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A chaos related investigation into small manufacturing business financial decision-making dynamics

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## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY</td>
<td></td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td></td>
</tr>
<tr>
<td>DECLARATION</td>
<td></td>
</tr>
<tr>
<td>(A) INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>(B) METHODOLOGY</td>
<td>8</td>
</tr>
<tr>
<td>1 Problems</td>
<td>12</td>
</tr>
<tr>
<td>1.1 Content of the chaotic literature</td>
<td>13</td>
</tr>
<tr>
<td>1.2 Paucity of references to small manufacturing businesses</td>
<td>13</td>
</tr>
<tr>
<td>1.3 Form of the literature</td>
<td>14</td>
</tr>
<tr>
<td>1.4 Definitions of key terms</td>
<td>16</td>
</tr>
<tr>
<td>1.5 Diversity of literature</td>
<td>16</td>
</tr>
<tr>
<td>1.6 Quality of the literature</td>
<td>16</td>
</tr>
<tr>
<td>1.7 Confidentiality of in-house information</td>
<td>16</td>
</tr>
<tr>
<td>1.8 Business anonymity</td>
<td>17</td>
</tr>
<tr>
<td>1.9 The ultimate audience</td>
<td>17</td>
</tr>
<tr>
<td>2 Overcoming the problems</td>
<td>18</td>
</tr>
<tr>
<td>2.1 Initial extended literature trawl</td>
<td>18</td>
</tr>
<tr>
<td>2.2 Literature search criteria</td>
<td>18</td>
</tr>
<tr>
<td>2.3 Clarification of terminology</td>
<td>19</td>
</tr>
<tr>
<td>2.4 Ultimate dissemination of findings</td>
<td>20</td>
</tr>
<tr>
<td>2.5 The literature</td>
<td>21</td>
</tr>
<tr>
<td>2.6 Synthesisation of cash flow data</td>
<td>22</td>
</tr>
<tr>
<td>2.7 Small manufacturing business variables</td>
<td>23</td>
</tr>
<tr>
<td>3 Identifying and appraising the constituents</td>
<td>24</td>
</tr>
<tr>
<td>3.1 Chaos, chaos theory and chaology</td>
<td>24</td>
</tr>
<tr>
<td>3.2 Financial decision-making and small</td>
<td>24</td>
</tr>
<tr>
<td>manufacturing businesses</td>
<td></td>
</tr>
<tr>
<td>4 Appraisal methodology</td>
<td>25</td>
</tr>
<tr>
<td>5 Alternative explanations and theories</td>
<td>25</td>
</tr>
<tr>
<td>6 Thesis conclusions</td>
<td>25</td>
</tr>
<tr>
<td>(C) REVIEW</td>
<td></td>
</tr>
</tbody>
</table>
7.3 Business transfers and acquisitions 80
7.4 Management buy-outs and buy-ins 81
7.5 Revamped existing businesses 81
7.6 Interim datum point problem 82
8. Conclusions 82

(E) APPRAISAL OF CHAOTIC POSTULATES 84

1 CHAOS
Overview 86
1.1 Working definition 90
1.2 Critique of working definition 91

2 CHAOS THEORY
Overview 93
2.1 Definitions of chaos theory 100
2.2 Theories related to chaos theory 104
2.3 Uses of chaos theory 119
2.4 Limitations of chaos theory 120
2.5 Section conclusions 121

3 CHAOTOLOGY
Overview 123
3.1 Models 126
3.2 Techniques 137
3.3 Hypotheses 160
3.4 Conjecture 161
3.5 Theorems 161

4 CHAPTER CONCLUSIONS
4.1 Substantives 164
4.2 Ambiguities 165
4.3 Incompatibilities 165
4.4 Possibilities 166
4.5 Confirmation of existing knowledge 167
4.6 Inputs to a novel technique for a decision support system 167

(F) ALTERNATIVE EXPLANATIONS
Overview 169
1 Localised variability theories 170
2 Human behaviour theory 176
3 Complex phenomenological theories 176
4 End point theories 180
5 Seminal theories 181
6 Conclusions 183

(G) A FINANCIAL INFORMATION TECHNIQUE FOR SMALL MANUFACTURING BUSINESSES

Overview 185
1 Introduction 187
2 Foundations 191
3 Technique design 193
4 Man-machine interface 209
5 Evaluation and comparison with specification 214
6 Discussion 216
7 Conclusion 219

(H) THESIS CONCLUSIONS

1 A financial management decision support technique 220
2 Tenuous support for relevance hypothesis 220
3 Limitations of chaos theory 221
4 Random dynamics in business 221
5 Future work 221

(J) APPENDICES

1 Synthesised and random cash flow data 228
2 Significance testing of Appendix I data 303
3 Schedule of value and temporal variables 304
4 Definition of decision-making 329
5 Chaos: Appraisal addenda 332

REFERENCES 425

GLOSSARY 443

FIGURES

A1 Thesis evolution 6
A2 Thesis anatomy 7
B1 Methodology overview 11
C1 Review overview 27
C2 Types of continuous systems 38
C3 Small manufacturing business value and time constrained couplings (linkages) 45
C4 Bipolar analysis of order volume determinants 55
C5 Inter-linked constraints on financial decision-making 58
D1 Flexible parameters and variable flows 65
D2 Imported exogenous chaos 73
D3 Small manufacturing business variable boundaries 78

E1 Chaos theories network 97
E2a A typical bifurcation 112
E2b Effect of increasing capacity 114
E3 Lyapunov exponents 144
E4 Phase space reconstruction with multiple strands 148
E5a Single line deconstructed phase space and template 150
E5b Single strand from deconstructed phase space 151
E5c Blob measurement 152
E6 Poincare sections 155
E7(a) Braid cross-over 157
E7(b) Braid cross-under 157

G1 Technique schematic 186
G2 Diagram of PC monitor display 188
G3 Origins of small manufacturing business financial information technique 192
G4 Technique design 194
G5 Individual cell template forms and aspects 201/1/2
G6 Monitor-wide grouping of cell templates 203
G7 Localised grouping of templates 204
G8 Zoom view of three adjacent cells 211
G9 Concurrent data cells 212
G10 Asynchronous link-up shapes 213

J1(a) Foreign currency losses 310
J1(b) Foreign currency gains 311
J2 Preferred and possible production sequences 313
J3 Choices available for amending time and value parameters by customers and credit controllers 319
J4 Cash flow permutations and combinations 322
J5 Changes in overdraft rates 324
J6 Chaos generating factory loading 328
J7 Conventional perceptions of chaos 346-7
J8(a) Daily cash balance 350
J8(b) Cash balance every tenth day 351
J9 Onset of chaos 353
J10 Insufficient working capital and increased order book chain reaction 358
J11 Oscillation (switching) in irregular payments 390
J12 (a) thru (e) Non-linearity 393-4
J12 (f), (g)  395
J13 Irregularity in receiving payments 398
J14 Intermittency 400
J15 Unpredictability 403
J16 Transcience 405
J17 Changes in net worth of cash introduced 408
J18 Cash flow complexity 413
J19 Cash transactions with cash balance trend 416

ANNEXURES

Letter from Green, Hallett & Co 26/1
Hill, Denys June 1996 Chaos and stability in operational cash flows (Management Accounting) 74.6 p14-15 422
Letter from The Mathematical Intelligencer 424

TABLES

C1 Financial transaction in one small business 46
C2 Similar decision-making and chaos attributes 50
C3 Similar scenarios of decision-making and chaos 51

E1 Chaos: Small manufacturing business summary of relevance 89
E2 Chaos theory: Small manufacturing business summary of relevance 95
E3 Theories linked with chaos 96
E4 Chaology: Small manufacturing business summary of relevance 124
E5 Cash movements in synthesised data 145

G1 Data acquisition 279
G2 Chaos-free verbal description 205

J1 Comparison of synthesised and random values 410

Total wordage (excluding Appendix 1)  66,188 words
Summary

Despite the fact that small manufacturing businesses are still the core of manufacturing in the UK very little is known about their financial dynamics. This thesis investigates these activities from a chaos and chaos theory related standpoint. Since chaos treats dynamic situations, and businesses are intrinsically dynamic, a reasonable expectation is that the one is relevant to the other.

However as the research progressed, into detailed appraisals, it became evident that initial, optimistic expectations regarding their relevance were ill-founded. Therefore a conclusion is reached that chaos and chaos theory, despite a voluminous literature, have little relevance to financial decision-making in small manufacturing businesses. The greater part of chaos literature relates to various branches of mathematics, the physical and life sciences. Economics occupies third place. Paucity of references to small manufacturing businesses justifies attempts, such as this, to bridge the gap between them and chaos by explanatory and interpretative research.

Chaos is the main artery, one of two main divisions. It is sub-divided into chaos, the condition, chaos and related theories, and chaology, the techniques. The other main division comprises first an extended study of small manufacturing businesses, which have many, sometimes difficult-to-quantify, financial variables, and secondly hands-on experience as an owner/manager.

Evaluating the two, by comparing and contrasting, was intended to be central to the thesis. Instead it became apparent that no there is no pre-existing agreement on key factors. Formulating working definitions ameliorates the problem and allows the evaluation of chaos, in the context of varied financial success in small manufacturing businesses, as well as other theories, to proceed. The financial information needs of their decision-makers, typically owner/managers focus the evaluation.

Contributions to knowledge are two. First is finding chaos to be only marginally relevant. Secondly, at the end of the research when considering chaological techniques, a chain of thought is triggered which leads to a novel, technology-based small manufacturing business financial information technique. Small business computerised accounting, and factory loading systems, image processing, (in which hands-on experience, mentioned in the study was gained), pattern recognition, shape analysis and artificial intelligence are combined in the technique.
Acknowledgements

I wish to record my thanks to Mr J G Hallett of Green, Hallett & Co., Chartered Accountants, for examining my Schedule of Value and Temporal Variables and also Cash Flow Inputs, Outputs and Balances and for giving it as his opinion that they are representative of small manufacturing businesses.

I am indebted to Professor D J Whitehouse for his encouragement and guidance especially when difficulties were encountered.

Declaration

The definitions of decision-making and small business are based on those developed for my MSc dissertation on financial decision-making in small businesses. This thesis is submitted only for the degree of PhD and has not been submitted for any other.
1 Personal note

This work is an extension of my dissertation, 'Financial decision-making in small businesses' for which I was awarded the MSc degree in 1991. It comes at the end of a business career which began with a graduate apprenticeship at Ransome & Marles Bearing Co Ltd in 1955. Working in my own, and other small and medium enterprises, multi-nationals and HM Government followed. Adversity, experienced in the business which I founded, and in other small manufacturing enterprises in which I was employed, stimulated me to research in the crucial area of financial information for decision-making from the standpoint of owner/managers in the expectation that applying chaos theory would effect improvements.

2 General

The word 'chaos' has common and technical meanings. It is often used loosely, in the written and oral forms, sometimes in jest, sometimes pejoratively, rarely if ever complimentarily, invariably in a popular rather than a technical sense, often subjectively, to describe a perceived, or actual, state of affairs. In businesses, of all sizes, the observation may apply to the whole or only to certain sections, or segments. In small manufacturing businesses, the field of study, persons making such observations are usually owner/managers, engaging in private conversation with a trusted peer, or disgruntled, symbiotic employees, or someone, not a member of the organisation, whose attention has been drawn to the enterprise by untoward events such as financial difficulties. 'Chaos can be
produced by real people in simple managerial systems' is an apt observation although people are not always individually identifiable. (Mosekilde et al 1991)

Technically 'Chaos is a condition. Chaos theory is a collection of mathematical, geometrical and numerical techniques that allows us to deal with non linear problems to which there are no explicit solutions'. (Cambel 1993)

This is only one of a confusing number of definitions, the majority with technical connotations, but it makes the distinction between chaos, the condition, and the amalgam of theories known collectively as chaos theory. Other definitions are considered in chapter (E) Appraisal of the Chaotic Postulates.

Given that observations are either accurate, inaccurate, unjust, biased even harmful, there is a need to investigate a number of associated issues. One issue is the relationship between the ordinary or common and technical versions of chaos. The objectivity, veracity, circumstances and, especially the information used for diagnosing chaos, common or technical or both, warrant investigation. First, in order to ascertain whether chaos and chaos theory at least confirms what is already known or, secondly what is more desirable, augments or surpasses what is currently available by showing how to make better information available so that better financial decisions may be made.

Information is the crucial factor for decision-making. If chaos and chaos theory are found to be relevant to small manufacturing business financial decision-making, the objective is an information package, a decision support
system, supported by state-of-the-art technology for use by real-life decision-makers. An improvement in the quality of both reactive and proactive decisions should then ensue.

Where chaos has already been accurately diagnosed, reactive decisions need to be made. On the other hand, if the imminence of chaos, an undesirable financial condition, were located and reliably recognised earlier, say with the aid of a user-friendly model, proactive decision-making is facilitated.

Another approach to technical chaos, is that, instead of owner/managers reacting or pro-acting against it in current, or imminent, crises, utilising it beneficially, and continuously, as a tool. There are precedents in other disciplines for beneficially harnessing chaos. Diagnosis of requirements preceded beneficial applications in engineering and medicine. For example chaos helps carry signals in fibre-optic cable and controls heart pacemakers. If chaos helps control flows of blood in human bodies, and gives insights into hydrodynamics, it is reasonable to expect benefits from it in connection with financial flows in small manufacturing businesses.

These applications have little in common with financial decision-making but they demonstrate that chaos has beneficial uses. (Roy 1998, Cambel 1993)

A major difference is that owner/managers make financial decisions in situations where, not just one set, but many goal posts are either moving or prone to do so. Moreover the dimensions of the goal mouth fluctuate.
Chaos theory has its detractors, (Horgan 1995, Cohen & Stewart 1994) as well as it advocates. The comment that chaos can be over played is salutary. (Perkel 1987) Investigation is needed to ascertain whether opinions of detractors or advocates should prevail.

If the detractors’ opinions are found to be incorrect, small manufacturing businesses, and the wider business community, are the potential beneficiaries.

Two statistics provide additional justification for a full scale, multi-faceted investigation of chaos theory in this segment of the manufacturing economy. In the UK, small businesses represent 40% of the manufacturing sector, (Parkin 1998) but their financial vulnerability is notorious. Secondly manufacturing accounts for 21% of insolvencies. (Business West Midlands 1998)

The initialisation of such an investigation requires difficulties, associated with the literature and availability of case study information, to be overcome.

Only a minute amount of the voluminous, and varied, chaos literature refers specifically to businesses, of any size. Nevertheless that literature is the launch-pad for an assessment of the relevance of chaos and chaos theory to financial decision-making in small manufacturing businesses.

In the interests of owner/managers, the national GDP (Gross Domestic Product), and the European Union, the investigation is justified. It is indisputable that
small manufacturing businesses need to become more financially robust and less
vulnerable. Chaos theory could possibly contribute to this aim in two ways.
First by giving insights into their dynamics. Secondly by providing improved
financial management control information - and a decision support system.

Fig A1, Thesis Evolution shows how the thesis developed.
Fig A2, Thesis Anatomy outlines the basic structure. Together they show the
research begins with expectation, passes through information acquisition, then
investigation by comparison, and finally leads to a novel technique for small
manufacturing business financial information. Information acquisition in
Fig A2 adds details not included in Fig A1. Bold type entries indicate the routes
and inputs leading to the novel technique summarised below:-

[Chaos (definitions + perceptions) + Chaology (analytical technique)] +
Graphical Processing (patterns + shapes) + Complimentary theory (adjuncts
→ Novel financial information technique
Optimistic expectation

Appraisal by detailed comparison

Chaos ← Comparison → Small manufacturing business financial ← Comparison → Alternative dynamics explanations

Appraisal conclusion: minimal relevance

Novel small manufacturing business financial information technique
EXCEPTION:-

That chaos, chaos theory and chaology are beneficially transferable from mathematics, physical and life sciences to small manufacturing business financial decision-making information improvements.

### INFORMATION ACQUISITION

<table>
<thead>
<tr>
<th>Literature</th>
<th>Field work</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
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<td>Chaotic</td>
<td>Other</td>
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<td>Chaos</td>
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</tr>
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<td>Business</td>
</tr>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Definitions</th>
<th>Financial variables</th>
</tr>
</thead>
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<tr>
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</tr>
<tr>
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<td>Diagrams</td>
</tr>
<tr>
<td>specific</td>
<td>Owner/individual managers</td>
</tr>
<tr>
<td>Chaology</td>
<td>Individual Images</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
</tr>
<tr>
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</tr>
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<td></td>
</tr>
<tr>
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</tr>
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</tr>
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<td></td>
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</tr>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MANIFESTATION BY COMPARISON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaos</td>
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<td>Chaology</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Many differences</th>
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</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
</tr>
<tr>
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<td>One relevant</td>
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</tr>
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</table>

<table>
<thead>
<tr>
<th>NOVEL TECHNIQUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaology</td>
</tr>
<tr>
<td>Analytical technique</td>
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SMALL MANUFACTURING BUSINESS FINANCIAL INFORMATION TECHNIQUE PARTIALLY SATISFYING INITIAL EXPECTATION
(B) METHODOLOGY

Chaos has no methodology to call its own. (Morrison 1991) Since chaos is the unifying theme of this research, in the setting of financial decision-making in small manufacturing businesses, an appropriate methodology has therefore to be devised. The investigation has to work with a combination of a diverse literature, secondly a study of small manufacturing businesses and thirdly typical cash flow data synthesised from one small business. (See Acknowledgements)

The chosen research methodology is explanatory, or interpretative, research. Chaos and chaos theory are explained, and interpreted, by comparing them to financial decision-making elements, in small manufacturing businesses with particular reference to engineering.

Many facets of chaos are necessarily appraised in a small manufacturing business context because initial expectations of relevance proved to be ill-founded. As a consequence of this lack of relevance an intermediate stage, the appraisal of alternative theories, is introduced.

The final stage is building on the rump, remaining after these appraisals, to formulate a technology-based technique which enhances the endogenous financial information currently available to owner/managers.

Fig B1, Methodology Overview, shows the stages of the investigation.

The standpoint is real life, small manufacturing businesses, connected into
extended trading networks. (Oliva et al 1988) The single business, used to provide a framework for the Synthesised Data Cash Flow Data (Appendix 1), was in the electro-optic engineering sector. (The term 'business' is used in preference to company, firm or enterprise). In order to ensure objective appraisal, as well as scenarios with which owner/managers are able to empathise, small businesses from other manufacturing sectors were incorporated in the investigation. The Synthesised and Random Cash Flow Data (Appendix 1) provides quantitative information to supplement the qualitative.

Other research methods were also considered. Quantitative methods are rendered unsuitable by problems of acquiring financial data relating to multiple variables and parameters. Reference is made to these problems in the Review, from an owner/manager’s, and then, in the section on Chaological techniques, from an analyst’s standpoint.

Using random numbers to overcome data acquisition problems is not an option where chaos is being investigated. The properties of random numbers are such that the order, said to underly the random appearance of deterministic chaos, would be undetectable. The null hypothesis used to compare the synthetic data and random numbers in Appendix 1, is rejected. (Appendix 2, Significance Testing of Appendix 1 Data) Another issue is whether white noise, a random process, constitutes another variant, random chaos. (Szulga 1998, Kuo 1996).

Processual analysis, a development of longitudinal research, was also considered
in an attempt to find a methodology which avoids ambiguities associated with other methods and fits scenarios likely to be encountered in the course of investigating chaos in a small manufacturing business financial information context. (Pettigrew 1997) Its advantage is comprehensive coverage because it is a trail through a business but it is hindered by lack of objectivity. Its drawback is that it is a craft activity, an art, full of intuition, judgement and tacit knowledge. In fact it suffers from drawbacks which this investigation aims to overcome by substituting science for art, paradigms for intuition, analysis for judgement and accessible information for tacit knowledge.

(E) Appraisal of Chaotic Postulates paragraph 3.1.1 finds that mathematical modelling is not an appropriate technology for the topic of small manufacturing business financial information. However the novel technique developed towards the end of this thesis, incorporates a diagrammatic model. Figs A1, A2 and B1 refer.
### PROBLEMS OF INFORMATION ACQUISITION

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### OVERCOMING THE PROBLEMS OF INFORMATION ACQUISITION

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### INVESTIGATION BY COMPARISON

1. Chaos, chaos theory, chaology $\leftrightarrow$ Small manufacturing businesses and their financial dynamics
2. Alternative theories

- Dissonance
- Contradictions
- Ambiguities
- Incompatibilities
- Congruence
- Compatibility

### NOVEL FINANCIAL INFORMATION TECHNIQUE

Technology-based small manufacturing business financial information technique.
1 PROBLEMS

Identifying problems, and devising methods to overcome them, clears the way for the statement, and subsequent appraisal, of chaotic postulates, their analysis and evaluation, within a small manufacturing business financial decision-making context.

Prior to implementing the overall research method three problems must be addressed, as well as literature-based ones. First of these is the confidentiality of quantitative cash information appearing on bank statements. It is fiercely guarded by businesses and their bankers. Even civil servants, signatories of Official Secrets Acts, when responding to invitations for diagnostic surveys, were not allowed to see clients' bank statements. This non-availability of typical real life data could affect the evaluation stage of the research, the more so if 'cash [really] is king'. (Yorkshire Bank 1997, Jones 1997)

The second problem relates to the objective of ultimately making the results of the research accessible to owner/managers, only a tiny majority of whom are educated to university standard and whose business experience ranges from a few months to many years. (Woodcock 1989) The problem of making the research available is compounded by one of their proclivities. Empirical evidence highlights a firm belief in the uniqueness of their business. ‘Our business really is different’ is a comment frequently made by personnel in small manufacturing businesses to consultants.

The third problem is that of the associations and perceptions of ‘chaos’ which
were deeply rooted in the human psyche long before the birth of Poincare, one of the fathers of technical chaos. (Imbs 1997)

1.1 The content of the chaotic literature

A preponderance of the subject matter concerns topics in:-

1.1.1 Mathematics, at levels much higher than those at which the majority of business people have studied the subject. eg fractal geometry, topology, set theory, difference and non-linear differential equations, wavelets, bifurcations and transforms such as FTs (Fourier Transforms)


1.1.3 Applied sciences, such as control engineering and electronics, which are increasingly attracting interest, particularly in connection with the control of chaos. (Abed & Wang 1995, Stewart et al 1995)

1.2 Paucity of references to small manufacturing businesses

References to [technical] chaos in business are scarce in more than 7,000 papers and books. (Feichtinger 1993) A rare exception to this is Stacey 1992 which deals with managing chaos, albeit in large-scale business.
There are references to chaos in economics, econometrics, futures and stock-markets, soft sciences, but few to its presence in specific business situations. (Gleick 1987)

If the number of references to large scale business is few, those referring to small business are infinitesimal.

Care has to be exercised when using economics and its constituent parts. Like small businesses, they are concerned with money but the sums are many times greater. Throughputs with an aggregate value of several million £ sterling daily pass through each of the financial markets, in London alone, whereas the sales turnover of many small manufacturing businesses is in the region of only £1 million for a whole year.

Large corporations similarly differ from small manufacturing businesses in several respects. The majority of them are quoted on one or other the world’s stock exchanges, account to institutional as well as private investors, operate multi-nationally, if not globally, and have easier access to funds. (Prince & Thurik 1995)

1.3 The form of the literature

The nomenclature, used in the majority of publications, often has situation or academe specific meanings eg determinant, parameter, non-linear, dimension, intermittent, instability. Entries in the Glossary provide examples whose meanings differ in mathematics, statistics and
physics. To these differences should be added the further complication of established English usage meanings. The Glossary has three main uses:

- Smoothing the flow of (D) and (E), the two appraisal chapters.
- Indicating compatibility between chaos and small business in *italics*.
- Indicating incompatibility between chaos and small business in **bold**.

The style of writing is not always readily comprehensible on account of the proliferation of mathematical notation which is not confined to mathematical publications. ‘You need an excellent mathematical mind to understand chaos, fractals and catastrophes’, (Julesz 1995) is a telling comment.

An additional problem is the small number of variables in the chaos literature topics compared to those in small manufacturing businesses. A distinction made between the number, and complexity, of variables in physics and biology pales in comparison with the financial ones in small manufacturing businesses. ‘In physics, classical science worked well but less well in complex entities such as biology in respect of information systems’. (Avgeron & Cornford 1998) The form of the literature militates against an easy transposition of chaotic literature from scientific to business scenarios.
1.4 Definitions of key terms

No consensus on definitions of key chaotic terms exists. (Mees 1981)

1.5 The diversity of literature.

Books, papers, dictionaries, journals, newspapers, business magazines and leaflets comprise the literature used for the thesis. The references provide evidence of its diversity. Branches of the physical, life and social sciences and mathematics constitute the major part of the chaotic element, climatology and Christian apologetics the minor.

1.6 The quality of the literature

Appraisal difficulties are exacerbated by unevenness in the quality of the huge literature on chaos. 'There is a huge literature on chaos of rather uneven quality'. (Ruelle 1989)

1.7 Confidentiality of in-house business information

Businesses resist requests to release sensitive financial information, such as bank statements and current order books. Annual company accounts, as required by the Companies Acts, are reluctantly filed at Companies House. Small businesses defend their reluctance to release, to researchers, information in addition to that publicly, and historically, available. They draw attention to the fact that they trade in an environment which features an intelligence network, in which corporate predators and credit agencies operate.

Clearing banks similarly co-operate with their customers by safeguarding information of this kind.
1.8 Business anonymity

Protecting the individual identity of businesses in the study from some which examples are drawn, with the exception of CUEL Ltd, is also a sensitive issue. Legally binding non-disclosure undertakings must be honoured. However this research may be validated using businesses similar to those in the sectors and counties enumerated in the Review.

1.9 The ultimate audience

Conclusions of this research, which could improve the decision-making processes of small manufacturing businesses, are intended for dissemination. A major problem is the lack of educational qualifications by personnel. Only 3.8% are educated to degree standard. (Woodcock 1989) More recently a survey found that most entrepreneurs preferred previous experience over a formal business qualification. (Business Round-up 1998)

The target audience is not homogeneous. It is made up of entrepreneurs, CEOs (Chief Executive Officers), executive directors and owner/managers. (As it would be pedantic to list all their differing titles, whenever there is a need to personalise endogenous, core decision-makers, the term owner/manager is preferred unless the context requires use of another title.)
2 OVERCOMING THE PROBLEMS

Several methods were devised to overcome the problems.

2.1 Initial extended literature trawl

The trawl of the literature, using the selection criteria described below, erred on the side of collecting many references, even those whose relevance appeared tenuous, because insularity is not a trait of research into a cross-disciplinary subject such as chaos. One school of thought sees chaos as universal! (Schuster 1984, Zalavsky 1985)

2.2 Literature search criteria

The following criteria were used to link chaos literature with small manufacturing business financial variables:

2.2.1 Common terms


2.2.2 Similar scenarios

There a number of apparently similar scenarios eg turbulence. (Feigenbaum 1984, Axelsson 1979, Tritton 1988, Frisch and Orsog 1990)

2.2.3 Comparable concepts

A number of comparable concepts eg drivers (determinants) of dynamic systems are found in the literature. (Connolly & Huckerby 1998, Ruelle 1989) The transfer of the forced oscillator to international trade models, (Gandolfo 1996) and predator-prey dynamics to
commodity price fluctuations, (Lichtenberg & Ujihara 1989) establish an important principal by dispensing with application specific exclusivity, - where there is compatibility.

2.2.4 Connections already made

Although references to business are few, some of them make connections between chaos and business eg price - quantity dynamics and chaos. (Hommes 1994, Jensen & Urban 1984)

2.3 Clarification of terminology

Compilation of key term working definitions, where no suitable ones exist, and compilation of a Glossary are used to overcome the clarification problem. Scientific dictionaries, books with their own glossaries, technical business magazines and inter-disciplinary comparisons clarify the majority of terms and technical words eg wavelets. (Ling 1997)

The principal words and terms relating to chaos, chaos theory, small manufacturing business and financial decision-making, in the Glossary are appraised in detail in the Review and Appraisal of Chaotic Postulates chapters. Detailed explanation, appraisal, and interpretation, of multiple aspects of chaos requires the semantics of ambiguities, and contradictions to be confronted. Comparison first with other words and terms, and then with small manufacturing business scenarios, follows.
2.4 Ultimate Dissemination of Findings

While the eventual outcome of this research is unknown, it is expected that its findings will achieve its objective of beneficial outcomes. If that is the case, dissemination of those outcomes to owner/managers in a suitable manner, will be justified.

2.4.1 Avoidance of mathematical notation

Mathematical notation is avoided because its inclusion in this thesis would confuse instead of clarify.

2.4.2 Preference for business terminology

If the meaning of a word depends on its context, its business meaning prevails.

When 'money' is used, it is in the business sense of cash, not the economics one, which makes distinctions between broad and narrow money, M0, M2 and M4.

2.4.3 Glossary of terms and definitions

The Glossary of terms and working definitions uses business language and format. In the main body of this thesis *italics* indicate words and terms found in the Glossary.

2.4.4 Highlighting key words and phrases

Underlining, and bold type, are used occasionally to highlight key words and phrases.
2.5 The literature

2.5.1 Containment of the chaos literature search

The literature search began by making use of university borrowing and reference facilities supplemented by inter-library loan borrowing of foreign journals. Business publications, mailed to CUEL Ltd, were also consulted so as to maintain the real-life focus of the thesis.

In the later stages, searching of pre-1990 publications was scaled down so as to concentrate on recent ones. Non availability of publications on campus, and incompatibility with the search criteria, pragmatically restricted the number of publications consulted in the later stages.

References from other disciplines, which do not readily transfer to, and have minimal interpretative value to small business financial decision-making scenarios, also figured in the literature search. Later these are either passed over or mentioned only in passing when their relevance is tenuous. However some tenuous connections are retained when there is cross-disciplinary transferability.

2.5.2 Diversification of the search

This is not a contradiction of the previous paragraph B 2.5.1. As the findings of the research began to emerge, the need to search image processing, pattern recognition and information systems publications became apparent.
2.5.3 Form of the review

The idiosyncracies of the chaos literature, especially its quantity and diversity, led to the literature review being spread through chapters like a common spine, in preference to there being one short, separate chapter.

2.6 Synthesisation of cash flow data

Cash flow data for evaluating the postulates was synthesised using actual time series data from a small business. Dates of receipts and disbursements were taken from my own company, CUEL Ltd’s current account bank statements for its final three years’ trading. The values, appearing alongside the dates in dates (Appendix 1), are based on uncoordinated lists of stock exchange share prices for different sections of the market as published in the financial press. If the published figures are expressed in £ sterling, the resulting values are typical of small manufacturing business transactions. Some amounts were altered so as to take account of real life “What if...?” situations eg Day 517 receipt of £22,012. This reflects the trading experience of CUEL Ltd which unexpectedly received a one-off order, from a General Motors company, of much higher value than either the arithmetic mean, median or mode, current at any time during the three year period used for synthesising the data.

The amounts of periodic payments for wages, National Health Insurance, commercial insurance, rent, rates, heating and bank charges were taken from a business start-up guide. (National Westminster Bank 1994)
Warwick District Council and HM Collector of Taxes supplied details of methods for making periodic payments. After discussion with HM Customs and Excise (VAT), Coventry, it was decided to exclude VAT because a number of different accounting schemes are available.

The data, which combined real dates and empirically synthesised amounts, were then tested for significance. Random numbers, corresponding to time intervals between receipts and disbursements, together with amounts received and disbursed were listed alongside the real and synthesised data. The null hypothesis that the figures were from the same [random] sample was not supported. (Appendix 2)

Lastly the data were empirically verified and declared to be representative by an accountant with 30 years' experience of auditing the accounts of small manufacturing business clients under Accounting Standard client confidentiality rules. (Confidential current account bank statements are one of the principal source documents for auditing clients' accounts).

Annexure M1, Letter from Green, Hallett & Co., refers.

2.7 Small manufacturing business financial variables

In addition to cash flow data, many other value and time financial variables are stated in Appendix 3, Schedule of value and temporal variables, so as to ensure that all appraisal, and evaluation, is anchored in real life situations.
3 IDENTIFYING AND APPRAISING THE CONSTITUENTS

Diagrams are used, when appropriate, to illustrate statements of the constituents parts if the elements and their appraisals. Small diagrams appear in the text, larger ones follow pages to which they refer.

3.1 Chaos, chaos theory and chaology

After devising ways of overcoming the problems, the pertinent chaotic postulates, are stated and appraised. A separate chapter is allocated to them on account of their number and complexity; chaos, the condition, is the first section, followed by chaos theory and chaology.

Although chaology, the study of chaos, is part of chaos theory, a separate section is allocated in order maintain the cohesiveness of the thesis and prevent the chaos theory section becoming unmanageably lengthy.

3.2 Financial decision-making and small manufacturing businesses

As they are more straightforward than the chaotic part of the thesis, the representative small manufacturing business, and germane aspects of financial decision-making, are allocated sections in the Review rather than short, separate chapters. The sections allocated to them utilise the same method of identification, and appraisal, as that adopted for (E), Appraisal of Chaotic Postulates chapter. They too have an accompanying interpretative commentary.
Comparisons and contrasts, matching and testing, eliminating and substantiating, are the methods used. Analogy, a type of comparison, also assists the appraisal, (Day 1992) because the amount of small manufacturing business chaos literature is so small. However care is exercised when effecting a transfer from chaos, in a physical science, to a predominantly financial scenario. (Kelsey 1988) Using more than one reference to support the same point, where possible, plays a part in exercising that care.

Comparing and contrasting is therefore used, as stated above, not only to find in the literature, any common ground, potentially capable of being transferred to financial decision-making in small manufacturing businesses, but also any contradictions and incongruities. The use of similar words and scenarios provides leads in the search for this common ground.

**5 ALTERNATIVE EXPLANATIONS AND THEORIES**

As chaos has its detractors, while its advocates are tempted to force fit inappropriate scenarios into a chaotic mould, other explanations are considered before reaching Final Conclusions.

**6 THESIS CONCLUSIONS**

This chapter (H) collects what, if anything, from chaos, chaos theory and chaology, is relevant to financial decision-making in small manufacturing
Dear Denys

I have examined the Schedule of Value and Temporal Variables and the dates of Cash Flow Inputs, Outputs and Balances which are part of your PhD thesis.

In my opinion they are representative of the small manufacturing businesses quoted in your Review.

Yours sincerely

JOHN HALLETT
GREEN, HALLETT & CO
### Context of the research

<table>
<thead>
<tr>
<th>Small manufacturing businesses</th>
<th>Financial decision-making</th>
<th>Chaos theory</th>
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<tbody>
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<td>Composite definition</td>
<td>Postulates</td>
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<td>Field work</td>
<td>Types of decisions</td>
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<td>Financial information</td>
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<td>Postulates in (D)</td>
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### Chapter Conclusions

| Human involvement | Financial variability | Defective financial Information |

### Inputs to subsequent chapters

- Small manufacturing business financial diversity
- Appraisal of chaos, chaos theory, chaology
- Alternative explanations
Small manufacturing businesses, financial decision-making and chaology, which underpins both the chaotic condition and chaos theory, are key elements in this research. The main artery of this research comprises chaos, chaos theory and chaology because the alternative, management accounting decision theory, is itself a complex, ill-defined body of knowledge (Horngren 1984) which, if pursued, could divert attention from the main thrust of this research. However management accounting decision and information theory, and practice, are potential beneficiaries of whatever this research finds to be advantageous for financial decision-making in small manufacturing businesses because the research standpoint, although targeted towards the practitioner, also works from a theoretical base.

The first recorded use of chaology, the study of chaos, was in the eighteenth century (Oxford English Dictionary) The reasons for adding it to 'chaos' and 'chaos theory' in the thesis are explained in (B) Methodology paragraph 3.1.

The sources, for this research, are a study of small manufacturing businesses, representative cash data from a single business, together with literature on decision-making, small businesses and chaos in all its aspects. Decision-making, and small business literature, is focused but that on chaos, is diffuse. Conventional consultancy methods were used in the study which, with decision-making, feeds into chaos, the backbone of this investigation. These included:-
- Activity observation, and measurement, where appropriate
- Analysis of available and disclosed documentation
- Interviewing personnel, representative of all levels within organisations, with a view to diagnosing causes of various financial problems, as well as devising and occasionally implementing solutions.

The first two elements, small manufacturing businesses and financial decision-making, are introduced, at this point, so as to contextualise chaos.

A chapter entitled Appraisal of Chaotic Postulates follows. Then the merits of alternative explanations and theories are assessed to ascertain whether the detractors from chaos are justified.

Working definitions of decision-making and small manufacturing businesses are extricated from the literature. In the definition of decision-making, symbols indicate words with chaotic equivalents and near equivalents.

1 SMALL MANUFACTURING BUSINESSES

These are the first of the two branches feeding into the mainstream of chaos.

1.1 Working definition

A number of different definitions of small businesses are in use.

Bolton (1972) defined "small" in nine different ways. The Late Payment of Commercial Debts (Interests) Act 1998 classes small businesses as those with up to 50 full-time, or part-time equivalents, employees. Belgium, Denmark, Ireland and the Netherlands have their own definitions, France,
Italy, Japan and the European Commission have a single category for small
and medium enterprises. The one by Gingembre (1960) reads:-

'Small and medium enterprises are those

- Which are run by their owners,
- Who risk their own capital in the business,
- Who carry out effective technical and administrative management.
- Who have permanent contact with personnel'

Although 'medium' is included in the Gingembre's definition it is still a
good fit for the majority of UK small manufacturing enterprises. It is therefor e adopted as the working definition for this thesis.

1.2 Field work in small manufacturing businesses

The following are typical small business manufacturing sectors. The
majority of the locations are in the English Midlands. The
list, although it does not include all manufacturing sectors, provides real life
examples for the appraisal of chaotic postulates.

Products from each of the sectors may be either catalogue products
or products manufactured to a customer specification, either singly or in
batches, on a produce-to-order or produce-to-semi-finished or finished stock
basis. A number of structural changes affecting some of the businesses
below, mergers, take-overs, relocations, have taken place since the study
began in 1970.

1.2.1 Engineering - mechanical, electrical, electronic, railway, packaging,
gas, water, aircraft, automotive, electro-optic, wire,
refrigeration, cycle, machine tool.
Locations: West Midlands, Warwickshire, Worcestershire, Oxfordshire, Staffordshire, Leicestershire
In the West Midlands most engineering SMEs tend to produce one or two standard products for a narrow range of customers on whom they are critically dependent. (Levy & Powell 1998)

1.2.2 Clothing - knitwear, outerwear, hosiery, trimmings, leather, swimwear and foundation garments.
Locations: Leicestershire, Nottinghamshire, Northamptonshire.

1.2.3 Textiles - carpets, knitted and woven cloths.
Locations: West Midlands, Lancashire.

1.2.4 Wood - furniture.
Location: Shropshire.

1.2.5 Metal manufacture - forgings, castings, rolled metal products.
Location: West Midlands.

1.2.6 Printing - cartons.
Location: Northamptonshire.

1.2.7 Food and drink - cakes, pastries, meat pies, fruit juices and soft drinks.
Locations: Warwickshire, Northamptonshire.

1.2.8 Footwear - shoes, slippers, walking boots, findings.
Location: Northamptonshire, Leicestershire.

1.2.9 Ceramics - earthenware, cups, saucers, plates.
Locations: Derbyshire, Staffordshire.

1.3 Sectors of the economy supplied

Sectors in the wider economy are the source of exogenous drivers, determinants, for the small manufacturing businesses in 1.2 above.

Macro economic changes, for example in the supply and cost of money, affect the potency, the strength or weakness of determinants.

1.3.1 Consumer

Baking, packaging, clothing, footwear.
1.3.2 Consumer durables
Automotive, furniture.

1.3.3 Utilities
Gas, water.

1.3.4 Capital goods
Special purpose machinery for packaging.

1.3.5 Transport
Railway engineering.

1.4 Financial decision-making information

1.4.1 Its importance
'Information is important for success'. (Lybaert 1998 )
In certain situations it assumes maximum importance. These are when owner/managers are pessimistic about the future or are short on experience. Entrepreneurs value information for facing the future.

It is needed to answer questions for financial decision-making such as:-

• What is happening and Where?
• What is imminent?
• What is the cause?
• What insights does it reveal into relationships, linkages and couplings?
• What if …?

Resorting to intuition when information is unavailable may force economically inefficient decisions. (Bell 1985 )
1.4.2 Two categories of information  (after Lybaert 1998)

Both categories are divisible into quantitative and qualitative.

1.4.2.1 Endogenous information

Endogenous information is internal information contained within a business and focused on it. Some of the information may possibly be confined to the owner/manager's brain. (Mpitsos 1990)

The specification below in paragraph 1.4.4.4 refers to this category.

1.4.2.2 Exogenous information

Exogenous information is external to the focal business and more broadly based and widely circulated. Economic intelligence in business newspapers and journals and sector market research reports by specialist houses are in this category. Two axis graphs, with succinct commentaries, are extensively used to present this information in broad-sheet newspapers and business magazines. The widespread use of this practice enters a caveat against the adoption of more sophisticated methods such as 3D graphs for presenting information to decision-makers.

1.4.3 Information deficiencies

1.4.3.1 Typical deficiencies

dated. These deficiencies militate against using mathematical modelling as an investigative method.

1.4.3.2 Causes of the deficiencies

Shortage of staff, because they are expensive, defective procedures, inadequate facilities and inappropriate systems are the principal causes. (Hill & Rockley 1990, Powell 1997) A different [information]'system' is developed at the end of this thesis.

1.4.3.3 Consequences of the deficiencies

Management is handicapped by lack of information when attempting to deal with inter-dependent, 'chaotic', financial issues.

1.4.4 Optimum small manufacturing business information specification

Although written as a statement of the learning needs of growth orientated entrepreneurs, Sexton et al make a significant contribution towards specifying optimum information needs. (Sexton et al 1997)

The following specification results from the opposites of the shortcomings, at 1.4.3.1 above, and Sexton et al's positive statement

Information should be:-

- Contemporary,
- Comprehensive,
- Comprehensible,
- Co-ordinated,
- Compressed,
If this specification is met, the problems of information agedness, incompleteness, lack of co-ordination, incomprehensibility, leaking, availability to peripheral decision-makers before owner/managers, cost, comparability and credibility will be overcome.

1.4.5 Uses of financial information

Control, of the immediate situation, through decisions, is one of the principal uses of factual financial information. The temporal framework, within which control is exercised, flexes in response to the trading situation of a business. In difficult trading situations the temporal framework unit is the working day. It extends to the working week in favourable situations, unencumbered by liquidity resource and capacity problems.

Diagnosis of causes and escape from crises is the predominant use of financial information in critical situations, sometimes pejoratively referred to as chaos. Its use changes to optimisation, or maximisation of financial advantage, in favourable situations.

In the medium and long term, planning and budget preparation are also
1.5 The small manufacturing business as a system

In the chaotic literature, systems are described in a number of different ways. It is necessary to consider whether any of the descriptors are relevant to small manufacturing businesses.

The majority of systems bear some resemblance to small businesses, to the sub-systems within them (departments and sections), and also to the larger trading and economic systems of which they are a part.

Systems are described as discrete, open (conservative, dissipative), autonomous, non-autonomous, feedback, feed forward and complex.

1.5.1 Descriptors of Systems

Dynamical systems fall into two categories – continuous and discrete. (Lauterbach 1996) Fig C2, Types of Continuous Systems, shows the basic types of system to which reference is made below.

1.5.1.1 Discrete

‘Discrete’ fits in only two ways. Incorporated small businesses have a beginning and an end as is attested by records at Companies House. For limited companies, the date of incorporation is effectively the beginning and the exit date the end. Dissolution, voluntary or compulsory liquidation, dis-incorporation, merger and take-over are the main exit routes.

Beginning and ending dates for sole traders are not public property.
because they are held on file by the Inspectorate of Taxes.

There is great diversity in the time elapsing between the beginning and end, the exit, in small manufacturing businesses. At the one extreme are enterprises which do not survive beyond their first year. At the other are established family businesses in which, for example, members of the fifth generation are the current core decision-makers.

Secondly 'discrete' also fits, in the context of manufacturing orders, whether on a produce-to-order, or a produce-to-stock, basis. Every order has an inception date and a completion date. Whilst in progress, each order is a miniature discrete system with a financial core around which are gathered manufacturing resources.
(a) Conservative.

(b) Dissipative

(c) Feedback (simple)

(d) Feedback (complex)

NB Feedback (complex) shows only 3 of many financial variables. Trajectories 1 and 3 feed forward before feeding back.
'Open' is loosely applicable although there are difficulties with the terms 'conservative' and 'dissipative' when attempting to fit precise definitions. (Pickover 1995) ‘Open for business’ a popular expression, signifies the openness of small business systems over time. After start-up, inputs take the form of sales orders and receipts of money. But there are constraints on the openness. Some orders are declined because a business does have resources to fulfil them. Other orders are declined because a risk-averse vendor has doubts about the credit worthiness or motives of a would-be purchaser.

However their raison d'être is to accumulate and amplify, multiply, financial energy, not merely conserve its initial levels. Profit making or capital growth are the accountancy terms for amplification and multiplication. Accumulation of assets is equivalent to potential or latent energy, as defined scientifically. Possession of assets, financial, human and physical, gives the power to generate income. A business with a large unencumbered cash surplus has the energy to do more than one strapped for cash. Kinetic energy is analogous to positive cash flow. The analogy is invalidated when comparing scientific energy, which is only positive, to negative cash flow when financial outputs exceed inputs.

A healthy cash flow, one with frequent inputs, gives positive energy to
Creditors do not doubt the ability of business to discharge its liabilities and customers place their trust in its ability to supply. The opposite situation occurs when cash flow is erratic and the momentum is sluggish.

Conservation of energy, as defined scientifically, is the reverse of what happens when bodies [business resources] interact mutually. Because, when manufacturing resources interact profitably, potential financial energy is increased but decreased when the interaction is a loss-making one. Fig C2, Conservative, shows perfect balance between inputs — equal in time phase and equal in value.

Dissipation occurs in small businesses when unsecured bad debts are not paid, investors lose investments and a business is contracting. Fig C2, Dissipative, shows a business running down.

1.5.1.3 Autonomous and Non-autonomous

The behaviour of independent-of-time autonomous systems (Pickover 1995) does not equate to businesses because references to time are ubiquitous. Payments, and payment terms, are based on time, similarly deliveries of goods and services as are borrowing facilities. Even if time is disregarded and ‘autonomous’ taken in its usual organisation sense, it remains an unsuitable adjective. Autonomy is in business is bounded (Stacey 1992) because it is linked to bargaining strengths in the marketplace for orders and for resources.
Moreover businesses, small, medium and large interact with one another so there are degrees of autonomy. Without interaction there would be no trade. The business with a cash surplus has more autonomy than one which is heavily indebted to its bank, and other creditors. The boundaries of a business enjoying a cash surplus are further away and less constraining than those of debtors. A business with a single customer is vulnerable, subordinate and, therefore, has no autonomy. On the other hand a business with many small customers has a higher degree of autonomy.

'Non autonomous' is a better fit for small manufacturing businesses because time and trading relationship constraints are taken into account.

1.5.1.4 Feedback

Interaction is part of the feedback. Businesses are recognised in the chaotic literature as non-linear feedback systems. (Sterman 1989)

'What happened yesterday affects what happens today and that affects what happens tomorrow'. 'Every performance indicator is inter-connected with every other in some way and they are all subject to time lags, unlike autonomous systems. (Stacey 1992) This observation is valid both within businesses and external to them.

Two examples illustrate this feedback. Yesterday's absence of a uniquely skilled employee jeopardises a delivery promise made in good faith because zero absenteeism was assumed. External to the business, delays in clearance of imports by HM Customs & Excise
dislocate to-morrow’s factory load plans. Both examples have cash flow implications.

Endogenous feedback is information within a business, a closed loop. Management information is its usual description. It is subject to the problems mentioned in the Review. However when the feedback is prompt and precise, expenditure on plant, premises and personnel is liable to increase immediately prior to the end of a successful financial year so as to reduce the burden of corporation tax.

Exogenous feedback occurs because firms are members of trading networks comprising customers and suppliers. (Halinen & Tornroos 1998) Formal feedback is subject to delay because companies are allowed time to prepare and file annual accounts. Variable delay is also a feature of informal feedback via the grapevine.

Fig C2, Feedback (simple), illustrates the complexity of feedback. A one dimension, single variable, loop (eg cash balance) comprises 4 merging trajectories. Movement in a downward direction resembles disbursements, upwards receipts. Trajectory 1 shows slow decline merging into modest increase as direction of movement changes from slowly down to slowly up. Trajectory 2 shows growth, positive feedback, being overtaken by sharp decline, negative feedback, as it merges into Trajectory 3. Trajectory 4 continues to decline, a slower rate, before the onset of recovery.
Fig C2, Feedback (complex), shows three inter-linked variables. Variable 2 and 3 start after 1. Diagrams of this kind are of little use as a co-ordinated financial tool because they are too cluttered. Variable 1 could be cash balance, variable 2, liabilities and variable 3, receivables. Without liabilities for production materials, no income is generated to lead to receivables. Without cash, no financial resources are available to pay for resources not supplied on credit terms. In the section on chaology, in the Appraisal of Chaotic Postulates chapter, reference is made to knots resulting from trajectory crossovers of loops 1 and 2 together with 2 and 3.

At start-up many small manufacturing businesses are temporarily feed forward systems, without feedback. Those businesses which start with an introductory cash sum, an introduction of capital, feed it forward into actions such as asset acquisition, sales promotion and employee recruitment. Receipts from trading, hopefully soon after start-up, change them into feedback systems. Owner/managers investing redundancy payments from previous employment are typical starters of business feed forward systems.

1.5.1.5 Complex

The large number of variables affecting small manufacturing businesses is witness to the complexity of their financial decision-making scenarios. Fig C3, Small Manufacturing Business Value and Time Constrained Couplings, shows the linkages

1.5.2 Working definition of small manufacturing businesses as systems

The above descriptive critique of adjectives applicable to small manufacturing businesses gives the following composite definition, which is independent of changeable circumstances:-

Small manufacturing businesses are:-

- non-autonomous
- complex
- feedback

sub-systems operating in, and dependent on, larger systems.
Small Manufacturing Business
Value and Time Constrained Couplings (Linkages)

Money

Start-up & Continuity #

External funds

Overdraft *

Loans *

Grants

Equity

Disbursements

Personnel *

Premises *

Plant *

Materials *

Services *

Marketing

Added Value

Activation and re-activation of business

# Orders

Determinants

Firm

Stock

Work in progress

Sales deliveries

# Payments received

Exit

Taxes *

Retention

Discharge of liabilities

Investment

Owner/manager drawings

Feedback

Of

Dr & Cr

Cash Flows

* Time constrained

# Time interval between stages varies
1.6 Data on financial transactions in one small business.

The systems may be complex but the data are small in number. The synthesised data based on dates of actual transactions in CUEL Ltd for 1,792 calendar days, shows:

**Financial Transaction in One Small Business** Table C1,

<table>
<thead>
<tr>
<th>Type of transaction</th>
<th>Number</th>
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<tbody>
<tr>
<td>Disbursements irregular</td>
<td>447$</td>
</tr>
<tr>
<td>periodic</td>
<td>101#</td>
</tr>
<tr>
<td>Receipts irregular</td>
<td>203</td>
</tr>
<tr>
<td>periodic</td>
<td>0</td>
</tr>
</tbody>
</table>

# Periodic payments $ - often paid in advance or deposit needed

**Monthly** wages, salaries to employees, NHI (National Health Insurance) and PAYE (Pay As You Earn) to the Collector of Taxes rates to the local authority (10 monthly payments $) hire purchase and leasing of assets $ [usually monthly] (Telecon Lombard Business Finance/Hill 1997)

**Quarterly** payments for utilities (gas, water, electricity), rent, bank charges.

**Annual** payment for insurances $ (Hill & Rockley 1990)

The Royline Account Master, designed by a bank able to analyse the current accounts of its small business customers, presumably including some manufacturers, confirms, by implication, the paucity of their transactions. (Business Start-ups Royal 1997) The top limit is only 50 payments per month.
2. FINANCIAL DECISION-MAKING

Financial decision-making, the second branch feeding into the main chaos artery, is divided into two parts. The first part deals with 'financial', the second with 'decision-making'. Financial decision-making is closely allied to information. As decision quality is adversely affected by information deficiencies, this thesis investigates whether chaos provides ways of overcoming or at least of ameliorating them.

2.1 Definition of 'financial'

'Finance' refers to the pecuniary resources of a business. (Hill & Rockley 1990) 'All decisions within a business organisation have a financial context. (Starr 1972) Consequently all decisions made in small manufacturing businesses are ultimately financial. They operate on the variables shown in the schedule to (D) Small Manufacturing Business Financial Appraisal and also display feedback. There are three groups:-

2.1.1 Directly financial decisions

The first group comprises decisions concerned with buying, selling, borrowing and lending (ie investing short or long term). Some of the decisions are so commonplace as to be routine eg purchasing production materials. Others, such as those concerned with fixed assets, have a much higher profile eg rates of pay, payment systems and salaries.

2.1.2 Quasi financial decisions

The second are quasi financial. They embrace topics such as factory loading. Initially the measurement of these decisions is hours, space or
numbers of artefacts. They are sooner or later translated into values of money.

2.1.3 Qualitatively Induced Decisions with Quantitive Implications

The third group are fundamentally qualitative, and therefore difficult to quantify, because they are precipitated by shocks, dynamic changes in public relations, international politics and managerial lifestyles but have financial implications. (Day 1992, Lichtenberg & Ujihara 1989)

Typical circumstances are those in which local residents object to the working of a night shift in a neighbourhood factory, whose order book has increased, the imposition of international sanctions, with drastic, effects on export sales and imported materials, or the illness of an owner/manager. All these circumstances are potential causes of chaos, in its usually understood sense.

2.2 Definition of ‘decision-making’

The complexity of financial decision-making is reflected in the definition assembled from a number of publications in Appendix 4. Tables C2 and C3 extract and summarise words, phrases and terms common to decision-making and chaos found in Appendix 4, Definition of decision-making, and in (E) Appraisal of Chaotic Postulates chapter. The titles of Tables C2 and C3 are respectively titled: Similar Attributes, and Similar Scenarios.

Not all the items in the definition have chaos similarities. However a
sufficiently large number of chaotic synonyms remains, after omitting dissimilar items, to sustain initial expectations of plausible connections between chaos and decision-making. More detailed investigation is justified in order to ascertain whether these similarities are superficial.
### Similar Decision-making and Chaos Attributes

<table>
<thead>
<tr>
<th>Decision-making word, phrase or term</th>
<th>Chaos synonym</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a) Temporal (time-related)</strong></td>
<td></td>
</tr>
<tr>
<td>Smooth or interrupted</td>
<td>Irregular</td>
</tr>
<tr>
<td>Varying in duration</td>
<td>Transient</td>
</tr>
<tr>
<td>Uncertain [future]</td>
<td>Unpredictable</td>
</tr>
<tr>
<td>Fluid</td>
<td>Changeable</td>
</tr>
<tr>
<td>Sporadic</td>
<td>Intermittent</td>
</tr>
<tr>
<td><strong>(b) Dimensional variability</strong></td>
<td></td>
</tr>
<tr>
<td>Amplitude</td>
<td>Intensity</td>
</tr>
<tr>
<td><strong>(c) Structural</strong></td>
<td></td>
</tr>
<tr>
<td>Intricacy</td>
<td>Complexity</td>
</tr>
<tr>
<td>Decision-making word, phrase or term</td>
<td>Chaos synonym</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>(a) <strong>Milieu</strong></td>
<td></td>
</tr>
<tr>
<td>Dynamic activity</td>
<td>Dynamical system</td>
</tr>
<tr>
<td>Multiple criteria</td>
<td>Parameters</td>
</tr>
<tr>
<td>Influenced by the environment</td>
<td>Bounded</td>
</tr>
<tr>
<td>Constricted</td>
<td>&quot;</td>
</tr>
<tr>
<td>(b) <strong>Agents</strong></td>
<td></td>
</tr>
<tr>
<td>Personnel with differing attributes, styles and commitment.</td>
<td>'Real people'</td>
</tr>
<tr>
<td>(c) <strong>Mechanisms</strong></td>
<td></td>
</tr>
<tr>
<td>Stimulated by goals, opportunities and problems</td>
<td>Determinants</td>
</tr>
<tr>
<td>Chain of inter-related activities</td>
<td>Parameter interaction</td>
</tr>
<tr>
<td>Reaction</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
2.3 Financial decision-making flows

Flow is a word frequently used in business, especially cash flow, and found in chaos literature. (Ammer & Ammer 1984, Froehling et al 1981)

2.3.1 Outward flows

Spending on the factors of production (labour, materials, plant and premises), servicing of borrowings and revenue generation in the short, medium or long terms to yield an amplified feedback. The majority of payments are in £ sterling but other convertible currencies are used for some purchases.

Outward investment of surplus funds at fixed, or variables rates of interest, for fixed and variable terms so as to earn interest for feeding back into the business.

2.3.2 Inward flows

(a) Encumbered

Borrowing to provide working capital, acquisition of assets, (including buy-outs and buy-ins) seed capital, expansion and rescue. The sources are:-

Retail divisions of clearing banks.

Secondary banking sector – hire purchase, lease

Investors. Occasionally venture capitalists or business angels.

Security for encumbered borrowing:-

Asset based Personal guarantees

Business assets
Debt based. Sales invoices assigned to a factor or invoice discount house by businesses with turnover above the minimum threshold required to access the facility.

(b) Unencumbered

Capital introduced into the business by owner/managers, directors entrepreneurs, families and friends over a long time span.

Income flowing from trading activities with customers and investments.

2.4 Decision drivers

References to businesses and owner/managers being driven, pushed, pulled and led are as common in business parlance, and literature, as determinism in chaotic literature. (Dewhurst & Burns 1993)

**Determinants**, pressure and drivers are part of business vocabulary 'R & D related capabilities as determinants'. (Lefebvre et al 1998) 'Weather drives demand' [in businesses]. (Cowe & Weston 1998) 'Deterministic simulation models have aided management decision-making'. (Wagner 1975). 'Managers make decisions in response to situational pressures'. (Trevino 1986). 'Driving forces are task related or people related'. (Clackworthy 1994)

Other decision-drivers and determinants in addition to weather are:-

Market, technology and service provider drivers. (Connolly & Huckerby 1998). Information driven customer management
and data driven marketing. (Elan 1998)

In-house, endogenous drivers are present alongside exogenous ones. Several references point to their being clearly recognised ‘A business is driven by non-linear feedback mechanisms.’ (Stacey 1992)


Push factors such as unemployment, job dissatisfaction, life changes and lack of income together with pull factors such as perceptions of opportunities and the desire to be rich lead people to set up in business. (Dewhurst & Burns 1993).

Despite the fact that the drivers and determinants are individually identifiable, financial measures of performance do not always expose the factors driving the business on account of the way factors relate to one another in complex situations. (Davis & O’Donnell 1997)

Fig C4, Bipolar Analysis of Order Volume Determinants, details the sales order determinants together with their upper and lower boundaries.
### Bipolar Analysis of Order Volume Determinants Fig C4

<table>
<thead>
<tr>
<th>Factor</th>
<th>Upper boundary</th>
<th>Lower boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td>Restricted entry</td>
<td>Unrestricted free entry</td>
</tr>
<tr>
<td></td>
<td>eg monopoly</td>
<td>entry</td>
</tr>
<tr>
<td>Market structure</td>
<td>Growing</td>
<td>Contracting</td>
</tr>
<tr>
<td>Evolution velocity</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Product evolution</td>
<td>Newly introduced</td>
<td>Declining</td>
</tr>
<tr>
<td>Customers' propensity to spend</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Active competitors</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Active customers</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Service to customers</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td></td>
<td>Improving</td>
<td>Deteriorating</td>
</tr>
<tr>
<td>Vendor rating</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Quality</td>
<td>Good</td>
<td>Bad</td>
</tr>
<tr>
<td>Price</td>
<td>Improving</td>
<td>Deteriorating</td>
</tr>
<tr>
<td>Nature of product</td>
<td>Essential</td>
<td>Low</td>
</tr>
<tr>
<td>Sales promotion</td>
<td>Effective</td>
<td>Unessential</td>
</tr>
<tr>
<td>Endogenous resources</td>
<td>Extensive</td>
<td>Ineffective</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimal</td>
</tr>
</tbody>
</table>
2.5 Decision-making objectives

The desire to be rich is one driving objective. In one form, it may mean short term profit maximisation but in another, long term capital growth. The objective is frequently determined by owner/managers' personal circumstances. The debt ridden family bread-winner looks to profit maximisation in the short term, the risk averse older person, running down to retirement is content to "jog along".

Financiers, banks, venture capitalists, venture trusts and business angels expect minimum targets, [objectives] to be met but are delighted when maximised profits or capital growth exceed their expectations.

At the other extreme are those who objective is loss-making for tax reasons. In between are those who look to a middle way known as satisficing (Simon 1959); the driving is less forceful. (Satisficing militates against the use of game theory as an alternative explanation for chaos). Game theory assumes that all participants in business to try to maximise personal gain. (Coveney & Highfield 1995)

2.6 Decision-makers

Two groups of decision-makers, core and peripheral, are involved. The decision-making behaviour, of both, groups can produce chaos. (Casti 1991) possibly because there is chaos in the brain function. (Basar 1990) Both groups are the target audience for this research although core decision-makers rank first.
2.6.1 Their identity

2.6.1.1 Core decision-makers

Core decision-makers are endogenous, often owner/managers, based on a business. They have a strong influence of a firm’s evolution. (Feichtinger & Kopel 1993) Many, if not all the employees in small manufacturing businesses participate in some decision-making processes. However there is often a decision-making hierarchy.

In many small businesses the principal decision-maker is an individual. S/he may be the owner/manager, chair/managing director or CEO (Chief Executive Officer) In other businesses, a small group makes important decisions. The small group may be members of the governing family or a management buyout or buy-in team of directors.

Fig C5, Inter-linked Constraints on Financial Decision-making, shows how exogenous and endogenous boundaries constrain core decision-makers. Constraint features in bounded chaotic systems. Decision-makers have to work within a series of fluctuating, interconnected boundaries. For example exogenous economic boundaries ‘A’ on the diagram, feed forward, through money supply and cost mechanisms, to form first endogenous boundaries on financial liquidity and then secondly constraints on personnel availability and ability. The other exogenous feed forward boundaries
For the sake of clarity lines are not drawn between all linked items.
The links make a series of chains all of which affect liquidity eg:
Money supply + cost of money → liquidity → personnel availability
ability, cost → markets → personnel
plant → premises → materials → markets → profits
are technological, political, sociological and environmental. They too generate primary and secondary boundaries but at a macro economic level not within the compass of this thesis.

Fig C5 Inter-linked Constraints on Financial Decision-making, also shows that liquidity is a focal point for other endogenous constraints, besides finance and personnel. Plant, premises, and materials feed back to liquidity. The line A,B,C,D,E illustrates this feedback.

As feedback varies in time and quantity, the constraints and boundaries are not rigid but fluctuate. For example low revenue flow, trading losses and late payments tighten all boundaries connected to the primary one of liquidity. Boundaries and constraints are eased by the reverse of the above. Late payments in cash strapped businesses cause chaos, of the conventional variety, in the feedback.

High quality information regarding these value and time fluctuations is highly desirable for good decision-making.

The office of principal decision-maker(s) is a human centre around which all business activities are concentrated. The majority of these businesses lack the advantage of expert personnel. (Lybaert 1998) Routine decisions are taken at lower levels in the decision-making hierarchy by functional executives who follow rules eg on logistics.
Peripheral decision-makers, are exogenous, external to the business. These are customers, suppliers and financiers. Their decisions impact on a core decision-makers' territory. All three are able to over-ride core decision-makers. For example powerful customers amend order quantities, placed on small manufacturers, at any stage in a production process or sequence. The chaotic attributes of unpredictability, intermittency, changeability and transience are apposite descriptors. Their actions impact on core decision-makers' boundaries.

Decisions about premium time and short-time working are effectively determined, off-site, by them. They enforce their trading terms insofar as their terms prevail taking precedence over whatever appears on a small manufacturing business' quotation or sales invoice. The practice whereby large corporations delay payments to small businesses has been extensively reported in the business media.

Suppliers likewise enforce their terms by with-holding further supplies, or declining to supply goods and services, unless payment accompanies orders.

If borrowing and investment rates are varied, financiers do not consult the small business before changing the rates. The applicable period for borrowing on overdraft is, de facto, at the bank's discretion. Overdrafts are called in and security realised when repayment is not
forthcoming. The bank's assessment of lending risk prevails.

Secondary banks repossess assets if the small business fails to comply with their repayment terms. Their decisions stake-out, determine, a core decision-maker's territory.

### 2.6.2 Capabilities of Decision-makers

Great diversity is the feature of decision-makers' capabilities.

'Humans are allegedly poor and unsystematic decision-makers'. (Taylor 1982) 'Most decision-makers lack the capacity or confidence for complicated information processing'. (Brunsson 1990) while those who possess greater expertise have greater facility in handling complex decision-making task environments. (Enis 1986)

In general [potentially chaotic] variations exist in the velocity with which they adapt to changes. (Currie & Kubin 1997, Bourgeois & Eisenhardt 1987)

### 3. CONCLUSIONS

3.1 Human involvement, an acknowledged cause of chaos, is a dominant feature in the complex, deterministic processes of small business financial decision-making.

3.2 Variability is a key characteristic both of the decision-makers and the scenarios in which they operate.

3.3 The financial information with which they operate is defective because it is inaccessible, incomplete, misleading, backward-looking, fragmented and
dated. It contributes to the chaos caused by the actions of human agents who, in the absence of good information, are compelled to rely on intuition when making decisions.
Overview of Chapter

This chapter begins the main appraisal and comparison of small manufacturing business financial dynamics in a chaotic context.

Intricate linkages are discernible in the 8 groups comprising 77 small manufacturing business financial variables in the Schedule in Appendix 3. The groups are:

1. Personnel
2. Premises
3. Production materials
4. Production processes
5. Plant
6. Products manufactured
7. Markets and marketing
8. Financial flows and structures.

Variation is shown in parameters (resource and opportunity constraints) and flows within parameters.

Financial flow variables fluctuate over differing time scales, are inter-connected, collectively interactive, within businesses, and also at interfaces with wider trading networks. Moreover priorities change. They provide evidence of chaos, as conventionally perceived. Variables, subject to less frequent changes, constitute fluctuating parameters or boundaries.

The cumulative effect of this fluid intricacy is that it does not augur well for harnessing benefits of chaos to small manufacturing businesses.

The chapter concludes that a great deal of incompatibility exists between chaos and small manufacturing business finance. Nevertheless there are sufficient similarities to justify further investigation.
This chapter provides an explanatory framework for comparing and appraising chaos in small manufacturing business dynamic scenarios. The framework is so multi-faceted as to be formidable in individual detail and collective diversity. The framework comprises:

- Multiple, inter-dependent financial variables.
- Quantification and measurement of variables.
- Causes of variation.
- Effects of variation.
- Specification for a financial management technique.
- Obstacles impeding matching of chaos theory and business.
- Meanings of initial conditions.

It is evident in this chapter that juxtaposing small manufacturing businesses and chaos produces a few points of contact but also a number of mismatches, some of which, such as initial conditions, are major hindrances.

The study of small manufacturing businesses, mentioned in the Review, is the starting point for this chapter.

Some interpretative references to conventional chaos are made so as to maintain the focus of the thesis and prepare for its detailed appraisal of technical, as well as conventional, chaos in the next chapter.

Consultancy field work and owner/management, in small manufacturing businesses between 1970 and 1993 was used to identify, the variables and their
characteristics as in an inter-dependent *value system*. (Oxford English Dictionary)

1 **Multiple, Inter-dependent financial variables**

There are many inter-dependent endogenous and exogenous dynamic financial value and associated time variables relating to human and physical resources, (all of which are ultimately financial) structures and trading, more in number than those encountered in papers dealing with scientific chaos. Appendix 3 contains 77 variables in 8 groups. These variables are of two kinds.

- Flexible parameters bounding flow variables.
  - Available human, physical and financial resource limits
  - Income generating opportunities
- Flow variables associated with frequent business inputs and outputs.

Fig D1, Flexible Parameters and Variable Flows, illustrates the two types of variables. Appendix 3 paragraph 9 gives examples of parameter flexibility.

**Flexible parameters and variable flows**

Flexible parameter eg factory capacity analogous to pipeline changing inside "diameter" so as to increase or restrict flow. Capacity key: ______ after increase ......... after decrease

\[\text{Flow} \leftrightarrow \text{eg sales revenue between financial parameters.}\]

\[\text{top limit after increase} \]
The connections between flow variables and parameters form a complex network of collection and distribution channels for the forward and reverse flows of cash, the common denominator joining all other variables in the Schedule value and temporal variables, Appendix 3.

Analogies relating to pipelines, water supply catchment and distribution are only partly useful for visualisation. Unlike the walls of water pipes, parameters change their capacity to carry flows.

Networks only able to collect and distribute whatever variable is flowing eg cash, but also chaotic flows. Moreover the existence of networks enables chaos in one variable flow to be distributed throughout a business. Cash flow chaos in a well-understood source of chaos which afflicts a whole business. Owner/managers with a manufacturing background are well aware of chaos caused by machine breakdown.

Flow variables, and parameters, cannot realistically be ranked in order of importance because priorities change with circumstances, sometimes from day to day. Parameters, such as a bank borrowing facility, another type of variable, change less frequently than flow variables such as a bank balances.

A second reason for an inability to rank variables in order of importance is that a business is a *gestalt*, the whole is more than the sum of the parts. (Forrester 1961) All the variables in the Schedule have a symbiotic dependence on one another. (Skarda & Freeman 1987)
2. Quantification and measurement

Value and time are the two variable quantities relevant to financial information. In basic chaos terminology financial variables are two dimensional. (Glenn & Littler 1994) Other more sophisticated chaos dimensions entered in the Glossary are considered in the next chapter.

Changes are stepped, although some steps are so small as to appear smooth as in Figs E4 and 5. Acquisition of a new machine, or resignation of a key employee, are typical stepped changes in resource availability parameters.

Continuously compounded interest appears to produce a smooth curve although, in actual fact, day-to-day changes are very small steps.

2.1 Value

2.2.1 Parameters

Business top and bottom limits apply to human, financial and physical resources. They are synonymous with chaos parameters insofar as they stake out its phase space. This changes as parameters change. Of the resources of a business, to which limits apply, human, social, physical, organisational and financial; the latter is most easily quantified and knowable. (Greene & Brown 1997) However when it is known, information is not always in written form and up-to-date. Owner/managers often economise on financial administration costs by memorising rather than recording information.

Collision between a parameter, and a flow variable, is a potential source of
chaos. For example inadequate factory loads cause chaos with overhead recovery budgeting as do excess loads on demands for working capital.

Parameters differ from chaotic parameters on the other hand because they are not universal laws, in a scientific sense such as those relating for example to expansion, contraction, heat transfer and electrical resistance. Factory capacity is a local parameter, changing when plant availability and personnel resources to operate it increase or decrease. Inability to obtain value and time, for all variables adversely, affects techniques, such as those evaluated in the section on Chaology, for identifying and measuring chaos. Paragraph E3.2 below refers.

Small manufacturing businesses, with efficient information procedures may be unable to quantify all parameters precisely but a few flow variables at, shortly before, or soon after, a point in time are known. This is true of relatively fast moving written accounts such as payroll, purchase and sales ledgers, together with the cash book.

2.1.2 Flow variables

Flows of variables such as cash, sales and production range upwards from zero to a difficult-to-quantity, parameter-bounded upper limit, which interferes with their flow. Flow may be either forward or reverse. Positive cash flow is forward, defective manufacture in need of either rectification or replacement is negative flow. This equates
to oscillation, an attribute of chaos.

2.2 Time elements

Value is not the only dimension for variables. All have a time element which is describable in terms of frequency of movements, or time intervals, before and after events. In some respects the familiar term flow is a misnomer because there are interrupts attributable to:

- shortage of inputs,
- shortages of resources,
- congestion, excess demand for a resource.

These are not smooth Brownian motion fluid flows such as those modelling chaos with Navier Stokes equations. (Morris R 1992)

References to time are common in manufacturing businesses of all sizes. Lead times intervene between commencement and completion. Delivery time, cycle times, delay and advance are other time-based terms in common use. Waiting time, another commonly used, albeit an undesirable one, indicates that flows are interrupted.

The properties of time variables are not constant as in chaos theory. Sometimes delivery times are good approximations accepted by consenting customers. At other times they harden into zero tolerance rigid limits when delivery after a specified date is unacceptable to a customer.

Appendix 1, columns 3 and 5 show that regular frequency, another time
element, applies only to some periodic disbursements. Although regularity is the opposite of chaos, the interaction of regular disbursements with irregular ones (column 2) is actually a potential source of chaos because payment, in full on due dates, is a statutory obligation, a value and time limit which cannot be ignored. If tests for chaos are to be made, they should not be applied to columns 3 and 5 but to 6 and 7 which record deficits and surpluses for all inward and outward flows of cash.

In basic chaos terminology individual financial variables and parameters are two dimensional. (Glenn & Littler 1994) Other more sophisticated chaos dimensions are in the Glossary and (E) Appraisal of Chaotic Postulates.

The definition of phase space, a term often encountered in chaos literature, in the Glossary allows the adjectival term, spatio-temporal found in chaos literature, to be translated into value-temporal in this thesis. ‘The set of all possible states [parameters] of a system’, (Frank & Stengos 1988) is neither exclusive to physical and life science systems, which feature prominently in chaotic literature, nor to their associated spatio(or value)-temporal (time) data.

2.3 Quantification difficulties

The facility with which the value and time co-ordinates of cash are quantifiable does not apply to all financial data. Consequently difficulties in quantifying are considered below because they adversely
affect the possible transfer of chaos theory and chaology to small manufacturing businesses.

3. Causes of variation

As chaos is deterministic, typical prime causes of variability, such interaction with other variables, are stated alongside them in the schedule in Appendix 3. (Hsieh 1991) (E) Appraisal of Chaotic Postulates deals with interaction as a cause of chaos. (Paragraph E1.4.2.3).

4 Effects of variation

Change generates change. Parameters and variables do not change in isolation. When circumstances change, changeability is an attribute of chaos, the ranking order of importance of the variables changes within the cash centred feedback infrastructure of a business. For example, in dire circumstances liquidity is of critical importance, not in isolation from, but in the context of liabilities and receivables and their due dates. ‘Cash is king’ advocates, in stressing the pre-eminence of cash, need to recognise that their slogan requires modifying so that it becomes ‘Cash in its Context is King.’

However in favourable trading circumstances, a combination of human, physical and financial resource availability considerations relaxes attention on cash as the critical factor. The bounds constraining decision-making relax so that strategic decisions may be contemplated as well as tactical ones concerned with extrication from chaotic crises. This relaxation of a
parameter, is linked to the amplification and/or diminution of flows, as value is added or subtracted. Profitability is positive amplification, (inputs < outputs) loss-making negative (outputs < inputs). An example is borrowing facilities curtailed by low sales revenue throughputs.

4.1 Responses to changes

Besides variations in degrees of relaxation, or tightening, of parameters, there are others responses to changes. Value and time are both involved. Responding to one change is similar to chaos caused by single point perturbation. Change at one data point has knock-on effects on others because consequential proactive and reactive decisions are made in response to, or in anticipation of, problems, goals and opportunities.

Fig D2, Imported exogenous chaos, shows how chaos is either transmitted, wholly or partially absorbed. For example in adverse financial, cash-starved circumstances, the usual four stage pattern is to reduce expenditure on "soft targets" followed by "harder" targets such as curtailing human resources and changing logistical arrangements then finally making changes to fixed assets, land, premises and plant. Cancellation of overtime, short-time, voluntary and compulsory redundancy are terms heard in connection with reducing human resources, together with leaseback for releasing capital tied up in premises and expensive plant.

In favourable financial circumstances the pattern is surprisingly similar but in reverse. Small sums of surplus cash are quickly spent on modest
International chaos

↓

Small manufacturing business

↑

National chaos

1. Total absorption → No onward transmission

2. Partial damping
   or

3. Onward transmission

Employees

Customers

Suppliers
advertising followed by the acquisition of human resources. Response time to the welcome changes in financial circumstances is proportional to money available and forecasts of future prospects for obtaining resources together with market opportunities.

Variability is found in the amplitudes of changes and timing but also in the response rate. Human involvement in tactical and strategic decision-making contributes to differing amplitude and time responses to changes. First is the lag before any change. Some act quickly on impulse. Others think long and hard.

Then there are variations as to the number of response stages. Some choose to make one major change, others respond in several stages.

4.2 Factors influencing responses

A substantial proportion of the factors which influence responses to change are either unknown and, moreover, unknowable: -

- International and national economic policies.
- Circumstances prevailing in individual firms, when changes occur.
- Contractual arrangements, and longstanding relationships, between vendors and customers in different tiers of supply chains.
- Characteristics of industrial sector(s) of which vendors and suppliers are members.

5. Financial management information technique specification

Faced with such fluid, multi-faceted diversity, a stringent specification for
an information package must cope with:-

- Many differences in times and values
- Large numbers of interacting variables and parameters within the 8 groups in the schedule. (Appendix 3).
- Unknown and unknowable factors, external to businesses.

This large scale and widespread diversity also has adverse implications for dynamic modelling, (Cheng & Van De Ven 1996) as well as chaotic consequences. (Shaffer 1991)

The connection between change and modelling is recognised in management literature. ‘A good financial model needs to be flexible enough to be expanded quickly to meet changing requirements’. (Hopes 1998, Freeman 1991) However, if the financial information requirements of small manufacturing businesses are to be satisfied, that brief specification needs expanding into a specification capable of modelling and presenting co-ordinated, comprehensive, contemporary, comprehensible (ie accessible) information. The technique proposed in (G), A Financial Information Technique for Small Manufacturing Businesses, aims to provide information with those properties.
6. Obstacles impeding matching of chaos theory and business

6.1 Multiple variable inter-dependence

Relationships between variables are more complex than mathematically pairing of dependent variables. The variable quantity of human resources depends not only on liquidity, forward order book value and local availability of labour, with requisite skills, but also on the characteristics of markets supplied and individual customer policies especially decision-maker behaviour.

6.2 Human involvement

In the section on core and peripheral decision-makers in the Review, reference is made to inconsistencies in their actions and the absence of decision-making norms. Real people cause chaos. (Mosekilde et al 1991)

6.3 Place in logistic chains

The response of third tier manufacturers, at the beginning of the supply chain, has a different time phase from that of those in the first and second tiers. Contractual obligations and differences in lead times are two of the reasons for the difference, a damping effect challenging the chaotic butterfly concept.

6.4 Multiplicity of variables and parameter instability

The number of endogenous and exogenous variables, with financial
decision-making implications, is undoubtedly large. The view that these organisations should be seen as complete systems made up of complex inter-related parts is apposite. (Jackson 1991) The parameters bounding the variables are also themselves subject to instability. (Lux 1998)

The number of variables typically exceeds the number in scientific experiments. (McCarthy 1998) Unlike other factors that does not present an insurmountable obstacle to transferring chaos theory to small manufacturing business financial scenarios.

6.5 Quantification problems

6.5.1 Individual variables

Moreover some of the variables are inconvenient to measure in practice. For example work-in progress quantification, for annual accounts, extends over several days even in businesses where records are in good order. Fig D3, shows five groups of variable boundary parameters.

6.5.2 Forecasting and estimating

Complexity arises from the multifarious ways in which the variables react with one another, feedback and generate different activity patterns. (Forrester 1961, Cohen & Grossberg 1987) Many have direct financial couplings. If chaos theory teaches that trajectories generated by chaotic maps are potentially perfectly predictable, provided that one can measure the state perfectly, it means prediction is highly unlikely because some variables are exceedingly difficult to measure.
Small Manufacturing Business Variable Boundaries Fig D3

* Includes European, National and Local Governments and their agencies.

---

**Own resources**
- personnel, plant, premises, funds, liquidity

---

**Customers**
- Orders placed
- Financial arrangements & behaviour
- Profitability

---

**Suppliers**
- Credit terms
- Standard of service
- Quality
- Prices

---

**Financiers**
- Amount & duration of borrowing
- Facilities
- Secondary banks
- (lease & hire purchase)

---

**Government Bodies**
- Management of the economy
- Social, employment & environmental legislation
- Purchases & budgets
6.5.3 Quasi-financial variables

In the case of some variables, an intermediate conversion process is necessary before any dependence of the variables can be given a financial base. For example, manufacturing process times require conversion to money.

7. Meaning of initial conditions: a major obstacle

As they feature so prominently in chaos literature, a separate section is devoted to their explanation and interpretation. (Ford 1986, Yang & Brorsen 1993) Inability to specify them exactly is a major stumbling block standing in the way of transferring any benefits of technical chaos to small manufacturing business financial scenarios. ‘Predictions of chaotic systems are very sensitive to the exact conditions at the outset of the period’. (Gray 1992)

They differ within the life-cycle of businesses, small, medium and large as well as in what they include, or exclude.

7.1 Starter businesses

Businesses which begin by manufacturing in garages, under railway arches, in local authority starter and development nursery units, sometimes in response to incentive grants, are in this category. Often they possess more difficult-to-quantify “sweat equity” than measurable financial resources.

The sources, feeding forward, and allocation, of capital initially introduced
varies extensively. Not all starter businesses are under-funded in their seed stage. A privileged few attract venture capital. One venture capital provider prepared to consider small businesses, Industrial Technology Securities Ltd, lists seed and start-up stages with a minimum investment of £150k. (British Venture Capital Directory 1992/3) Recent changes point to a lowering of minimum investment. (Midland Business Update 1998) Although the percentage varies successful applications for funding are reported as only 5% of applicants.

A related issue is what to include in initial conditions. Should all the 77 variables in Appendix 3 be included because they are all potential sources of chaos? If not, what is to be excluded because priorities change and ranking of financial variables is inappropriate because it is intrinsically unstable.

7.2 Mature businesses

Many mature businesses are proud to show the date of commencing trading on their literature. An unusual example of the futility of using initial conditions, even if ascertainable, as a datum was provided by an engineering business in (C) Review. It began making a range of small forges in the late 1700s and had done so without interruption at the time of the field work used as input to this thesis.

7.3 Business transfers and acquisitions

These introduce the additional problem whether one set of start-up initial
conditions is replaceable by a subsequent set because transfer and acquisition change business scenarios. Initial conditions in this setting differ from the first ones when say an entrepreneur began trading at the age of 20 and retired at 65. New owners often introduce changes extending beyond changes in ownership of equity. Banking arrangements, customer and supplier bases change, new products are introduced while others are discontinued. A new generation of decision-makers takes over responsibility.

7.4 Management buy-outs and buy-ins

Management buy-outs resemble acquisition. Often they are former subsidiaries re-engineered, or re-focused, holding companies divesting themselves of businesses which no longer fit their profile. Their initial conditions often include considerable fixed asset, an extensive customer base, manufacturing know-how, skilled and loyal personnel, financial loan, overdraft facilities and equity packages.

7.5 Revamped existing businesses

These are businesses with “a new lease of life” They step from one stage of their evolution to another, from start-up to expansion and growth, alternatively from profitability to rescue, down-sizing and contraction. New initial conditions are associated with embarking on landmark changes in the life of businesses. These differ from gradual, imperceptible changes in parameters.
7.6 **Interim datum point problem**

Although initial conditions vary they all have a starting point. In addition to event based ones in the preceding sections are arbitrary ones such as accounting periods. These show more inter-firm variability. Some business prepare monthly, quarterly or half yearly management accounts. Of these monthly ones have no consistency. Some businesses use thirteen 4 week periods, others 12 calendar months. Others prepare only statutory accounts. These accounts do not correlate the 77 variables in Appendix 3. They consolidate them, eventually. Agedness is a persistent problem with management accounts which is addressed by the technique in chapter (G), A Financial Information Technique for Small Manufacturing Businesses.

8 **Conclusions**

The result of these quantification and measurement difficulties is to undermine confidence in measurements of chaos as meaningful financial decision-making information tools. However contiguity with chaotic attributes shows that chaos is not totally remote small manufacturing businesses.

Further investigation, from a chaos standpoint, is justified in order to ascertain whether substantive benefits, such those now enjoyed in control engineering are realisable or, on the other hand, whether alternative theories are more apposite. Theories in economic textbooks, such as market
behaviour, demand, supply, market price, price dynamics, competition, productivity, accelerator investment, exchange rates, National income, Income and Employment, Monetary theory and the theory of International trade are "competitors" to chaos. (Lipsey 1975, Maunder et al 1991)
APPRAISAL OF THE CHAOTIC POSTULATES

The appraisal of these postulates moves the investigation forward from conventional, colloquial chaos into the technical arena. The chaotic element is the main artery of this investigation into its relevance to small manufacturing business financial information and decision-making.

Without an understanding of chaos, chaos theory and chaology, it is impossible to assess their relevance to financial decision-making in small manufacturing businesses. Chaology, although part of chaos theory, is considered separately in order to prevent the section on chaos theory becoming unmanageably long. For the same reason, detail supporting the appraisal of chaos, a condition, is assigned to Appendix 5, Chaos: Appraisal addenda.

Additional justification for that appendix derives this investigation being one of few into small manufacturing business financial dynamics. It therefore needs to be placed on record for use by other researchers especially because it finds that chaos has negligible relevance. However its main contribution is a small input to the development of a chaos-inspired technique supporting financial decision-making.

As considerable amounts of explanation, and elucidation are required, for meaningful investigation of chaos, overviews begin each section so as to lead into detailed investigation.

The manner in which the postulates are dispersed throughout the literature,
sometimes associated with chaos, at other times with chaos theory, bears out Morrison's opinion, cited in chapter (B) that chaos has no methodology to call its own. References to Appendix 1, Synthesised and Random Cash Flow Data, provide illustrations of these three chaotic elements.

Despite these difficulties there are benefits.

*The conclusions at the end of this chapter, identify these benefits.*

- A catalyst, a perception of chaos and attribute diagrams contributing to the development of a novel technique, for small manufacturing business financial decision-making information.
- Insights into small manufacturing business financial dynamics.
- A detailed assessment showing that three chaos elements have minimal relevance to small manufacturing business financial dynamics. as well as some incompatibilities.
1 CHAOS

Section and Appendix 5 Overview

Definitions

Chaos is a condition.

*Inadequacy of chaos definitions* Substitute working definition

Chaos in a small manufacturing business is bounded instability

Perceptions

Contradictory perceptions – beneficial, neutral, adverse

*Chaos is to be avoided and overcome where resources are scarce.*

Types of chaos

Deterministic          Random

*Chaos is deterministic although it looks random*

Onset of chaos

<table>
<thead>
<tr>
<th>Sources</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditions for onset</td>
<td>Evolution depends on initial conditions</td>
</tr>
</tbody>
</table>

*Chaos is caused by internal and external decision-makers perturbing one or more financial variables which then interact with other variables*

Manifestations of chaos

<table>
<thead>
<tr>
<th>Business situations</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>In small manufacturing businesses dynamic fluctuating feedback systems</td>
<td></td>
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</tbody>
</table>

Attributes of chaos (chaotic phenomena)

Non-linearity, irregularity, intermittency, unpredictability, transience, changeability, random appearance disguising underlying determinism.

*Small manufacturing businesses already exhibit all these attributes either simultaneously or at different times*

Componentry of chaos

Trajectories, Orbits, Fractals, Bifurcations, Attractors

*These have negligible relevance.*

Continuous time and value graphs show single variable trajectories.

*When several variables are aligned they are plotted as closed orbits, as in phase space deconstruction. Although inessential for its development, the chaological technique, for deconstructing clusters of trajectories and orbits, triggers chain of thought leading to a novel technique.*
Attractors, although prominent in chaos literature, are only occasionally components of business chaos because feedback systems, which predominate in small manufacturing businesses, never stabilise. Only when attractors are components is there a possibility that one of their associated components, bifurcations, fits small manufacturing business scenarios.
Chaos Section and Appendix 5 Overview, summarizes sub-divisions of chaos related to the thesis findings. Table E1, Chaos: Small Manufacturing Business Summary of Relevance, shows different categories of relevance.

- **Primary relevance to financial information technique** (Bold underlined)
- **Relevance to related topics eg randomness and system types** (Bold italic)
- Negligible relevance

The subject of chaos is extensive and diffuse so Appendix 5, Chaos: Appraisal addenda, is allocated to detailed appraisal of definitions, perceptions, types of chaos, its manifestations, attributes and componentry.

Appraisal finds chaos to be a condition:-

- Beset by ambiguous, subjective, often contradictory definitions.
- Associated with conflicting perceptions.
- Deterministic, not random.
- Caused by human agents, real people with conflicting allegiances.
- Possessing qualitative attributes, and phenomena, similar to small manufacturing businesses.
- Lacking componentry strongly relevant to small manufacturing business.

Appraisal of chaos provides two inputs to the novel financial information technique. First the foreboding perception of chaos translates into ‘chaos line’ templates against which actual data are compared. Secondly the attributes of
<table>
<thead>
<tr>
<th>Appendix 5 Paragraph</th>
<th>Heading</th>
<th>Relevance findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Definitions of chaos</td>
<td>Ambiguous</td>
</tr>
<tr>
<td>1.2</td>
<td>Perceptions: Foreboding</td>
<td>Compatible perception</td>
</tr>
<tr>
<td></td>
<td></td>
<td>incorporated in technique</td>
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<td></td>
<td></td>
<td>templates in (G) below</td>
</tr>
<tr>
<td></td>
<td>Beneficial</td>
<td>Irrelevant</td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
<td>Irrelevant</td>
</tr>
<tr>
<td>1.3</td>
<td>Types of chaos: deterministic</td>
<td>Business is not random</td>
</tr>
<tr>
<td>1.4</td>
<td>Onset</td>
<td>Some causal relevance</td>
</tr>
<tr>
<td>1.5</td>
<td>Manifestation in systems:</td>
<td>Business dynamics are not permanently</td>
</tr>
<tr>
<td></td>
<td>Feedback</td>
<td>associated with any system</td>
</tr>
<tr>
<td></td>
<td>Feed forward</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dissipative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conservative</td>
<td></td>
</tr>
<tr>
<td>1.6</td>
<td>Attributes</td>
<td>Relevant as a descriptor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and provider of shapes for</td>
</tr>
<tr>
<td></td>
<td></td>
<td>novel information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>technique in (G) below</td>
</tr>
<tr>
<td>1.7</td>
<td>Componentry</td>
<td>Not relevant</td>
</tr>
</tbody>
</table>
small manufacturing businesses provide shapes by which the imminence, presence and intensity of unwanted chaos may be diagnosed in actual data. They also illustrate the complexity of scenarios about which owner/managers require good information so as to make good financial decisions.

In the final analysis, chaos is caused by various human agents whose actions converge on owner/managers. They aim to avoid, eliminate or control chaos because it is perceived as harmful. To fulfil this aim it must be possible for owner/managers to have good information. Key questions are:-

- What is chaos – what to avoid, eliminate and/or control?
- Where is it found – where does it show itself usefully?
- What are its characteristics, harmful and harmless effects?
- What are its causes – prevention of chaos is better than its cure?

1.1 Working definition

Evaluating its relevance to financial decision-making in small manufacturing businesses necessitates the formulation of a working definition based on answers to these key questions. The Glossary shows that there are no readymade definitions, while confusion is a feature of definitions in chaos literature.

The following working definition of chaos is based on detailed appraisal in Appendix 5, Chaos: Appraisal addenda. Chaos is defined as:-

A dynamic condition (Chernikov et al 1988, Cambel 1993) in the high dimension [complex] category,
usually perceived as a state of confusion
[to be avoided] (Nee Gieringer 1989)
found in non-autonomous systems [such as businesses] (Skowronski 1990)
caused by amplification of minute, single point perturbations (Geisel & Nierwelberg 1982), by real people (Mosekilde 1991)
and/or interaction with, coupled endogenous and exogenous parameters

1.2 Critique of working definition
The definition suffers from a number of weaknesses. The absence of absolutes is one weakness. Without absolutes it is neither possible to distinguish objectively between chaotic and non-chaotic conditions nor to measure their intensity so as to reduce, or preferably eliminate the subjectivity which bedevils conflicting interpretations of the same financial information. This subjectivity leads to confrontation between core and peripheral decision-makers. A related weakness is that, being qualitative,
and therefore without a datum, the definition is capable of being applied subjectively. With the exception of the reference to measuring trajectories, the definition does no more than use chaos terminology to provide language to summarize the contents of (D), the preceding chapter, Appraisal of Small Manufacturing Business Financial Postulates chapter.
2 CHAOS THEORY

Section overview

Definitions

Chaos theory is a generic term comprising parts of theories relating to complexity, dynamic systems, phenomena, componentry and analysis theories in a network as well as a free-standing theory

Related theories

Theories related to chaos:-
- Chaotic phenomena
- Componentry of chaos
- Onset of chaos
- Analysis of chaos

Other theories have as much relevance to small manufacturing business financial information as chaos theory.

Uses of chaos theory

- Control of instrumentation and human organs
- Modelling for artificial intelligence
- Problem-solving in systems
- Underlying process detection in operations management

The last item empathises with the beneficial outcome of the thesis.

Limitations of chaos theory

It is incapable of capturing all wide range of dynamics encountered in small manufacturing businesses

Judgements on Chaos Theory

1) Adaptability, dynamic systems, complexity and non-linear dynamics theories, also correspond to financial decision-making scenarios and they do not suffer from the pejorative overtones of the word 'chaos'.

2) A gulf exists between theory and practice
'Chaos theory' has considerably fewer entries in the literature than 'chaos', the condition, which is considered in the preceding section of this chapter and its appendix. As there are fewer entries in the literature, a separate appendix is not justified because the danger of the thesis theme becoming lost in a mass of detail, as in the case of chaos, is less of a problem. However the need to contribute to knowledge through comprehensive investigation and appraisal needs to be honoured. A second reason for allocating more pages, in the main body of the thesis, to chaos theory than to chaos, is justified because its use has led to successful applications.

Unfortunately the principal finding on chaos theory in this, an investigation focused on a real life application, is a largely negative one. Its limitations make it incapable of a capturing all the wide range of dynamics encountered in small manufacturing businesses. (Paragraph E2.4)

Other findings about chaos theory, one of several alternative theories, caution against over-rating its importance in connection with financial management topics. For example, the majority of the items in Table E2, Chaos theory: Small manufacturing business summary of relevance, show minimal relevance.

However before investigating chaos theory in greater detail a definition of theory, in general is a necessary starting point. A condition, such as
chaos, is a state whereas a theory addresses principles concerned with a certain concept and the facts postulated about it. (James 1992)

**Chaos theory:**

Small manufacturing business summary of relevance

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Heading</th>
<th>Relevance findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Definitions</td>
<td>Ambiguous</td>
</tr>
<tr>
<td>2.2</td>
<td>Related theories</td>
<td>Minimal relevance</td>
</tr>
<tr>
<td>2.3</td>
<td>Uses: control</td>
<td>Some relevance</td>
</tr>
<tr>
<td>2.4</td>
<td>Limitations</td>
<td>Indicate little relevance</td>
</tr>
</tbody>
</table>

If 'Chaos theory is based on a dynamical system', (Crownover 1995) it engages with small manufacturing businesses because they are dynamical systems. However one potential drawback, obstructing its relevance to improving financial information for decision-making, a current need of owner/managers is its early stage of development. (Polkinghorne 1994)

In the literature, chaos theory is both a theory in its own right and also part of a network of theories into which its individual identity is subsumed. The relationship between chaos and these other theories is established in a number of ways. Table E3, Theories linked with chaos, shows how link ups with 11 other theories are effected through opinions expressed in literature, common attributes, explanations of the onset of chaos, its analysis and control.
### Theories linked with chaos

<table>
<thead>
<tr>
<th>Related theory</th>
<th>Link</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>Explicit opinion</td>
<td>Mihata 1997</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eve 1997</td>
</tr>
<tr>
<td>Systems</td>
<td>&quot; &quot; &quot;</td>
<td>Jayanthi &amp; Sinha 1998</td>
</tr>
<tr>
<td>Complex feedback systems</td>
<td>&quot; &quot; &quot;</td>
<td>Stacey 1992</td>
</tr>
<tr>
<td>Non linear</td>
<td>Attribute</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Determinism</td>
<td></td>
</tr>
<tr>
<td>Quantum</td>
<td>Uncertainty</td>
<td>Polkinghorne 1994</td>
</tr>
<tr>
<td></td>
<td>Unpredictability</td>
<td>Boothroyd 1997</td>
</tr>
<tr>
<td>Adaptability</td>
<td>Uncertain</td>
<td></td>
</tr>
<tr>
<td></td>
<td>environment</td>
<td>Conrad 1986</td>
</tr>
<tr>
<td>Perturbation</td>
<td>Onset of chaos</td>
<td>Gutzwiller 1992</td>
</tr>
<tr>
<td>Critical phenomena</td>
<td>&quot; &quot; &quot;</td>
<td>Kadanoff 1983</td>
</tr>
<tr>
<td>Dynamic systems</td>
<td>Componentry</td>
<td></td>
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<tr>
<td></td>
<td>Attractors *</td>
<td>Hunt 1996</td>
</tr>
<tr>
<td></td>
<td>Fractals *</td>
<td>Crownover 1995</td>
</tr>
<tr>
<td>Ergodic</td>
<td>Analysis of chaos</td>
<td></td>
</tr>
<tr>
<td>Qualitative theory of ordinary</td>
<td>&quot; &quot; &quot;</td>
<td></td>
</tr>
<tr>
<td>differential equations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed oscillator</td>
<td>Control of chaos</td>
<td>Unattributed 1997</td>
</tr>
</tbody>
</table>

*A rare chaos component in small manufacturing businesses*

Investigation of these as individual theories, which together comprise the network, leads to the conclusion that few of them are relevant to small manufacturing business financial information. Fig E1, Chaos theories
network, shows the network outline based on thesis appraisal headings.

Appraisal of these theories takes place in subsequent paragraphs.

Chaos theories network

The issue of whether chaos is the lead theory or a subordinate one in the network is immaterial for the purposes of this thesis.

The applications in which chaos theory has shown itself to be useful are specific control engineering applications such as coiled spring
 manufacture and lasers together with share price movements on stock markets. These applications are alien to the mindset of the majority of owner/managers who manufacture neither springs nor lasers and who hold no securities quoted on stock exchanges, although many company articles of association permit holding stocks and shares by businesses, as well as owner/managers in a personal capacity.

On the positive side, 'systems' is a word often heard in manufacturing circles, irrespective of sector. There is broad-based empathy between small manufacturing businesses and systems dynamic theory but not in every respect. Paragraphs below indicate that this empathy disappears when detailed definitions are related to small manufacturing business financial dynamics. Additional limitations on the inability of dynamic systems theory to compete with chaos in small manufacturing business financial systems on account of its attractors associations, are considered below.

Not all theories cited in chaos literature appear in Fig E1, Chaos theories network. Theories relating to turbulence are not regarded as part of that network because their properties do not qualify them for inclusion. For example the onset of turbulence differs significantly from that of chaos. 'A system becomes turbulent through a succession of instabilities', (Feigenbaum 1993) conflicts with the causes of chaos, perturbation and interaction, and mentions only one of a number of attributes of chaos.

The other group of theories not included in the network are the
unequivocally mathematical ones viz theories of functions, analytic numbers, bifurcations whose relevance extends to several theories, chaos being only one of them.

Nor are decision and financial theory on Fig E1 because they are major subjects in their own right. Their inclusion would divert attention away the mainstream of this investigation, chaos theory.

Some of the more esoteric mathematical theories are also subjects in their own right. Those treating functions, analytic numbers, bifurcations, sets, primes, knots and braids for example are mentioned because some writers make a connection between them and chaos theory. Riemann's zeta function theory is mentioned in chaos literature although it has yet to be proved or disproved. Even if relevant, it will not begin to gain acceptability by owner/managers until it is proven. For the sake of clarity the definitions of these theories and associated terms are in the Glossary, not the main body of the thesis.

Theories related to chaos on Fig E1, Chaos theories network, are useful pointers in that they address its phenomena, dynamics, componentry, onset and environment in more detail than the general ones.

Chaos theory itself shows a lack of consensus similar to that associated with definitions of chaos is a feature of chaos theory definitions examples of which are in the Glossary.
Now that a working definition of ‘business chaos’, albeit an imperfect one, has been assembled, a comparable one of chaos theory is added.

2.1 Definitions of chaos theory

Several definitions of ‘theory’ appear in the standard English, scientific and technical dictionaries. All have limitations. There are also several definitions of chaos theory in the literature appraised at this point in the thesis. Definitions for ‘chaos theory’, in economics, mathematics and sociology, are in the Glossary. That for sociology is the best fit for small manufacturing business financial dynamics.

2.1.1 Limitations of available definitions

Considering the limitations of the definitions of chaos, and related theories, narrows the field of possibilities leading to a working definition for this thesis.

Some definitions are linked to their mathematical, scientific and technical uses. Definitions in the dictionaries are better suited to settled, formalised situations, and those which can be experimentally observed, than to those, such as chaos theory, at an earlier stage of their evolution, without a distinct identity. (Polkinghorne 1994).

References to principles, (James) systematic statements, (Oxford English Dictionary 4c) explanations, (Chambers) schemes, systems (OED 4a) and facts, (OED 4b) are premature when a theory is still evolving.
Mathematical definitions relating chaos theory to 'small changes in initial conditions' cannot be related to information about small manufacturing business financial dynamics because initial conditions are so diverse. (James R C 1992)

Besides terms such as 'initial conditions' undermining the transfer of chaos theory to small manufacturing business financial information dynamics, individual words also exemplify its irrelevance. References to periodicity (bifurcation theory – a chaotic component on Fig E1) do not fit the irregular cash disbursements in Appendix 1 column 4.

'Functions' (analytical number theory and differential equations – analysis) is also a stumbling block to transfer from science or mathematics to small manufacturing business finance because individual pairings of financial variables cannot be identified exactly. Personnel, premises, plant, logistics and finance are functions of one another. They are also subject to shifting priorities. In tight labour markets personnel are in pole position but premises, plant and logistics displace personnel when finance is tight.

An additional problem, in assigning numerical values to functional relationships, is that of valuing plant and premises, fixed assets. Circumstances exert a major influence here because valuation lacks the exactitude of functional relationships in mathematics. Book values,
after depreciation, by whichever uses the two alternative methods, may not be the same as market values. When expanding a business, trading-in well-maintained machines as part exchange for state of the art equipment usually reveals a welcome difference between written-down book and trade in values. On the other hand retrenchment, and disposing of whatever is saleable, or can be leased back, tends to depress prices of capital equipment whether the sale is private or via a second user merchant or finance house. Buoyancy of the economy and the condition of machines, when offered for sale are factors affecting values, irrespective of whether a business is expanding or contracting.

Another definition of chaos theory, an economics one, has only limited relevance to the majority of small manufacturing business financial dynamics scenarios, not because it involves an unrealisable need for assigning numerical values but because it erroneously links quantification with randomness. The scope of the definition in question encompasses companies, small, medium and large, whose shares are traded on the stock exchange. (Rutherford 1992)

Quantification [pricing] of small manufacturing business shares listed on the AIM (Alternative Investment Market] is determined by people, market makers, fund managers for institutional investors and to a lesser extent by small investors. Movements of shares prices are not random.
They reflect assessments made by these people of the performance and prospects of investee companies. However the definition includes a word universally applicable to chaos theory, whatever its context. The word is ‘analysis’; it harks back to the interpreted requirement for financial information in the specification in the Review.

In view of these limitations, a conglomerate working definition is selectively assembled from entries in these dictionaries, and from the above working definition of chaos. If research into chaos continues at its present rate, eventual amendment of the working definition is to be expected.

2.1.2 Relevant definitions

The most relevant definition of chaos theory in the literature relates to sociology, (Turner 1997) because it is not tied to initial conditions, or advanced stages of development, but includes the key words, ‘dynamic’ ‘movement’ and ‘change’. These words also describe small manufacturing business financial scenarios.

2.1.3 Working definition of chaos theory

The growing body of explanatory knowledge, based on original reasoning and analogy, purporting to explain the complex, dynamic nature, intensity and onset of chaos, as well as its manifestation, attributes and phenomena, in the financial decision-making of small manufacturing businesses in a feedback system setting.
2.2 Theories related to chaos theory

The names of these theories, complexity, non-linearity, adaptability, critical phenomena and perturbation, mirror small manufacturing business financial decision-making situations. Although their names do not suggest it, quantum and ergodic theory also touch business situations; quantum theory, because it takes account of two business attributes, uncertainty and unpredictability, ergodic theory because it could offer a means of measuring chaos objectively were data available. Paragraphs E2.2.1.6 above & E3.2.1.1 below refer.

*Complexity and systems theory* address wider issues than theories dealing with individual attributes [non-linearity] responsive behaviour [adaptability], mechanisms [perturbation], componentry [trajectories], and analysis [differential equations].

A number of these related theories are relevant to more than one topic

Systems theory is concerned not only with the wider issue of systems, whole entities, but also at detail level with attractors, a chaos theory component, not normally found in small manufacturing feedback systems.

2.2.1 Complexity of chaotic phenomena

2.2.1.1 Complexity theory makes a connection between chaos and complexity because chaotic phenomena, attributes, are collectively complex, (Francois 1997) but a lack of consensus regarding
definitions and perceptions appears again; this time in connection, not with chaos, but complexity and chaos theories.

'Chaos theory is separate but overlaps complexity theory', (Mihata 1997 conflicts with 'Complexity theory is an alternative to chaos', (Eve 1997), a partisan opinion. The latter does not recognise the complimentarity of the two theories so Mihata's opinion about overlapping theories is preferable.

Comments, made in discussion with academic peers, corroborate the overlap between the two theories inasmuch as interest in complexity is ascending while that in chaos static but not yet in decline.

Conversation, (Carpenter/Hill May 1998) refers.

The ascendancy of complexity over chaos does not however mean that chaos theory can have no relevance to financial decision-making in small manufacturing businesses although the mathematical accoutrements, and associations, of both theories interfere with their relevance to small manufacturing business financial information.

Access by owner/managers is inhibited as a result of these accoutrements and associations.

2.2.1.2 The theory of non-linear dynamics is said to prove that deterministic systems, of which there are several in small manufacturing businesses, can in, varying degrees, mimic true randomness. (Ford 1983)

Time and value data in Appendix 1, Synthetic Cash Flow Data,
do not support it. Random amounts, inward receipts and outward payments, and the delays between them, differ greatly from synthesised data. Significance testing of the synthesised data for the whole period, as opposed to daily movements in separate columns, also fails to support mimicking of randomness. The appearance may be haphazard, a way in which 'random' is colloquially understood, but it is not random in scientific sense in this instance.

2.2.1.3 Quantum theory, of which there are several major branches in physical sciences, accords with chaos theory, in small manufacturing businesses insofar as both feature unpredictability and uncertainty. (Boothroyd 1997, Polkinghorne 1994)

At basic level, contiguity exists between quanta and small manufacturing business finance because both deal with accumulations of small particles. In business particles are not photons, or other physical particles, but accumulations of the smallest units of trading currencies such as pence and £ sterling, cents and $, centimes, ripolis and francs. However complexity theory is said to place quantum theory in jeopardy, (Ford 1986, Francois 1997) because it is concerned with patterns not particles.

In prosperous times, owner/managers are primarily concerned with complex patterns involved in matching human, physical and financial
resources to demands on them. In those circumstances complexity theory is apposite. However in lean times owner/managers look in detail at pennies as they pare expenses. Concepts of quantum theory displace complexity.

2.2.1.4 Adaptability theory deals with the ability of a [biological] system to continue to function in the face of uncertainty and an unknown environment. (Conrad 1986) Complexity and non-linear theory begin with phenomena, quantum theory with inanimate ingredients, but adaptability starts with living organisms. The situation is not far removed from that of owner/managers who similarly adapt to an environment which cannot be completely known. Paring expenses is an example of adaptation to changed circumstances.

A contemporary example, of adaptability in practice, is the 4,900% surge in demand for omelette pans manufactured for the past 40 years by Lune Valley Metal Products Ltd, Morecambe. The surge resulted from a complimentary remark made on TV by Delia Smith in November 1998. This small manufacturer adapted to the surge by recruiting 150 temporary employees. Subsequent reporting in the press sustained the surge in demand.

As adaptability takes different forms an unresolved problem is how different parts of a system react given the constraints that are present. (Conrad 1986) Differing responses by personnel in
small manufacturing businesses epitomise different forms of adapting to chaos in differing circumstances. At a time of falling order books sales personnel adapt by seeking to fill unused factory capacity whereas their production counterparts reduce the capacity and align it with current order book values.

In times of high activity sales managers adapt by slackening promotional activity but production managers drive hard for increased output, as at Lune Valley Metal Products Ltd.

2.2.1.5 Perturbation theory, another theory linked with chaos, also has a name indicating identification with small manufacturing business financial scenarios. They are familiar with perturbation associated with various events. On the positive side are events, such as unusual influxes of sales orders, which strain their resources. Negative perturbations are large-scale cancellations of orders, major machine breakdowns, withdrawals of financial support together with long term sickness and resignations of key employees. However perturbation is not relevant to providing co-ordinated financial information for decision-making because it deals with single points not patterns. 'It is incapable of deducing [subsequent] patterns of chaotic behaviour'. (Morrison 1991) Unpredictability is an attribute of chaos. (Paragraph J1.6.4) Owner/managers are able to recognise the single point but their ability to assimilate consequential patterns makes much greater demands on
their limited time and thinly spread cognitive powers.

A further difficulty is its association of perturbation theory with solutions to partial and ordinary differential equations which are considered in the next section of this chapter. (Paragraph E3.1.1 below)

'Chaotic phenomena [plural] necessitate a change in emphasis away from perturbation, (Thompson & Bishop 1994) rightly focuses on the phenomena not the perturbation'. Owner/managers can empathise with phenomena because they constitute their working scenarios. Chaos theory is said, by a leading chaologist, to be outside the range of perturbation theory although single point perturbation is one of its causes. (Gutzwiller 1992) If that opinion is valid it removes perturbation theory from the network of related theories. The justification for its retention, despite its deficiencies, is that it makes owner/managers vigilant because they must always be on the look-out for perturbation. Surges and shortages both perturb businesses.

2.2.1.6 The ergodic theory of chaos provides quantities such as Lyapunov Exponents. (Le Berre 1986) They are considered in the next section of this chapter in connection with techniques for measuring chaos. (Paragraph E3.2.1.1 below)

2.2.1.7 The relationship between systems theory and chaos theory provides another example of the lack of consensus, on this occasion without any
reference to complexity theory. ‘Chaos theory is a sub set of systems theory’, (Jayanthi & Sinha 1998) does not rule out the chaos-complexity overlap. (Paragraph E2.2.1.1 above) ‘System’ has an advantage - being more acceptable to owner/managers than ‘chaos’. The word is already part of the structural vocabulary of manufacturers and not hindered by the pejorative associations of ‘chaos’ in its traditional meaning. It is also recognised than individual businesses are systems within larger trading systems.

Unfortunately it has a major drawback making its relevance to small manufacturing business financial dynamics episodic. It has associations with attractors, a chaotic component only found in businesses when they become dissipative. (Paragraph J1.5.2.2 & J1.7.3)

2.2.2 Componentry of chaos theory

Chaos components are attractors, fractals, trajectories and orbits

2.2.2.1 The limited relevance of attractors to chaos has already been considered in J1.7.3 above. That limitation precludes dynamic systems theory as being relevant because that theory includes attractors, a chaotic component of dissipative, but not all systems relevant to small manufacturing businesses. (Froehling et al 1981, Hunt 1996)

Moreover it has been observed that the results of dynamic systems theory are a fine structure, comprising a number of components, which
is difficult to reconcile with observed economic behaviour. (Kelsey 1988)

Therefore only at a broad conceptual level does dynamic systems theory appear to be relevant because small manufacturing businesses are dynamic systems and they evolve in time. (Devaney 1986)

Eventually dynamical systems theory may become indirectly relevant if ideas in connection with trading systems, of which small manufacturing businesses are a part, are shown to be valid. 'Little effort had gone into extending the ideas of dynamical systems theory to high dimensional, spatially extended trading systems', (Gundlach & Rand 1993) summarises the current situation.

In addition, to current difficulties of reconciling theory and practice, to which this attests, is the connection between randomness and dynamic systems theory made without any reference to determinism, a characteristic of chaos. (Tabor 1989)

Other unnamed theories have recently purported to explain why strange attractors appear as the forcing amplitude increases. (Jordan & Smith 1987) These theories have marginal relevance because large scale indebtedness not infrequently precipitates businesses into dissipation and decline. As well as undermining the relevance of dynamical systems and these other theories, it does the same for
bifurcation theory and ergodic theory. They also are associated with the chaotic component, strange attractors. (Falconer 1985)

2.2.2.2 Fractal theory is, as it name suggests, associated with fractals. (Crowiiovcr 1995) Fractals are not a component of small manufacturing business financial dynamics because generating profit, input value amplification, not fractal self-similarity, is a characteristic and time a permanent parameter. Fractals take no account of time which, together with value, is the second dimension of all small manufacturing business financial variables.

2.2.2.3 Bifurcation, another chaotic component with a major associated theory treats splitting as a parameter is changed. In chaos literature time, although absent from fractals, is often the one used to illustrate bifurcation as a parameter is changed. Fig E2 (a) is a typical illustration of a bifurcation associated the period doubling route to chaos. Note the smooth curves.

A typical bifurcation

![Bifurcation Diagram](image)

Small manufacturing business financial dynamics are much less tidy than textbook illustrations of symmetrical bifurcations although the concept of responding to parameter change is essentially tactical.
decision-making.

Time periodicity applies only to a small number of disbursements in Appendix 1; the periods do not double or change. Nor does taking steps to shed excess factory loads follow tidy bifurcation patterns. These steps are taken to escape from chaos, the opposite of period doubling and bifurcation routes to chaos. When factory load exceeds capacity the usual objective is to honour delivery dates by using overtime and shift working as supplements or sub contracting if the overtime + shift working option is not available. The inflexible time parameter, delivery to customer, must remain unchanged. Steps such as those are shown diagrammatically in Fig E2(b), Effect of increasing capacity, show that real world manufacturing variables are asymmetric bifurcations.

Introducing overtime and shift working in one’s own plant is one bifurcation, using one sub contractor gives two, “trifurcation”. If more than sub- contractor were used there would be yet another branch. An additional cause of untidiness is that the usual works management problems of employee absence cause dips in the straight line trajectories both in one’s own and sub-contractors’ plants.
Although Fig E2(b) shows an empirically based bifurcation, and "trifurcation", arrangement; it does no more than communicate to owner/managers what they already know. More important is knowing the consequences of authorising premium time working and sub-contracting on cash flow and working capital requirements. Without that information, factory overload chaos generates consequential cash flow and working capital chaos - in the ordinary meanings of the word.

2.2.3 Onset of chaos

The theory of critical phenomena has been associated with the difficult task of identifying what triggers the onset of chaos, (Kadanoff 1983) in
connection with turbulence in condensed matter physics. The features of the behaviour are said, unlike feedback systems, to be independent of a system’s make-up. The particular theory is difficult to transfer to small manufacturing business financial dynamics because it deals with triggers, not underlying causes, which are dependent on a system’s make-up; they are inter-dependent.

Identification of an ultimate trigger is well rehearsed but it does not probe deeply enough. Shortage of working capital may be the ultimate trigger overall cause but it results from several underlying causes as expressed by references to chicken and egg situations. First it begins as an effect of underlying causes before itself assuming the role of a feedback cause because it is really a conglomeration of contributory causes. Sudden mushrooming of sales orders, delays in making payments against irrevocable letters of credit, unforeseeable consequential bad debts because a customer’s customers default, lack of reliable suppliers for essential production materials, cancellation of orders are a few examples of underlying contributory causes accounting for the onset of working capital chaos.

This does no more than confirm existing knowledge. The theory offers nothing new to the practitioner. Owner/managers are well aware that the majority of the critical phenomena, which impact critically on their working capital, are outside their own business system.
2.2.4 Theories for the analysis of chaos

Several techniques, for the analysis of chaos, have substantial theoretical foundations not solely related to chaos theory. KAM theory (also known as a theorem), ergodic, (Paragraph E2.2.1.6) theory and the qualitative theory of ordinary differential equations have developed as disciplines in their own right. (Devaney 1986)

KAM theory is disadvantaged, in its relevance to small manufacturing business financial dynamics, because it is associated with conservative systems which do not amplify inputs by adding value. (Morris C 1992) However it fits business experience in that oscillatory motions persist when small perturbations are added to the system. Small perturbations are the minor operation hiccups which, being damped by a business, do not deflect trends eg in cash flows.

2.2.4.1 Analytic number theory has supplied concepts and techniques for the analysis of torus orbits. (Vivaldi 1987) Orbits are associated with discrete systems not open-ended, continuous time businesses for which trajectories are chaotic component relevant to small manufacturing business financial dynamics. The association of orbits with phase space reconstruction and attractors also distances analytic number theory from small because they are not found in feedback systems.
However single strands, from deconstructed phase spaces, are visually indistinguishable from closed orbits because the tracking end of the orbit maintains contact with the starting point of the orbit. Using information technology to analyse single strand orbits is the climax of this thesis.

2.2.4.2 Quantum chaos theory, a hybrid of chaos and quantum theories, is possibly linked with number theory, and with Riemann theory patterns of prime numbers, where there is no human involvement, (Boothroyd 1997) comparable to that in small manufacturing businesses. However there are some subtle and unresolved problems about the inter-relation of chaos theory and quantum theory. (Polkinghorne 1994)

2.2.4.3 Qualitative theory of ordinary differential equations, (Devaney 1986) is not considered here but in connection with other equations in the section on chaology.

2.2.5 Control of chaos

Delayed oscillator theory is yet another theory apparently relevant to the decision-making needs of owner/managers because it is reported as being a method of controlling chaos. Owner/managers aim to control exogenously caused chaos where it is perceived as threatening in two sets of circumstances. Control before the onset of chaos aims to avoid or minimise it, and after onset, if unavoidable, to minimise or eliminate it. The theory is said to control El Nino, a collection of climatic...
phenomena. (Unattributed 1997) Media reports in 1998, concerning the exceptional dislocation attributable to El Nino, however raise doubts concerning the veracity of such an ambitious claim about its control! This lack of credibility means that it does not merit further consideration as a potential antidote to chaos. The chaotic attribute, irregularity, is a more apposite descriptor than oscillation for major deviations from normal patterns. (Wheeler 1998)

In addition to its lack of credibility, there are other drawbacks. Linking two global systems, atmospheric and oceanic, does not emulate small manufacturing businesses which have linkages to many, countless systems. Another weakness is its use of partial differential equations. These are considered in the next section.

2.2.6 Complex management feedback systems theory

Chaos theory is said to be a new theory of management which builds on the discoveries of mathematicians and scientists about the chaotic and self-organising behaviour of complex feedback systems. (Stacey 1992) This theory takes a stance which accommodates two fundamental aspects of small manufacturing business dynamics — complexity of variable and parameter interaction and secondly the organising behaviour of decision-makers. It will be in a position to move forward when the small manufacturing business financial technique developed by this thesis improves the information on which self-organising behaviour is based.
2.3 The uses of chaos theory

Large parts of this section point towards chaos as being on the margins of real small manufacturing business financial dynamics while the application of delayed oscillator theory verges on incredulity. It is therefore necessary to issue a reminder that chaos theory is useful for control, modelling, problem-solving and detection of underlying processes.

2.3.1 Control

Electronic circuits, cardiac arrhythmia and lasers are among the specific uses involving flows with few dimensions [unlike the many in small manufacturing businesses]. Human interference, by businesses decision-makers, does not change these control applications involving flows of electrons, blood and photons, (Vassiliadis 1994, Pecora & Carroll 1990) as it does in financial decision-making.

2.3.2 Modelling

As a branch of artificial intelligence, chaos theory is used for financial modelling. (Chorfas 1995) No details are given so it is impossible to ascertain whether the application is successful given irrational, human involvement in finance. (Shapiro 1987)

Chaos theory is also used for simulation modelling. (Jayanthi & Sinha 1998). If simulation modelling is to attract owner/manager interest, its relevance to real life scenarios must be crystal clear given their entrenched
2.3.3 Problem-solving

Even less specific than its use in connection with artificial intelligence is the stimulus which modelling gives to problem solving such as the search for internal constraints on the ultimate predictability of a system. (Moran 1998)

However the specific opinion, that chaos theory allows us [currently] to deal with non-linear problems to which there are not explicit solutions, is premature when the theory has not yet attained maturity. (Cambel 1993, Polkinghorne 1994) If the theory is intrinsically incapable of providing the explicit solutions to financial problems, for which owner/managers search, its relevance as a decision-support tool is minimal. Owner/managers are required to find specific solutions.

2.3.4 Detection of underlying processes

Chaos theory is used for the detection of underlying processes in operations management, (Jayanthi & Sinha 1998) is one use of chaos theory with which owner/managers may empathise. Operations and management relate to their daily responsibilities. Moreover underlying processes could be of more significance, for proactive financial decision-making, than explicit ones.

2.4 Limitations of chaos theory

This thesis is not alone in recognising the limitations of chaos theory. Others writers emphasise the limitations of chaos theory mathematics
Beginning in the 1970s chaos theory provided many mathematical tools useful for the study of complexity but it did not capture the wide range of dynamics exhibited by complex systems. (Ruthen 1993) Appraisal of chaos theory postulates in this section of the thesis supports that opinion.

Chaos theory suggests that the long-range prediction of non-linear processes may be subject to the same mathematical limitations as long range weather prediction. (Weiss 1991) Limitations, common to long range weather prediction and small manufacturing business financial dynamics, are the acquisition of detailed data and information on patterns matching it. The superiority of the solar weather technique over conventional weather forecasting techniques, on which daily forecasts are based, is due to it being backed by a large library of patterns to which acquired data is related. (Nat West Innovation Business 1998)

A consequence of data acquisition limitations is ‘numbers arising from the application of available chaos theory must be viewed cautiously’. (Mpitsos 1990) The word ‘available’ is significant. It implies that chaos theory is still evolving, a process to which the new small manufacturing business financial information technique propounded in this thesis contributes.

2.5 Section Conclusions

Practical core decision-makers will find it difficult to relate to chaos theory.
- First it is in the tradition of practitioners to distrust theories.
- Secondly theory with limitations is even less likely to find acceptance.
- Thirdly chaos, and related theory, does not appear to be far enough developed for it to attract the attention of training organisations who disseminate information on up-to-date management techniques.

Adaptability, dynamic systems, complexity and non-linear dynamic systems theories have names corresponding to financial decision-making scenarios in small manufacturing businesses with which owner/managers are able to empathise in concept but they lack relevant substance.

However those pessimistic conclusions are not final because one chaological technique, found while investigating models, techniques, theorems, hypotheses and conjectures catalyses the development of a novel tool for financial decision-making information in small manufacturing businesses.
Definition

The study of chaos

Models

Mathematical

Diagrammatic

*Models are unable to cope with the full range of diverse financial variables in small manufacturing businesses*

Techniques

Quantification and measurement

Analysis

*The diagrammatic, analytical technique of phase space construction contributes to a novel financial information technique, the principal contribution to knowledge of this thesis.*

Hypotheses

Riemann

*References to infinity are inappropriate for small manufacturing businesses*

Conjecture

*There is contiguity between evolving complex systems at the edge of chaos and small manufacturing businesses*

Theorems

*Li Yorke's Period 3 is for a special case*

*Taken's theorem recognises the existence of a lot of variables, as in small manufacturing businesses, and undetected, or undetectable, underlying order*

Conclusions of the Sections on Chaos, Chaos Theory and Chaology

Substantives Ambiguities Incompatibilities Possibilities
Confirmation Foundation

*The substantives confirm what is already known to owner/managers. The possibility refers to the previously mentioned financial information technique for which chaos is relevant but not essential.*
This is the third of the three postulates, the one with a clear definition, unlike the other two. Those parts of it which deal with techniques and models are potentially relevant to an investigation whose aim is to find/develop a tool supporting owner/manager financial decision-making. The phase space deconstruction diagrammatic technique is found to be the most relevant. Investigation also finds that some conjecture and theorems accord with small manufacturing business financial scenarios.

The comparative method of appraisal, mentioned in (B) Methodology is, in this section, primarily a comparison with small business financial scenarios. In the preceding two sections, while not losing sight of small manufacturing business financial dynamics, much of the comparison focused on ways in which parts of chaos and chaos theory interface, it at all.

**Chaology:**

Small manufacturing business summary of relevance  Table E4

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Heading</th>
<th>Relevance findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Models</td>
<td>Minimal relevance</td>
</tr>
<tr>
<td>3.2</td>
<td>Techniques: analytical diagrams</td>
<td>Relevant and useful</td>
</tr>
<tr>
<td>3.3</td>
<td>Hypotheses</td>
<td>Not relevant</td>
</tr>
<tr>
<td>3.4</td>
<td>Conjecture</td>
<td>Tenuous relevance</td>
</tr>
<tr>
<td>3.5</td>
<td>Theorems: Takens</td>
<td>Some relevance</td>
</tr>
</tbody>
</table>

Table E5 is similar to those for chaos (E1) and chaos theory (E2) above.
The number of publications relating to technical chaos has escalated since the time of Poincare, one of its "fathers". Combining the working definition of chaos theory, the solution to the problem of mathematical incomprehension in Methodology and lastly the results of the critique of the other postulates, shows a lack of publications relating to the constituents of chaology relevant to financial decision-making in small manufacturing businesses.

In addition to chaos and related theory, chaology comprises models, techniques, theorems and conjectures. The majority of them have a mathematical content. Fractals, strange attractors, initial conditions, autonomous and dissipative systems feature prominently. This is unfortunate, because they have limited relevance to small manufacturing businesses. (Paragraph E2.2.2 above)

After appraisal, one of the diagrammatic techniques catalyses the processes which culminate in the improved financial decision-making information outcome at the end of the thesis.

Although this compendium of chaology appears extensive it is, in fact, limited in its scope, because chaotic behaviour cannot be analysed by either traditional mathematics [differential and difference equations], or the limitless "number crunching" of super computers, (Morrison 1991) or, in the social sciences, by traditional statistics. (Nicholson 1995).
Non availability of these analytical methods adds impetus to the propounding of a new theory which builds on a fragment of chaos theory.

Although traditional mathematics are beyond the reach of owner/managers, there remains the possibility that mathematicians may offer new forms of mathematics, with accompanying user-friendly software.

3.1 Models

Field study of small manufacturing business, and statements in chaos literature, suggest that models have minimal, if any relevance to small manufacturing financial dynamics scenarios. References to a variety of models proliferate in the chaotic life, physical and social science literature.

In practice chaotic systems are difficult model although chaos theory is said to include a wide variety of non-linear models. (Vaga 1990, Morrison 1991) The reasons given for the difficulty, in the literature, are relevant to small manufacturing business financial dynamics scenarios. ‘They have irregular cycles which may disappear for a time and then return’ Only businesses which have a sufficiently long trading history, to which owner/managers are able to refer, are in a position to assess whether any cycles of activity, regular or irregular, are discernible. Start-up businesses with no significant trading, as is the case with large proportion of registered businesses, do not have a history to which they may refer.

There is the additional difficulty of human decision-maker involvement
"Emotions make people irrational" [and difficult to model], (Shapiro 1987) leads to the conclusion that "Scientific models are inappropriate for management practice". (Hughes 1988) Humans cause chaos.

Satisfying a specification stating 'Models for managers should be simple, robust and easy to control', (Little 1970) is inappropriate because small manufacturing financial dynamic scenarios are complex, not simple. It is therefore more realistic to incorporate complexity in models but that introduces another difficulty. 'If a model is really complex it needs complex formalism [ordinary differential equations] to describe it'. (Raczynski 1996) Difficulties, encountered in attempting to formulate complexity, are considered in the next sub section. The prognosis for a successful outcome of these attempts is not encouraging. Meanwhile the model should be 'flexible enough to capture unique and multiple equilibria, hysteresis and reversibility, jumping and smooth behaviour' provides an unfulfilled specification to which all attempts at modelling for the detection and control of small manufacturing imminent and manifest chaos should aim. (Lye & Martin 1994)

The few references to models in business are not encouraging. The author of a paper, on a specific example of chaos in a bank account, writes, 'There is no sufficiently simple model available for business', (Tofallis 1995) makes an accurate observation on the current model availability situation. The opinion that 'Science research models are
inappropriate because management practice does not flow from the prior acquisition of knowledge, (Hughes 1988) is prematurely dismissive. The small manufacturing business financial information technique, constitutes a source of knowledge from which decisions flow.

In economics, a discipline with business affinities, 'economic models involving chaos are not particularly realistic', (Kelsey 1988) is another less than encouraging opinion to add to those above.

3.1.1 Mathematical models

Publications concerned with mathematical modelling provide a barrage of objections to their use in situations such as small manufacturing business financial dynamics. 'The fine structure of the chaotic regime is mathematically fascinating but is irrelevant for most practical purposes. (May 1976) Laws of the engineering variety, used for mathematical modelling, do not exist. (Burton 1994)

'Ordinary Differential Equation models may not work in complex [social] systems. (Raczynski 1996) Mathematical models are limited in having a finite number of variables and a finite arithmetical precision. (Morrison 1991) 'Mathematical proofs of chaotic behaviour are difficult, and not available for many systems of interest', (Feichtinger & Kopel 1993) are examples of objections to mathematical modelling.

The absence of laws means that, if mathematical modelling is attempted, it has to be done by applying common-sense and intuition to
devise mathematical relations that approximate reality. (Burton 1994)

Unfortunately common-sense is an imprecise term and financial decision-making in small manufacturing businesses prefers precision although approximate management accounting information is often all that is available.

These misgivings about the feasibility of mathematical modelling are a feature of the publications after 1990. Optimism is a feature of literature published before 1990.

Subsequent searching of chaos literature discovered that the optimism relates to scenarios which are not transferable to small manufacturing business financial dynamics. Optimism is expressed, in a paper on strange attractors in a multi-sector business cycle model, that it should be possible to construct a multi-sector business cycle model in which chaotic dynamics emerge. (Lorenz 1987) Business cycles undoubtedly affect small manufacturing businesses but levels of activity, which contradict business cycles, are common. Some businesses defy downturns in economic cycles and prosper. Other business lose orders on account of their inability to supply increased quantities to customers when the cycle enters an expansion stage. Customers defect to suppliers who are able to supply increased quantities of product.

'Simple mathematical systems exhibit complex patterns of behaviour that
can serve as models for chaotic behaviour' another opinion indicative of the possibility of transferring from one chaotic scenario to small manufacturing businesses, was expressed in connection with turbulent flows in hydrodynamics. (Kadanoff 1983) Although 'flow' is common to both scenarios the variables show significant differences. First there are more variables in business than hydrodynamics. Secondly friction, a variable in hydrodynamics, has no equivalent in business cash flow. Thirdly cash flow is a misnomer because it is a mixture of dynamics and statics. Appendix 1, columns 6 & 7, shows that cash balances often remain unchanged for several days. Production and material flows exhibit the same combination of dynamic and static features. Production flow charts have different symbols for dynamic movement and static storage.

Associated with the mathematical modelling of chaos are first order differential delay equations, four non-linear ordinary differential equation orders, partial differential equations and difference equations.

Mathematical equations used to model chaos are foreign to the majority of owner/managers. GCSE mathematics, which superseded 'O' level removed simple calculus, differentiation and integration, from syllabuses in 1988. 'A' level mathematics syllabuses, current in 1998, do not require candidates to solve non-linear differential equations. Moreover not all universities include difference equations, which are also mentioned in
connection with modelling chaos, in under-graduate mathematics courses. (Walton [mathematician]/Hill 16 11 98) Chaos literature supports that conversation. 'Ordinary differential equations are a discipline in their own right'. (Devaney 1986) Thus there is currently a divide between mathematical academe and the majority of owner/managers. The exception is the minority, such as engineers who use mathematics. That divide would be removed if owner/managers were taught using mathematical syllabuses including non-linear difference and differential equations. Anecdotal evidence indicates this divide does not exist in South Korea and Japan.

However opinions expressed in chaos literature indicate that such equations are remote from real life complexity such as financial decision-making information in small manufacturing businesses. 'Mathematical models built on chaotic dynamics [do not] involve the full three dimensional situation of real life'. (Casti 1989) 'Chaotic systems have no equations' rules out complex scenarios. (Thom 1987) That first order non-linear differential delay equations describe, and display, a broad diversity of dynamical behaviour, including limit cycle oscillations, appears to apply only to a single variable trajectory oscillations, not multiple interacting ones in systems, (Mackay & Glass 1977) generating patterns.

The numerous investigations of non-linear Ordinary Differential Equations,
with a few degrees of freedom, may have made strikingly clear the transition to chaos, in purely deterministic evolution models applied to physical flows, but they are less complex than financial decision-making in small manufacturing businesses. (Moon et al 1983) They do not have exact solutions required for differential problems in the sciences and engineering. (Gray et al 1997)

Another inherent weakness is that instantaneous rates of change feature in definitions. (Coveney & Highfield 1991) In small manufacturing businesses, time usually elapses, lags, before owner/managers respond to changes. They do not respond instantaneously to increases in order intake by seeking to recruit additional employees. When customers expedite delivery of products already on order, action to comply with a customer's request may be delayed until an owner/manager is convinced that the request is genuine. In effect owner/managers devise systems of response time weights which they apply to expediting requests. The weights are based on first customer history, eg "crying wolf", followed by suspension of deliveries or reduction of quantities or alternatively only expediting when urgency is real, secondly on the person making the request and thirdly on the desire to impress new customers. Requests from progress clerks have a lower weighting than those from directors. Mathematicians also recognise other limitations. "Mathematical modelling of fluctuations [an attribute of chaos] typically leads to additive
random terms eg white noise whose fluctuations are propagated through time by the rest of the system. (Stutzer 1980, Mihata 1997)

The problem of excess accuracy to which ‘If your differential equations are too accurate you end up modelling sound waves not weather’, (Stewart 1987) is unlikely to affect small manufacturing businesses.

Difficulties associated with data acquisition, model capacity and formulation together with caveats and opinions, expressed by the several authors cited above, make modelling of small business financial dynamics unlikely although that was the expectation before this investigation began in depth.

There are drawbacks in addition to those already cited. Difference equations, an alternative to differential equations, also have a drawback. Their parameters are difficult to adjust. (Morrison 1991)

Appendix 3, Schedule of value and temporal Variables, specifically refers to parameters, which need to be adjusted if they are to represent reality.

The relevance of difference equations is therefore placed in doubt because value and temporal parameters affect all resources – physical, human and financial. Fig D1, Flexible parameters and variable flows, refers.

There is also an interpretative problem ‘Simple first order deterministic difference equations may exhibit seemingly random fluctuations which might be mistakenly [be interpreted] attributed to the influence of excluded
variables or the influence of included, but assumed, random variables. (Stutzer 1980)

Financial variables in small manufacturing businesses are driven by a variety of agents but they are not random.

Definitions of difference equations show their unsuitability for small manufacturing business financial dynamic modelling because functional relationships and independent variables are part of them. (Parker S P 1989) Many of the functional relationships defy exact specification. Interdependence between variables predominates, not independence of one from another as (D) Small Manufacturing Business Financial Postulates Appraisal shows.

A further drawback of models is their limited ability to cope with complex scenarios comprising multiple, coupled, interactive variables - 'the jumble of trajectories'. (Boothroyd 1997) For example non-linear models are valuable as short term forecasters and as diagnostic tools for identifying and quantifying low dimensional chaos in time series. (Casdagli 1992) Their relevance to small manufacturing businesses is therefore limited because decision-makers must reckon not only with temporal, time series, but also with multiple value-temporal variables whose criticality shifts in accordance with prevailing circumstances. In difficult situations having sufficient cash
for the required length of time is critical. But also critical, in cash-rich prosperity, may be the financial consequences, an opportunity cost, ensuing from a frustrating scarcity of human and physical resources.

In the case of owner/managers, many of whom believe that their situations are unique, models also suffer from a lack of acceptability due to their tendency to over-simplify real life situations.

3.1.2 Diagrammatic models

These are an alternative to number crunching super-computers, traditional mathematics and statistics. Unfortunately a single diagram is unable to include all the variables affecting small manufacturing businesses.

The non-linear cobweb model, with adaptive expectations and non-linear supply and demand is relevant, if fixed assets are excluded, to the items scheduled in Appendix 3, Schedule of value and temporal variables, but on an item-by-item basis, not the whole picture at once. It illustrates that chaos may occur under simple and reasonable economic assumptions. (Hommes 1994) An ancillary problem, similar to that encountered when framing budgets and business plans, is however deciding what assumptions to make in volatile trading situations.

3.1.3 Neural net models

In a paper on finding chaos in noisy statistical systems, neural net models are said to be computationally expensive, a disadvantage,
(Nychka et al 1992) when small manufacturing businesses have few PCs on their premises. Discussion with image processing hardware, and software, suppliers suggests that much work needs to be done before neural networking becomes the first choice for processing complicated images. (Telecon Loker [Vision Dynamics]/Hill 1997) References to ‘systems’ in quotations suggest that the technique has too broad platform for owner/managers who must wrestle with variables in localised contexts.

On the other hand there are visionaries looking further into the future whose pronouncements touch complex and real world small manufacturing business scenarios. A proposed model, for neurons, has a specification involving ‘abundant spatio-temporal patterns’ with possible roles for biological information processing. (Aihara 1990) could be relevant but a future date. ‘The complex problems of the real world have much in common with neural networks’, (Maddox 1990) is an optimistic pronouncement. Small manufacturing business financial decision-makers will need to be assured that an optimistic opinion expressed about the real world, in the prestigious journal ‘Nature’, relate to their own unique real business world.

3.1.4 Emergent models

Two examples of emergent modelling illustrate the great gulf between views as to its usefulness. The first verges on the simplistic. Its basis is the calculation of a point strange attractor for stock-market prices. No
expression of the difficulties is expressed by the author. (Lewis 1997)

It claims to find outliers that no ordinary simulation would find and predict when stocks are about to become unstable. Using the small perturbations of El Nino, as a simile, adds to the feeling of incredulity because other chaologists, researching into stock-market fluctuations, report complexity, not emergent simplicity. (Hsieh 1991)

The second example rightly recognises the problem of precisely formulating the suppleness which is a characteristic of mental phenomena, (Bedau 1997) because decisions are made in businesses using the mental processes of decision-makers.

3.2 Techniques

A number of techniques have come to be closely identified with chaology. Some of the analytical techniques use diagrams to assist visualisation. These techniques are of two types — measurement and analytical. Of the two, phase space reconstruction, and deconstruction analytical techniques, appear to be especially associated with the analysis of chaotic data. Quantification and measurements techniques are widely used ones applied in chaotic scenarios.

3.2.1 Quantification and measurement techniques

The measurement of chaos ranges from simple chaos present/chaos absent through broad categories to finer, numerical measures of its intensity. The non-availability of an objective, agreed definition of chaos leads to
difficulty in assessing whether or not chaos is present. If chaos is to be avoided and controlled, owner/managers need to be directed to variables where chaos is manifest so that decisions can be taken.

The first measurement requirement is detection but, 'No one measurement establishes the absence, or presence, of chaos'. (Cambel 1993)

This means that busy core decision-making owner/managers and peripheral decision-makers, such as financiers, who need one agreed measure to confirm or deny the absence or presence of chaos still have to make do with subjective interpretations of whatever financial information is available, with or without its context.

In economics there is restrained optimism, to which this thesis subscribes, albeit in respect of small manufacturing businesses. 'The hope is that new technologies based on chaos theory will, [future tense] help in detecting low dimensional chaos'. (Brock et al 1991) The outcome of this thesis changes the word order in that quotation to read:- Chaos theory based on new technologies [image processing] will help in detecting chaos. The technology is capable of detecting both high and low dimensional chaos. The unresolved problem is whether decision-makers are able to use all that technology offers.

Brown's reference to assessment technique non-availability is less serious for owner/managers because it refers only to time. It is
combinations of two elements, time and value, which together generate chaotic situations for owner/managers. Three customers, owing £1 for a series of time periods up to 1 year, is not chaotic but one customer owing £15k which is 1 month in arrears is, especially when placed in a context of liabilities exceeding receivables. 'There is no such thing as a definitive set of procedures to analyse a chaotic time series'. (Brown 1995) He says that Fourier time frequency analysis is unreliable, because it does always give a clear indication of chaos, to back his opinion. An additional problem, identified in Appendix 5 is the absence of consensus on a definition of chaos. (Paragraph J1.8)

Time and value must be correlated if a technique is to be relevant to small manufacturing business financial scenarios using variables in Appendix 3. The following equation expresses the relationship:

\[
\text{Criticality} = \text{Duration} \times \text{Value.}
\]

where:

Values are +/- but times always + because the past cannot be recovered. High + values mean success, high negative (-) ones adversity [chaos]

Small manufacturing businesses are concerned with several time series. They are in decision-making language, polyphase (Appendix 4, Definition of decision-making). All have different so-called time series. Some of the time series are well-known such as payment procedures operated by customers and cycle times in factories.
Interaction between different customer time series, coupled with amounts of indebtedness, typically lead to chaotic cash flow situations for owner/managers when combined with sums of money remaining unpaid.

Also in the broad quantification category are the relative strengths of chaos. There are degrees of chaos. (Brown & Chua 1998) Weak chaos, one of the broad categories, is associated with intermittency, one of the qualitative attributes, (Paragraph J1.6.3) strong chaos with the transitivity mixing condition, chaos and periodicity. (Crownover 1992, p152 quoting Gulick 1992, Gutzwiller 1992)

Mixing, although it takes different forms, is the essence of owner/managers information requirements involving measurements of chaos. Value and time are mixed in each variable and parameter.

An obstacle currently standing in the way of replacing broad with finer measurements of chaos is the inability of computers to process data involving many decimal places and intrinsic system noise. (Morrison 1991, Diamond et al 1994, Isham 1992)

Developments in computers could overcome that inability in the foreseeable future but other problems remain.

Fully chaotic systems propagate error exponentially. (Ford 1983) The requirement for accurate financial information is therefore compromised. Secondly measurement error [of parameters and flow variables]
Dimensions are an integral part of measurement but the word is one of those mentioned in (B) Methodology 1.3 as having academic specific meanings of which entries in the Glossary provide examples. There are numerous and not always equivalent dimensions. (Cheng & Tong 1992) In the chaos literature the term usually has mathematical leanings, with references to Hausdorff, (Nicolis 1986) embedding, correlation, box and topological dimensions (eg Crownover 1995) and values. (Sprott & Rowlands 1995) The word 'dimension' also refers to the number of coordinates required to specify any one state in phase space. (Glenn & Littler 1994)

The use of the correlation dimension to distinguish between determinism and stochasticity [randomness] in economics is not relevant to business, (Martin & Sawyer 1994) because a business is a deterministic feedback system. (Paragraph J1.5.2.2)

The fractal dimension for attractors applies, not to business feedback systems, but to dissipative ones, (Peters 1991) providing more evidence of the incompatibility of the concept and business finance.

As the majority of owner/managers only understand 'dimension' as referring to measurements of any kind, such as value and time in this thesis, the introduction of other [mathematical] meanings could lead to
3.2.1.1 Individual Trajectory Chaos

Besides the need to detect chaos, especially if it is undesirable, is the need to quantify its intensity. (Abraham & Shaw 1988, Daido 1984) Global and local Lyapunov (Characteristic) Exponents may be one of the most frequently used finer measures of chaos, but they too are problematic. Chaos literature tells us that their calculation can be 'tricky', (Abaranel 1992) 'real world systems are generally too complicated for Lyapunov Exponents to be useful', (King 1992) and that their success in distinguishing chaos from stochasticity, is not universal. (Wolff 1992). Fig E3, Lyapunov Exponents, refers.

In view of their inability to distinguish chaos they do not provide the reliable objective demarcation, which is needed to supersede subjective interpretations of small manufacturing financial information, especially in confrontational situations such as those involving owner/managers and financiers.

An additional drawback is that notwithstanding their unreliability they have their own scale of values:-

$< 3.3 =$ no chaos, $3.4 - 6.9 =$ mild chaos $> 7 =$ acute chaos.

Having to learn another scale of values is a burden for owner/managers because they are already obliged to deal with financial values, when few of their number are trained accountants. As of now
owner/managers in the various manufacturing business must deal in a whole range of values. Feeds, speeds, limits, fits, tolerances and surface finish are examples of values which engineers need to know.

There are particular problems in relating them to small manufacturing business finance. First is the major one of quantifying initial conditions, the datum point, from which the trajectories diverge or converge, positively or negatively. ‘If management’s assessment of a certain factor [variable] is slightly false, the forecasted and effective system level will be totally different’. (Feichtinger & Kopel 1993, Brock et al 1993, Brown 1995, Gray 1992)

A second problem is that Lyapunov Exponents only average changes in “dimensions” whereas some financial decision-making, especially that involving cash, has to operate with precise information bounded by parameters. (Percival 1989, Nicolis & Tsuda 1985) Mathematically Lyapunov Exponents are ‘simply generalised eigenvalues’. (Blank 1991, Cook 1994) Generalising, and averaging over a preceding period of time, does nothing to help hard-pressed owner/managers. They must wrestle, not with averages, but with actual plummeting cash balances as Days 231, 243 and 590 in Appendix 1. For businesses reliant on external finance, be it asset or debt based borrowing, parameters are fixed for a stated period and rarely allow for occasional spikes which would breach those parameters.
Lyapunov exponents

Fig E3

Notes:
1. No chaos $LE < 3.3$
2. Mild chaos $LE 3.4 - 6.9$
3. Acute chaos $> 7$
4. Irregular time intervals between financial transactions
5. Asynchronous, out of phase, measuring points
6. Differing transaction values
A third problem is the need for a quantity of data far in excess of what a typical small manufacturing business is able to provide for their calculation. (Day 1992) Appendix I Cash inputs (receipts) and outputs (disbursements) in the Synthesised Data, for a 5 year trading period, 1,792 calendar days, show the small quantity of data available in real-life, small manufacturing businesses.

Cash movements in synthetic data

<table>
<thead>
<tr>
<th>Disbursements</th>
<th>Receipts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periodic</td>
<td>Periodic</td>
</tr>
<tr>
<td>Irregular</td>
<td>Irregular</td>
</tr>
<tr>
<td>101</td>
<td>0</td>
</tr>
<tr>
<td>447</td>
<td>203</td>
</tr>
</tbody>
</table>

The cumulative effect of these problems is to demolish the suitability of Lyapunov Exponents for measuring the intensity of financial chaos in small manufacturing businesses.

3.2.1.2 System-wide chaos

Measurements in this sub section deal not with individual and their trajectories but whole systems. Knowing that a business, a small feedback system, is chaotic is of limited value because it does not pinpoint individual source(s) of chaos for attention by owner/managers.

Entropy measures chaos in systems Its several definitions all relate to systems but they differ significantly in their detail. The amount of
information required to specify the state of a system known to be on attractor implicitly limits entropy to dissipative systems. (Parker & Chua 1989) ‘Evolving irreversibly through time’ fits business evolution because ‘the clock cannot be put back’. (Coveney & Highfield 1995) A third definition, given with reference to physics, comes closest to being useful to owner/managers. ‘Entropy is a measure of randomness and disorder of a system’. (Morris C 1992) For deterministic systems, such as small manufacturing businesses, ‘randomness’ is a misfit, although ‘disorder’ approximates to chaos. The consequence of these conflicting definitions, and the wideness of systems, results in entropy having limited relevance to owner/managers whose attention needs directing to precise source of financial problems, key variables and their immediate contexts.

3.2.2 Analytical techniques

Phase space reconstruction, and deconstruction, Poincare sectioning, wavelets, braids and Riemann prime numbers are analytical techniques mentioned in the chaotic literature. Wavelets and braid analysis are among the more recent techniques in the literature. ‘There is no such thing as a definitive set of procedures to analyse a chaotic time series’, (Brown 1995) bodes ill for analyses of chaos taking their place alongside established business ratio analytical procedures which “freeze” financial dynamics at a point in time, typically a year end.
In chaos literature, novel diagrams facilitate analysis and comprehension of figures by non-mathematicians. Construction and deconstruction of phase space, wavelets, knots and Poincare sections are described in the chaos literature.

**3.2.2.1 Phase Space Reconstruction**

This technique provides a diagrammatic overview, a plan view, of several variables based on their axes. It makes continuous time system variables, as in small business finance, appear as discrete closed loops. The clustering of trajectories and isolated outliers is portrayed. Clusters of trajectories show the zones, and points, of greatest activity, their scatter, the range. Outliers, exceptions, are the places of least, but possibly most significant, activity in bounded systems.

One drawback is the convoluted, jumble of trajectories which develop as the system evolves in time. (Coveney & Highfield 1991, Hunt 1996) Another is the inability to include all variables affecting a small manufacturing business on one diagram so the information is incomplete even if a two "eye" diagram, with three axes per eye, is used. Fig E4, Phase Space Reconstruction, has one eye or stable island.

**3.2.2.2 Phase Space Deconstruction**

This technique stimulated and inspired the novel small manufacturing
Phase space reconstruction with multiple strands  Fig E4  
(after Vidal 1988)

Notes: 1 More dispersion around A-P than X-P and Z-P  
2 Crossing strands on Z-P as with braids  
3 Clustering of strands on A-P  
4 Uneven spacing on A-P exception 4 almost parallel strands in the centre of the diagram
Several techniques are advocated with a view to making phase space reconstruction more easily comprehensible. Deconstruction, the first of them, extracts trajectories from the difficult-to-analyse jumble. (Lefranc et Glorieux 1997) For owner/managers, whose time frames are often immediate, the latest trajectory strand is pre-eminently interesting.

However if a single trajectory is to be useful, for interpreting up-to-date control information, a template eg of boundaries, parameters or the immediate past, is needed because the axes of the variables are in different planes.

A suitably shaped template, not necessarily geometrically regular, permits the recognition of any basic patterns in the relationships between variables. Patterns of shapes and/or maximum and minimum datums, in a PC's memory, provide single or combined time and templates on TV monitors. Fig E5(a), Single line from deconstructed phase space with template, combines two time and two value templates.

The close similarity between Fig E5 (b), from Lefranc et Glorieux’ chaos paper, and Fig E5 (c), from an image processing book, (Batchelor 1985) points to the possibility of using image processing technology to simplify the application of a chaological
Single line and template from deconstructed phase space E5(a)

Actual strand

Template
After Lefranc et Gloreix 1997

Note the similarity between the single strand from a deconstructed phase space and an image processing blob
After Batchelor 1985 Principles of Digital Image Processing p393

Note the similarity between the blob and a strand from a deconstructed phase space
technique to a real world financial decision-making information.

Applying phase deconstruction to small manufacturing business financial information dynamics is believed to be novel but the basic idea of using image processing technology for processing images [of data] has been advocated for another application not involving its usual applications of earth resources mapping, industrial artefacts and laboratory specimens.

Non-parametric density estimation and discrimination from images of shapes is the application. (Wright et al 1997)

Having found one analytical technique, potentially applicable to the provision of financial information for small manufacturing business decision-making, other similar techniques mentioned in chaos literature are investigated. These techniques are:-

- Poincare sections,
- Braids and knots,
- Spectral analysis,
- Wavelets,
- Existing algorithms.

If any of these are found to be suitable, their suitability must be compared with phase space deconstruction in association with image processing. On the other hand, if they are irrelevant, the development of phase space deconstruction into a technique, for the small manufacturing business financial information, becomes
the main task after investigating alternative, non-chaotic theories.

3.2.2.3 Poincare Sections

Phase space diagrams provide a plan view of dynamic activity whereas sections, Poincare in the case of chaos, cut through the phase space. Modern dynamical systems theory began with Poincare but the infusion of geometric and topological techniques has led mathematicians away from the study of dynamical systems themselves to the underlying geometric structures. (Devaney 1986) Studies of systems are of limited value, but underlying structures, for established businesses with a sufficiently extensive library of data, may find them a useful input for heuristics, assuming that history repeats itself. They co-ordinate information relating to several variables.

Poincare sections complement phase space reconstruction by sectioning the jumble of trajectories and producing a discrete mapping. (Burton 1994, Parker & Chua 1989) They have come to be associated with chaotic attractors. As a deconstructed phase space has only a single strand, Poincare sections are incompatible with that technique.

Concentration, and dispersion are easily seen. The drawback is selecting where to section an amorphous phase space. Comprehensive coverage, of an enclosed phase space, requires sections representative of changes among interacting variables. Having a large number of sections precludes compliance with the information
Poincare sections FigE6

a) All trajectories coincident
   so only one strand is identifiable
   The section is a single dot

b) Vertical outline without any infilling strands
   but with some self-similarity (symmetry)


c) Horizontal outline with some trajectory clusters
   and self-similarity

d) Widely dispersed asymmetric trajectories
   and isolated outlying trajectory
specification in (C) Review paragraph 1.4.4 unless assistance from artificial intelligence becomes available; chaos theory is said to be one of the potential applications of artificial intelligence in finance. (Chorfas 1995) Fig E6, Poincare Sections, illustrates the diversity of possible sections.

To date nobody appears to have recommended the use of templates to facilitate their analysis and interpretation.

3.2.2.4 Braids

In phase spaces, trajectories not infrequently cross when variables change. Fig C2, Feedback systems (c) simple and (d) complex, in (C) Review and Fig E4, Phase space reconstruction, refer. Braid theory, an adjunct of mathematical knot theory, has been put forward for the analysis of such crossovers in fluctuating, non-linear systems. (Pieranski & Skieltorp 1997) Trajectories may cross under, or over, one another as they approach higher and lower value-time points in phase space. Figs E7 (a) Braid cross-over and (b) Braid cross-under refer.
The ability to recognise equivalence, between crossovers [of one pair of variables and another], is a reported braid analysis technique. (Dehony 1997)

When a more developed stage is reached, it is still unlikely to provide insights into crossover patterns in phase space alongside other pattern recognition techniques. The need for large data sets, larger than those available even in long established small manufacturing businesses, essential for any study of braid points, is one caveat, The reluctance of owner/managers to release sensitive financial information, to specialist third parties, for processing is another.
On a number of occasions reference has been to differences between scientific and non-scientific uses of words. 'Spectrum' is a word the meaning of which is not the same in physical sciences as in mathematics. In this context 'spectrum' does not refer to analyses of different parts of the electro-magnetic spectrum, which is taught in schools, but to the set of all eigenvalues. (Schwartzmann 1994)

Superficially it appears to be relevant to the needs of owner/managers for financial information on which to base decisions.

The descriptive words for spectral analysis, a mathematical analysis technique, indicate kinship with small manufacturing financial dynamics. 'Perturbation', 'coupled [trading] systems', 'random appearance' and 'parametric adaptive control' [by owner/managers] are words and terms with which this appraisal of chaotic postulates finds to be comparable with business scenarios.

Spectral analysis is used, in analytic models, to assess the effect of small perturbations at any point in a coupled system. (Gutzwiller 1992)

Small manufacturing businesses are points in a coupled [trading] system. As a non-linear statistical test it uncovered, in nature, completely deterministic processes that look random. (Brock & Sayers 1988) It is the foundation of parametric adaptive control in physics, (Vassiliadis 1994) and therefore analogous to what
managers do to align actual behaviour with goals, by adapting what scientists call ‘transients’, to advance and delay activities within business boundaries. For example product manufacture is often advanced and payments to suppliers delayed, when opportunity presents itself.

Although as a modelling technique it is valid for research, owner/managers are likely to be slow to accept it because it resembles the established management technique of sensitivity analysis. Yet another drawback is that the spectrum is the set of eigenvalues, a mathematical term defined as characteristic values in the Glossary. A major problem, insuperable in practical terms, is deciding a characteristic value for financial variables in small manufacturing businesses when the range is large. In Appendix 1 receipts range from £7 (Day 121) to £22,012 (Day 517).

3.2.2.6 Wavelets

Wavelets simplify the interpretation of irregular, non-symmetric data presented in space-time form, line graphs eg Fig J19, Cash flow transaction and cash balance, without the drawbacks of Fourier Transforms (Ling 1997, Meyer 1993, Mees 1986) but they last for only a few cycles. (Ling 1997) They are more suited to discrete scenarios eg flow in electronic circuits than to the multi-financial variability of small manufacturing businesses, with each variable
having its own range of flow time scales and unlikely-to-recur amplitudes [values].

Owner/managers are concerned with to-day's problems not yesterday's bigger one which they know they survived. Wavelet analysis presents, in diagrammatic form, what they already know experientially.

A more serious deficiency is that wavelets analyse only one set of trajectories at a time and do not show interactions with trajectories representing other financial variables. It would be rash to dismiss wavelet analysis as valueless on account of these deficiencies, they could provide a confirmatory input to owner/manager heuristics, given large enough data sets.

3.2.2.7 Algorithms

'Practical Numerical Algorithms' by Parker & Chua 1989 made a significant contribution to the need for a comprehensive publication on one particular analytical technique. However difficult-to-quantify variables, in small manufacturing businesses, are one of the states which are algorithmically inaccessible. (Peres 1987)

3.3 Hypotheses

Riemann's hypothesis originated in a branch of number theory. He made connections between prime number theory and analysis. (Clapham 1996) Theoretical physicists are interested in the hypothesis that there is apparently an intimate connection between an infinite set of energy levels, in quantum chaos and prime number patterns, (Boothroyd 1997) but for
bounded feedback systems unbounded infinity is a doubtful opening premise although the hypothesis has some contiguity with business energy. Assets, negative and positive cash balances are the potential energy of a business. They are the source of energy for discharging liabilities, acquiring goods and services. Depleted potential energy leads to downsizing, accretion to expansion.

However this technique has yet to reach a stage of development at which it becomes an alternative to analytical techniques such as phase space deconstruction. Any resemblance between prime numbers in template patterns, used to analyse a group of related financial variables, and financial values, is likely to be coincidental. If it is to make inroads into management theory, attention to human activities is essential.

3.4 Conjecture

'Complex systems, that evolve, will always be near the edge of chaos, poised for that creative step into emergent novelty, (Coveney & Highfield 1995) accords with beneficial perceptions of chaos drawn from the experience of large corporations. Owner/managers, and their employees, for whom weak chaos is a daily experience and strong chaos a calamity are not so ambivalent.

3.5 Theorems

Two well-known theorems are mentioned in the chaos literature. One is relevant to small manufacturing business financial information dynamics,
the other only for some businesses in some circumstances.

Li Yorke's Period 3 Means Chaos theorem was based on the earlier one by Sarkovski. (Li Yorke 1975) Reservations are now expressed because it referred to a special case. (Ruelle 1991) 'Applied to consumer choice [a business topic] it would hold if consumption of a commodity produced a temporary satiation for two successive periods before demand dropped to its former level' [chaos]. (Heiner 1989)

In fast moving environments eg making kitchen utensils, satiation is experienced but falls in demand are linked to more than one cause and range over differing and imperfectly demarcated periods. Factors such as product obsolescence, product life, market segment (luxury or essential) and changes in consumers' disposal income all cause falling markets. They operate on differing time scales. Product obsolescence causes markets to drop slowly, unless there is a sudden appearance of a better substitute product. Warning of imminent price rises temporarily stimulates demand and leads to satiation.

A related problem of this marginally relevant theorem is what constitutes a 'period'. To accountants a month is a clearly defined temporal entity, a period, but to a sales manager near the consumer market, the period is a less precisely demarcated buying season. Unlike accounting periods, which are backward looking, selling seasons are forward looking and anticipate climatic seasons.
Taken's theorem hypothesises that although observations may behave erratically they are nevertheless generated by an underlying non-linear system unknown to the observer and may involve a lot of variables. (Grandmont & Malgrange 1986) It is relevant to this thesis on two counts. First because there are 'a lot of 'variables' and secondly because underlying patterns may be unknown to an owner/manager.
At first sight the situation is discouraging. One over-riding problem for assessing the relevance of chaos and chaos theory, as a whole, to financial decision-making, in small manufacturing businesses, is the ambiguity surrounding the meanings of the key terms as well a number of incompatibilities. The ambiguity means that no firm basis is available for making a meaningful assessment.

However that does not preclude the possibility of discovering, in such a large body of knowledge, as chaos, chaology and chaos theory, seeds for improving financial decision-making in the target businesses.

Marginally, but not centrally, relevant summarises the findings.

One spin-off of the appraisal is the clarification of the type of system descriptions which fit small manufacturing businesses.

4.1 Substantives

4.1.1 Small manufacturing businesses are connected, continuous, complex, bounded, non-linear feedback systems with an amplification mechanism, and behavioural attributes, analogous to those mentioned in the chaos literature.

4.1.2 Chaos, an ill-defined collection of phenomena, is caused by single parameter perturbation and/or interaction between variables. People are invariably involved at some point in its causation.

4.1.3 Trajectories are a two dimensional visual representation of variables. They cannot be reliably designated as chaotic or non-chaotic because
there is no agreed definition of chaos.

4.1.4 A characteristic visual representation of chaotic phenomena is a growing, entwined, outer, disorderly mass of trajectory or orbital lines enclosing usually one or two amorphous, unadulterated, chaos-free ‘eyes’ as in a Lorenz attractor. No clear-cut delineation of chaos from non chaos, based on the density and distribution of lines, size and shape of the topological ‘eyes’, in the representation is available.

4.2 Ambiguities

Reference has already been made to an inability to distinguish objectively between chaotic and non-chaotic conditions. There are other ambiguities.

4.2.1 Currently available chaological models, and analytical techniques, neither provide reliable insights into, nor relate to, small manufacturing business financial decision-making scenarios.

4.2.2 Perceptions of chaos range from beneficial, through neutral, to foreboding. There is no agreement. The foreboding one, something to be avoided, is an input to the novel technique developed in this thesis.

4.3 Incompatibilities

4.3.1 Comparing initial conditions in chaos theory, on which great emphasis is placed, with those for a small manufacturing business is the first incompatibility. Initial conditions in business take several different forms so they are unsuitable for use as a datum.

4.3.2 Strange attractors and fractals, chaotic components, are only relevant in a small minority of small manufacturing business financial scenarios.
4.3.3 Self similarity is only relevant in break-even situations.

4.3.4 Chaos in inanimate mechanisms is controllable but ubiquitous human involvement in every business situation, be it the international stage or a small manufacturing business in an inner city suburb, erects impenetrable obstacles to chaos as a controller.

4.4 Possibilities

Chaos has no role as controller but it has one as informer on no-go areas.

The greater part of the situation regarding the relevance of chaos and chaos theory to financial decision-making in small manufacturing businesses may be discouraging but it is not entirely without relevance. Although the contiguity between chaos and chaos theory, and small manufacturing business financial dynamics, is predominantly episodic the two, not situation specific, phase space techniques, when applied to information needs of owner/managers, add to management knowledge.

Phase space deconstruction, an analytical technique for finding and quantifying the couplings in a tangled mass, derived from phase space reconstruction (see 4.1.4) is capable, in conjunction with image processing technology, of being developed into a decision-support system for the lifetime of a small manufacturing business.
4.5 Confirmation of existing knowledge

The substantives confirm what is already known to small manufacturing business financial decision-makers or can be ascertained without recourse to chaos literature.

4.6 Inputs to a novel technique for a decision support system

Comparing Decision-making (Appendix 4), (D) Appraisal of Small Manufacturing Business Financial Postulates and this chapter, (E) Appraisal of Chaotic Postulates, shows a tinge of relevance but also much irrelevance.

Phase space deconstruction is relevant to the complex information specification (paragraph (C) 1.4.4 in the Review) so the hypothesis has small, but significant, support but not in isolation from data acquisition and processing technologies and other, non-chaotic, theories.

The technological complements of phase space deconstruction, which contribute to a novel technique of small manufacturing business financial information for decision-making, are considered below.
(F) ALTERNATIVE EXPLANATIONS

The purpose of this chapter is to assess whether, and to what extent, other theories are more relevant to financial decision-making in small manufacturing businesses in view of the limited relevance of chaos and chaos theory.

If other theories are found to be superior, sceptics who opine that chaos has been overplayed are vindicated. (Perkel 1987) On the other hand, failure to find alternatives supports the hypothesis that chaos theory is the more relevant, albeit imperfectly, to owner/managers’ decision-making financial information needs, because nothing better is available.

Between these two extremes of superior or inferior relevance lies another alternative, an intermediate one. This is an amalgamation of relevant parts of chaos and alternative theories to form a foundation for a dedicated theory of small manufacturing business financial information dynamics information technique.
Conclusion: The alternative theories, as with chaos theory, are only marginally relevant to small manufacturing business financial information dynamics.

However pattern and shape theory combine with part of chaos theory to contribute a positive outcome for this thesis.
These alternative theories, to chaos theory, do not share common perspectives. Some focus on single issues, such attributes and human behaviour, others more broadly on system dynamics, flows, patterns and structures. Theories defined in the Glossary are italicised.

1 Localised variability theories

When applied to single, attributes descriptive of small manufacturing business financial variable behaviour, some theories show that chaos theory is not their sole possible alternative. Among the alternatives are:

- Probability theory
- Turbulence theory
- Catastrophe theory

1.1 Probability theory

Probability theory is an integral part of SPC (Statistical Process Control) systems in many factories where upper and lower limits, giving bands of acceptability, are known in advance for a comparatively small number of dimensions. This is an example of a variable which is ultimately financial because products, outside specification, are not saleable at full price. Setters have to check and re-set machines. Occasionally material specifications are changed.

In a less formal setting, owner/managers unconsciously apply probability theory when estimating quotation to order conversion rates for resource planning purposes. Estimating overall conversion rates smooths
out differences in size between orders. No examples of owner/managers using probability theory to estimate sizes of individual sales orders are available. If attempts are made to estimate probabilities of converting a particular quotation into a sales order market intelligence is used, not probability theory.

Probability theory, as applied to inspection and test specifications, differs from variables which are primarily financial. (D) Appraisal of Small Manufacturing Business Financial Postulates and Appendix3, Schedule of value and temporal variables, refer to difficulties preventing quantification of upper limits for the majority of variables and zero bottom limits because they can be no lower. Upper limits on borrowing, a precisely expressed quantity bounding a business, are an exception. Away from the shop floor references to measures of probability are unknown because immediacy dictates the owner/managers' decision-making environment. Flexibility, one of the acknowledged characteristics of small manufacturing businesses, conditions owner/managers to live with surprises.

The irregularity attribute, seen in these variables, does not lend itself to formal expressions of probability theory whichever distribution is used. It is therefore accurate to observe that overall, traditional statistics are 'useless for analysing chaos', (Nicholson 1995) because irregularity is only of several attributes, all of which contribute to chaos in both its meanings. Another attribute, unpredictability (paragraph (E) 1.6.4 in the Appraisal of Chaotic Postulates chapter) calls into the question the value of ascertaining any
probabilities.

Moreover owner/managers do not have time to be concerned with the 'ifs', 'buts', probabilities and assumptions of individual statistics in addition to their daily workload. Owner/managers are obliged to wrestle, often simultaneously, with whole array of decision-making issues. (Mintzberg et al 1976) Secondly immediate determinism drives decisions, especially tactical ones, in changing financial decision-making environments, not past history which serves as the basis of probability. Opportunities, problems and resolves to reach targets, or goals, help drive small manufacturing businesses.

Thirdly precise values, from which probabilities can be calculated, for a large number of variables, are few. Calculation of probabilities, with meaningful confidence limits for them, is therefore impossible. Even when endogenous, internal, information is available, its exogenous counterpart, for calculating those probabilities, is often unobtainable and typically unaffordable.

Two examples from the trading experience of CUEL Ltd illustrate this non-availability of information regarding imminent sales opportunities in small segment industries. First was the receipt, of what in the light of experience with university research departments was expected to be a one-off, never-to-be-repeated, order for a customised 250W stabilised light source, filters and special light guide for botanical research into oxygen emissions by plants at the University of Sheffield. Unexpectedly, and uncharacteristically for research
of this kind, identical kits were then supplied, in larger numbers, to the universities of East Anglia, Keele and Essex as well as for export to Saudi Arabia. The demonstration of this kit, on the BBC-TV programme Tomorrow's World, was unexpected, unsolicited and unannounced in advance. The response to this programme did not match of the TV exposure of Lune Valley Metal Products Ltd! There was no way of knowing that one order would lead to several more from other universities. Had one used previous experience to forecast these follow-on orders their statistical probability would have been zero.

The second example, illustrating the inappropriateness of probability theory for forecasting cash receipts, relates to fibre optics for the inspection of hydraulic manifolds in coal mine roof support systems. One kit, comprising a light source and PMMA light guide was supplied to be followed, at very short notice, by ten others as sub-contractors rushed to ensure compliance with the roof support manufacturer's specifications for removing burrs from hydraulic components.

Statistical multi-variate analysis of variables, each with their own probabilities, is disadvantaged by these measurement and information availability difficulties in small manufacturing businesses.

Financial variables, subject to external audit, are more accurate than variables with financial implications. For example abilities and capabilities of
individual employees are known to vary but accurate quantification is difficult. Where standard costs have been set, data are more accurate than in businesses where best estimates have to suffice.

1.2 Another attribute of chaos, with an associated non-chaotic theory, is intermittency. The theory of turbulence, in association with wavelet transforms, is relevant to it although more usually associated with the physics of fluids. (Farge 1992, Manneville 1990) ‘Turbulence’ is used only occasionally, much less frequently than ‘chaos’, in business scenarios, (Axellson & Rosenberg 1979, Polley 1997) but lack of usage does not make it irrelevant. In economics, turbulence and chaos are regarded as synonymous. (Brock et al 1993) Turbulence fits small manufacturing business financial decision-making scenarios in that it is dynamic and deals with change.

A drawback of turbulence theory, which embraces a package of physical variables, such as heat input, absorption, dissipation, viscosity, is that they are fewer in number than financial ones in manufacturing businesses. A second drawback, recognised in (E) the Appraisal of Chaotic Postulates chapter, is its association with backward looking wavelets. Owner/managers need to look forward even if their decision-making horizons are very close.

However the principal reason disqualifying turbulence from consideration as an alternative to chaos theory is its definition. One of the properties of chaos is underlying order, whereas turbulence is a mess of disorder on all scales. (Gleick 1987) The implication, of applying that definition of turbulence, is
that every section and department is a mess – manufacturing, marketing, logistics, finance and personnel. Order is non-existent in turbulence but present in large, or small measure, in chaos theory and in small manufacturing businesses.

Turbulence theory is therefore not an alternative to chaos theory.

1.3 Catastrophe theory accords with the discontinuity attribute but only when there are sudden and large-scale changes in the one attribute in correspondence with small changes in others. (Brown 1995, Oliva et al 1988) This does not match small manufacturing business scenarios. For example an unusually large sales order has major, not small, effects on manufacturing, finance, purchasing (logistics) and human resources departments.

Catastrophe theory’s ‘image’ advantage, is applicability to non-physical systems, (Castrigiano & Hayes 1993) such as competitive dynamics in business. Competition is not only relevant to the market place but also, internally, within businesses where departments compete for finance, leaving owner/managers to trim budgets. Catastrophe theory’s disadvantage is not treating multiple inter-variable relationships [a feature of feedback systems] and the different chaotic attributes associated with them. (Oliva et al 1988)

‘Catastrophe theory does not offer an easy solution, it merely helps identify it’, (Morris R 1997) sums up its minimal contribution to small manufacturing business financial decision-making.
The cusp model, a refinement to overcome the shortcomings of the Cobb model, treats only a three dimensional surface with one dependent and two independent variables. (Oliva et al 1988) It is therefore unable to handle multiple, complex, inter-dependent, inter-active financial variables of a small manufacturing business feedback system.

2 Human behaviour theory

2.1 The theory of social imitation, based on the Fokker Planck equations, and distinct from chaos theory, is less relevant to chaotic attributes than the preceding theories but it treats one aspect of decision-makers' behaviour when they meet in social groups. (Vaga 1990) That aspect is the tendency to polarise towards a common interpretation of prevailing economic activity indicators. Social gatherings, where discussion of business is acceptable eg Rotary and Round Table clubs, play a part in formulating common interpretations. In that respect the theory of social imitation provides one of a number of inputs which influence the human behaviour, which is a cause of chaos.

3 Complex phenomenological theories

The complex theories investigated in this section are:-

- Systems theory
- Complexity theory
- Information theory

As single, and small number of attributes, theories are at best fragmented
alternatives to chaos theory, and limited in their ability to satisfy the information specification (paragraph 1.4.4 in (C) Review), the second group of potential alternative theories to chaos, those which encompass an array of inter-related situations, is considered. In this chapter systems and complexity are lead theories taking precedence over chaos theory. In (E), the Appraisal of Chaotic Postulates chapter they were regarded as subordinate members of a chaos theory family.

3.1 Systems theory is relevant because it is associated with developing information systems. 'General systems theory is a logico-mathematical field, applicable across conventional disciplines, addressing issues of inter-relationships within a whole'. (Avgeron & Cornford 1998) Its relevance is based on small manufacturing businesses being feedback systems not a collection of unconnected variables and their attributes.

An 'image' advantage is that 'systems' unlike 'chaos' does not come to the owner/manager handicapped by a long history of detrimental associations. However its image suffers from the disadvantage of being used to describe mundane administrative procedures eg sales and purchase ledger 'systems' not dynamics.

Another image advantage is that it is not identified with particular disciplines as chaos is principally with the physical and life sciences.

However a major disadvantage, disqualifying it as an alternative to chaos theory
Complexity theory's association with approximation, (Barnsley 1986) is only compatible with investment appraisal, not with the daily round of cash-centred decision-making where precision is of paramount importance. Investment appraisal involves only a selection of the multiple variables which affect small manufacturing businesses. As accurate information on future interest rates, and returns, is not available when appraising investment possibilities, approximation cannot be bettered.

The debate continues, in academe, as to whether chaos theory is part of complexity theory or overlaps it. (Mihata 1997) This was mentioned in the (E) Appraisal of Chaotic Postulates chapter paragraph 2.2.1.1.

3.3 Information theory has been advocated for quantifying the motion between macro [economics] and micro [business] systems, (Shaw 1981) using Lyapunov Exponents and generally for the study of dynamical systems. (Crutchfield & Packard 1982) Even large businesses are 'micro' when placed in the context of a national economy. The term does not refer to micro, one man businesses, which are smaller than small ones. The shortcomings of Lyapunov Exponents are appraised above (paragraph 3.2.2.1 (E) Appraisal of Chaotic Postulates).

It is recognised empirically that macro economics and micro economics interact. Typical arenas for interaction are changes in the supply and cost of money which affect borrowing by companies. Existing facilities are not renewed, new applications for financial facilities declined. Little quantitative
information, about lag times between the event of interaction, and its impact on small manufacturing businesses, is available. Anecdotal evidence, gleaned from banks, suggests that lending policies affecting money supply to small manufacturing businesses change rapidly, often on a daily basis, and fluctuate widely.

4 End point theories

The two end point theories in this investigation are:

- Optimisation theory
- Game theory

4.1 Optimisation theory accords with small manufacturing financial decision-making situations. Its definition fits two different scenarios. It fits profit maximising businesses looking for the most profitable choices in its decision-making and also those seeking to extricate themselves from adverse situations by making the least disadvantageous ones. A requirement for mathematical techniques and numerical data puts it beyond the reach of the majority of owner/managers and restricts it to those variables for which numerical data is available.

4.2 Game theory is principally concerned with strategic problems; hence its use in economics. Its name, 'game', disadvantages it from consideration by owner/managers for whom running a business is serious. In terms of this thesis its principal disadvantage is its use of stochastic techniques to represent confrontational situations.

An advantage of game theory is that it recognises the existence of
confrontational situations. These arise between owner/managers and financiers, between small manufacturing businesses and their suppliers.

Confrontation between them, and their customers, while not unknown is usually avoided owing to superior bargaining positions of many customers, especially large ones.

5 Seminal theories

Pattern theory and shape theory are included in this chapter because they help release information from difficult-to-interpret, amorphously-shaped, single strand phase space diagrams which may or may not represent chaotic scenarios.

Lines of demarcation between pattern and shape theories are unclear. Their associations are a convenient method of demarcation. Pattern theory has affinity to pattern recognition techniques which have a small number of industrial applications. Shape theory is closer to higher mathematics than operational systems in factories and is not exclusively associated with data presented in diagrammatic form.

No evidence has been found in the field, or in literature, linking either theory with financial information for small manufacturing businesses. For that reason the heading, seminal theories, has been chosen for this section of the Alternative Explanations chapter.

5.1 Pattern theory is now being used to analyse diagrams of open and closed patterns in single line shapes, (Grenader 1996) similar to deconstructed phase spaces. Examples in the literature resemble open-ended trajectories of small
business financial variables and closed deconstructed phase spaces.

Figs E8 (a), (b) and (c) refer to important relationships between variables are revealed by applying pattern theory. In one respect pattern theory may do no more than confirm, in the present, relationships of which owner/managers are already aware. However it could, more importantly, satisfy four of the criteria in the (C) Review specification (paragraph 1.4.4) that financial decision-making information should be contemporary, comprehensive, comprehensible, co-ordinated, compressed, clandestine, cost effective, comparable and credible.

Patterns help first with information co-ordination, diagrams, incorporating patterns, secondly with comprehensibility (visualisation) and thirdly comparability. As all this information is endogenous, it ought to be fourthly clandestine, inaccessible to peripheral decision-makers, financiers, customers, credit agencies, until owner/managers have had opportunity to act on it.

Having contemporary and credible financial information, for decision-making, has more to do with data acquisition procedures than with chaos and other theories. Data acquisition procedures in conjunction processing facilities affect the cost effectiveness and compression criteria in the specification.

Before that stage is reached work needs to be done on deciding which patterns signify chaotic relationships and providing for owner/managers to access the requisite IT equipment and facilities. Without these inputs the combination of
pattern and chaos theory will be solely of academic interest.

5.2 **Shape theory** also is currently associated with the analysis of regular and amorphous shapes such as E8(c) in the life sciences. (Dryden & Mardia 1998) These amorphous, single strand shapes resulting from joining several data points, resemble illustrations of deconstructed phase spaces in chaotic literature. (Lefrance & Glorieux 1997) Patterns developed to launch pattern theory + chaos theory into small manufacturing business financial decision-making may later serve as patterns to assist more complicated shape analysis.

At this stage combining shape, or pattern theory, with chaos theory to improve financial management information in small businesses, is innovative. If evolution of this innovative financial management information package, and its acceptance by its target audience, progresses in a typical manner, the emphasis is expected to shift from predominantly pattern to predominantly shape orientated. Although outlines in the literature for both patterns and shapes are similar, there are more landmarks, data points, in shape illustrations than in pattern ones. Eventually, after proving with a small number of data points, for simple patterns, it is reasonable to expect that additional data points will be added so that outlines, (of deconstructed phase spaces) will become more difficult to analyse with pattern recognition techniques.

6 **Conclusions**

6.1 Neither chaos, nor the above theories, jointly or separately, satisfy all the requirements of small manufacturing business decision-making financial
However complexity, systems, pattern and shape provide inputs for the formulation of a novel small manufacturing businesses financial information technique, in conjunction with but not as a substitute for chaos theory.

6.2 A new theory, is needed because there are multiple, complex, inter-related, interacting financial variables in small manufacturing businesses which currently available theories only kiss. For that reason a novel technique incorporating parts of chaos, and theories considered in this chapter, is proposed at the end of this thesis. Development and implementation of the technique cannot proceed without a technology input otherwise it would be so time-consuming as to deter busy owner/managers.
(G) A FINANCIAL INFORMATION TECHNIQUE FOR SMALL MANUFACTURING BUSINESSES

Overview

Introduction

Foundations of the technique

Technique design

- Flow variable value and time data acquisition, representation and arrangement
- Templates, boundaries and parameters ('chaos' lines)

Information processing technology

- Image processing comparing actual variables and templates

End product:

- Reports to financial decision-makers

Man-machine interface

- Clicking onto flagged 'chaotic' cells for zoom view in PC monitor window
- Selecting groups of 4 enlarged cells in PC monitor window to examine concurrent and asynchronous relationships between them

The technique is technically feasible so improvements in the quality of endogenous financial information for decision-making in small manufacturing businesses are realisable. The drawback of the technique is that its setting up and maintenance require the involvement of real people, who could embed chaos if not given specialist support.
Technique schematic

<table>
<thead>
<tr>
<th>Theoretical</th>
<th>Technological</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>stimulus &amp;</td>
<td>foundations</td>
<td>parameters acquisition interpretation in PC memory from: - by: -</td>
</tr>
<tr>
<td>foundations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Chaos to Accounting Artificial be avoided & intelligence shapes

(2) Last factory - patterns update loading - shapes procedures

Chaos + Graphical Pattern + (image)

Shape processing

Improved financial information

Interpreted diagram (Decision support system) for control of chaos

More detailed information → Owner/manager ← Human interpretation

(1) Written records + after artificial intelligence
(2) Aural sources

Complementary Information

Reactive & Proactive
Financial Decisions:

To Control Financial Flows & Structures and Avoid Chaotic Confusion
1 Introduction

The purpose of this chapter is to develop the phase space deconstruction technique into one which satisfies the optimum specification in (paragraph (C) Review 1.4.4) in order to control, within a framework of small manufacturing business financial diversity, chaotic confusion. The Working definition of chaos in (E) Appraisal of Chaotic Postulates paragraph 1.1 refers.

Fig G2, Diagram of PC monitor display, shows the end-product.

Chaos theory is relevant to this purpose but only in association with more important elements. The technique is chaos inspired although chaos is not an essential ingredient. The use of the term, 'chaos lines', as an alternative to templates, is only in deference to its foreboding perceptions and chaos initiating the chain of thought leading to the development of the technique. ‘Chaos lines’ in cells could equally well be designated ‘alarm thresholds’ or simply referred to as ‘templates’. The latter term is the preferred one because it is in common manufacturing use. These templates are the yardsticks against which actual financial variables are detected and measured.

Fig G1, Technique Schematic shows three inputs to the technique: –

- Theoretical foundations, (Chaos, pattern and shape theories)
- Technological foundations (image processing)
- Data (flow variables and templates)

The ultimate aim of the technique is improved financial information leading
Cells representing key financial variables – consolidated and individual

eg cash, capacity, liabilities, receivables, manufacturing

resources, customers alongside templates.

(1) Actual data for each cell obtained from accounting, sales and production

planning records. Data entered as by-product of above or separately.

(2) Chaos templates for each cell based on experience, heuristics, business

ratios, restrictions eg on borrowing, available capacity, credit control

limits, targets, business plans, budgets, delivery obligations.
to well-informed reactive and proactive financial decisions.

Diagrammatic reports of actual versus template situations, in financial cells, do not replace numerical information in financial accounts, budgets, spreadsheets, business plans, business ratios, accounting and factory records. On the contrary the technique acts as pointer to these primary sources and complements their usefulness because it:-

- Automatically directs attention to vulnerable financial variable groupings for which conventional records then provide more detailed information.
- Provides information in user-friendly diagrammatic form

The technique originates in chaology, part of chaos theory, is founded on shape analysis theories, realised through image processing technology and operates on data relating to financial variables. (Hill, Batchelor, Hodgson 1984, Grenader 1996, Dryden and Mardia 1998, Loncaric 1998)

Fig G1, Technique Schematic, shows the anatomy of this novel technique which is an application of technical possibilities in the management information field. (Parsson & Malmsjo 1998) Moreover it assists management accountants who have historically been constrained in their major role of supporting decision-making by lack of appropriate information technology. (Sudit 1998)

Fig G2, Diagram of PC Monitor Display, shows the end product.

Cells of various shapes and sizes are arranged round the periphery of the
monitor. There are upper and rows, left and right hand columns each having an average of 40 cells. The total number of cells available for allocation to variables is 160. The centre of the monitor is a window available for zooming onto 'chaotic' and any other selected cells. Without the zoom facility information contained in cells cannot be accessed. An average of 40 cells in each row or column on a 14" monitor means that individual cells measure approximately 0.5 x 0.5mm which is too small to be useful. Each cell has an average of 75 x 75 pixels allocated to it. That is the basic cell module which may be extended or reduced to match required x and y axes, time and value, for variables. As axes differ in length cells are either squares or rectangles.

Individual cells, irrespective of its size and the length of its axes, contain:-

- One or two templates (chaos lines), in the form of straight, curved, horizontal, tilted or vertical lines.

- 2D plot of actual time and value data – a shape

- A name label eg cash balance, factory load, liabilities, project expenditure, customer or supplier, small versus large customers etc.

- A red spot, when chaos line templates and actual data approach one another or intersect.

- A linear scale of chaotic intensity in the cell below its x axis.
The foundation of this small manufacturing business financial dynamics information technique is a combination, believed to be unique, of:

- **Chaos theory** — *phase space deconstruction*, a chaological technique
- **Pattern theory** - Templates of differing shapes and aspects for:
  - Detection of unwanted current and anticipated chaotic situations
- **Shape theory**  Assessing the intensity of chaos by comparing templates actual data shapes with those representative of chaos.
  - Building a reference library of chaos-critical shapes beginning with attributes of chaos 2D diagrams.
- **Image processing technology** for comparing actual flow variable data, shapes and templates in order to produce chaos detection and intensity reports for financial decision-making.

Fig G3, Origins of small manufacturing business financial technique, shows how these elements come together.

Although this novel technique owes it origin to one version of the phase space deconstruction technique, reported in French chaos literature, chaos is not a permanent essential ingredient. (Lefranc et Glorieux 1997) First the term *phase space* is not exclusive to chaos. Secondly the technique does not use a single undivided strand with loose ends, as in Lefranc et Glorieux' paper. In this technique, a strand is a composite one of joined segments assembled from
Origins of small manufacturing business
financial information technique

Image processing of shapes

Tangible
(+/- Pattern recognition)

Earth Laboratory Industrial resources specimens artefacts

Intangible

Applied Applied Accounting Factory statistics

shape analysis

PC add-ons

Templates

Small manufacturing Businesses financial Information

Artificial intelligence

Chaos theory
cells through which it passes. There are two strands, one for templates and one for actual data. Another difference is that template strands are not unbroken. Paragraph G3.2.1.2 below refers to some cells which have no template and other which have more than one. Cells without a template cause a break in the composite strand. Second templates are isolated island templates when adjacent cells have either only or zero templates.

The pattern and shape theory ingredients have two uses:-

- Current evaluation of undesirable, 'chaotic' situations and actual ones
- Compilation of a library of 'chaotic' shapes for future use as a failsafe should incorrect templates be used for comparison.

Besides the use of image processing for industrial applications, the technology ingredient, is its use for density estimation and discrimination using shape data in the form of pixel images. (Wright et al 1997)

3 Technique Design

Fig G4, Technique Design, summarises the elements. It shows:-

- Flow variables (actual financial data)
- Templates (boundaries and parameters)
- Image processed information outputs

Specifying the outputs (C) impinges on template design
A  Flow variables

Identify:- Value & Time ranges ---→
to form information cells

(Chapter (D) refers)

Design cell shape to suit range

→

Group into financial, human, physical, logistics (D & Appendix 3)

Time axis: x  Value axis: y

Arrange neighbouring cells
within groups
round perimeter

B  Templates indicative of chaos

Identify - necessity

Decide shape - linear/non-linear

Decide aspect - horizontal/vertical
  - slope up/ down

Decide durability - permanent

Quantify

→

in linear/non-linear form

* Value(s)

* Time(s) - duration, frequency

Decide numbers of templates

* Only one - upper/ lower or

* Two - upper and lower

* None

Decide tolerances in range

0% → maximum

Join actual data points for all
information cells and neighbours

C  Outputs

Decide reports required:-

Chaos - incidence and extent

Current

Imminent

- in Group and Cell

→

End product - Financial information for decision-making

D  Information processing

Image processing of templates,
flow variables and patterns in text
and/or diagrammatic form
3.1 Data acquisition

Data are of two types. They comprise flow variables and flexible templates. Both relate to value and time.

In order to maximise benefit from the technique data, on all financial variables, however many, which could lead to chaos, should be acquired. Moreover the technique operates on the same procedural time-scale as its primary records. If the purchase ledger is posted daily, liabilities on which it is based, are ‘chaos-monitored’ daily.

3.1.1 Flow variable value and time activity data

Frequently moving data on inward and outward, actual and forthcoming transactions are acquired as a by-product of PC:-

- Accounting procedures.
- Production planning and control
- Sales order recording
- Purchase order recording

Slow moving data, without computerised records, is inputted manually.

3.1.1.1 Automated sources of data

As the extent to which accounting records are computerised, and software installed, differs in small manufacturing businesses, Table G1, Data acquisition, gives examples of cell designations in the left hand column and the source documents in the centre one.

In a few small manufacturing businesses data acquisition is completely
<table>
<thead>
<tr>
<th>Data (periodic and irregular)</th>
<th>Source(s)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>Cash book</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bank statements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sales and purchase contracts</td>
<td>Progress payments</td>
</tr>
<tr>
<td></td>
<td>Financiers' letters</td>
<td>Venture capital</td>
</tr>
<tr>
<td></td>
<td></td>
<td>draw-down</td>
</tr>
<tr>
<td>Receivables</td>
<td>Sales ledger &amp; invoices</td>
<td>Due dates or permitted dates</td>
</tr>
<tr>
<td></td>
<td>Customs &amp; Excise rebate letters</td>
<td>VAT refunds</td>
</tr>
<tr>
<td>Factory load</td>
<td>Production planning</td>
<td>Measured in value</td>
</tr>
<tr>
<td></td>
<td>Costings</td>
<td>Options:-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Total factory load</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Critical capacity limit</td>
</tr>
<tr>
<td>Liabilities</td>
<td>Purchase ledger &amp; invoices</td>
<td>Due or permitted dates</td>
</tr>
<tr>
<td>(periodic and irregular)</td>
<td>Wages and salaries</td>
<td>Regular periodic payments</td>
</tr>
<tr>
<td></td>
<td>Taxation</td>
<td>Business rate</td>
</tr>
<tr>
<td></td>
<td>Customs and Excise</td>
<td>Corporation tax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VAT due</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Import duties</td>
</tr>
</tbody>
</table>
automated, especially those with expensive and critical machines. A number of those machines have load and output recording loggers attached. These are linked to a central production control unit.

Factory load data is then inputted alongside accounting data.

The range of this data affects the shape and size of information cells and consequently the way in which they fit together around the monitor periphery.

3.1.1.2 Data quality

(a) The degree of inaccuracy in financial data varies. Cash actually received, and paid, is the most accurate item in the data. Invoices and negotiable instruments are entered into the cash book and the sales and purchase ledgers. Costs, for production planning of critical resources are less precise. They are subject to noise and unlikely to be audited, unless improper trading is suspected. The Schedule of value and temporal variables, in Appendix 3, itemises several imprecise variables. especially at item 7.

An addition to these imprecise variables, is the vexed question of equitably allocating overhead costs. (Hill & Rockley 1990)

Receivables, although more precise than costs, may also be imprecise because bad debts and foreign exchange variables affect them. Values of liabilities are similarly affected by variability of spot foreign exchange transactions.
(b) The other variable is time. Discrepancy between due and remittance dates is a frequent source of comment because many, although not all, large corporate customers, peripheral decision-makers, practise delaying payments. (Comments on the effects of the 1998 legislation, to curb late payment to small businesses would be premature). Therefore, plotting due dates, on a diagram, yields misleading management information.

For start-up business, which are short on experience, they can only guess when payment will be made. Whereas businesses, which have been trading for longer, are able to incorporate their experience into an expected payment week number.

Factory loading, an endogenous activity, also incorporates some time and value imprecision because production planners advance, and anticipate, some orders whilst others are delayed by the vicissitudes of manufacturing.

### 3.1.1.3 Data overlaps

Table G1, Data Acquisition, shows sources of four flow variable cells. These four cells of data are not mutually exclusive. Liabilities to pay labour overlap with factory loading commitments in value although their time phases are not coincident. Labour is paid regularly at prescribed times whereas some material has to be paid for before suppliers make it available to labour for conversion into product. The
advantage of showing some variables in separate cells, even when they are also consolidated into other cells in a hierarchy of importance, is that information facilitates tracing causes of problems. The Roman policy of divide and rule is still valid because greater detail removes compensating errors.

Showing factory load, as well as liabilities, means that a decision-maker’s attention is drawn to the financial consequences of under- and over-loads. Both conditions require sufficient working capital. Under-loads, in the short term, to cover a future shortfall attributable to factory under-loading. Over-loads, also in the short term, to cover manufacturing lead time and customer credit periods.

Factory load data are also linked to order intake data. Too low a value orders today affects factory loading tomorrow.

3.1.1.4 Data hierarchy

The technique enables data to be divided into categories such as liabilities, receivables and factory load but also to be further subdivided. Liabilities are sub-divisible to show indebtedness to key suppliers, receivables that of major customers factory loading related to critical machines.

3.1.1.5 Data derivatives

Loss, consequent on the materialisation of risks, is a source of chaos. A second analysis derived from sales order information into another
cell allocated to the split between major and minor customers
indicates exposure to risk. A business dependent on one customer
for 80% of its profit is more exposed to risk than dependent on
twenty customers.

3.1.2 Templates

Templates represent value and time parameters and boundaries relevant to
chaos criticality in the financial variable cells. They specify limits as
what is to be avoided. Foreboding perceptions of chaos are an integral
part of them. The section on chaos in (E) Appraisal of Chaotic
Postulates refers. Actual data is compared with these templates as soon
as it becomes available.

Templates are embedded for the duration of their life. When
circumstances changes templates are changed. These semi-permanent,
flexible templates are distinct from floating templates which compare to-
day’s situation with yesterday’s. These floating comparisons assist
identification of the causes preceding chaotic situations. They show
events leading to current situations. Floating templates do not have to
be specified, designed and loaded to PCs because they are derived from
actual historical data.

3.1.2.1 Appearance of Semi-permanent Templates

(a) Fig G5, Individual cell template forms and aspects, shows
templates either as simple straight or curved lines, pointing up or
Individual cell templates, forms and aspects

1 Straight lines

(a) Horizontal lines
   Upper ceiling : Maximum Available resource
   Lower floor : Minimum viable load

(b) Tilted lines
   (i) Upward
       Productivity per employee
   (ii) Downward
       Tightening of credit limit on bad payers

(c) Vertical post
   Obligatory time limit

(d) Multiple spikes
   Cash flow problems:
   1. Disbursements quickly follow receipts.
   2. Zero growth

Curved line templates follow on the next page
2 Curved lines

NB Possibility of many different slopes

(a) Upward

(b) Downward

Planned profitability

Reduction in borrowing

3 Compound forms

(a) Upward step in horizontal straight line template

NB Height of step varies

New machine increases capacity

(b) Downward step in curved template

Investment income
Changes in templates are shown either as up or down steps, or modifications to slopes of curves.

(b) Fig G6, Monitor-wide Grouping of Cell Templates, shows how the templates for individual cells are joined. The simplest form is a balanced quadrilateral without any skew, the more usual ones blobs either with smooth or abrupt transitions.

(c) Fig G7, Localised Grouping of Templates, shows the spiky arrangement indicative of cash flow problems. An input is immediately followed by an approximately equal output. It also shows the 'chaotic' combination of cash balance-liabilities-receivables-unfilled factory capacity.

3.1.2.2 Compilation

Compilation of templates begins with a cell by cell verbal description of what it is to be chaos-free. The next stage is a description of what constitutes harmful chaos.

Quantification follows verbal description.

Inputs to the compilation of cell templates are jointly or separately:-

- Quantitive limits on financial and physical resources
- Targets, aims, budgets, objectives and plans
- Business ratios
- Heuristics

These inputs are either self- or externally imposed. An owner/manager
Monitor-wide grouping of cell templates

Frame of Monitor

Straight line comprising individual templates

Interruption - one cell with zero templates.

Blob – made by combining various individual curves

Zoom window

Isolated cell template - cell with 2 templates

Individual cells (Arranged round perimeter in 2 column 2 row format)

(1) Template sizes, values, times and position in perimeter array

(2) Variable financial data (by product of existing procedures)

Click and drag up to 4 cells from perimeter to Zoom window
Examples: Cash balance | Liabilities | Receivables | Unfilled capacity |

Trend: Decreasing Increasing Decreasing Increasing
may voluntarily opt for certain rate of growth, but a key supplier cell has an imposed mandatory credit ceiling.

**Chaos-free Template Verbal Description**

A chaos-free template applicable to four flow variables shows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Chaos-free Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash balance</td>
<td>Positive and sufficient to cover all liabilities</td>
</tr>
<tr>
<td>Receivables</td>
<td>Zero for current week (efficient credit control)</td>
</tr>
<tr>
<td></td>
<td>Minimum for each subsequent week =</td>
</tr>
<tr>
<td></td>
<td>Liabilities for same period</td>
</tr>
<tr>
<td>Liabilities</td>
<td>Zero for current week</td>
</tr>
<tr>
<td></td>
<td>Maximum for each subsequent week =</td>
</tr>
<tr>
<td></td>
<td>Receivables for same period</td>
</tr>
<tr>
<td>Factory load</td>
<td>Load = Capacity</td>
</tr>
</tbody>
</table>

Anecdotal evidence indicates that a number of templates exist only in the minds of owner/managers and are not committed to writing. If templates are to be compiled that information will need to be made available.

Development of the technique in future will eventually yield a library of norms and options similar to business ratio publications which give values for relationships between variables in year end...
3.1.2.3 Number of templates per cell

Templates relate to value and time. For each variable the number of templates is either:-

- Zero ie no limits eg cash surplus, no known limit on borrowing
- Upper ceiling only eg overdraft borrowing
- Lower floor only eg minimum weekly sales per representative
- Both upper and lower eg factory capacity. Upper physical resource availability ceiling, lower floor on financially viable loading of fixed assets.
- Vertical post eg latest time.

The maximum number of templates per cell is:-

Upper ceiling + Lower floor + Vertical post = 3

Compilation of templates is expected to be a joint effort between academe and providers of add-ons to existing PC accounting and production planning installations. PC and software providers have a vested interest in expanding into another segment of IT markets.

Pixel counting, on a scale of 1 to 10, measures chaotic intensity once the technique is fully computerised. Logarithmic scales are used to assist rapid visual assimilation of worsening chaos by owner/managers.

3.1.2.4 Modification of templates

This modification is subsequent to modifications to templates made at the time of installation and verification. It can take place long after
Established businesses use past experience to identify and quantify chaotic and non-chaotic conditions for template design. Start-ups rely on intuition and later modify templates in the light of experience.

3.1.2.5 Tolerances

Reference was made in paragraph G3.1.1.2 above to imprecision in data. In practice templates need tolerances ranging upwards from 0% so single lines are an over-simplification for some, but not all, parameters. For example the tolerance on exceeding agreed overdraft limits is effectively 0% because unauthorised borrowing attracts penalties. Another example of 0% tolerance is the payment of some insurance premiums by due dates. If unpaid on the due date, insurers remove cover.

On the other hand, a nominal 100% datum for factory loading (capacity = load) may have a tolerance of +/- 20% Overtime working releases capacity in addition to that normally available. Similarly late payments on credit terms may have days of +5% informal allowance after the due date. That is an example of a single parameter because no one imposes penalties on early payment. Templates need to be tolerance bands not fine lines in these cases.

3.2 Financial information processing technology

'Image processing' or 'graphical processing' are preferred names for the technology for a number of reasons. It is an example of technology
playing an important role ...... in management methods. (Fin 1998)

‘Graphical processing’ while it describes what happens in the novel technique was used in pre-computer times. The other alternative names also have drawbacks. Picture processing implies fine art. Pixel, picture point, processing is preferable in circles where the term is already in use. Machine and computer vision are disqualified because they use data acquired via cameras which does not apply to this information technique.

Automated processing is necessary for satisfying the optimum specification in (C) paragraph 1.4.4.4. Without a technology based information processing costs outweigh benefits. The heart of processing is first comparison, according to prescribed sequences, followed by exception reporting.

3.2.1 Processing aim

To produce exception reports for owner/managers showing:-

- Incidence, intensity and location of current chaos in cells
- Future chaos, its anticipated incidence and intensity.

These are relationships between actual and datum positions. (Cohen & Grossberg 1987)

3.2.2 Processing procedure

Processing is based on comparing actual flow, time and value, variable data with associated templates in cells or groups. (Hutton 1994).

Time and value are translated into numbers of pixels for processing
purposes.

This takes the form of:-

- Comparing runs of data points, or anatomical landmarks as they are known in shape theory terminology. (Dryden and Mardia 1998)
- Comparing line lengths representing value and time by pixel counting
- Comparing shapes of lines representing actual data and templates
- Comparing current and past actual data for floating templates.

Processing covers either data in single cells or arranged in small groups.

3.2.2 Processing outputs

There are two options.

(a) The first option is printed exception reports, in diagrammatic or numerical form, of cells in which actual data lines intersect with templates ('chaos' lines).

(b) The second option is for an owner/manager to interrogate cells flagged as chaotic because they have a red [chaos] spot in them.

4 Man-machine interface

4.1 Zoom view of single cell in monitor window

The owner/manager clicks on the red spot and a 2D graph zoom view of the chaotic cell appears in the central window of the monitor. Plots of data for the immediate past and anticipated future, in addition to templates, assist interpretation.
4.2 Zoom views of cells in monitor window

Fig G8, Zoom view of three adjacent cells, focuses on one and shows part of its two neighbours.

Fig G9, Concurrent data points. is a view of four adjacent cells in the monitor window. These four cells need not be flagged as chaotic but are selected for interrogation because they may be contributors to it.

4.3 Asynchronous processing of four selected cells

In (D) Appraisal of Small Manufacturing Financial Postulates reference was made to flow variable activity having different time phases and in Appendix 4 to decision-making being polyphase. Image processing allows time phases and scales to be manipulated.

Four variables are used to illustrate asynchronous processing in Fig G10, Asynchronous link-up shapes. Days are available in weeks 1, 2 and 3 because they are nearest to the present. Time and value are shown on log/log scales, when required to assist visualisation and assimilation.

With asynchronous iteration for example Week 1 for variable 1 is correlated with week 2 for variable 2, week 3 for variable 3 and another week for variable 4. In this way the technique provides what-if information for financial planning, with its lead and time lag effects on production materials, procured in advance of manufacture, and also customers taking advantage of credit facilities stretching beyond completion of manufacture. When they coincide
Zoom view of three adjacent cells  

Fig G8  

211

Cell x-1  Focal Cell  Cell x+1

Value

Chaotic zone

time

No chaos  Weak  Moderate  Strong

Scale of chaotic intensity

Actual trajectory

Chaotic datum trajectory

NB Scale of chaotic intensity based on extent and shape of area between curves
Note:
Anchor points are based on a key variable eg cash
Differences in relationships between Variables 1 & 3 and 2 & 4
cause shape areas to change while included angles remain constant
with critical values, thresholds, leads and lags are sources of chaos. Numerical data is available to support diagrams when required.

5. Evaluation of technique and comparison with optimum specification

5.1 Conciseness

Winston Churchill, a very busy man when prime minister during World War II, reportedly insisted that all reports to him were on a single page. There is also a proverb. One picture is worth 1,000 words. This technique not only produces a graphical report, a picture, flagged with chaos indicators, and supporting numbers, to comply with the proverb, and it follows Churchill's dictate by doing it on a single sheet of paper.

5.2 Dynamic co-ordination

The report co-ordinates typical causes of small manufacturing business failure such as insufficient working capital, excessive liabilities, overdue and insufficient receivables and uneven factory loads, (Hill & Rockley 1990) through the zoom or peripheral group formats.

Although primarily intended for day to day control, not simulation or modelling, the set-up is suitable for visualising What if ...? relationships such as business planning or factory loading. (Shelley 1992)

The fact that a report is viewable as a still on a TV monitor, with an image processing zoom facility, enables decision-makers to interface effectively with the machine and avoid absolute reliance on a computer. (Gurton 1989)
5.3 Contemporaneity

The diagram combines information on the immediate past and the short term future. The effect of this contemporaneity is that financial decision-making can be based on the best information currently available. The alternatives are attempting to delay decision-making until information becomes available or making decisions based on best guesses. Up-dating is carried out as part of normal accounting and factory loading procedures. In many, although not all, small manufacturing businesses these procedures are performed daily.

The downside of contemporaneity is that some imprecision in the data on which diagrams are based has to be tolerated.

5.4 Comprehensiveness

Although concise, diagrams are comprehensive for selected groupings of key financial variables. In small manufacturing businesses, owner/managers are intimately involved with decision-making so that using artificial intelligence to flag deviance on a diagram prompts the question Why? Finding answers to questions directs owner/managers to inventory, asset utilisation and order intake, as well as vulnerability and structure of the customer base together with manufacturing efficiency and asset utilisation.

The potential merit of the technique is dependent on the quality and amount of financial information fed into the computer. In the late 1950s, in the
DEUCE computer room, at The English Electric Co Ltd. Whetstone, 'garbage in garbage out' was often heard. That still applies with the additional caveat 'nothing in, nothing out'. Difficulties of quantification, mentioned in (E) Appraisal of Chaotic Postulates chapter, result in its comprehensiveness being undermined. This aspect is considered further in connection with future work on its extension and development.

5.5 Confidential

The adjective 'confidential' was included in the optimum specification because all the other requirements begin with the letter 'c' so recall is facilitated.

For the time being the information processed by this technique is confidential. It cannot be accessed by third parties because there is no statutory requirement to disclose it all even in year end accounts. Once the merits of the technique are recognised owner/managers, in negotiating situations, must prepare themselves for the eventuality of disclosure becoming obligatory

6 Discussion

This small manufacturing business financial information technique has some drawbacks. Noise, imprecision, present in some variables, makes them difficult to quantify. Diagrams are therefore imprecise and less accurate than business ratios and year end accounts
but, on the contrary more up to date as part of day-to-day accounting procedures.

The resolution of *pixels*, on PC monitors, is an additional source of noise.

As this application is for small manufacturing businesses with limited resources, additional expenditure on sub pixel resolution is extremely difficult to justify.

Figs G9, Concurrent Data Points and G10, Asynchronous Link-ups, have only four manually selected symmetrically arranged cells. Eventually developments in computing power and processing speeds, together with supervised neural networks, will process non-linear variables in the additional cells. (Karnofsky 1993) Automatic linked cells will follow.

More than 30 years ago the difficulty of deciding such relationships with sub-systems was recognised. (Hart 1964)

Although the interpreted information suffers from some noise, it is nevertheless more accurate than many stock and work-in-progress valuations.

Lack of consensus on what constitutes undesirable chaos standards undermines the use of the technique for negotiations between financiers and owner/managers. Subjective interpretations of data and unilateral perceptions of "templates" have soured many trading relationships! However a report is available to owner/managers before
7 Conclusion

Translating the technique into a commercially available financial information package, for use by small manufacturing business owner/managers, requires the writing of software, PC specifications and field tests before making it generally available.

The case for undertaking this work is based on the advantages of replacing defective financial information with the good quality information made available by the technique in compliance with stringent specification. Having good quality cost-effective contemporary financial information available increases the likelihood of good decision being made by owner/managers.

This opens up several possibilities:-

- An increase in owner/manager earning power
- A decrease in owner/manager stress
- A decrease in small manufacturing business failure
- An increase in contributions to the GNP by small manufacturing businesses
- A decrease in the PSBR (Public Sector Borrowing Requirement) because unemployment caused by business failure will decrease and taxation revenue from prospering businesses will increase.
- Extension to large corporations financial directors, fund managers and
  FOREX (Foreign Exchange) traders.
1 A financial management decision support technique

The useful end-product of the thesis is a time-efficient financial management decision support tool, or technique, of benefit to owner/managers and ultimately the wider community which stands to benefit from success in small manufacturing businesses.

The technique also appears to be relevant to large corporations, and the financial services industry, because it reports on current, and immediate past, actual value and temporal information, in may cells, alongside their datums.

2 Tenuous support for the relevance hypothesis

With such a large volume of material, it is surprising that this research finds only one technique from chaos theory and one perception from chaos, the condition, is relevant to financial decision-making in small manufacturing businesses. Chaos theory provided the stimulus for developing, in conjunction with image processing, pattern recognition and shape analysis, a novel small manufacturing business financial information technique. Insofar as the technique of phase deconstruction contributed to this information technique, chaos is relevant to financial decision-making in small manufacturing businesses. The hypothesis is therefore supported but in only tenuously.

One can only speculate about whether removing ‘chaos and chaos theory’
from the thesis title, and substituting ‘the relevance of image processing, pattern recognition and shape analysis to financial decision-making in small manufacturing businesses’, would have achieved an identical outcome in providing for their information needs.

3 Limitations of chaos theory

Optimistic expectations and speculation about the contribution which chaos and chaos theory are potentially able to make to financial management have minimal support. Both are restricted by confusion over definitions, inappropriateness in available modelling and analytical techniques, when faced with decision-making information complexity multiple, and sometimes difficult-to-quantify, financial small manufacturing business variables. The greater part of chaos, and chaos theory, is not relevant.

4 Random behaviour in business

Chaos theory does however challenge the entrenched belief that randomness prevails in businesses. Investigation shows that determinism not randomness prevails.

5 Future work

5.1 Testing the technique

If this novel technique is to be tested software, integrating small business account and factory loading procedures with image processing and pattern recognition, needs to be written after completion of systems analysis so that the technique may be field tested. The reluctance of
owner/managers to divulge real data, and their widespread belief that real
data from businesses other than theirs is unrepresentative, means that
realistic synthesised data for cash, liabilities, receivables and factory
loading will be needed for any initial laboratory and eventual field
testing.

Research is also needed to discover ranges of values, and times, as well
as tolerances, which owner/managers expect to be flagged on diagrams
and PC monitors; diagrams which should be described as chaotic. The
results of that research will show whether or not there is a consensus
among owner/managers and peripheral decision-makers as to what they
regard as chaos. The outcome of this survey is expected to be chaotic
bands, similar to those on AQL quality control charts, rather than chaotic
points or thresholds like those mentioned in chaos literature.

Grey scales pictorially indicating the degree of ‘chaoticity’ within the
cells are an alternative to graduated intensity scales below cells.

Specifying correct band widths of tolerances, for processing template-
activity financial information relationships is critical for the success of
the technique. Bands too narrow lead to owner/managers being
bombarded with time-consuming chaotic incidences. Their response to
‘chaotic report saturation’ is abandonment of the technique and reversion
to traditional so-called control methods. The theory of social imitation
suggest that disillusionment would soon be disseminated to
other small manufacturing businesses. Bands too wide fail to detect chaotic situations requiring decision-making attention. The width of tolerance bands should distinguish between significant and insignificant chaos, as understood by owner/managers and peripheral decision-makers.

When a consensus of what constitutes significant chaos is achieved, a software library of non-chaotic, and chaotic shapes, as well as bandwidths together with patterns and pattern sequences, to serve as industry standards, should be compiled so as to provide objectivity when core and peripheral decision-makers interpret the same data. The shapes and sequences provide templates for artificial intelligence, and automatic exception reporting, to owner/managers. Ideally the end result should be standards, British or international (ISOs) similar to those for many artefacts and operations.

In the absence of consensus on what constitutes chaos, software must allow for businesses to make their own templates. The drawback of setting their own parameters is to perpetuate the customary subjectivity which leads to interpretative conflict between core and peripheral decision-makers. 'Two men looked out from prison bars one saw mud the other stars' is an apposite commentary on conflict caused by lack of objectivity. Convention associates entrepreneurs with starry-eyed visions and financiers with muddied pessimism. Examples are on record showing that neither party has
been right all time. Some entrepreneurs succeed despite the pessimism of financiers but other fail.

Small business associations may be willing to co-operate with academe, and open their books, if they are convinced that the outcome of the research will improve their financial decision-making and ameliorate their onerous working lives.

Having established a library of standard shapes and sequences, the next research task is that of applying computational geometry to find complex non-chaotic and chaotic combinations of shapes so as to reduce the computer processing time required to roll forward week by week.

On completion of this work, a Small Manufacturing Business Interpreted Financial Information software package, comprising:-

- Accounting,
- Factory loading
- Bank checking (continuously compounded interest) programs
- Image processing and comparison of patterns, segments and shapes

should be made widely available. 'Chaos' should not appear in its title because the word has adverse, undesirable perceptions for many people and would be commercially detrimental.

Market research is a necessary pre-requisite of a wider release of a software package.
Ancillary research tasks are investigating the man-machine interface because accounting procedures and factory loading, in organisations, are traditionally undertaken by different personnel. The impact of resultant changes in information technology on organisation theory, is one of these ancillary research tasks.

5.3 Success or failure evaluation

Research will eventually be needed to assess whether improvements, in small manufacturing business financial decision-making information, improve their survival rate, longevity and performance. The beneficiaries of such improvements would be owner/managers, and their families, and also employees, released from job security uncertainties, together with the community as a whole.

There are also wider economic consequences to be researched. On the one hand, locally and nationally, success for small manufacturing businesses would result in more disposal income, a higher Gross Domestic Product, fewer demands for social security benefits and increased revenue, for the Exchequer, as a result of higher yields from direct and indirect taxes. On the other hand it is possible that increases in disposal income could add to inflationary pressures.

5.4 Extension to large corporations and more variables

Extension to large corporations, project and fund management, with
more financial variables, and artificial intelligence, is likely to require a major input from academe skilled in fractal geometry, [for shape analysis]

If tests of this small manufacturing business technique prove positive, as is expected, a basis for investigating its extension exists. Large corporations have advantages over small manufacturing businesses. They have a greater number of financial information records which need to be related to one another in analysis and evaluated like the cells in this technique.

5.5 Extension of artificial intelligence

The next stage of development is using higher levels of artificial intelligence, extending over longer time periods, and more variables, to forewarn decision-makers about possible future chaos. Papers on more sophisticated compound curve analysis techniques such as arc vectorisation are now appearing in pattern analysis literature. (Weynin & Dori 1998) In essence arc vectorisation analyses template and actual data curves into measurable arcs. Templates and actual data may then be artificially compared, rearranged and then artificially compared again.

5.6 Developments in hardware

Developments in computer frame stores and increases in processing speeds are likely to benefit the technique. The peripheral arrangement of information cells in G3, Technique Design, assumed the use of a 4096 x 4096 frame store working at 955 frames per second. Current computer processing speeds are not fast enough for all the permutations and
combinations involved when there may be as many as 80 variables. $20!$ produces $2,432,902,008,176,640,000$. When computer processing speeds increase it will be possible to iterate all cells in all possible arrangements in order to discover which combinations of cells are chaotic.
Numbers with outlines are cited in the thesis
Numbers with outlines are cited in the thesis
Null hypothesis: There is no difference between the data taken from random number tables and the synthesis data. If $U > 2$ at the 0.5 significance level the hypothesis is rejected. Rejection indicates that the synthesised data is not random.

<table>
<thead>
<tr>
<th>Sample size</th>
<th>Synthesised data</th>
<th>Random number tables</th>
<th>$U$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Column in Appendix 1</td>
</tr>
<tr>
<td>200</td>
<td>£1,130</td>
<td>£1,751</td>
<td>8</td>
</tr>
<tr>
<td>409</td>
<td>426</td>
<td>7,102</td>
<td>2</td>
</tr>
<tr>
<td>200</td>
<td>8.80</td>
<td>7.45</td>
<td>13</td>
</tr>
<tr>
<td>409</td>
<td>4.36</td>
<td>5.21</td>
<td>12</td>
</tr>
</tbody>
</table>

- Item 1: Value of irregular receipts
- Item 2: Value of irregular payments
- Item 3: Time delay between irregular receipts
- Item 4: Time delay between irregular payments

Formula

$U = \frac{\bar{x}_{\text{random}} - \bar{x}_{\text{synthesised}}}{\sqrt{\frac{S^2_{\text{random}} + S^2_{\text{synthesised}}}{n_{\text{random}} + n_{\text{synthesised}}}}}$

where $\bar{x}$ is the arithmetic mean
$S$ is the standard deviation
$n$ the number of members in a statistical population or sample in Appendix 1

Conclusion: The hypothesis is rejected for all 4 items. The synthesised data is not from the same population as the random numbers.
The key ← → shows the directions in which cash moves. Some variables experience both inward and outward movements of cash. The amplitude, value, of movements differs as do time aspects.

0 bottom limit is zero activity, income or expenditure.

The use of ‘chaotic’, the penultimate item in the key below, is a prelude to a consideration of differences between its technical and ordinary meanings in the Appraisal of Chaotic Postulates chapter.

Key >>>>> disbursements (outward movement of cash)

<<<< revenue receipts (inward movement of cash)

# variable with 0 bottom limit.

( ) negative change

** potentially chaotic when an adverse change occurs.

~ difficult to measure

In many cases, the upper limit constraints are not easily quantified because they fluctuate. Manufacturing and financial capacity, skills and fundamental economic laws of demand, diminishing returns and economies of scale are typical constraints affecting businesses. (Stacey 1992) Using infinity, as in mathematics, fails to overcome the problem of quantifying upper limits because owner/managers have difficulty in empathising with a theoretical concept, which is not a practical reality.

1 Personnel → disbursements

1.1 Attendance
Absence, lateness, short time, withdrawal of labour. #
illness of an employee, or a dependent, transport and
industrial relations reasons affect attendance. **

1.2 Overtime

Prepared to work overtime #
The state of industrial relations, the need for money, continually or only
at holiday times, family responsibilities and attitudes to active and
spectator leisure pursuits eg football matches, are among the principal
determinants.

Range: All employees unwilling to work any overtime **
Some employees prepared to work moderate overtime
sometimes**
Willingness to work amounts limited only by the number of
hours in a day, as and when required.
All employees expect to work overtime.

1.3 Short time

Short-time working arrangements range from reduced pay for reduced
hours to normal pay irrespective of reductions ** in factory loading.
Pay agreements and conditions of employment, for some employees,
determine variations in the working week.

1.4 Performance

Rate of working is affected by motivation, skill, the learning curve, (D 1.3.2)
job satisfaction and financial rewards.
Range: Better than standard (or expected). **
Worse than standard (or expected) **

1.5 Level of ability or skill

1.5.1 Number of personnel available with particular skills 
Training, retention of labour, pay, conditions and geographical location are the reasons for the variation. (Neal 1998)
Numbers are upwards from zero bottom limit **

1.5.2 Learning curve — rate of improvement in skill level over time.
Training, trainability and the frequencies of opportunities to practise a particular skills affect the learning curve.
Better training, all-round employee quality and the higher the frequency with which a skill is practised, are factors contributing to high levels of performance. The opposite applies **

1.6 Versatility
The ability to perform more than one task, or operate differing machines, on a single or multiple activity basis, ranges from single skill ** to multiple skill personnel. #
Conditions of employment, pay and educational achievements are the determinants.

1.7 Labour turnover costs
The reasons for labour turnover are complex **. Pay and conditions, availability of labour, unemployment and unfilled vacancies, “going rates” of pay, and “perks”, together with the image of the business and its
perceived stability, or instability, are some of the factors.

1.7.1 Vacancies.

1.7.1.1 Length of time a post remains unfilled ranges ** #

1.7.1.2 Selection and recruitment costs vary from 0 for recommendation, without the need to advertise or retain the services of employment agents. #

1.7.1.3 Costs of "carrying " unfilled vacancies.

(a) Loss of revenue ** #

(b) Temporary employees ** #

(c) Sub-contractors ** #

1.7.1.4 Cost of inducting and familiarisation of new employees #

1.8 Rates of pay

1.8.1 Premium time for weekdays, shifts and holidays and anti-social hours

1.8.2 Adjustments to retain and attract workers ** # (Meier 1998)

1.8.3 Performance related incentives ** # Fig J12, Non-linearity

2 Premises >>>>>> disbursements

2.1 Maintenance and repairs expenditure

Policies in small businesses vary from practising varying levels of preventative maintenance on the one hand to carrying out only essential repairs on the other. ** In the latter case it is theoretically possible for there to be zero expenditure in a given financial period.

2.2 Periodic Semi-variable costs

Utilities – lighting, heating, metered water and
effluent disposal. The size of the order book, overtime, rate of working, machine efficiency, shift working and weather affect these costs. (Cowe & Weston 1998)

3 Production materials ➔ disbursements

Local, and global, shortages or surpluses of materials, levels of business activity (order books), international economics and the liquidity position of businesses and their suppliers are the complex reasons affecting production variables.

3.1 Delivery time financial penalties

3.1.1 Too early

Implications for storage, and possibly supplier payment.

3.1.2 Too late - ** #~

Implications for financing and storage of delayed work in progress, as well as consequential delays to following orders. Deliveries to customers delayed, and therefore delayed income possibility of cancellations and vendor rating demotion by customers.

Premium payments to personnel to make up time lost whilst awaiting late delivery of goods. ** #

Substitution of more expensive but readily available materials.

Cost of waiting time ** #

3.2 Price
3.2.1 Affected by fluctuations on the commodity, metal and foreign exchange markets. Prices can change in instantaneous jumps. (Gleick 1987, Lye & Martin 1994)

(a) Loss ** (#) Fig J1 (a) Foreign Currency Losses
(b) Gain (windfall profit) # Fig J1 (b) Currency Gains

3.2.2 Subject to suppliers' breakpoints relating to quantity ordered and type of delivery service.

3.2.3 Premium prices for faster than normal delivery but no storage costs.

3.3 Quality penalties and gains

These impact on labour costs material and machine utilisation.

3.3.1 Non – compliance with specification ** # ~

3.3.2 Goods supplied to a superior specification # ~

4 Production process penalties and gains \( \rightarrow \) disbursements

Production process variables are coupled to the personnel, premises and plant factors in a feedback system.

4.1 Duration of manufacturing operations

The actual duration of manufacturing operations, for items in the product mix, ranges from shorter than standard (or expected) to longer **.

4.2 Manufacturing processes

4.2.1 Variation in some manufacturing sequences.

Range of processes to make a product or component in the product mix at a given time. Fig J2 shows the preferred and possible production sequences with alternatives.
Losses resulting from change in £/foreign currency spot exchange rate  

(i) Sale invoiced in foreign currency

Receipt
Converted
To £ sterling

Expected

Actual

Loss of revenue

(ii) Purchase invoiced in foreign currency

Converted to
£ sterling

Actual

Expected

Extra cost
Gains resulting from change in £/foreign currency spot exchange rate

Fig J1(b) 311

(i) Sale invoiced in foreign currency

<table>
<thead>
<tr>
<th>Receipt Converted To £ sterling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>Expected</td>
</tr>
</tbody>
</table>

Gain of revenue

(ii) Purchase invoiced in foreign currency

<table>
<thead>
<tr>
<th>Converted to £ sterling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected</td>
</tr>
<tr>
<td>Actual</td>
</tr>
</tbody>
</table>

Reduced cost
4.2.2 Variation in charge-out rates and cost per piece processed

Range is down, or upwards, from a planned norm, or standard, for a preferred manufacturing sequence to an emergency alternative.

4.2.3 Variation in process times per piece

These are allied to charge-out rates and costs. They range from long set-up times followed by fast processing eg a CNC machine to short set-up times and long processing eg a capstan lathe.

4.2.4 Variation in process times, manufacturing routes and order volume causes unevenness in the loading on manufacturing cells. Not untypical is a mixture of cells where load and capacity are finely balanced, alongside adjacent under- and over-loaded cells in spite of the efforts of production planners.

4.2.5 Variation in queuing time for access to a manufacturing facility.

5 Plant ➔ disbursements

5.1 Efficiency

Range from 0% (total breakdown ** to 100% unlimited efficiency and perfect performance. #

5.2 Suitability for processes

Match, and mismatch, between the specification of the plant and its suitability for required manufacturing operations (range from 0% for totally unsuitable ** to 100% for the ideal).

5.3 Ownership

Liquidity and policies on asset replacement affect ownership.
Notes:
1. The model is based on five processes capable of manufacturing diverse products.
2. The alternatives incur cost penalties so they are potential causes of traditional, ordinary, chaos.
3. * indicates preferred or obligatory manufacturing sequences.

Sequences available

All 5 processes 1,2,3,4,5 *
(No alternatives ie strong coupling between processes)

4 processes 2,3,4,5: 1,3,4,5: *
(1 alternative)

3 processes 1,2,3: 2,3,4: 3,4,5: 1,3,4: 1,4,5: 2,3,5: 1,3,5: * 2,4,5: 1,2,4: 
(8 alternatives ie weak coupling between processes)

2 processes 1,2: 1,3: 1,4:* 1,5: 2,3: 2,4: 2,5: 3,4: 3,5: 4,5: 
(9 alternatives ie very weak coupling between processes)

Number of possible manufacturing sequences 22
Number of possible alternatives 18
5.3.1 Leasing and hire purchase arrangements with variable or fixed rates and de facto fixed duration from a finance company or secondary bank.

5.3.2 Owned by the business.

5.3.2.1 Changes in the book value attributable to depreciation and accounting policies adopted.

Plant written off #

5.3.2.2 Expenditure on servicing and repairs **.

6 Products manufactured ← inward revenue

Propensity to purchase by customers, together with product development investment, and market conditions affect the product mix.

6.1 Product mix

Customer propensity to purchase, terms of trade, investment in product development, the market life of products and market conditions, such as competition levels determine the product mix.

6.1.1 Changes in mix between variable negative (loss-making)** and positive mark-up (profit margins) #

6.2 Manufacturing batch size

Endogenous drivers, such as decisions on levels of inventory in the light of cash available for investment in liquid assets, anticipated future sales demands, target levels of service for deliveries to customers, machine loads, and capacity, and the retention of labour, when order books are low, are the principal determinants of batch size. ~ Exogenous drivers are customer orders.
6.2.1  Quantity ranges upwards from 1 piece to many.

6.2.2  Charge out rates increase when alternative facilities have to be substituted, and sequences changed, because the plant or process specified is not available eg in times of overload or non-availability of facilities.** (Paragraph D4.2.1 above)

6.3  Manufacturing policy

6.3.1  Make to order or for semi-finished or finished stock affects level of work in progress and sales revenue. Sales revenue is maximised and work in progress minimised and premium costs avoided when inventory and sales are in equilibrium.

6.4  New product introductions

6.4.1  Design – short or long ** duration low or high cost # ~

6.4.2  Testing and prototyping time and cost ~

Range: Trouble free with no unforeseen difficulties and costs Extensive unforeseen, and unforeseeable, problems

6.5  Position in the logistical chain

6.5.1  Ranges from being the first tier manufacturer, processing raw material, to the one at the, next to the end user at the top tier, and therefore the first to react to market change on a macro scale eg changes in money supply and interest rates.

6.6  Balance between size of order book and manufacturing capacity

Order book ranges from 0 **, no load, through perfect match between facilities and load, to varying amounts of overload The feedback, due to
discrepancy between actual and desired output, is either late deliveries (and justifiable later payments by customers) or premium time where the physical and human resources make this correction possible.

7 Marketing ← disbursements and revenue receipts

7.1 Expenditure

Liquidity (surplus cash and borrowing facilities) of business, type of product, current and optimum market penetration and target market location cause expenditure to vary.

(a) Ranges from £0 00# to very high

(b) Performance incentives for sales personnel #

7.1.2 Advertising

7.1.2.1 Revenue generated by advertisements ~

The buoyancy of the market, the suitability of the advertisement form, and choice of medium affect the amount of revenue generated.#

7.1.2.2 The actual cost of advertising ranges from no charge for recommendation, free listing in directories and free editorial in magazines # The cost then rises through paid advertising in magazines, directories, newspapers, direct mail telesales and the INTERNET. It is determined by factors such advertisement size, colour and print run for printed media, the size of the database for direct mail, elapsed time of telesales, and involvement of outside agencies.
The effective cost = \text{Actual cost.} \\
Life of the advertising medium \\
It varies from very short for tele-sales to very long for 
directories published annually eg Engineering Buyer’s Guide.

7.1.2.3 The effectiveness of the advertising ranges from totally ineffective **to 
better than expected ~

7.2 Customer base

7.2.1 Number of active income generating customers ranges upwards from 
0** # (Dewhurst & Burns 1993)

This is another example of interacting variables. Product quality, price, 
promotion, levels of service and number of alternative sources, prevailing 
economic conditions and manufacturing capacity affect the number of 
active customer accounts.

7.2.2 Split between customers measured by value.

7.2.2.1 Major and minor: Range: from 0% major 100% minor to 
100% major 0% minor

7.2.2.2 Domestic and export (affected by foreign exchange fluctuations if £ 
sterling unacceptable to customers) Figs J1 (a) and (b) 
show the effect of changes in spot rates.

7.2.2.3 Frequency and regularity (or irregularity **) of ordering

7.2.4 Support required to retain and develop customer loyalty 
so as to minimise risk of defection to competitors and slippage from being 
a principal, preferred supplier to only a secondary, emergency only
7.2.5 Customer behaviour

7.2.5.1 Ranges from single delivery small orders to firm, extended order, immutable cover for several future deliveries of differing quantities.

7.2.5.2 Characterised by cancelling and bringing forward of required delivery times, with notice given, without reference to manufacturing lead times. Fig J3 illustrates the range of possible customer and credit controller actions.

7.2.5.3 Anecdotal evidence supports theories of escalating success and accelerating failure. The old adage, 'success breeds success' has business manifestations in that satisfied customers progressively increase trade with good suppliers whereas dissatisfied ones desert failing suppliers with increasing rapidity. Fig J3, Adjustment Choices illustrates the two types of response.

7.2.6 Logistical policy of customers

7.2.6.1 Inventory policy

Ranges from JIT (Just In Time) stock or reserve stock on own or customer premises.

7.2.6.2 Hysteresis

Exemplary service by a small manufacturer causes customers to add their name to list of preferred suppliers and its elevation to a higher rank.

(a) A level of service below customer expectations leads to permanent
Choices available for amending time and value parameters by customers and credit controllers

VALUE

Increase

TIME [.....|......] NO CHANGE [.....|......] time intervals

Bring forward

Delay

0
Cancellation/Indefinite suspension

Dec decrease

Note: Time and value may be combined eg order quantity increased but delivery time delayed
7.2.6.3 Strength of coupling or bonding with customers ~

In decreasing order of strength are: monopoly, duopoly, oligopoly, principal supplier, second source, personal customer-supplier relationship with one of very many, practically uncountable suppliers as the weakest.

7.3 Market trend

7.3.1 Shrinking market for obsolete products declining towards zero ** # ~

Product life cycles are becoming shorter. (Von Braun 1990)

7.3.1.1 Increasing market share for manufacturers remaining after others have withdrawn.

7.3.1.2 Decreasing market share if manufacturers continue in the market and invest in competition to maintain original levels of sales turnover.

7.3.2 Expanding market for new products.

Range upwards from zero # ~ (Boswell 1972 )

8 Financial flows and structures

← revenue receipts → disbursements

These are affected by liquidity, assessments of credit worthiness, (Business Ratios 1986) their enforcement by in-house credit controllers, invoice factors and discounters, magnitude of external borrowings, magnitude of liabilities and the size of the order book. If external borrowings are approaching the limit and/or unusually large sums paid eg Corporation Tax, businesses take a "tough line" on credit **.
8.1 Payment practices and polices affecting suppliers and customers

Fig J4, Cash Flow Permutations and Combinations, refers.

8.1.1 Payment in advance of receiving goods

When demanded by suppliers

8.1.1.1 With order.

8.1.1.2 On delivery eg Cash on Delivery, irrevocable letters of credit, proforma invoice.

8.1.1.3 Amount ranges from a nominal deposit to full payment.

8.1.2 Deferred (credit) terms

8.1.2.1 Range from 7 day accounts to net monthly for domestic customers to longer periods for promissory notes and letters of credit (documentary credits).

8.2 Payment behaviour

8.2.1 Ranges from payment in accordance with contractual terms with 0 delay to deliberate delays until recovery proceeds are imminent, activated and judgements enforced.

8.3 Assets

8.3.1 Value of liquid assets

8.3.2 Revenue generating propensity of fixed assets

8.3.3 Market value of intangible assets

8.3.4 Effect of operational cash flow of over-investment in fixed assets

8.4 Funds

8.4.1 Changes in interest rates and premiums charged by lenders
A  **Irregular payments involving customers and suppliers**

Note the number of variables.
Choice of payment method can reflect a payer's aim to delay payment for as long as possible eg cheques in the post and their presentation take longer than BACS.

<table>
<thead>
<tr>
<th>POSSIBLE TERMS OF PAYMENT</th>
<th>EXTENT</th>
</tr>
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<tbody>
<tr>
<td>Advance with order</td>
<td>Full</td>
</tr>
<tr>
<td>Progressive staged during manufacture</td>
<td>or part</td>
</tr>
<tr>
<td>On delivery</td>
<td></td>
</tr>
<tr>
<td>In Arrears</td>
<td></td>
</tr>
<tr>
<td>Within 7 days with cash discount</td>
<td>payment</td>
</tr>
<tr>
<td>30 days net</td>
<td></td>
</tr>
<tr>
<td>Net monthly account</td>
<td></td>
</tr>
<tr>
<td>On acceptance (payment of retainer)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PAYMENT BEHAVIOUR METHODS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pay before due date</td>
</tr>
<tr>
<td>Pay on due date</td>
</tr>
<tr>
<td>Pay after due date</td>
</tr>
<tr>
<td>Within reasonable time</td>
</tr>
<tr>
<td>After threat</td>
</tr>
<tr>
<td>After litigation</td>
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<td></td>
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</tbody>
</table>

B  **Regular periodic payments**

VAT is excluded because several options are available.
Payees are able to impose sanctions for default.
Business rate is collected in 10 monthly instalments.

<table>
<thead>
<tr>
<th>PERIODICITY</th>
<th>TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annually</td>
<td>In advance</td>
</tr>
<tr>
<td></td>
<td>Most insurance</td>
</tr>
<tr>
<td>Quarterly</td>
<td>Rent</td>
</tr>
<tr>
<td></td>
<td>Some hire purchase</td>
</tr>
<tr>
<td>Monthly</td>
<td>Business rate</td>
</tr>
<tr>
<td>Weekly</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: DD Direct debit  SO Standing order

BACS  Banks' automated clearing system  NHI  National Health Insurance
Macro economic changes are passed on, at the micro level, to businesses whose borrowings track changes in the bank rate.

(Calcagnini & Iacabucci 1997) Fig J5, Changes in Overdraft Rates refers

8.4.2 Availability of short, medium and long term funds

8.4.2.1 Changes in money supply at national level.

8.4.2.2 Changes in the perceptions of risk by providers of finance and the length of time for which borrowing is permitted range from aversive to risk seeking.

8.4.3 Available operational cash balance

Cash in bank + cash on premises + permitted borrowing

8.4.4 Capital introduced initially

Ranges upwards from statutory minimum for an incorporated business.

Grants from local, national and international agencies. The type of product and the geographical location of the manufacturer and the size of the fund affect grants. Personal capital introduced has its own set of variables. Typical sources are savings from previous employment, redundancy payments, legacies, cash realised by the sale of a previous company.

The financial energy of a business depends on the available operational cash balance and the capital introduced. A business constrained by cash shortages and liquidity problems has less energy. It is unable to do what other, less constrained, businesses do. For example its
Notes: Interest rates are continuously compounded (exponential)
The amount borrowed remains unchanged i.e. no credits or debits so the indebtedness continues to increase but at different rates
Higher rates have tighter curves
promotional expenditure is curtailed: it is unable to realise economies of scale when buying goods and services, pay the going rate for personnel.

8.4.5 Earnings

The range of earnings varies from making losses to profits. All the above variables feedback to earnings.

8.4.6 The sources of funds varies from total independence of external sources to maximum high gearing.

9 Parameters

Parameters are either constant or almost constant whereas flow variables fluctuate. None of the items in the schedule above are permanently fixed parameters. Those variables in the groups which might be more accurately designated parameters instead of variables are considered below.

9.1 Personnel

At any one time 'All employees unwilling to work any overtime' constitutes a fixed parameter but the resolve of employees changes. The resolve may persist because of resentment after a period of no overtime or short time working but its breaks down when extra money is needed to pay for annual holidays or Christmas festivities.

9.2 Premises

Premises are only constant for a time. When a small amount of extra space is needed planning permission is invariably forthcoming for temporary buildings outside a factory. Inside mezzanine floors are installed to increase working area. Another method, a more expensive
one, is to operate a second site.

When premises are too large, areas are sub-let to other small businesses.

9.3 Production processes and plant

Feeds and speeds are one part of the production process which are a parameter in the sense that they are constant given optimum tooling, production materials and plant. In factories continuously manufacturing only one product, feeds and speeds are a parameter. However in the vast majority of factories, changes in set-up times support the view that production processes, and plant, should be treated as a variable not a parameter. Set-up times depend on preceding jobs. Manufacturing a product very little different from the previous one on a machine, means minimal set-up time. On the contrary a product vastly different from its predecessor requires extensive machine changeovers.

9.4 Products manufactured

In an ideal factory, insulated against the impact of technological and market changes, products would be designated parameters. In practice technological, and market, changes not only affect individual products but also cause product mixes to vary in accordance with customer behaviour. The product mix is therefore a variable, not a parameter.

9.5 Financial borrowing facilities

Viewed apart from other elements in a financial packages, loans are constant parameters, especially when interest rates are fixed for a specified
term and they are properly serviced by borrowers. However reasons for treating borrowing as parameter disappear because loans are part of a financial package comprising overdraft and capital from internal sources. As overdrafts and capital from internal sources, eg owner/manager’s own money, vary the borrowing package as a whole varies. Maximum overdraft borrowing facilities are only fixed for a stated term eg 12 months interest rate change cause them to vary. Borrowing is therefore treated as variable in this thesis with limits on it acting as a fluctuating de facto financial boundary or parameter.

Fig J6 Chaos Generating Factory Loading

The optimum is Factory load = Factory capacity However owner/managers have their own mental, unwritten benchmarks are to what constitutes chaos. Factory loads > 60% capacity or Factory loads < 30% capacity are typical benchmarks demarcating chaos as conventionally perceived.
Chaos generating factory loading

% Excess factory load = chaos

130

___ Optimum Load = Capacity ___

60

Inadequate factory load = chaos

0

Benchmarks vary with business scenarios. Loading on a standby, normally unused simple machine is much less critical than that on a newly installed numerically controlled, fully tooled machining centre.
Definition of Decision-making

Chaotic similarities are shown in [italics] The majority are attributes of chaos, rather fewer refer to its causes eg parameter interaction and context eg boundedness. (Disagreements between those who contend that chaos is bounded, and those who do not, are appraised in (E) Appraisal of Chaotic Postulates.)

# indicates the three aspects which would be changed for the better if chaos theory is found to be relevant.

Decision-making is a voluntary or mandatory (D10 1983, Abbott 1986)

often polyphase [several time series] (Dutton 1988, March & Shapira 1987)

smooth or interrupted [irregular] (Rowe 1989)

dynamic activity, or chain of inter-related activities [parameter interaction] (Bateman 1986, Keeney 1982)

varying in duration, [transience] frequency,

velocity, (Bourgeois & Eisenhardt 1987)

amplitude [intensity] and (Shirley & Kinnunen 1974)


crucial for organisational survival (Kayaalp 1987)

with single or multiple objectives (Easton 1973, Jones 1972)

usually multiple criteria [parameters] (Gemunden 1985, Barrow 1987)

often made more by chance, than by rational organisational action # (Axelsson & Rosenberg 1979)

with inadequate information # (Smith 1989, Weber 1987)

in form, either prescriptive, normative or descriptive, reactive [parameter interaction] or
proactive (McKenna 1987)

varying in quality from wholly good to very bad [irregular],
invariably much influenced by the environment [bounded] and
the need to negotiate a path through an uncertain [unpredictable]
(Lindsay & Norman 1972, Bell 1985)
constricted [bounded], (Granelle 1973-4)
sporadic [intermittent] or, less (Holloway 1979, Mintzberg 1976)
frequently, an unrestricted context (Kiesler & Sproull 1982)
ocasionally involving conflict, [parameter interaction] (Bennett & Cropper 1987)
regret and disappointment (Bell 1985)
undertaken by authorised personnel with differing attributes, styles
and abilities (Lindsay & Norman 1972, Mullen & Strumpf 1986-7,
and commitment but (Janis & Mann 1977, Wood & Bandura 1989)
increasingly taken artificially, or with the aid of computers
manipulating, algorithms, models # shells, decision analysis and
support systems# (Harris 1975, Keeney 1982, Barki & Huff 1990)
on behalf of their own, or other (Choffay & Lilien 1985)
businesses (Carbonell 1989, Goslar et al 1986, Parker & Al-Utaibi 1986)
when sufficiently stimulated by (Howe & Cohen 1990)
problems, goals and opportunities [determinants]
to make an immediate, or delayed response (Cyert 1956)
and manifesting itself, sometimes after finding
only one possible solution,  (Simon 1959)
but, at other times, after evaluating alternatives
in choices                         (Encyclopedie cybernetique 1960)
known as decisions which may,
or may not, be implemented         (Brech 1975)
1.1 Definitions of chaos

Definitions aim for objectivity: they state the precise nature of something. Perceptions are more subjective; intuitive recognition is their hallmark. The diversity of definitions of chaos is one of the difficulties mentioned in the chapter on methodology. The word itself has very little explanatory power, (Thom 1987); hence the need for definitions.

For one author the outcome of the diversity makes definition an impossibility. ‘I may not be able to define chaos, although I know it when I see it’, (Robinett 1997) may be subjective but it illustrates the difficulties encountered when addressing the definition issue.

Unfortunately there is no agreement about definitions of [technical] chaos. (Mees 1981, Isham 1993) Some of them are contradictory eg whether or not chaos is bounded or unbounded.

1.1.1 Definitions in the literature

One of its simpler definitions makes the distinction between chaos and chaos theory. ‘Chaos is a condition. Chaos theory is a collection of mathematical and numerical techniques that allows us to deal with non-linear problems to which there are no explicit solution’. (Cambel 1993)

The diversity, and abundance, of definitions of chaos is, in one respect, advantageous, although confusing in others.. It provides fragments for possible selection and assembly into a composite definition.
comparable in detail to that for financial decision-making.

A critique of this plethora of definitions illustrates the non-availability of a ready-made consensus definition for a research topic such as this thesis. However it is advantageous in that it becomes a catalogue of what is available for possible incorporation into a tailor-made business chaos definition.

Some of the definitions of chaos are broad, others more specific eg 'dynamical chaos is the appearance of apparently random motion in a deterministic dynamical system'. (Chernikov et al 1988) Businesses are both deterministic and dynamic.

Some refer to its dynamics, others to its static visualisation. Some include only one of the attributes of chaos, such as irregular behaviour, (Rasband 1990) others more. 'A non-linear deterministic process that looks random', (Hsieh 1991) includes two attributes. The use of 'random' is unfortunate because, in English usage, it means haphazard; stochastic, a more precise term for 'random', does not have 'random' connotations.

Some definitions reflect an author's academic affiliation. 'Chaos: in a very general sense a dynamic system is a map of a set into itself', (James, R C 1992) and 'Chaos is a mathematical phenomenon', (Casti 1989) are definitions by mathematicians. To an owner/manager a map is
a geographical document, not a dynamic rule for obtaining an image point or map of a function. (Rasband 1990)

'A heuristic definition of chaos is behaviour over time that appears random but is actually deterministic' is published in the Journal of Economic Behaviour and Organisation. (Shaffer 1991) That definition matches the oxymoric attribute of chaos, [the paradox between deterministic order and stochastic disorder]. (Polkinghorne 1994)

A definition, in the context of sensory perception, is application specific 'Chaos is the basic form of collective neural activity for all perceptual processes and functions'. (Skarda and Freeman 1987)

A further problem is that the definitions do not all use the same base and format. Some definitions focus on where chaos starts, its causes and initial conditions, eg 'deterministic chaos is sensitive dependence on initial conditions' [where it starts], (Physica 1983) others on its evolution. 'Determinism is an intrinsic feature of chaos'. (Parker & Chua 1989)

The definition in the Academic Press Dictionary of Science and Technology is based, not on initial conditions but on its subsequent dynamical evolution and two of its attributes. (Morris 1992)

The majority of definitions adopt the form - Chaos followed by a definition However a few insert an attributive, adjectival qualification
of chaos before completing the definition. ‘Deterministic’, (Physica 1983) and ‘dynamical’, (Chernikov et al 1988) are two such adjectives met in definitions of chaos. However if these two attributes are used in definitions other attributes, such irregularity, changeability, transience, irregularity should also be included in them to ensure complete coverage.

Some definitions are simple positive statements such as those above with only one adjective; others are more complicated. Comparisons and negatives are used in complicated definitions to distinguish between non-linear attributes of chaos and its random appearance. The ‘science of erratic movements, is a broad definition, (De Gennes 1994) based on one attribute, erratic movements; ‘Positive metric entropy’ (Farmer 1982) and ‘systems with a positive Lyapunov Exponent’, (Seydel 1994) use few words but are restricted, mathematical ones incomprehensible to owner/managers.

The lack of consensus is also seen in the number attributes of chaos appearing in the various definitions. The ‘science of erratic movements’ and ‘exponentially sensitive dependence on initial conditions’, (Ford 1986) include only one of the attributes, ‘constrained instability’ (Stacey 1992) ‘irregular, unpredictable behaviour caused by inherent non-linearities in a dynamical system’, (Rasband 1990), ‘a non-linear, deterministic process that looks random’ three, (Hsieh

Although mentioning only one of several attributes found in small manufacturing business Stacey’s definition is a better fit for small businesses than Parker and Chua’s because they are bounded, endogenously and exogenously, by fluctuating constraints on core and peripheral decision-makers. In business the bounds and organisation bands are not immutable. Agreed prices and borrowing arrangements are subject to review, and amendment, on or after a stated date. They are elastic parameters not the fixed ones of science. Similarly changes in personnel, fixed asset investment and trading conditions affect organisational structures.

Items described in Small Manufacturing Businesses Financial Diversity epitomise the endogenous boundedness associated with values and time. Liquidity is one boundary, factory manufacturing capacity another. Both are measurable in a business. Collision with these upper boundaries has a skittle effect on related boundaries. Cash shortage imposes limits or promotional activities and resources cutbacks. Shortage of manufacturing capacity or its misuse has a skittle effect on
deliveries, analogous to cascading chaos, because lead times become protracted.

In addition to endogenous boundaries are exogenous ones which are expensive to quantify. For example market research companies use direct mail to advertise their reports on the size and characteristics of markets for particular product groups eg fibre optic communications which they have researched. Owner/managers, when required by financiers to prepare business plans, invariably resort to self-help and best estimates of the size of markets which they plan to enter or increase their presence. Market share is another exogenous boundary which is difficult to ascertain without dedicated, and usually expensive, market research unless a business is a monopoly supplier.

Decision-makers on the periphery, customers, suppliers and financiers, impose other exogenous bounds, or limits, on the whole business as a trading unit eg through the orders which they place, payment terms which they accept (and impose) and permitted borrowing facilities. These match static variables, parameters, which are stationary for a designated period. (Ditto & Pecora 1993) Dynamic variables such as liquidity and order cover are those with short term fluctuations. Business cycles are dynamic variables which fluctuate in the longer term.

The disparity between random appearance and deterministic underlying
order, a chaotic phenomenon, to which attention is often drawn, is expressed in another definition. 'A non-linear deterministic process that looks random' is called oxymoric, ordered-disorder, by one author. (Polkinghorne 1994)

Analogies with turbulence, do little to resolve differences between the numerous definitions of chaos. 'Turbulence in fluid dynamics generally means spatio-temporal chaos', two dimensions, (Tabor 1989) compares with 'turbulence is now considered a case of spatial chaos', one dimension. (Schroeder 1991) The academic context in which 'turbulence' is used compounds the problem. Mathematical chaos is said to be primarily concerned with random behaviour in time, one dimension only, whereas physical turbulence adds stochastic spatial behaviour as well. (Casti 1989) 'Chaos is a dynamic term for describing such turbulent phenomena as weather', (Crownover 1995) fails to take into account differing perceptions of turbulence in a small country such as the British Isles.

The perception of weather turbulence is an unreliable analogy because inhabitants of exposed coasts and uplands are accustomed to severer forms of weather turbulence than the population of the industrialised English Midlands which occasionally experience a stormy night, with above average wind speeds. Significant proportions of the workforce in the English Midlands are natives of these exposed areas. As perceptions of
weather 'turbulence' vary it is unwise to use it as analogy for chaos. 339

Dissension associated with the use of 'turbulence' has even led to a proposal to impose restrictions on its use. (Bohr 1991) The absence of references to 'turbulence' in this thesis is in response first to Bohr's proposal and secondly to references, such as Casti's, to stochastic and random behaviour which do not apply to deterministic business financial dynamics.

In addition to these qualitative definitions there are some quantitative definitions eg Lyapunov Exponents. Fig E3, Lyapunov Exponents, refers. Bands of numerical values are at the foot of the page.

One way of escape from the definition impasse is to define chaos by default. 'Chaos and chaotic should be reserved for systems that cannot be described either quantitively or qualitatively'. (Thom 1987)

Applying this to small manufacturing businesses would result in their being chaotic all the time for two reasons. First difficulties obstruct quantification of many variables to describe so any quantitative description is inevitably incomplete.

Qualitative description is not a substitute for quantitative. It suffers from lack of objectivity. For example a young, inexperienced owner/manager considers order intake to be irregular, in time, whereas an experienced one looking at the same record regards it as normal.
1.2 Perceptions of chaos

Unlike definitions of technical chaos, the standpoint from which this chapter began, perceptions of ordinary chaos are often, although not always, associated with troublesome situations, similar to Ford’s historical chaos. He makes a distinction between ‘historical’ and ‘chaos at a more technical level’. (Ford 1986) ‘Historically chaos has meant irregular, erratic, disordered or seemingly unpredictable’ is an accurate observation but it understates the persistent, incessant equating, in the financial, broad sheet and popular press, of chaos with disorder. Polley’s pointing out the risk associated with the metaphorical use of scientific terms is salutary, (Polley 1997) because anecdotal evidence points to a falling back on perceptions of historical chaos to fill the vacuum caused by the lack of consensus on the meaning of technical chaos.

‘Chaos’ was in the English language long before it came into common use to describe road and air traffic disorder, stock market upheavals, market chaos, (Nee-Gieringer 1989) and as a pejorative for weak business management. These are but a few of the examples of the metaphorical use of ‘chaos’. Dr Samuel Johnson defined chaos as ‘irregular mixture’ in his dictionary published in 1755. Pre-dating Dr Johnson’s Dictionary, by almost 400 years, was a definition of ‘chaos’ as ‘the state of confusion before the organisation of the world’. (Imbs 1997) It appeared in 1377, in a dictionary of the French language published during the long occupation of large parts, of what is now France, by the English at a time when there were
close links between the intelligentsia. Annexure J2 letter of 21 01 99 refers

Although first associated with historical chaos, 'irregular', 'erratic' and 'unpredictable' are attributes matching the current experience of small manufactures of car components, and also large corporations. For example suppliers of parts for models, no longer available in MEDCs (More Economically Developed Countries), but licensed for local assembly in an LEDC (Less Economically Developed Country), experience stop-go manufacturing situations because credit lines are exhausted before a follow-on ones became available. Meanwhile parts manufacture is suspended and no-one is able to predict when it will resume. Financial decisions affecting personnel, materials, premises and plant ensue.

'Chaos' is also used pejoratively. When interviewed, employees, not infrequently, tell visiting consultants about the chaos on the shop floor where they work. Reliable information, to support their opinion, is not often forthcoming.

1.2.1 Beneficial perceptions of chaos

Contrasting with those who regard chaos with trepidation, are those who claim benefits for it. In 1907, many years before the need to distinguish between technical and common or historical chaos arose, Henry Adams wrote about a beneficial outcome of chaos. 'Chaos brings order'. In other words chaos has a beneficial backlash.

Eighty five years later, but in similar vein Stacey writes, '[management]
systems develop over time by passing through times of instability, crisis or chaos new forms of order and directions spontaneously'. (Stacey 1992)

He takes it further. 'That chaos has much to do with success can be seen by considering the nature of decision-making, or control processes, appropriate for conditions of great uncertainty.

He is not alone in recognising the contribution of chaos to success.

'Excellent firms of tomorrow [that includes small manufacturers] will cherish impermanence and thrive on chaos'. (Peters 1987)

Creativity is one of the benefits of chaos acknowledged by more than one scientific author. 'Innate creativity may have an underlying chaotic process'. (Crutchfield 1986)

Another advocate of the benefits of chaos, writing about continuous system modelling, without specific reference to management or business, also singles out creativity.

'Without chaotic feedback we never create new or original ideas'. (Cellier 1991)

In a chapter on the virtues of chaos first it says, 'It [chaos] can be functional and adaptive' and secondly 'Chaos offers a new approach to modelling erratic processes'. (Garfinkel 1987)

As multi-purpose flexibility is essential to higher life forms, there is speculation that chaos may be a necessary ingredient in the brain. (Ott, Grebogi & Yorke 1990)
1.2.2 Neutral perceptions of chaos

A paper, on one dimensional chaos in a bank account earning interest on a credit balance, comment neither on the benefits or drawbacks of chaos. (Tofallis 1995) Chaos is seen as purely technical and divorced from innovation, creativity and foreboding. Neutrally perceived chaos has no relevance to financial decision-making in small manufacturing businesses. The large receipt of £22,012 on Day 517, although technically chaotic, would be described in euphoric terms by a grateful owner/manager because 364 days of uninterrupted positive cash balances, except for day 598 (£127 deficit) ensued. Appendix 1 refers. Diagrams in the paper, depicting growth in interest show, a linear relationship when, in practice, continuously compounded interest produces an exponential curve.

1.2.3 Sceptical perceptions of chaos

Beneficial perceptions of chaos do not have unanimous support.

Three contributors to publications on chaos in [human] brains are less than enthusiastic about the benefits of chaos. As decision-making is largely dependent on human involvement, their observations are helpful. ‘The capacity to respond to both novel and familiar inputs can exist even in the absence of chaos’, (Levine 1987) and ‘chaos can be overplayed’, (Perkel 1987) illustrate the reservations. A possible explanation for them is the difficulty in assessing whether chaos occurs in behavioural processes. (Mpitsos 1990) But even in fluid
dynamics, where there is no personal involvement, the usefulness of studies of chaos, in simple dynamical systems, is questioned. (Fowler et al 1983)

Similar misgivings have been expressed on the subject of chaos in markets These misgivings question the very existence of chaos by suggesting that it is mistaken for cycles of long periodicity. (Currie & Kubin 1997)

Chaos is aperiodic

1.2.4 Foreboding perceptions of chaos

Anyone who has been exposed to the Arts, either for pleasure or in connection with preparing for GCE ‘O’ levels or GCSE examination will be pre-conditioned to perceive chaos as a detrimental disorder. Typical quotations from well-known poets and dramatists illustrating this pre-conditioning are:

‘chaos is come again’ (Shakespeare in ‘Othello’)
‘frighted the reign of chaos’ (Milton),
‘chaos of thought and passion all confused’ (Pope)

Other author’s such as De La Mare and Byron have similar perceptions of chaos. In music, Haydn’s oratorio begins with

‘Representation of chaos’

In addition to extracts from the arts illustrating foreboding perceptions of chaos is one from the world of international business and politics. In launching the famous Marshall Plan in 1947 George Marshall announced ‘our policy against desperation and chaos’. (Beck 1980)
Evidence in today's media points to chaos as being a reality, more to be feared than welcomed.

Field work in small manufacturing businesses indicates that forebodings have an experiential base. They are connected with clashes, interaction, between limits on availability of resources, boundaries, and demands for them. Non-availability of funds, a financial resource causes owner/managers to try, not always successfully, to find additional financial facilities, especially when sales order books are over-full. Shortage of manufacturing capacity, another boundary, is a potential cause of chaos when order books are full. The demands of customers, for delivery of goods, collide with manufacturers' capacity ceilings.

At the other extreme, to excessive demands, is chaos resulting from the impact of cancellations or unexpected surcharges, levels of activity below those required to break-even, excess surplus capacity and insufficient order cover. The break-even point is another de facto floor boundary.

Fig J7, Conventional perceptions of chaos, shows chaos as perceived by three different groups - an owner/manager, a banker and accountant

Excessive demands on all resources - financial, human and physical - and excess surplus capacity are both stressful scenarios for owner/managers. As these scenarios are conventionally chaotic, owner/managers are
Conventional perceptions of chaos

(a) Owner manager
Chaos a mixture of:
- Extended credit taken by customers
- Insufficient working capital
- Insufficient income
- Insufficient borrowing facilities

Value

\[ \begin{align*}
\text{Value} & \quad \text{Payment received} \\
+ve & \quad \text{Supplier paid} \\
-ve & \quad \text{Deliveries resumed}
\end{align*} \]

\[ \begin{align*}
\text{Disbursements} & \quad \text{Unable to pay supplier}
\end{align*} \]

\[ \begin{align*}
\text{Time} & \quad \leftarrow \text{Deliveries} \rightarrow \\
\text{Credit} & \quad \text{Never in credit}
\end{align*} \]

(b) Banker
Chaos a mixture of:
- Account persistently in debit, never in credit
- Requests for additional borrowing facilities

Credit

\[ \begin{align*}
\text{Credit} & \quad \text{Never in credit}
\end{align*} \]

\[ \begin{align*}
\text{Debit} & \quad \text{Balance always at or near borrowing limit}
\end{align*} \]

\[ \begin{align*}
\text{Additional borrowing requested & refused}
\end{align*} \]
Chaos a mixture of:- Insufficient working capital
   Over investment in illiquid assets – under
   utilised and depreciating machines, slow moving
   stock, aged sales debts – all attracting CCIR
   [continuously compounded interest charges]
   Inadequate ROCE [Return On Capital Employed]

Value

\[ \frac{\text{Required income from over investment in fixed assets}}{\text{Actual average income from assets based on demand minus interest charges}} \times \text{Time} \]

\[ \text{SHORTFALL} = \text{CHAOS} \]

Owner/managers would be more inclined to describe the persistent, and
increasing, negative cash balances from Days 881 to 1792 in Appendix 1
as stressful rather than chaotic because in their position such relentless
cash problems are chaos personified.
justified in having foreboding perceptions of chaos.
1.3 Types of chaos

Attempts to demarcate one type from another are based either on the two major scientific systems, classical and quantum, or spatio-temporal parameters. ‘Classical chaos is at the macro level, quantum chaos at the micro’. (Gutzwiller 1992) This demarcation between macro and micro is not clear cut, in finance, because macro systems consist of an enormous number of the same currency units [quantum particles] They only differ in that the denominations are larger. Further problems are:

- Dissimilarity between the jagged waves in Fig J8 (a), Daily cash Balances, and Fig J8 (b), Cash balance every tenth day, and smooth waves as in quantum chaos. (Gutzwiller 1992)

- Absence of a mathematical definition of quantum chaos. (Adachi 1990)

In non conservative systems, a classification based on energy, the implicit separation between macro and micro breaks down because there is an information flow between them. (Shaw 1981) The way in which macro monetarism impinges on micro business variable rate borrowings, and cash deposits, the day after changes in interest rates by the Monetary Policy Committee, indicates not separation but strong coupling between macro and micro. The infrastructure which transmits chaos from international and national organisations to small manufacturing businesses also transmits changes in the cost of money.

Using the familiar handshaking parameters, time and value, instead of only
Cash Balance

Every Tenth Day

Note: Numerous spikes and no "plateaux"
Daily Cash Balance
(in Synthesised Data
Appendix 1)

Note: Numerous "plateaux" but no spikes
energy, to measure business chaos, would be satisfactory if a definition were available. The simplest scenarios, and models, show interplay between these two dimensions, time and value, for a few variables; the more complex, far more. For example a shortage of working capital, a value dimension, results in manufacturing delays, a temporal effect, which is then projected onto incoming receipt delays, for goods supplied on credit, and ultimately cash balances. Fig J7 (a) Owner/manager’s perception of chaos shows the interplay.

1.4 Onset of chaos

Sources, causes, routes and conditions are the four constituents for the onset of chaos. Fig J9, Onset of chaos, extracts the salient points from the literature.
Onset of Chaos

Potential Sources of Chaos

Erratic time and value dynamic flows

in the

Conditions Ripe for Its Onset

Causes Triggering Onset

(1) Single point perturbation and/or (2) Parameter interaction
   (a) Small butterfly effect
   (b) Bigger upheaval

Possible Responses to Chaos

(1) Complete or (2) Partial or (3) Onward transmission absorption damping

across

Chaos/No-chaos Threshold

Manifestation if Threshold is Crossed

in

Business situations Systems

Subsequent Evolution

(1) Growth or (2) Steady continuous chaotic state or (3) Decline

There is said to be a threshold at which chaos occurs. (Huberman & Zisook 1981) One side of the threshold, a demarcation line, is chaotic, the other not. Summit is better descriptor than threshold because chaos is reached after a culmination of dynamic changes.
The pre-requisite for identifying any threshold is the ability to distinguish between the two sides, chaos and no chaos. Making the distinction depends on having possible a formal definition by which chaos may be identified. The working definition of chaos, as applied to small manufacturing businesses is at best a demarcation zone. It is too imprecise to be likened to a threshold and bears no resemblance to nominal dimensions and go/no-go gauging in engineering, a sector well represented amongst small manufacturing businesses.

1.4.1 Sources

The absence of consensus, already noted in other sections, is also found in the debate on the sources of chaos. Two authors, writing from a generic systems standpoint, state that dissipative systems, described by non-linear equations, are the source of both order and deterministic chaos. (Coveney & Highfield 1995) But the sub-section below, on the manifestation of chaos, shows that it is present in feedback systems, a classification fitting small manufacturing businesses. If that is the case, there are two possible explanations. First the sources of chaos are not confined to dissipative systems. Secondly chaos originates in dissipative systems which subsequently change to another type of system. The first explanation accords with chaos occurring in business feedback systems and not being confined to dissipative ones.

The second explanation reflects the evolution of a business.
of Taxes are aware that new businesses incur trading losses for a time after commencing to trade. In chaos language, they are dissipative. But while 'dissipation' describes the overall direction being taken by the business, feedback is a persistent feature. Descriptors of systems are therefore not mutually exclusive because feedback systems co-exist with others.

Describing business systems in terms of non-linear equations, as stated by Coveney & Highfield, is considered in the section on Chaology. Another author, writing from the specific standpoint of undifferentiated commodities in futures markets, states that intuition leads to expectations of multiple sources of chaos. (Blank 1991) Introducing the human element of 'intuition' is helpful because decision-making is a human activity. It supports the hypothesis that all core and peripheral decision makers are potentially multiple sources of chaos.

1.4.2 Causes of chaos

Causes are who, or what, produces an effect. (Oxford English Dictionary) As the source is the origin of that effect, sources and causes are almost indistinguishable from one another. There are three main causes.

1.4.2.1 Single point perturbation of the system

A small perturbation to a system causes a major effect. (Ducroq 1996, Chorfas 1995) The use of the singular 'A' is significant. A single perturbation at any point in the system is capable of producing a
major effect. 'Chaos confirms scientifically what accountants know experimentally. A small disturbance in cash flow can have major repercussions'. (Hill 1996)

'Un seul mot malheureux peut instaurer une situation chaotic' (Ducrocq 1996) shows the internationalism of chaos.

Although small single point perturbation produces a major [chaotic] effect large external perturbations also produce major effects. Small businesses, supplying automotive components, experience major disruption when industrial unrest interferes with production at car assembly plants.

Perturbation may be internal or external. (Geisel & Nierwelberg 1982) For example externally large differences in the value of variables on the foreign exchange markets result from minute differences in inputted variables. (Rutherford 1992) 'Chaotic behaviour can result from competitive markets. (Heiner 1989) The July 1998 example of the high value of the £ sterling, on foreign exchanges, caused not only chaos for Rover but also for many components manufacturers, small and large in the English Midlands and elsewhere. Bad decisions, made endogenously, similarly perturb businesses. 'Our problems began when we decided to expand'. [Conversation Brown (Chairman, Spirax Sarco)Hill June 1973] implies that expansion was a cause of chaos.
The perturbation point may not be easily detectable due to noise, such as system inertia and inadequate information. Internally an example is the tardy realisation that the "wrong" employee has been recruited, an example of internal perturbation causing chaos. Some time later, a lag, serious consequences result from the mistake.

On the other hand it is not only minor perturbations which have major effects. A decision to buy capital equipment for £10,000 on day 569 (Appendix 1) was a major perturbation which swallowed surplus cash balances which would have mitigated difficulties from day 881 onwards, especially after day 1267 when deficits circa £10,000 persisted. Fig J10, Insufficient working capital, is a major exogenous, external, perturbation chain with endogenous effects. Reservations have been expressed about Li & Yorke's paper 'Period 3 means chaos' as a cause of chaos because it is a special case. (Li & Yorke 1975, Ruelle 1991)

1.4.2.2 People

'Chaos can be caused by real people in simple management systems'. Mosekilde 1991) Some of these real people are identifiable by name. George Soros, the international money market speculator, is one such person who caused newspapers to carry headlines such as 'CHAOS IN THE MONEY MARKETS' and, in so doing, affected the earnings and expenditure of many businesses. Owner/managers who are not capable of finding solutions to problems
Increased working capital and increased order book chain reaction Fig J10

Note the chain reaction:

Increased order book $\rightarrow$ Working capital shortage $\rightarrow$ Late payment
$\rightarrow$ Goods despatched late $\rightarrow$
$\rightarrow$ Customers reduce orders
in their businesses cause endogenous chaos. Their shortcomings may propagate chaos for their customers because products are delivered late.

1.4.2.3 Parameter interaction

This is the plural version of single parameter perturbation. The interaction between only three inter-dependent variables, population growth, labour force and output, is found to be an impersonal cause, a triggering mechanism, of chaos in an economics model. (Kelsey 1988) ‘A few things reacting together produce deterministic chaos’. (Lewin 1993) Interaction in competitive markets, in which the number of competitors, all of them variables, is not always precisely known, can cause chaotic behaviour. (Heiner 1989) Similarly simple interactions, among species, produced chaos in a biological model and complex patterns. (Ives 1991)

Action and reaction, by identifiable as well as anonymous players, are therefore the common causes of chaos. ‘You start with an apparently well-behaved mechanism, make some minor perturbations, in a parameter or initial conditions, and all hell breaks loose’. (Connolly & Vajda 1995, Geisel & Nierwelberg 1982) (D) Appraisal of Small Manufacturing Business Financial Postulates considers the principal parameters which may be individually, or collectively, perturbed.
Action and reaction between different parameters in a business is also a cause of chaos. An example from publicly quoted businesses is the chaos caused by a fixed dividend payment combined with declining marginal productivity. (Shaffer 1991) Fixed loan repayments, without any provision for payment holidays is the small manufacturing business equivalent.

However chaos is not an inevitable consequence of action and reaction if reactants are damped. For example businesses absorb wage awards by increased productivity and find alternative suppliers when prices are increased.

1.4.3 Routes

'Routes to Chaos' is a recurring phrase in chaos literature, especially relating to the physical and life sciences. 'Route' has associations with orderliness such as the formalism of departing from one point, proceeding via an existing surface or air communications network and eventually arriving at a destination.

That concept is foreign to many small manufacturing business situations because orderliness applies only to some types of decision-makers. (Klein & Peio 1989) The association between bifurcations and attractors, considered below in the section on chaotic componentry is an additional reason for dissociating them from small manufacturing
Even in orderly situations there exist different routes to chaos.

(Daido 1984) Computer simulations show that the same physical system can even follow different routes in different experimental runs. (Giglio 1982) Of these period doubling bifurcations, the pitchfork type, are frequently quoted as being a route to chaos in the physical and life sciences. (Roux 1983, Casti 1989, Di Cera et al 1989, Schuster 1984)

Bifurcations are not self-starters. They need a stimulus, a cause, to start the period doubling. That stimulus is perturbations; they are causes. (Chernikov et al 1988) In fact, the presence of bifurcations is a sign, in one dimensional systems, of which there are few in business, because time and value are both important, that chaos is developing. (Barnsley 1986)

Giglio goes further. In fluid dynamics experiments, the route to chaos, through period doubling, avowedly has universal character. (Giglio 1982) Universality is disputable because in Appendix 1 cash disbursements, and receipts, show that periodicity applies only to some of the disbursements, not all of them, and that it does not change during the 1,792 days synthesised. The other disbursements are aperiodic. Secondly there is no discernible periodicity in the receiving of payments from customers.
But bifurcations are only one of three possible routes to chaos in non-linear oscillators in dissipative systems recognised by Lakshmanan & Murali 1996. In the minority of cases, where small manufacturing businesses are dissipative systems, the Pomeau Manneville model is relevant. Although financial trends are predominantly downward it is not unusual for there to be intermittent bursts giving rise to speculation that the trend may be reversed. The other two are irrelevant. The Feigenbaum scenario has already been considered in connection with bifurcations. The Ruelle-Takens-Newhouse scenario is irrelevant because small manufacturing businesses do not have a (one) single control parameter. They have several which interact. A more fundamental problem is the question of what are initial conditions ('initial stationary state'), a question considered in the preceding chapter (D) paragraph 7.

These routes to chaos are:

1. Period doubling bifurcations - the Feigenbaum scenario,

2. Ruelle-Takens-Newhouse (quasi periodic) when the control parameter is changed and the initial stationary state becomes unstable and undergoes a Hopf bifurcation

3. The Pomeau Manneville (intermittency) with short chaotic bursts as a parameter is changed, beyond a critical value, before the system moves into a chaotic regime.

None of these routes comfortably conforms to the dynamics of small manufacturing businesses. Fluctuations of their financial variables
are irregular, not the regularly oscillating periodicity and amplitude observed as pendulums swing and increase in speed.

When routes bifurcate in small manufacturing businesses two subsidiary asymmetric routes appear. For example the usual behaviour pattern for overcoming a factory overload problem is recourse to sub-contracting as little as possible of the overload and retaining as much as possible in one's own factory ie a "trifurcation".

1.4.3.1 Degrees of freedom

The relationship between chaos and degrees of freedom, not only in the area of small manufacturing business finance, is doubtful. As degrees of freedom appear in statistical and scientific literature, in connection with quantities, their association with chaos, in small manufacturing businesses, is consequently restricted to those [value and time] variables which are quantifiable. One problem is that the absence of datums for a number of parameters, to which degrees of freedom may be related, because they fluctuate. (Paragraph E2.1.1)

Another serious problem, when investigating a cross-disciplinary subject such as chaos, is that definitions of degrees of freedom vary according to academic discipline. Several examples are in the Glossary. Definitions referring to 'random variables' are excluded because randomness is not a feature of deterministic chaos. (Borowski
Also excluded are definitions referring to ‘minimum numbers of variables required to describe the state of a system’ because there is no minimum number. Unexpected perturbation of any variable, in a small manufacturing business, is potentially a cause of chaos. This inter-connectedness similarly precludes the inclusion of degrees of freedom relating to only one variable as with chi-square, t and F statistical distributions.

Less specific definitions referring to ‘leeway in a system’ may lack precision but are conceptually acceptable because they fit small manufacturing business financial scenarios and the information pertaining to them. (Francois 1997) Leeway ranges from zero to a mental estimate. Some exogenously imposed parameters, such as upper limits for overdraft borrowing have zero leeway but credit terms, allowed by some suppliers have a little more leeway; typically a few days. There is still more leeway for endogenously controlled in-house resources such as increasing available human resources by voluntary overtime working.

Another definition fitting these practical situations is that referring to ‘estimates of parameters’. (Statistics Notes: Work Study School Cranfield) Owner/managers often make a mental estimate of break even point [parameter] in the absence of an accurate datum.
Published opinions relating to unspecified numbers of degrees of freedom have some credence in small manufacturing businesses.

'The onset of chaos does not require a large [unspecified] number of degrees of freedom, (Chernikov et al 1988) in conditions of non-linearity. (Rasband 1990)

Quantification difficulties and fluctuating parameters suggest relative values, large and small, rather than absolute ones such as Basar’s are more fitting to small manufacturing business financial scenarios.

Basar specifies the number required. 'Mathematically all non-linear dynamic systems with more than two degrees of freedom can generate chaos'. (Basar 1990)

Although expressed in connection with lasers, the opinion, that most interesting phenomena eg pattern formation, occur in extended systems, involving both temporal and spatial degrees of freedom, is another concept transferable to the information objective of this thesis, (Winful & Rahman 1990) because small manufacturing businesses are part of extended trading systems. In those systems time and value are involved.

Problems, associated with quantifying degrees of freedom, impinge on the task of specifying template tolerances for the novel technique developed in (G) below, later in this thesis. Those
1.4.3.2 Sensitivity to initial conditions

Reference has already been made to major difficulties associated with specifying initial conditions for small manufacturing businesses. (D) paragraph 7 refers. Their consideration in this section is against a background of whether it is worthwhile to make a major effort to overcome the previously mentioned major difficulties.


As a definition of chaos, (Gulick 1992, Percival 1989) it is challenged on the grounds of redundancy. (Crownover 1995) If £25,226 had been the opening credit cash balance on Day 1 of Appendix 1, any chaos would have been purely technical, not the stressful ordinary variety resulting from large and persistent deficits.

In classical systems, sensitivity to initial conditions is a sign of chaos, (Robinett 1997), a symptom, not a cause.

The aspect of chaos and chaos theory, closely related to this sensitivity, which has generated mirth, as well as invective, is the butterfly effect. (Knudsen 1994) 'The butterfly fallacy' starts with the observation that a chaotic system can have its future state changed
dramatically by small changes in initial conditions or minute perturbing influences', (Morrison 1991), exemplifies the invective as well as defining its meaning.

Relating the butterfly effect to minute perturbing influences has validity, although reference to initial conditions are best avoided on account of previously cited difficulties. Moreover minute single point perturbation has been recognised as a cause of chaos in paragraph J1.4.2.1 above. However values of ‘minute’ vary according to prevailing circumstances. They are relative not absolute values because a minute change, affecting a business experiencing difficulties is the ‘last straw that broke the camel’s back’ while a prosperous business is unaffected.

Given noise-free initial conditions, inelastic couplings between players and no damping, to reduce the sensitivity by absorption, the butterfly effect is possible. It is not remote from the financial affairs of small manufacturing businesses if allowance is made for a time lag, For example minute inputs, into spot foreign exchange markets, swiftly produce large differences, (Rutherford 1992) as dealers hedge against the potentially undesirable effects of future inputs. Fixed forward exchange contracts remove the butterfly effect from that variable but it can still happen to other non-banking variables.
A delayed butterfly effect is also seen sometimes in inventory management when a stock controller, reprimanded for a small temporary stock-out, over-compensates and increases minimum stock levels to such an extent that slow moving stock causes a liquidity problem.

The oil price rises of the 1970s were of greater magnitude than the butterfly effect. (Parker & Stacey 1994) They could not be damped by the usual market mechanisms when oil producing countries, acting in concert, perturbed, almost destroyed, existing market mechanisms as they imposed massive price rises. The effect resembled the amplification discovered by research into industrial dynamics, which preceded research into chaos, (Forrester 1961) as wary oil users, acting like small manufacturing business stock controllers, took steps to protect themselves against more increases.

Where the initial conditions are known with precision, the opposite of chaos, stability, becomes possible, according to meteorologists. ‘A dynamical [dissipative] system, whose initial conditions are known with precision, may be drawn towards some stable state known as an attractor’. (Moran et al 1997) Otherwise ‘the smallest error of description, of what is being, studied may quickly amplify into a huge disparity’. (Barrow D 1993)
Chaos resulting from the butterfly effect, where applicable, is not instantaneous. The *forgetting factor* may delay the response. It varies with the type of business. In fast moving, simple product environments it operates quickly but more slowly when complicated capital goods, with complex contractual terms involving deposits and progress payments, a form of system inertia, are manufactured.

However a major problem is that the set of them [conditions], which produces chaotic behaviour, is uncountable. (Heiner 1989) Although numbering seventy seven, it would be unwise to claim that all possible variables are included in Appendix 3, Schedule of value and temporal variables.

In the case of manufacturing businesses, all seem to be linked either directly or laterally as trading partners, (Halinen & Tomroos 1998) or tenuously, through the extended world-wide hierarchy of logistical and financial networks, the set, in which multi-national corporations are major players. Counting the number of manufacturers involved is impossible. The linkages between them attract attention in times of crisis when orders and investments are curtailed.

The many, interacting, lateral as well as tiered, permutations and combinations formed by these trading networks further emphasise
uncountability. For example the world wide ramifications of difficulties experienced in 1998 by the Japanese and Asiatic "Tiger Economies", linked through the international banking infrastructure, are witness to them. Banking problems in Tokyo affect automotive components manufacturers in the English Midlands who supply Nissan and Toyota, Japanese car assembly plants.

Omission of 'initial' to leave 'conditions for chaos' directs attention to the need for comprehensive information so that the onset of chaos may be discerned even in unlikely variables. The need for comprehensive information is in (C) Review above, with a specification and a technique for providing it in (G) below.

1.5 Manifestation of chaos

The chaotic literature indicates that chaos is manifest in business, in systems and in people. A three dimensional system of first order differential equations is said to be needed for the manifestation of chaos. (May 1976) Other authors have recognised its manifestation without resorting to the rigour of mathematical equations. However without a formal definition the manifestation of technical, as opposed to conventional chaos cannot be independently validated.

1.5.1 In business situations

Although references to chaos in business are few in number, some them relate to the main decision-making activities of
business, such as managing two bank accounts, product planning and logistics.

The time base varies greatly. Of immediate concern, in the short term, are operational issues such as product planning crises and changes in purchasing power. In the longer term are planning and structural issues concerned with describing the evolution and future development of the business.

Chaos in stock markets, (Shaffer 1991) is relevant only to the small number of small businesses which have a stock-market quotation for less than 49% of their equity. If the proportion of shares held by outsiders exceeds 49%, the business does not match my working definition of small manufacturing business. However chaos in stock markets affects the value of pension funds for individuals, and business wide schemes, but, being long term investments, chaos in this area lacks the immediacy of chaos in day-to-day small manufacturing financial operations.

The study of small manufacturing businesses showed chaos to be manifest in external and internal relationships when actual requirement and availability boundaries collide. Chaos results from requiring too many products [overload] but also from requiring too few [under load]
Relations are soured when a bank changes the borrowing boundary by refusing requests for additional facilities, withdrawing a borrowing facility or reducing permitted level to cope with these chaotic over and under load situations.

Vendor-customer relationships suffer particularly when delivery arrears occur and promises are not honoured. CUEL Ltd's failure to deliver fibre optic light guides caused chaos for a manufacturer of spectrometers.

Internally, short notice changes to production programmes lead shop floor employees to accuse their management of chaos; their expectations of manufacturing programme inviolability collide with management's tactical resource reallocation decisions, whether reasons for making changes are valid or invalid.

1.5.1.1 Bank accounts

Innocuous chaos is shown in the simple one-dimension bank account model incorporating an attractor. (Tofallis 1995) The usual perception of chaos in bank accounts, common to borrowers and lenders, is associated with deficits frequently in close proximity to borrowing limits. Time and value are the two dimensions.

1.5.1.2 Product planning

Chaos, with a financial penalty, the loss resulting by being obliged to cancel a development project, was the immediate outcome of Ukita's failure to develop an 8mm CD (Compact Disc). It was a crisis, but
the eventual outcome was personal information systems which were successfully launched into a world wide mass market. (Stacey 1992)

1.5.1.3 Logistics

As the micro-economics of price changes, concomitant with alterations in supply and demand, affect all businesses, in market economies, excluding them from this sub-section, because they appear in economic journals, not business ones, cannot be justified.

In respect of commodity prices, long term prediction cannot be justified on account of the 'very existence of chaos'. (Lichtenberg & Ujihara 1989) Unpredictability is an attribute of chaos. (Paragraph J1.6.4)

In the shorter term chaotic price-quantity dynamics can occur even if both the supply and demand are monotonic. (Hommes 1994).

Both these papers imply that chaos is endemic, embedded in the logistics function. However other authors, in a book on chaos and fractals, not targeted towards a particular discipline, write 'there is said to be a discernibly precise moment at which chaos occurs [when the threshold is crossed], with corresponding behaviour which is neither chaotic nor non-chaotic'. (Feigenbaum et al 1992) If such a moment exists, its detection requires first the acquisition of contemporary information, as accurate as realistically possible, for all potentially chaotic variables.
Secondly a reliable detection method. The third requirement is a definition of chaos, a datum, as in J1.4 above, against which the acquired contemporary information is compared. The effect of information deficiencies, discussed in (C) Review, is that a chaos moment is unlikely to be discernible, in advance, in typical small manufacturing businesses even if a threshold datum is available. Only those businesses which have immutable, firm commitments from trading partners and reliable information relating to their future intentions address issues of chaos avoidance. Strong vendor-customer couplings, which exist in a few places, are a step in that direction.

Having prior knowledge of a moment when chaos occurs is theoretically advantageous as an indicator fore-warning of its onset, Works managers, and production controllers, warned in advance of oncoming chaos, are given opportunities for proactive decision-making. Panics involving manufacturing personnel and materials, with their financial consequences, are avoided.

The ability to discern the point at which chaos occurs is potentially a cause of unnecessary alarm because one attribute of chaos is transience, (J1.6.5) so no decision-making, pro or reactive, is required. The key practical issue for decision-making is not when chaos occurs, or does not occur, but its expected intensity. Chaos
may be weak and short-lived, and, if transient, will soon pass.

1.5.2 Chaos in systems

'System' is a word used locally and globally in business. Locally, in small manufacturing businesses, it is often synonymous with functional procedures - accounting, inventory control, production control, sales and purchase ledger systems although, it has been argued, that organisations should be seen as complete systems, made up of inter-related parts, (Jackson 1991) [not a collection of procedures loosely described as 'systems']. For the purposes of this thesis, the parts of small manufacturing businesses and also trading systems, are resources - human, physical and financial. Resources are a common factor in all businesses irrespective of size so 'system' is applicable both globally, and locally, to describe the dynamics of businesses as well as the trading systems of which they are members.

The many sub-divisions of these parts, ways in which they are combined, varying dynamics, variables and parameters, justify using 'complex' to describe business systems. (Gemunden 1985) Chaos is just one aspect of dynamical systems. (Ermentrout 1991)

The discovery that simple non-linear systems, the most basic, may exhibit complicated, erratic behaviour, (Feichtinger & Kopel 1993), and continually produce novel activity patterns, (Freeman 1991) corresponds
with owner/managers and financial decision-making in small businesses
the more so because authors, using a psychological perspective, viewed
the individual as an information processing system. (Rowe 1989)

The literature indicates that chaos in systems is widespread, although not
ubiquitous, and that numerous unstable orbits exist. (Cambel 1993)
It is impossible to say ahead of time which dynamical systems
will result in chaos, (Turner 1997) as not all dynamical systems
are chaotic although ‘system’ is also often linked with chaos while non-
chaotic systems are ‘sparse as hen’s teeth’. (Ford 1983) Moreover
chaotic and non-chaotic systems can co-exist, (Nicolis 1986) but
distinguishing between chaotic and non-chaotic systems is difficult,
(Casdagli 1992) as between chaos and no chaos. (Paragraph J1.4)
Computer studies have shown that chaos is present in many
systems not yet analysed mathematically. (Ruelle 1989)

Unfortunately there is much ambiguity in the literature so the critical
commentary method used in the section on definitions is also
used in this section because there is a similar lack of consensus. It
features, for example, in the debate about the manifestation of chaos in
both in real life and model systems.

1.5.2.1 Real systems and models

A distinction therefore has to be made between real systems and
system models. In almost all real systems there exist ranges and
parameters of initial conditions for which the system turns out to be a system with chaos. (Chernikov 1988)

As for mathematical modelling, a three dimensional system of *first order differential equations* is said to be required for the manifestation of chaotic behaviour. (May 1976) That statement may be true of biological models but expressing the real life manifestation of chaos at Ukita, a electro optic engineering business, in differential equations verges on impossibility because there was human involvement. A corollary to May's statement is, if a system cannot be modelled in that way, chaotic behaviour is not manifest.

Difficulty exists in reconciling May with Cellier who writes that, in a continuous time model, no chaos can result for a system of *orders* one or two. (Cellier 1991) There is also another consideration. Do Chernikov, a physicist and May, a biologist, agree on the meaning of 'chaos' if they disagree about the orders in equations?

Writing 12 years after May, Billings et al, in their book on non-linear system design, a real world scenario, observed that there are no established means of checking in advance [as in modelling] whether a given non-linear system will give rise to chaotic behaviour. (Billings et al 1984) That is one of the principal reasons for focusing this research on real life business systems. Future work on the new
small manufacturing business financial information theory, set out in the final chapter of this thesis, should provide the means to check, in advance, whether combinations of non-linear variables will give rise to chaotic behaviour.

However at least one model has contributed to an understanding of chaos in systems affecting business. Writing in 1984 about chaotic price behaviour in a non-linear cobweb model, Jensen & Urban stated, ‘Until recently it was believed that only complex systems, with many degrees of freedom, could exhibit complicated, unpredictable behaviour. Recent studies of non-linear difference and differential equations have led to discovering that many simple deterministic dynamical systems can exhibit chaotic time dependence behaviour that is indistinguishable from a random process’. (Jensen & Urban 1984) Underlying determinism masquerading as randomness is an attribute of chaos. (Paragraph J1.6.7) The merit of this cobweb model is that it does not make chaotic behaviour dependent on system size. Its deficiency is that chaos is only linked with time dependence; value dependence needs to be included. Paragraph E3.1.1 refers.

In addition to ‘simple’ and ‘complex’, a number of other adjectives applied to systems are in the literature.

1.5.2.2 Descriptors of systems

Dissipative, continuous, conservative, discrete, classical, non-linear
autonomous, oscillatory and feedback systems are all descriptors of dynamical systems associated with the manifestation of chaos. Reference has already been made to some of them in a small manufacturing business context in the Review. (Fig C2, Types of continuous systems)

At different times and in different situations, it is possible for manufacturing business, small and large, to relinquish the characteristics of one system and change to another. A successful business, in which typical feedback mechanisms operate, becomes predominantly dissipative if expenditure exceeds income and leads to a run down. In those circumstances dissipation coexists with feedback.

A large business changing into a dissipative system distributes dissipation in varying amounts to trading partners. The demise of Rolls Royce Derby in 1971 had repercussive effects on small businesses over a wide area, in Coventry, Shrewsbury and East Kilbride as well as Derby.

In another scenario a similarly successful business becoming dormant, for whatever reason, changes into a conservative system. The reverse is a dormant business beginning to trade. This occurs when a business is incorporated, in order to register a name, before it is ready to begin
trading.

Although they are dynamical systems, movement is not uninterrupted. They have stationary states as Eric Heller showed in 1980. (Gutzwiller 1992) The synthesised data similarly shows many stationary states without inputs and outputs eg days 1,177 to 1,185 inclusive (9 days) but very few time sequences on which there were changes. each day such as when the cash balance changed every day for 4 days on days 77,78,79 and 80.

The question of whether this shows intermittency, one of the features of weak chaos, (Chernikov et al 1988) or stability in chaotic systems, such as Lorenz' meteorological system, (Devaney 1986) is considered in paragraph J1.6.3 below.

Distinguishing between chaotic and non-chaotic systems, can be hard. (Casdagli 1992) One problem is that some of the elements of chaos being system-specific, are not found in all chaotic systems. In view of this limitation, the system types, of which small manufacturing businesses could theoretically become a member, were therefore introduced in the Review.

'Chaos in classical and conservative systems has quite different properties. For example strange attractors, one of the most often mentioned of chaotic components, only appear in dissipative systems'. (Graham 1987) If strange attractors only appear in dissipative systems that precludes their appearance in all business
systems except those which are dissipative because they are running down or making trading losses.

Small manufacturing businesses only become stable, ie reach an attractor, when they cease to trade or become dormant. Attracting sales orders, the raison d'être for the majority of businesses, is a different concept from chaotic attractors, be they points or regions. Orders received in excess of factory capacity, successful attraction in business language, and insufficient order intake, weak attraction, both cause chaos.

However some situations match the chaotic attractor concept of moving towards stability. In small manufacturing businesses, in which budgetary control has been implemented, the budget figure is a point attractor at which the budget holder should aim. Exceeding expenditure budgets leads to problems, under-achieving income budgets also leads to problems. Both categories of problems have caused some commentators to describe resulting situations as chaotic – in its ordinary, not its technical, sense.

Additional to these endogenous situations which have some compatibility with chaotic concepts of attractors, are endogenous ones involving a point attractor. Providers of funds, banks and venture capitalists, set targets to which business should aim. There may be
only one target or series extending over a period of time to which draw down conditions apply. Success in reaching or exceeding targets, point attractors, is acceptable, failure may not be tolerated. If a business is no longer supported, and without alternative sources of funds, it becomes a dissipative system.

The deduction from this is that not all chaos is accompanied by a strange attractor because not all systems are dissipative. (Bird 1997)

1.5.2.2 (a) Dissipative systems

Definitions of dissipative dynamical systems in the literature, of which there are several, match a down-sizing business and, in the case of Pickover, one about to terminate its trading activities. Fortunately these are not the majority.

‘Dissipative dynamical systems are those in which the volume of phase space, occupied by an ensemble of starting points, decreases with time’. (Pickover 1992) It is corroborated by a statistician, mathematicians and neural scientists. (Isham 1993, Thompson & Stewart 1986, Patterson 1995)

For small manufacturing businesses the ensemble of starting points comprises capital introduced into the business, its tangible and intangible assets, human, physical and intellectual, its customer and supplier base.

A second definition introduces a qualification affecting the suitability
of the term 'dissipative' for some, but not all, business system situations. They only run down if there is no intervention to reverse the process of running down. Management would have to be unusually lethargic to embrace a policy of zero intervention.

The definition is: ‘Dissipative systems exchange resources with the external environment [peripheral decision-makers – suppliers, customers, Government and its agents in the case of small manufacturing businesses]. If left alone, without inputs of money from sales, they would run down or dissipate internal resources and reach an equilibrium (an attractor) with the environment, (Polley 1997) cessation of trading.

The alternative use of ‘equilibrium’ is its application of to break even situations, in which disbursements, outputs and receipts, inputs, are in equilibrium, and the exchange of resources is monotonic. Instability, in respect of exchanges with customers and suppliers in the external environment, is a feature of temporary loss and profit making situations. Dissipative systems therefore do not fit the majority of profit-seeking businesses which have an amplification mechanism, if not in the total system, in segments of it. (Mosekilde 1991) In profitable businesses disequilibrium, instability, exists occasionally when inputs exceed outputs.

Moreover dissipative systems are irreversible. (Nicolis 1986)
This suggests the inevitability of a business running down. In real life businesses move from loss to profit-making and venture capitalists put rescue packages together to save failing businesses. Run down is not inevitable and irreversible.

Some business and economics authors disagree with the view that businesses are not dissipative systems. ‘Business organisations .. are essentially dissipative structures’, (Parker & Stacey 1994) opines that they are.

The inclusion of adverbs, to qualify ‘exchange’ and ‘run-down’, in the preceding paragraphs, would improve their likelihood of being suitable for business situations in which chaos is suspected. ‘Exchange resources irregularly’ is typical of trading between businesses. In the case of ‘run down’ there is variability of in the rate of run down. ‘Run down gradually’ matches the situation of an owner/manager preparing for retirement. On the other hand ‘run down irretrievably’ fits a business which will never recover.

A third definition is only suitable for down-sizing businesses. ‘Volume elements shrink as time increases’, (Schuster 1984) transfers into business situations where expressions such as ‘volume of business’ and ‘volume of orders’ are common.

Shrinking, in the third definition, is synonymous with running down in
the second one.

One characteristic of these dissipative, non-conservative systems is loss of energy, the presence of attractors another. (Shaw 1981, Ruelle 1991) (C) Review paragraph 1.5.1.2 deals with the question of what constitutes the energy of a business?

Chaos is recognised as being present in dissipative systems. (Coveney & Highfield 1995) A business, in which liabilities exceed receivables + cash balances, is able to identify with the chaotic condition as attempts are made to rectify the situation.

Another identity between physics and business is the intensity of chaos. When chaos is present in dissipative systems it may be weak, a concept borrowed from turbulence theory. (Chernikov 1988)

1.5.2.2 (b) Conservative systems

Historically chaos was first mentioned as a non-dissipative system. (Brown & Chua 1998) Conservative, of which Hamiltonian and Newtonian systems are examples, maintain energy eg heavenly bodies. They do not entail a continuous decrease of energy, (Pickover 1995, Feigenbaum 1992) as do dissipative ones. Their business equivalent is businesses which stagnate and constantly breakeven. Chaos in conservative systems receives less attention in the literature than chaos in
dissipative ones. (Percival 1989)

1.5.2.2 (c) Feedback systems

The descriptor ‘feedback’ refers not to whether energy is dissipated, or conserved, but to a system’s connected network. For that reason feedback systems have relevance to business chaos. The future state of a system depends on the earlier state of the same system. (Turner 1997 cf random) Feedback systems may be chaotic, (Mees 1987, Cellier 1991) although that view does not have the support of all authors. The implication of ‘In continuous time, the possibility of chaos normally requires a minimum of three independent variables’ is that chaos cannot occur in small manufacturing businesses because there are insufficient independent variables. (Brown 1995) In small manufacturing businesses variables are inter-dependent and difficult to separate from one another.

A connection between business and chaotic systems – and complexity - is recognised. ‘Successful business organisations are what scientists call non-linear feedback systems. The dynamics of non-linear feedback are so complex that the links between cause and effect are lost in the detail of what happens’. (Stacey 1992) The complexity of the endogenous and exogenous feedback is evidenced in the variables in Appendix 3, Schedule of value and temporal variables.
Given the information deficiencies of small manufacturing businesses,
at a cursory glance, there appears to be randomness in the feedback.
For example revenue receipts suggest a spread either side of the
arithmetic mean with a mixture of customers. The payment times
vary from very early, through early, on time, to late and very late.
However closer analysis, and investigation of known, established
customer payment practices and credit taking policies, shows that the
payment is not random but can be realistically estimated in individual
cases by experienced controllers of ledgers.

Unlike the dissipative, discrete and other systems which are, on
limited occasions, suitable descriptors for businesses, the causal
relationship in feedback systems, even if lost in detail, persists in
prosperity as well as adversity. Financial flows increase in value
and time elements change. Prosperity leads to more expenditure
on plant, premises and sales promotion, adversity to less as cutbacks
are implemented. Expenditure flows are often higher in value and
infrequent because capital projects are involved. A one time
purchase of premises, so as to avoid payment of quarterly rentals, is an
example. In the opposite situation leaseback is a one time sales
leading to regular rental payments to purchasers.

1.5.2.2 (d) Autonomous

As autonomous systems are independent of time their relevance
is minimal because time is a prominent feature in small manufacturing businesses. (Pickover 1995) ‘Time’ is embedded in external dealings with customers and suppliers’ deliveries and payments, in-house with internal annual budgets, plans and shop and production period loading. Businesses are not independent of time.

Non-autonomous systems controlled by an external input, (Skowronski 1990) resemble small manufacturing businesses driven by external inputs such as sales orders, overdraft, loan facilities and occasionally grants.

1.5.2.2 (e) Oscillatory

Non-linear oscillatory systems possess an element of feedback. (Percival 1989) Consequently they have a recognised affinity with the feedback business systems described in 1.5.2.2 (c) above. In fact feedback varies greatly and may show all the attributes of chaos besides being smooth. There is also oscillation between payment priorities. Sometimes the feedback from receivables is immediate, for regular critical disbursements such as payments for utilities, but at other times to irregular ones, after some leeway.

One of their characteristics is the great variety of types of response as prevailing conditions or parameters change. (Jordan & Smith 1987) Due to their feedback structure, and inherent adjustment delays,
managerial systems tend to oscillate in response to external
disturbances [changes in short term variables and longer term
parameters]. (Rasmussen & Mosekilde 1988) A price acceptable in
a market, for the foreseeable future, is a parameter whereas a flow
variable is this month's sales value. The Endogenous Boundaries
in Fig C5, Inter-linked constraints on financial decision-making, are
all potential sources of external disturbances, as are the variables in
Appendix 3, Schedule of value and temporal variables. These
oscillate irregularly and intermittently not smoothly like alternating
current sine waves. Vacillate is a better descriptor than oscillate.

Fig J11, Oscillation (switching) in irregular payments,
shows priority switching involving 10 purchase invoices
over a period of 55 days. Purchase invoices are not paid in the
same order as received. Only A, availability of cash, constitutes a
voluntary reason, prevailing at the time of payment. B, C and D,
logistical, contractual and legal reasons, involving peripheral decision-
makers, determine the value and time priorities of payments.
Oscillation (switching) in irregular payments  

<table>
<thead>
<tr>
<th>Payment day</th>
<th>Arrival sequence in purchase ledger</th>
<th>Waiting time in days</th>
<th>Payment sequence determinants</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>4</td>
<td>3</td>
<td>A  Financial</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cash received from customer</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td>13</td>
<td>B  Logistical</td>
</tr>
<tr>
<td>34</td>
<td>1+ 9</td>
<td>1</td>
<td>Factory awaiting parts</td>
</tr>
<tr>
<td>39</td>
<td>8</td>
<td>1</td>
<td>Electricity supply - essential.</td>
</tr>
<tr>
<td>40</td>
<td>10</td>
<td>1</td>
<td>C  Contractual</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Supplier’s terms CWO (Cash with Order)</td>
</tr>
<tr>
<td>55</td>
<td>3</td>
<td>40</td>
<td>D  Legal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impending recovery action</td>
</tr>
</tbody>
</table>

Oscillation takes three forms: periodic, quasi periodic and chaotic.
irregular. For the last of the three forms, the description ‘chaotic’ is often substituted for ‘irregular’. However substitution is only valid when the meaning of ‘chaotic’ is already known.

1.5.2.2 (f) Discrete time

Discrete time systems are more prone to chaos than continuous time systems. (Cook 1994) Although small manufacturing businesses are continuous enterprises, short discrete time systems exist within the overall organisation especially in logistics. Shop floor chaos is associated with failure to deliver within a required, or promised, period of time. Few sales managers are unfamiliar with the chaos resulting from the failure of the factory to honour delivery promises. Works managers have similar experiences when suppliers fail to deliver on time.

1.5.3 Chaos in people

Although the individual is called an information processing system there are good reasons for not including people in the systems section. (Lachman et al 1979) First there are difficulties in assessing whether chaos occurs in behavioural processes. (Mpitsos 1990) People may cause chaos but that does not mean that the people, who cause it, are themselves chaotic although erratic [irregular] decision-making suggests that they are (eg Slovic et al 1972) because irregularity is one of the attributes of chaos.
1.6 Attributes of chaos

These show chaotic phenomena, as manifest in systems, and people, to be non-linear, irregular, unpredictable, transient, changeable and deterministic, in varying degrees, but featuring the incongruity of being random in appearance. Diagrams of some attributes, such as irregularity, are useful for generating the diagnostic shapes incorporated in the novel technique.

A number of authors have seen fit to include one or more of these attributes in their definitions of chaos. Drawbacks caution against including attributes in definitions. First is the need for a sufficiently long reference period. There is no guarantee that one attribute will be seen at all while another may appear on several occasions within the same reference period. Too short a reference period could coincide with a temporary chaos-free lull.

Some of these attributes are also specified as conditions for chaos not its symptoms. This is questionable because the attributes result from interaction between deterministic forces operating on variable parameters. Non-linearity, irregularity, instability, transience and changeability all result from the effects of determinants on interacting parameters such as available resources — human, physical and financial.

The attributes may manifest themselves at single trajectory level, or collectively, in a system-wide miasma of complexity.
1.6.1 Non-linearity

Fig J12, Non-linearity, shows the individual curves and possible Combinations. Figs J12 (f) and (g) show stepped non-linearity

Constant non-linear accumulation

(a) Concave curve  
Value

\( \includegraphics[width=0.3\textwidth]{concave_curve.png} \)

(b) Convex curve  
Value

\( \includegraphics[width=0.3\textwidth]{convex_curve.png} \)

Changeable accumulation of joined trajectories

(c) Compound concave-concave  
Value

\( \includegraphics[width=0.3\textwidth]{compound_concave_concave.png} \)

(d) Compound convex-convex  
Value

\( \includegraphics[width=0.3\textwidth]{compound_convex_convex.png} \)

(·) Vertical Linear interruption  
Value of unchanged curve

\( \includegraphics[width=0.3\textwidth]{vertical_linear_interruption.png} \)

Note:  
Tight/fast curves = high rates of change

eg Cumulative values trend in accounting period – shipments

Interest bearing accounts eg  
Money on deposit continuously compounded interest

Change in cumulative trends

“Slow” curve, then “fast”, horizontal linear stagnation,

Reduction in rate of interest on deposits

“Fast” curve then “slow”

eg cash introduced to reduce overdraft
Non-linearity, an attribute as well as a condition, (Zaslavsky et al 1991 and 'large classes of non-linear systems [although not all] exhibit transitions to chaos'. (Cvitanovic 1984) It is not the sole, isolated, qualitative attribute by which the presence of chaos is diagnosed; there must be others as well. Wherever dynamic chaos is found, it is accompanied by non-linearity. It means that measured values of the properties of a system at a later state depend, in a complicated way, on measured values at an earlier state because a datum is needed. (Rasband 1990)

Fig J12 (e) has a short linear portion between two non-linear curves. Consequently non-linearity and initial conditions are related.

In business, feedback systems are non-linear when such determining parameters as capacity, finance, skills and economic laws of demand, diminishing returns and economies of scale are themselves non-linear. Capacity jumps up and down. Willingness to work overtime by personnel makes it increase linearly, absenteeism makes
(f) Purchase break points and service levels

Price

Quantity
Low High
Service level (a) Premium (b) Normal

(g) Sales agents' commission steps

Sales invoiced

Commissions %
it decrease. Additional capital introduced by owner/managers increases financial resources, in step form, bad debts similarly decrease it. Economics textbooks show returns on investment and economies of scale increase, and then diminish, because other factors such as floor space availability close in.

Non-linearity may be either concave, or convex, or stepped interspersed with stationary [linear] plateaux. There are several examples of these plateaux in Fig J8 (a), Daily Cash balances. They can be seen in both credit and debit balances situations. Fig J8 (b), Cash balance every tenth day, shows that concave non-linearity does not alternate periodically with convex. Instead, for example, one concave shape may be succeeded by another ‘wave’ with a different shape, trajectory length and duration. The first “curve” runs from Day 1 to Day 280, the second a visually asymmetric one, from Day 280 to Day 510. Fig J12 (f), Purchase break-points, and J12 (g), Sales agent’s commission, show stepped non-linearity determined by quantity, not curves.

Visual representations of chaos in graph form, such as in oscillatory systems, show non-linearity most clearly although, for mathematicians, ‘non-linearity’ also refers to the form of the underlying equation. (Polley 1997) However mathematicians recognise that many non-linear initial value problems are not well-posed. (Derrick & Grossman 1997)
Such a recognition militates against any expectation that mathematical chaos is transferable to small manufacturing business financial information.

1.6.2 Irregularity

Irregularity is a concomitant of chaotic non-linearity. When shown in line graph form, the line usually has oscillatory irregular peaks and troughs, not the smooth oscillations of a periodic sine wave. The irregular or jagged waveform of chaotic vibrations resembles that in Fig J13, Irregularity in receiving payments, and sharp changes in time path trajectories. (Baumol & Benhabib 1989, Feichtinger & Kopel 1993)

Irregularity is a symptom of chaos. 'Large scale fluctuations are the mark of chaos'. (Gutzwiller 1992) Fluctuations in wave height, and length, are experienced in small manufacturing business finance so common ground exists. Unless heights of waves, distances between troughs and crests, together with their frequency measured, innocuous irregularity is indistinguishable from unwanted chaotic irregularity.

Disbursements for days 1 to 24 (Appendix 1) are irregular in both value and time. Values range from a low of £11 to a high of £1,518. Intervals between disbursements are 6,1,2,5,2,3,2 and 2 days. Subjectively assessed, disbursements between days 7 and 8, an increase of £101 is mild, but between days 10 and 15 an increase of £1,507 constitutes more serious irregularity. More significant than this
Irregularity in receiving payments

Note: (1) Irregular values

(2) Irregular time intervals between receipts
irregularity is the upward cash deficit trend which persists until day

In a *phase space*, chaotic motion is recognised by fuzzy irregular looking trajectories [shapes]. (Alonso & Finn 1992) This recognition is visual, not quantitative. Without a template, or definition, chaotic and non-chaotic motion are indistinguishable from one another.

In markets the irregular behaviour, is bounded, (Parker & Stacey 1994, Ehrich 1995) although boundaries are frequently unknown to owner/managers because it is uneconomic to spend money on finding out the size of markets. The usual price for market research reports from MSI Marketing Research for Industry Ltd, exogenous information, is £195. The same observation applies to surplus factory capacity, endogenous information, because it changes in accordance with factory loads and the incidence of operational problems associated with plant eg breakdowns and personnel eg absenteeism.

Non-linearity and linearity, in the vertical plane, are occasionally joined. This joining occurs when the non-linear, continuously compounded interest curve jumps vertically from one value to another on the day on which rates change.
1.6.3 Intermittency

Fig 11\textsuperscript{4}\textsuperscript{k} Intermittency, illustrates the attribute of the same name

Intermittency

\begin{itemize}
  \item Regular
  \item Chaotic
  \item burst
  \item Regular
  \item Lengthy
  \item upheaval
\end{itemize}

\begin{itemize}
  \item \textbf{Value}
  \item \textbf{time periods}
\end{itemize}

In addition to being non-linear and irregular, chaos is also intermittent.\textit{Intermittency} is regular, or \textit{periodic}, behaviour interrupted by chaotic bursts, (Tsuda 1992) in complex systems. (Devaney 1989) Regions of chaos are interwoven with islands of stability. (Rasband 1990, Cvitanovic 1984) Chaotic regions co-exist with non-chaotic ones.

Recently a few authors have tried to relate this to the discontinuous evolution of an enterprise. (Feichtinger & Kopel 1993) In attempting to do this they imply that an intermittency time frame extends over months. Other authors give no indication of whether the time frame applies to days, as in the case of cash balance fluctuations, or
longer as with an expansion programme, extending over many months, because it is linked to acquiring expensive new machines.

Weak chaos is reported as a property of intermittency but strong chaos has greater continuity and weak chaos can be veiled (damped) by other factors. (Chernikov et al 1988) For example a temporary factory overload, weak chaos, may be sub-contracted without customers being informed – unless purchase order terms make it mandatory.

Strong, persistent chaos is evidenced when credit controllers permanently restrict credit facilities because a debtor's previous history of complying with settlement terms has been unsatisfactory, not in all cases, but overall compliance with settlement terms has been intermittent. Escape from strong chaos situations, such as that, is difficult. In both the above examples subjective interpretation of numerical data is involved.

1.6.4 Unpredictability

Fig J15, Unpredictability, shows that unpredictability takes one or more of three forms. First the trajectory may move in a positive or negative direction. Secondly the value of the movement is unpredictable and thirdly the time when it takes place.
In contrast to the noticeable absence of agreement, on many aspects of chaos, is the agreement regarding the unpredictability of outcomes from chaotic situations. (eg Nychka et al 1992, Devaney 1993)

Banks recognise the unpredictability of cash flow. (Business Update 1996)

Measurement difficulties, (Parsons 1997, Rasband 1990, Brock et al 1993) and sensitivity to initial conditions, (Robinett 1997, Brown 1995) are given as the principal reasons, with divergence of trajectories over time, the main effect. Human involvement may be the underlying reason for it. (Hill 1996 – Annexure 1)

Although unpredictability, allegedly has patterns, (Hutton 1994) chaos makes prediction very difficult because there is often more than one right answer. (Gray 1992, Weiss 1991) In a chaotic regime, arbitrarily close initial conditions can lead to trajectories which, after a
sufficiently long time, diverge widely. (May 1976) Their future paths cannot be predicted.

The time frame for this unpredictability is the long term ‘It is practically impossible to predict, in the long term, if there is any indeterminacy in one’s knowledge or ability to compute’, (Blank 1991) calls into question the practicality of forecasting. (Feichtinger & Kopel 1993)

Short term predictability is however reported as being possible. (Sugihara & May 1990) In small manufacturing businesses, short term predictability assumes zero absenteeism by personnel, uniform abilities, zero delay in deliveries of exact specification materials, zero breakdowns of machinery and financial resources sufficient to pay for all foreseeable and unforeseeable situations.

In the absence of quantification of their duration, ‘short’ and ‘long term’ are at best approximations because the context in which they are used affects their meaning. For example ‘short term’ means days for the manufacturer of a single artefact such as a small reamer. On the other hand ‘short term’ means months for a manufacturer of lathes.

1.6.5 Transience

Fig J16, Transience, illustrates the meaning of this attribute of chaos.
Although there are few references to it, as an attribute of chaos, transience needs to be segregated from intermittency, (J1.7.3) because it assists in comprehending the meaning of 'chaotic bursts'. It has a part to play in the characterisation of chaos. (Tel 1990)

Transience is defined as short bursts (OED) whereas no indication of duration is given in the case of intermittency (OED). When the initial conditions vary so does the length of the chaotic transients. (Kantz & Grassberger 1985)

1.6.6 Changeability

Changeability, although similar, is not synonymous with temporal intermittency and transience. It is a prime characteristic of chaotic systems, (Freeman 1991) and also of the working environment of a
Changes vary between smooth almost imperceptible ones to jumps.

Through its definition, in terms of alterability, it has shades of meaning linking changeability causally with the smooth, deterministic evolution of chaos, (Rasband 1990) and the alteration of parameters, value as well as temporal, causing chaos In chaotic time series, changes can be abrupt. (Feichtinger & Kopel 1993) The cash balance for Day 989 in the Synthetic Cash Flow Data lasted only one day before a debit jump from (£61) deficit to (£2293). Abrupt changes such as these are more easily detected than smooth.

Distinguishing between a jump and a blip is difficult because the variable concerned and its context. Unless details of other variables are to hand a (£221) debit cash balance for days 223 – 224 is no more than a blip although the deficit jumps to a deficit of (£3,515) at day 233.

Technically the credit of £22,012 on day 517 is chaotic but an owner/manager would describe it as a ‘cash bonanza’

Moreover an ability to respond to intervention is implied. One of the earlier papers on chaos, based on physics, was a precursor in identifying this attribute. The paper describes how the laws of dynamics produce a continuum transformation group in which chaos remains as chaos but changes its character. (Wiener 1939 ) Changes may be sharp.
More specifically changeability has relevance to decision-making because it is a prime characteristic, an attribute, of many chaotic [eg physiological perception] systems, (Freeman 1991) and of a manager's shifting threshold with its interrupts, delays and speedups. (Mintzberg et al 1976) In engineering machine shops managers have to cope with changeability attributable to personnel, plant and material.

Fig J17, Changes in net worth of cash introduced, illustrates changes over a longer period of time.
Changes in net worth of cash introduced

Fig J17

408

Value

...Cash introduced...

time

Interest foregone by not depositing cash in building society at variable rate of interest

Business trading profitably

Cash introduced repaid. Business generating surplus

Low rate

Increased rate

Decreased rate

Note: Line curvature tightens as interest rates increase and vice versa.

1.6.7 Oxymoric determinism and randomness

The incongruity, the paradox, between the order of determinism and the disorder of randomness, is a phenomenon of [technical] chaos often drawn to the attention of readers by authors. (Crutchfield 1986, Freeman 1991, Morrison 1991)

(‘Structured randomness’ and ‘ordered-disorder’ are used in order to convey the meaning of the incongruity. (Polkinghorne 1994)
Of the several definitions of ‘random’, that meaning haphazard is used more often than the statistical one. As the haphazard meaning has been in use in the English language since at least 1655, it is possible that as with ‘chaos’ it is embedded in the human psyche. If that be the case the use of stochasticity, a synonym for randomness, is to be preferred in chaos literature.

Determinism, the chaotic concomitant of randomness, is the doctrine that everything that happens is determined by a necessary chain of causation. In the case of small manufacturing businesses the causation has two roots. Past events are one root, as in feedback systems, future expectations the second. Financial success, or failure, in the past, stimulates decisions in the present. Future expectations, sometimes backed by market research and investment appraisal, affect decisions on inventory, staffing, premises and plant.

Randomness, statistically, means that every event has an equal chance of happening but it has complicated causes. (Sheynin 1991)

For a system to be truly random there must be no causal connection between an observation at some present time and a past observation at an incremental time. (Cambel 1993) This contrasts with the causal linkage in business feedback systems.

The presence of order in a chaotic system, despite its random appearance,
is due to an attractor. (Yam 1994) No reference is made in the paper to the type of system. If it is true that attractors are only found in dissipative systems, it means that no order is present in the other types of system. (Paragraph J1.6.2.2)

Table J1 is a comparison between synthesised and random values compiled from Appendix I and Random number tables.

**Comparison of synthesised and random values**  
**Table J1**

<table>
<thead>
<tr>
<th>Days</th>
<th>Synthesised</th>
<th>Random</th>
</tr>
</thead>
</table>
| 28 and 78  
(disbursements – outward payments) | £783 | £181 |
| 10 and 76  
(inward receipts) | £1,230 | £6,132 |
| 21 and 24  
(lag between receipts) | 11 days | 8 days |
| 93 and 95  
(lag between irregular payments) | 14 days | 3 days |

**1.6.9 Local instability**

Three synonyms for instability, changeability, transience and unpredictability, listed in a thesaurus, (Collins 1986) have already been considered as attributes in this section. However it is not tautologous to consider instability separately because another synonym, in the same thesaurus, *disequilibrium*, is relevant to fractals, one of the frequently mentioned components of chaos. The separate
consideration of instability is necessary to obtain an understanding of fractals in a small manufacturing business setting and also to obtain a comprehensive statement of chaotic attributes. Instability is one of them. (Chernikov et al 1988) Even low dimensional chaos involves it. (Blank 1991) Measurement error is cited as one reason for it, (Brock et al 1991) but conspicuous consumption, and increasing returns to companies explanations, correspond to real life scenarios. (Hutton 21 03 94) Instability is manifest in trajectories. (Golia & Sandri 1997) Paragraph J1.7.1 below illustrates this instability.

References to instability fit a small manufacturing business scenario by being locally, not globally, bounded, (Stacey 1993) and low dimensional. It is claimed, in a short computer science paper, that calculation of the strange attractor can be used to predict when stock-market prices are about to become unstable. (Lewis 1997) The claim should be treated cautiously because the strange attractor is firstly assumed to be a point whereas the majority view regards it as region. (eg Gandolfo 1995, Tofallis 1995) and secondly that every potentially chaotic system, has an attractor, when only dissipative systems have them. Introducing the word ‘calculation’ implies that quantitative information is available. Longer papers on similar topics follow the majority by regarding a chaotic attractor as a set of points. (Peters 1991, Baumol & Benhabib 1989)
The complex patterns resulting from the interaction of chaos-producing trajectories is cited above in J1.4.2 on the causes of chaos. It is analogous to spatio-temporal chaos caused by multi-phase oscillations, not of small manufacturing business financial variables, but coupled trajectories of lasers. (Winful & Rahman 1990)

The importance of complexity, in many real life scenarios, has led to the development of complexity theory which is relevant to the environment of small manufacturing businesses. There a large number of players and important aspects that influence each other in complicated ways. (Schaub1997) In fact there is network of variables as in Appendix 3, Schedule of Value and Temporal Variables.

Fig J18, Cash flow complexity, shows seven shifting elements affecting cash balances. Disbursements and receipts are one pair of elements, director's drawings and director's loans another. If directors withdraw their loans, the shaded area disappears and the rectangle moves outside the cash balance rectangle, as indicated by dotted lines. On the other hand if loans increase the shaded area increases pro rata.

The borrowings rectangle intersects both the cash balance and the bottom right hand corner of investments because some investments in assets, usually fixed, are made with the aid of borrowed money.

The time scale of the shifts varies. Disbursements and receipts are
remitted in the short term. Transfers to reserves, director’s drawings and investment in fixed assets tend to be at, or near, a year end if a small manufacturing business has had a ‘good year’. But transfers from reserves and top-up loans by directors are made at times of liquidity problems. Investment in liquid assets is also ad hoc for example in anticipation of a surge in sales or for the retention of skilled labour at times of falling order books. Overdraft borrowings fluctuate in the short term whereas loans are usually for the medium term.

1.7 Componentry

Attributes categorise chaotic behaviour; chaotic components illustrate its structure. Trajectories, orbits, attractors and fractals are the componentry of chaos. Open trajectories and closed orbits approximate to paths portraying chaotic behaviour. Attractors to destinations drawing particles towards them. Fractals to balanced off-axis chaotic shapes.

1.7.1 Trajectories

Trajectories on line graphs help with the visualisation of value-temporal attributes of chaos in 2D. (Lefranc et Glorieux 1997) Figs J12 ff, Attributes of chaos J8 (a), Daily cash balances, and J8 (b), Cash balance every tenth day, which are based on Appendix 1, show how trajectories are joined together in 2D graphs. They vary in length, slope and direction, negative or positive. They illustrate attributes such as non-linearity, irregularity, intermittency, transience, changeability and local instability but do nothing to explain their causes.
As they are line graphs they are not closed, (Tabor & Klappen 1994) like phase space.

Their dynamical instability is measured by Lyapunov exponents. (Golia & Sandri 1997, Paragraph E3.2.1.1) A jumble of trajectories is a feature of 'classical chaotic behaviour'. (Boothroyd 1997)

Every item in the Schedule of value and temporal variables, (Appendix 3) is a source of data for a trajectory so it is not difficult to visualise a jumble. Fig J19, Cash flow transactions and cash balance trend, is an example of continuously joined trajectories which change with a time or value change. J13 above shows similar irregularity but for a shorter time span.

1.7.2 Orbits

*Orbits*, which are closed, have some relevance chaos to open systems as well as closed tori. 'In chaotic systems numerous unstable orbits exist'. (Cambel 1993) Sets of them can be complicated. (Devaney 1986)

Their relevance to business finance arises from the complex patterns in which seemingly endless phase space reconstruction evolves. Fig. E14, Phase space reconstruction refers. The single trajectory is very long but is converted to a complex series of loops.

1.7.3 Attractors

References to *attractors* in chaotic literature are numerous. Some references are lengthy. (eg Shaw 1981) In ordinary language,
Cash transactions with cash balance trend

Value

Cash balance

Surplus

+ve

Deficit

-ve

Target

Time (1 division = 10 days)

Cash balance trend

Daily transactions in fast moving environment
attractors are conceptually relevant to business scenarios because it is only by attracting orders that businesses prosper.

Unfortunately a dichotomy exists between attractors in chaos literature and conventional ones in business. In chaos literature they are mathematical abstractions whose location is difficult to find and visualise. The existence of strange attractors is recognised on vibrating machine tools but locating them is difficult. Even in a very simple four dimensional system they are difficult to visualise. (Lorenz 1986)

Moreover they only appear in dissipative systems, a description which has limited application to businesses, (Pike & Sarkar 1987) because they are only dissipative in some circumstances. (Paragraph J1.5.2.2 (a))

Not all chaos, is accompanied by a strange attractor nor is every strange attractor a sign of chaos. (Bird 1997, Jacobs et al 1997) Thirdly the attractor is the manifestation of the system’s self-organisation. (Graf & Elbert 1990) Self-similarity, the usual term in life sciences for self-organisation, has limited application to business scenarios due to the activities of peripheral decision-makers who influence and in some cases, eg bankers, fix and change parameters. Self-organisation implies aiming for the status quo, standing still, with zero growth and zero decline. The majority of businesses aim to grow, not stand still.

Even in science ‘It [self-similarity] withered as a scientific principle
1.7.4 Fractals

In the chaotic literature fractals often appear alongside attractors. (Crownover 1995, Peitgen et al 1992) Interest in them has resulted in fractal geometry gaining recognition as a branch of mathematics. (Falconer 1997, Crownover 1995) There are no generally accepted definitions, (Isham 1990, Falconer 1997) and there are several types eg Voronoi. (Boissonat 1998)

If an attractor has a fractal dimension, it is called strange or chaotic. (Graf & Elbert 1990) As attractors are only associated with dissipative systems it is incorrect to state, without qualification, ‘[all] chaotic systems have fractal attractors’. (Parsons 1997)

Their properties are:-

- Fine structure that is irregular at arbitrarily small scales.
- Too irregular to be described by calculus or traditional geometry either locally or globally.
- Has some sort of self-similarity or self affinity. (Davidson 1997, Stewart 1993)
- Usually the fractal is greater than the topological dimension.
- In many cases the set has a recursive [backwards bending] definition.
- Often has a natural appearance, (Falconer 1997); snowflakes are frequently used to illustrate fractals on book covers as they bend backwards and as only structures are involved, without reference to their
differences in size.

Difficulties are encountered in relating fractals to small manufacturing businesses, especially self-similarity and scaled down sets being a version of the whole. (Clapham 1996) Breaking-even matches self-similarity but making profits, the usual objective, gives imbalance between revenue receipts and disbursements. A forward order book, equal in value to current indebtedness to a bank, is an example of self-similarity. However as banks are often reluctant to provide a facility to bridge the intervening time interval before sales orders are converted into cash because risks are assessed pessimistically, with some justification. Juxtaposing forward orders and bank indebtedness gives a fractal structure which is unlikely to have real life manifestation.

A major reason for incompatibility between fractal structures and small manufacturing businesses is the requirement that inputs should be amplified. Manufacturing and engineering are cost incurring, cash disbursing, but value adding, whereas marketing departments aim to generate revenue in excess of disbursements on product promotion. The familiar quotation, about swings and roundabouts, attributed to Patrick Reginald Chalmers is an expression of hoped-for self-similarity, not actual, used to boost morale after a loss has been incurred on a large order or project. (Beck 1968)
Of 1,792 days in Appendix I there are only four instances of approximate balance. Table J2, Days Showing Self-similarity, refers

### Days showing self-similarity

<table>
<thead>
<tr>
<th>Days</th>
<th>Duration of cash balance days</th>
<th>% of total period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 58</td>
<td>4</td>
<td>0.22</td>
</tr>
<tr>
<td>86 to 90</td>
<td>4</td>
<td>0.22</td>
</tr>
<tr>
<td>212 to 216</td>
<td>5</td>
<td>0.27</td>
</tr>
<tr>
<td>220 to 222</td>
<td>3</td>
<td>0.16</td>
</tr>
</tbody>
</table>

Debit balances persisted from day 882 to 1,792 without any self-similar credit balances.

Financial scaling, asset and organisational structures in business are another incompatibility between fractals and business. They vary greatly between departments. Manufacturing departments have a greater proportion of fixed assets than purchasing. Employees in engineering departments have more design skills than accountants. Engineers always contend that accountants earn more so professional similarity does not exist. The orientation of a business is another factor. Some are market orientated, others towards manufacturing.

If there is a fine structure, it very difficult to find. Manufacturing does not have a natural appearance because from time immemorial it has centred on human endeavour.
The fact that both physical and financial systems are both complex, and
dynamic, does not mean that fractals and finance are connected.
(Kirkegaard 1997)

1.7.5 Bifurcations

These are part of the componentry of some chaotic systems. They are
associated with routes to chaos considered above. Any
change in the qualitative nature of the attractor is called a bifurcation.
(Stewart 1991) Logically if attractors do not usually exist in
small manufacturing businesses it follows that bifurcations, which result
from qualitative changes in them, do not.
Dear Dr. Hill:

Thank you for your submitted manuscript. Your thought is good and some of your references are outside the usual scope, so I will very likely end up accepting it, perhaps in somewhat expanded form; but let me begin (i) by making a few impromptu comments and (ii) consulting a referee.

Loose comment: Would "Chaotic chaos" be too smart-alecky a title?

Supplement to p. 2: "Khaos" in Russian is also negative. A well-known and beautiful poem by Zinaida Gippius personifies "drevnii khaos" as the opposite of love.

Comment to bottom p. 2: It would be possible to mention Norbert Wiener's failed attempt in the 1940s to entrench the term "homogeneous chaos" for something like white noise.

More substantial comment: Some of the same difficulties besetting use of "chaos" today arose regarding "random" in the 18th and 19th centuries (continuing to some degree today). Many of us are led to say things like "helter-skelter" to mean what is in non-technical talk meant by "random," as a random process for us has some structure permitting probability theory to be brought to bear. Do you agree with me that this is very much like your problem?

Major suggestion: Do you want to propose a new term?!

Sincerely,

[Signature]
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Conflict with the findings of the research is shown in **bold** type, compatibility in *italics*.

Some words have situation-specific definitions, in addition to those relevant to the thesis. They are not included. Moreover other published definitions require re-phrasing to make them compatible with the statement, in Methodology (para 242), about business language taking preference over mathematical notation so as to make definitions accessible to owner/managers.

**Analytic number theory:**
Deals with the distribution of prime numbers, studies in the behaviour of number-theoretic functions and the theory of algebraic and transcendental numbers (qv) Hazewinkel 1995

**Aperiodic:**
*Irregular* occurrence, not periodic. (Parker, S P 1989)

**ARCH:**
Auto-Regressive, Conditional Heteroskedasticity (qv) (Hsieh, D A 1991)

**Artificial intelligence:** An enabling information technology. (Sudit 1998)

**Assets:**
Resources or rights incontestably controlled by an entity at the accounting date that are expected to yield its future economic benefits (Solomons, D 1989)

(a) Current assets: cash, short term deposits, debtors, stocks of raw materials, work in progress and finished stocks.

(b) Fixed assets: buildings and machinery.

(c) Intangible assets: patents, designs, goodwill (Hill, D A & Rockley, L E 1990)

**Attractor:**
A set of points in the phase space of a dissipative dynamical system that are visited in asymptotic (infinitely long) evolution of a trajectory (qv) (Morris, C 1992)

A set of points in the space of variables for a dissipative system to which orbits or trajectories (qv) tend in the course of dynamic evolution. (Rasband, S N 1990)

The equilibrium level of a system ... The level that a system reverts to after the effects of perturbation have died away (Peters, E E 1991)

A pattern of behaviour towards which the system **periodically settles.** (Yam, P 1994)

Dynamical systems can show many attractors within an associated
An attractor binds a system to a pattern of behaviour. This may be attraction to a stable point, to a regular cycle or to more complex forms of behaviour (Parker, D & Stacey, R D 1994).

Several different adjectives are used to describe the characteristics of attractors:

- **Chaotic attractor** can be thought of as a bag in phase space (qv) defined by variables of position and momentum. It contains an infinite number of periodic (qv) states all of which are unstable.
- **Emergent attractor**, one characterised by a progressive drive away from equilibrium. They represent different states of the system in different environments.
- **Fractal attractor**, A discontinuous attractor that governs the behaviour of a complex system. (Francois, C 1997)
- **Strange attractor** has multiple points of attraction within a finite space and gives rise to unstable behaviour (Parker, D & Stacey, R D 1994, Peters, E E 1991) Where certain points of orbits (qv) tend to cluster. (James, R C 1992)
- **Temporary attractor** is a bubble equilibrium. (Lux, T 1998)
- Lorenz, Henon, Rossler and other attractors, named after individuals, have distinct mathematical properties

**Autonomous:**
- A dynamical system independent of time, (Pickover, C A 1995)

**Axiom:**
- A statement that is accepted without proof. (James, R C 1992)

**Bifurcation:**
- Any value of a parameter at which the number and/or stability of the steady state changes, (Pickover, C A 1995)

**Braid:**
- Parallel strands that interweave in certain ways (Schwartzman, S 1994)

**Break even:**
- The level of output or value of sales where total costs equal total revenue. (Rockley, L E 1984)

**Butterfly effect:**
- The large differences in the values of dependent variables resulting from minute differences in inputted variables. (Rutherford, D 1992)

**Buy-out:**
- The transfer of ownership of a business from a large corporation, or company, to its current managers; also called 'management buy-out) (Hill, D A & Rockley, L E 1990)

**Cantor set:**
- A simple fractal (qv), infinitely dessicated [unbounded] set

Thompson, J M T & Bishop, S R 1994)
Cash flow:
Cash received less cash paid out. 'Flow' indicates company's cash position is a constant state of flux. [without ever being stationary] (Ammer, C & Ammer, D S 1984) My comment:- It is sometimes stationary see Appendix I Synthetic Data.
All cash movements in a business. (Bannock, G & Manser, W 1994) The lifeblood of any business. It may be positive or negative (as in Appendix 1) Even the most profitable company can find itself in financial difficulties through poor housekeeping if it has insufficient funds to pay debts as they fall due. (Holliwell J 1997)

Catastrophe theory:
The study of singularities in certain types of mathematical models together with the application of this to the study of discontinuous events in nature: the study of classifying singularities of systems whose behaviour, usually smooth, unlike chaos, but which sometimes (and in some places) exhibits discontinuities which are then used to propagate mathematical models for discontinuous events in other situations (James, R C 1992 Parker, S P 1997)

Changeability:
Liable to change (Oxford English Dictionary, 1989)

Chaology:
The history, study and description of chaos (Oxford English Dictionary 1989)

Chaos:
Behavioural sciences;
Complex behaviour that seems random but has some hidden order (Freeman, W J 1991)
English usage;
A state of utter confusion and disorder (Oxford English Dictionary 1989)
Finance;
A non-linear deterministic process which "looks" random (Hsieh D A 1991)
Science & technology;
The dynamical evolution that is aperiodic (qv) and sensitively dependent on initial conditions. For continuous systems chaos requires at least three dimensions in phase space (qv) The technical term has an intrinsic feature of determinism and some characteristics of order. (Morris, C 1992)
Mathematics;
(1) From a practical point of view [chaos] can be defined negatively as not bounded steady state behaviour that is not an equilibrium point not periodic and not quasi periodic (Parker, T S & Chua, L O 1987)
(2) Irregular, unpredictable behaviour caused by inherent non-linearities in a dynamical system (Rasband, S N 1990)
A subset of complexity (Lewin, R 1993)

An example of a dynamical system which is chaotic belonging to families with differing number of parameter (qv)

(i) Logistic family with one parameter (eg population dynamics

(ii) Henon family with two parameters

(iii) Lorenz family with three parameters

(Hazewinkel M 1995)

Chaos theory;
Economics;
An analysis of random movements applied to the price data of stock and currency markets as well as to meteorology (Rutherford, D 1992)
Mathematics;
Basically the study of complicated behaviours of some dynamic systems under repeated iteration and changes in that behaviour that result from small changes in initial conditions (James, R C 1992)
Sociology;
A dynamic theory that captures movement and change (Turner, F 1997)

Classical system:
Based on concepts, pre-dating relativity and quantum theories, conforming to the direct cause and effect linkages of Newtonian mechanics. (Walker, P M B 1995)

Cobweb model:
A dynamic model of the relationship between supply and demand in a particular market. Central to the model is the assumption that there is a time lag between planning and completing production. Whether there is a movement towards equilibrium depends on the relative elasticities of the demand and supply curves (Rutherford, D 1992)
cf Butterfly effect (qv)

Complex:

English usage;
Consisting of or comprehending various parts united or connected together: formed by a combination of different elements (Oxford English Dictionary 1989)

Mathematics;
Containing or characterised by complex numbers (Oxford English Dictionary 1989)

Complexity theory:
The branch of mathematics concerned with classifying computational methods and determining their degrees of complexity (Borowski & Borwen 1989)

Conjecture:
Conservative:

Dynamical systems, also known as Hamiltonian, are frictionless and do not entail a continuous decrease of energy (Pickover, C A 1995)

Continuous system:
Statistically, not discrete (qv), having a continuum of possible values (Borowski, E J & Borwein, J M)

Core decision-maker(s):
The person(s) responsible for making the principal decisions in a small manufacturing business. In normal trading circumstances this is either the owner/manager, CEO (chief executive officer), entrepreneur or an executive management committee. In financially adverse situations these personnel may be replaced by administrators, liquidators or receivers.

Credit rating:
Appraisal of credit worthiness of existing and potential customers; usually implies checking of financial standing and, if satisfactory, setting up credit limits [bounds]. (Johannsen, H & Page, G T 1990)

Degrees of freedom:
(1) The measure of the leeway or variability in a system. In chaos fewer correlated degrees of freedom induce chaos more easily, or in other terms, commensurability is a determinant factor of chaos (Francois, C 1997)
(2) The number of independent variables needed to specify the configuration of a system (Rasband, S N 1990)
(3) 1a The minimum number of parameters necessary to describe completely a state or property of system.
(4) (Statistics) The number of independent unrestricted random variables constituting a statistic; the number of degree of freedom is usually one less than the number of variables. (Borowski & Borwein 1989)

Derivative:
Instantaneous rate of change of a function (qv) (James & James 1968)
computed by differentiation (qv) (Hazewinkel 1995)

Determinant:
Mathematics;
A real-valued function (qv) of the column vectors of a square matrix which is zero if, and only if, the matrix is singular (Parker, S P 1997)
English usage;
Who or that which determines Determining factor or agent (Oxford English Dictionary 1989)

Determinism:
The doctrine that everything that happens in determined by a necessary
chain of causation (Oxford English Dictionary 1989, Rasband, S N '90)

Deterministic system:
A system with causality. (Peters, E E 1991)

Differentiation:
An operation which relates a function to its derivative (qv). The derivative or the differential being considered may be defined at a point or some set or else partial derivatives, directional derivatives and total derivatives may be considered while the functions themselves need not necessarily be numerical but may be functions of a more general nature (Hazewinkel, M 1995)

Difference equation:
An equation expressing a functional relationship of one or more independent variables, one or more functions (qv) dependent on these variables and successive differences of these functions. (Parker, S P 1989)

Differential equation:
An equation involving the instantaneous [no lag] rate of change of certain quantities with respect to others. (Coveney & Highfield 1991 ) An equation containing derivatives (qv) or differentials of a function. A partial differential equation contains the partial derivatives of a function of more than one variable; otherwise the equation is an ordinary differential equation. First order (qv) partial differential equations are reducible to systems of ordinary differential equations. (Boronski, E J & Borwein, J M 1989)

Dimension:
In general the number of co-ordinates required to specify any one state in a phase space (qv). (Glenn, J & Littler, G 1994)
The minimum number of parameters necessary to determine the co-ordinates of the points of the object.

Correlation dimension
The most widely used measure to describe chaotic activity. It can be that the correlation dimension of a system's behaviour is the minimum number of dimensions of a space that can contain the trajectories generated by a system. It has also been expressed as:- the dimension of a system is its number of degrees of freedom (qv) (Francois, C 1997)

Information dimension
The dimension of a probability (qv) distribution

Topological dimension
An integer that makes rigorous the notion of the number of locally distinct directions in a set (Farmer, J D 1982)

Discrete:

Dissipative dynamical system:
One in which the volume of phase space (qv) decreases with time (Pickover, C A 1991)

Dynamical system:
Physical sciences:
Any process which evolves in time. (Devaney, R L 1993)

Mathematics:
An abstraction of the concept of a family of solutions to an ordinary differential equation (qv) namely an action of the real numbers (qv) on a topological space satisfying certain flow properties (Parker, S P 1994)


Energy, potential:
Potential, latent or static; the power of doing work possessed by a body in virtue of the stresses which result from its position relative to the other bodies. [cf inter-dependence of accountancy headings] (Oxford English Dictionary 1989)
Potential energy of a system is the capacity for doing work possessed by the system on account of the relative positions of its parts [cf uncommitted cash balances] (Noakes, G R 1960 p79)

Entropy:
The extent to which the energy of a system has ceased to be available energy (Considine, D M 1995) A measure of the level of complexity. (Brown, R & Chua, L O 1998)

Ergodicity:
In a dynamical system, the property of passing through all available points in a phase space (qv) compatible with the system's energy (Morris, C 1992)

Feedback:
A future state of a system depends on an earlier state of the same system (Turner, F 1997)

FFT (Fast Fourier Transform):
The name given to various reduced complexity methods of evaluating either direction of the Finite Fourier Transform (qv) (Borowski, E J & Borwein, J M 1989)

Forgetting factor:
The progressive loss of memory over a period of time (Francois, C 1995)

Fourier Transform:
A mathematical relation between the energy in a transient and that in a continuous energy spectrum of the adjacent component frequencies (Walker, P M B 1988)

Fractal:
Typically sets with infinitely complex structure and usually possessing some measure of self-similarity whereby any part of the set contains, within it, a scaled down version of the whole set eg Cantor set (qv) (Clapham, C 1996, Morris, C 1992) A mathematically conceived curve such that any small part of it enlarged has the same statistical characteristics as the original. It is usually related to natural objects
Fractal geometry:
The geometry used to describe *irregular patterns* (Coveney, P & Highfield, R 1991)

Function:
A mathematical rule between two sets which assigns to each member of the first exactly one member of the second. (Parker, S P 1989,)

Futures:
A contract for the future delivery or receipt of a certain quantity of a commodity or other product (Ammer, C & Ammer, D S 1984)

Game theory:
A branch of mathematics that deals with strategic problems, especially in situations of conflict, such as those that arise in business by assuming that participants involved *invariably try to maximise personal gain*. (Coveney, P & Highfield, R, 1995 Parker, S P 1997)

Gearing:
The relationship between the endogenous and exogenous capital of a business.

Heteroskedasticity:
Bivariate. A distribution with two random variables (Porkess, R 1988)

Hopf bifurcation:
A bifurcation under which a solution loses stability by oscillation (qv) about the previous solution. (Morris, C 1992)

Homeomorphic:
A one to one continuous transformation of topological space whose inverse is also continuous (Morris, C 1992)

Hyperchaos:
More than one Lyapunov Exponent (qv) is chaotic

Hysteresis:
*A temporary change* in one factor *causes a permanent change* in another. Positively it can mean that sales remain at a higher level despite competitors' responses. Negatively a lost sales position is never recovered (Simon, H 1997)

Intermittency:
*Ceases* for a time, *then resumes*, comes at intervals (Oxford English Dictionary 1989)

Irrational number:
Any number that cannot be expressed as ratio eg pi (Borowski & Borwein 1989)

KAM theory (also known as a theorem):
A theorem that the oscillatory motions in *conservative dynamical systems* persist when small perturbations are added to the system (Morris, C 1992)

Knot:
A curve in a space formed by weaving a string in any manner
Labour turnover:
= Personnel ceasing to be employed by a business
Number of employees required by the business
usually expressed as percentage

Lyapunov exponents:
Global and local Lyapunov Exponents, one of which may be the
dominant one, are a primary tool for the study of attractors. They are
coefficients that quantitatively describe the rates at which nearby
trajectories (qv) in phase space (qv) positively diverge and negatively
converge from initial conditions. They measure the average
exponential separation of adjacent trajectories and orbits. One positive
exponent [indicative of trajectory divergence] is frequently taken to be a
definition of chaos. The more sensitive to initial conditions, and the
more chaotic the motion [non-linear oscillations], the larger the
Lyapunov Exponent. (Parker, S P 1989 Farmer, J D 1982
1986 Schaffer, W M & Kot, M 1986 Frank, M & Stengos, T 1988

Markov probability:
In a series of random (qv) events the probability of an occurrence of
each elements depends only on the immediately preceding outcome
(Morris, C 1992)

Martingale:
A stochastic (qv) process (James, R C 1995)

Model:
A pattern that is supposed to represent a real situation (Schwartzman S
1994)

Network:
A structure of inter-firm relationships that emerge and evolve through
continuous interactive processes (Halinen, A & Tornroos, J-A 1998)

Non-autonomous:
Constrained.

Non-linear equations:
Where the output is not directly proportional to the input. The
response of the non-linear system can depend crucially on initial
conditions (Pickover, C 1995)

Non-linearity:
A property of a dynamical system whereby the evolution of its
variables depends on products of two or more of the values of the
variables. This feature is a necessary (though not sufficient) ingredient
of systems that might be chaotic (Morris, C 1992)
Oligopoly:
Control of the market by a few independent organisations. (Greener, M 1971)

Open system:
One which is in some way dependent on other systems, (after Maunder, P et al 1991)

Opportunity cost:
The highest value alternative that must be sacrificed to attain something (Maunder, P et al 1991)

Optimisation theory:
A mathematical technique for determining the most profitable or least disadvantageous choice of a set of alternatives (Francois, C 1997)

Orbit:
An approximately circular elliptical path described by something in motion. (Oxford English Dictionary 1989)

Order (mathematics):
The number of times a given function must be differentiated to obtain a given derivative (Borowski, E J & Borwen, J M 1989)

Oscillation:
A periodic movement to and fro or up and down (Oxford English Dictionary 1989)

Parameter:
English usage;
A quantity which is constant (as distinct from ordinary variables) a particular case considered but which varies in different cases. (Oxford English Dictionary 1989)

Mathematics;
An independent variable in which each co-ordinate if a point is expressed independently of other co-ordinates

Statistics;
A numerical characteristic of a population Oxford English Dictionary

Period doubling:
A bifurcation sequence of periodic orbits for a dynamical system in which the period doubles at each bifurcation (Rasband, S N 1990)
See also Hopf bifurcation.

Periodic:
Recurring at regular intervals (Oxford English Dictionary 1989)

Perturbation theory:
The study of solutions to partial and ordinary differential equations based on the assumption that perturbations in the given conditions of a problem cause only small changes in the solution. (Morris, C 1992)

Phase space:
The set of all possible states of a system (Frank, M & Stengos, T 1988)

Pixel:
Planar geometry:
The study of the properties of and relations between figures all drawn on the same plane (Borowski, E J & Borwein, J M 1989)

Poincare section:
A section whose plane is chosen to intersect the trajectories (qv) of a dynamical system. (Rasband, S N 1990)

Postulate:

Probability:
Mathematics. The amount of antecedent likelihood of a particular event as measured by the relative frequency of occurrence of events of the same kind in the whole course of experience: estimating by the ratio of successful cases to the whole number of possible cases (Oxford English Dictionary 1989)

Quadrilateral:
A geometric figure bounded by four straight line segments called sides, each of which intersects two adjacent sides called vertices but fails to intersect the opposite sides (Parker, S P 1997)

Quasi periodic:

Random:

Statistics:
Each number has an equal chance of occurrence (Oxford English Dictionary 1989)

Rational number:
Any number that can be expressed as a ratio eg 7/3 – 14/35 (Borowski & Borwein 1989)

Real number:
Any rational or irrational number (James & James 1968)

Satisficing:
The practice whereby a manager must settle for limited rationality because the future involves uncertainties (Koontz, M et al 1980)

Sensitivity analysis:
Statistical analysis to determine how sensitive the outcome of a process is to small changes in data inputs (Solomons, D 1989)

Set:
Mathematics;
A collection of objects which has the property, that given any thing, it can be determined whether or not the thing is in the collection (Parker, S P 1997)

Statistics;
A collection of numbers that usually have at least one common
property (Porkess, R 1988)

Set theory:
The study of structure and size of sets (qv) from the viewpoint of the axioms (qv) imposed (Parker, S P 1997)

Spectrum: In mathematics the set of all eigenvalues (qv) of a matrix (Schwartzmann, S 1994)

Stochastic:
Randomly determined, may be analysed statistically, but not predicted precisely (Oxford English Dictionary 1989)

Strange attractor: see attractor

Theorem:
A statement that has been proved if certain hypotheses (axioms [qv] are true. (James, R C 1992)

Theory:
The principles concerned with a certain concept and the facts postulated or proved about it (James, R C 1992)

Topology:
Concerned with those properties of figures and surfaces which are independent of size and shape are unchanged by any deformation that is continuous neither creating new points nor fusing existing hence with those abstract spaces that are invariant under homeomorphic (qv) transformation (qv) (Oxford English Dictionary 1989)

Trajectory:
A sequence of points in which each point produces its successor according to some mathematical function (Pickover, C A 1995) A curve described by the motion of a point (Hazewinkel, M 1995) A path. (Borowski & Borwein 1989)

Transcendental number:
Not algebraic and thus not the root of algebraic equations with rational coefficients (Borowski & Borwein 1989)

Transience:
Passing through space without staying in it (Oxford English Dictionary 1989)

Transform:
The operation of changing (as by rotation or mapping) one configuration or expression into another in accordance with a mathematical rule. (Pickover, C A 1995) without alteration of quantity or value (Parker, S P 1989)

Value:
Mathematics. The precise number or amount represented by a figure (Oxford English Dictionary 1989)

Financial values, *subject to external audit, are precise but approximation, and best estimates, often suffice for those values [financial management information] which businesses are not obliged to divulge to third parties.

*1999 onwards, many small businesses are not exempt from external