individuals and organisations have limited capacities for dealing with many problems simultaneously. Individuals have a tendency to choose easy, simple problems to solve while other, more important problems are neglected. When a large number of problems come simultaneously, a system of 'fire fighting' normally replaces planning and deliberation.

From empirical studies, a description can now be given of the problem solving process that holds for a rather wide range of activities. First, problem solving generally proceeds by selective search through large sets of possibilities, using rules of thumb or heuristics to guide the search. The possibilities in realistic problem situations are generally multitudinous and therefore, trial and error search would simply not work; the search must be highly selective. Chess grandmasters seldom examine more than a hundred of the vast number of possible scenarios that confront them and similar small numbers of searches are observed in other kinds of problem solving search.

A common, powerful procedure to guide search is means-ends analysis where the problem solver compares the present situation with the goal, detects a difference between them, and then searches memory for actions that are likely to reduce the difference.

A key element in the solving of problems is the ability of the organisation to learn from its experience. One of these learning mechanisms is referred to as the connexionist hypothesis, which postulates that organisations learn by changing the strengths of their interconnections in response to feedback. Learning is of particular importance for successful adaptation to an environment that is changing rapidly.

Rationality comes in many forms as depicted in **FIGURE 07** which indicates that ‘Visions of rationality’ are split between ‘Demons’ and ‘Bounded Rationality’. The use of the word ‘Demon’, is used in its original Greek sense to refer to a divine (rather than evil) supernatural being.



**FIGURE 07: Visions of Rationality**

### 3.4.1 UNBOUNDED RATIONALITY

Nature is deterministic and certain but for humans it is fickle and uncertain. People cannot precisely know the world but must rely on uncertain inferences and on their intuition rather than demonstrative proof.

The 1814 astronomer, philosopher, Pierre Simon Laplace contemplated the ultimate genius as an omniscient superintelligence characterised as follows: “Given an intelligence which could comprehend all the forces of which nature is animated and the respective situation of the beings who compose it; an intelligence sufficiently vast to submit these data to analysis, nothing would be uncertain and the future, the past would be present to its eyes.” In real world situations, complex problem situations make unrealistic demands on the mind and in many situations, a rational model cannot be specified because the problem space is unbounded.

Expecting people’s inferences to conform to classical rational norms in such complex environments requires believing that the human mind is a super calculator with unlimited time, knowledge and computational power. In effect, they would have to be likened to *Laplacean Demons* possessing super human intelligence hence the listing of unbounded rationality under Demons in figure 07.

Proponents to the vision of unbounded rationality paint humans in a divine light who do not worry about limited time, knowledge or computational capacities. The greatest weakness of unbounded rationality is that it does not describe the way real people think. Due to its unnaturalness, unbounded rationality thinking has often come under attack and has given rise to its close 'demonic relative', optimisation under constraints.

### **3.4.2 OPTIMISATION UNDER CONSTRAINTS**

To think is to take a risk.

Peoples inferences are inevitably based on uncertainty and forces them to go beyond the information that is given. Also, information is very rarely given but must be searched for. This information search can be internal in the searching of the contents of individuals memory or external where it must be gathered from the surrounding environment.

The basic difference between unbounded rationality and the other three visions depicted in figure 07 is that they all involve limited information search whereas, models of unbounded rationality assume that the search can go on indefinitely. In reasonable models, the search for information must be limited because real decision makers have only a finite amount of time, knowledge, attention or money to spend on a particular problem. Limited search implies that a 'stopping rule' is applied to decide when to stop looking for information. Models in the class of optimisation under constraints therefore assume that the stopping rule optimises the search with regards to time, computation, money and other resources. This vision of rationality holds that the problem solver should calculate the benefits and cost of searching for each further piece of information and stop searching as soon as the costs outweighs the benefits.

The motivation for replacing unbounded rationality with optimisation under constraints was originally to build empirically more realistic models that respected the limitations of the human mind. The rule 'stop search when costs outweigh benefits' sounds feasible at first but again requires that the mind has essentially unlimited time and knowledge with which to evaluate the costs and benefits of each further piece of information search.

Instead of these 'demonic' visions of rationality, the idea of 'bounded rationality' has come to the fore.

### 3.4.3 BOUNDED RATIONALITY

Herbert Simon's vision of bounded rationality has two interlocking components, namely, the limitations of the human mind and the structure of the environment in which the mind operates. The first component of his vision means that models of human judgement and decision making should be built on what is actually known about the mind's capacities rather than on fictitious competencies. A good example of this is the game of chess where the moves and strategy of the game are well defined and where an optimal, best move does exist at each point of the game. However, no strategy can calculate that move in a reasonable amount of time (neither by human mind nor computer) despite the well defined nature of the possibilities to be searched. In less defined natural situations, the hope of identifying a useable optimal solution is even further diminished. The human mind limitations result in the use of approximate methods to handle most tasks. These methods include recognition processes that largely negate the need for further information search. Use is made of heuristics that guide the search and determine when it should end and simple decision rules make use of the information that is found.

The second component of Simon's view of bounded rationality is environmental structure that is of crucial importance because it can explain why certain heuristics perform well if they are structured to adapt to the structure of the environment. The term 'ecological rationality' is used to bring environmental structure back into bounded rationality and describes the degree to which the heuristic is adapted to the structure of an environment.

One form of bounded rationality is the concept of 'satisficing' (refer FIGURE 07) and is a method for making a choice from a set of alternatives encountered sequentially when not much is known about the possibilities in advance.

Satisficing takes a shortcut of setting an aspiration level (target) and ending the search for further alternatives as soon as one is found that exceeds the aspiration level.

Satisficing is a way of making decisions about a set of alternatives that respects the limitations of time and knowledge, it does not require finding out or guessing about all the other options and consequences the future may hold. Some forms of satisficing can still require large amounts of deliberation on the part of the decision maker with regards to setting an appropriate aspiration level in the first

place or to calculate how a current option compares to the aspiration level. Rather than letting large amounts of mental computations slip back into the picture of human rationality, it is necessary to narrow the focus still more to focus on fast and frugal heuristics for decision making.

#### **3.4.4 FAST AND FRUGAL HEURISTICS**

Fast and frugal heuristics employs a minimum of time, knowledge and computation to make adaptive choices in real life situations. They can be used to solve problems of sequential search through objects or options as in satisficing. They can also be used to make choices between simultaneously available objects, where the search for information about the possible options must be limited rather than the search for the options themselves.

Fast and frugal heuristics limit the search of objects or information using easily computable stopping rules and make choices with easily computable decision rules. Satisficing and fast and frugal heuristics can be seen as two overlapping, but different categories of, but with the latter being considered to represent the purest form of bounded rationality.

#### **3.4.5 PRINCIPLES FOR THE USE OF HEURISTICS**

Decisions must be made between alternatives and be based on information about those alternatives. In different situations, alternatives and pieces of information may need to be found through active search. Cues can be searched for in a random manner or in order of some priority based on their usefulness or based on a recollection about which cues worked when making the same decision previously.

Fast and frugal search guiding principles do not use extensive computations or knowledge to determine where to look next. Such simplicity need not lead to a disadvantage in decision accuracy because simple search strategies can help heuristics to be more robust than those that attempt to optimise their information search. Heuristics that try to make use of the enormous number of cues to find the optimal one for a given data set, may be slightly more accurate, but only relative to the data set that is already known. When making predictions about new data, simple information search methods that ignore dependencies between cues can actually be more practical and yield more accurate choices.

The temporal limitations of the human mind must be respected as much as any other constraint in a problem solving or decision making process. This implies in particular that search for alternatives or information must be terminated preferably as soon as possible. Also, the method for determining when to 'stop search' must be as simple as possible and must not require computational capacities not available to the human mind. One simple stopping rule to cease searching for information and make a decision may be as soon as the first cue or information that favours and supports one alternative is found. This and other cue based stopping rules do not need to compute an optimal cost benefit trade off as in optimisation under constraints. For searching through viable alternatives, simple aspiration or target stopping rules can be used as was detailed earlier in Simon's satisficing notion.

Once search has been guided to find the appropriate alternatives or information and then stopped, a final set of heuristic principles can be called upon to make the decision or inference based on the results of the search. These principles can also be very simple and computationally bounded. A decision or inference can be based on only one cue or reason, whatever the total number of cues found during search. Such 'one reason decision making' does not need to weigh or combine cues and so no evaluation between cues need be determined. Decisions can also be made through a simple elimination process in which, alternatives are thrown out by successive cues until only one final choice remains.

The simplest kind of choice (numerically, at least) is to select one option from two possibilities, according to some criterion on which the two can be compared. In the most limited case, if the only information available is whether or not each possibility has ever been encountered before, then the decision maker can do little better than rely on partial ignorance and choose recognised options over unrecognised ones. This 'ignorance based reasoning' is embodied in what is referred to as a 'recognition heuristic'. When choosing between two solutions or alternatives, if one is recognised and the other is not, then humans normally select the former. Chase and Gigerenzer summarised recognition heuristics in their paper 'Trends in Cognitive Sciences' (Chase, Gigerenzer, 1998) as follows: 'If you recognise one object and not the other, then infer that the recognised object has the higher value on the target variable. If you do not recognise either object, then guess'. Following the recognition heuristic is adaptive, yielding good

decisions more often than would random choice.

The recognition heuristic can be useful in cases in which several options are to be chosen from a larger set of possibilities.

When multiple cues are available for guiding decisions, the most frugal approach is to use a stopping rule that terminates the search for information as soon as enough has been gathered to make a decision. Making good decisions need not rely on the standard rational approach of collecting all available information and combining it according to the relative importance of each cue. Simply betting on one good reason, even a reason selected at random, can often yield a better solution.

Simple heuristics are meant to apply to specific environments, but they do not contain enough detail to match any one environment precisely. General strategies that can be made to conform to a broad range of environments, on the other hand, can end up being too highly focused to be of much practical use. Consequently, having a large number of free parameters to deal with can be a hindrance and is referred to as 'overfitting' and assumes that every detail is of the utmost relevance.

Thus, there is an important difference between the two typical applications of a strategy, fitting, where decisions are modelled on a given set of data and generalisation, where predicting or inferring is based on new data. In fitting, it is usually true that the more parameters a model has, the more information it uses and the better it will fit the given data. In generalisation, in contrast to the limited number of parameters in fitting, more is not necessarily better. A computationally simple strategy that uses only some of the available information can be more robust, making more accurate predictions for new data, than a computationally complex, information guzzling strategy that overfits.

Robustness goes hand in hand with speed, accuracy and especially information frugality. Fast and frugal heuristics can reduce overfitting by ignoring the noise or 'flack' inherent in many cues and looking instead for the swamping forces reflected in the most important cues. Thus, simply using only one or a few of the most useful cues can automatically yield robustness. Furthermore, important cues are likely to remain important even when the environment changes to some degree. In this way, fast and frugal heuristics pay attention to informative cues while overlooking more variable, uninformative cues and as such, can ride out a

degree of environmental change without suffering much decrement in performance. Laplace's superintelligence would never overfit because it does not have to make uncertain predictions.

Models of inference that try to be like a Lapacean superintelligence are doomed to overfitting when they inevitably swallow more data than they can digest. Studying ecological rationality enables the problem solver and decision maker to go beyond the widespread fiction that basing decision making on more information and computation will always lead to more accurate inferences. There is a point where too much information and too much information processing has a detrimental effect on the outcome. Cognition is the art of focusing on the relevant and deliberately ignoring all other information.

### **3.5 CONCLUSION**

The purpose of this chapter was to make known to the reader three of the different methodologies that exist together with their respective characteristics and is not intended to instruct the reader in their application. Should the reader wish to become expert in any or all of these methods then further reading and studying would be required from the reference material listed.

Each of the methodologies detailed are powerful in their own right and have proven extremely useful in the solving of problem situations. Both managers and engineers alike should be well trained in their use for the solving of complex problem situations. Systems dynamic modelling is particularly useful in determining the effect on the output of a system as a result of the effect of varying conditions. Unfortunately, much time and expertise is required in developing the complex mathematical model that is required to represent the system in question. However, once developed, the model simulation can be used repeatedly to understand and predict possible future outcomes caused by different scenarios. The accuracy and level of the complexity of the model will, of course, determine the accuracy of the predictions. The knowledge gained from the simulation model is extremely useful in understanding the critical processes within the system, and through the control of these processes, it is possible to manage the output of the system.

System Dynamic Modelling is very much a 'hard system' approach to problem solving in that it believes that there is a desired state of the system which is

known. It also believes that there is a present state of the system and that there are many alternate ways of getting from the current to the desired state. It is therefore, the role of the problem solver to find the best means of getting from the present to the desired state. Hard system approaches demand that objectives are clearly defined at the very beginning of the process. This may be fine for simple, mechanistic type problems where ends are easy to specify but, in the vast majority of managerial situations, the very definition of objectives could constitute a major part of the problem faced. Role players are likely to see the problem situation differently and to define objectives according to their own world views, values and interests.

Strategic Assumption Surfacing and Testing on the other hand, is very much a 'soft system' approach which concentrates on the political and human aspects of an organisation and is extremely useful in the solving of problems that relate to the differing opinions of the people involved in ill-structured problem situations. Until some compromise is reached between the main role players, it will not be possible to overcome the problem situation. Managers and problem solvers faced with these types of problems can make use of this methodology to gain a full understanding of the different view points of all who are involved. The strength of this methodology lies in the sweeping in of all the different perspectives of the role players and bringing them together through a process of synthesis into a position that is acceptable to all.

Soft System Methodology, as the name implies, was developed to be better able to handle problems relating to complex situations where the objectives and the measures of performance are not so clearly defined. The analysis in this soft system approach consists of the building up of the richest possible picture of the problem situation with no attempt made to represent it in terms of systems. Out of the analysis, a range of systems relevant to improving the problem situation, each expressing a particular viewpoint, are developed into conceptual models. The use of Soft System Methodology leads to the construction of a number of models to be compared with the real world situation, rather than just one as is the case in hard methodology approaches. It can be said that the models produced by hard approaches are blueprints for design while, conceptual models produced by soft approaches are contributions to a debate about change. Hard systems,

therefore, lead to the design of systems, while soft system approaches lead to the implementation of agreed changes.

The section on Herbert Simon's Heuristics has been added to illustrate to the problem solver a realistic approach for dealing with problem and decision making in real life situations. They capture how real minds make decisions under the constraints of limited time, knowledge and computational resources. Of particular importance is the vision of 'bounded rationality' and the simple steps taken to simplify and reduce the amount of resources necessary to make good decisions.

All systems approaches are committed to looking at the world in terms of 'wholes' that exhibit emergent properties, rather than falling back on to a reductionistic viewpoint that understanding is best obtained by breaking down situations into their fundamental elements. Problems can therefore be categorised according to the systems in which they exist as detailed previously in Chapter 2.0. Systems can be classified, very generally, on a continuum where, at the one end, the systems are relatively simple and are characterised by having a small number of elements with few, or at least regular, interactions between them. These simple systems are likely to be governed by well defined laws of behaviour, to be largely closed to the environment, to be static over time, to be unaffected by behavioural influences and to have subsystems that are passive and do not pursue their own goals. Within these systems, problems are more likely to be of a mechanistic, simple nature. At the other end of the continuum, the systems are of a very complex nature and characterised by having a large number of elements that are highly interrelated. These systems are probabilistic, open to the environment, evolve over time, are subject to behavioural influences and have purposeful parts. Problems found within these systems are more than likely to be of a complex nature.

The majority of problems facing an engineer operating within a Japanese controlled, mass production environment are simple and mechanistic in their nature. Japanese management system require that the problem solving methodology used in the solving of these problems be standardised in its application, simple and quick to use yet remains effective in that it delivers results in line with targets set. Before moving to this standardised problem solving framework, referred to later in Chapter 5.0 as the 'Quality Story', it is

important to have an overall understanding of the Japanese management practices as described in Chapter 4.0.

University of Cape Town

## CHAPTER 4.0

### STANDARDISED APPROACH TO SHOP FLOOR MANAGEMENT

*Before continuing with the introduction of a standardised framework for problem resolution, it is important that the engineer or problem solver has a good understanding of Japanese management systems. To this end, the Nissan Plant Management System (NPMS) has been used to describe in detail such systems as Policy Management, Shop Floor Management, Standardisation and Synchronised Production. These systems have been developed to enable targets to be set for the business with regards to quality, cost and delivery together with the measurement of performance against these targets. These systems rely heavily upon standardisation of operation to enable benchmarking to take place between the different Nissan plants world wide.*

*The framework for problem resolution referred to later as 'The Quality Story' is yet another of the standardised procedures.*

Over the past few years, Nissan has undergone change in ownership from a wholly South African owned company with Japanese (Nissan) interest to a fully owned Japanese plant. During this transition, Japanese management style became a way of life to the point where now it is no longer negotiable.

With the advent of Renault purchasing a large portion of Nissan's equity, a plan has been formulated that, through rationalisation, strict cost and headcount reduction, Nissan will return to profitability by 2001. This plan has been named the Nissan Revival Plan (NRP) and effects all Nissan plants around the world. One important aspect of the Nissan Revival Plan is globalisation whereby the vision is to create a global network capable of producing products to equitable standards of quality, cost and delivery. In achieving this, parts can be sourced from any part of the world and improvements and cost performance can be compared from one Nissan plant to another via benchmarking exercises.

In order to achieve this globalisation, the Nissan Plant Management System (NPMS) was developed for incorporation into all Nissan plants throughout the world. The aim of the plant management system is to achieve quality, cost and delivery (QDC) targets with the minimum resources and quality built into the process, that is maintainable and can be constantly improved upon to compete favourably within a world market. An underlying principle of NPMS is to secure quality to an appropriate level that will satisfy the customer and in so doing, obtain superiority within the market. This implies that a quality level is built into the process that is commensurate with customers expectations but does not mean excessive quality which could be detrimental to cost and delivery expectations. In the words of a previous Nissan president, the following statement pretty much sums up Nissan's previous philosophy towards quality and styling prior to the merger with Renault: "No matter how inexpensive a vehicle or how attractive it's styling may be, it will not stay competitive if it fails to live up to customers expectations in terms of reliability. On the other hand, even if a vehicle is conservative in appearance and styling and does not incorporate a lot of new technology, it will certainly appeal to customers if it gains a reputation for continuous, trouble free operation."

Another important aspect of NRP is the standardisation of practises with regards to Management style, targets and control under the umbrella of Nissan Production Way (NPW) that encompasses Policy Management (Hoshin Kanri) and Shop Floor Management (Genba Kanri).

Japan's need and drive toward standardisation comes from its past in that the Japanese automobile industry relied not on innovated engineering but on excellent shop floor workmanship. The background to this was the Japanese lifetime employment system and wage structure based on seniority.

Consequently, certain models of cars could be manufactured in Japan to a quality level that could not be matched in other countries where the level of shop floor personnel was not as skilled. However, over recent years, Japan has seen a decrease in the working population coupled with an increase in temporary workers and an increasing aged work force.

Taking these elements into account, it became no longer sufficient to rely upon the workers skill but required a shift to engineering a system whereby the operations could be de-skilled. This engineering of standardisation enabled any worker to produce the product to the Quality, Cost and Delivery level required.

#### **4.1 NISSAN PLANT MANAGEMENT SYSTEM**

Nissan's management goal is to be number one in the "Customer Satisfaction Index" (CSI) by achieving world class standards in QCD through continued comprehensive productivity improvement activities with quality driven and waste free operations. Figure 08 following is a pictorial map of the Nissan Plant Management System indicating the relationship between the different management activities. Underlying the whole system is the need to be Quality Driven in that quality must be built into the process to reduce repair work at the end of the process and in so doing, reduce the cost of manufacture. The basis of the emphasis on quality lies in the fact that customer satisfaction will not be achieved without it.

Built in quality implies that the following conditions are evident:

- a) All units in the process are to the quality level required by the downstream process (no passing on poor workmanship)
- b) Units are produced using the minimum resources (labour, material and equipment).
- c) Units are produced at the rate required by the downstream process.
- d) High degree of consideration given to the requirements of employees.

Fundamental to the whole system is the support, development and motivation of all employees based on the Nissan Global Personnel Management Principles.

In co-ordinating efforts for Nissan and all its overseas plants to the attainment of its common goal, management should strive to achieve the following:

- More effective and complete planning
- Strong leadership and the drive towards achievement of targets set
- Activities for achievement of targets through the participation of all employees
- Promotion of standardisation
- Establishment and implementation of purchasing policy for long term partnership and coexistence with suppliers.

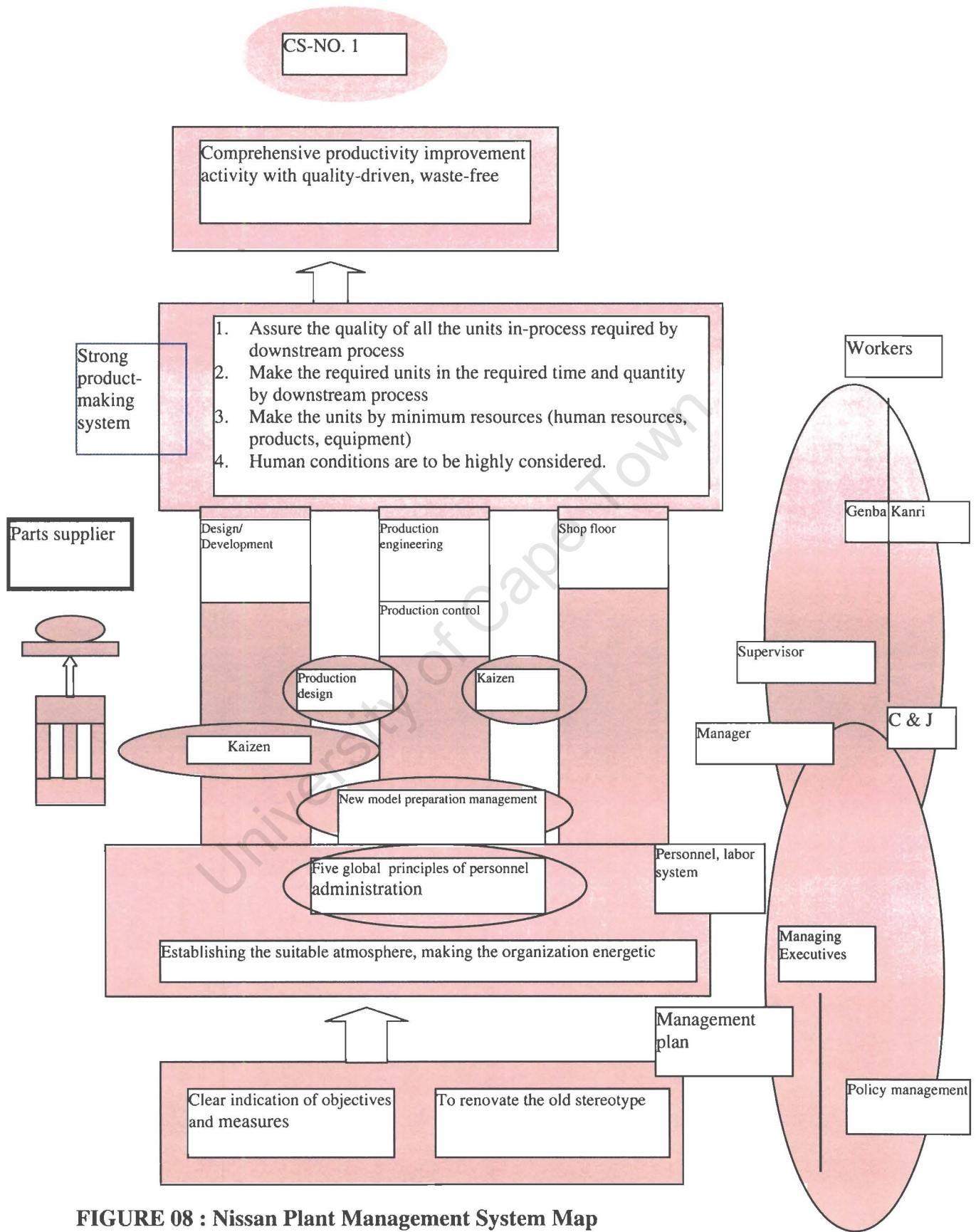


FIGURE 08 : Nissan Plant Management System Map

## **4.2 POLICY MANAGEMENT ( Hoshin Kanri)**

Policy management is a system for improving the business constantly through continual use of the PDCA cycle to control achievement towards a medium term and annual plan. The system makes use of the utilisation of human resources, materials and funds to raise the whole companies potential by achieving the best combination of quality, cost and delivery based on the objectives of the plan. It defines what is important for the plant, how it can be achieved, by who and by when and clarifies what type of plant is desired for three to five years in the future.

The condition of the plant in the future will reflect senior management's vision today and their efforts to make that vision a reality. Conversely, a companies current condition reflects the vision and objectives set by the senior management five to ten years previously.

In order to achieve these visions, it is necessary to have

- A good understanding of the present situation
- A good idea of the desired future state
- Ideas on how to achieve these visions

When formulating these visions, the focus should be on the following conditions:

- Quick response to market and customer needs
- Vehicle quality must be a given
- Manufacturing costs
- Quality and suitability of production equipment and levels of automation
- Maintenance level of plant facilities with emphasis on reliability, quality and utilisation
- Streamlining of logistics, synchronised production and inventory levels
- Creation of a culture in which employees are motivated and eager to perform
- The 3 S of the operation  
( The principle of 3S will be explained later in the text under Genba Kanri-Shop Floor Management)
- Standardisation of operations.

Once the plants objectives have been set, they must be made known to all employees.

Senior management should take a lead role in the establishment of action plans to achieve the targets set. This implies motivation of employees through a management style and policy that joins everyone together in a vigorous effort to attain the plant objectives.

In other words the degree of achievement will be determined by three aspects, namely,

- Senior management's vision for the future
- Objectives and targets set for achieving that vision
- Success rate of management in mobilising the employees to achieve the objectives set.

Once targets have been set it is necessary to make use of every available method, assume leadership for all related departments without regards for limits of responsibility and carry out any steps necessary to achieve the aims.

The management plan is broken down into clearly defined objectives and measures of success which are entered onto a Business plan format under the categories of Quality, Cost, Delivery and Management. ( The most recent form of the Nissan Plan has substituted Management for People and safety objectives). The plan is cascaded down and side ways from CEO to each level of the organisation with each plan supporting the plan of the previous level as well as supporting other departments on the same level. In this way, each level of management is focused on the activities that they need to achieve in order to support the overall strategy of the business to ultimately satisfy the customers requirements.

Policy management must take cognisance of the fact that it is increasingly difficult to expect to make profit and increase sales if the same methods are use year on year in an ever changing environment. As the company grows and improves, so the plan must be changed in line with the new requirements.

The constitution of the company must be aware of and strive to make improvements on the following concern areas:

- awareness and consciousness of customers needs
- division of the company for the benefit of individual departments at the expense of the advancement of the total company
- to attach importance to only the result and not pay attention to the process
- no awareness to the utilisation of data and information
- poor ability to the solving of problems
- management dependant on individuals

A successful company has the following constitution characteristics;

- capable of grasping problems
- attaching importance to a plan
- attaching importance to a process and improving upon it
- consciousness to priorities
- all members unified towards the same plan

Management plan must take consideration of two distinctively different activities, namely;

- activities towards maintaining the current situation through standardisation
- activities towards making changes to the current situation in order to make improvements and keep ahead of changes taking place in the external environment

Fundamental to the plan is the establishment of an operations room for each level of management where the plan together with the control graphs are displayed. Regular monthly or weekly review meetings are held in the operations room to evaluate the results of the plan and to make the necessary adjustments where targets are not being met. Six monthly and annual reviews of the plan together with full analysis of results achieved are carried out and adjustments made to the plan in line with changes that have taken place internally and externally in order to keep the plan dynamic and to keep the business on track with its longer term objectives.

### 4.3 SHOP FLOOR MANAGEMENT ( Genba Kanri )

Genba Kanri or Shop Floor management is the management of the shop floor making maximum utilisation of man, machine and material to build quality into the process and to pursue efficiency based on ‘ Quality Driven and Waste Free’ operations.

The product is manufactured by means of the three elements of man, material and machine and through some productive operation, a final product of value is produced. The control of the output is the result of the control of the operation and the control of the process and underlying the whole process is the need for training and standardisation. (Refer figure 09 following for a diagrammatic representation of the Genba Kanri process).

#### OUTLINE OF GEMBA KANRI (GK)

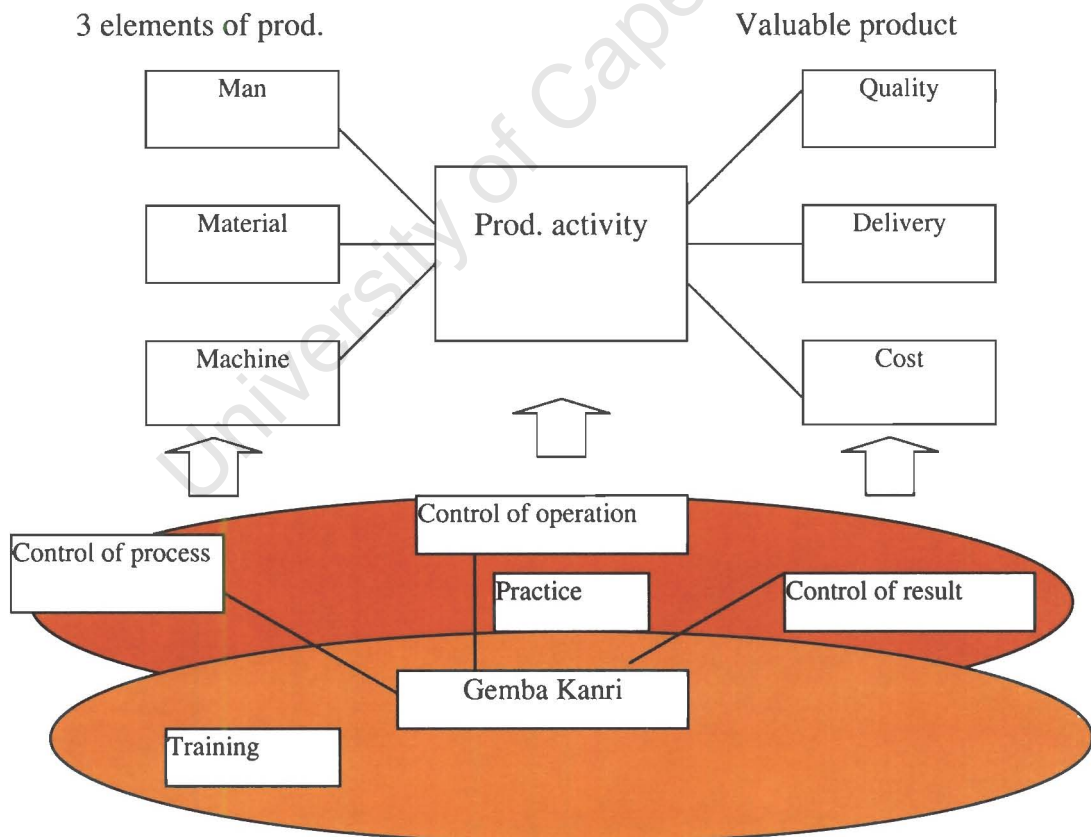


Figure 09 : Structure of Genba Kanri, Shop Floor Management.

#### **4.3.1 BASIC PHILOSOPHY OF GK**

The key person for the achievement of production is the shop floor foreman and his tool for achieving this is GK making use of standardisation, continual improvement techniques and training. His basic role is to achieve his QCD targets through instruction and training of his subordinates and to perform operators observation and skill evaluation. In the event of problems he must investigate the real cause and take the necessary action through repeated application of PDCA cycle and in this way he is able to improve on the standard process and in so doing, create a stronger work place.

Instruction and training of the operators is carried out through skill evaluation against a standard operation sheet (more about this process later) and a process of continual improvement called Kaizen which results in the modification of the standard and improvement in the process. The key to promoting spirited kaizen activities involving workers on the shop floor is a management which cares for its employees. The traditional management style of imposing decisions by senior upon junior employees needs to be changed to a culture that recognises that shop floor workers have brains and the ability to think of improvements to their own working environment. Kaizen improvements should be done in small but steady steps that are maintainable as opposed to the western style of large improvements that soon slips back to the original situation.

#### **4.3.2 FOREMAN TRAINING FOR GK**

In order to be successful in the carrying out of GK on the shop floor, a foreman requires training in the following three areas:

- **Management ability**

This requires that the candidate foreman has been trained in all the different GK philosophies and activities by means of theoretical training in the class room making use of text books as well as practical experience on the shop floor.

- **People ability**

Leadership ability to lead and have the respect of a small production team as well as other related production areas. Must be able to train and motivate the

workers under his control (each foreman has approximately 20 workers in his small team) in the following disciplines:

Operation control

Quality control

Facility control

Personnel and labour control

Safety and environmental control

Cost control

Training will be by means of instruction and on the job training

- Technical skill

Each foreman must be able to carry out the operations of all his subordinates within the standard time and to the expected quality standard and be able to train others in the carrying out of the operation. He must be capable of reading and interpreting engineering process sheets and establishing Standard Operation Sheets for each of the operations within his area of control. Operator training and skill evaluation must be carried out in line with the following'

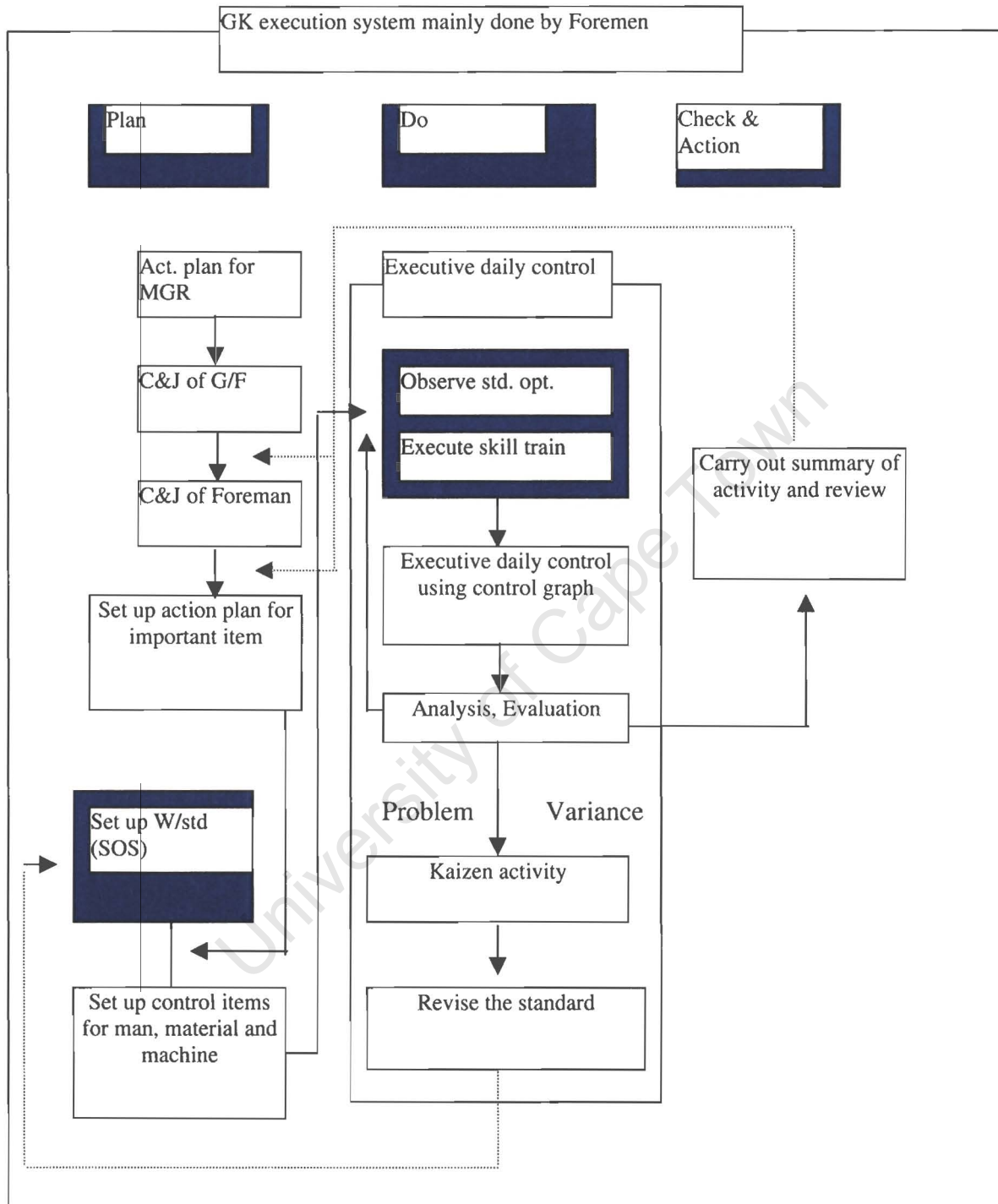
iILU Evaluation matrix:

#### **iILU SKILL EVALUATION STANDARD**

<b>Classifications</b>	<b>Required level</b>	<b>Points to master</b>	<b>Expected level</b>
— i Level	Able to build in Quality	To know main steps and key points of operation	New operator's level
T I Level	Can work within standard time	Needs repeated skill training	General operator's level
L L Level	Can do non-cyclic work and trouble shooting	To get the knowledge about equipment and products	Group leader's level
U U Level	Can teach others	Foreman who learned N-TWI can instruct others	Foreman's level

**TABLE A : SKILLS EVALUATION AND TRAINING STANDARD**

### 4.3.3 PRACTICE AND IMPLEMENTATION OF GK



**FIGURE 10 : Diagrammatic Representation of GK Activities**

The management cycle of Plan, Do, Check, Action (PDCA cycle) is turned and actioned continuously making use of the following fact finding techniques:

- 3 Reals and 2 Theory

REAListic approach to see the REAL problem in the REAL workshop based on the principle and theory. This methodology implies that problems can only be solve once the problem solver has seen, touched and experience the real problem on the shop floor.

- Problem Solving based on Data

Technique for problem solving based on the 'Quality Story' (refer chapter 5) making use of the 7 new and 7 old quality tools (refer chapter 6).

- 5 W and 2 H

Method of honing down to the root cause of the problem by making use of the following questions:

When, Where, Who, What, Why, How and How much.

- 3 S

Method of maintaining neatness, cleanliness and order in the work place ( see section following).

#### 4.3.4 3'S' ACTIVITIES

Konosuke Matsushita, the late founder of Panasonic, once said that:

“You can tell whether a plant is profitable or not just by stepping inside the door. A plant that is running smoothly has a certain sense of tension, ease, vitality and beauty about it, no one is loitering around, everything is in it's place and a place for everything”.

The '3 S' level of a plant expresses the spirit of senior management and is a clear indication of whether that spirit has permeated throughout the entire plant.

The terminology '3 S' comes from three Japanese words, Seiri, Seiton, Seiso which mean, Usefulness, Orderliness and Cleanliness. This does not imply that more cleaning staff must be engaged but is rather the culture of how people work and look after their own work place.

#### 4.3.5 STANDARDISATION

The aim of standardisation is to enable anyone to perform the operation safely by following the procedure and thereby accomplishing the objectives set for quality, cost and delivery. In order to control standardisation of the process, the foreman must establish a Standard Operation Sheet (SOS) for each and every operation performed by the operators.

The initial information on the SOS is obtained from the engineering process sheet from which the main steps of the operation are established together with the key points. The main steps are the motions that are necessary for a product to be assembled in a sequential manner. In order to establish these main steps, it is necessary to carry out the actual operation under normal production conditions. Normal principles of motion economy are applied to ensure that an effective operation is obtained, namely

- Reduce the number of motions  
Elimination of unnecessary motions, related motions or unreasonable or wasteful motions
- Performance of motions simultaneously  
Consideration to be given to the use of both hands simultaneously to carry out symmetrical operations. Reduction of idle time through the balancing of operations.
- Shorten moving distance  
Reduction of walking distance and generally the application of good ergonomically accepted principles with regards to sitting, working heights and arm and hand movements.
- Make motions easier  
Eliminate factors that restrict motion and make use of gravity where ever possible to reduce the amount of weight to be lifted.

Once the main points have been established, the Key points are determined by carrying out the operation and listing all the actions required in performing the Main points. The purpose of the key points is to make it clear to the operator exactly what is required to be done to carry out the operation.

From the main and key points, a Standard Operation Sheet is established that makes it clear what is to be done in performing the operation and can be used in training the operator.

Skill evaluation as mentioned earlier in this chapter for the determining of iILU rating of the operators can only be performed by evaluation against the SOS. Standard operations, once set are continually being challenged and changed through kaizen activities in the drive for continuous improvement.

When problems are experienced in the work place, whether of a quality, manning or delivery nature, the following three questions are posed:

- ~ Is a Standard Operation Sheet available?
- ~ Is the operator working to the standard?
- ~ Are the standards correct?

Through this process, it is possible to get to the root cause of the problem.

#### **4.3.6 ROLE OF MANAGER IN GK**

The role of the Manager is to set up policy in line with the Management Plan or Hoshin Kanri and through his business plan, cascade clear targets and expectations down to the foreman level. He must establish the organisation and environment that is conducive with the work that must be carried out and a system of practise that will enable the foreman to obtain good results through his actions. Resources in the form of man, material, machine and money must be made available to enable the carrying out of the activities. Proper actions must be taken to encourage, maintain and enrich the GK process.

#### **4.4 SYNCHRONISED PRODUCTION ( Douki Seisan)**

The basic production philosophy of the Toyota system is based on the 'Just in Time' and 'Line Stop Concept' whereby, the just in time delivery of components is effected by means of a pull system in support of a down stream process or customer. Line stop concept aims at stopping production when a problem has occurred and to take action immediately. This is a lean manufacturing system that has been made possible by Toyota in Japan due to the close proximity of the majority of its main suppliers to the assembly plant. The Toyota system is a primitive JIT system that is effective particularly when the operators are unable to

read, write and calculate. The operators begin working when parts and product are delivered to their working station and stop when the stock runs out or the down stream process is full of stock.

When a quality problem occurs, production is stopped and the operator informs the foreman of the situation and takes action immediately together with supervision to overcome the problem. The production schedule is planned according to the anticipated receiving schedule and stock is reordered 'Just in Time' by means of a Kanban system. Kanban is a system that makes use of cards to control the level of stock in production. Simply put, cards represent lots of stock and as the stock is used, the cards are placed into a rack and when the cards reach a certain level, stock is reordered. In this way, the rate of production determines the rate of reordering stock. The Toyota system, due to its simplicity is readily accepted by both operators and management as an effective method of achieving production objectives.

The Nissan system or Nissan Production Way (NPW) is achieved through up-stream control based on the basic philosophy that Quality is a non negotiable and the continual strive towards the elimination of waste. Waste according to the Nissan definition relates to excessive stock levels, reject or defective components and down time of production.

An ideal situation in line with NPW would be as follows:

- Quality of the products 100% in line with the requirements of the down stream processes needs
- Production timing and volume in line with down stream needs
- Products produced with the minimum resources of Man, Material and Machine.

In this way, the Nissan way aims to achieve acceptable quality products on time to satisfy the customer at the lowest possible cost (QDC).

Douki-Seisan or Synchronised Production is the activity by which Nissan achieve the NPW through the carrying out of production from up stream process (like the Stamping Plant) to down stream (like into stock) based on a customer order. In

this way, the up stream process carries out synchronous production in accordance with the off line schedule.

The basic principles of Douki-Seisan are:

- Carry out production in response to an actual customer order from Marketing
- Sequence of production in line with customer order sequence
- Production lead time shortened to the minimum.

In this way, Douki-Seisan attempts to combine JIT, SQC (supplier quality) and TPM (total productive maintenance) to achieve synchronous, smooth flow of production making use of minimum stock, defect free components and no down time. The aim of the activity is to achieve maximum levels of QDC and in so doing, maximise profits while ensuring customer satisfaction by shortened periods of delivery.

Advantages of this activity are:

- a. Initial quality of the vehicles is increased through receipt of defect free components, minimum stock levels and no down time.
- b. Production responds flexibly to market requirements with short production lead time and guaranteed delivery promoting customer confidence.
- c. Minimum stock levels improves stock turn ratios and cash flow.

Management effectiveness is easy to measure by means of the following ratios as control items:

- Delivery Timing Observation Ratio (TOR)  
Ratio of achievement of individual vehicles against the off line schedule within one hour of the schedule.
- Production Sequence Observation Ratio (OR)  
Observation ratio of production ratio in line with plan. No delayed or sided tracked vehicles.
- Production lead time reduction

Nissan planned the introduction of Douki-Seisan through a five step process, namely,

1. Synchronise production between vehicle assembly plant and engine assembly plant

2. Synchronise production between vehicle assembly plant and in house manufacture components like body stamping parts. Current long lead time of stamping makes short lead times for vehicle very difficult except through high levels of inventory.
3. Synchronised production between vehicle assembly plant and external parts suppliers like seat assembly, fuel tanks, exhaust pipes etc.
4. Synchronised production between vehicle assembly and vehicle transportation. Currently, production does not take into consideration the transportation constraints in delivering the vehicles to the dealers resulting in vehicles sitting unnecessarily in the stock yard.
5. Synchronised delivery between vehicle assembly and delivery to the customer.

As previously mentioned, one of the main achievements of Douki-Seisan is the reduction in lead time from order to delivery of the vehicle to the customer.

Currently, this lead time in Nissan Japan sits at 5 weeks made up as follows:

1 week- receipt of order to inclusion in the production schedule. Production schedule can sometimes be delayed due to availability of production capacity.

1 week- from schedule to actual start of production due to the time required in preparing the components required.

1 week- lead time for manufacture of vehicle from body shop, through the paint shop, through trim and mechanical and off line in the case of low volume models. In the case of high production models, this time can be reduced to just 2 days.

1 week- from off line to the local delivery centre where the vehicle is finally inspected in line with customer acceptance levels and any non standard optional extras required are fitted.

1 week- delivery from the inspection centre to the customer through the dealer. Nissan goal through Douki-Seisan is to reduce the current 5 week lead time to a total of 2 weeks.

In order to achieve this drastic reduction in lead time, the following actions by the various divisions of the company must be carried out:

### **Product Development**

Reduction of production and supplier variation through commonisation.

Increase commonisation between different models by the use of common floor construction (platforms) and common components in order to reduce the amount of production fluctuation in the change over from one model to the next.

### **Production Control and Planning**

Devise a system whereby the receipt of an order automatically updates the production schedule and places the necessary orders for components.

### **Engineering Division**

Introduction of flexible line system (FMS) that is capable of producing multi models on the same line.

Enhance maintenance through TPM and preventative maintenance activities to eliminate production losses through breakdowns.

### **Production Division**

Increase production flexibility for model and volume changes.

Reduce die set-up time in the stamping plant and move towards one day lot size production runs.

Achieve production operator awareness to quality to ensure that all components and operations are correct to the required quality levels before passing it on to the next process.

### **Quality Assurance Division**

Ensure that all components received from suppliers are to the required quality level.

### **Logistics Division**

Establish transportation system that delivers vehicles both day and night.

Douki-Seisan can not be readily transferred to Nissan overseas operations due to their reliance on the supply of CKD ( Completely Knocked Down) or imported

components from Japan. Lead time for the ordering of CKD is approximately four months resulting in the need to plan and order stock well in advance of receiving customers orders. Consequently, production scheduling is based on the delivery of stock rather than on the receipt of fixed orders. This is not to say that this situation can not be changed, if stock was to be ordered differently, say by telephone or facsimile unit for unit on a daily basis, it could be possible to reduce this lead time down to one month. This system is currently being used by Toyota for some of its overseas operations.

The following aspects of Douki-Seisan can however be introduced into the overseas operations with tremendous benefits:

Inventory of stock throughout the entire operation from Stamping through to the stock yard and even the dealers must be reduced to the absolute minimum due to the excessively high rates of interest charges. Quality improvement through defect free components and products is important for customer satisfaction as well as stability of production.

Reduction of down time caused by maintenance breakdowns, parts shortage and operation delays is essential for achievement of planned production schedule on a daily, weekly and monthly basis.

Table B following indicates a five step introduction plan for Douki-Seisan in Production system, Kaizen activities, and production control or scheduling. Also included are the step up improvements of JIT, SQC and TPM.

**TABLE B:STEP UP ACTIVITY FOR DOUKI-SEISAN**

	<u>Prod. System</u>	<u>Kaizen method</u>	<u>Production control</u>	<u>JIT</u>	<u>SQC</u>	<u>TPM</u>
Step-1	Lot prod. Lot supply	Genba Kanri SOS 3S	Forecast prod. M/S No.1	Motion study First in, first out	Sample check QRQC activity Job observation	Time utilizat. B/down maint. 3S activity

Step-2	Small lot Daily supply	Kaizen QC PM	WIP control M/S No.2 Stop after finish	Job allocation Stock reduction Approaching	100% inspect. A&B defect Pokayoke	Small stop loss Planned maint. Morning check
Step-3	Contentious prod Hourly supply	Minimal stock Defect free No down time	CCR M/S No.3 Flexible work hrs	2 day kaizen one unit flow connecting	Process control Side truck reduct. In-line check	Speed down loss Corrective maint. Oil & add wrench
Step-4	Sequent prod. Synchro sup	Rectifying line Required tact Quality maint.	Order a.card M/S No.4	JIT kaizen No WIP Into line	Process assur. Straight run Auto measure	Defect loss Maint. prevent Light repair
Step-5	Douki- seisan	Douki- seisan	Douki-seisan	Douki-seisan	Douki- seisan	Douki- seisan

#### 4.5 CONCLUSION

The engineer within the Nissan management system is responsible for the establishment of process and maintenance of that process within the production environment. The process must be capable of achieving the required quality and volume levels at minimum cost by the reduction or elimination of waste. Hence the need for this chapter to indicate to the engineer the major systems within which he must operate. The systems are regimented and rigid in their execution and are based on many thousands of standards describing their purpose and application. All activities are geared towards the attainment of prescribed levels of achievement with regards to quality, cost and delivery, with very little, if any, consideration towards the human element of the operation. This philosophy of treating people as if they are just another component to be engineered like other mechanical parts of the system falls very much in line with the criticism of hard system methodology towards problem resolution.

This criticism relates to the failure of hard systems approaches to pay proper attention to the special characteristics of the human component in the sociotechnical systems with which they are dealing. The fact that human beings possess understanding and are motivated to support change and perform well if they attach favourable meanings to the situation in which they find themselves, is ignored. This deterministic perspective in hard systems thinking, which puts the system before people and their perceptions, extends to the ability of humans to intervene in their own destiny. Hard system thinkers take the future to be determined by factors outside the control of organisational actors.

With this likeness to the criticism of hard system methodologies, it is small wonder that the standardised procedure prescribed by Japanese management for problem resolution is very much a hard system approach.

The Japanese need for standardisation is to be consistent with performance and measurement to enable global comparison with other Nissan plants around the world.

The next chapter moves into the detailed explanation of the standardised framework for problem resolution that should be used for the solving of all problems within the Japanese production environment.

## CHAPTER 5.0

### THE QUALITY STORY

*The Quality Story is not a methodology but rather a framework for the solving of problems. Like most Japanese systems, it is not revolutionary in its concept but is rather simple and very effective. Rather than being seen as an alternate, it should be seen as additional to other problem solving methodologies such as those described in Chapter 3.0. Many of these methodologies will be used from time to time in some of the steps of the QC story to determine, for example, the current situation, the real problem or the possible countermeasures for improvement. One of the strengths of this system is that it encourages the problem solver to fully understand the current situation in which the problem exists. It also requires the setting of targets for improvement before the taking of countermeasures so that the effectiveness of the solution can be measured against original objectives. This framework for problem solving has many similarities to the principles of heuristics described in chapter 3. Both heuristics principles and the QC story rely heavily on the use of 'means-ends' analysis, a clear definition of the problem and the setting of the target or aspiration level early in the process. The framework fully subscribes to the PDCA cycle in that, if the result obtained does not meet the target set, the problem solver must go through the steps again for further improvement. In this way, the QC Story can be used for problem resolution as well as a method for continual improvement.*

Japanese management is very standardised in the control of policy and shop floor management, so too is their approach to problem solving. The methodology that is used within the Nissan Plant Management system is called the 'Quality Story' and is a system of problem solving and continuous improvement making use of data and a step-by-step approach. Rather than a problem solving methodology, the QC story is more a rigid framework for problem detection and resolution. Due to its simplicity, this framework is very useful for the solving of mechanistic, simple as well as other more complex problems and is a very powerful tool for engineers to solve problems on the shop floor.

The first question that most engineers ask when attempting to use this framework for the first time is: "Is there a standard form that can be filled out?" The answer

to this question is a simple no. The QC story is a 7 step framework and although it is a rigid procedure, each problem is different and will require a different method of solving. Participants should be discouraged from trying to reduce the framework to a standard form as once this is done, the job becomes filling out the form rather than solving the problem. What is important is not the format but rather that each step has been thoroughly investigated before moving on to the next. In this way, the problem solver gains maximum knowledge about the problem and will be lead towards solutions that are both practical and appropriate.

The following five tasks are essential for effective shop floor management:

- 1) Maintain and improve **quality** through the carrying out of operations to standards without mistakes.
- 2) Reduce the **cost** of inputs through the reduction of overheads.
- 3) Achieve production targets and **delivery** schedules.
- 4) Assure **safety** through the elimination of injuries, illness and accidents.
- 5) Improve interpersonal relationships and **morale** in working together as a team to create a pleasant working environment.

The QC Story approach to problem solving can be used to solve problems and make improvements in all of the above mentioned areas.

### **5.1 STEP ONE - Selecting a Theme**

The first step of the framework is to define the problem or problem situation. This sounds simple but many people make the mistake of thinking that they know what the problem is and set off to solve the wrong problem. The immediate response when problems are experienced in a production environment is to implement countermeasures that address the symptoms of the problem. These countermeasures, although essential to stabilise the process so that production can continue, will more often than not, not solve the problem. The reason for this is that we have not analysed the problem situation to understand what the root cause of the problem is. Remember that this framework is used for both problem solving as well as improving on current situations through continuous improvement.

In the case of continuous improvement, the following diagnostic questions can be useful in identifying the problem or selecting the theme:

- a) Is the work tiring or hard to do?
- b) Is there waste, strain or lack of uniformity in the final outcome?
- c) Are there items that are defective or the need for rework?
- d) Are there any requests or complaints from upstream or downstream processes or from other work places?
- e) Is there anything that inconveniences or causes customers dissatisfaction?

The objective of the investigation must be explicitly expressed in terms of what, where, when and how much and the 'why-why' technique can be useful in honing down to the real cause of the problem.

## **5.2 STEP TWO - Understanding the Current Situation**

It is impossible to know that you have improved a situation unless you fully understand what the situation was like before you intervened. To this end, it is essential to have a complete understanding of the current situation with regards to the problem situation, is it an ongoing problem, or is it a sudden or chronic occurrence. This requires the gathering of data on defect size, degree of fault etc. and to express the situation numerically making use of the Seven QC tools such as graphs, Pareto diagrams and Histograms ( the Seven QC Tools as well as the new tools and their application are described in detail in Chapter 6)

The first step in determining the present or current situation is to thoroughly observe the actual circumstances of the defect closely and carefully. The important points of the attitude with which this observation is made are as follows:

- Observe with an open mind  
Observations made on the basis of preconceptions and bias will lead to the wrong understanding of the problem. Do not accept existing information and data but probe deeply to establish the true cause of the problem. Assume nothing, go back and check the basics. Remember that situations can change due to the action of your investigation so, if necessary, observe from a distance.
- Commit to make the improvement no matter what it takes

Improvement of defects or the solving of problems is accomplished through extreme efforts with tenacity and the devotion to achieve the final objective. Carrying out the same old actions will deliver the same old result.

- Go immediately to the shop floor

When a problem occurs, go immediately to the shop floor and observe and ascertain the true situation. It is important to observe the actual situation as soon as possible as situations can change with time and information obtained later may not lead to the true cause of the problem. Problems on the shop floor can not be solved from behind the desk in the office.

- Compare good and bad components to illustrate non-conformance

Make use of comparisons to identify the true extent of the defect.

Having carried out the observation, the next step in determining the current situation is to understand what the desired state is after the intervention and solving of the problem. It will be impossible to ascertain whether the problem resolution has been successful or complete unless the end point is established. To use an analogy, 'no journey is complete until you have reached the final destination'. It is helpful and advisable to know what the final destination is before embarking on the journey. To this end, a clearly defined target must be set at this early stage before embarking on the solution to the problem. Three elements should be defined as part of the target or goal, namely

1. Numerical value of the result after the improvement has been made. This value may be percentage number of defects or straight through ratio, reduction in downtime or any other specific achievement.
2. Deadline or timing in which the achievement must be achieved
3. Degree of effect the improvement will have on the operation stated in terms of improvement in quality, reduction in cost, elimination of manpower through easing of operation or improvement in volume throughput.

Setting of targets should take into account the targets of the department or section in which the problem is being investigated and should strive towards the overall objective of the plant. In the absence of clear targets relating to the problem situation, determine a target based on the importance of the defect, it's significance and difficulty of countermeasures.

### **5.3 STEP THREE - Creating a plan of action**

Having established a full understanding of the problem, the next step in the process is to determine a plan of action how to attack and improve the situation in order to achieve the target set. The problem solver makes use of the knowledge that he has gained about the current situation to determine the resources he will require and role assignments based on available expertise, background and aptitude of participants involved.

Up to this stage, no effort has been made to solve the problem but to gain understanding of the root cause and the area or type of intervention that will be required to improve the situation.

### **5.4 STEP FOUR - Analysing the factors.**

Making use of the information obtained about the current situation, the problem solver again observes the actual problem with a view to gain data and to process it into a format that will help lead to the solution. The search for information should be limited by means of a 'stopping rule' to limit time and the resources used.

The following QC tools will be useful at this stage (refer also Chapter 6) in collecting the data:

- Determining the magnitude of the problem  
Pareto Diagram, Tally sheet
- Find factors affecting the situation  
Cause and effect Diagram
- Check variation, differences and change  
Histogram, Graph, Control Chart
- Check temporary change and movement  
Graph, Control Chart
- Check relationship between factors  
Scatter Diagram

Analysis is the next step which involves the pinpointing of the root cause of the problem by selecting the major factors from the many identified. Once identified, the selected factors must be studied exhaustively.

In selecting the major factors, identify all factors likely to cause the problem and through techniques like the '5 why' ask why again and again to get down to the root cause.

It is necessary sometimes to choose the root cause from among many possible causes. The following pointers can be helpful in determining the one overriding root cause:

- Determine which factors contribute the most
- Ascertain the degree of contribution of each major factor through experimentation if possible
- If experimentation is not possible, judge the degree of contribution from the effect achieved by subsequent actions
- Examine the cause and effect relationship to pinpoint the root cause.

Problem solving methodologies as described in Chapter 3 previously, namely, Systems Dynamics, Strategic Assumption Surfacing and Testing and Soft Systems Methodology may be applied at this stage depending on the complexity of the problem situation.

Once the true root cause is known, the problem is best part solved

### **5.5 STEP FIVE - Developing and implementing countermeasures**

Once the root cause is identified, the problem solver and team can begin to think of how best to effect improvement. The improvement plan must be to eliminate or address the root cause and not to treat the symptoms. At this stage, the team members must be encouraged to think as laterally as possible and no solutions, no matter how bizarre, should be discarded. Techniques such as brain storming can be useful in determining a multitude of possible solutions. From the list of possible solutions, an improvement plan must be formulated for implementation taking into account the technical feasibility, practicality and cost of the proposed countermeasures as well as acceptability by the key participants in the problem situation.

Next part of this stage is to implement the plan. If possible, conduct a trial run of the plan to check for any adverse side effects, if there are no problems, implement the plan.

## **5.6 STEP SIX - Confirming Effectiveness**

This stage is to confirm whether or not the plan has had the desired effect in resolving the problem situation. In order to do this, it is necessary to monitor the effect on the situation after the countermeasures have been implemented and compared these results to those taken before in stage two ( current situation). Measurements must also be taken to determine whether or not the set target level of improvement has been achieved, bearing in mind that the intervention is not complete until the required level of achievement has been made. This equates to the comparison between the current and the desired states in order to gauge improvement.

In the event that the desired level of improvement has not been achieved, revert back to either stages two, three or four and revise the plan and your thinking and understanding about the problem and continue back through the step-up. This process is recursive until the required result has been obtained.

## **5.7 STANDARDISATION AND ESTABLISHING CONTROL**

This is perhaps the most important stage of all and the one that is more often than not neglected. If an effective countermeasure has been put in place and no change to the standard practise is made, the problem situation will eventually, in time, revert back to it's original state. This is a basic law of nature that any situation will revert to it's previous steady state if no form of control is imposed to keep it at it's current level. This is one of the reasons why many countermeasures are only temporary and old problems seem to reoccur.

The following actions should be taken to ensure that the operation remains at the new desired level:

- a. Standardise the change. Revise the Standard Operation Sheet (SOS), Process Sheet, Operation Sheet and drawing if applicable.
- b. Provide guidance through instruction and training based on the revised standard to ensure understanding, acceptance and adherence to it.
- c. Follow-up to make sure that the improvements are carried out and stay in place and that the required result is still being achieved. If applicable, check to see if any similar processes can also benefit from the changes and countermeasures implemented.

## Problem Solving Procedures

Proce dure no.	Basic Step	Things to do
1	Selecting a theme	<ul style="list-style-type: none"> <li>• Identify the problem</li> <li>• Decide a theme</li> </ul>
2	Understanding the current situation, and setting targets	<p><b>Understand the current situation</b></p> <ul style="list-style-type: none"> <li>• Collect facts</li> <li>• Decide what to attack (characteristic values)</li> </ul> <p><b>Set targets</b></p> <ul style="list-style-type: none"> <li>• Decide targets (target values and deadlines)</li> </ul>
3	Creating a plan of action	<ul style="list-style-type: none"> <li>• Decide what to implement</li> <li>• Decide schedule, role assignment etc.</li> </ul>
4	Analyzing the factors	<ul style="list-style-type: none"> <li>• Investigate characteristic values and current situation</li> <li>• List factors</li> <li>• Analyze factors</li> <li>• Decide countermeasures</li> </ul>
5	Developing and implementing countermeasures	<p><b>Develop countermeasures</b></p> <ul style="list-style-type: none"> <li>• Propose ideas for countermeasures</li> <li>• Think about specific countermeasures</li> <li>• Reconfirm the nature of the countermeasures</li> </ul> <p><b>Implement countermeasures</b></p> <ul style="list-style-type: none"> <li>• Consider method of approaching countermeasures</li> <li>• Implement countermeasures</li> </ul>
6	Confirming effectiveness	<ul style="list-style-type: none"> <li>• Confirm results of countermeasures</li> <li>• Compare with targets</li> <li>• Identify results (concrete and abstract)</li> </ul>
7	Standardisation and establishing control	<p><b>Standardise</b></p> <ul style="list-style-type: none"> <li>• Establish and improve standards</li> <li>• Decide control methodology</li> </ul> <p><b>Establish control</b></p> <ul style="list-style-type: none"> <li>• Raise consciousness of all concerned</li> <li>• Educate supervisors</li> <li>• Confirm that things can stay on track</li> </ul>

**Table C: Quality Story Problem Solving Procedure.**

The following 10 rules apply to problem solvers wishing to make use of the QC Story approach to problem solving:

Rule 1: Saying there are no problems is a cop-out. There are always problems and they must be addressed forthrightly.

Rule 2: Get a balanced viewpoint from all the different perspectives. Observe the workplace and situation carefully and use data to get an accurate grasp of the real problem.

Rule 3: You can not win empty-handed. Study the QC Story techniques carefully and implement them effectively and thoroughly.

Rule 4: Skill is important. Acquire specialised techniques and expertise to hone your skills.

Rule 5: A quick once-over will not work. You must proceed methodically through each problem solving step.

Rule 6: Don't get carried away with countermeasures. Only take action after you have analysed causes in detail and identified the root cause of the problem.

Rule 7: Computers can not produce ideas. Aim for personal ingenuity.

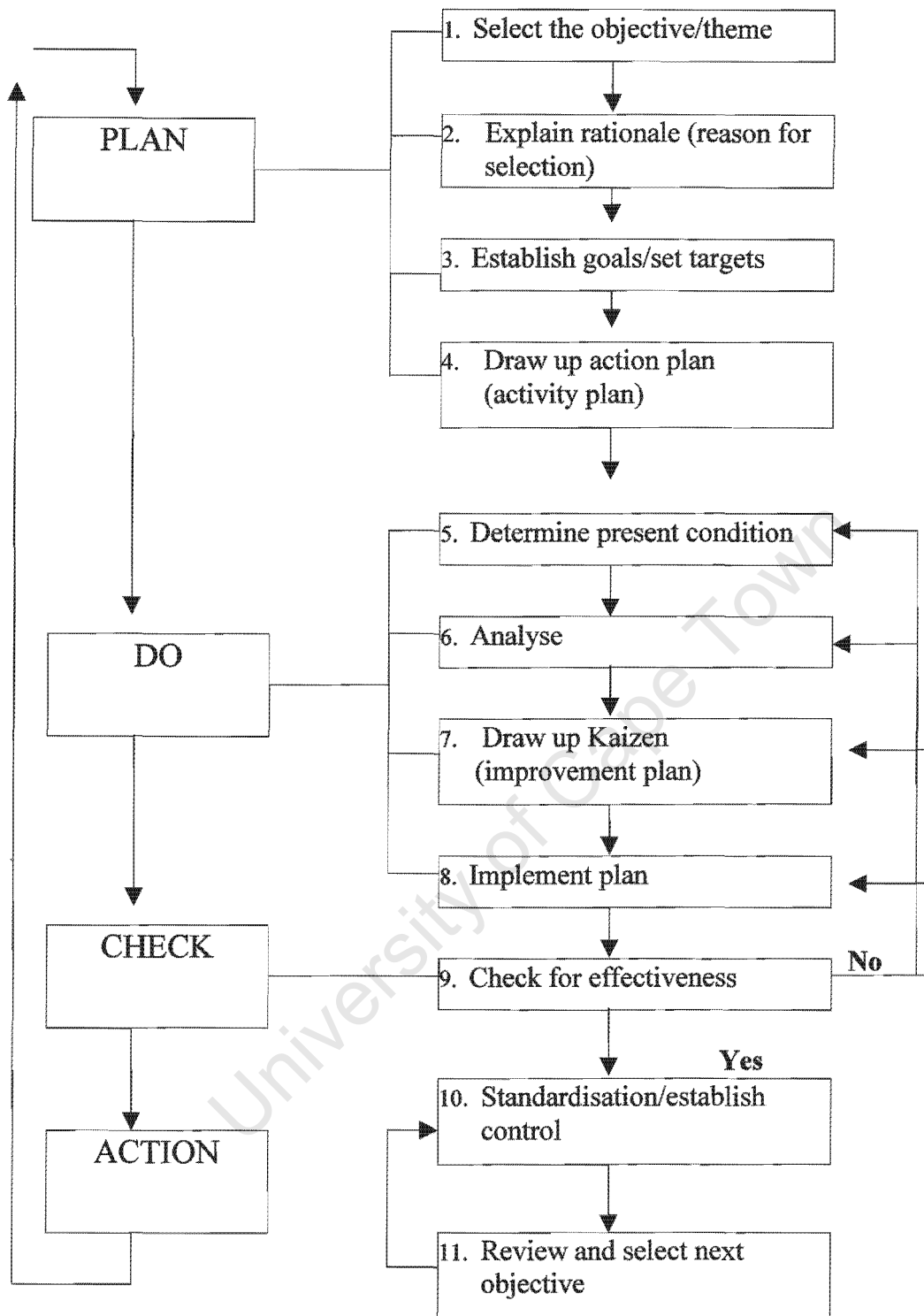
Rule 8: If you don't proceed logically, you will come to a dead end. As you go along, apply QC approach to your thinking.

Rule 9: It is no use to urge your subordinates on to greater efforts. You must tackle difficulties yourself.

Rule 10: Don't give up. Keep your spirits up and fight on to the end.

## **5.8 QC STORY AND THE PDCA CYCLE**

The QC Story problem solving procedure fully supports Shewart's learning cycle of Plan-Do-Check-Action (PDCA) in that each stage of the cycle is covered by actions within the step-up procedure. Feedback loops exist whereby, if results are not obtained, the process goes back to the plan or do stage for modification. Once complete, the process is recursive in that further objectives are selected for ongoing, continuous improvement.



**Figure 11: Alignment of the QC Story Problem Solving procedure and Shewart's PDCA cycle**

## 5.9 CONCLUSION

The problem solver now has a simple framework that can be used within the Japanese management system for problem resolution of any problem. The framework is simple yet demanding in that each step must be fully completed before moving on to the next. The framework can be used together with other problem solving methodologies and has the advantage of leading the problem solver through a very logical thought process. If used correctly, the engineer can hone down to the root cause of the problem rather than wasting his efforts on addressing the symptoms of the problem that manifest themselves on the shop floor. By fully understanding the current situation in which the problem exists, it is possible to establish effective and practical countermeasures to remove the real cause and solve or improve the problem situation. Once the real problem is understood, the problem solver is more than fifty percent on the way to solving it. This statement is fully supported in Herbert Simon's vision of bounded rationality. Use should be made in the framework of 'fast and frugal heuristics' as well as satisficing to reduce the time spent on researching information and alternatives. The job is not to develop better repair methods, but rather to remove the need to carry out the repair in the first place!

This framework follows very closely the aspects of a hard system approach in that the desired result is prescribed very early in the process and very little attention is paid to the human element of the process. This framework is a system analysis that is most suited to easy-to-structure problems in which technology dominates over people. It is however, a systematic approach to decision making and problem solving which constitutes an advance over ad hoc thinking about the management task. The careful setting of objectives, the search for alternative means of reaching those objectives and the evaluation of the alternatives in terms of a measure of performance, makes this an efficient, step-by-step approach to problem solving.

In order to effectively carry out the different stages of the 'Quality Story' framework, it is necessary that the problem solver conduct detailed analysis by making use of data. In this way, solutions or countermeasures can be based on data rather than personal experience or subjectivity. It is therefore necessary that engineers make use of the available tools for data collection, planning and analysis detailed in the following section.

## CHAPTER 6.0

### THE SEVEN QC TOOLS

*Before embarking on the resolution of a problematic situation, it is necessary to gain a good understanding of the current situation in which the problem resides. Data must be collected and refined into a format that will guide the problem solver towards the true cause of the problem. Analysis is also required to ascertain the feasible countermeasures as well as to analyse the results after the intervention has been implemented. The Seven QC Tools are structured graphical techniques that enable the problem solver to understand and measure the variations and the effects of those variations within the process. They also enable the prioritisation of problems and the measurement of whether the changes implemented have had the desired effect. Problems handled through the use of these tools produce better solutions than those handled in an unstructured manner.*

*The Seven Management and Planning Tools also known as the Seven New QC Tools are useful techniques to organise verbal information and to convert apparent chaos into a workable and implementable action plan. They help to convert raw, unrefined data into a plan acceptable by all through a physical process and identify patterns that were previously not apparent. In so doing, these tools separate complex situations into problems that are easier to solve and also help to eliminate errors during the planning stage.*

The strive for continuous improvement has two main elements:

#### **Philosophy of Improvement**

#### **Problem Solving Techniques**

With regards to the philosophy of improvement, the following are common points:

- Improvement of quality by removing the causes of problems in the system will inevitably lead to the improvement of productivity.
- The person doing the job is the most knowledgeable about that job.
- People want to be involved and to perform well.

- Every person wants to feel like a valued contributor and member of the team
- More can be accomplished by working together as a team to improve the system than having individual contributors working around the system.
- A structured problem solving process using graphical techniques produces better solutions than an unstructured process.
- Structured graphical problem solving techniques allow the problem solver to know where he is, where the variations lie, the relative importance of problems to be solved and whether the changes made have had the desired impact.
- Adversarial relationships between labour and management is counterproductive and outdated.
- Every organisation no matter how advanced it may be, has many undiscovered 'gems' just waiting to be discovered.

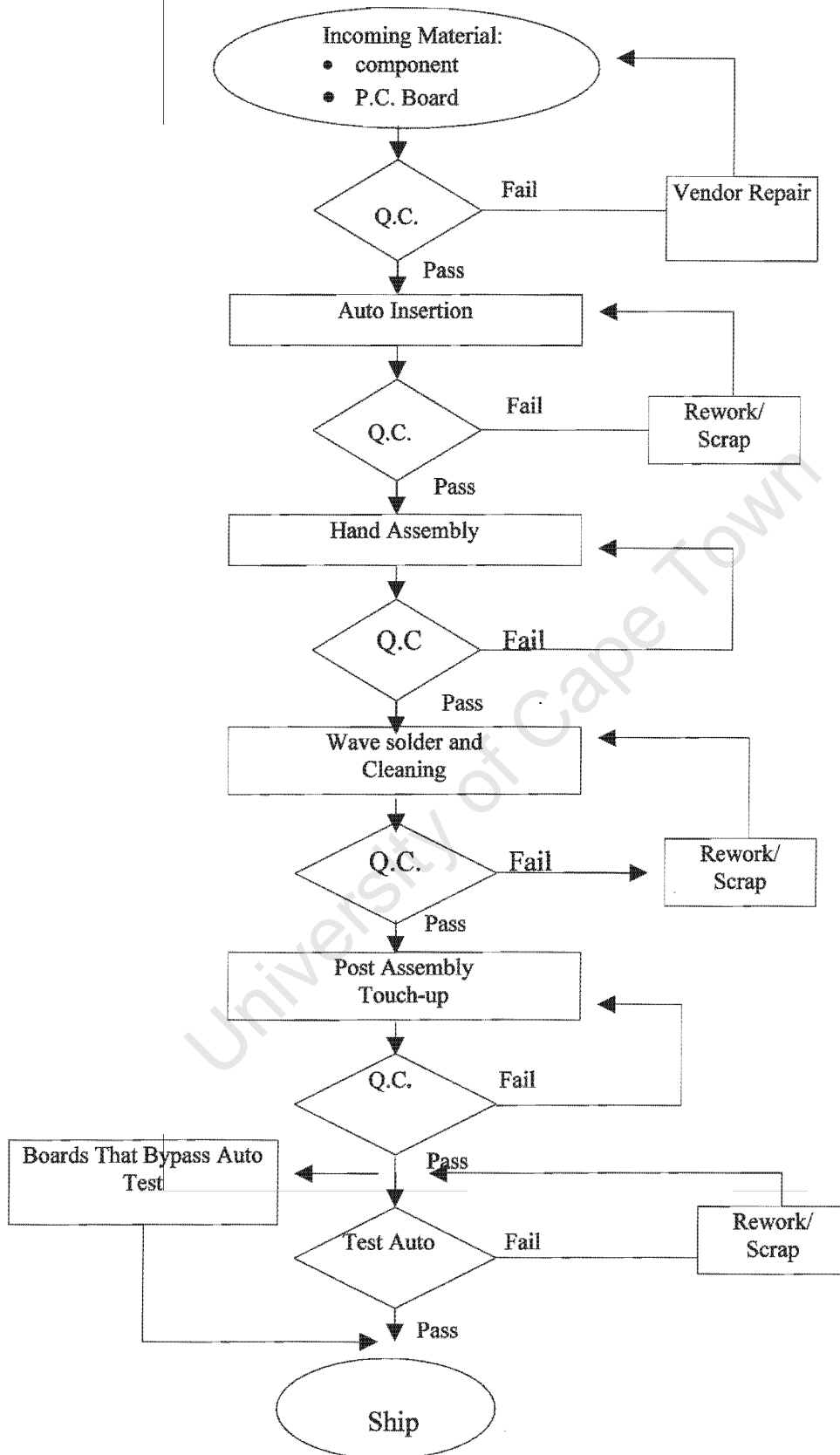
The rest of this chapter is dedicated to the different types of graphical, problem solving techniques.

Although not included in the techniques, flowcharts can be very useful for examining the various steps in a process and their relationship to each other. By studying these charts, it is possible to uncover loopholes which are potential sources of trouble.

The flowchart is mostly used in problem identification in a process called **Imagineering**. The people with the most knowledge of the process meet with the intention of completing the following:

1. Construct a flowchart of what steps the process **actually** follows.
2. Construct a flowchart of what steps the process **should** follow if everything was working right.
3. Compare the two charts to find out where they are different because this is more than likely where the problem arises.

## BOARD FLOW



**FIGURE 12 : Flow Chart for PC Board Assembly**

## 6.1 THE SEVEN QC TOOLS

Commonly referred to as **The Old Seven QC Tools**, these tools constitute basic techniques for problem solving that are useful for the correlation of 'hard' numerical data and facts. The tools are used to establish the following:

- Arrange problem areas
- Put data into diagrams
- Surface problem areas
- Bring up hidden truth
- Answer: what, why, when, where, who, how and how much
- Document and expose the existence and extent of variation
- Analyse and control variability

When problems are experienced, emergency measures must be taken to ensure continuance of production, but because the main cause is hidden, efficiency may still be unsatisfactory. These tools are used to help locate the root cause of the problem as well as to make continuous improvements and to increase work efficiency.

The commonly accepted seven tools are

1. Pareto Diagram
2. Cause and effect Diagram
3. Graphs
4. Check Sheets
5. Histograms
6. Scatter Diagrams
7. Control Charts

Sometimes, 'control charts' are included in 'graphs' and 'stratification' is added to make up the seven. For the sake of completeness, Stratification will be added at the end of this section.

### 6.1.1 PARETO DIAGRAM

The Pareto Diagram is a special form of vertical bar graph used to display the relative importance of many different conditions by displaying them in order of magnitude on a chart together with their respective ratio of importance. In this way, it is possible to select the number one priority problem or condition from many in order to direct resources for best effect. Another use of this chart is to confirm and compare results before and after improvement activities.

This chart method supports Pareto's theory that 80% of the problem is caused by 20% of the defects (the 80/20 principle) and by addressing the major causes, maximum effect can be achieved with the least effort.

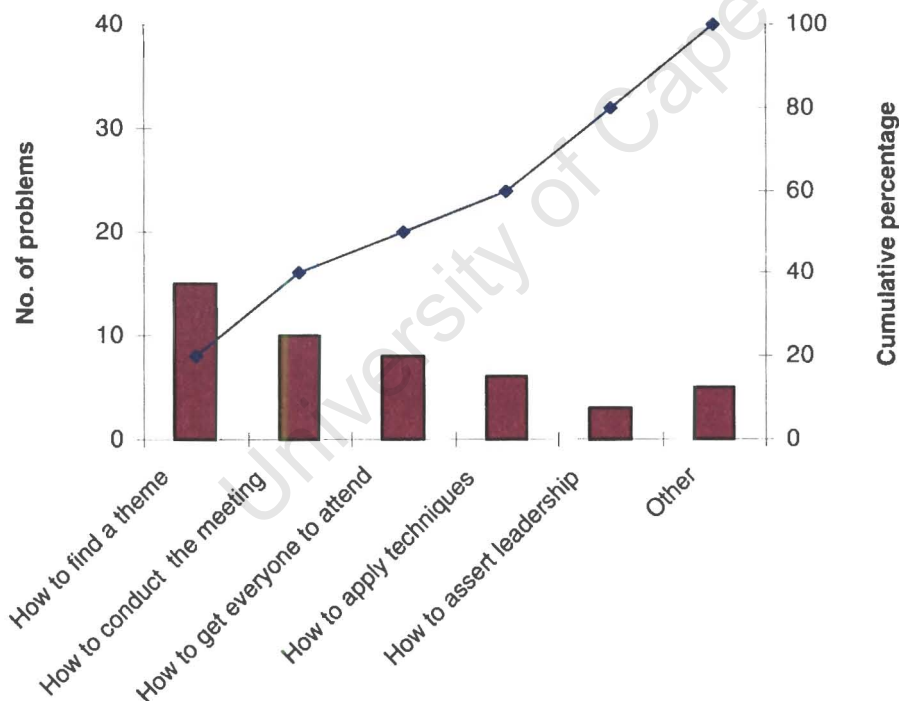


Figure 13 : Pareto Diagram for 'Problems in QC Circle Activities'

The following steps are used in the construction of the Pareto Diagram:

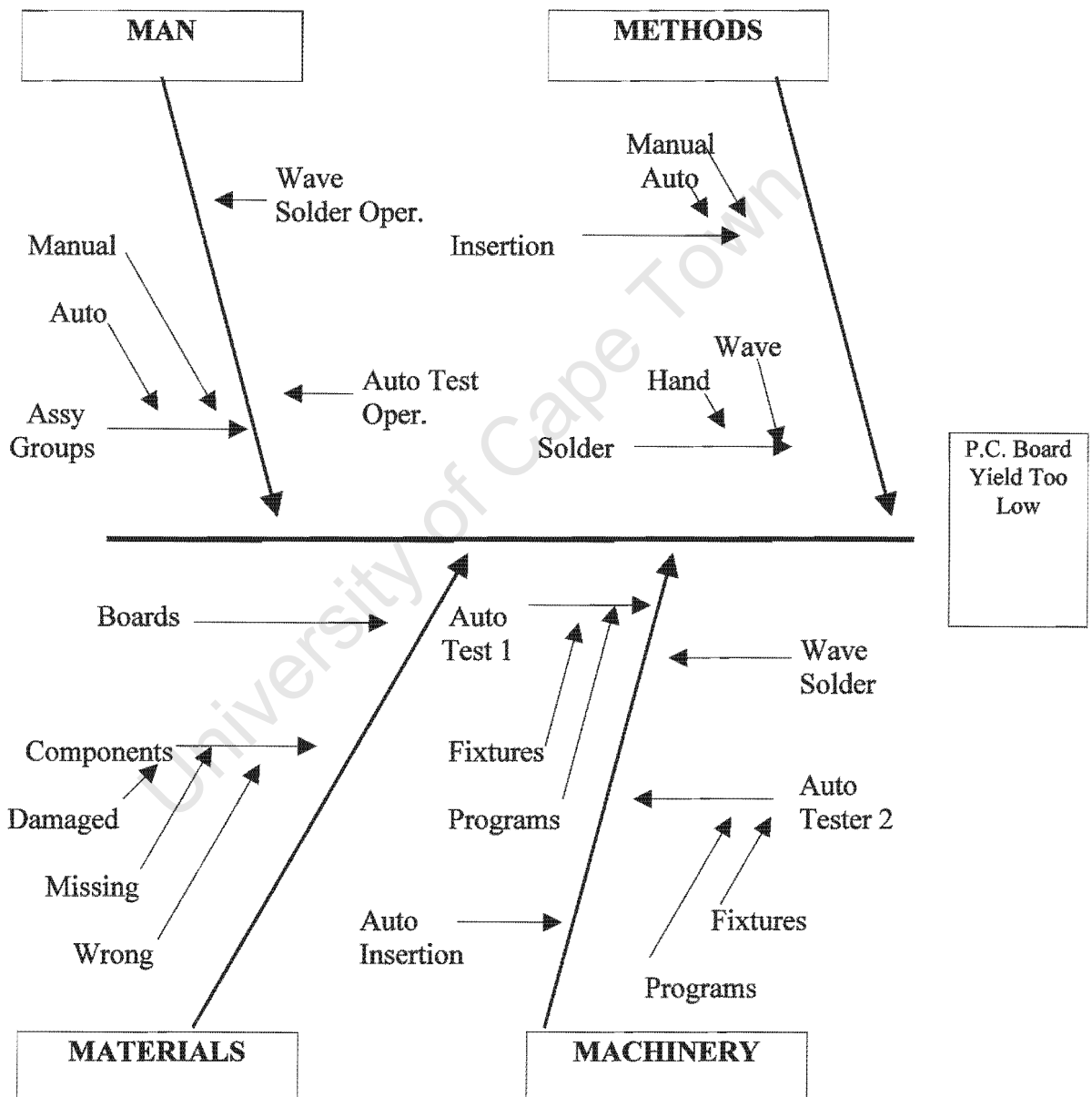
1. Selection of the problems or conditions to be compared and ranked by means of 'brainstorming' or analysis of the data existing about the situation.
2. Establish the most relevant unit of comparison for example, 'defects per unit' or 'units lost per downtime category'.
3. Select time frame for the study and collection of data.
4. Study and collect data of the 'real' problem on the shop floor. e.g. defect A occurred X times in the last week.
5. Compare the frequency of each category relative to the total of all the other categories.
6. List the categories from left to right on the horizontal axis in their order of decreasing frequency. The purpose is to bring out the most prevalent conditions so all the minor or least important conditions can be grouped into an 'other' category which is placed on the extreme right as the last bar.
7. Draw bars above each category, the height of which represents the frequency or size of that classification.
8. The vertical scale on the left indicates the comparison measurement and the scale on the right of the chart is the ratio as a percentage of the total problem. The line representing the ratio is the cumulative frequency and is useful to indicate that 80% of the problem is caused by 20% of the categories.

### **6.1.2 CAUSE AND EFFECT DIAGRAM**

Also known as the 'Ishikawa Diagram', the Cause and Effect Diagram is useful to identify, explore and display the possible causes of a specific problem or condition. Diagram was developed to represent the relationship between the effect or result and the possible causes that influence the result. Useful during brainstorming to determine the effect in question and to display all the possible causes influencing it.

The diagram is drawn with the effect in a box on the right hand side and the causes influencing it on the left in the form of a 'fish bone'. Generally, the causes are grouped under four main categories, namely, Man, Material, Method and Machinery (the 4M's), but this is not mandatory as any categories may be used if they help the participants to think creatively.

From the diagram indicating all the possible causes, the most likely are identified and selected for further analysis. When analysing the diagram, it must be remembered to cure the problem, not the symptoms, so the causes must be pushed down as far as possible towards the real cause of the problem.



**Figure 14 : Cause and Effect Diagram for Manufacturing Problem.**

The following steps are used in the construction of the Cause and Effect Diagram:

1. The effect is the problem at hand and the causes are determined through two different methods.

Structured brainstorming where the participants list the possible causes without prior preparation.

Check sheets where the participants track possible causes by studying the production process.

2. The diagram is constructed by:

Place problem statement in box at right hand side.

Construct the fish bone on the left using the major categories (4M's).

Place all possible causes under the main categories.

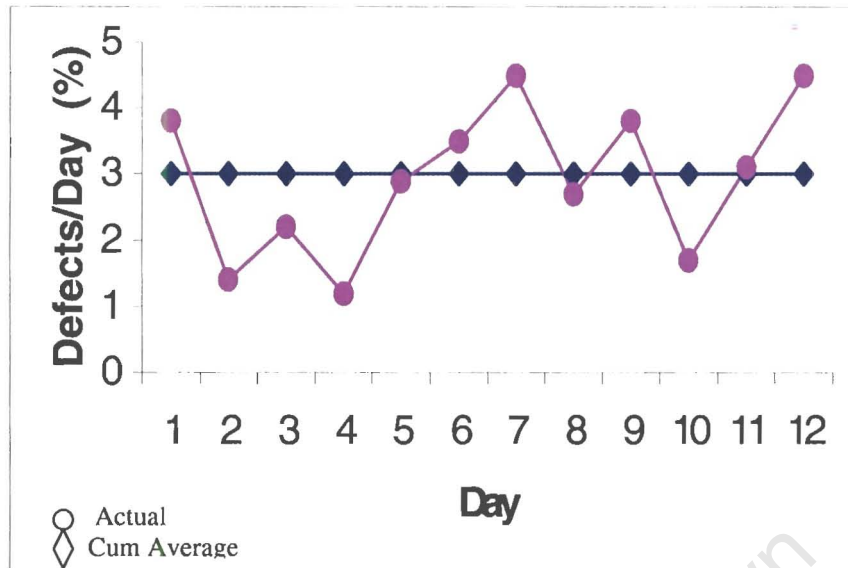
For each cause ask, "Why does it happen?" and then list responses as sub-branches off the major causes.

3. Interpret the diagram in order to find the most basic cause of the problem.
4. Gather data to determine the relative frequencies of the different causes.

### 6.1.3 GRAPHS

There are many different types of graphs and charts that can be used to display data and trends. The first is the most commonly used and is called a **Run Graph** or **Trend Graph** and is the simplest form of information display used to show trends and magnitude of individual readings over time in comparison with a set target of the average of the process. Run charts are used to visually represent data and to monitor a process to see whether or not the long range average is changing over time. Points are plotted on the graph in the order in which they are obtained and can be used to graph the results of such processes as machine downtime, cost of assembly and daily production as they vary over time.

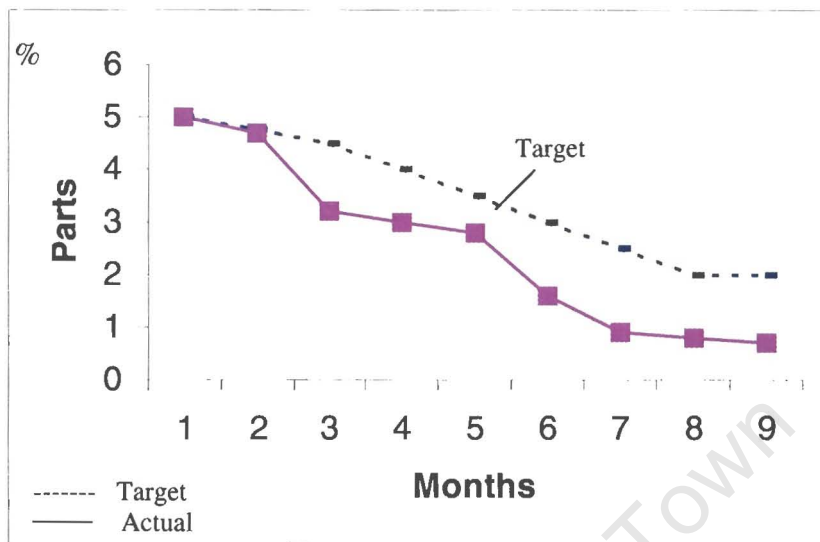
One of the dangers of this type of graph is that there is a tendency to see every variation as being important and to overreact to individual points rather than to focus attention on true changes in the process.



**Figure 15 : Run Chart for Percentage Defects Produced per day**

One of the most valuable uses of Run Charts is to identify meaningful changes in trends or shifts in the average of the process. When monitoring any process, it is expected that an equal number of points will fall above and below the average. When there is a run of consecutive points on one side of the average, it indicates that a statistical event has occurred and that the average of the process has changed. Changes such as this should be investigated to find out what has changed and whether or not it is for the better. If the shift is more favourable with regards to the result of the process, then it should be made as a permanent part of the process. On the other hand, if the shift is unfavourable, then it should be eliminated by bringing the process back to its original state. Another pattern of change that must be investigated is when points continually increase or decrease in magnitude indicating that something is influencing the process and should be eliminated.

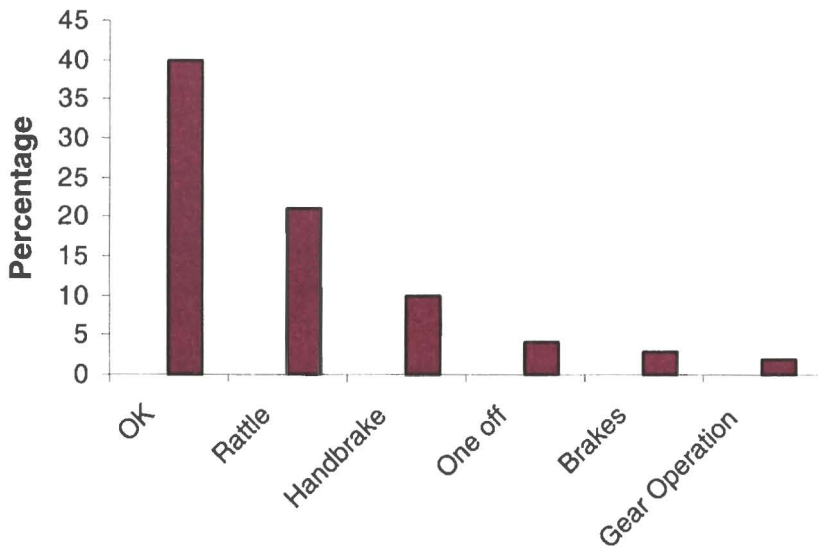
The next form of graph is the **Broken Line Graph** and although similar to the Run Graph, the points are plotted against a set target line. The purpose of this graph is again to monitor trends and performance against the target and any significant changes in the trend should be highlighted on the graph by means of a note.



**Figure 16 : Broken Line Graph for Parts Defect Ratio**

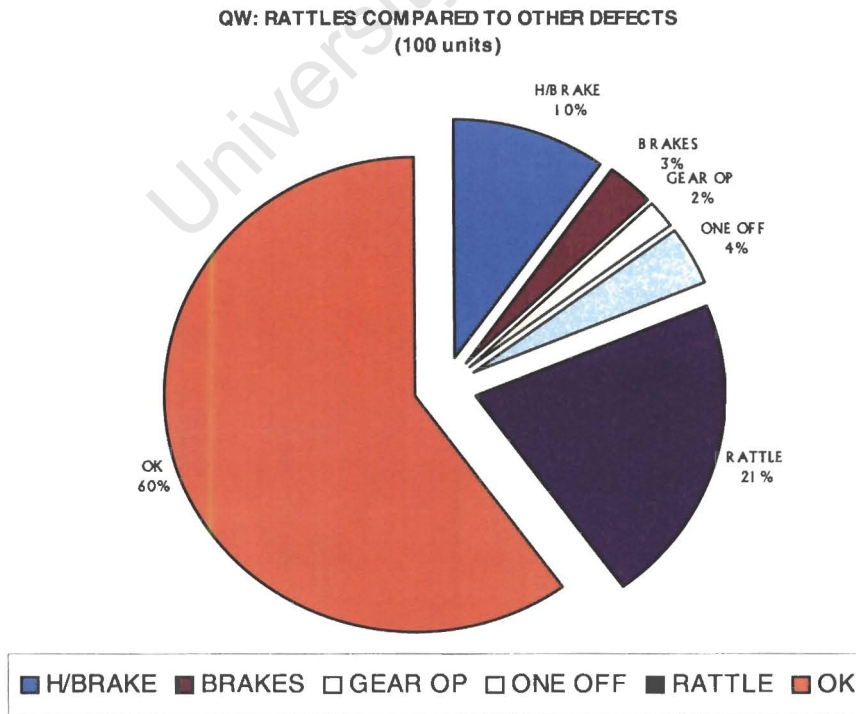
Graphs are constructed on two axis with the vertical or 'x' axis designating the magnitude of the individual points in a scale or ratio and the horizontal or 'y' axis designating the time frame. Each point plotted indicates the measurement or quantity observed or sampled at one point in time and must be kept in the order it was gathered so as to indicate the trend of the characteristic over time. Each consecutive point is connected to the previous point plotted by a line so that the trend can be easily seen and interpreted.

Another useful graph is the **Bar Graph** that is used to illustrate the magnitude of many different characteristics with one another. It can also be used to illustrate the change in magnitude of each of the characteristics from one time period to another.



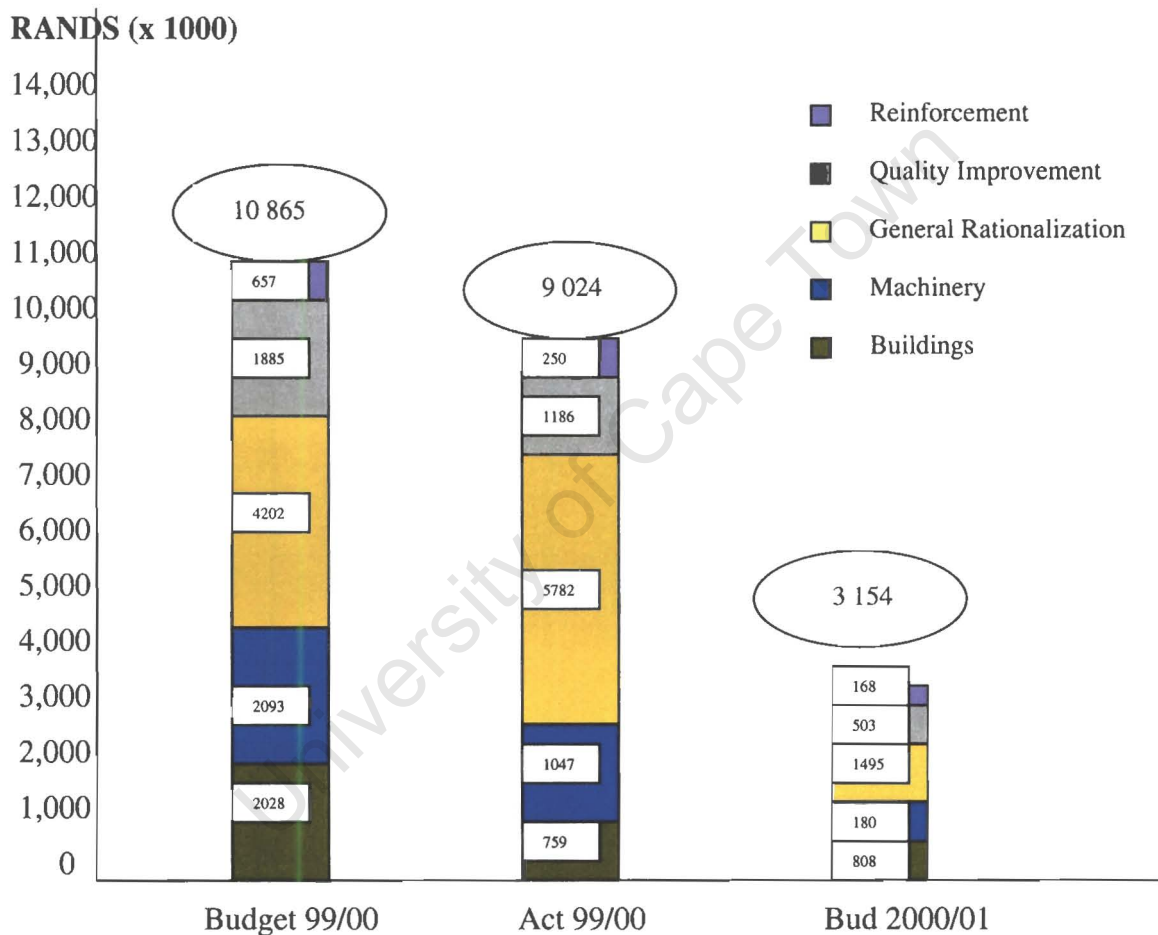
**Figure 17: Bar Chart of Vehicle Straight Through Ratio**

**Pie Charts**, like Bar Graphs, are used to illustrate the magnitude of the different characteristics in relation to each other, as a percentage of the whole. The Pie Chart represents 100% of the population of the data and is divided into slices, the size of which represents the percentage of each characteristic.



**Figure 18: Pie Chart of Vehicle Defects**

**Band Graphs** are a special form of Bar Graphs that are used to illustrate the magnitude of collective totals and the change in effect of the different characteristics over different time periods. The size of the individual bands may be their actual magnitude or may be expressed as a percentage of the whole which is represented as 100%.



**Figure 19: Band Graph of Capital Expenditure per annum.**

### 6.1.4 CHECK SHEETS

When gathering data based on sample observations to determine if a pattern exists, the easiest method is through the use of a Check Sheet. This is normally the first step or the starting point in most problem solving exercises.

Check Sheets are simple to construct and easy to understand and can be used to answer such questions as, “How often are certain events happening?” and “What is the most frequently occurring problem here?” It is the start of the process of converting unrelated and unrefined data into some form of meaningful facts that can assist the problem solver to understand the real underlying problem.

Product name	CS20-5D		Lot	LN1238	Date	From 1 Feb. 2000	
Process name	No.3 assembly line		number	LN1239 LN1240		To 6 Feb. 2000	
Measuring method	100% visual operation		Measuring instrument	—	Recorded by:		
Date/Day	2 / 1	2 / 2	2 / 3	2 / 4	2 / 5	2 / 6	<b>TOTAL</b>
Defect	<b>Mon</b>	<b>Tue</b>	<b>Wed</b>	<b>Thu</b>	<b>Fri</b>	<b>Sat</b>	
Loose screws	///	<del>///</del> ///	<del>///</del> <del>///</del>	///	<del>///</del> /		33
Dirt in distance sensor	<del>///</del>		//	//	///		12
Exterior scratches	//	<del>///</del> /	//	///	<del>///</del>		18
Soldering defect		//		//	/		5
Bonding defect	///		/	<del>///</del>			10
Operating defect		/	///		/		5
Gap defect		//		/			3
Part lost	///						3
Exterior dirt			//				2
Total	18	20	20	17	16		91
Number inspected	2037	Percentage defects					4.5%

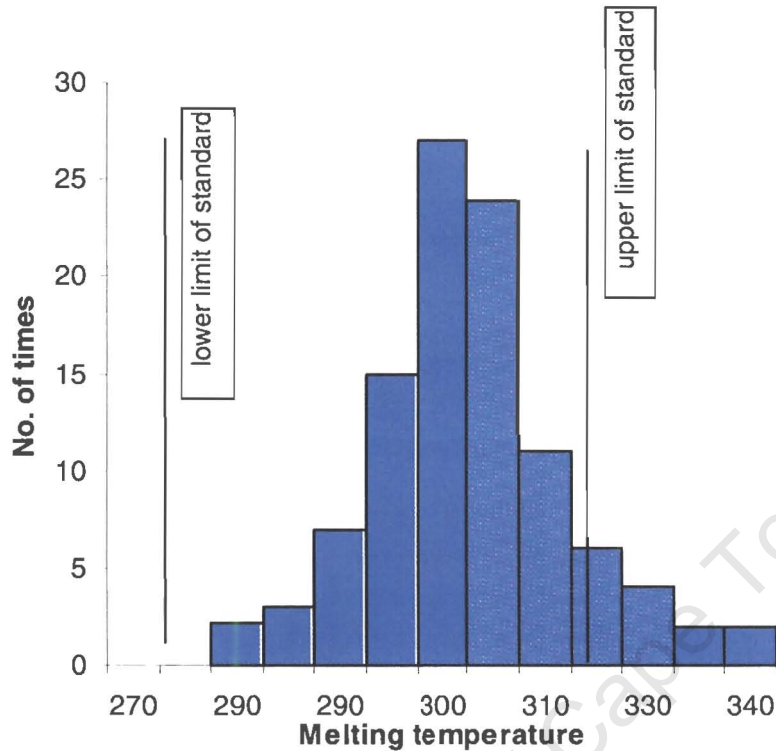
**Figure 20: Check Sheet for Defects in Assembly Process.**

When constructing a Check Sheet, it is important that all the participants are fully briefed as to the understanding of the problem being studied and are observing the same process. A time frame must be determined for the observation and the data must be collected and entered onto the Check Sheet

consistently and honestly. The Check Sheet form must be clear and easy to use with columns clearly labelled and adequate space for entering the data. A caveat when collecting the data is to ensure that the population is homogeneous, that is, all the samples are coming from the same process. If not, the population must first be stratified or grouped, with each group sampled individually.

### **6.1.5 HISTOGRAMS**

A Histogram is used to illustrate the frequency and distribution of the occurrence of different sample sizes and compares them to a standard. Whereas a Pareto Chart displays in bar graph from the frequency with which certain events occur, the Histogram deals with measurement data and displays its distribution. As we know, every process will eventually (depending on the number of samples taken) take the shape of a standard distribution curve. By studying the shape of the curve, it is possible to determine whether or not the process is in control or statistically capable. A normal distribution would display an equal number of readings above and below the mean and would take the shape of a normal distribution. Distributions may be skewed either to the left or the right of the mean indicating that the process being studied has a tendency for producing data in that direction. In the event that the data presents two distinct distributions with each having its peak indicates that the data is in fact coming from two machines (or operators for that matter). No two processes will produce exactly the same results because each has its own degree of variation. When studying Histograms, the important thing is to look for changes from the norm. If a process previously displayed a distribution skewed to one side and is now skewed to the other side, then something has changed in the process and should be investigated. Also of importance is whether or not the distribution or the spread of the curve, which indicates the variability of the process, falls within the prescribed limits.



**Figure 21 : Histogram for Melting Point of Fuses.**

When constructing a Histogram, the following steps should be followed:

- 1) Start with a set or list of unrefined data relating to a single characteristic of the process being studied.
- 2) Determine the range **R** by subtracting the smallest reading from the largest.
- 3) Determine the number of classes **K** that will be used. For this purpose, the following table is useful:

Number of Data Points	Number of Classes (K)
Under 50	5-7
50-100	6-10
100-250	7-12
Over 250	10-20

- 4) Determine the class width **H** by dividing the range **R** by the number of classes **K** chosen.
- 5) Determine the class boundaries for the each of classes chosen.

6) Construct a frequency table and place all of the data into their respective classes.

7) Construct the Histogram based on the frequency table.

The Histogram is an important diagnostic tool because it gives the problem solver an instant view of the variation of a data set and an indication of the amount of components that can be expected to be produced outside of the specification range.

The following points should be remembered when constructing the Histogram:

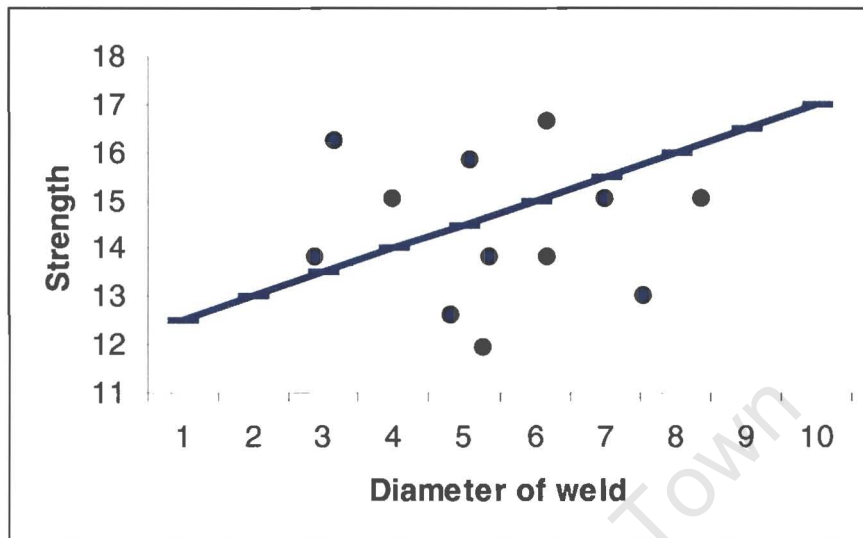
- The number of classes or bars will determine how much of a pattern is visible.
- Some processes are naturally skewed. Do not expect every distribution to follow a normal bell-shaped distribution curve.
- Be suspicious and question the data if the classes suddenly stop at one point ( such as a specification limit) without some previous decline in number.
- Always look for two peaks indicating that the data is coming from two or more processes e.g. different shifts, machines or change in operator.

#### **6.1.6 SCATTER DIAGRAMS**

The Scatter Diagram is used to illustrate the relationship between two variables and to display what happens when one of the variables changes. It can demonstrate the cause and effect relationship between the two variables. Although it can not prove that the one variable causes the other, it can make it clear whether a relationship exists and the strength of that relationship.

The scatter diagram is constructed on a vertical and horizontal axis, each of which represents one of the variables. The plots form a cluster pattern which gives the problem solver some indication of the relationship between the variables. The tightness and direction of the pattern indicates the correlation and whether the variables are proportional or inversely proportional to each other. As the pattern moves towards a straight line, the stronger is the relationship and the direction of the line indicates either a positive or a negative relationship. A straight line would mean that the two variables are

directly connected and that as one changes so does the other by the same proportion.



**Figure 22 : Scatter Diagram for Weld Diameter and Strength.**

A tight pattern increasing up towards the right would indicate a positive correlation between the two variables and that as one increases then so does the other. If the pattern increase up towards the left it is termed a negative correlation and indicates that as one of the variables increases, the other decreases. If the pattern is widely scattered then it can be assumed that no relationship exists between the two variables. Normally, when plotting the Scatter Diagram, the variable that is being investigated as the possible cause is on the horizontal axis and the variable which is believed to be the effect is on the vertical.

The following points are useful when diagnosing a scatter diagram:

- Negative relationships are as important as positive relationships.
- It can be deduced that the variables are related and not that the one causes the other.
- Straight line correlations are based on the formula  $y=a+bx$ . This, however is not the only form of relationship and other relationships may be exponential or logarithmic.

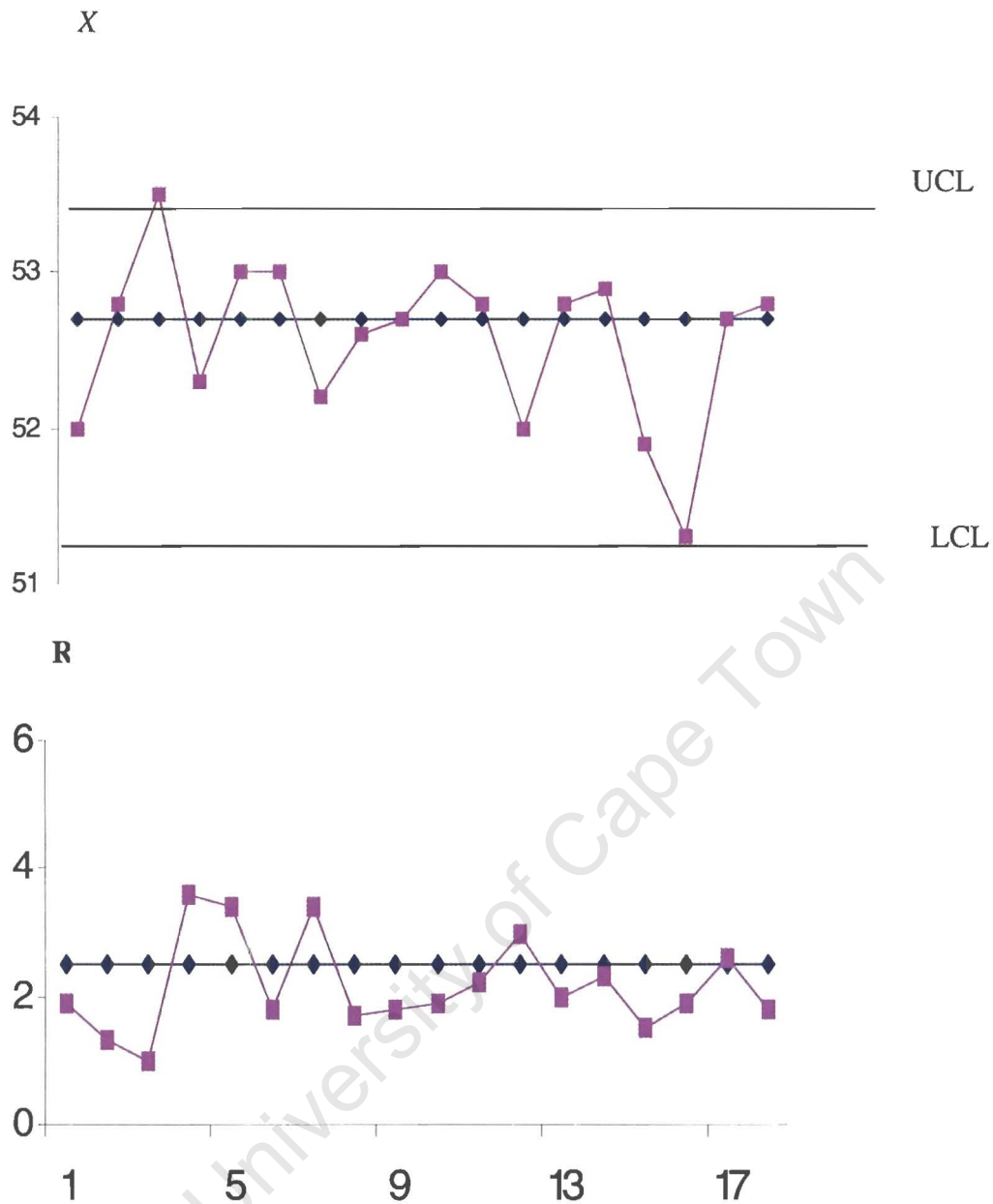
### 6.1.7 CONTROL CHARTS

Control Charts are used to determine whether or not a process is in control and stable and how much variability in a process is due to random variation and how much is due to unique events. The Control Chart is a simple Run Chart with statistically determined upper and lower control limits drawn on either side of the process average or mean. Controlling of a process by this means can determine if the process is in statistical control.

Statistical limits can only be calculated after the process has been allowed to run without any outside interference for a period of time. Readings should be taken at regular intervals (may be per hour, per day, per batch etc.) and then the average of each interval is plotted on the chart. After sufficient samples have been taken and their respective averages plotted on the chart, then the upper and lower control limits can be determined.

**Note:** The formulae for the calculation of Control Charts are complex and many and are outside the scope of this thesis and have therefore not been included. Should the reader require these formulae, reference can be made to many good books on 'Statistical Process Control'.

Once the chart has been established, the sample averages are plotted to see if any of them fall outside of the control limits or form unlikely patterns or trends. If any of these anomalies exists then the process is said to be 'out of control.' Fluctuations of points within the limits is as a result of the natural variation that exists within the process and are results from common causes within the system. These common causes can be as a result of design, choice of process etc. and can only be improved upon by making changes to the process. Points falling outside of the control limits come from special causes like operator error or unplanned events and are not part of the way the process normally operates. These special causes must be investigated and eliminated before the control chart can be used for 'Statistical Process Control.' Once these special causes have been eliminated, the process is termed 'In Control' and can be expected to perform within the control limits.



**Figure 23 : Control Chart for External Diameter Dimensions. ( $\bar{X}$  and R Chart)**

A process is said to be out of control if one or more of the following conditions are evident:

- One or more points fall outside of the upper or lower control limits
- Two out of three successive points are on the same side of the centreline and close to the control limit.
- Four out of five successive points are on one side of the centreline and midway between the mean and the control limit.
- Nine successive points are on one side of the centreline.

- Nine successive points are on one side of the centreline.
- There are fourteen points in a row alternating up and down.

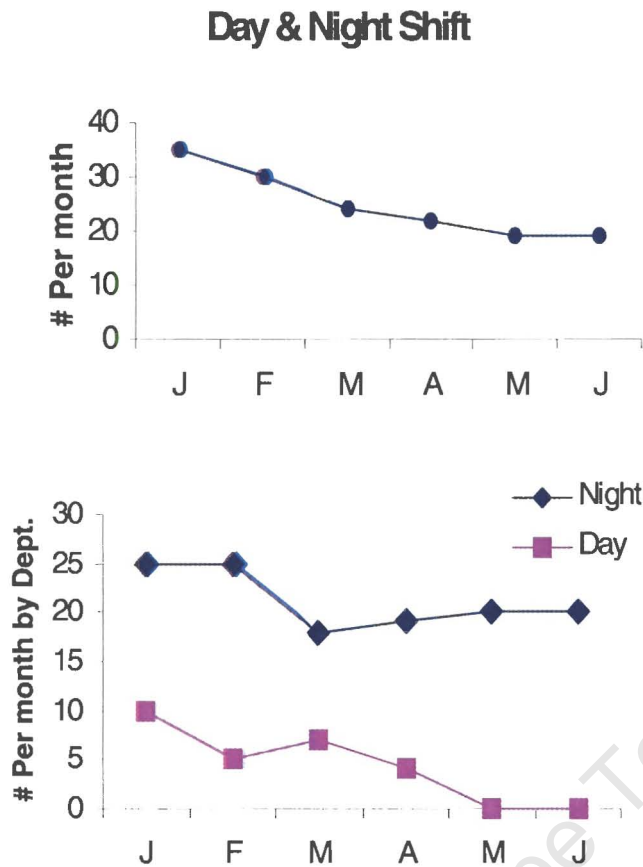
The following points should be noted when constructing a Control Chart:

- a. At least 20 to 25 groups of samples must be collected from the process before calculating the control limits.
- b. The upper and lower control limits must be calculated from the results of the process.
- c. Do not confuse specification limits, which are based on product requirements, with control limits which are determined from the process.
- d. Variation in the process caused by natural causes can only be improved upon by making some change either by better management, design or process improvement etc.
- e. Data must be plotted in the same order in which it was obtained.

When a process is in control, it does not mean that the products produced will be within specification. It means that the process is consistent and known and if the end result is not to specification then the process must be improved upon or else the specification changed in line with the process. The specification is what is expected for the product and the control limits are what the process can consistently deliver.

### **6.1.8 STRATIFICATION**

Stratification is a process that breaks down data into more meaningful categories or classifications to enable more focus on the right corrective action. In other words, a single population is broken down into different classifications in order to better understand the problem.



**Figure 24 : Stratification of Plant Injuries.**

As can be seen from the above figure, to consider the total injuries does not necessarily lead to the real reason for the problem, however, once the data is separated between day shift and night shift, a more clearer picture emerges that can help lead management to the true cause of the problem. A further stratification that could be carried out is to break down the injuries by injury type, or by location, or by department which again could give management a more clearer picture as to how to solve the problem.

Typical categories for stratification could be as follows:

- **Time:** month, week, day, day shift, night shift, day of the week, time, morning, afternoon, etc.
- **Workforce:** section, work group, task force, age, expertise, etc.
- **Machinery:** machine number, position, age, tools, etc.
- **Working Conditions:** temperature, pressure, humidity, weather, etc.
- **Process:** working method, procedure, measuring method, etc.
- **Material:** place of manufacture, supplier, previous process, lot, etc.
- **Product:** product category, destination, age, standard, order, etc.
- **Measurement:** inspection method, instrumentation, inspector, etc.

## **6.2 SEVEN MANAGEMENT AND PLANNING TOOLS**

Also commonly referred to as the Seven New QC tools, these techniques have been developed to organise verbal information and to convert apparent chaos into a workable, implementable action plan. Previously a management tool, Japanese plants now include these tools into the training for the use of the QC story in problem solving. Creativity and conceptualisation are encouraged with the systematic approach to innovation and the conversion of raw data into team consensus through a physical process. The use of these tools can separate complex problems for easier solutions and omissions and errors can be eliminated at the planning stage whilst gaining new insights into the problem situation.

Genius has been defined as “ the ability to recognise patterns unseen by others.” The Seven Management and Planning Tools allow a team to make these patterns visible and therefore make emergent thinking possible rather than traditional pigeonholing.

The Seven Management and Planning Tools are

- Interrelationship Digraph
- Affinity Diagram
- Tree Diagram
- Matrix Diagram
- Matrix Data Analysis
- Process Decision Program Chart (PDPC)
- Activity Network Diagram.

### **6.2.1 INTERRELATIONSHIP DIGRAPH**

The Interrelationship Digraph is used when the root cause of a situation or problem must be identified and when there are a large number of interrelated issues that are not clearly defined. Data is not readily available and scarce resources can not be used to identify the root cause of the problem. The Interrelationship Digraph is a graphical map indicating the cause and effect links between all the items and issues raised. The clustering of the arrows indicates the issues and causes that are the most fundamental among all the related items.

### INTERRELATIONSHIP DIGRAPH-MISSED DELIVERY DATES

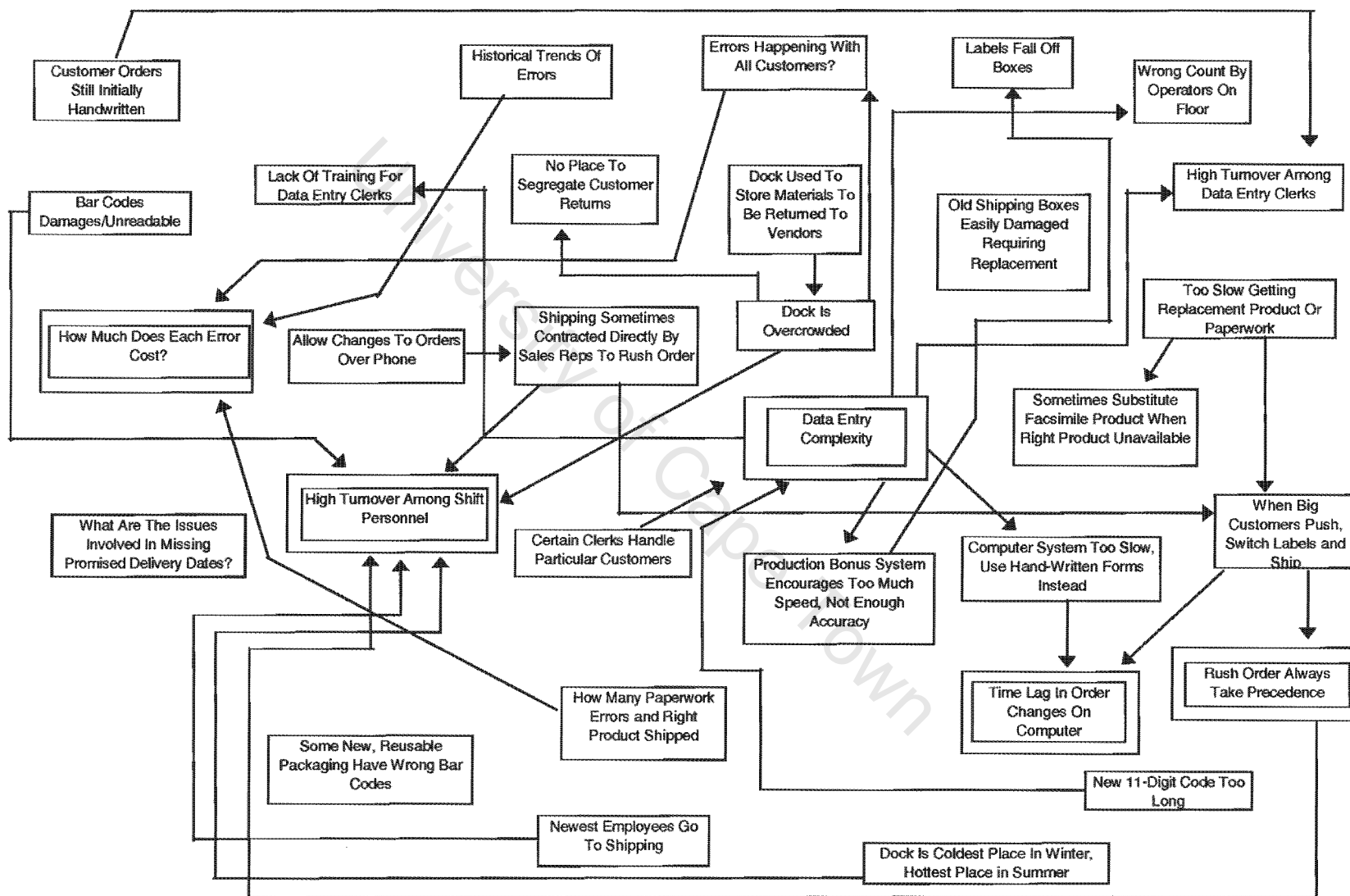


Figure 25 : Interrelationship Digraph for Missed Delivery Dates

Before commencing on the construction of the Interrelationship Digraph, select a team of four to six members with intimate knowledge of the issue at hand.

Brainstorming for issues should be done making use of a flip chart or white board. Issues raised should then be transferred to portable cards in the form of 'Post-it' labels and should be restricted to a maximum of 20 but can be as high as 50.

The following steps are used in the construction of the Interrelationship Digraph:

- 1) Assemble the team members who have intimate knowledge of the problem.
- 2) Agree upon a problem statement that is simple and best describes the problem.
- 3) Brainstorm the causes of the problem and establish the cards. Each card must be worded simply and contain only one meaning. Be specific and to the point and avoid large, sweeping, general statements.
- 4) Display the cards randomly on a board or a large piece of butcher paper.
- 5) Draw the cause and effect relationship by means of arrows between each of the cards by asking the following questions: "Does card A cause or influence card B, card C etc?" Repeat until all cards relationship with each other has been reviewed. Draw only one way arrows. In the event of a two way relationship, indicate the stronger cause of the two.
- 6) Select the key items by reviewing all cards for those with the most number of outgoing arrows and the least incoming which indicates a 'Key Driver.' The card with the highest number of incoming arrows and the least outgoing is a 'Key Outcome'.
- 7) Identify all the key items by means of a double box or by colouring or cross hatching.
- 8) Summarise the result and choose one of the key drivers for further investigation.

Note: Focus team members away from the apparent complexity of the large volume of issues and arrows and on to the simple clustering of converging and emerging arrows. The most critical and difficult decision is the direction of the arrows. When summarising the result, do not rely entirely upon the number of arrows to decide, but rather rely upon the experience of the team members.

## 6.2.2 AFFINITY DIAGRAM

Affinity Diagram is used to find the major themes out of a large number of ideas, opinions and issues. It groups the items that are naturally related and then identifies the one concept that ties each grouping together.

This is a creative rather than logical process of sorting cards by means of consensus rather than by discussion.

This tool is particularly useful when chaos exists with the team drowning in ideas and breakthrough thinking is required. Through this process, broad issues and themes can be identified for further investigation and study.

Teams should be small consisting of four to six members with varied perspectives, open minded and capable of creative thinking. In the event of a large group of people, break down into smaller teams and do multiple affinities that can be combined later into one common Affinity Diagram. During the creation of ideas phase, the normal rules of brainstorming apply in that all ideas are listed and no members are allowed to criticise.

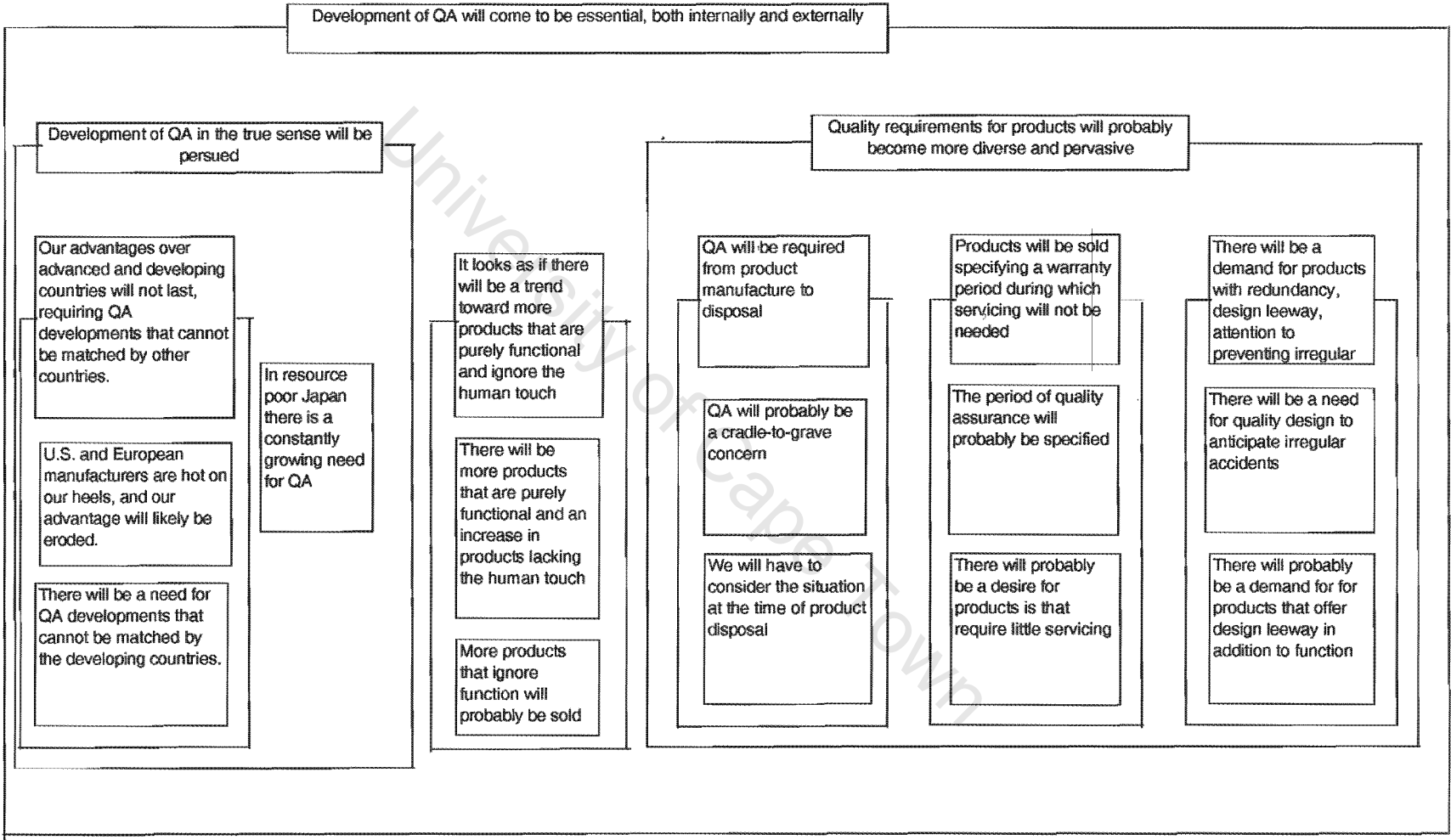


Figure 26 : Affinity Diagram for "What is the future of QA"

The following steps are used in the construction of the Affinity Diagram:

1. Decide on the theme defining it in a broad and neutral statement that is clearly stated and well understood by the team members.
2. Generate ideas through the process of brainstorming and record each idea on a card. Cards should be concise and clear with the idea summarised into a short and simple phrase.
3. Randomly lay out the cards on a wall, table or flip chart.
4. Team members now rearrange the cards, in silence, into related groupings using their gut feel. This should be a quick process and discussion can only be used for clarification purpose until consensus is reached.
5. Header cards must be created for each grouping with a statement that is concise but makes sense standing alone and captures the essential link in all the ideas in that grouping. Wherever possible, this statement should include a noun and a verb.
6. Draw the Affinity Diagram by boxing in all the ideas that belong under the respective headers and all headers under the original theme.
7. Review by the team and by other important non-team members and amend if necessary.

If one of the groupings is overwhelmingly larger than the others, it should be re-analysed for possible subheaders. The total number of headers should be between five and ten. Avoid one word cards which could be ambiguous and use complete sentences and phrases. In the event of disagreement when moving the cards between the different groupings, examine the desired grouping of the other person. In this way, it may be possible to see the other persons logic and reach consensus.

### **6.2.3 TREE DIAGRAM**

The Tree Diagram is used to systematically map out in increasing detail the full range of paths and tasks that need to be accomplished to achieve a primary goal. The broad objective is broken down into specific implementation detail and then assignable tasks can be created.

## TREE DIAGRAM-REDUCING DATA ENTRY COMPLEXITY

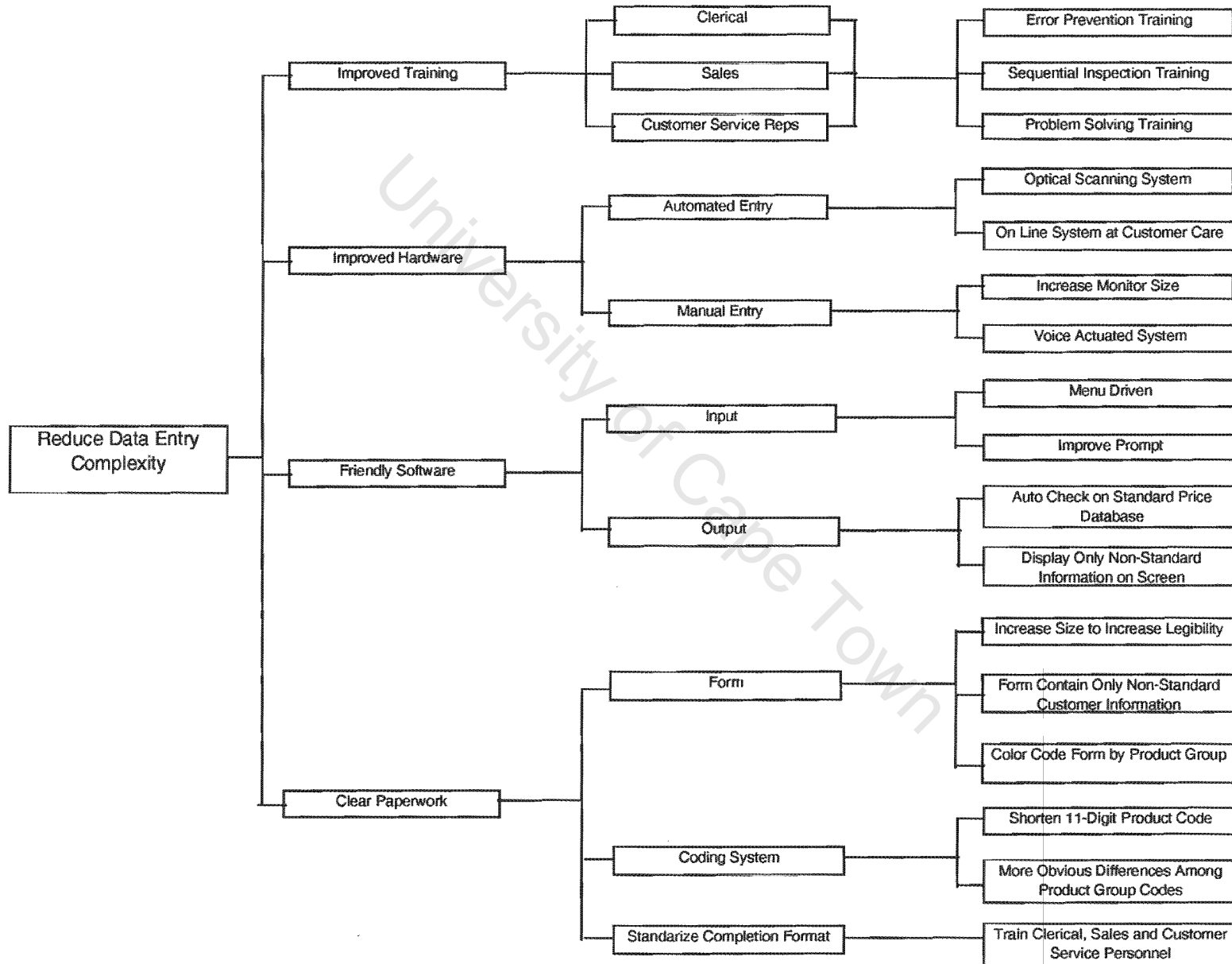


Figure 27 : Tree Diagram for Reducing Data Entry Complexity

The following steps are used in the construction of a Tree Diagram:

- 1) The Tree diagram goal statement can be derived from one of three sources, namely, the Key Driver outcome from the Interrelationship Digraph, one of the header cards from the Affinity Diagram or through a consensus discussion with no use of other tools.
- 2) As per the previous two tools, assemble a team with knowledge of the situation at hand.
- 3) Generate the major tree headings which are the broadest implementation paths to pursue. These may be established through an Affinity Diagram or through brainstorming.
- 4) Complete each branch of the Tree Diagram by asking “What needs to happen, or be addressed to resolve or achieve this problem or goal statement?” Fill in the detail at all levels of the diagram.
- 5) Review the completed diagram and check the logic at each level by asking, “Will these actions actually lead to these results?”
- 6) Always start with the broadest level of detail on the left hand side of the diagram and follow a logical sequence down each of the branches. If the diagram is started with the tasks on the right hand side first, these are usually the ones we know how to do or which we want to do rather than those that we should do.

#### **6.2.4 MATRIX DIAGRAM**


A graphical means to show the logical connecting points between two or more sets of ideas or issues. A Matrix Diagram is a means of clarifying problems by multidimensional thinking and in so doing, show the presence and strength of any relationship between the different issues.

There are no standards for judging quality					<input checked="" type="radio"/>
Production bottlenecks are not identified				<input checked="" type="radio"/>	
Quality of claim resolution is poor			<input type="radio"/>		
There is no clear grasp of nature of the claim, or its causes	<input checked="" type="radio"/>		<input type="radio"/>		
Countermeasures are only stop-gap	<input type="radio"/>	<input checked="" type="radio"/>			
Exchange of information on the claim is poor			<input checked="" type="radio"/>		
System for promoting elimination of claims is weak	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>		
Factors	Countermeasures				
Specific actions taken		Strengthen further countermeasures to prevent recurrence	Strengthen follow-up on countermeasures to prevent recurrence	Hold more quality improvement meetings	Strengthen quality improvement at the production stage
Set forth main countermeasures to be implemented in respect to unanswered claims	<input checked="" type="radio"/>				
Prepare a "Main Countermeasures Follow-up Sheet" to strengthen follow up	<input type="radio"/>	<input checked="" type="radio"/>			
Hold a Quality Improvement Meeting involving production, sales, engineering and service, and including the production operation	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Strengthen the functions of the Quality Improvement Meeting (considering quality in general, including claims)			<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Prepare a "Claim Development Table" for horizontal development of countermeasures	<input type="radio"/>				
Prepare a "Sheet for Remedying Manufacturing Difficulties" to set forth and remedy bottlenecks at the production stage					
Prepare a "List of Unclear Quality Standards" to set forth items that are unclear				<input type="radio"/>	<input checked="" type="radio"/>
Prepare a "Table of Quality Characteristics" to clarify quality standards				<input type="radio"/>	<input checked="" type="radio"/>


**Figure 28 : Matrix Diagram for Countermeasures to Eliminate Claims Against Products.**

The following steps to be followed when constructing a Matrix Diagram:

- 1) A team should be assembled consisting of individuals with influence and power at the highest level possible.
- 2) Decide on the matrix format to be used. There are many different shapes that can be used depending on the number of sets of items under consideration. An L-shaped format is used for two sets of items and a T-shaped is used for three and an X-shaped is used for four sets of items.
- 3) Relationship symbols are used to indicate the strength of the relationship between the different items.

Standard accepted symbols are:  = Strong Relationship

 = Some Relationship

 = Weak or possible Relationship.

Symbols rather than numbers are used to allow a visual pattern to emerge in the diagram.

The Matrix Diagram is useful to help an organisation to prioritise present activities against new activities.

### 6.2.5 MATRIX DATA ANALYSIS

A useful technique when the key issues have been identified and now the action options must be narrowed down and prioritised. It can also be used when there is a disagreement amongst the team members on the relative importance of the different decision making criteria. Limited resources normally make it impossible to implement all the various options, it is therefore useful to rank the options by their relative importance to the situation.

Three distinct steps are necessary to construct the Matrix data analysis as follows:

- Step 1 Ranking of the Criteria

The list of criteria under analysis previously obtained from a directive or brainstorming session. For each of the criteria, an operational definition is created. Each criteria is rated against all the other criteria making use of an L Shaped Matrix diagram. Once completed, each column is added up and the total entered at the bottom with the grand total in the bottom right hand corner.

Each row is added across and the total as well as the percentage of the grand total is entered on the right hand side of the matrix. The percentage must be expressed as a fraction.

- Step 2 Ranking Options by Criteria

The options are usually taken from the lowest level of a Tree diagram or from brainstorming and consensus of the team and again, making use of an L shaped matrix, each option is ranked against each other for each of the key criteria identified making use of the same rating scale and methodology as was used in step 1.

- Step 3 Ranking Options by Criteria

Making use of the L shaped matrix, the criteria are listed on the horizontal and the options on the vertical. The rating of each criteria from step 1 is multiplied with the rating of the options from step 2. Totals are added across and down, and expressed as percentages indicating the relative importance of each of the options for implementation.

### STEP 1: RANKING THE CRITERIA

	Low Cost to Implement	No Customized Technology	Quick to Implement	Easily Accepted by Users	Minimal Impact on Other Depts	Row Totals (% of Grand Total)
Low Cost to implement		5	1/10	1/10	1/5	5.4 (.08)
No Customized Technology	1/5		1/5	1/10	1/5	.7 (.01)
Quick to Implement	10	5		1/10	1/5	15.3 (.21)
Easily Accepted by Users	10	10	10		1/5	30.2 (.42)
Minimal Impact on Other Depts	5	5	5	5		20 (.28)
COLUMN TOTAL	25.2	25	15.3	5.3	.8	Total Across Columns 71.6 Grand Total

### STEP 2: RANKING OPTIONS BY CRITERIA

(Note: Only ranking for one of the criteria shown.)

Quick to Implement	A	B	C	D	E	F	G	Row Totals (% Grand Total)
<b>A.</b> Error Prevention Training		1/5	1/5	5	5	5	1/10	15.5 (0.11)
<b>B.</b> Sequential Inspection Training	5		5	10	10	5	1/5	35.2 (0.26)
<b>C.</b> Problem Solving Training	5	1/5		5	5	5	1/10	20.3 (0.15)
<b>D.</b> Optical Scanning System	1/5	1/10	1/5		1	1/5	1/10	1.8 (0.01)
<b>E.</b> Shorten 11-Digit Product Code	1/5	1/10	1/5	1		1	1/10	2.6 (0.02)
<b>F.</b> More Obvious Difference Among Prod. Grp. Codes	1/5	1/5	1/5	5	1		1/10	6.7 (0.05)
<b>G.</b> Train Clerical Sales & Customer Service Pers.	10	5	10	10	10	10		55.0 (0.40)
<b>Column Totals:</b>	20.6	5.8	15.8	36	32.0	26.2	0.7	137.1

### STEP 3: RANKING OPTIONS BY CRITERIA

Options \ Evaluation Criteria	Quick to Implement	Easily Accepted by Users	Minimal Impact on Other Depts.	Row Totals (% Grand Total)
<b>A.</b> Error prevention Training	$.11 \times .21 = .023$	$.03 \times .42 = .013$	$.03 \times .28 = .008$	0.044 (0.09)
<b>B.</b> Sequential Inspection training	$.26 \times .21 = .055$	$.04 \times .42 = .017$	$.02 \times .28 = .006$	0.073 (0.16)
<b>C.</b> Problem solving Training	$.15 \times .21 = .032$	$.04 \times .42 = .017$	$.03 \times .28 = .008$	0.057 (0.12)
<b>D.</b> Optical scanning System	$.01 \times .21 = .002$	$.06 \times .42 = .025$	$.10 \times .28 = .028$	0.055 (0.11)
<b>E.</b> Shorten 11-digit Product code	$.02 \times .21 = .004$	$.12 \times .42 = .050$	$.03 \times .28 = .008$	0.062 (0.13)
<b>F.</b> More obvious Differences among prod. group codes	$.05 \times .21 = .011$	$.10 \times .42 = .042$	$.13 \times .28 = .036$	0.089 (0.18)
<b>G.</b> Train clerical sales and customer service personnel	$.40 \times .21 = .084$	$.03 \times .42 = .013$	$.04 \times .28 = .011$	0.108 (0.22)
<b>Column Total</b>	0.211	0.177	0.105	Grand Total 0.493

**Figure 29: Matrix Data Analysis for the Reduction of Data Entry Complexity.**

### 6.2.6 PROCESS DECISION PROGRAM CHART (PDPC)

The PDPC is a methodology for the mapping out of all the conceivable events that can occur during an implementation plan and identifies feasible countermeasures for the solving of these problems. It is also used to plan the possible chain of events that need to occur for the successful implementation of a new goal or objective. The underlying principle behind the PDPC is that the achievement of any goal is filled with uncertainty and is operating in an imperfect environment. If this was not true, then Deming's PDCA cycle could be simplified to Plan and Do in the certainty that nothing was going to go wrong. The PDPC anticipates the unexpected and attempts to carry out the 'check' from PDCA cycle during the planning of the process. The PDPC not only identifies the possible problem areas, but it also helps to develop countermeasures that will either prevent the occurrence, or be in place in the event of them happening. In the case of prevention of the occurrence, it may be decided, due to limited resources, not to implement the countermeasure and take the chance that the problem does not occur. In the event that it does occur, the contingency plan is known and can be implemented.

PDPC should only be used when uncertainty exist in the implementation of a new or unique plan and not on task that are routine and have been implemented before.

Although an extremely useful planning tool, the PDPC has very few guidelines for its implementation and it's most common form is that of a modified Tree Diagram. The team assembled should be those people who have the most knowledge about the plan to be introduced. The Tree Diagram can be positioned either vertically or horizontally with the objective at the top and then establish the skeleton around the basic implementation flow or Process Flow Chart. The first level branches of the diagram are listed in sequential order of implementation. Ask "What could go wrong?" or "What various and unexpected paths could this step take?" Enter these answers as the next level of the Tree. Brainstorm possible countermeasures for each of the contingencies generated and branch them off each item within cloud-like balloon's. Evaluate each possible countermeasure for feasibility and mark accordingly.

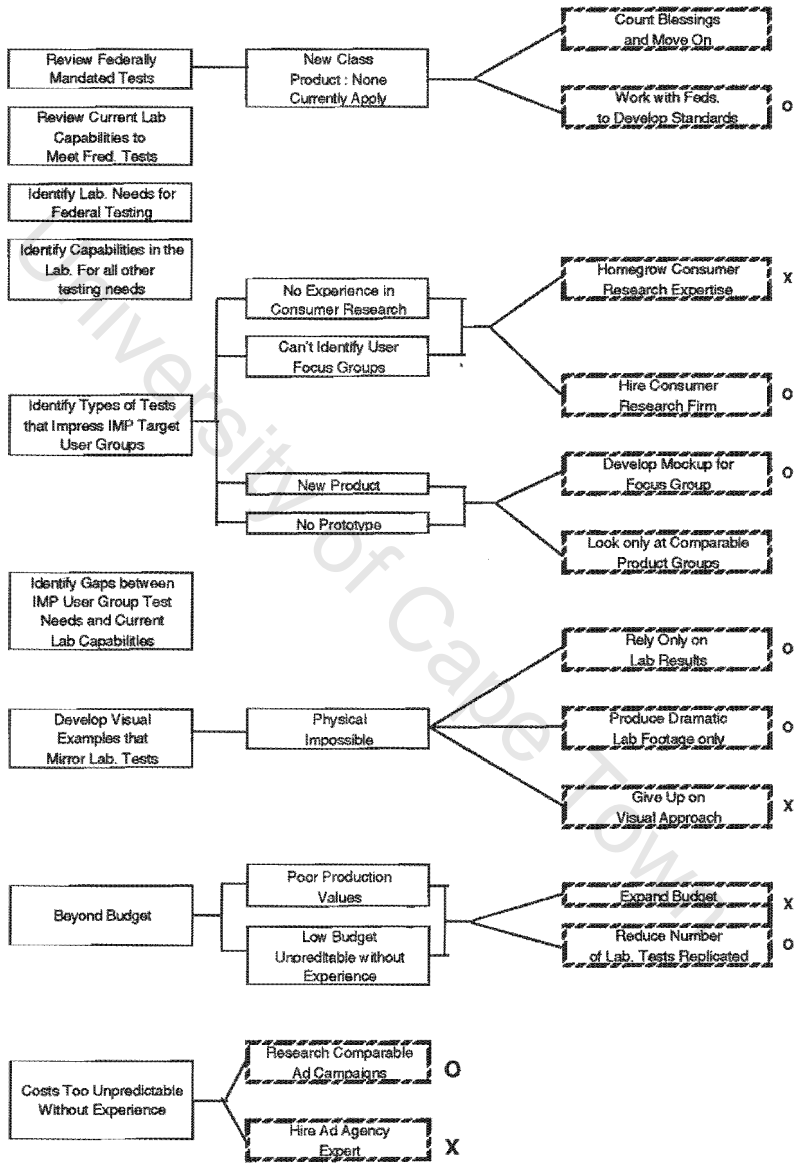


Figure 30 : Process Decision Program Chart (PDPC)

### 6.2.7 ACTIVITY NETWORK DIAGRAM

*Arrow diagrams are derived from the scheduling diagrams of the Program*

*Evaluation and Review Technique PERT developed by the U.S. Navy in 1958.*

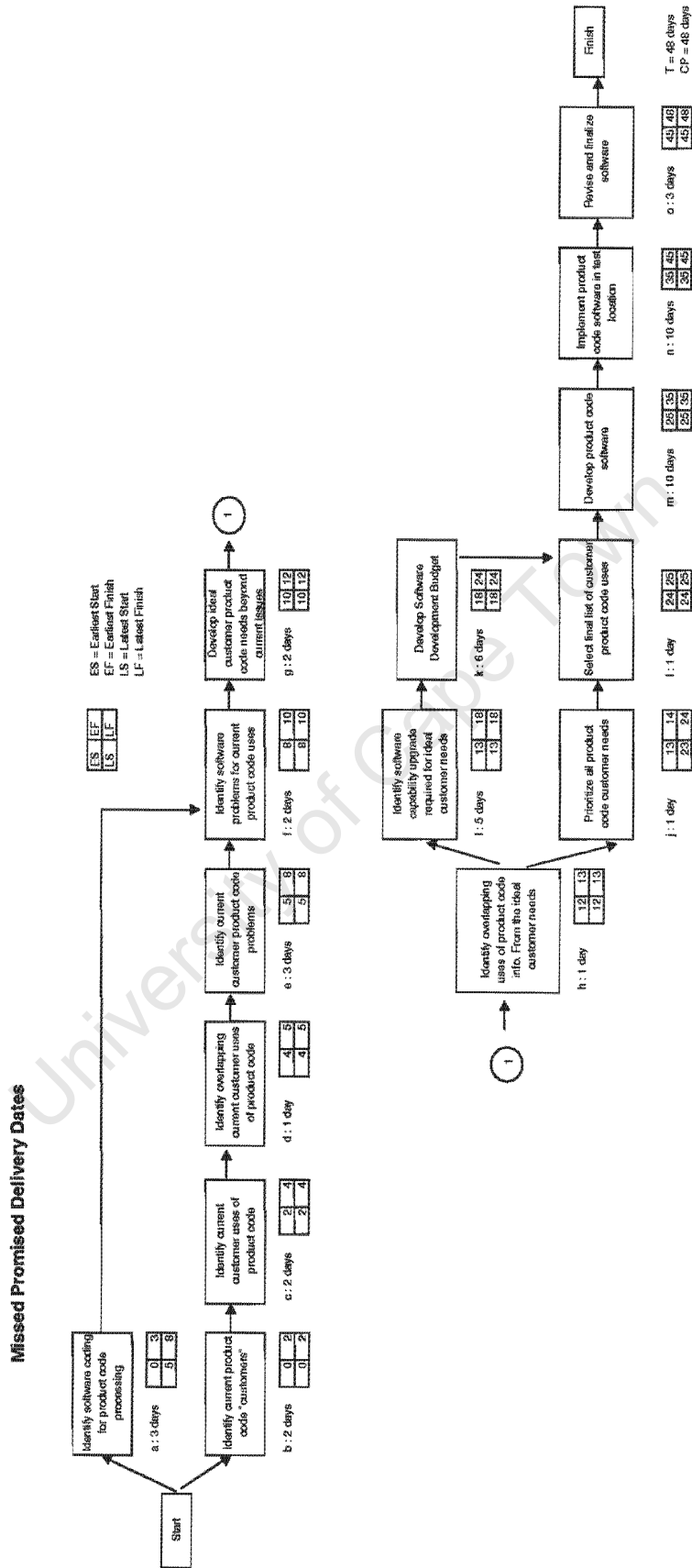
Activity Network Diagrams are used to plan the most appropriate schedule for the completion of a complex task where the duration of all the activities and sub-activities are known. It is also used to monitor the progress against the plan and to determine the effect if certain activities fall behind plan. It makes use of a network of arrows to represent the activities in a daily schedule indicating flow as well as the duration of each task.

Network diagrams have the following advantages over Gantt Charts often used for the control of projects:

- Easy to determine the effect a slowdown or delay in one operation will have on related operations and on the overall schedule
- Easy to identify which operations can be performed concurrently and which are crucial for the overall timing of the project

The following steps are used in the construction of the Activity Network Diagram:

- Assemble a team of the people with the most knowledge about the project or task to be performed.
- Brainstorm all the activities needed to complete the project making use of past experience and similar projects already completed.
- Create the sequence flow by placing in a row all the operations that form the longest path of sequential tasks. Create the other paths of operations that can be performed simultaneously with the critical path operations. Draw the necessary connections between the different paths.
- Establish the duration of each task and sub-task and enter the timing onto the diagram. Calculate the shortest possible implementation timing by establishing the path with the longest cumulative duration and mark this path with bold arrows to distinguish it as the Critical Path.
- Calculate the earliest start and finish times for each operation and enter onto the diagram. Review and revise as necessary.



**Figure 31 : Activity Network Diagram**

### 6.3 THE QC STORY AND THE QUALITY TOOLS

The following matrix summarises the steps of the Quality Story framework and indicates the various Quality Tools that can be useful in each step.

		QC 7 Tools							New QC 7 Tools						
		Parato chart	Fish-bone chart	Histogram	Check sheet	Graph	Scatter diagram	Control chart	Relation diagram	Affinity diagram	Tree diagram	Matrix diagram	Arrow diagram	PDPC method	Matrix data analysis
Quality maintenance				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>							
P	Selection of Theme	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
	Reason for selection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>					
	Target setting	<input type="radio"/>				<input type="radio"/>		<input type="radio"/>							
	Draft of activity plan					<input type="radio"/>							<input type="radio"/>	<input type="radio"/>	
D	Grasp of current status	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			
	Analysis	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>				<input type="radio"/>		<input type="radio"/>	<input type="radio"/>		<input type="radio"/>	<input type="radio"/>
	Drafting improvement plan		<input type="radio"/>								<input type="radio"/>	<input type="radio"/>			
	Execution														
C	Confirmation of effect	<input type="radio"/>		<input type="radio"/>		<input type="radio"/>		<input type="radio"/>							<input type="radio"/>
A	Preventing recurrence			<input type="radio"/>			<input type="radio"/>				<input type="radio"/>	<input type="radio"/>			
	Reflection & Future subjects														

Figure 32 : Application of Quality Tools in QC Story Framework.

### 6.4 CONCLUSION

It is imperative that problem solvers have a good grasp of the different Quality Tools and their uses and make use of them in their problem solving activities. As mentioned previously, problems solved making use of data and graphical problem solving methods while following a logical thought process, have better countermeasures and solutions. Data that is unrefined can be more confusing than helpful, but once refined by means of the graphical methods, it can quickly guide the problem solver to the root cause of the problem and to the most logical and appropriate solution.

Following the logical thought process of the Quality Story framework and making use of the different QC tools in each stage of the process should lead the problem solver to better problem resolution, the effects of which are measurable and defined.

The next chapter is a practical application of the Quality Story making full use of the different quality tools to illustrate the effectiveness of the methodology for problem resolution and continual quality improvement.

University of Cape Town

## CHAPTER 7.0

### PRACTICAL APPLICATION OF QUALITY STORY

*This section is used to illustrate to the reader a practical application of a Quality Story making maximum use of the Quality Tools detailed in Chapter 6.0.*

*As mentioned previously, the Quality Story framework can be used for both the solving of problems as well as for continual improvement activities. The Quality Story detailed is one of continual improvement targeted at the reduction of paint defects in the paint shop. In this example, the target for improvement of a reduction of 30% on the current situation has already been set in the selection of the theme. Much effort has gone into the understanding of the current situation to gain a full understanding of exactly what the problem is before making any attempt at improvement.*

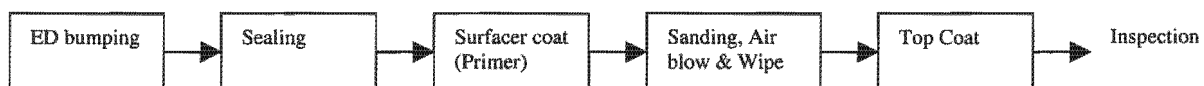
#### 7.1 STEP ONE : Selecting a Theme

Implement a plan for the reduction by 30% of the defects in the paint shop.

#### 7.2 STEP TWO : Understanding the current situation

##### Outline of the Paint Shop

1. Production Volume : 8 unit/shift x 1 shift/day (only day shift operation)
2. Process : ED bumping, Sealer, Surfacer coat, Sanding-Air blow & Wipe, top coat.  
(9 Operators / 5 stages).
3. Layout:



**Inspection data of the initial paint quality**

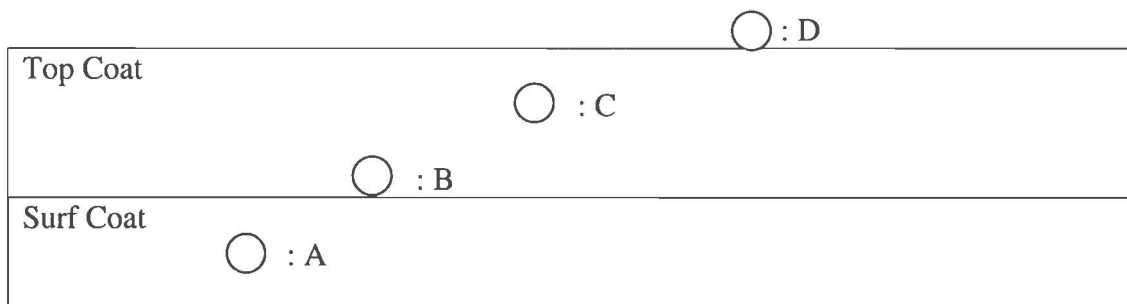
<u>Inspection date</u>	<u>Prod. no</u>	<u>Defects per Unit</u>
Monday	1	5
	2	4
	3	7
	4	4
	5	3
	6	6
	7	6
	8	5
Tuesday	9	2
	10	1
	11	2
	12	1
	13	2
	14	3
	15	2
	16	2
Wednesday	17	2
	18	2
	19	2
	20	1
	21	1
	22	2
	23	1
	24	2
Thursday	25	3
	26	2
	27	2
	28	1
	29	3
	30	2
	31	2
	32	2
Friday	33	2
	34	1
	35	2
	36	2
	37	3
	38	2
	39	1
40	2	
<b>Total</b>		<b>100</b>

Average of 2.5 defects per unit

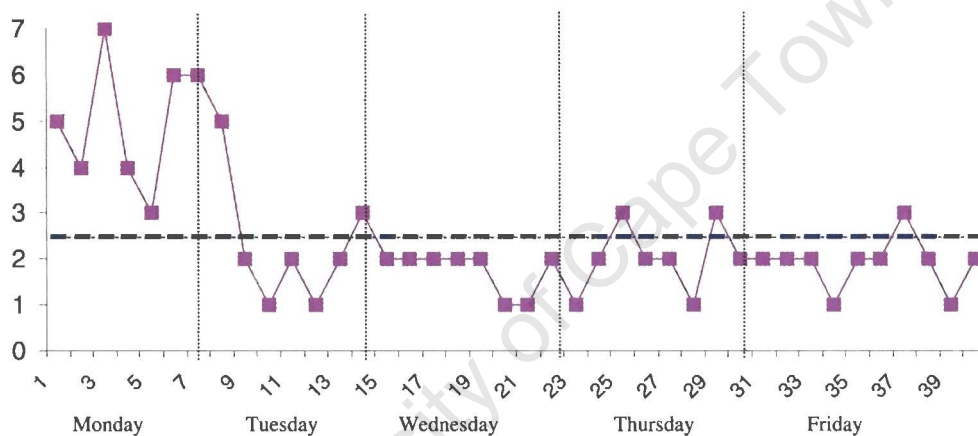
**Contents and Portion of Defects (Stratification data)**

			Right side		Left side		Total
			Horizontal	Vertical	Horizontal	Vertical	
Monday	Dirt, Dust	A	0	1	0	0	1
		B	15	8	6	3	32
		C	0	0	1	0	1
		D	0	0	0	0	0
	Crater		0	1	1	0	2
	Dent		1	0	0	0	1
	Thin paint		0	0	1	0	1
	Flow, Run		1	0	0	0	1
	Sander mark		0	0	1	0	1
	Sealing fault		0	0	0	0	0
Sub Total			17	10	10	3	40
From Monday to Friday	Dirt, Dust	A	1	0	1	1	3
		B	10	6	7	5	28
		C	1	0	0	1	2
		D	1	1	1	0	3
	Crater		2	0	3	0	5
	Dent		1	1	3	0	5
	Thin paint		1	2	0	1	4
	Flow, Run		0	1	1	2	4
	Sander mark		2	0	1	0	3
Sealing fault		2	1	1	0	3	
Sub Total			20	12	18	10	60
One week	Dirt, Dust	A	1	1	1	1	4
		B	23	13	14	10	60
		C	1	0	1	1	3
		D	1	1	1	0	3
	Crater		2	1	4	0	7
	Dent		2	1	3	0	6
	Thin paint		1	2	1	1	5
	Flow, Run		1	1	1	2	5
	Sander mark		2	0	2	0	4
	Sealing fault		1	1	1	0	3
<b>Total</b>			<b>37</b>	<b>22</b>	<b>28</b>	<b>13</b>	<b>100</b>

### Phenomenal classification of the dirt



### Daily Defects (Trend Graph)



### 7.3 STEP THREE : Creating a Plan of Action

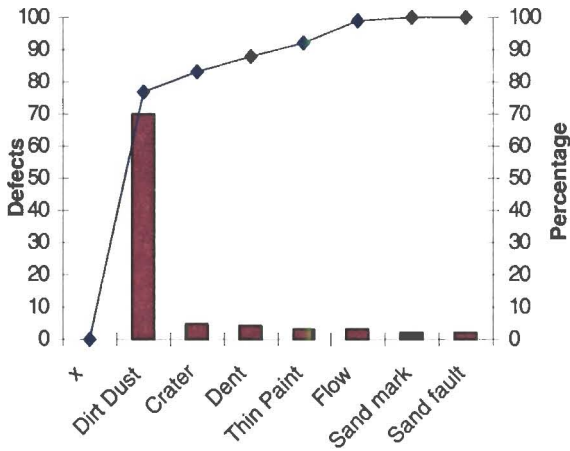
It is clear from the data that the majority of the defects are caused by dirt and occur on Mondays. It can also be seen that more defects occur on the horizontal surfaces than on the vertical surfaces. Each of these phenomena will have to be understood and counter measured if the reduction of 30% is to be achieved. Measures must be taken to prevent dirt from settling on the bodies over the weekends and the paint shop operators must be trained to properly clean the bodies before painting.

## 7.4 STEP FOUR : Analysing the Factors

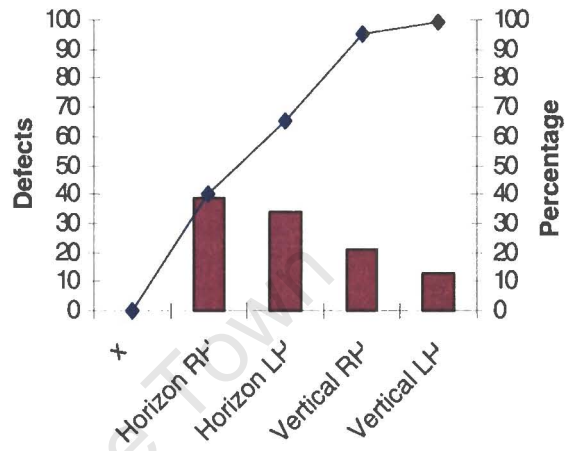
### Parato analysis about the phenomena of defect (Parato diagram)

#### One week's data

Parato diagram by defect type

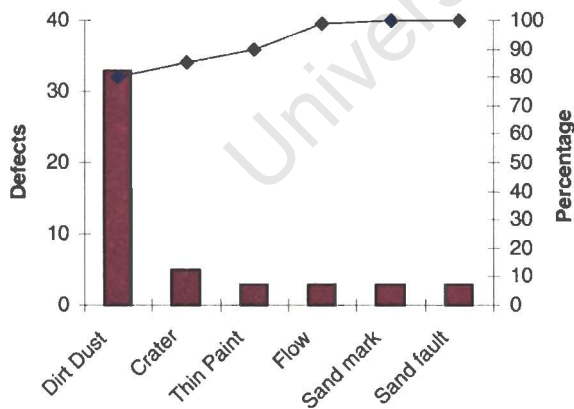


Parato diagram by defect position

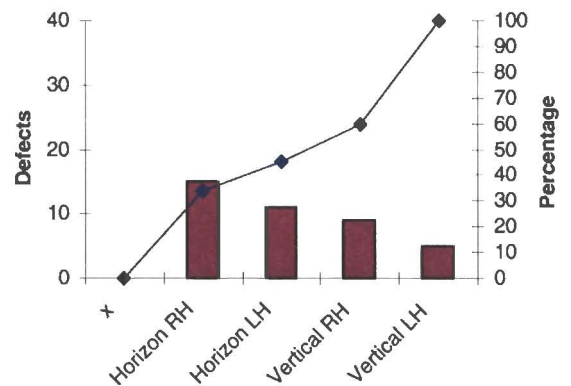


#### Monday's data

Parato diagram by defect type



Parato diagram by defect position

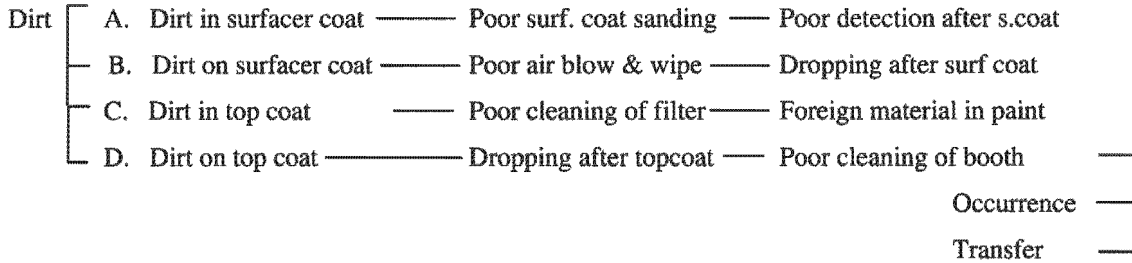


From the analysis of the data collected, the following conclusions can be made: -

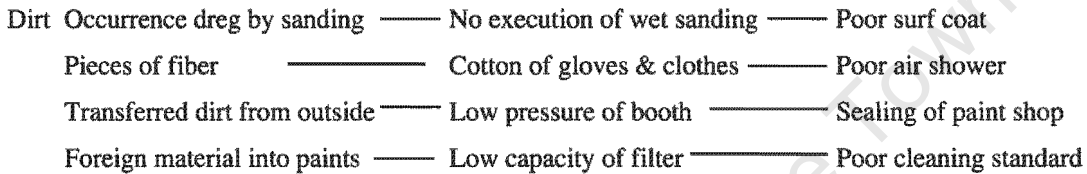
- 70% of the defects are dirt related
- 40% of the defects occur on Monday
- 70% of the defects are on the horizontal surfaces.

### Kinds of dirt and dust (Tree diagram)

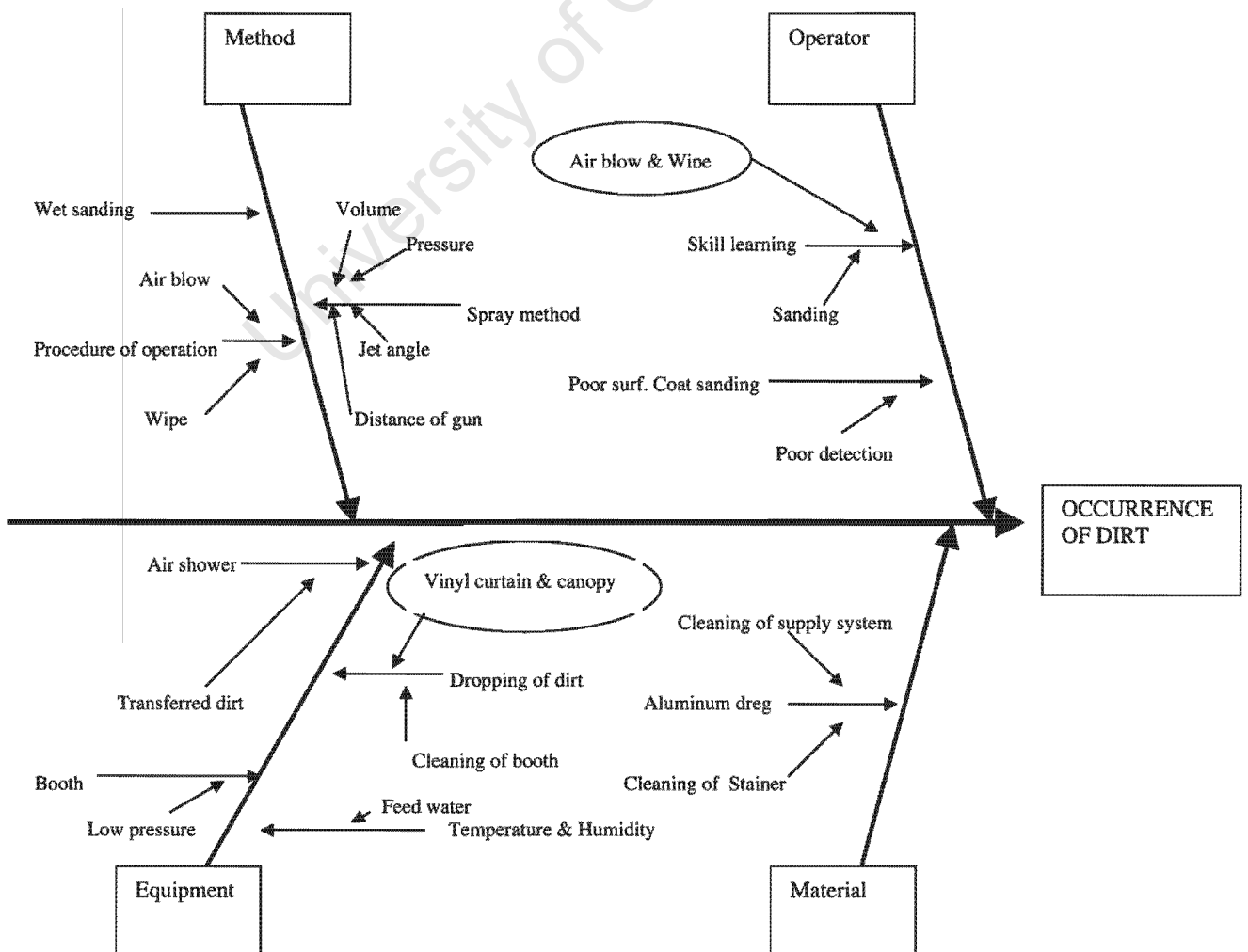
Position of Dirt related to paint bed



### Elements of Dirt and Dust



### Reason for dirt occurrence (Fish-bone chart)



			Factor : Process that causes defects																				
			Ed bumping			Sealing			Surf. coast			Sanding			A. blow & wipe			Top coat			Total		
			RH	LH	Total	RH	LH	Total	RH	LH	Total	RH	LH	Total	RH	LH	Total	RH	LH	Total	RH	LH	Total
Result	Dirt	A								2	2	4							2	2	4		
		B											36	24	60				36	24	60		
		C															1	2	3	1	2	3	
		D															2	1	3	2	1	3	
Phenomenon of defect	Crater												3	4	7				3	4	7		
	Dent		3	3	6														3	3	6		
	Thin paint																3	2	5	3	2	5	
	Flow																2	3	5	2	3	5	
	Sander mark										2	2	4							2	2	4	
	Seal fault					2	1	3												2	1	3	
	<b>TOTAL</b>			3	3	6	2	1	3			0	4	4	8	39	28	67	8	8	16	59	41

Overall conclusion is that dirt is settling on the bodies that stand in the paint shop over the weekend. From the matrix of the processes, it is clear that by far the most defects occur in the blow and wipe and top coat spray area and that these defects are classification 'B' (dirt on top of surfacer and underneath top coat). The operators in these areas are not skilled enough to realise that on Monday special care must be taken to thoroughly wipe down and blow off the cars before painting to remove the dirt that has settled.

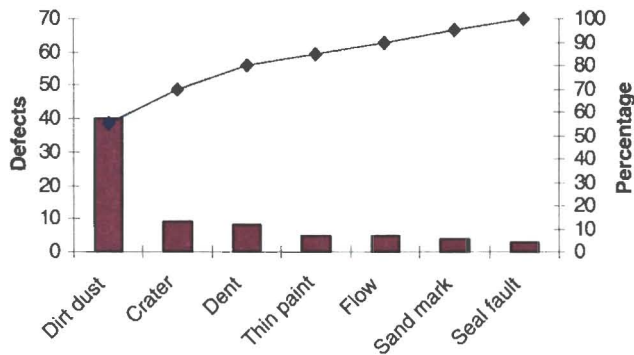
### 7.5 STEP FIVE : Developing and Implementing Countermeasures

From the understanding of the analysis of the current situation, it is clear that two distinctive actions are required to improve the current situation, namely:

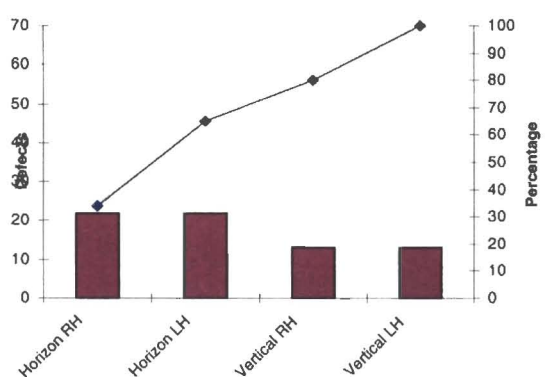
- Facility must be improved to prevent dirt from settling on the bodies over the weekends. This can be cost effectively achieved through the installation of vinyl curtains and canopy.
- Operators in air blow and wipe area must be upskilled through training to carry out the effective cleaning of the bodies prior to top coat painting. Particular attention must be given to the operator on the right hand side who is causing 50% more defects than the operator on the left hand side. Included in this training must be the observation of the operation in line with the Standard Operation Sheet (SOS) and the evaluation of the operators skill level (iILU Level).

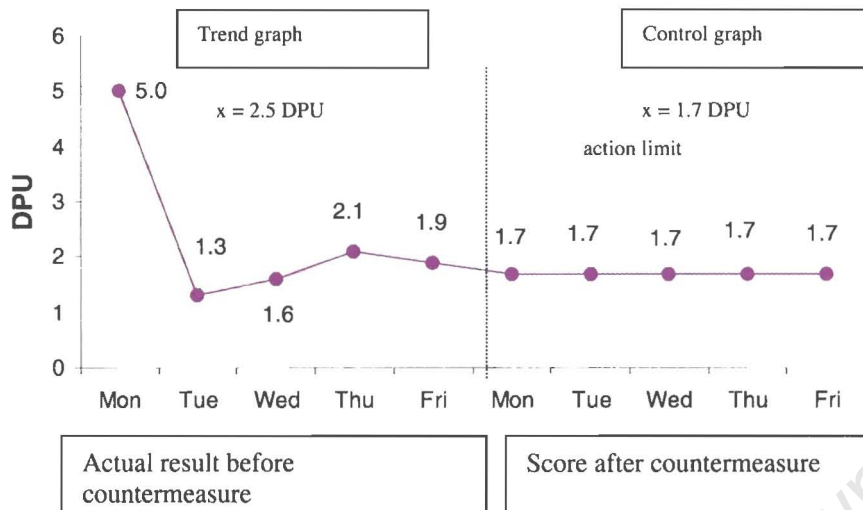
### 7.6 STEP SIX : Confirming Effectiveness

Parato diagram by defect types



Parato diagram by defect position





After implementation of the countermeasure the number of defects due to dirt has reduced from 70% to 50% and the occurrence of defects on horizontal to vertical surfaces is more in balance. The trend graph indicates that the abnormal situation on Monday has been eliminated and a further slight improvement on the rest of the week has been achieved. The average defect per unit of 2.5 before implementation of the countermeasures has reduced to 1.7 indicating that the targeted improvement of 30% has been achieved.

## 7.7 STANDARDISATION AND ESTABLISHING CONTROL

Changes made to the facility in the way of the vinyl curtains and canopy should ensure that the higher occurrence of dirt should be prevented in the future. The operators on the other hand have been retrained to blow off and clean the units more effectively. If some control is not put in place, over time they will revert to the previously, unacceptable process. To this end, the standard operation sheet for the operation must be changed to reflect the new method and periodic observations carried out against the SOS by the foreman to ensure that the operator is working correctly. Dirt can never be eliminated completely from the paint shop process but, through this type of action, the effect of dirt can be reduced.

*This exercise has illustrated how effectively the Quality Story framework can be used for problem resolution and continual improvement.*

## CHAPTER 8.0

### REFLECTION

As stated by Ian Mitroff in his book 'Smart Thinking for Crazy Times', and I quote "The danger lies not only in picking the wrong problems on which to spend limited energies- solving the wrong problem precisely- but far worse, in creating more serious problems as a result."

One of the aims of this thesis was to identify to the problem solver or engineer that problems are very rarely as simple as they may at first appear and the first definition of a problem is almost always wrong. The existence of problems in itself is not surprising in that problems will always exist within complex organisations. What must be understood is that problems have a nature of their own and change form depending on the actions taken to their existence and invariably, give rise to new problems appearing somewhere else. Another important aspect is to understand the nature of the organisation in which the problem resides and why the problem exists at all. Depending on the role players involved, the problem can take on a much higher or for that matter, a much lesser degree of importance. This belief is supported by Checkland's Soft System Methodology that is based on the understanding that problems do not exist independent of the people involved. Failure to acknowledge the political aspects of the organisation and those that wish to perpetuate the existence of the problem for whatever reason can lead to much frustration and ineffective solutions.

Organisations are complex systems and problems can not be considered as stand-alone entities without taking cognizance of the total systems in which they exist. Understanding failure and learning from the experience is a vital component of problem resolution. Organisations must be able to increase their ability to learn and in so doing, be able to meet the requirements of an ever-changing environment. Equally important is that individuals are free to share their thoughts and experiences without fear of recrimination.

Failure is an emotive subject that causes people to hide things, which can deprive the organisation of a valuable learning experience.

From understanding the cause of failure, it is possible to use the knowledge to predict or prevent failures in the future. Problem solvers must take care not to confuse actions to correct a situation with countermeasures to ensure that the problem will not happen again. A reliability approach to failure making use of a system called 'failure mode and effect analysis' can reduce the impact by anticipating and planning for failure. This approach makes use of reflective investigation and involves questioning whether a situation has a potential for failure.

Further complicating the situation is the emergence of Japanese management systems and the need for standardisation. To this end, the Quality Story format is a useful tool in that it leads the problem solver through a step by step process forcing a full understanding of each step before proceeding to the next. In this way, it is possible for the problem solver to avoid the most common mistake made in problem resolution, namely, the precise solving of the wrong problem. Much time and effort is taken in the first step of the framework to fully understand the current situation before attempting implementation of any countermeasures towards improving the situation. Many problem solvers jump straight in with much enthusiasm to solve what they believed to be the problem without fully understanding what the true problem is. By using the framework, it is possible to fully understand the root cause and to correctly formulate the problem before any attempt at countermeasures is made. There is a saying that 'the person who controls the definition of a problem controls its solution' and that 'once a problem has been well defined, it is half way to being solved.' Equally important in the framework is the setting of the target for improvement in the initial stages. This forces the problem solver to analyse and understand what it is that is hoped to be achieved before embarking on the countermeasures for improvement. This is very useful in the later stages of the framework to measure whether or not the original objective of the exercise as defined in the target has been achieved. Perhaps the most important stage of the framework is the last in that many good problem resolution activities have failed after a short period of time due to no changes or actions taken to ensure that the new improved state remains in place. This condition is supported by Clemson's theory that basins of stability are bordered by areas of instability. If no physical or concrete efforts are implemented to ensure that the changes made are kept in place, the situation will

revert back to its previously unacceptable steady state and the problem will reappear.

The Quality Story framework supports many of the principles of Herbert Simon's vision of 'fast and frugal' heuristics. In particular, a clear definition of the problem statement, setting of goals in the initial stages of the process and the use of means-ends or gap analysis are common to both models.

Humans are not capable of possessing the intelligence contemplated by Laplacean's ultimate genius and therefore, do not have the time, knowledge or resources to use unbounded rationality in researching problems. In real world situations, no matter which problem solving methodology is used, the principles of bounded rationality should be applied.

Much criticism has been levelled at hard system approaches to problem resolution for their treatment of organisations as if they were machines, but they have proved very useful for the solving of well structured, simple mechanistic problems, in which technology dominates over people. In the light of the criticism however, problem solvers must be cautious when using these approaches in the solving of complex, ill-structured problem situations. Japanese management systems are geared towards the achievement of very specific, corporate goals, and the Quality Story format proves very effective in ensuring that these goals are reached with optimum efficiency. Decision making is assumed to be rational and strict control procedures are introduced to ensure conformance with rationally laid plans and that ultimate objectives are achieved. Hard system approaches are concerned with achieving objectives and are modelled on the natural scientific method and so aims to provide generalisable knowledge about structured occurrences. They seek out this knowledge by concentrating on the logic of the situation within organisations and are seen as driven by official goals. Unfortunately for the hard approach, in social systems, the logic of the situation is usually much less significant in terms of what happens than the cultural interconnections forged from the meanings attributed to the situation by individuals and groups. Soft systems approaches on the other hand, recognise this and seeks to work with the different perceptions of the situation, setting in motion a systemic process of learning in which different viewpoints are discussed and examined in a manner that should lead to purposeful action in pursuit of improvement. Hard system approaches are more concerned with how

goals are to be achieved with prediction, control and optimisation. Soft systems thinking places more emphasis on what ought to be done and on participation and learning.

Data is essential for the analysis and understanding of problem situations and must be refined by means of the likes of the QC Tools. Problems solved making use of these structured graphical techniques lead to better problem resolution with results that are defined and measurable and open to scrutiny.

In conclusion, this thesis will give the problem solver a complete understanding of the difficult task that lies ahead when attempting to improve a problematic situation. Even in the light of the criticism of hard system thinking, I believe that the Quality Story framework adequately satisfies the engineers need for a method to go about the solving of problems in a Japanese managed production facility.

The Quality Story proves to be a practical framework to guide the thought process and enable engineers to solve problems in a logical manner. Its strength lies in its simplicity and rigidity in that each of the steps must be completed before moving on to the next. The engineer must fully analyse and understand the current situation in which the problem exists and set targets for its successful solution. Failure to achieve the target level set will mean that the problem solver must go through the steps again until the desired result is obtained. In so doing, the engineer is forced to approach problems logically, to think and to learn from the experience. Care however should be exercised not to lose sight of the importance of the perspectives of the individuals involved in the problem situation and, whenever it is suspected that the people involved could have a direct effect on the outcome of the intervention, a more appropriate, soft system approach should be considered.

Finally, in the words of Mitroff:

“Organisations that know how to think critically will dominate, individuals who know how to think critically will make better and wiser decisions in their lives.”

## REFERENCES

**ACKOFF, RL**

REDISIGNING THE FUTURE,

Wiley, 1974

**BEER, S**

THE HEART OF ENTERPRISE

Wiley, 1979

**BIGNELL, V and FORTUNE, J**

UNDERSTANDING SYSTEMS FAILURE

The Open University, 1989

**CHASE, V and GIGERENZER, G**

TRENDS IN COGNITIVE SCIENCES: VISIONS OF RATIONALITY

Max-Planck Institute for Human Development, 1998

**CHECKLAND, PB**

SYSTEMS THINKING, SYSTEMS PRACTICE,

Wiley, 1981

**CHURCHMAN, CW**

THE SYSTEMS APPROACH

Dell, 1968

**CLEMSON, B**

CYBERNETICS, A New Management Tool,

Abacus, 1984

**DORNER, D**

THE LOGIC OF FAILURE

Metropolitan, 1989

**FLOOD, RL and JACKSON, MC**

CREATIVE PROBLEM SOLVING, Total Systems Intervention,  
Wiley, 1991

**FORTUNE, J and PETERS, G**

LEARNING FROM FAILURE, The Systems Approach  
Wiley, 1995

**FUNKE, J and FRENSCH, P**

COMPLEX PROBLEM SOLVING RESEARCH IN NORTH AMERICA  
AND EUROPE, AN INTEGRATIVE REVIEW  
Joachim Funke & Peter Frensch, 1995

**GIGERENZER, G and TODD, P**

SIMPLE HEURISTICS THAT MAKES US SMART  
Oxford University Press, 1999

**JACKSON, MC**

SYSTEMS METHODOLOGY FOR THE MANAGEMENT SCIENCE,  
Plenum, 1993

**JENKINS, GM**

SYSTEMS BEHAVIOUR, The Systems Approach, 1972

**MITROFF, I**

SMART THINKING FOR CRAZY TIMES, The Art of Solving the Right  
Problems, Berrett-Koehler, 1998

**SENGE, P**

THE FIFTH DISCIPLINE,  
Brealey, 1995

**SIMON, H**

**DECISION MAKING AND PROBLEM SOLVING**

National Academy Press, 1986

**WICKENS, P**

**THE ROAD TO NISSAN, Flexibility, Quality, Teamwork,**

Macmillan, 1987

**GENBA KANRI**

Shop Floor Management, Nissan Japan

**HOSHIN KANRI**

Policy Management, Nissan Japan

**NISSAN PLANT MANAGEMENT SYSTEM**

Management Standards, Nissan Japan

**SEVEN MANAGEMENT AND PLANNING TOOLS, The Memory Jogger,**

Goal/QPC, 1993

**SOFT SYSTEMS ANALYSIS**

An Introductory Guide, THE OPEN UNIVERSITY,

Walton Hall, Milton Keynes, 1984

**SYSTEMS APPROACH TO FAILURES**

Systems Paradigms Studying Systems Failures, THE OPEN UNIVERSITY,

Walton Hall, Milton Keynes, 1993

**SYSTEMS DYNAMIC MODELLING**

Roberts N, Andersen DF, Deal RM, Garet MS, Schaffer WA, 1982