A Mathematical Model to determine Strategic Options for a Firm using time based Financial Accounting and Physics equations

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by

RUI MANUEL ROTEIRO CARIAS

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This report is dedicated to the Most High God, family and friends without which this would have been impossible.

I certify that, except as noted above, the report is my own work and all references used are accurately reported.

Signed

The Programme Administrator: MBL 3

Unisa Graduate School of Business Leadership

P O Box 392

UNISA

0003

Fax no: +27 11 6520299

Notification of submission of research report (30 October 2007)

....

I Rui Manuel Roteiro Carias student number 7058 610 1 intend to submit my research report entitled:

A Mathematical Model to determine Strategic Options for a Firm using Time Based Financial Accounting and Physics Equations

this year to be examined.

....

Study leader Date

The Programme Administrator: MBL 3

Graduate School of Business Leadership

P O Box 392

UNISA

0003

Fax no: +27 11 6520299

Consent to submit research report

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Executive Summary

This report uses modified physics and the basic business relationship equations to describe the business system. The physics - business equations are derived using conformal mapping, while thermodynamic and kinematic relationships are further developed and related before being applied to a business situation. The system developed has general applicability to business and can be used for strategic competitive positioning, amongst other postulated uses.

The main purpose of this project is to build on existing work in the area of process modeling and strategy formulation to define a quantitative management tool that will effectively enable the formulation of a generic framework, to measure the effects of various strategic options using time based financial management and physics models.

The main aims of this research project are to provide an evaluative summary of the existing literature on the applications of process modeling and physics to business limited in scope to competitive strategic planning through a literature review of existing business models and the subsequent development of a mathematical model based on kinematics and thermodynamics for strategic formulation.

From the literature review derive a mathematical framework relating business and physics based on an indirect relationship of physical laws to business models based on existing knowledge. Further explain why the derived model has applications to business, and derive a non-rigorous mathematical proof thereof. From these equations make recommendations on how this model can be utilised as a tool to assist in strategy formulation. Thereafter provide statistical proof that the model is applicable to a defined set of companies and show by means of applications how to determine optimal strategies using the model.

The main objectives of the research project are to utilise the quantitative tool to determine where a company is, and where it should position itself in future to optimise its competitive position. Further, the framework must be developed into a strategic tool that would allow for the fast turnaround in the implementation of strategy, and the ability to quickly predict necessary changes in direction.

The statistical hypothesis tested asks if it is possible to relate the laws of physics to business and use the resultant mathematical framework to analyse a firm's competitive position in an industry and position it accordingly.

From the derived equations a mathematical model to determine strategic options for a firm using time based financial accounting principles and physics equations can be formulated and used to find profitable options for a firm. By implication the model can be applied to strategic positioning of the firm. Unfortunately there is no work in the literature reviews to build this study on and much of it is built from first principles. This leads to complex mathematical relationships, which may prove difficult to follow.

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Chapter 1

Introduction to the Research Problem

1.1 Introduction

With the proliferation of writings on business strategies, the availability of multitudinous business tools, and the increasing need for effective strategy formulation due to increasing competition, technological advances and globalization, why is it so difficult to create winning strategies, even with the move to quantitative strategy formulation?

Although various tools exist to create and evaluate competitive strategies for companies, most are limited in application and scope, and it is difficult to quantify best fit strategies. Amongst these tools are Porters Five Forces and Value Chain, which using mathematical manipulation can be adapted using the laws of physics, and the equations derived there from to provide quantifiable data upon which to base strategic decisions.

The application of the model derived from this abstraction has wide scope and application in business, and as such only certain areas of relevance will be analysed in this report. The report will assess the competitive positioning of the company amongst conflicting forces at play and the choice of optimised strategies. This limit to the scope of the model does not preclude its application in other areas of business. It is proposed that further study be conducted using the derived model, to test its applicability in other areas of business

Currently physics is not used by business to solve common problems in certain areas. One of the most obvious areas is logistical supply. Aspects of mathematics have been applied in Quantitative Management and Operations Research, but ascertaining the direct relationship of physical laws and business laws has not been attempted, as this is a complex matter, and difficult to prove in practice. However, it may be possible to link various aspects of physics indirectly using mathematical models to business (analogy). The project will attempt to define and develop models, which can adequately predict viable strategies within an organisation, and prove the validity of the derived constructs statistically, logically and mathematically where appropriate.

1.2 Purpose of the study

The purpose of this paper is to relate the laws of physics to business and use the resultant mathematical framework to analyse a firm's competitive position in an industry and position it accordingly.

The report will provide an evaluative summary of the literature on the applications of process modeling and physics to business limited to strategic planning (through the provision of a literature review) as the applications of the model are wide ranging.

We will derive a mathematical framework relating business and physics based on an indirect relationship to existing knowledge of physical laws. We will explain why the model has applications in business, and attempt a non-rigorous mathematical proof thereof and thereafter make recommendations on how this model can be utilised as a tool to assist in strategy formulation. Furthermore we provide statistical proof that the model is applicable to a defined set of companies, and define how it is applied to determine optimal strategies.

The main objectives of the research project are:

Develop a quantitative tool that can define where a company is positioned, and where it should position itself in future to optimise its competitive position.
Prove the tool mathematically and statistically while defining its scope and limits of applicability.
Develop a time based financial tool, which would allow for fast turnaround in the implementation of strategy and the ability to quickly predict necessary changes in direction, while optimizing them.

Chapter 2

Literature Review

Introduction

There is a paucity of Quantitative analysis applied to Strategic Management, as strategy is an art rather than a science. A perusal of the available literature yielded some models in the Journal of Strategic Management, but none related to a framework based on physics capable of analysis and determining the strategic options and best fit of various strategies available to a firm. However various operational and some tactical models exist, based on particular business models, or business process models (BPM).

In the Journal of Management Science there were many models to determine specific aspects of a firm's strategy, and operations but none of these were in any way comprehensive nor based on physics per se.

The closest models to the proposed PBR model – as espoused in this paper- are process management models, but these again are limited to specific problems, at the operational and tactical level.

All businesses begin with a vision, that requires goals and objectives to reach, requiring strategic, tactical and operational strategies to attain and maintain success

Process models tend to define who does what and when, and ignore the "whys" and "what's" (Makrides, 1999). At the strategic level however the models should be defined at all levels, to reach the exact strategic goals of the firm. This paper intends to provide a framework to define the strategies needed (based on measurable business model variables) in order to achieve the companies goals.

Process modeling is too narrowly defined to allow for all the variables needed to fully describe the strategic position of a firm, because the models tend to be complex and unwieldy.

There are two approaches to overcome this.

The model can be narrowed down from the universal laws to physics laws to business laws. This is the approach followed in this paper. The other approach is modular, where parts are added to the process model, to create a descriptive whole defining the business model. The drawback with this system is that it is too limiting and complex. It is simpler to work from the general case to the specific, narrowing down options and models as we define a more compact concept.

From Nurcan S, Etien A, Kaabi R, Zoukar I & Rolland C. 2005 we note that process management models used by various authors allowed for development of business process modeling with the aim of improving performance and fit of technology in firms.

We also note that due to the popularity of process modeling a large number of mathematical models were developed and are continually being developed and improved by various authors including a workflow analyzer process model, and workflow systems to monitor implementation.

These models are used to describe operational performance of tasks and are not useful at the strategic level. This improved the operational efficiencies of processes, but as we will see later there is a limit to improvements.

From Nurcan S et al. 2005 we have that a systems approach would handle the bigger picture, if abstraction to a goal model is used. Goal-driven modeling is used in a number of approaches to building models and to underpin BPR (Business Process Re-engineering). A formal relationship from the strategic direction of the firm needs to be aligned to the tactical and operational levels. This relationship is needed to handle external changes and for internal changes. The PBR (Physics Business Relationship) model proposes just such a relationship. The problem with business process modeling, change management, standardization and rollout across borders of processes, and creating synergy due to company merges is that the devil is in the detail.

To overcome these problems various strategies can be used, including systems modeling, a map-driven process, or any model that can determine global variables applied across the industry and the firm, and measure the effects of firms on these, such as the PBR model, which uses modified physics equations, to understand the underlying drivers of business.

The next section of this paper presents the PBR model. It uses tables to compare and contrast physics models with the associated business model. The proposed business model is then integrated to analyse the UK car market. In this section a mathematical proof will be derived.

Statistical analysis is then used to determine if the model fits a data set. Further literature review will be used throughout the text as applicable, as no relational models exist at present. The model proposed is built mainly from first principles of accounting, strategy and physics. This entails complex mathematical relationships and means considerable manipulation of the components and variables in an attempt to explain the process as well as the resulting model.

2.1 The physics/business relational system

This section introduces the key concepts of physics and their relationships to the business process. We further define the relationship between the physics and business components.

The PBR model is a multi process model active at all levels of strategy formulation and capable of dealing effectively with change and positioning. It is capable of defining multiple business strategies and optimizing the response. The strategies proposed are only as accurate as the information provided.

PBR is a top-down model and is capable of drilling down to operational levels. Various levels of management can be considered. The model is fully capable of integrating all the levels. This black box approach aids in reducing complexity.

Recent object-oriented methodologies (OOM) relate business models to software models using a loose indirect, coupling. The proposed PBR model alleviates this problem to some extent.

Again from Nurcan S et al. 2005 we note that physics models and business models are expressed in different languages giving rise to "'conceptual mismatch" as described by the business and physical models. However should the languages be modified we can reduce this mismatch considerably.

The main concerns to be overcome are excess detail, information quality, and PBR model inconsistencies.
To overcome excess detail only that information which is relevant, timely, and accurate will be used. Since there is little or no direct model to build on, we must use first principles to derive and build the PBR model. The relevant literature used will be quoted throughout the text as needed. As the system is built from first principles we will use a physics framework to build a model of business, but only examine in depth some aspects of the model as it is complex.

Chapter 3

A Framework for the Strategic Analysis of Firms

Index of Units used in the Text

Units	**Business**	**Physics**
Fv	Future Value Monetary units	
Pv	Present Value Monetary units	
i	Interest rate Ratio	
n	Number of periods	
Profit	Profit Monetary units	ΔU Joules
Revenue	Revenue Monetary units	ΔQ Joules
COS	Cost of Sales Monetary Units	Wd Joules
P laws		Physics Laws
U laws	Universal Laws	Universal Laws
B laws	Business Laws	
Temperature	Σ Kinetic Energy of Firms or individual businesses	Temperature
Mass	Unit sales	Kilograms
Length	Ratio of Sales (Market share - Revenue) or Units (based on average prices)	Meters
Time	Days, Weeks, Months, Years	Seconds
Q	Heat = Revenue = Monetary units	Joules
U	Internal Energy = Monetary units	Joules
H	Enthalpy = Monetary units	Joules
W	Work = Monetary units	Joules
R	Market Share Revenue	Money
v	Velocity = Market Share Ratio / Time	m/s
a	Acceleration = Market Share Ratio / Time^2	m/s/s

Other derived units are defined in the text.

3.1 Introduction

The PBR model relates business strategy using a physics framework developed from Giancoli DC, 1984 and other physics references, and business frameworks from Porter ME, 1980, 1998 and others as expressed in the relevant portions of he text extrapolating for industries and competitive analysis of firms.

3.2 Financial Information and PBR framework

Normal financial accounting data only provides a static picture of business. Accounting relates goods and services to cash flows, which are not always matched, nor do they accrue in the same period. Hence we need to have an understanding of underlying business concepts. The PBR uses underlying concepts to optimize business strategies and proposes a time based financial model, as follows:

For a system at equilibrium and using GAAP definitions and framework:

$$\Pr ofit = \operatorname{Re} venue - CostofSales$$
$$CostofSales - Expenses = Net \Pr ofit$$
$$Net \Pr ofit - Tax = Net \Pr ofitafterTax.$$

In reality most firms are not at equilibrium, and the time based profit equation becomes:

From Bingham EF & Ehrhardt, 2005 we note the following:

$$Fv_n = Pv(1+i)^n$$
$$Pv = \frac{Fv}{(1+i)^n}$$

$$\Pr ofit = \operatorname{Re} venue - CostofSales$$
$$dP = dR - dCOS$$
$$For - Future\_Value$$
$$(1-i)^{p-profit} dP = (1-i)^{p-revenue} dR - (1-i)^{p-\cos} dCOS$$
$$For - \Pr esent\_Value$$
$$Pv = \frac{Fv}{(1-i)^n} divide - by (1-i)^n$$

This model assumes that the accrual and matching principles do not apply in business, as costs and sales (based on cash flows) are not accrued and matched in the same periods. We will consider the special case of Profit = Revenue – COS throughout this paper, to simplify understanding of the underlying concepts. However it should be borne in mind that the time based accounting equation can be applied at any stage to the derived equations. COS implies all costs to the company of making a sale including expenses and taxation. The model looks at the costs of moving units into the marketplace – all the costs of operations, all other functions as defined by value and supply chains, and sales.

3.3 Derivation of the PBR framework

The relationship is based on accepted physics and mechanical laws, theorems and relationships. These have been proven over the centuries and a proof of them is beyond the scope of this paper.

If we consider universal laws then:

$$U_{laws} \supset P_{laws} \supset B_{laws}$$

Business Laws are a subset of Physics Laws which are a subset of Universal Laws.
From this it follows that:

$$U_{laws} \cap P_{laws} \cap B_{laws}$$

Business Laws encompass some Physics laws and all Universal Laws. Universal laws underlie all physics laws and business laws. No system can exist outside the bounds of Universal Laws.

From this we can infer that there is a relationship between physical laws and business laws, because business cannot exist outside of natural laws.

3.3.1 Mappings

Let S, S' be sets where S = {the sets of physics laws, theorems, rules} and S'= {the sets of business laws, theorems, rules}. A map of S to S' is a rule that associates for every element of S an element of S'. If, f: S→S' is a mapping and x is an element of s then we can denote for f(x) the elements associated to x by f. We can call f(x) the value of f at x or an image of business under physical laws. It does not necessarily have to be a one to one mapping, and can be many to many (n → n).

One implication of this is that all things created by mankind are a subset of the laws of the universe, and all these things cannot exist outside of that which allows their expression. We are in this case examining an abstract emulation (business) created by man as a subset of nature or natural laws.

We are concerned with conformal mapping, only to the extent that changing the variables and the measurements used will change the outcomes. The forms of the equations describing business are limited by their physical performance. The actual abstract form of the equations are not important as we are using them to measure within an industry, or within a firm, to compare against the competition, and we are only using their relation between physics and business laws as a starting point to better understand business. For the purposes of this paper we are examining two subsets of these mathematical models.

The study of motion, force and energy are referred to as Mechanics. In this part of the model the mechanics (Kinematics) of business will be analysed.

Consider the mappings of basic units:

Physics	Business
Mass (Kg)	Units (units sold)
Length (m)	Money ($,R,£,¥) Ratio or Unit Ratio
Time (s)	Time (days-years)

Market share as a ratio (Sales units or Revenue $_{firm}$/Sales units or Revenue $_{Industry}$) can be related to Relative Length as both are a ratio scale. We may also consider only units as well, where the prices of the firms are more or less the same. We will consider Temperature in thermodynamics as translational Kinetic Energy. We can consider market share based on units, or money, as they are equivalent based on average pricing, but not if actual prices are used. If actual prices are used then Revenue must be used to calculate Market Share. However we must consistently utilize the same units. We must use a relative length as a ratio as money is related to energy, and units to mass and we need to eliminate units, to define a distance. We therefore have no other units to relate to length and must create a unit. For consistency the unit created must be the same throughout analysis of the industry. Revenue ratios are not the only units we can use for distance. For this paper we will limit our discussion to these two ratios to simplify the underlying application to the mathematical relationships.

We will relate two models, one where money is related to energy and money as market share is (Revenue = Units * Price) is a basic unit (length), and another where we only consider units (mass) as market share. There are $3^2 = 9-3 = 6$ models that can be formulated for a 3→3 relationship, but because time is always itself, we can have 2→2, that is $2^2-2=2$ potential relationships. Because mass can be related to units sold, there is potentially one relationship. However we can also relate to units outside this relationship as money makes things happen and logically would be related to energy. So we will consider both models, for the sake of completeness. As we shall see for a more accurate description of the system it is better to use Revenues to calculate market share as this is a full mass energy balance of the system. Using units only is a mass balance only, and can only be used where there are small differences in prices in the system.

3.3.2 Scope and Assumptions

Although the scope of this report is limited to competitor analysis and strategy formulation, the complete time based financial accounting system is derived as well as the thermodynamic model, as it is necessary to understand its function in the formulation of quantitative strategy. Also mass (units) exists in conjunction with energy (money) and for a complete description of any system we must consider both entities.

There is conformal mapping of business strategy and physics - only the units of measure change, but the equations measure the same concepts. There is an n -> n mapping (many too many) which means that various physical laws can apply to various business concepts, provided they are applied consistently.

The derived equations are true, if the underlying physical theorems and axioms are true. There is a current debate about Newtonian physics and Einstein. However, Newtonian physics is still applicable at the micro level. Man can only create things within the constraints of universal laws. Because nothing can exist outside the general laws of nature, any man created system can only exist within that, or as a subset of the laws of nature.

All units are derived and applied consistently. Unfortunately, there may be equivalent units, which complicate analysis. We will note the equivalent units as necessary, but will not develop them within the context of this model. Because of the assumptions listed above, the equations are generic and have general applicability (slight modifications might be necessary to accommodate certain peculiarities of industries/services) to all industries.
Because the model is comparative and we are examining ratios, the applicability is general, as long as we can maintain consistent equations and measures. This means inter- alia that the model may be applied using the same

basis of measures and be an accurate enough approximation of the industry to draw conclusions from. This extends to the derivation of possible strategies, which a firm might choose. Due to resource and other constraints, the firms chosen are restricted by other variables not examined in depth here. These include skills, training, management, soft issues and any other variables and factors which affect the bottom line (mass energy balance) of the firm.

There are some interesting applications to economics, evaluation of a firm, lifecycle of a firm and other applications, but at his stage, we concentrate on competitive strategy development. The system may also be applied to competitive strategy development between countries, economic modeling for deliverables in a firm, industry or a country and other applications which we will not consider here.

3.3.3 The relationship between Physics and Business

At any stage in this report we can convert between mechanics, thermodynamics and business by using the following relationships:

Where a mass appears in a physical equation we can replace this with units (services rendered, or units sold), and calculate a relative business unit, which is useful for comparison purposes, based on company units/Industry Units (Market share or market share % for accuracy based on units and prices - revenues) analogous to the relative distance traveled. Or we can use revenue (units x money) as this is a mass energy balance directly as a measure of distance. Where the actual units are unknown we can use Sales and COS, provided that the units sold are non-differentiable to calculate market share. Where we know the costs involved, we can take the relationship proposed deeper, where we can use cost per unit to convert units to costs. This is a cost per units in whatever physical units we are measuring. In the text we will be working with basic units, and only where we need to develop the relationship to a greater depth will we do so. This relationship leads to a time based accounting system, which is used to understand time based competition. It is always better to use revenues to calculate market share and COS per unit, as well as Profit per unit as all these quantities make use of the full mass energy relationship.

The relationship is the following:

Mass → Units (services rendered or product sold) this is related to the mass balance within a firm.

Mass balance

$\text{Mass}_{in} = \text{mass}_{conversion} + \text{waste} = \text{mass}_{out} + \text{Accumulation}$ (Physics)
And
$\text{Units}_{in} = \text{units}_{conversion} + \text{waste} = \text{units}_{out} + \text{Accumulation}$ (Business Equivalent)

Time→ Time and we will not elaborate here.

Distance → Market share as %, or fraction, based on units sold or revenue. (*Model 1*) This model we use only the units (mass) balance, and is only applicable in a highly competitive industry where firms are price takers.
Distance→Money based on Sales, or COS, or revenue. Sales or Revenue (*Model 2*) can be used because Sales Revenue = units x price. The two models at the average price sales and units are equivalent. Model 1 is based on a mass (units) balance only, while model 2 is more accurate as it is based on a mass energy balance.

Energy Balance

$\text{Energy}_{in} = \text{energy}_{conversion} + \text{waste} = \text{energy}_{out} + \text{accumulation}$
And
$\text{Money}_{in} = \text{money}_{conversion} + \text{waste} = \text{money}_{out} + \text{accumulation}$

Business consists of a mass (units) and an energy (money) balance. The link between these balances is sales, and cost of sales. Sales converts units to money while cost of sales changes money into units for sale. The links can be considered as mass to energy balances similar to heat of formation/evaporation. We will develop this relationship further in the section on thermodynamics, to completely describe the cyclic process. To fully describe any system it is necessary to use both mass (units) and energy (money) balance, or model 2.

Mass and Energy Balance

Mass and energy are related, by Mass X Energy (Physics), or Units X Money (Business). Therefore

$$Thermo$$

$$mEnergy_{in} + mEnergy_{waste} = mEnergy_{out} + mEnergy_{accumalation}$$

$$m\Delta U = m\Delta Q - m\Delta Wd$$

$$Business$$

$$n\Delta Profit = n\Delta Revenue - n\Delta COS$$

A sales volume is actually units sold in an area of operations for a firm. Hence we have three dimensions distance (height) x area m^2 where units represent the height or relative distance. Because we are already using money for energy and units for mass we need to create a new variable for distance. Hence we can consider the fractional relative unit sales (market share based on revenue or units) as equivalent to length. We use a ratio because we need to define a scale and to compare to the average or the market leader-(benchmarking) - also we need to remove the units of measurement. The distance in the business model is dimensionless, because it is a derived ratio.

For Thermodynamics we also need Temperature i.e. T, for which we can use Net Translational Kinetic Energy.

We can multiply both sides of any equation containing mass or units by cost/unit. This will render the cost of whatever relationship we are examining to a cost. This is the relationship converting mass to energy. Of course we can also convert energy (money) to units.

We can also modify both sides of any equation containing time with units/time or cost/time. This will render the units (mass) converted or sold, or cost over that time frame.

Hence we can convert any physical equation, law, or theorem containing units, distance and time into useful business relationships, which we can directly relate to business analysis, to use for strategy formulation or other functions. We can also convert any equation in business using the time based equation for present or future value.

For ease of calculation we can work with units only (mass balance), and multiply by Cost/Unit after calculation to get total cost (or mass energy balance). This we can do only if units are price comparable. We can also work with costs all the way through if necessary. It may be necessary to use revenue and costs, as these may change and only using a mass balance may be inaccurate. If however prices are relatively stable and homogeneous, the units can be used safely. It is better to use the full mass energy balance throughout, as this gives an undistorted picture of the business. It is far safer to work with aggregates, as this eliminates the need to convert to contributions per unit, and then convert to full costing at the end.

Proof of the relationships between business and their underlying kinematical and physical constructs is provided for each physics equation proposed in the text. We relate the following:

First Model

Basic Quantities	Engineering Unit	Business Unit	Conversion
Length	Meter (m)	Relative Share based on units. (Dimensionless) Market, Suppliers, Customers etc.	Distance on nominal scale, either base year, or industry total, or competition maximum
Time	Seconds (s)	Days, Years	
Mass	Kilogram (Kg)	Sales Units	
Temperature	Kelvin (K)	Translational Ke of the firm	Translational Ke of Firm

Table 1: First Model Units

Second Model

Basic Quantities	Engineering Unit	Business Unit	Conversion
Length	Meter (m)	Money (R)/R Revenue = units X price	Market share based on money
Time	Seconds (s)	Days, Years	
Mass	Kilogram (Kg)	Sales Units	
Temperature	Kelvin (K)	Relative Market Share Or translational KE	We do not use Revenue for Temperature in this report.

Table 2: Second Model Units

These models are equivalent if we work with averages. They are not equivalent when there are various prices, and units are not directly comparable. The model we consider here is of the form:

Profit = Revenue – Costs

We are interested in maximizing Profit. To do this we need to:

$\text{Profit}_{max} = \text{Revenue}_{max} - \text{Costs}_{min}$

Profit = f (revenue generating activities – cost generating activities)

To maximize the value chain we need to maximize the unit sales (revenues) of a company, at a minimum cost of sales.

n = f (Internal Factors + External Factors) affecting a company. To optimize this we need to find the best fit of strategy to the capabilities of the company. For a SWOT analysis we normally consider Internal Factors – External Factors to discover the gap, or where the firm should concentrate.

n = f (Industry Effect + Competitors Effect + Vector Field (Force Field) Effects (Global) + Entropy Loss) $_{\text{External}}$ + ((Internal Value Mix-Marketing and Service Mix (7Ps) + Internal Energy (f (Finance, HR, R&D….Internal Functions) + Entropy loss)*Synergy (Efficiency of operations)) $_{\text{Internal}}$ + other factors.

Considering that to sell units a firm must perform work:

$$W_{net} = W_g + W_N + W_p + W_{friction}$$

Net work done by a firm is the work against gravity, the normal force, against frictional forces, and other forces acting on the firm. The firm must overcome all forces acting against it and utilize all the forces acting with it, e.g. collaborators, team work, both internal and external. The firm pays to overcome all the forces acting against it (COS), and it does work to do this.

Or we can relate force, velocity, or units sold at the lower level. However a firm must do work to move units into the market, and that work costs money, or cost of operations (COPS) + (COS) cost of sales. We relate thermodynamics and kinetics using the work energy theorem $Wd = \Delta Ke$.

$W_{internal} = \Sigma W_{purchase\ materials} + \Sigma W_{conversion} + \Sigma W_{distribute} + \Sigma W_{sales} + \Sigma W_{other}$ = COS (Total cost to firm of selling a unit)

These are all the costs associated with the manufacture and sale of goods and services. The internal work is proportional to the money expended to carry out the operations.

$$Wd = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 .... + \beta_n x_n + \beta_{error} X_{error} = COS$$

$$\left(\frac{\text{Re}\,venue}{Unit}\right)_{\max} - \left(\frac{COS}{Unit}\right)_{\min} = \left(\frac{\text{Pr}\,ofit}{Unit}\right)_{Optimum}$$

$$\Rightarrow \Delta Q - \Delta Wd = \Delta U ....1stLawThermo$$

$$where \Delta Q / T = \Delta S_{\text{int}\,ernal} ....2ndLawThermo$$

$$\Delta U = (Gross\ \text{Pr}\,ofit_{\text{int}\,ernal} - Expenses_{\text{int}\,ernal}) = Net\ \text{Pr}\,ofit_{\text{int}\,ernal}$$

$$NPAT = (Net\ \text{Pr}\,ofit_{\text{int}\,ernal} - Tax_{external})$$

$$3rdLawThermo........no100\%\ \text{Re}\,\text{cov}\,eryofEfficiencies$$

$$\text{Pr}\,ofit = \Delta U$$

$$\text{Re}\,venue = n \times price = \Delta Q$$

$$COS = Wd = \Delta Pe + \Delta Ke = Fd$$

$$COS = Wd = \Delta Ke = nad$$

$$Where \Delta Pe = 0$$

From the first law we have energy in = energy out + accumulation

Hence

$$\Delta Q = \Delta Wd + \Delta U$$

$$then - it - follows - that$$

$$\text{Re}\,venue = COS + \text{Pr}\,ofit$$

$$and\ \text{Re}\,venue = (COS) + NPAT + Tax$$

We are interested for this paper in competition only and the thermodynamics can be left for a later paper, but for completeness we propose a thermodynamic model but only prove it mathematically, not statistically.

$$Wd_{actual} = Wd_{company4sales} + Wd_{overcomeCompetition} + Wd_{other}$$

Based on SWOT analysis we can use f (internal – external) for all factors that would influence the firm and its competition. For each of these factors that affect the firm - if the internal measure > external measure (that is a strength), and a weakness if internal measure < external measure. The factors can be calculated at the strategic level using 2 0r 3 dimensional conservation of energy analysis (momentum), and at the tactical level using vector field effects and other competitive effects. If the company can sustain a factor advantage, this may be turned to a competitive or at the very least a comparative advantage.

Work is included in the COS, of a company and is not always obvious. However it costs money to move units into the external environment of the firm. This is manifest inside the firm i.e. what it pays to move units is a function of its costs. Should the firm expend less than its competitors to move units it has a competitive advantage, provided it can keep growing and selling units. This must be analysed against the actual factors affecting the variables contributing to the lower COS.

There is a relationship between the modified physics equations derived and business practice. This means that we can measure performance, compare firms and industry, and use the proposed framework to measure competitive advantages, and decide which to use, and develop strategies specific to the firm that fits its goals with internal capabilities, that are optimal for that firm. Also we need to develop short and long term strategies, as companies now compete on time, and the proposed time based financial model is an excellent tool for this application.

$$\Pr ofit = \operatorname{Re} venue - CostofSales$$
$$dP = dR - dCOS$$
$$For - Future\_Value$$
$$(1-i)^{p-profit} dP = (1-i)^{p-revenue} dR - (1-i)^{p-\cos} dCOS$$
$$For - \Pr esent\_Value$$
$$Pv = \frac{Fv}{(1-i)^n} divide - by(1-i)^n$$

This model aims to measure competitive advantage over time. If a firm is better at converting money into work, i.e. moving units at a lower operating or lower cost it has a competitive advantage over its competitors if it can sustain this. If a firm can charge more because it can differentiate its products, based on perceived value it has a competitive advantage provided it can manufacture and sell units in a range consistent with its competitors. **The model postulates that a firm must do work to move units.** Internal and external forces that act on a firm affect the amount of work or COS a firm must do to compete successfully in its marketplace**.** This is the underlying principle of the PBR model and differs from PORTER, and all the other writers on strategy**.** How it does this is up to the firm, and forms part of its business model.

Money is proportional to energy, because the efficiency of conversion of money to work and other forms of energy is dependent on factors such as skills available, including management, processes, products, people, plant and other factors. As such we cannot derive a direct relationship, but can use efficiency factors (conversion), which will vary between firms and industries. Because external and internal forces act with varying effect on COS and Revenue, we need to consider the mass energy balance in the firm at all times. Competition, the company and customers affect the ability of a firm to generate revenue, and Complementors, context, and the firm itself affect COS. See Appendix 8 for further details.

For a sustainable competitive advantage a company must move units over a longer period more efficiently than its competitors - this is a firms power. The lower the power (work done over time or COS per unit time) a firm uses, the more efficient its operations. However the more power used based on units moved means that the firm has more power to do work in that industry. If it has more efficient functions in its value chain it will have an advantage. However the competitive advantage of today normally becomes the key success factor of tomorrow, as firms cannot afford to allow others in the same industry any advantage. All the extra costs needed to implement and maintain key success factors and gain competitive advantage tend to raise the barriers to entry of new firms, and the costs for competing in that business for players. These factors do not improve the cost/benefit equation for firms, and tend to increase the entropy of the industry, and firms therein based on the prices that have to be charged to compete. We will examine this in more depth in the thermodynamics section.

In our consideration of the United Kingdom (UK) car market, we note amongst other things that there is a driving force to improve, to be more competitive. All industries face an unprecedented rate of change. Radical changes to compete on a time based perspective will only increase pressures on all industries to speed up and improve quality, cost and delivery to customers. Unless suppliers in a value chain can continuously improve to remain competitive they run the risk of loosing the race. There is a downside to this which is the increase in entropy.

The example cited here is drawn from the UK automobile industry. We are only considering the major groups. In practice we would consider the actual brands and their positioning, to find differences (weaknesses) to exploit. We will also consider a full competitive analysis of the brands, but not their positioning, for illustrative purposes. We need to do perceptual maps and need to assess qualitative and quantitative aspects for positioning. Business is an interrelationship of quantitative and qualitative functions. Why people prefer one firm's value proposition over another is a field we do not examine in depth here.

In the data set we are examining we have left out the minor players, and only examine the major groups, due to complexity and to simplify the illustration.

3.3.4 Data Sets

Application: Throughout this text **Example** will indicate the application of the derived equations to a practical example, drawn from the UK car market, as data is readily available.

The data set we are examining is the following:

Example

New Cars Sold **Group Data**

MARQUE	2003	2004	2005	2006
BMW	134,332	145,860	156,436	153,634
DAIMLER	121,653	110,037	107,406	106,561
FIAT	85,130	80,897	42,224	64,080
FORD	488,783	481,735	457,820	444,211
GM	341,895	345,816	345,057	328,641
HONDA	81,858	91,241	98,344	97,728
HYUNDAI	53,415	71,030	76,389	71,403
MAZDA	37,854	47,739	45,706	49,631
MG	95,848	76,768	29,091	4,805
MITSUB	18,074	22,573	24,972	19,713
NISSAN	105,798	90,223	86,727	69,157
PSA	302,542	273,418	239,907	243,708
RENAULT	189,427	189,342	174,743	138,094
TOYOTA	131,533	135,269	137,106	136,785
VW	320,888	329,186	339,343	346,939
Total	**2,509,030**	**2,491,134**	**2,361,271**	**2,275,090**

Table 3: New Car Sales 000's Units

See appendix 1 for a summary of all other data used.

Car Market in the UK

Sales of units: by limiting the sales volume to the total of these companies only we eliminate the noise of the smaller competitors. This is dangerous as we can miss a fast new entrant gaining market penetration. In practice all possibilities must be considered including all other forms of transporting people around. In this case we should consider motorbikes, light delivery vehicles, and some trucks as well as busses. If bus sales increase it can be assumed that fewer people would use private transportation to work as cities become more congested. We need to look for trends in the transportation industry, and the change of market share or velocity is a major indicator of changes in brand acceptance and industry performance.

For simplicity we are only examining competition. In practice we could include Porters five forces, and other industry specific forces including force fields (vector forces), and determine their effect on the firm, and what effect changes would have. We would perform a sensitivity analysis around the effects of forces.

As an example of this consider government legislation. In the USA, legislation enforces policing by a company of trade relations with its overseas suppliers. In Nikes case 75 employees in 2004 were tasked with this. We can calculate the cost to the company of this legislation as the wages paid to these people, and any other changes necessary to comply. This is a friction force as it is not conservative (see friction forces). See also the forces of taxation and other government effects on an industry or business as a whole.

The net effect of these forces, (some would assist the firm and others would affect it negatively) all affect the amount of work a firm must perform in order to get a product/service to market. The greater the opposing net force the higher the force the company must exert to do the work needed to overcome them and the lower the profitability of an industry. We prove this assumption in the section on forces.

In the example we examine the effects only of competitive forces, as we are limiting the scope of this paper to competition, otherwise it becomes too cumbersome and complex.

3.3.5 Simple Market Share Analysis

Example

Market Share **Percent**

MARQUE	2003	2004	2005	2006
BMW	5.353942	5.855165	6.625076	6.752876
DAIMLER	4.848607	4.417145	4.548652	4.683815
FIAT	3.392945	3.247397	1.788189	2.816592
FORD	19.480955	19.337980	19.388711	19.524986
GM	13.626581	13.881871	14.613189	14.445187
HONDA	3.262536	3.662629	4.164876	4.295566
HYUNDAI	2.128910	2.851312	3.235080	3.138469
MAZDA	1.508711	1.916356	1.935652	2.181496
MG	3.820122	3.081649	1.232006	0.211200
MITSUB	0.720358	0.906134	1.057566	0.866471
NISSAN	4.216689	3.621764	3.672895	3.039748
PSA	12.058126	10.975644	10.160079	10.712016
RENAULT	7.549810	7.600635	7.400379	6.069826
TOYOTA	5.242385	5.430017	5.806449	6.012290
VW	12.789325	13.214303	14.371201	15.249463
Total	**100.000000**	**100.000000**	**100.000000**	**100.000000**

Table 4: Simple Market Share Analysis

BMW, VW, Daimler, GM, Honda, Hyundai, Mazda, Toyota increased their market share.
However it is not apparent why. In the model below we take a simplified look at a method of analyzing competitive advantage.

It is apparent that the market declined by 17 896 units from 2003 -2004, and from the figures below it is in decline.
The market declined as follows, in the years under review 17,896→ 129,863→ 86,181units.
There is not much information that we can glean from the figures above, so we need a more sophisticated modeling tool.

3.3.6 Relative Market Share

Relative market share can be based on the largest competitor (benchmarking) or total units sold for that industry or the average. In this paper we work with the total market share.

3.4.0 Derived Equations, and Units of Measure

Equations are specified from standard physics relationships, and then derived for application to business. The units of measure are based on basic units in physics (meters, seconds, Kelvin etc) while business units are (units, days, money etc.) Care should be taken in converting equations literally, and using the correct units of measure. The same units should be used throughout the analysis.

3.4.1 Speed

Speed	Physics: Speed = Distance / Time
$v = d / t$ $v = ms / t$	**First Model** In business we are interested in the volumes sold. This refers to units sold, and can be a percentage or fractional units of the industry total. Market Share = Units sold by firm / Total Industry Units Business: Speed = Market Share / Time
$v = M / t$	**Second Model** Velocity = Market share revenue based.

This section would be useful as well to measure time based competitive advantage.
Speed to market, supply and service, are important as customers demand instant gratification. This is a tactical advantage as we are considering the physical distribution of models to the dealerships and hence customers. This can be included in our overall mathematical model. (See also vector fields)

3.4.2 Reference Frames

Every measurement must be based on a frame of reference. In business we use ratio, unit, and money scales, and the reference frame is based on the industry or major competitor units or any other convenient reference to measure a business.

3.4.3 Average Velocity

Average Velocity and Displacement	Velocity has magnitude and direction. It is a vector. Physics: Displacement is the change in position of an object Velocity = displacement / elapsed time
$v = \Delta d / \Delta t$ $v = \Delta ms / \Delta t$	Business: Velocity = Change in Market Share / Change in Time This will either be positive (increase) or negative (decrease) and the sign is important because velocity is a vector. However as direction is limited to up, or down, therefore we do not need to consider the direction, other than the sign.
$v = \Delta M / \Delta t$ $v = \frac{M_2 - M_1}{t_1 - t_2}$	Displacement moved per change in time

3.4.4 Instantaneous Velocity

Instantaneous Velocity and Displacement	Velocity at a moment in time. Physics: Displacement is the change in position of an object Velocity = Limiting value of displacement / elapsed time
$v = Lim \frac{\Delta d}{\Delta t}$ $v = Lim \frac{\Delta ms}{\Delta t}$	Business: Velocity = Limiting value of change in Market Share / Change in Time Limit as t -> 0
$v = Lim \frac{\Delta M}{\Delta t}$	Displacement traveled per infinitesimally small unit of time

In measuring velocity we are measuring the change of market share, hence the company with the fastest growing market share has the highest velocity. The drivers of velocity are the movement of units per unit time. Hence either the firm moves more units in that time or the same units in less time to improve performance.

Example

Speed/Velocity

MARQUE	2003	20004	20005	20006
BMW	1.466833305	1.592712875	1.708197115	1.67760078
DAIMLER	1.328385433	1.201544951	1.172815844	1.163588898
FIAT	0.929573886	0.883351799	0.461063406	0.69971919
FORD	5.337247888	5.260287513	4.999148555	4.850545583
GM	3.733309806	3.77612502	3.767837148	3.588583243
HONDA	0.893845403	0.996302724	1.07386367	1.067137281
HYUNDAI	0.583263117	0.775609458	0.83412686	0.779682417
MAZDA	0.413345353	0.521284245	0.499084976	0.541943869
MG	1.046608691	0.838265336	0.317658098	0.05246802
MITSUB	0.197358374	0.246485039	0.27268083	0.215255374
NISSAN	1.155257347	0.985186711	0.947012268	0.755157303
PSA	3.303596178	2.985577737	2.619655612	2.661160491
RENAULT	2.068441119	2.067512965	1.908099725	1.507912325
TOYOTA	1.436269728	1.477064842	1.497123895	1.493618748
VW	3.503924646	3.59453435	3.705443336	3.788387577
Total	**27.39726027**	**27.20184556**	**25.78381134**	**24.84276110**

Table 5: Sales Velocity

Since we consider the speed over a year the velocity has been multiplied by a factor of 100 (Hence we are dealing with market share as a percentage) to increase its magnitude, to prevent errors in calculation and to make the trends more obvious. The distance is calculated using a fraction or percentage market share (based on units in this case or sales revenue). This ratio scale enables the model to be quantified. Without this step the model cannot be calculated.

From the numbers above it is clear that the UK car market experienced a decline in sales, as fewer units were sold over that period which implies a slowdown in velocity. From the numbers BMW, VW, Honda, Hyundai increased sales over the period as their velocities increased steadily, though slowly toward 2006. We would then examine these companies looking for commonalities, and differences. We would examine their model breakdown, and segmentation in more detail, using the same framework to determine why they had higher sales in a declining market. All the other players had declining sales, so they lost market share to the gainers. There is a difference in the winners found using simple market share analysis above and the examples.

3.4.5 Acceleration

Average Acceleration	The change of velocity over time. Acceleration is a vector Physics: Acceleration = Velocity / Elapsed time
$a = \Delta v / \Delta t$ $a = \Delta v / \Delta t$	Business: Acceleration = Change in Velocity / Change in Time
$a = \frac{(M_2 - M_1)}{(t_2 - t_1)^2}$	Velocity change per time change

Instantaneous Acceleration

Instantaneous Acceleration	Acceleration per infinitesimally small change in time Physics: Acceleration = Limiting value of change in velocity / Elapsed time
$a = \Delta v / \Delta t$ $a = \Delta v / \Delta t$	Business: Acceleration =Limiting value of change in Velocity / Change in Time
$a = \frac{(M_2 - M_1)}{(t_2 - t_1)^2}$	Instantaneous velocity change per time change

Uniform Acceleration

If the acceleration changes are minimal can use this construct as well

Uniform Acceleration	Acceleration is constant and motion is in a straight line.
$a = (v - v°) / t$ $v = v° + at$ $x = x° + vt$ $v = (v + v°) / 2$ $x = x° + v°t + \frac{1}{2}at^2$ $v^2 = v°^2 = 2a(x - x°)$	Acceleration after time t Determine the velocity of company after a given time V is the average velocity Calculate position of company after time t Calculation of average velocity Calculate final velocity from the position of company.
Modify above equations using $a = \frac{(M_2 - M_1)}{(t_2 - t_1)^2}$	Constant acceleration only

This is a measure of growth, stagnation, or decline in market share**.**

Falling Bodies

Acceleration Due to Gravity	All objects fall at a uniform acceleration Physics: Acceleration due to gravity.
$g = \Delta V / \Delta t$ $g = \Delta V / \Delta t$ Of industry	Business: Acceleration due to market growth =Acceleration increase/constant /decrease due to market forces. Either an increase or decrease or constant acceleration depending on growth of industry or product in a monopoly. (Life Cycle Changes) over that time we examine in industry.
$g = \frac{(M_2 - M_1)}{(t_2 - t_1)^2}$	Macro environment market acceleration changes Based on industry.

Example

The market is clearly in decline as its acceleration has fallen: 8.052→ 7.915→ 7.793→ 7.682 in the four years under review. This is synonymous with gravity. The industry is not buoyant enough to overcome gravitational effect/business cycle effects. A company must accelerate faster than the market to grow. If it accelerates at the same rate it stagnates, and slower it is in decline.

Variable Acceleration

Variable Acceleration	Acceleration calculation using calculus. Physics: Acceleration = Change in velocity / Elapsed time
$\Delta x_i = v_i \Delta t_i$ $x_2 - x_1 = \sum_{t1}^{t2} v_i \Delta t_i$ $x_2 - x_1 = \int_{t1}^{t2} v(t)dt$	Business: Acceleration = Change in Velocity / Change in Time Use calculus because it may be easier to calculate as acceleration is not necessarily constant. However over a long period, days month years, used here aggregate measures may be more applicable.

Example

Acceleration **Velocity/time**

MARQUE	2003	20004	20005	20006
BMW	4.018721383	4.363596916	4.679992097	4.59616652
DAIMLER	3.639412146	3.291903976	3.213194093	3.187914788
FIAT	2.54677777	2.420141915	1.263187414	1.917038876
FORD	14.62259695	14.41174661	13.69629741	13.28916598
GM	10.22824604	10.345548	10.3228415	9.831734912
HONDA	2.448891515	2.729596505	2.942092247	2.923663783
HYUNDAI	1.597981141	2.124957418	2.285279068	2.136116212
MAZDA	1.132453021	1.428176013	1.367356099	1.484777722
MG	2.86742107	2.29661736	0.87029616	0.143747999
MITSUB	0.540707875	0.675301475	0.747070768	0.589740752

NISSAN	3.165088623	2.699141674	2.59455416	2.068924119
PSA	9.050948432	8.179665033	7.177138663	7.29085066
RENAULT	5.666961971	5.664419082	5.227670478	4.131266643
TOYOTA	3.934985556	4.046752991	4.101709302	4.092106158
VW	9.599793551	9.848039315	10.15189955	10.37914405
Total	**75.06099**	**74.52560**	**70.64058**	**68.06236**

Table 6: Sales Acceleration

The calculation has again been multiplied by a factor of 100 to enhance understanding. It is clear that the industry is decelerating (declining), although Hyundai and VW are both increasingly gaining market share and accelerating away from all the others, thus bucking the trend. Hence deeper analysis of their value proposition, their products, sales strategies etc, should be examined to determine their competitive advantage. Benchmarking can be used, but care must be taken to focus on the causes of their excellent performance. Toyota has maintained consistent results, so they need to find new ways of beating the opposition. All the other contenders are loosing pace quickly. We can convert this to costs, to do a cost comparison, but that is not our purpose here.

3.4.6 Kinematics in Two or Three Dimensions

To understand competitive factors we need to understand vectors and their effects in space time. In this instance we are interested in competitive analysis. A vector has both magnitude and direction, and has an effect on the work a firm must do to be competitive.

Addition of vectors

$V_R = V_1 + V_2$	Resultant vector
$V_1 + V_2 = V_2 + V_1$	Communicative Law
$V_1 + (V_2 + V_3) = (V_1 + V_2) + V_3$	Associative Law
$A - B = A + (-B)$	Subtraction

A three dimensional vector

In this model we consider only two dimensional signed vector, as the scale only allows for two directions either increase (+), or decrease (-). However in certain industries if the attack of competitors or substitutes is indirect, or there are many competitors the direction (cosθ) will have to be considered.

$$V = V_X + V_Y + V_Z$$

$$V_X = V\cos\theta$$

$$V_Y = V\sin\theta$$

$$V = \sqrt{V_X^2} + V_Y^2$$

$$\tan\theta = \frac{V_Y}{V_X}$$

Vectors can also be added by using its components.

$$V_X = V_{1X} + V_{2X}$$

$$V_Y = V_{1Y} + V_{2Y}$$

$$V_Z = V_{1Z} + V_{2Z}$$

$$V = \sqrt{V_X^2} + V_Y^2$$

$$\tan\theta = \frac{V_Y}{V_X}$$

For a further explanation of the uses of the equations see Vector Forces in the Appendixes, and follow the sections on kinematics below.

3.4.7 Relative Velocity

In business relative velocity of market share - change of one firm with respect to others in its industry are important, because we base all market measurements on the total units sold or the maximum sold by any firm. If velocities are along the same line then vectors can simply be added or subtracted. We will examine this in more depth in competitive analysis. We can measure relative to other companies or industry, or benchmark as required by the type of analysis we want to conduct.

3.4.8 Vector Kinematics

Displacement Vector

$$\Delta r = (x_2 - x_1)i + (y_2 - y_1)j + (z_2 - z_1)k$$

$$v = \frac{\Delta r}{\Delta t}$$ Average Velocity Vector

$$v = \lim \frac{\Delta r}{\Delta t} = \frac{dr}{dt}$$ Instantaneous Velocity Vector

$$a = \lim \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$ Instantaneous Acceleration Vector

For two dimensions with constant acceleration

X Component	Y Component
$v_x = v_{x0} + a_x t$ $x = x^\circ + v_{x^\circ} t + \frac{1}{2} a_x t^2$ $v_x^2 = v_{x^\circ}^2 + 2a_x (x - x_\circ)$	$v_y = v_{y0} + a_y t$ $y = y^\circ + v_{y^\circ} t + \frac{1}{2} a_y t^2$ $v_y^2 = v_{y^\circ}^2 + 2a_y (y - y_\circ)$

We will consider Vector Fields at a later stage as these are important in determining net effect of forces acting on a firm on the global stage.

Projectile Motion

The motion of a projectile fired into the air. This can be used as a simple measure of the comparative life of a firm (sustainability) in an industry.

$$v_{x^\circ} = v_\circ \cos\theta_\circ$$
$$v_{y^\circ} = v_\circ \sin\theta_\circ$$
Initially

$$v_x = v_{x^\circ} = v_\circ \cos\theta_\circ$$
$$x = v_{x^\circ} t$$
Horizontal motion at constant speed

$$v_y = v_{y^\circ} - gt$$

$$y = v_{y^\circ} t - \frac{1}{2} g t^2$$ Vertical motion is accelerated. $a_y = -g$

$$v_y^2 = v_{y^\circ}^2 - 2gy$$

This is a simple measure of competitive advantage. The bigger the market share of a firm, the longer the lifecycle will last and the more competitive the firm is. This measure assumes that no changes are made in direction, or changes affecting the product. This is a simple measure of sustainability of position in an industry, at a point in time.

Example

Falling Bodies

MARQUE	2003	2004	2005	2006
BMW	2.672275212	3.205146352	3.744370766	3.663328522
DAIMLER	2.191633187	1.824118002	1.765072409	1.762372738
FIAT	1.073216864	0.985916828	0.272787324	0.637303344
FORD	35.37972125	34.96164413	32.06970482	30.62526173
GM	17.3104246	18.01630032	18.21743064	16.76272724
HONDA	0.992303403	1.254167434	1.479793712	1.482310597
HYUNDAI	0.422521378	0.760079599	0.892826537	0.791287143
MAZDA	0.212200194	0.343338165	0.319633191	0.382302592
MG	1.360468003	0.887842436	0.129485978	0.00358334
MITSUB	0.048376092	0.076763366	0.095413998	0.060312403
NISSAN	1.657590074	1.226337402	1.150837721	0.742289782
PSA	13.55481419	11.26236636	8.806255475	9.218086152
RENAULT	5.31380954	5.400940177	4.672023465	2.959721248
TOYOTA	2.562074021	2.756588914	2.876195231	2.903876492
VW	15.24857199	16.32518682	17.61908012	18.68131468
Total	**100.00000**	**99.28674**	**94.11091**	**90.67608**

Table 7: Falling Bodies / Industry

Compare this to the actual market shares in Table 4 above. Because we are looking at the furthest range that the industry and its players can go, we notice that the biggest player's gain market share at the cost of smaller players. Firms in decline will decline faster than others still growing, if the market is contracting.

This is the market share of firms if the industry was in free fall. The total industry is contracting, and the owners of the biggest market share will gain at the cost of the smaller players, necessitating buyouts, mergers, and exits from the industry. The furthest point a firm can achieve is defied by velocity squared divided by the gravity in the business.

3.5.0 Dynamics: Newton's Laws

These laws form the basis of kinematics and the interactions of firms in an industry.

Newton's First Law of Motion
Every firm continues in its state of rest or uniform speed in a straight line unless it is compelled to change that state by forces acting on it. The forces can be internal or external in our case.

Newton's Second Law of Motion
The acceleration of a firm is directly proportional to the net force acting on it and is inversely proportional to units sold. The direction of the motion is in the direction of the applied net force.

Newton's Third Law of Motion
Whenever one firm exerts a force on a second firm, the second firm exerts an equal and opposite force on the first. (Otherwise it would be out of business)

We now apply these laws to business.

3.5.1 Force

Average Force	Physics: Newton's Law of Motion. Force = mass multiplied by acceleration.
$F = ma$ $F = na$ $\frac{FR}{n} = Ra$	Business: Force = units moved against competition multiplied by acceleration. F = Ra is the total cost per force applied. Multiply both sides by R (Cost or revenue)/n (units) This is the unit cost - can use Cost of Sales, or whatever measure is available. This is a cost per total Force applied=FR/n
$F = n\frac{(M_2 - M_1)}{(t_2 - t_1)^2}$	Force used to move objects.

Force exerted by a firm, is its capability to influence external forces. If the net force is positive the firm can move product (do work). PORTER considers the forces but does not quantify their effects. The greater the forces acting against a firm the more it must spend (COS increases) to remain competitive and move product. The higher the competitive and other forces in an industry the higher the entropy and the greater the waste. Waste (MUDA) are costs incurred that cannot be set off against benefits accrued.

Proof

Model 1	**Model 2**
$FR/n = Ra$ $FR_{revenue}/n - FR_{\cos tofsales}/n = FR_{profit}/n$ $Ra_{revenue} - Ra_{\cos tofsales} = Ra_{pofit}$ $FR_{revenue} - FR_{\cos} = FR_{profit} = Ra_{profit}$ $R_{revenue} - R_{\cos} = R_{profit}$	$F = na$ $W_{profit} = W_{revenue} - W_{\cos}$ $na_{profit} = na_{\text{Re}venue} - na_{\cos}$ $(M_2 - M_1)_{profit} = \Delta M_{\text{Re}venue} - \Delta M_{\cos}$ $ifM_{1-profit} = M_{1-revenue} = M_{1-\cos}$ $M_{\text{Pr}ofit} = M_{\text{Re}venue} - M_{\cos}$
$F = na$ $F_{\text{Pr}ofit} = F_{revenue} - F_{\cos}$ $na_{profit} = na_{revenue} - na_{\cos}$ $na_{profit}R/n = na_{revenue}R/n - na_{\cos}R/n$ $Ra_{profit} = Ra_{revenue} - Ra_{\cos}$ $Let: a_{p,} a_r, a_c = 1,$ $R_{profit} = R_{revenue} - R_{\cos}$	

Using the financial accounting equation we assume that income and costs are matched (matching principle). In reality expenses and costs are not incurred at the same time. Hence it is possible to calculate when the acceleration, or velocity of revenue and any other costs, are not synchronized i.e. not equal to 1. We can use the time based financial equation if the system is not at equilibrium.

Hence to improve profits increase revenue forces or increase price, or price acceleration, and decrease cost of sales and decelerate acceleration of costs. This is the basis of time based competition.

Example

Force

MARQUE	2003	20004	20005	20006
BMW	539.8428809	636.4742462	732.1192436	706.1274472
DAIMLER	442.7454059	362.2312378	345.1163248	339.7073878
FIAT	216.8071915	195.7822205	53.33682537	122.8438512
FORD	7147.276807	6942.642753	6270.438881	5903.193709
GM	3496.986181	3577.656027	3561.96872	3231.111193
HONDA	200.4613616	249.0511147	289.3371199	285.7238142
HYUNDAI	85.35616267	150.9357254	174.5701827	152.5251059
MAZDA	42.86787667	68.17969467	62.49637788	73.69100313
MG	274.8365747	176.3067215	25.31778559	0.690709137
MITSUB	9.772754135	15.2435802	18.65585121	11.62555943
NISSAN	334.8600462	243.5246593	225.0178986	143.0805853
PSA	2738.292041	2236.467654	1721.845805	1776.838633
RENAULT	1073.475605	1072.512438	913.4988224	570.5031358
TOYOTA	517.5804552	547.4002304	562.3689556	559.7387408
VW	3080.458553	3241.83667	3444.976049	3600.929856
Total	**20,201.61990**	**19,716.24497**	**18,401.06484**	**17,478.33073**

Table 8: Competitive Force

It is apparent that the net force of all the competitors acting in the industry is declining, as fewer units are sold. The force exerted by BMW, VW, and Honda is increasing, as is Mazda. Interestingly Hyundai's force increased then decreased. This is an early indicator of problems at Hyundai.

All other force exerted by competitors decreased in the industry as did overall force. Force is equivalent to units multiplied by acceleration.

3.5.2 Weight

Weight	Physics: Force of gravity =mass x gravity
$F_g = mg = w$ $F_g = ng$ $\frac{F_g R}{n} = Rg$	Business: Force of Industry = units moved against competition x force of industry. (Change in industry units sold) F = Rg is the cost of gravitational attraction in the industry. There is a loss of Ke, market as competitors, compete. This results in force acting downwards in industry.
$F_g = n[\ \frac{(M_2 - M_1)}{(t_2 - t_1)^2}\ ]_{gravity}$	Force used to move objects against an external force.

Weight is the force a firm needs to move units against the total industry competition. The firm must overcome this before it can move units.

Proof

Model 1	Model 2
$F_g R/n = Rg$ $F_{g-profit} R/n = (R_{revenue} - R_{\cos})g$ $FgRn/n = n(R_{revenue} - R_{\cos})g$ $FgR = n(R_{revenue} - R_{\cos})g$ $FgR/n = Rg = (R_{revenue} - R_{\cos})$ $R_{profit} = R_{revenue} - R_{\cos}$	$W_d = ng$ $W_{profit} = W_{revenue} - W_{\cos}$ $ng_{profit} = ng_{\mathrm{Re}venue} - ng_{\cos}$ $(M_2 - M_1)_{profit} = \Delta M_{\mathrm{Re}venue} - \Delta M_{\cos}$ $ifM_{1-profit} = M_{1-revenue} = M_{1-\cos}$ $M_{\mathrm{Pr}ofit} = M_{\mathrm{Re}venue} - M_{\cos}$
$FR/n = Rg$ $FR_{revenue}/n - FR_{\cos tofsales}/n = FR_{profit}/n$ $Rg_{revenue} - Rg_{\cos tofsales} = Rg_{pofit}$ $g = cons\tan t$ $R_{revenue} - R_{\cos} = R_{profit}$	
$F = ng$ $F_{\mathrm{Pr}ofit} = F_{revenue} - F_{\cos}$ $ng_{profit} = ng_{revenue} - ng_{\cos}$ $ng_{profit} R/n = ng_{revenue} R/n - ng_{\cos} R/n$ $Rg_{profit} = Rg_{revenue} - Rg_{\cos}$ $Let: g_{p,} g_r, g_c = cons\tan t,$ $R_{profit} = R_{revenue} - R_{\cos}$	

Using the financial accounting equation we assume that income and costs are matched (matching principle). In reality expenses and costs are not incurred at the same time. Hence it is possible to calculate when the force of gravity in an industry is not synchronized to revenue and any other costs. If we use a time based accounting system it becomes possible to integrate it into kinematics equations. Hence to improve profits increase revenue forces or increase price, or price acceleration to overcome g, and decrease cost of sales and decelerate acceleration of costs. This is the basis of time based competition. We of course also need to consider time based costs of money or interest. The faster we can convert sales into money, and reinvest revenues to generate more sales, the higher the efficiencies of the firm. The quicker the stock turn ratio, or minimize stock, the better for the firm.

Hence it is apparent that there is a relationship between business and the underlying physics equations, based on costs per unit, and gravitational force in an industry. This equation implies that there is a force arising from the industry which acts on revenue, profits and COS of a firm therein.

Example

Weight

MARQUE	2003	20004	20005	20006
BMW	1081.582924	1154.418627	1219.084544	1180.289951
DAIMLER	885.9701353	850.071898	830.4154291	818.6526252
FIAT	651.3475107	334.1846435	499.3667542	492.2932426
FORD	3878.721004	3623.446701	3461.676112	3412.641598
GM	2784.360245	2730.976472	2561.054767	2524.777521

HONDA	734.6329063	778.350099	761.5810574	750.7932898
HYUNDAI	571.9027119	604.585798	556.4339006	548.552035
MAZDA	384.3736951	361.743163	386.7676557	381.2891062
MG	618.1025959	230.2426455	37.4447137	36.91431071
MITSUB	181.7479926	197.6425473	153.620737	151.4447049
NISSAN	726.4364124	686.4065834	538.931127	531.2971875
PSA	2201.442991	1898.759835	1899.18341	1872.281547
RENAULT	1524.499553	1383.015043	1076.147824	1060.90423
TOYOTA	1089.127241	1085.134514	1065.946964	1050.847865
VW	2650.462707	2685.75264	2703.648601	2665.351518
Total	**19,964.71063**	**18,604.73121**	**17,751.30360**	**17,478.33073**

Table 9: Weight in an Industry

The total weight of vehicles sold has decreased, therefore the weight decreases. Weight is the minimum force necessary to start to move units. It is an inertial force, see frictional forces below. We must still impart an inertial force. This is the force that competitors are expending against each other in the industry. The net force determines the competitions interaction, as it is the sum of all their interactions. Note that the net weight is < force measured above, but for BMW the weight > force, and VW the force > weight. We need to calculate the resultant force, as the firms are doing work against the pull of the industry and other forces, and work to move cars. This is a vector addition because the firm must do work against all forces. At a minimum the carmakers must overcome gravitational force within an industry and inertial forces to compete. Weight is the units sold / gravity in the industry. Weight is units moved by the firm divided by gravity in the industry.

Resultant Force

MARQUE	2003	20004	20005	20006
BMW	0.120882255	0.131824953	0.142202873	0.137539098
DAIMLER	0.099043757	0.092403122	0.089927474	0.088633697
FIAT	0.068648302	0.038731131	0.05022071	0.050738866
FORD	0.813191505	0.78313252	0.716251389	0.681863759
GM	0.447007543	0.450087271	0.43870973	0.410055863
HONDA	0.076149213	0.081722416	0.081469115	0.080332351
HYUNDAI	0.057823731	0.06231417	0.05831753	0.056936214
MAZDA	0.038675676	0.036811219	0.03917844	0.038834488
MG	0.0676451	0.028999265	0.004520063	0.003692077
MITSUB	0.018201055	0.019822952	0.015474938	0.015189026
NISSAN	0.079990069	0.072832565	0.058402039	0.055022609
PSA	0.351348752	0.293378194	0.256352308	0.258120005
RENAULT	0.186452374	0.175014672	0.141158572	0.120457113
TOYOTA	0.120585558	0.121538633	0.120519781	0.119062534
VW	0.406376395	0.420984231	0.437922091	0.448004403
Total	**2.95202**	**2.80960**	**2.65063**	**2.56448**

Table 10: Resultant Force

This is the force needed to move units. We do not need to consider the vector direction as it is up to move units (fractional market share). The resultant force is force squared plus weight squared.

3.5.3 Frictional Forces

$F_{fr} = \mu_k F_N$ Kinetic Friction μ_k Coefficient of Kinematic Friction

$F_{fr} \leq \mu_s F_N$ Static Friction μ_s Coefficient of Static Friction.

These forces are not conservative and must be taken into account in competitive analysis. Frictional forces act against the work force of the firm. Static friction is the friction arising from getting the company moving and is a measure of barriers to entry and forces within a firm. Kinematic friction arises from any industry external force that opposes the firm selling units. It is part of the system (industry or environmental) being examined, e.g. legislation which has cost implications for the firm.

3.5.4 Terminal Velocity

There is a drag force in a fluid. This is analogous to resistance to moving units in business, usually from buyers, suppliers and competition. Collaborators are forces assisting the firm and are positive.
The terminal velocity is experienced by firms that are merely surviving. They eventually reach a certain amount of near constant sales.

$v_t = mg / b$ b is the resistive force.

At this point the firm is in free fall, and unless it acts against the force pulling it down it will expire, when it runs out of energy (money) to oppose the force acting on it.

3.5.5 Newton's Law of Universal Gravitation

Law of Universal Gravitation

Universal Gravitation	Physics: Every particle in the universe attracts every other particle with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them.
$F = G\frac{m_1 m_2}{r^2}$ $F = G\frac{n_1 n_2}{d^2}$ $\frac{FR_1 R_2}{n_1 n_2} = G\frac{R_1 R_2}{d^2}$	Business: This law can be used to calculate the attractiveness of an industry, and the attractiveness of firms. There are other factors at work in business as well, but it is an interesting starting point. The attractive force between two firms is dependent on the units moved, the difference between their core businesses and G which can be determined experimentally and is different for each industry, but the same for firms within that industry. Can use profitability or some other measure for G. The force can be related to profitability per unit or cost per unit depending on which force we want to measure.
$F = G\frac{n_1 n_2}{M^2}$	Law to calculate attractive forces.

Measurement of Gravitational Field Intensity

Gravitational Field Intensity	Physics: The gravitational force per unit mass at any point in space.

$g = \frac{F}{m}$ $g = \frac{GM}{r^2}\hat{r}$	Business The force experienced by a firm in moving one unit. The gravitational field due to total units sold in that industry N, then r is the distance from n to N. If several firms contribute to field intensity then g is the vector sum of all the firms in that industry. Inertial mass = Gravitational mass.
	Law to calculate intensity of competition

3.5.6 Work and Energy

It is here that this paper differs from Porters Interpretation of Industry Forces. All firms must do work to compete in an industry. Without this work they cannot move units in an industry. There are forces acting in an industry but their effect is on the amount of work a firm must do to move units. The higher the amount of work done the more it costs (COS). Hence models of forces, and vectors in industries, must be applied in a broader sense to their effects on the firms ability to perform, or do work. A measure of a firm's relative strength in an industry is measured by its power. Energy is related to enthalpy, entropy (chaos) and hence to what a firm spends to get a product to market. Work and Energy are scalars. We examine this in more detail in thermodynamics section. As the net effect of forces acting on a firm increase, it will sell less units (decrease revenue) and its costs to compete COS increases. The origins and effects of external forces can be determined using the models proposed. Internal forces can be determined by using value chains, and COS, or Wd in moving units within a firm.

3.5.7 Work done by a Constant Force

Work Done **Constant Force**	Physics: The product of the magnitude of the displacement times the component of the force parallel to the displacement.
$W_d = Fd\cos\theta$ $W_{net} = \sum W_n$ $W_p = mgh$ $W_b = ngh$ $W_b R/n = Rgh$	Business: Work = Force x distance moved in increasing sales volumes x direction component. The work done to move units up the sales scale. Work needed to increase market share. A good starting point to align the goal of increased market share with internal capabilities, using gap analysis and resistances to that change.
$W_d = naM$	Work done to sell more units. In economics work done to sell one more unit is marginal work done.

Proof

Model 1	**Model 2**
$W_d R/n = Rgh$ $W_{d-profit} = W_{d-\mathrm{Re}venue} - W_{d-\cos}$ $W_{dp} R/n = g(Rh_{revenue} - Rh_{\cos})$ $W_{dp} R = ngh(R_{revenue} - R_{\cos})$ $R_{\mathrm{Pr}ofit}\, gh = ngh(R_{revenue} - R_{\cos})$ $R_{profit} = n(R_{revenue} - R_{\cos})$	$W_d = naM$ $W_{profit} = W_{revenue} - W_{\cos}$ $naM_{profit} = naM_{\mathrm{Re}venue} - naM_{\cos}$ $M_{\mathrm{Pr}ofit} = M_{\mathrm{Re}venue} - M_{\cos}$

$W_d R/n = Rgh$ $W_{Profit} = W_{revenue} - W_{\cos}$ $Rgh_{profit} = Rgh_{revenue} - Rgh_{\cos}$ $Let: h_{p,} h_r, h_c = 1, g = cons\tan t$ $R_{profit} = R_{revenue} - R_{\cos}$	

In reality the work done to raise revenue and the work lost to costs, is the energy gained as profit. However matching does not work in practice, hence the energy balance might not be in equilibrium at all times, but at some time it will balance.

3.5.8 Work done by a Non-constant Force

$W_d = \int_a^b F\cos\theta dl$ $W_d = \int_a^b F \bullet dl$ $W_g = \int_{y=0}^{y^\circ} mg \bullet dl$ $W_b R/n = \int_{y=0}^{y^\circ} Rg \bullet dl$	Physics: The product of the magnitude of the displacement times the component of the force parallel to the displacement . This is the total work done by a firm over a period.
$W_d = \int_1^2 ng \bullet dM$	Business: Work = Force x distance moved in increasing sales volumes x direction component. The work done to move units up the sales scale. This is the most general formula for work. Work done against gravity.
	Work done to sell more units. In economics work done to sell one more unit is marginal work done.

Example

Work Done

MARQUE	2003	20004	20005	20006
BMW	0.006471965	0.007718568	0.009421049	0.009287844
DAIMLER	0.004802242	0.00408158	0.004090488	0.004151438
FIAT	0.002329199	0.001257753	0.000898041	0.001429107
FORD	0.158417469	0.151442012	0.138871909	0.133133802
GM	0.060911844	0.062480533	0.064109483	0.059233335
HONDA	0.002484395	0.002993189	0.003393087	0.003450729
HYUNDAI	0.001231015	0.001776771	0.001886619	0.001786926
MAZDA	0.000583504	0.000705434	0.000758358	0.000847173
MG	0.002584125	0.000893655	5.56874E-05	7.79768E-06
MITSUB	0.000131113	0.000179622	0.000163658	0.000131609

NISSAN	0.003372933	0.002637824	0.002145045	0.001672549
PSA	0.042366075	0.032200146	0.026045597	0.027649856
RENAULT	0.0140768	0.013302226	0.010446269	0.007311537
TOYOTA	0.006321559	0.006599568	0.00699792	0.007158384
VW	0.051972798	0.055630133	0.062934664	0.068318264
Total	**0.35806**	**0.34390**	**0.33222**	**0.32557**

Table 11: Work Done to Move Units

As per the data increasing sales at BMW, Hyundai and Toyota are not synonymous with increasing work. Only VW has increased work with amount of units sold sustainably. As sales drop for the other marques, so work decreases, as expected. Since the W_d (based on resultant force) is done over a comparatively long time we can consider it as a constant force, which it isn't over the short term. Work is the force needed to move units and increase/decrease market share. Work is calculated by using force multiplied by distance. Work is also related to Ke.

3.5.9 Kinetic Energy

Ke is the energy of a particle associated with its motion.

Kinetic Energy	Physics: The net work done on an object is equal to its change in Kinetic Energy. This is the energy due to movement and is related to the work done.
$W_d = \Delta Ke$ $Ke = \frac{1}{2}mv^2$ $W = \int_1^2 mvdv = \frac{1}{2}(mv_2^2 - mv_1^2)$ $KeR / n = \frac{1}{2}Rv^2$	Business: Ke =1/2*units moved *change in units or revenue / industry squared. F is the net force, hence W is the net work done on/by a firm. Ke is a conservative force. Relation of work done to cost. This is the total Ke of a firm.
$Ke = \frac{1}{2}n\frac{(M_2 - M_1)^2}{(t_2 - t_1)^2}$	Work done to sell more units. In economics work done to sell one more unit is marginal work done.

Proof

Model 1	**Model 2**
$Ke = Wd$ $KeR / n = \frac{1}{2}Rnv^2$ $KeR_{profit} = Ke(R_{revenue} - R_{\cos})$ $R_{revenue} - R_{\cos} = R_{profit}$	$Ke = Wd$ $W_{profit} = W_{revenue} - W_{\cos}$ $Ke_{profit} = Ke_{\mathrm{Re}venue} - Ke_{\cos}$ $\frac{1}{2}n\frac{\Delta M}{\Delta t}_{profit} = \frac{1}{2}\frac{\Delta M}{\Delta t}_{revenue} - \frac{1}{2}\frac{\Delta M}{\Delta t}_{\cos}$ $(M_2 - M_1)_{profit} = \Delta M_{\mathrm{Re}venue} - \Delta M_{\cos}$ $ifM_{1-profit} = M_{1-revenue} = M_{1-\cos}$ $M_{\mathrm{Pr}ofit} = M_{\mathrm{Re}venue} - M_{\cos}$

$Ke = \frac{1}{2}nv^2$ $F_{\Pr ofit} = F_{revenue} - F_{\cos}$ $\frac{1}{2}nv^2{}_{profit} = \frac{1}{2}nv^2{}_{revenue} - \frac{1}{2}nv^2{}_{\cos}$ $Rv^2{}_{profit} = Rv^2{}_{revenue} - Rv^2{}_{\cos}$ $Let: v_{p,} v_r, v_c = 1,$ $R_{profit} = R_{revenue} - R_{\cos}$	

Example

Kinetic Energy

MARQUE	2003	20004	20005	20006
BMW	0.001445144	0.00185004	0.002282352	0.002161895
DAIMLER	0.001073349	0.000794308	0.000738683	0.000721386
FIAT	0.000367807	0.000315624	4.48798E-05	0.00015687
FORD	0.069617888	0.066649542	0.057208011	0.052256521
GM	0.023825982	0.024655159	0.024493175	0.021161078
HONDA	0.000327006	0.000452838	0.000567043	0.000556454
HYUNDAI	9.08578E-05	0.000213648	0.000265745	0.000217031
MAZDA	3.23376E-05	6.48623E-05	5.69236E-05	7.28839E-05
MG	0.000524955	0.00026972	1.46774E-05	6.61383E-08
MITSUB	3.51994E-06	6.8571E-06	9.28394E-06	4.567E-06
NISSAN	0.000706	0.000437849	0.000388898	0.000197188
PSA	0.016509335	0.012185795	0.008231924	0.008629426
RENAULT	0.004052268	0.004046816	0.003181061	0.00156999
TOYOTA	0.001356678	0.001475596	0.001536533	0.001525766
VW	0.019698493	0.02126653	0.023296423	0.024896135
Total	**0.13963**	**0.13469**	**0.12232**	**0.11413**

Table 12: Kinetic Energy

The table represents the kinetic energy used to move units. As can be seen the net kinetic energy in the industry has decreased, because the number of units sold is decreasing. Kinetic energy is the energy due to motion of a system and is equal to the units moved halved multiplied by the velocity of change of market share squared.

3.5.0 Conservation of Energy

Two types of forces exist; conservative and non-conservative.
A conservative force exists when;

1. The force depends only on position
2. The work done by the force on a unit moving between any two positions is dependant only on initial and final positions and independent of the path.

The force of friction is not conservative, and is non-recoverable. Hence in business friction forces must be minimized. Friction forces are all those forces within and external to the firm which reduce its competitiveness.

3.5.1 Potential Energy

Pe is the energy associated with the position of a body relative to its surroundings.

Potential Energy	Physics: Work done to raise a mass to a height against gravity
$\Delta U = Wg = -mg(y_2 - y_1)$ $Pe = mgh$ $\Delta U = -\int_1^2 F_g \bullet dl$ $PeR / n = Rgh$	Business: Work that needs to be done to enter a business, or to increase market share. Pe is a conservative force. Pe is associated with the interactions of 2 or more bodies, and Pe = 0 can be chosen anywhere. This is the total Pe of a firm. We calculate Rgh. Note h is distance or market share. Hence Pe is the work done to increase sales in an industry.
$Pe = ngM$	Work done to sell more units, or potential to do work.

Proof

Model 1	**Model 2**
$Pe = ngh$ $PeR / n = Rgh$ $PeR_{profit} = Pe(R_{revenue} - R_{\cos})$ $R_{revenue} - R_{\cos} = R_{profit}$	$Ke = Wd$ $W_{profit} = W_{revenue} - W_{\cos}$ $Ke_{profit} = Ke_{\mathrm{Re}venue} - Ke_{\cos}$ $\frac{1}{2} ngh_{profit} = \frac{1}{2} gh_{revenue} - \frac{1}{2} gh_{\cos}$ $(M_2 - M_1)_{profit} = \Delta M_{\mathrm{Re}venue} - \Delta M_{\cos}$ $ifM_{1-profit} = M_{1-revenue} = M_{1-\cos}$ $M_{\mathrm{Pr}ofit} = M_{\mathrm{Re}venue} - M_{\cos}$
$Pe = ngh$ $Pe_{\mathrm{Pr}ofit} = Pe_{revenue} - Pe_{\cos}$ $ngh_{profit} = ngh_{revenue} - ngh_{\cos}$ $Rgh_{profit} = Rgh_{revenue} - Rgh_{\cos}$ $Let : h_{p,} h_r, h_c = 1, g = cons\tan t$ $R_{profit} = R_{revenue} - R_{\cos}$	

Example

Potential Energy

MARQUE	2003	20004	20005	20006
BMW	0.005790732	0.006759311	0.008076528	0.007970351
DAIMLER	0.004749196	0.00384687	0.003807224	0.003834417
FIAT	0.002325625	0.002079193	0.000588396	0.001386589
FORD	0.076666683	0.073730373	0.069173669	0.066631779
GM	0.037511116	0.037994453	0.039294609	0.036470883
HONDA	0.002150289	0.002644905	0.003191883	0.003225082
HYUNDAI	0.00091559	0.001602927	0.001925808	0.001721614
MAZDA	0.000459831	0.000724064	0.000689442	0.000831781

MG	0.002948089	0.001872365	0.000279298	7.79632E-06
MITSUB	0.000104829	0.000161886	0.000205806	0.000131222
NISSAN	0.003591943	0.002586215	0.002482332	0.001615009
PSA	0.029372833	0.023751128	0.018994905	0.020055909
RENAULT	0.011514849	0.011390006	0.010077455	0.006439504
TOYOTA	0.005551929	0.005813352	0.006203892	0.006318002
VW	0.03304315	0.034428075	0.03800398	0.040645178
Total	**0.21670**	**0.20939**	**0.20300**	**0.19729**

Table 13: Potential Energy available to a Firm due to Previous Sales

Because the number of sales is decreasing the potential energy is decreasing. This implies that there is a reduction in the firm's capacity to do work, as Potential Energy Pe is converted to Kinetic Energy Ke. Hence the more a firm sells, the more it is capable of selling due to increases in energy (money), available to the firm. Potential energy is calculated by multiplying the number of units by the gravitational forces at work in the industry by the relative market share of the firm.

For three dimensions we have:

$$F(x, y, z) = -i\frac{\delta U}{\delta x} - j\frac{\delta U}{\delta y} - \frac{\delta U}{\delta z}$$ The components of Force

$$F_x = \frac{\delta U}{\delta x}; F_y = \frac{\delta U}{\delta y}; F_z = \frac{\delta U}{\delta z}$$

3.5.2 Conservation of Mechanical Energy

$\Delta Ke + \Delta U = 0$ Only for conservative forces

$E = Ke + U$ Where E is total mechanical energy

$$E = Ke + U = const$$

$E = \frac{1}{2}mv^2 + U = const$ For conservative systems only

$$\frac{1}{2}mv_1^2 + U_1 = \frac{1}{2}mv_2^2 + U_2$$

For a study in Economics can examine Elastic Forces (Price /Demand/Supply Elasticity).
This study is outside the scope of this paper at this stage.

3.5.3 The Law of Energy Conservation

The total energy is neither increased nor decreased in any process. Energy can be transformed from one form to another, and transferred from one body to another, but total energy remains the same.

$$\Delta Ke + \Delta U + \Delta(other) = 0$$

$W = \Delta Ke + \Delta U = (\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2) + (mgy_2 - mgy_1)$ Where Ffrl is the internal energy

$$\frac{1}{2}mv_1^2 + mgy_1 = \frac{1}{2}mv_2^2 + mgy_2 + F_{fr}l$$

Example

Energy Balance

MARQUE	2004	2005	2006
BMW	-0.009254859	-0.010703447	-0.011602632

DAIMLER	-0.00672841	-0.006121103	-0.006181572
FIAT	-0.003721387	-0.002307086	-0.001773236
FORD	-0.014129625	-0.019046488	-0.026340915
GM	-0.027024427	-0.028140727	-0.030111238
HONDA	-0.00401535	-0.004816908	-0.005293468
HYUNDAI	-0.002214011	-0.003049342	-0.003164645
MAZDA	-0.001086694	-0.00129172	-0.001391415
MG	-0.004025779	-0.001867266	-0.000272351
MITSUB	-0.000256338	-0.000351551	-0.000323177
NISSAN	-0.005034308	-0.0042418	-0.003511256
PSA	-0.02442883	-0.022328314	-0.022189465
RENAULT	-0.014805771	-0.014239584	-0.011765908
TOYOTA	-0.008533007	-0.009005114	-0.009459594
VW	-0.026506202	-0.027869101	-0.0304566
Total	**-0.15176**	**-0.15538**	**-0.16384**

Table 14: Internal Energy

Hence the industry's internal energy decreased as the potential energy > kinetic energy.
The industry is in a decline phase. However not all marques are in decline.

Also Fords internal energy increased which means its costing more to sell cars, and they are loosing work efficiency (diseconomies of scale). (see section on Entropy and efficiency) We calculate the internal energy using Ke - Pe.

3.5.4 Gravitational Potential Forces and Escape Velocity

$$W = \frac{GmM_e}{r_2} - \frac{GmM_e}{r_1} = -\Delta U$$ This is the potential energy to enter

$$v_{esc} = \sqrt{\frac{2GM_e}{R_e}}$$ Velocity needed to escape an industry.

We are more interested in work needed to exit

$$\tfrac{1}{2} m v_{esc}^2 - G\frac{mM_e}{R_e}$$

$$\tfrac{1}{2} R v^2 - G\frac{rR_e}{R_i}$$

The work needed to exit an industry.

Potential Energy can be at stable or unstable equilibrium. In business due to changes in highly competitive industries most firms will be at unstable equilibrium in their lifecycle.

$$\tfrac{1}{2} m v^2 + \tfrac{1}{2} k x^2 = E = \tfrac{1}{2} k x_0^2$$ Used to obtain v at any position x., and plotted.

3.5.5 Power

Power is the rate at which work is done.

Power	Physics: Rate of doing work

$\overline{P} = W / t$ $P = \frac{dW}{dt} = F \bullet \frac{dl}{dt} = F \bullet v$ $P = \frac{dE}{dt}$ $FR / n = R / nnad = Rad$	Business: Rate of doing work. A measure of potential to increase market share by doing work. Power is the rate at which energy is transferred.
$P = F \bullet \frac{dM}{dt} = F \bullet v$	

Example

Power

MARQUE	2003	20004	20005	20006
BMW	1.77314E-05	2.11468E-05	2.58111E-05	2.54461E-05
DAIMLER	1.31568E-05	1.11824E-05	1.12068E-05	1.13738E-05
FIAT	6.38137E-06	3.4459E-06	2.46039E-06	3.91536E-06
FORD	0.00043402	0.00041491	0.000380471	0.00036475
GM	0.000166882	0.00017118	0.000175642	0.000162283
HONDA	6.80656E-06	8.20052E-06	9.29613E-06	9.45405E-06
HYUNDAI	3.37264E-06	4.86787E-06	5.16882E-06	4.89569E-06
MAZDA	1.59864E-06	1.9327E-06	2.07769E-06	2.32102E-06
MG	7.0798E-06	2.44837E-06	1.52568E-07	2.13635E-08
MITSUB	3.59213E-07	4.92116E-07	4.48377E-07	3.60571E-07
NISSAN	9.24091E-06	7.22691E-06	5.87684E-06	4.58232E-06
PSA	0.000116071	8.82196E-05	7.13578E-05	7.5753E-05
RENAULT	3.85666E-05	3.64445E-05	2.86199E-05	2.00316E-05
TOYOTA	1.73193E-05	1.8081E-05	1.91724E-05	1.9612E-05
VW	0.000142391	0.000152411	0.000172424	0.000187173
Total	**0.00098**	**0.00094**	**0.00091**	**0.00089**

Table 15: Power of a Firm

Power is the rate of doing work. As the market declines less power is required as fewer units are needed. Power will be greatest in the market leader and follower, as is apparent from the table. A bigger share of the volumes sold allows a player a higher influence in the market. Conserving energy as the bigger players is not always possible. We need to look at efficiencies of conversion of energy into work (or power). Also notice that Fords power is being eroded, as it looses market share and the market shrinks. We look at this in more detail, in entropy losses. Power is work done per unit time.

3.5.6 Conservation of Linear Momentum

For a system of firms or an industry, that can be considered to have a continuous distribution of matter the centre of mass is:

$$x_{cm} = \frac{\sum m_i x_i}{M}; y_{cm} = \frac{\sum m_i y_i}{M}; z_{cm} = \frac{\sum m_i z_i}{M}$$ or

$$x_{cm} = \frac{1}{M}\int xdm; y_{cm} = \frac{1}{M}\int ydm; z_{cm} = \frac{1}{M}\int zdm$$

The centre of mass of the industry moves like a single firm with mass M, when acted on by a net external force F_{ext} This is why we need to discriminate on external forces that influence a firm, and forces influencing the industry. A force influencing an industry will have the same effect on all firms therein.

3.5.7 Momentum

Momentum	Physics: mass x velocity
$p = mv$ $P = m_1 v_1 + m_n v_n = \sum p_i$ $\frac{dP}{dt} = M \frac{dv}{dt}$ $pR / n = Rv$	Business: units x velocity. Maintain/increase the velocity of increasing sales to maintain/increase growth. Used for competitive analysis.
$p = n\frac{(M_2 - M_1)}{(t_2 - t_1)}$	

Proof

Model 1	**Model 2**
$pR/n = Rv$ $pR/n = R_{Revenue}v - R_{\cos}v$ $nvR/n = nv(R_{Revenue} - R_{\cos})$ $R/n_{Profit} = R(R_{Revenue} - R_{\cos})$	$p = nv$ $W_{profit} = W_{revenue} - W_{\cos}$ $p_{profit} = p_{Revenue} - p_{\cos}$ $nv_{profit} = nv_{revenue} - nvgh_{\cos}$ $(M_2 - M_1)_{profit} = \Delta M_{Revenue} - \Delta M_{\cos}$ $ifM_{1-profit} = M_{1-revenue} = M_{1-\cos}$ $M_{Profit} = M_{Revenue} - M_{\cos}$
$P = mv$ $P_{Profit} = P_{revenue} - P_{\cos}$ $nv_{profit} = nv_{revenue} - nv_{\cos}$ $Rv_{profit} = Rv_{revenue} - Rv_{\cos}$ $Let: v_{p,} v_r, v_c = 1,$ $R_{profit} = R_{revenue} - R_{\cos}$	

Example

Momentum

MARQUE	2003	20004	20005	20006
BMW	19.70426515	23.23130999	26.72235239	25.77365182
DAIMLER	16.16020731	13.22144018	12.59674585	12.39931965
FIAT	7.913462491	7.146051049	1.946794126	4.483800567

FORD	260.8756034	253.4064605	228.8710191	215.4665704
GM	127.6399956	130.584445	130.0118583	117.9355585
HONDA	7.3168397	9.090365688	10.56080488	10.42891922
HYUNDAI	3.115499938	5.509153977	6.371811669	5.567166364
MAZDA	1.564677498	2.488558855	2.281117793	2.689721614
MG	10.03153498	6.435195334	0.924099174	0.025210883
MITSUB	0.356705526	0.556390677	0.680938569	0.424332919
NISSAN	12.22239168	8.888650063	8.2131533	5.222441363
PSA	99.94765948	81.63106937	62.84737189	64.8546101
RENAULT	39.18185959	39.14670398	33.34270702	20.82336446
TOYOTA	18.89168661	19.98010841	20.52646688	20.43046404
VW	112.4367372	118.3270385	125.7416258	131.4339398
Total	**737.35913**	**719.64294**	**671.63887**	**637.95907**

Table 16: Momentum of Firms

This is the momentum of firms in the industry. Collisions tend to decrease the Kinetic Energy, and thus work done by firms in direct competition, or merging together.
As expected the total momentum in the industry is slowing, because the industry is declining. Momentum and Kinetic Energy (Ke) conservation can be used extensively to measure competitive moves, and optimize responses. Because Ke is the net work done we can use it to analyse gaps between goals and internal capabilities and choose the appropriate strategy. We can also use it to analyse the synergy of potential mergers, and alliances. Momentum is calculated as units multiplied by velocity.

When the net external force on a system is zero, the total momentum remains constant. The total momentum of an isolated system of bodies remains constant.

$$m_1 v_1 + m_2 v_2 = m_1 v'_1 + m_2 v'_2$$

Total momentum is conserved if two bodies collide. The momentum lost by one firm is gained by another. Momentum, Work done and Entropy in the car industry is affected by the rest of the transportation supply industries.

3.5.8 Collisions and Impulse

$p_f - p_i = \int_{pi}^{pf} dp = \int_{pi}^{pf} F dt = J$ Thus the change of momentum = Impulse J

3.5.9 Conservation of Energy and Momentum in Collisions

$p_1 + p_2 = p_1^{/} + p_2^{/}$ Hence momentum is conserved, but only if impulse forces in an industry are very much greater than the external forces acting on firms in that industry.

The law of energy conservation states that the total energy will be conserved during a collision. This means that Kinetic energy is conserved or Wd (COS) is conservative.

3.5.10 Elastic Collisions in one Dimension

$m_1 v_1 + m_2 v_2 = m_1 v_1^{/} + m_2 v_2^{/}$ Conservation of Momentum

$\frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} m_1 v_1^{/2} + \frac{1}{2} m_2 v_2^{/2}$ Conservation of Kinetic Energy if collision is elastic

$v_1 - v_2 = v_2^{/} - v_1^{/}$ For elastic collision

3.5.11 Special Cases

Equal Masses $m_1 = m_2$

$$v_2^{/} = v_1$$
$$v_1^{/} = v_2$$

The firms exchange velocities.

Implications for companies selling equal units, if your velocity is higher do not attack the firm with the lower velocity.

$$v_2 = 0 \leftrightarrow m_1 \rangle\rangle m_2$$

The velocity of the bigger body is nearly unchanged, but the smaller particles velocity increases by twice that of the larger body.

Implications for market leaders are: do not attack very small competitors as this will increase their velocity, and sales.

$$v_2 = 0 \leftrightarrow m_2 \rangle\rangle m_1$$

The bigger body remains at rest and the small body rebounds at the same speeding opposite direction.

For a small company attacking a bigger company, do not attack a large slow moving firm, as the smaller body will loose direction, and ultimately loose sales.

For any elastic head on collision:

$$v_2^{/} = v_1 \left(\frac{2m_1}{m_1 + m_2}\right) + v_2 \left(\frac{m_2 - m_1}{m_1 + m_2}\right)$$

$$v_1^{/} = v_2 \left(\frac{2m_2}{m_1 + m_2}\right) + v_1 \left(\frac{m_1 - m_2}{m_1 + m_2}\right)$$

3.5.12 Elastic Collisions in Two or Three Dimensions

$$m_1 v_1 = m_1 v_1^{/} \cos\theta_1^{/} + m_2 v_2^{/} \cos\theta_2^{/}$$

We only consider two dimensions in business, for purposes of this paper.

3.5.13 Inelastic Collisions

Kinetic energy is not conserved after collision. Ke can be transferred to other energy forms. If the firms merge the collision is said to be completely inelastic. Work done (COS) will be lost, and their velocities will be shared (averaged out). Consider a merger between a large firm and a smaller one.

$$mv_1 = (m + M)v^{/}$$
$$\tfrac{1}{2}(m + M)v^{/2} = (m + M)gh$$
$$v_1 = \frac{m + M}{m} v^{/} = \frac{m + M}{m}\sqrt{2gh}$$

This implies that conservation of momentum is valid but not conservation of mechanical energy. We can use the Centre of Momentum Reference Frame, where the total momentum is zero.

Systems of Variable Mass

$$M\frac{dv}{dt} = F_{ext} + v_{rel}\frac{dM}{dt}$$

$$F_{ext} = na - (u - v)\frac{dM}{dt}$$

We can use this equation to calculate the external forces acting on a firm. The firm must do work to compensate for these forces.

The Relationship between Momentum and Kinetic Energy

$$\frac{dv}{dt}mv = m$$

$$\frac{dv}{dt}\tfrac{1}{2}mv^2 = mv$$

$$\int mv\frac{dv}{dt} = \tfrac{1}{2}mv^2$$

Hence the derivative of Ke is momentum, and the integral of momentum is Ke.

This example is based on the UK Car Market.

3.5.14 A heuristic for the analysis of the competitive interactions of competing firms

Optimization Criteria

The equations we will use are the following:

Model 1

$$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$$

$$v_1 = (m_1u_1 + m_2u_2 - m_2e(u_1 - u_2))/(m_1 + m_2)$$

$$v_2 = (m_1u_1 + m_2u_2 + m_1e(u_1 - u_2))/(m_1 + m_2)$$

$$LossofEnergy = \frac{m_1m_2}{2(m_1 + m_2)}(1 - e^2)(u_1 - u_2)$$

$$Ife = 1, lossofenergy = 0$$

$$ife = 0 lossofenergy \langle\rangle 0$$

To optimize the Industry we need to minimize collisions, because after any collision where the companies do not merge or move in the same direction, we have an energy loss, as stated above. As this is impossible, we need to form allegiances, and bigger groupings. In the UK there are only two large groups, Ford and GM. All the other companies are small by comparison.

To optimize for a particular firm, that firms momentum must increase (the sign is positive), as the other firms momentum decreases (the sign is negative because it losses). Momentum is equal but opposite in sign because of the law of conservation of momentum. What one company gains the other must loose.

On collision there is a net loss kinetic energy. The Industry looses energy, as do the protagonists. Hence after collision a firm must choose to increase its velocity at a cost to the other company.

We can also optimize using cost. Where the units sold are unknown the following equations can be used:

$$R_1 v_1 + R_2 v_2 = R_1 u_1 + R_2 u_2$$
$$v_1 = (R_1 u_1 + R_2 u_2 - R_2 e(u_1 - u_2))/(R_1 + R_2)$$
$$v_2 = (R_1 u_1 + R_2 u_2 + R_1 e(u_1 - u_2))/(R_1 + R_2)$$
$$LossofEnergy = \frac{R_1 R_2}{2(R_1 + R_2)}(1 - e^2)(u_1 - u_2)$$
$$Ife = 1, lossofenergy = 0$$
$$ife = 0 lossofenergy \langle\rangle 0$$

Where R is total revenue or sales, or Cost of Sales, if that is known. From this we can determine capability of the company to attain that momentum i.e. resources needed. We can also determine the kinematic profit of the company. This gives an indication of what can be improved at the company to optimize profit generation.

We have:

ΔV_1 → Positive and maximum- to increase gains to the attacker.
ΔV_2 → Negative and maximum - to increase the damage to the competitor.

From this we have

The change in the attacker's momentum must be as great as possible in the desired direction.

ΔP_1 → Positive and Maximum
ΔP_2 → Negative and Maximum

The attacking firm must also minimize Kinetic Energy, or Work done loses, as this costs money. It must also try to increase the costs to its victim, as it does not want to encourage retaliation.

ΔKe_1 → Positive and Minimum
ΔKe_2 → Negative and Maximum

As a comparative tool we can use the following:

$\Delta Ke_1 / \Delta P_1 = Z_1$ and $\Delta Ke_2 / \Delta P_2 = Z_2$

We need to increase our momentum for the least amount of work or, Δ Ke and ensure that it costs the opposition as much as possible to retaliate. For competitive systems from the work energy theorem W = Δ Ke. Hence we need to minimize Δ Ke, or work to minimize COS.

But the victim we need to invert, as we want to make their Ke as large as possible (This means we want to increase their Wd or COS as much as possible i.e. it will cost them more to sell a unit).

Hence we can use, when we subtract the effect of the victim,

$\Delta Ke_1 / \Delta P_1 - \Delta P_2 / \Delta Ke_2 \geq 0$

The term $\Delta P_2 / \Delta Ke_2$ is negligible, and can be ignored, though for our purposes we will be using the full calculation. We are comparing the efficiency of converting Ke to momentum. The higher the conversion the better the firm is at doing wok as opposed to its competitors. It is better to take on smaller competitors with smaller momentum, as it is easier and more efficient as the attacker needs to do less work (=Ke) to take the momentum from the other firm. We can also as a quick approximation look at optimizing velocities only – hence the firm with the strongest market share growth wins. This is not the full picture, and other factors must be considered.

To Calculate Market Share Increase Profit, Revenue and Costs use the market share fraction. To calculate the Total increase in Market share, after the increase us 1+market fraction.

$$R_{\Pr ofit} = R_{\text{Re}venue} - R_{COS}$$

$$needtochange \partial v$$

$$\frac{\partial v}{\partial t} R_{\Pr ofit} = \frac{\partial v}{\partial t} R_{\text{Re}venue} - \frac{\partial v}{\partial t} R_{COS}$$

If we only consider the velocity increase, then the effects of other factors such as units which play a major role won't be accounted for.

Calculation of Heuristic

Start Heuristic:
Function 1
Start

1. Collect data and arrange it. Calculate units sold per the same time frame if possible.
2. Calculate velocity, using fractional market share / time or percent market share / time.
3. Calculate U1, U2, V1, V2, m1, m2, P1, P2, ΔP1, ΔP2, ΔKe1, ΔKe2.per e, per model.
   Calculate ΔKe1/ $\Delta P_1 - \Delta P_2 / \Delta Ke_2 \geq 0$. For competitive systems from the work energy theorem W = Δ Ke. Hence we need to minimize Δ Ke, or work to minimize COS.
4. Repeat calculations for all combinations
5. Check which of the calculations are maxima?

Main Program
Start
Check the Generic Market: Example = Transport {Busses, Trucks, Taxis, Trains, Cars, Motorbikes etc.} Use function 1 to calculate.
Check the Group Market: {Ford, GM, and other Manufacturing Groups}
Check for individual Brands {Ford, Vauxhall etc.} Then
Check for those models in those segments in direct competition with each other. {Mondeo, Vauxhall, Golf …….}

Compare Generic Market → Group Market → Individual Brands → Segments.
This will allow a comparison of the overall transport market, to car market, and segments. From this analysis we can see GAPS in the market, and best seize opportunities based on the firms' capabilities. We can also use the cost models, as proposed above, and optimize profitability.

It is unnecessary to minimize energy loss as the company that looses momentum carries most of it. However it might be important in the case where competitors are close together, and there is a Ke loss.

The coefficient of restitution e can be defined using Newton's Law of Impact as
$v_1 - v_2 = e(u_1 - u_2)$. E ranges from 0 to 1.

0=Inelastic no separation = merger or same market	**Velocity 1 = Velocity 2**
1 = perfectly elastic.	**Kinetic Energy Loss = 0**
0-1 elastic	**Velocity approach and separation not equal.**

End Heuristic.

We can use market share based on largest competitor, or the sum of all units sold.
For competitive systems from the work energy theorem W = Δ Ke. Hence we need to minimize Δ Ke, or work to minimize COS

Model 2

We can also use the following

$$n_1 \frac{(M_2 - M_1)}{(t_2 - t_1)}_1 + n_2 \frac{(M_2 - M_1)}{(t_2 - t_1)}_2 = n_1 u_1 + n_2 u_2$$

$$v_1 = (m_1 u_1 + m_2 u_2 - m_2 e(u_1 - u_2))/(m_1 + m_2)$$

$$v_2 = (m_1 u_1 + m_2 u_2 + m_1 e(u_1 - u_2))/(m_1 + m_2)$$

$$LossofEnergy = \frac{m_1 m_2}{2(m_1 + m_2)}(1 - e^2)(u_1 - u_2)$$

$$Ife = 1, lossofenergy = 0$$

$$ife = 0 lossofenergy \geq 0$$

We use the equations generated by Model 2. The rest of the Heuristic stays the same.

In this case we need to know the value of Sales. In Model 1 it is unnecessary, as we consider money as a measure of energy. Hence depending on the information available we can choose the model to use, depending on the application, as they are equivalent sets, and as long as the units are the same, for comparison purposes, either model will work, provided that the price of goods is comparable.

From calculation of the Heuristic:

Example

Starting from the generic market we have:
(Based on second hand sales)

Analysis of Transport Market

	2001		2002		2003		2004		2005		2006	
Cars	407	Total	407	Total	409	Total	411	Total	413	Total	409	Total
Light	836	Cars	836	Cars	842	Cars	846	Cars	850	Cars	838	Cars
Heavy	15232	Bike	15282	Bike	14170	Bike	13863	Bike	13278	Bike	16960	Bike
Bus	248021	Agric	247947	Agric	225991	Agric	187904	Agric	182098	Agric	192232	Agric
Bike	6345	Light	6319	Light	6009	Light	5798	Light	5618	Light	6243	Light
Agric	75472	Heavy	74221	Heavy	72570	Heavy	66804	Heavy	66451	Heavy	69273	Heavy
Spec	461421	Bus	488487	Bus	462565	Bus	420064	Bus	421134	Bus	387177	Bus
Total	0	Light	0	Light	0	Light	0	Light	0	Light	0	Light
	807733		**833499**		**782556**		**695690**		**689841**		**673132**	

Table 16: Analysis of Second Hand Market

Based on this, second hand car sales should take on the whole market, where this is in their interests and they have the expertise or can purchase it. Their power is relatively constant throughout this period.

From the table we can see that the car manufacturers have enough size, momentum and Kinetic Energy, leading to Power in the transport industry. Now we examine competition in groups of car manufacturers.

Competitive Analysis For Years 2003 - 2004

Group

	2003		2004		2005		2006	
BMW	**RENAULT**	60.9	**RENAULT**	57.5	**RENAULT**	53.4	**PSA**	46
DAIMLER	**TOYOTA**	73.7	**TOYOTA**	77.7	**TOYOTA**	74.5	**TOYOTA**	72

FORD	Total	6.6	Total	6.6	Total	6.6	Total	7
GM	FORD	23.7	FORD	23.5	FORD	22.8	VW	25
HONDA	FIAT	110.7	DAIMLER	94.3	DAIMLER	85.6	DAIMLER	83
HYUNDAI	HONDA	147.7	MG	125.4	NISSAN	108.9	HONDA	105
MAZDA	HYUNDAI	215.9	HYUNDAI	166.2	HYUNDAI	155.8	FIAT	155
MG	NISSAN	93.0	FIAT	116.8	FIAT	261.3	MITSUB	769
MITSUB	MAZDA	369.7	MAZDA	292.2	MG	330.5	MAZDA	273
NISSAN	DAIMLER	83.2	HONDA	100.5	HONDA	96.0	HYUNDAI	119
PSA	VW	29.8	VW	31.5	VW	32.0	GM	31
RENAULT	PSA	40.8	PSA	42.4	PSA	44.5	BMW	58
TOYOTA	BMW	69.2	BMW	65.9	BMW	60.6	RENAULT	61
VW	GM	28.0	GM	27.2	GM	25.3	FORD	22

Table 17: Competitive Analysis

From the results obtained e makes very little difference to who should be attacked. This analysis is based on the size and velocity (change of market share over time) alone using momentum and work, as we have not looked at particular models or market segments. Hence Ford the market leader in 2003 – 2006 should attack or defend the whole market. It should not concentrate only on the big players. GM the market follower should attack Ford from 2003 – 2006, and VW in 2006, due to changing circumstances, though Ford should still be attacked as it is close. VW is threatening GMs position. Daimler should attack Toyota from 2003 -2006, but only in those segments where it poses a threat, but with all the Daimler cars, they compete in most segments. Honda should attack Daimler, or merge its interests, which it has, in some countries.

Hyundai should attack Honda, MG, and Nissan, in the segments where they compete. Mazda should attack Hyundai. MG should attack Nissan, Fiat and Mitsubishi. To take on other carmakers means it won't win enough ground. Mitsubishi should attack Mazda and MG. PSA should attack VW, but change its focus to GM, which means it is also threatening the main market follower. Renault should attack PSA, as they are I the same markets, and BMW. VW should tackle GM, and is in a position in 2006 to attack Ford.
However we need to look at retaliation, in analyzing competition. If GM attacks Ford what happens when Ford attacks GM, or Mercedes takes on BMW. The momentum a firm gains per unit of work must exceed 7, which is the market average.

BMW	**BMW**	**Mercedes**	**BMW**						
Mass	93,822	93,625	93,822						
Velocity	0.06890	0.06875	0.06890						
Cost/Unit	1	1	1						
e	1		*CHECK*						
Merc	0.068752	0.0688971		m1	m2	d ke1	dke2	14.46	*BMW*
Final m	6450.4993	6450.4992	12900.998	-13.558	13.5584	-0.9331	0.93315	0	*Merc*
Initial	6464.0577	6436.9408	12900.998		Ke Loss	5.5E-14			
BMW	0.0688971	0.0687525							
	6450.499	6450.4993	12900.998	13.5584	-13.558	0.93315	-0.9331	14.46	*BMW*
	6436.940	6464.057	12900.998		Ke Loss	5.5E-14			

Table 18: Competitive Analysis BMW and Mercedes

When BMW attacks Mercedes their momentum becomes negative, which means they loose ground, while when Mercedes attacks BMW, Mercedes momentum increases, thus gaining ground on the market leader. Hence BMW should concentrate on the market, and the follower on the market leader. A smaller competitor should attack a niche market of Ford, not take on Ford as a whole. However as a whole they both loose Ke or Wd, and will eventually loose market shared to other players. This means effectively that it costs more (COS) for them to attack.

Strategies based on optimization of Momentum $_{max}$ and Ke $_{min}$

Strategy	Market Position	Strategies
Growth/Stagnant	Market Leader	Defend/Attack Defend and attack against all threats, especially rapid climbers in market share, in own spheres of operation. Look to attack other territories, as have strong base for attack. Defend lines of supply and try to prevent access by weaker players. Promote more than competitors to build and maintain strong branding, and have an excellent distribution chain (defend chains).
Growth	Main Followers and Big Sharers	Attack/Defend Gains Attack market Leader position, attack on weaknesses. Attack other companies on the way up, if they threaten your position, but not the market Leaders share. Defend gains, but look to enter new markets/products (see Ansoff Matrix)
Survival	Guerilla Attack Niches/ Weaknesses	Attack wherever an opportunity presents itself, but do not defend if costs are too high. Actively challenge the pecking order.

Table 19: Competitive Strategies

Example

However we need to breakdown the models and do a segment analysis, of directly competing models. If e = 0, we can calculate the results of a merger, as the companies go in the same direction, or if the companies compete directly in the same market. The firm's resultant velocities are equal. However Ke loss can lead to problems with keeping market share. Merger assumes pure synergy and that the companies move in the same direction after merging. This is hardly the case in practice. The merged companies velocities = sum of their individual velocities before merge. However this is only in the case where they both go in the same direction after the merge.

Since we are measuring effectiveness of converting Ke to momentum, we can order this as follows:

The average conversion of Ke to momentum is 7, and this tends to stay constant throughout the years. This is based on companies competing with all the players in the industry. If they compete against other players they can increase their conversion, and thus their effectiveness. This implies that selective targeting is better at achieving results, than the shotgun approach, which expends more energy.

Against the industry we have:

Effectiveness Analysis

	2003		2004		2005		2006
Ford	6.77	Ford	6.78	Ford	6.78	Ford	6.77
Vauxhall	6.83	Vauxhall	6.83	Vauxhall	6.83	Vauxhall	6.82
Renault	6.96	Renault	6.96	Renault	6.96	Volkswagen	6.94
Peugeot	6.96	Volkswagen	6.96	Volkswagen	6.96	Peugeot	6.98

Volkswagen	6.97	Peugeot	6.97	Peugeot	6.97	Renault	6.98
Citroen	7	Toyota	7	Toyota	7	Toyota	7
Toyota	7	Citroen	7.01	Citroen	7.01	BMW	7
Nissan	7.01	BMW	7.01	BMW	7.01	Honda	7.01
BMW	7.01	Honda	7.01	Honda	7.01	Citroen	7.01
Mercedes-Benz	7.01	Nissan	7.01	Nissan	7.01	Audi	7.01
Honda	7.02	Mercedes	7.02	Mercedes	7.02	Mercedes	7.01
Fiat	7.02	Audi	7.02	Audi	7.02	Nissan	7.02
Audi	7.02	Fiat	7.02	Fiat	7.02	Fiat	7.02
Rover	7.02	Mazda	7.02	Mazda	7.02	Mazda	7.02
Land Rover	7.02	Rover	7.02	Rover	7.02	Land Rover	7.02
Mini	7.02	Mini	7.02	Mini	7.02	Skoda	7.02
Volvo	7.02	Land Rover	7.02	Land Rover	7.02	Mini	7.02
Mazda	7.02	Volvo	7.02	Volvo	7.02	Kia	7.02
MG	7.02	Hyundai	7.02	Hyundai	7.02	Hyundai	7.02
Skoda	7.02	Skoda	7.03	Skoda	7.03	Seat	7.02
Seat	7.03	Suzuki	7.03	Suzuki	7.03	Volvo	7.03
Suzuki	7.03	Kia	7.03	Kia	7.03	Suzuki	7.03
Hyundai	7.03	Seat	7.03	Seat	7.03	Saab	7.03
Daimler	7.03	Daimler	7.03	Daimler	7.03	Daimler	7.03
Kia	7.03	MG	7.03	MG	7.03	Mitsubishi	7.03
Daihatsu	7.03	Mitsubishi	7.03	Mitsubishi	7.03	MG	7.03
Mitsubishi	7.03	Saab	7.03	Saab	7.03	Rover	7.03
Jeep	7.03	Daihatsu	7.03	Daihatsu	7.03	Daihatsu	7.03
Saab	7.03	Jeep	7.03	Jeep	7.03	Alfa Romeo	7.03
Lexus	7.03	Alfa Romeo	7.03	Alfa Romeo	7.03	Lexus	7.03
Subaru	7.03	Subaru	7.03	Subaru	7.03	Jeep	7.03
Smart	7.03	Chrysler	7.03	Chrysler	7.03	Smart	7.03
Chrysler	7.03	Lexus	7.03	Lexus	7.03	Subaru	7.03
Alfa Romeo	7.03	Smart	7.03	Smart	7.03	Chrysler	7.03
Average			**7**		**7**		**7**	**7**

Table 20: Effectiveness Analysis

The players have very little effect on the market; because the market is big, and only the biggest players can influence it to a greater extent. The firms are not becoming more effective at converting Ke (Work) into momentum. An interesting trend is that as the manufacturers increase in size, their effectiveness increases, their conversion of Ke to momentum decreases, (Wd/ momentum decreases) although this does not apply in some instances. The most effective are Ford and GM, due to economies of scale. The bigger the bodies are that collide the more effect they have on each other. Small bodies colliding with bigger bodies tend to bounce off and have less effect on the industry as a whole.

One measure of efficiency in business = Cost of Sales / units sold. The company with the lowest cost per unit is the most efficient, and has the most efficient value chain. It is better to attack individual companies as BMW does Mercedes, as the returns, improved momentum for a slight shared market loss (Ke). However to stay this way implies an entropy loss and the competitors will loose market share to other players. This is a self perpetuating spiral downwards. BMW and Mercedes must also counter other players e.g. Lexus and Audi or they will loose in the long run.

Value added to a firm can be calculated as: Sales/units –COS/units = Profit/unit

There are two ways to increase profits: charge more, or save more. Provided the units are comparable and non-differentiated, we can rank firms, or industries to determine the most favorable industry to enter.

Car Marque Analysis 2003 - 2006

2003	2004	2005	2006

BMW	96	Nissan	90	Citroen	77	Toyota	72	Toyota
Mini	229	Land R	210	Rover	195	Mazda	220	Skoda
Chrysler	914	Alfa	972	Lexus	930	Smart	676	Lexus
Jeep	1093	Lexus	1278	Alfa	1529	Alfa	1226	Smart
Mercedes	99	BMW	110	Nissan	106	Audi	103	Audi
Smart	945	Chrysler	636	Saab	856	Lexus	1164	Subaru
Alfa	805	Saab	1117	Subaru	1229	Subaru	1483	Jeep
Fiat	121	Honda	125	Audi	243	Hyundai	136	Nissan
Daimler	310	Hyundai	282	Seat	329	Saab	347	Saab
Land R	201	Rover	220	Mini	199	Mini	188	Mazda
Volvo	236	Mini	229	Land	226	Kia	270	Seat
Ford	7	Total	7	Total	7	Total	7	Total
Saab	599	Mitsubishi	442	Mitsubishi	316	Seat	301	Suzuki
Vauxhall	27	Ford	27	Ford	27	Ford	27	Ford
Honda	109	Mercedes	98	BMW	89	Citroen	82	BMW
Hyundai	287	Suzuki	242	Volvo	237	Skoda	236	Kia
Kia	396	Daimler	276	Suzuki	215	Land R	231	Mini
Mazda	244	Volvo	167	Fiat	153	Mercedes	161	Fiat
MG	291	Mazda	445	Daimler	609	Rover	3702	Rover
Rover	150	Audi	203	Mazda	486	Mitsubishi	2711	Daihatsu
Mitsubishi	492	Kia	362	Daimler	346	Daimler	407	Daimler
Nissan	85	Toyota	102	Honda	98	Honda	116	Mercedes
Citroen	68	Volks	84	Toyota	85	BMW	87	Honda
Peugeot	50	Renault	54	Volks	57	Renault	53	Volks
Renault	40	Vauxhall	40	Vauxhall	49	Volks	60	Peugeot
Subaru	960	Smart	1032	Chrysler	975	Chrysler	977	Chrysler
Suzuki	280	Seat	272	Skoda	265	Fiat	275	Volvo
Daihatsu	1644	Jeep	1844	Jeep	1899	Jeep	1923	Alfa
Lexus	973	Subaru	877	Smart	742	Rover	521	Mitsubishi
Toyota	79	Citroen	69	Peugeot	68	Peugeot	68	Renault
Audi	130	Fiat	118	Mercedes	102	Nissan	98	Citroen
Seat	267	Skoda	278	Kia	298	Suzuki	250	Hyundai
Skoda	252	Mazda	259	Hyundai	231	Volvo	211	Land R
Volks	52	Peugeot	50	Renault	39	Vauxhall	37	Vauxhall
Total	0	Mini	0	Mini	0	Mini	0	Mini

Table 21: Car Marque Analysis

From the data, depending on the efficiency of conversion of Ke to momentum, and depending on the performance of the marque, for that particular year, we can determine which brands should compete on the same terrain. A collision will cause maximum Ke loss when e = 0, and here bodies do not separate after impact and are inelastic (merge or stay on the same track/ market). Velocities in become velocities out, both bodies become one and share the same velocity. To improve velocity and momentum optimize velocity after collision. A collision which causes Ke loss = 0, is where e = 1, and is said to be elastic. The bodies go their separate ways after collision. Here we want to optimize momentum after collision for the firm we work for, and maximize momentum loss for the firm we don't. The model is limited in that it should compare models competing in the same market space. We assume there is no real difference in the firms offering, as all marques compete in all market segments. We would have to examine the segments and competitors (direct and indirect) separately, to identify weaknesses or segments that are increasing, so that we can determine where to pitch our offering.

The most efficient conversion of energy to momentum should be considered. As can be seen the interactions are becoming more complicated and vary from year to year. When examining the interactions we need to optimize for greatest gain. We can optimize for conversion of Ke to momentum, but we also need to attain the maximum momentum, or velocity increase.

From the table we see that Ford (as market leader) should attack the whole market (or defend its position), and Vauxhall (the biggest GM brand the market follower) should attack Ford. VW should start attacking Vauxhall as it moves up the pecking order, with Peugeot attacking VW. We could set up pecking order based on the volumes sold by the players. As the volumes of the players change their place in the order will change, as will their power within the industry. Power will be greatest in the market leader and follower. We now need to analyse competition in segments, and so on down to competition between models. We can analyse gaps, niches, and profitable markets and decide where to compete in the industry, and against whom.

From the momentum models proposed, the motorcar industry does not follow the model exactly, as in real life; strategy is developed to take advantage of the opponents, and is an organic thing. Hence the model can never correlate exactly with real life, but can explain some of the phenomena observed over the short and long term, and is a starting point for competitor analysis, and to define competitive advantage in an industry.

3.5.15 Equilibrium, Elasticity and Fracture

Static's is the study of bodies at equilibrium. A force is at equilibrium if the net force acting on is zero. Here the firm or industry is at rest, or the centre of mass of the industry is moving at constant velocity, which means acceleration is zero, and hence force is zero.

The total force acting on an industry is:

$F = m_1 g + m_2 g + ...m_n g = \sum m_n g = Mg$ If g is not the same because of distance along market share, then individual g must be used.

For a firm/industry to be in equilibrium the vector sum of all external forces acting on the firm/industry must be zero.

Hence $\sum fx = 0; \sum fy = 0; \sum fz = 0$

The second condition for equilibrium is that the vector sum of all external torques acting on a firm/industry must be Zero. This means that the firm/industry cannot rotate around itself – run around chasing itself.

Hence $\sum \tau_x = 0; \sum \tau_y = 0; \sum \tau_z = 0$ We can calculate torque about any axis.

3.5.16 Elasticity and Elastic Moduli - Stress and Strain on Firms

This is shape changing under strain applied forces. If external forces are great enough then the firm will fracture. This can be applied to determine the flexibility of the firm and its ability to withstand external uncontrollable forces.

The elasticity can be defined as: (Flexibility of a firm)

$$\Delta L = \frac{1}{E}\frac{F}{A}L_o$$

And Stress = Force/Area =Pressure

Strain = Change in Length / Original Length.

$$E = \frac{F / A}{\Delta L / L_0} = \frac{Stress}{Strain}$$

The sheer strain in a firm can be calculated using:

$$\Delta L = \frac{1}{G}\frac{F}{A}L_0$$

If a firm is subject to pressure on all sides its volume will decrease.

$$\frac{\Delta V}{V_0} = -\frac{1}{B}\Delta P$$

$$B = -\frac{\Delta P}{dV}$$

Volume decreases with an increase in Pressure. Volume is sales volume for a firm, or area x units, or industry.

3.5.17 Fracture

If stress is excessive the firm breaks. Fracture can occur under conditions of excessive shear, compression, or tension.

3.5.18 Fluids at Rest

Fluids can flow, and do not retain their shape. Hence a market is amorphous and is constantly changing.

3.5.19 Density

Density	Physics: Density = Mass / Unit Volume
$\rho = m / v$ $\rho R / n = R / A$	Business: Density = Units / Area Sales volume per area

Example

Density

MARQUE	2003	20004	20005	20006
BMW	1.34332	1.4586	1.56436	1.53634
DAIMLER	1.21653	1.10037	1.07406	1.06561
FIAT	0.8513	0.80897	0.42224	0.6408
FORD	4.88783	4.81735	4.5782	4.44211
GM	3.41895	3.45816	3.45057	3.28641
HONDA	0.81858	0.91241	0.98344	0.97728
HYUNDAI	0.53415	0.7103	0.76389	0.71403
MAZDA	0.37854	0.47739	0.45706	0.49631
MG	0.95848	0.76768	0.29091	0.04805
MITSUB	0.18074	0.22573	0.24972	0.19713
NISSAN	1.05798	0.90223	0.86727	0.69157
PSA	3.02542	2.73418	2.39907	2.43708
RENAULT	1.89427	1.89342	1.74743	1.38094
TOYOTA	1.31533	1.35269	1.37106	1.36785
VW	3.20888	3.29186	3.39343	3.46939
Total	**25.09030**	**24.91134**	**23.61271**	**22.75090**

Table 22: Density of Market Share

Calculate density by dividing units by area covered in the firms operations. Density is a measure of physical coverage of a market. See also Vector Fields. The bigger the market share the higher the density.

3.5.20 Pressure

Pressure	Physics: Pressure = Force / Area
$P = F / A = \rho g h$	Business: Pressure = Force / Area Force applied per sales area.

Example

Pressure

MARQUE	2003	20004	20005	20006
BMW	5.39843E-07	6.36474E-07	7.32119E-07	7.06127E-07
DAIMLER	4.42745E-07	3.62231E-07	3.45116E-07	3.39707E-07
FIAT	2.16807E-07	1.95782E-07	5.33368E-08	1.22844E-07
FORD	7.14728E-06	6.94264E-06	6.27044E-06	5.90319E-06
GM	3.49699E-06	3.57766E-06	3.56197E-06	3.23111E-06
HONDA	2.00461E-07	2.49051E-07	2.89337E-07	2.85724E-07
HYUNDAI	8.53562E-08	1.50936E-07	1.7457E-07	1.52525E-07
MAZDA	4.28679E-08	6.81797E-08	6.24964E-08	7.3691E-08
MG	2.74837E-07	1.76307E-07	2.53178E-08	6.90709E-10
MITSUB	9.77275E-09	1.52436E-08	1.86559E-08	1.16256E-08
NISSAN	3.3486E-07	2.43525E-07	2.25018E-07	1.43081E-07
PSA	2.73829E-06	2.23647E-06	1.72185E-06	1.77684E-06
RENAULT	1.07348E-06	1.07251E-06	9.13499E-07	5.70503E-07
TOYOTA	5.1758E-07	5.474E-07	5.62369E-07	5.59739E-07
VW	3.08046E-06	3.24184E-06	3.44498E-06	3.60093E-06
Total	**0.00002**	**0.00002**	**0.00002**	**0.00002**

Table 23: Pressure of Marque in Industry

The force a firm can apply per physical area of sales territory. Pressure is force per unit area. Note that the total pressure in the industry is a constant, as the manufacturers tend to cover the same areas. If some firms are not represented in certain areas or these areas change, then the pressure is not constant. The market leader applies the greatest pressure in an industry.

PASCAL's Principle: The pressure applied to a confined fluid increases the pressure through the fluid by the same amount- pressure is the same everywhere in a fluid. Because Ford has the highest volume sales, it exerts the most pressure in the Industry. Hence pressure can be used to measure the effects of market distortions, in various industry areas.

3.5.21 Surface Tension

Surface Tension	Physics: Pressure = Force / Length
$\lambda = F / L$ $\lambda R / n = Ra / L$	Business: Pressure = Force / Length

The amount of work needed to increase a sales area is:

$$W = F \Delta x$$

$$\lambda = W / \Delta A$$

Example

Surface Tension

MARQUE	2003	20004	20005	20006
BMW	1.44514E-08	1.85E-08	2.28E-08	2.16E-08
DAIMLER	1.07335E-08	7.94E-09	7.39E-09	7.21E-09
FIAT	3.67807E-09	3.16E-09	4.49E-10	1.57E-09
FORD	6.96179E-07	6.66E-07	5.72E-07	5.23E-07
GM	2.3826E-07	2.47E-07	2.45E-07	2.12E-07
HONDA	3.27006E-09	4.53E-09	5.67E-09	5.56E-09
HYUNDAI	9.08578E-10	2.14E-09	2.66E-09	2.17E-09
MAZDA	3.23376E-10	6.49E-10	5.69E-10	7.29E-10
MG	5.24955E-09	2.7E-09	1.47E-10	6.61E-13
MITSUB	3.51994E-11	6.86E-11	9.28E-11	4.57E-11
NISSAN	7.06E-09	4.38E-09	3.89E-09	1.97E-09
PSA	1.65093E-07	1.22E-07	8.23E-08	8.63E-08
RENAULT	4.05227E-08	4.05E-08	3.18E-08	1.57E-08
TOYOTA	1.35668E-08	1.48E-08	1.54E-08	1.53E-08
VW	1.96985E-07	2.13E-07	2.33E-07	2.49E-07
Total	**0.00000**	**0.00000**	**0.00000**	**0.00000**

Table 24: Surface Tension on Market

This is a measure of the amount of work needed to increase a sales area. The work done to increase the surface area (i.e. enter other markets).

3.5.22 Wave Motion

This is applicable to lifecycles and economic cycles. Further investigation is recommended, as there are many models in existence, especially in economics.

3.5.23 Kinetic Theory

The average translational kinetic energy of a fluid (based on units sold) is directly proportional to the absolute Temperature. From the work energy theorem we also have $Wd = \Delta Ke = Ke2 - Ke1$

3.6.0 Thermodynamics

3.6.1 Heat (Analysis of a Firms Capability)

Heat is energy that is transferred from one body to another because of temperature differences. In our case using kinetic theory heat is transferred because of a difference in translational Ke of a market. Q is the energy that the firm has available to transfer into work or the COS of the firm.

The total of all the energy in a firm is called internal/thermal energy or profit. Temperature is a measure of the average translational Ke of all the firms in an industry. Internal energy is a measure of all the profit available to firms in that industry. Heat (Revenue) is the transfer of energy from one firm to another because of a difference in temperature or a difference in average Ke's. Hence we can consider it as the energy transferred in collision. Ke is the work (COS) a firm needs to do to sell units provided we assume Pe = 0 at that point.

Internal Energy of an ideal Gas

$$U = N(\tfrac{1}{2}m\overline{v}^2)$$
$$U = \tfrac{3}{2}NkT$$
$$U = \tfrac{3}{2}nRT$$

The internal energy of an Industry depends on the Temperature (Σ Ke), and the number of sales.

As a first approximation consider the following:

$$T_{industry} = n\sum Ke_{firms}$$
$$T_{firm} = n\sum Ke_{internal}$$

3.6.2 Specific Heat

$$Q = m_c\Delta T$$
$$Q_b = m_c R\Delta T$$
$$Q_b R / n = R(K_{e2} - K_{e1})$$
$$Q_b R / n = R^2(v_2^2 - v_1^2)$$

ΔT for Model 2 can be considered as Change in Market Share, where a dimensionless number based on ratio scale is used. Logically this seems a better fit, but Model 1 which uses translational Ke also seems a better relationship.

m_c is the specific heat of the industry. This is the amount of energy (money) to raise the temperature by 1 T. Thus Model 1 makes more sense at this level.

This is the average for that firm. The heat capacities of firms differ, and the Heat of an industry is

$$Q_{industry} = Q_1 + Q_2 + \dots Q_n$$
$$Q_{industry} = \sum_{i=1}^{n} Q_n$$

Or for a firm we have over an interval:

$$QR / n = \int_2^1 R_c dT$$
$$dQR / n = R_c dT$$

3.6.3 Conservation of Heat

Since heat is a form of energy, Heat $_{in}$ = Heat $_{out}$ and

$$Q_{industry} = Q_1 + Q_2 + \dots Q_n$$
$$Q_{industry} = \sum_{i=1}^{n} Q_n$$

$$Q_{industry} = Q_1 + Q_2 + \dots Q_n$$
$$Q_{industry} = \sum_{i=1}^{n} Q_n$$

The total Q available to an industry is the total revenue of that market.

3.6.4 Latent Heat

The energy (money) required to convert one unit from raw materials to finished goods = cost of manufacture.

Q = m*l*
QR/n= R*l*

Latent Heat is all that energy in a firm that is not directly involved in producing a unit. It is indirect energy needed to ensure the conversion of energy (money) to units. This is analogous to Lean Manufacturing: Strip out all the latent heats that don't add value to the firm, and improve the value adding steps, by reducing the heat capacity of the firm.

Energy conduction across a firm;

$$\frac{\Delta Q}{\Delta t} = kA\frac{T_2 - T_1}{l}$$
$$\frac{dQ}{dt} = -kA\frac{dT}{dx}$$

k = thermal conductivity of the firm. We can use translational Ke instead of Temperature to approximate conduction. This gives an indication of the ability of a firm to respond to demand changes for work, across its organizational chart. The smaller the area, i.e. fewer departments and people, and fewer levels (l) the easier it becomes to do work, i.e. the more flexible the organization. We can relate this to work efficiencies as well, see Carnot Efficiency.

3.6.5 First Law of Thermodynamics

In a typical Money/Units cycle of a business we have:

Money (Energy) →Materials/Services→Money (Energy) →Units (Materials/Services) →Sales →Money (Energy)

This is applicable to cash cycles and efficiencies in a firm.

Money is used to buy materials/services, and convert this to units for sale. After these are sold some of the money is used to start the cycle again.

Energy is transferred as heat (Q- Revenue) or work (W - COS). We want to maximize revenue, and minimize Wd to raise the revenue. A firm is an open system, as mass and energy enter are converted and exit the boundaries of the firm. We are looking at changes of state.

$$\partial W = F \bullet dl = PAdl = PdV$$
$$W = \int dW = \int_{v1}^{v2} PdV$$
$$Isothermal T_2 = T_1, and, P = \frac{nRT}{V}$$
$$W = \int PdV = nRT\int_{V1}^{V2} Pdv = nRT\ln\frac{V_2}{V_1}$$
$$W = \int_{V1}^{V2} PdV = P_2(V_2 - V_1)$$
$$\Delta V = 0, nowork$$

Work is not a property of a firm. The work done in changing a company's state depends on its starting and final states as well as the process followed.

U = Σ (All energy of the firm or industry – dependant on what we want to examine)

$$\Delta U = Q - W$$
$$\partial U = \partial Q - \partial W$$
$$Isobaric \Delta P = 0$$
$$Isochoric \Delta V = 0$$
$$Isothermal \Delta T = 0$$

Molar heat capacities raise one mole of fluid gas by 1 degree

$$\Delta V = 0; ....Q = nCv\Delta T........Cv = MCv$$
$$\Delta P = 0; .....Q = nCp\Delta T.......Cp = MCp$$

$$nCp\Delta T - nCv\Delta T = P(\frac{nR\Delta T}{P})$$
$$U = N(\tfrac{1}{2}mv^2) = \tfrac{3}{2}nRT$$
$$\Delta U = \tfrac{3}{2}nRT\Delta T = nCv\Delta T$$
$$Cv = \tfrac{3}{2}R$$

3.6.6 Adiabatic Expansion (Growth of a Firm)

$$dU = dQ - dW = -dW = -PdV$$
$$dQ = 0, ...(adiabatic)$$
$$dU = nCvdT$$
$$nCvdt + PdV = 0$$
$$PdV + VdP = nRT$$
$$andCpPdV + CvdP = 0$$
$$PV^{\frac{Cp}{Cv}} = cons\tan t - contraction$$
$$\frac{V_2}{V_1} = \frac{P_1}{P_2}^{\frac{Cv}{Cp}} \exp ansion$$
$$\frac{V_2}{V_1} = \frac{P_1}{P_2} ....cons\tan tT$$

3.6.7 Second Law of Thermodynamics

No cyclic process is possible where heat at one temperature is transferred to work. The implication for a firm is that there are losses of revenue due to the inability of the firm to make all the available sales at a point in time because it is unable to provide units, is limited by competition or other factors in its environment.

Efficiency of Heat Engines: As firms convert money to work, and units to money, we can consider them a heat engine. This implies that money cannot be directly transferred to units, or work to produce units, that directly translate into revenue. There are inefficiencies involved.

$$\varepsilon = \frac{W}{|Q_H|}$$
$$\varepsilon = \frac{W}{|Q_H|} = \frac{|Q_H| - |Q_L|}{|Q_H|} = 1 - \frac{|Q_L|}{|Q_H|}$$

3.6.8 Carnot Engine (Reversible/Irreversible Processes)

Most processes at a firm are irreversible.

Carnot Efficiency

$$\varepsilon = 1 - \frac{|Q_L|}{|Q_H|} = 1 - \frac{T_L}{T_H} = 1 - \frac{\Delta S_L}{\Delta S_H}$$

All reversible processes operating between the same two temperatures have the same efficiency – no firm can operate at a greater efficiency than this. For firms operating in the same industry, there is an upper limit to the efficiency of any process, or sub-process. This is not 100% by the third law of thermodynamics.   A firm must look at other ways to improve efficiencies, as the law of diminishing returns also applies. As it pours more money into improving its efficiencies, the returns from the improvements decrease, faster than the costs of implementation.

3.6.9 Entropy (Chaos Theory)

$$\frac{Q_H}{T_H} + \frac{Q_L}{T_L} = 0 ......CarnotCycle$$

$$\oint \frac{dQ}{T} = 0 ....\mathrm{Re}\,versibleCycle$$

$$\int_a^b \frac{dQ}{dT}_1 = \int_a^b \frac{dQ}{dT}_2 .....\mathrm{Re}\,vesible\,\mathrm{Pr}\,ocess$$

The integral δQ/T is path independent. Therefore:

$$dS = \frac{dQ}{T} ......\oint dS = 0$$

$$\Delta S = S_2 - S_1 = \int_1^2 dS = \int_1^2 \frac{dQ}{T}$$

Entropy is a state variable and is independent of the process. This implies it is present in a system whatever its state, and improvements in processes do not necessarily improve entropy losses.

The total sales available to an industry can be considered a heat reservoir.

$$\Delta S_{firm} = \int \frac{dQ}{T} = \frac{1}{T}\int dQ = \frac{Q}{T} + c$$

And Q = ml removed from total sales for firm

$$\Delta S_{firm} = -\frac{Q}{T}$$

Total Entropy Change

$$\Delta S_{firm} - \Delta S_{industry} = 0$$

$$\Delta S_{fim} = -n\frac{Q}{T} = \frac{R}{n}\Delta S = -R\frac{Q}{T}$$

$$if \Delta U = 0$$

$$Q = -\partial W = R\frac{-\partial W}{T}$$

Adiabatic Growth Process of a Firm

$$dQ = Dw = PdV$$

$$\Delta S_{firm} = \int \frac{dQ}{T} = \frac{1}{T} \int_{V1}^{V2} PdV$$

$$\Delta S_{firm} = nRT / T \int_{V1}^{V2} \frac{dV}{V} = nR \ln \frac{V_2}{V_2}$$

$$\Delta S_{industry} = 0$$

$$\Delta S_{firm} - S_{industry} \geq 0$$

There is always a trend toward entropy loss in the industry, and hence the firm.

3.6.10 Disruptive Technologies (Conduction)

$$\Delta S_{disrupt} = \int \frac{dQ}{T} = nc \int_{T1}^{T2} \frac{dT}{T} = nc \ln \frac{T_2}{T_1} = -nc \ln \frac{T_1}{T_2}$$

This is a gain by the disruptive technology at the expense of the industry. But is it now a part of a new industry or the industry it's disrupting?
Industry receives:

$$Q = nMc(T_2 - T_1)$$

$$\Delta S = \frac{\partial Q}{T}$$

The entropy of a disruptive firm decreases, as the sum of entropy increases. Disruptive technologies can increase industry sales.
In an industry the flow of heat Th→Tl, results in an increase of total entropy, or disorder.

$$\Delta S = \Delta S_H + \Delta S_L = (-\frac{Q}{T_{Hm}}) + \frac{Q}{T_{Cm}}$$

Where m is an intermediate temperature:

$$\Delta S = Q(\frac{1}{T_{Lm}} - \frac{1}{T_{Hm}}) > 0$$

$$\Delta S = \Delta S_{firm} + \Delta S_{industry} = 0$$

This is applicable to a reversible process. However most processes in business are irreversible.

In isolated firms entropy never decreases, as the heat has nowhere to move. The entropy stays constant for a reversible process and increases for an irreversible process. Hence in a business entropy will always increase, as most firms' processes are irreversible.

The total entropy of a firm and its industry increases as a result of any business process.
Thus entropy in an industry/firm is not conserved, it increases with time. All processes tend to move towards disorder.

The higher the entropy of a system means the probability that the wrong decisions will be made increases. Ke (Kinematics of the company) +ΣKe internal of the company (energy even if sales =0). The internal energy of the company becomes more disordered over time.

Entropy is one of the by products of industry and it will effect the macro environment. With the progress of industry the effects of its entropy on the environment increases.

As probability is related to disorder of a system, it is also related to entropy. The state of the firm is the most likely at that stage of industry lifecycle. The processes occurring in a business are the most appropriate for the development of the industry. However Competitive Advantage is short lived, because entropy always raises the costs of competing in the industry, because the advantage becomes the minimum standard to be competitive for other firms.

3.6.11 Third Law of Thermodynamics

As it is impossible to attain absolute zero, on a finite number of processes, completely efficient firms are impossible.

The conversion for Thermodynamics remains the same. Hence the costs are:

$$PV = nRT$$
$$PV\frac{R}{n} = RRT$$
$$R = 1$$
$$PV\frac{R}{n} = RT$$

Further investigation is recommended. This section can be used for internal analysis of the firm and to determine competitive advantages, and which of these are best. The laws of Thermodynamics can be applied to determine this, amongst other things. The model will be further elaborated as required. All the properties examined above must be fully integrated to analyse a firm and determine optimal strategies. The model as it stands is incomplete, but will serve the purposes of this paper. Control points and measurement can be determined using the model and other financial and soft data to determine whether a firm has reached its goals, and from there determine corrective actions based on the data analysed.

3.6.12 Summary of Thermodynamics as Applied to Business

From J M Smith et al (1987), we have that:

1st Law of Thermodynamics

$$OpenSystem$$
$$\Delta U + \Delta Ke + \Delta Pe = \pm Q \pm Wd$$
$$\Delta U + \Delta Ke + \Delta Pe = Q - Wd$$
$$ClosedSystem$$
$$\Delta U = Q - Wd$$

Total Energy change = Heat added – Wd by the system

But Profit = Total energy change (Internal Energy)
Revenue = Money added or made (Heat Added)
Cost of Sales = Work done by the system

$$\Pr ofit = \operatorname{Re} venue - COS$$
$$NPAT = \operatorname{Re} venue - (COS + Expenses + Tax)$$ Are equivalent
$$\Delta U = \Delta Q - Wd$$

And

Wd = ΔKe only if ΔU + ΔPe = Q

Proof

$$\Delta U + (Ke + Pe) = \Delta Q - Wd$$
$$\Pr ofit + (Ke + Pe) = \mathrm{Re}\, venue - COS$$
$$\Pr ofit + \tfrac{1}{2} nv^2 + ngh = \mathrm{Re}\, venue - COS$$
$$but \Delta Ke + \Delta Pe = 0$$
$$Hence$$
$$\Pr ofit = \mathrm{Re}\, venue - COS$$
$$\Delta U = \Delta Q - Wd$$

2nd Law of Thermodynamics

ΔS = dQ/T = Revenue/ΔKe at a constant Temperature, Translational Ke = constant.

ΔS = 2 x n x Price/ n x (Revenue $_{firm}$/Revenue $_{industry)^2}$

$$\Delta U + \Delta Ke + \Delta Pe = Q - Wd$$
$$\Delta Ke + \Delta Pe = \Delta S / \Delta Ke - Wd$$
$$\Pr ofit = \Delta S / \Delta Ke - COS$$
$$\frac{\Pr ofit + COS}{\Delta Ket} = \Delta S$$
$$\frac{\Delta \mathrm{Re}\, venue}{T} = \Delta S$$

Entropy changes (or changes in chaos-disorder) arise from revenue changes at a constant translational Ke, or Temperature.

$$\frac{\Delta Q}{T} = \frac{\Delta \mathrm{Re}\, venue}{T} = \Delta S$$
$$Ket = \tfrac{1}{2} M v_{cm}^2 = \tfrac{1}{2} \frac{n_i}{n_p t^2}$$
$$Industry$$
$$\frac{2 \Delta n_i \Delta p_i n_p t^2}{n_{iBASE}} = \Delta S_{industry}$$
$$Firm$$
$$\frac{2 \Delta n_f \Delta p_f n_p t^2}{n_{iBASE}} = \Delta S_{firm}$$

M is the total units sold by the industry.
Np is the number of competitors
ni BASE is the base units chosen
P is the price of the firm or industry
nf and ni is the units sold by industry or the firm.
t is time

From the above equations:
The higher the number of competitor's n_p the greater the chaos or entropy. The longer the time period under consideration the greater the entropy as time is squared. The bigger the market and the higher the number of units sold by the industry into it the lower the entropy. The greater the difference in prices, or units sold by the individual firms or industry, the greater the entropy change.

At the start of the lifecycle of the industry t- time is small, as are units sold. There are few competitors, but prices may be high due to skimming. Hence entropy is low. As the market grows, more competitors enter; units sold increase, as with time, and entropy increases along with revenues. As the market becomes saturated, entropy reaches a maximum and a plateau as revenues stagnate. At this time prices may decline, as competition increases. As the market declines fewer units are sold, revenues decline and entropy decreases in line with the declines in prices and units. A firm must endeavor to reduce its revenue losses due to entropy changes. To do this the firm must compete as efficiently as possible.

Carnot Efficiencies

$$W = Q = |Q_H| - |Q_c|$$

$$\mu = 1 - \frac{T_c}{T_H} = \frac{networkoutput}{heatinput} = 1 - \frac{COS}{\mathrm{Re}\,venue}$$

$$\mu = 1 - \frac{|\Delta Ke_C|}{|\Delta Ke_H|}$$

If COS = Revenue then Efficiency = 1-1 = 0 (minimum), we are converting all the revenue to COS. However since a firm needs to make a profit in order to grow, revenue is normally greater than COS. Hence the efficiencies of a firm relate the ability to maximize revenue and minimize cost of sales.

3.6.13 Development of a mathematical expression to optimize n (units sold)

The derived model will be of the form:

Profit = Revenue – Costs

We are interested in maximizing Profit. To do this we need to:

$\text{Profit}_{max} = \text{Revenue}_{max} - \text{Costs}_{min}$

Profit = f (revenue generating activities – cost generating activities)

To maximize the value chain we need to maximize the unit sales of a company, at a minimum cost.

n = f (Internal Factors + External Factors) affecting a company. To optimize this we need to find the best fit of strategy to the capabilities of the company.

n = f (Industry Effect + Competitors Effect + Vector Field (Force Field) Effects (Global) + Entropy Loss) $_{\text{External}}$ + ((Internal Value Mix-Marketing and Service Mix (7Ps) + Internal Energy (f (Finance, HR, R&D….Internal Functions) + Entropy loss)*Synergy (Efficiency of operations)) $_{\text{Internal}}$ + other factors i.e. community, environmental etc.

$W_{net} = W_g + W_N + W_p + W_{friction}$ Or force, velocity, or units sold. W_d = Force X Distance.

$W_{internal} = \Sigma W_{purchase\ materials} + \Sigma W_{conversion} + \Sigma W_{distribute} + \Sigma W_{sales} + \Sigma W_{other}$ = COPS (Internal Wd)

These are all the costs associated with the manufacture and sale of goods and services. The internal work is proportional to the money expended to carry out the operations.

$W_{external} = \Sigma W_{suppliers} + \Sigma W_{competition} + \Sigma W_{customers} + \Sigma W_{entropy} + \Sigma W_{other}$ = COE (External Wd)

$$Wd = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 .... + \beta_n x_n + \beta_{error} X_{error} = COS$$

$$\left(\frac{\text{Re}\,venue}{Unit}\right)_{\max} - \left(\frac{COS}{Unit}\right)_{\min} = \left(\frac{\text{Pr}\,ofit}{Unit}\right)_{Optimum}$$

$$\Rightarrow \Delta Q - \Delta Wd = \Delta U ....1stLawThermo$$

$$where \Delta Q / T = \Delta S_{\text{int}\,ernal} ....2ndLawThermo$$

$$\Delta U = (Gross\ \text{Pr}\,ofit_{\text{int}\,ernal} - Expenses_{\text{int}\,ernal}) = Net\ \text{Pr}\,ofit_{\text{int}\,ernal}$$

$$NPAT = (Net\ \text{Pr}\,ofit_{\text{int}\,ernal} - Tax_{external})$$

$$3rdLawThermo........no100\%\ \text{Re}\,\text{cov}\,eryofEfficiencies$$

$$\text{Pr}\,ofit = \Delta U$$

$$\text{Re}\,venue = n \times price = \Delta Q$$

$$COS = Wd = \Delta Pe + \Delta Ke = Fd$$

$$COS = Wd = \Delta Ke = nad$$

$$Where \Delta Pe = 0$$

All the above equations can be converted to time based accounting equations, where we consider the time cost of money. For competitive systems from the work energy theorem W = Δ Ke. Hence we need to minimize Δ Ke, or work to minimize COS.

To further expand this model using Osterwalder, 2003, as an example we can use business modeling ontology (social systems model) consisting of product innovation, customer relationship, infrastructure management and financial aspects cycles, and expand these using the PBR model. The PBR model looks at the underlying equations of what a company makes, who to target, how to do it best, and how much can be earned. (Markides, 1999). Adapting Osterwalders Oncology model, we can say:

Value Proposition = value creation + value appropriation + value consumption + value renewal + value transfer.

For our car example we have:

Value Proposition = (Cars customized + service + insurance + finance + other services)$_{\text{value creation}}$ + (Right car + Right price + Right service + other) $_{\text{value appropriation}}$ + other.

Add to this Du Plessis, Jooste & Strydom, 2001 suggest the following model:

Customer Value = Perceived Benefits – Perceived Costs

= Functional Benefits + Emotional Benefits + Image Benefits + Social Benefits + Service benefits + Experiential Benefits – Monetary costs – time and energy component – psychic expenditure. Economists would use opportunity costs.

Incorporating the two models we have:

Value Proposition = value creation + value appropriation + value consumption + value renewal + value transfer + functional benefits + emotional benefits + image benefits + social benefits + service benefits + experiential benefits – monetary costs – time and energy component – psychic expenditure.

Customer Relationship = Target customer (Who) + Channels(How) + CRM(Acquisition, Retention, Resale's)

Infrastructure Management =Capabilities (Resources) + Value Configuration (Value Chain/Network) + Partnerships (Suppliers/Competitors/Substitutes)

Financial =Sustainable Profits (Energy gain)

Total value proposition = Revenue streams from customers – cost structures.

This is our Profit = Revenue – COS.

This is not a comprehensive model, as customers buy for different reasons, at varying times. Other parts of the models can be adapted. However we are interested for this paper in competition only, so will not develop this model further as it combines quantitative and qualitative elements, for which surveys need to be developed, to determine the best competitive positioning of a companies offering.

$$Wd_{actual} = Wd_{company} + Wd_{overcomeCompetition}$$

This is included in the COS, of a company and is not always obvious. However it costs money to move units into the external environment of the firm.

Consider the following:
(All units are monetary)
Internal Energy is Profits made by the company. (Energy gained by the company)
External Energy is the net effect of all the forces acting on the firm. (Energy needed to overcome them - breakeven)
Potential Energy is the energy available from previous sales; this is however affected by various efficiency factors and entropy loss in the company.
Conversion Energy = Latent Energy = making one unit without increasing the energy in the company i.e. making a unit, but not selling it.
Entropy is energy loss in the company, and in the industry.
Heat is the revenue generated by the firm i.e. units x price..

A unit sold is represented by:

n = f (Industry Effect + Competitors Effect +Vector Fields + Entropy changes) $_{External}$ + ((Changes in internal Energy + Value Mix + f (functions in firm) + Changes in Entropy)* Synergy) $_{Internal}$ + Other Effects.

This is a highly complex model and is by no means inclusive as the scope thereof is beyond this paper.

W_d = f (n, v, profit, revenue, Cost per Unit, Kinetic Energy, Friction Losses, Forces, Vectors, Capabilities, Time value of money, ……) = COS = Cost of Sales of the company including expenses and tax. Power = Wd per unit time.

As stated previously a company needs to do work to sell units. This work is affected by many factors, including Porters Forces, Vector Field effects, Entropy, and all sorts of other effects, some of which can be quantified. There are many effects on competitive forces, as business is a complex structure.

3.6.14 Industry Effect

This is a change in industry conditions.

$$Ie = \frac{n_2 - n_1}{n_1}$$

3.6.15 Competitors Effect

The competitor effect on units sold is calculated as follows:

$Ce = \Sigma\Delta v$, and $Ce = \Sigma\Delta Ke$

3.6.16 Vector Field Effects

$Ve = \Sigma VectorFields$ This would be an interesting study in itself, if we include potential difference and charge effects. See appendix 6.

The framework presented here can be used as a comparative tool to analyse industries, and the relationships existing in firms operational therein. This analysis can be used at the macro-environmental levels, as well as in industries and firms. For this paper due to the complexity of applying the full model, only competitor analysis and strategies based on these will be analysed. Further definition and use of the model has already to a great extent been determined, but more research is needed to fully complete and comprehend the intricacies of the model.

Because we can estimate the heat needed we can use the laws of thermodynamics to calculate efficiencies and examine value delivery problems in a firm.

Chapter 4

Statistical Research Methodology

4.1 Introduction

This research will be quantitative in nature. Secondary data of the motor industry which is readily available will be analysed using appropriate statistical methods, in order to test the propositions.
Structural Equation Modeling will be the main tool for analysis of the proposed competition model.

4.2 The Research Population

The population includes any firm that competes in an industry, with many players. These firms range in size from multi-billion pound annual turnover companies to smaller organizations that turn over a few million per annum. In this instance we analyse the UK car industry as data is readily available.

4.3 The Sample and Population

The sampling methodology is based on historical secondary data. This ensures accuracy, repeatability, validity and reproducibility. The choice of companies is limited to the larger players, as data is available on their operations and this will ensure that the sample is representative of the population.

4.4 Preliminary Study

The preliminary study will be used to determine establish the variables to be used in the structural equation modeling.

4.5 Validity and Reliability

The validity of an instrument is how well it measures what it is supposed to be measuring, while reliability refers to the accuracy and consistency with which the instrument produces results.

External Validity: The external validity is the extent to which the results of the study may apply to situations beyond the study itself. The sample is one of convenience, yet it is representative of the population.

Internal Validity: Internal validity refers to the extent to which the instrument allows inferences about the causal relationships between data elements.

4.6 Data Analysis

The data analysis for this study revolves around structural equation analysis.

4.7 Data Collection

The sample companies will be drawn from secondary data available at www.smt.co.uk.

4.8 Statistical Analysis of PBR models

The underlying data is not linear so there will be a problem applying correlation analysis.
We need to transform the data in some way before we can subject the model to statistical testing. As the models are equivalent, we may prove Model 1 and Model 2 will follow, automatically from the proof.

Hypothesis

H_0: There is a relationship between physical laws and business practice (Overall Framework)

H_1: There is no relationship between physical laws and business practice

Need to prove the momentum and kinetic model only, as this paper concentrates on competitive analysis. To do this we need to prove v = change in sales, or change in units (relative). If we can prove velocity, then the others follow as y = ax + c, and v = d/t, p = mv and Ke = 1/2mv^2. Because there is a relationship we need only find a statistical proof for v. Also as we use momentum, kinetic energy and collision theory to calculate the velocity due to competition, we are in effect testing the model as proposed for competitive interactions in its entirety.

From this

Mass→Units, this is a simple mass balance of the form mass $_{in}$ = mass $_{conversion}$ + waste = mass $_{out}$ + Accumulation

Time→Time, no proof needed.

Distance→ Here some proof is needed as we are using a ratio (we use velocity as time is already proven).

$$dis\tan ce = \frac{Sales_{firm}}{Sales_{industry}} \text{..........} average$$

$$dis\tan ce = \frac{Sales_{firm}}{Sales_{\max imum}} \text{.........} benchmarking$$

$$or$$

$$dis\tan ce = \frac{Units_{firm}}{Units_{industry-->\max imum}}$$

$$as \cdot Sales\,\mathrm{Re}\,venue = units \times price$$

To determine the distance a firm has moved its units. We can use the conversion sales = units x price only when working with averages. The conversion is not equivalent otherwise, and the sales ratio would be used i.e. the energy/money balance instead of mass/units balance.

Hence the problem is to prove that the distances calculated do not affect the underlying probability distribution function of the firm, and are in fact equivalent measures of it, or to prove that the velocities (distance/time) calculated by the competition model are from the same distribution and hence the momentum (units x velocity) and kinetic energy (1/2 x units x velocity) will follow because multiplying the means and variances by constants and other numbers does not affect the underlying distribution, as long as both sides of any equation are changed by the same amounts. As we utilise the entire model to calculate the velocity all the sub-problems are taken into consideration.

Sub Problems/ Sub Hypothesis.

Momentum Model

H_0: There is a relationship between the proposed momentum model and sales, under competitive conditions.

H_1: There is no relationship between the proposed momentum model and sales under competitive conditions.

Kinetic Energy Model

H_0: There is a relationship between the proposed Wd model and sales, under competitive conditions.

H_1: There is no relationship between the proposed Wd model and sales under competitive conditions.

Collision Model

H_0: There is a relationship between the proposed collision model and competition.

H_1: There is no relationship between the proposed collision model and competition.

We are not concerned here with the rest of the model. A direct mathematical proof of the relationship is provided in the text for the proposed hypothesis. This is proof sufficient, however a statistical proof needs to be considered if possible. Because we use the model to calculate velocity all aspects of the model are checked, and the sub-problems are checked at the same time.

4.9 Test Statistic

Because of the complexities of analyzing the model as it is an analytical model we will use structural equation modeling (SEM) and a combination of other tools as the actual data are non-linear, which means that the conclusions reached from SEM are suspect.
Structural Equation Modeling is a generalized, powerful multivariate analysis technique including specialized versions of other analysis methods for special cases.

Applications of SEM include:

causal modeling, or path analysis, that hypothesizes causal relationships amongst variables and tests the causal models with a linear equation system.
confirmatory factor analysis, an extension of factor analysis in which specific hypotheses about the structure and correlations of the factor loadings are tested;
second order factor analysis, a variation of factor analysis in which the correlation matrix of the common factors is itself factor analyzed to provide second order factors;
regression models, an extension of linear regression analysis in which regression weights may be set to be equal to each other, or to specified numerical values;
covariance structure models, which hypothesize that a covariance matrix has a particular form.
correlation structure models, which hypothesize that a correlation matrix has a particular form.

Many different kinds of models fall into each of the above categories, so structural modeling as an enterprise is very difficult to characterize.

Structural Modeling

The basis of SEM is that additive and multiplicative changes to an array can be done. By multiplying each number in an array by a constant, the mean and standard deviation are multiplied by that constant.
Variables inter-related by linear equations can be examined. SEM tests whether variables are interrelated by checking the variances and covariances of the variables.
The procedures to see if a set of variances and covariances in a covariance matrix fit a specified structure are as follows:
State the way the variables are inter-related - as stated by PBR model
Calculate the implications for the variances and covariances of the variables.
Test whether the variances and covariances fit this model of them.
Report the results of the statistical testing, and parameter estimates and standard errors for the numerical coefficients in the linear equations.
Decide whether the model seems like a good fit to the data.
No structural model fits nature perfectly — for a number of reasons. A structural model using linearity is always an approximation. The PBR equations and the underlying data are not linear. However the relationship between actual velocity and the effects of competitors on that velocity is linear. The statistical assumptions of SEM are doubtful. We are attempting to decide if the PBR models are a useful approximation of reality, and an explanation of the data. Should the model fitting the data be accurate this does not mean the model is correct. There may be many other equally accurate models predicting the data that is why we look at two models here.

Structural Equation Modeling

We are testing extremely complicated models. In this case we are only testing a small part of the model. As the equations increase in complexity, the covariance structures become more complex. Testing causal models with linear structural equations has many faults. In this case the underlying structures are not linear, but the relationship is proportional (hence linear). We need to test the relationship, not the underlying distributions. One way is to test the equivalence on models, and the other way is to relate the models. The variables used in this case are non-linear. They can be linear for reasons with nothing to do with causality. "Correlation is not causation" is true, even for complex and multivariate correlations. Causal modeling describes the failure to agree to a model of causality. Due to the faults inherent in SEM, we will apply other testing statistics as well.

4.10 Path analysis

Hypothesizes causal relationships among variables and tests the causal models with regression equation systems.

We are testing Y = AX + B or $Wd_{actual} = Wd_{firm} + Wd_{overcome\ competition}$ or a function of Wd. We Hypothesize $Velocity_{internal} = Velocity_{actual} + Velocity_{competition}$ to simplify the analysis.

As the underlying distribution of the UK car industry is not linear, we have to assume that the mapping is linear (or one to one for the respective models) and the underlying distribution does not affect the proposed model, or convert the data to linear or other regression forms. From regression analysis above it is apparent that none of the regression forms are good enough predictors. See Appendix 4.

Based on the ANOVA calculated it is apparent that there is no significant difference between the distribution calculated (sum of interactions based on collisions) and the actual distribution. This means that there is a high likelihood that the model as specified is a subset of the actual velocity of a company.

4.11 Confirmatory factor analysis

Hypotheses about the structure and correlations of the factor loadings are tested. As the factors giving rise to the distribution are non-linear we have to assume factor loadings for the variables. We Hypothesize $Velocity_{internal} = Velocity_{actual} + Velocity_{competition}$

See Appendix 5.

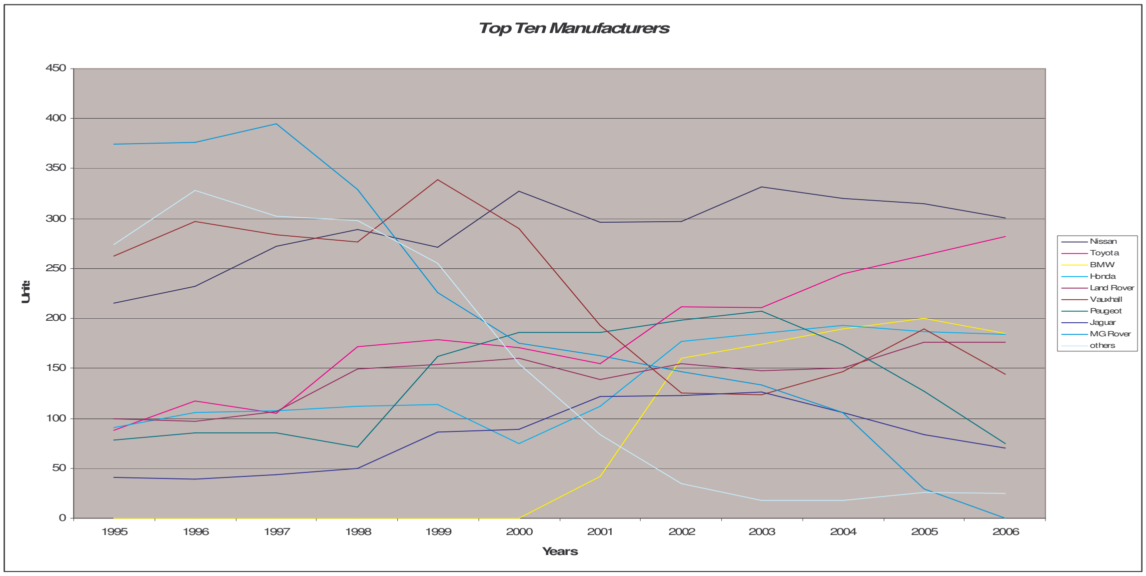
We use the correlation coefficient to check the form of the model. The hypothesis as specified above is the most correct i.e. the model is additive. The correlation coefficient is greater than 0.94, and the model is highly correlated to the actual velocity observed in practice.

4.12 Second order factor analysis

The correlation matrix is factor analyzed to provide second order factors. We Hypothesize $Velocity_{internal} = Velocity_{actual} + Velocity_{competition}$ but will not consider this here as we are not considering secondary factors here, although we are aware of them.

4.13 Regression models

A form of linear regression analysis in which regression weights may be constrained to be equal to each other, or to specific numerical values. We assume the weights are equal to each other. If we plot actual velocity versus predicted velocity based on collisions with competitors we have good regression models > 0.9.



Graph 1: Top Ten Manufacturers Unit Sales

As can be seen from the graph the unit sales are nowhere near linear. On application of regression models to each of the manufacturers we have the following:

Using multiple linear regression, and non-linear regression, the following results are obtained. For graphs, see appendix 3.

Manufacturers	Equations	R^2
Nissan	$t = 0.0297n^3 - 2.1235n^2 + 185.93$ $t = 43.105\ln n + 217.12$ $t = 219.15n^{0.1612}$ $t = 236.5e^{0.0296n}$	0.8518 0.8039 0.8245 0.6318
Toyota	$t = 0.1987n^3 - 3.639n^2 + 34.361n + 56.384$ $t = 74.258\ln n + 59.56$ $t = 80.725n^{0.4575}$ $t = 92.662e^{0.096n}$	0.9301 0.8212 0.8837 0.8857
BMW	$t = -0.7962n^3 + 17.098n^2 - 81.535n + 86.677$ $t = 93.71\ln n - 76.922$	0.9721 0.5429
Honda	$y = -0.2901n^3 + 6.3354n^2 - 29.155n + 130.41$ $y = 42.888\ln n + 65.5666$ $y = 77.34n^{0.316}$ $y = 80.672e^{0.0739n}$	0.7835 0.5429 0.5076 0.6537
Land Rover	$y = 0.197n^3 - 4.3936n^2 + 34.346n + 57.455$ $y = 31.6321\ln n + 89.89$ $y = 93.235n^{0.2439}$ $y = 102.3e^{0.0432n}$	0.8230 0.7747 0.7885 0.7105
Vauxhall	$y = 1.1021n^3 - 20.458n^2 + 98.429n + 173.74$ $y = -67.516\ln n + 335.04$ $y = 363.06n^{-0.3297}$ $y = 351.01e^{0.0793n}$	0.7938 0.4403 0.4540 0.5976

Peugeot	$y = -0.4292n^3 + 6.5935n^2 - 16.318n + 48.172$ $y = 31.784\ln n + 28.727$ $y = 34.457n^{0.4671}$ $y = 42.542e^{0.0873n}$	0.9079 0.2878 0.2922 0.1693
Jaguar	$y = -0.4292n^3 + 6.5935n^2 - 16.318n + 48.172$ $y = 31.784\ln n + 28.727$ $y = 34.457n^{0.4671}$ $y = 42.542e^{0.0873n}$	0.9402 0.5289 0.6287 0.5001
MG Rover	$y = 0.1623n^3 - 2.9906n^2 - 21.813n + 452.95$ $y = -163.75\ln n = 477.17$	0.9458 0.8271
Other	$y = 1.3377n^3 - 25.22n^2 + 96.389n + 212.81$ $y = -147.35\ln n + 396.93$ $y = 803.74n^{-1.3323}$ $y = 667.92e^{-0.3129n}$	0.9760 0.7130 0.6785 0.8517
Market	$y = 0.6301n^3 - 16.758n^2 + 113.92n + 1475.1$ $y = -22.58\ln n + 1664.9$ $y = 1663n^{-0.0041}$ $y = 1696e^{-0.0066n}$	0.4196 0.0283 0.0285 0.1434

Table 25: Regression and Equations for Marques

From the results it is apparent that no equation has a good correlation to the data presented. It is also apparent that the underlying data is not linear. Hence it is difficult to apply any linear form to the underlying data, and test this via correlation analysis. However we can apply an approximate test.

As we are only considering n = f (Factor of Competitive Forces) we can check actual results vs Σ Competitive Forces. We need to calculate the competitive factor and then run ANOVA and comparative t-tests for the models proposed. In this case we consider e = 0, 0.5 and 1for optimal merges (0), and industry competition (1 = max). See Appendix 4

One of the major limitations of using statistical analysis in this case is that most statistics models consider that we are drawing a sample from a particular distribution. In this instance the model is a modified model, and it is difficult to measure the variables involved in practice, as the data is hidden in the modified business distribution.

See Appendix 3 for Graphs, equations and correlation coefficients.

4.14 Covariance structure models

Hypothesize a particular covariance matrix. We Hypothesize $\text{Velocity}_{\text{internal}} = \text{Velocity}_{\text{actual}} + \text{Velocity}_{\text{competition}}$

We will not consider the covariance matrix.

4.15 Correlation structure models

Hypothesize a particular correlation matrix. We Hypothesize Velocity $_{internal}$ = Velocity $_{actual}$ + Velocity $_{competition}$

	N Cal	*N Act*	*T Cal*	*T Act*	*B Cal*	*B Act*	*H Cal*	*H Act*	*L Cal*	*L Act*	*V Cal*	*V Act*	*P Cal*	*P Act*	*J Cal*	*J Act*	*MG Cal*	*MG Atc*	*Oth Cal*
N Cal	1																		
N Act	**-0.93**	1																	
T Cal	0.85	-0.82	1																
T Act	-0.71	0.79	**-0.94**	1															
B Cal	-0.38	0.28	-0.1	-0.05	1														
B Act	-0.67	0.71	-0.84	0.89	**-0.07**	1													
H Cal	0.64	-0.61	0.73	-0.76	-0.05	-0.93	1												
H Act	-0.6	0.62	-0.8	0.86	-0.06	0.98	**-0.96**	1											
L Cal	0.88	-0.83	0.95	-0.84	-0.24	-0.68	0.55	-0.61	1										
L Act	-0.77	0.85	-0.9	0.92	0.11	0.7	-0.55	0.65	**-0.92**	1									
V Cal	-0.57	0.57	-0.64	0.66	-0.04	0.88	-0.9	0.9	-0.47	0.45	1								
V Act	0.73	-0.68	0.75	-0.71	-0.12	-0.9	0.92	-0.9	0.62	-0.55	**-0.97**	1							
P Cal	0.79	-0.57	0.56	-0.29	-0.42	-0.36	0.39	-0.28	0.64	-0.37	-0.33	0.5	1						
P Act	-0.79	0.57	-0.53	0.26	0.44	0.33	-0.36	0.24	-0.62	0.35	0.32	-0.49	**-1**	1					
J Cal	0.91	-0.74	0.75	-0.53	-0.49	-0.58	0.6	-0.52	0.8	-0.58	-0.54	0.7	0.94	-0.93	1				
J Act	-0.91	0.74	-0.73	0.52	0.53	0.57	-0.6	0.52	-0.78	0.57	0.55	-0.71	-0.93	0.92	**-1**	1			
MG Cal	-0.68	0.65	-0.76	0.71	**-0.03**	0.74	-0.63	0.65	-0.7	0.66	0.43	-0.54	-0.51	0.46	-0.58	0.54	1		
MG Atc	0.84	-0.86	0.96	-0.96	-0.08	-0.85	0.72	-0.79	0.91	-0.94	-0.59	0.69	0.52	-0.49	0.7	-0.68	**-0.79**	1	
Oth Cal	-0.82	0.81	-0.88	0.86	0.06	0.97	-0.9	0.93	-0.77	0.73	0.87	-0.93	-0.56	0.54	-0.74	0.74	0.76	-0.88	1
Oth Act	0.91	-0.88	0.92	-0.86	-0.19	-0.91	0.84	-0.85	0.86	-0.8	-0.78	0.88	0.68	-0.65	0.84	-0.84	-0.77	0.92	**-0.98**

Table 26: Correlation Table

From the correlation matrix we have:
A high correlation > 0.9 is evident for all models except BMW (too little data) and MG which is in terminal decline. Hence the data is highly correlated.

4.16 Statistical Conclusions

We have proved that changes in distance per unit time (velocity) are analogous to changes in the market share of a firm. This implies that all the other kinematic equations used throughout the text can be applied to business, as all the equations are directly related in physics via the basic physics units and the relationship between them. From the work energy theorem we can extrapolate the relationship between kinematics and business (mass – unit balances) into the realm of thermodynamics and energy- money balances. Hence by proving that market shares and changes in distance are equivalent we can postulate that thermodynamic relationships are applicable to business. There are equivalent equations and units which complicate matters further, but they will not be considered in this paper.

As we have proved that distance as defined in a business context by the market share is related contextually to distance in physics, which is related to speed (distance/ time since time is the same in both systems) it follows that we can define acceleration (distance/time squared), force (mass or units multiplied by acceleration) and work (force multiplied by distance or market share), power (work performed in a time frame), Kinetic Energy, and Potential Energy, since all these relations define the properties of the system they represent. It is therefore possible to define business in terms of the physics equations which represent its properties and use these to draw valid conclusions about an industry, and the firms operational therein.

Using the work energy theorem it is possible to relate kinematics and thermodynamics. Hence the mass and energy relationships describing the measurable properties of a system can be related, and equations derived to measure the interrelationships between them. Hence the link between business and physics needs to be built from basic units, and equivalent relationships between them derived. If $Wd = \Delta Ke$ (work energy theorem) is applied then it follows that ΔU

= ΔQ – Wd, and this interrelationship is proven. If ΔU = increase or decrease in internal energy or money of a firm i.e. its profit, then it naturally follows that Q is the revenue generated by a firm. The work done W_d by a firm is all the energy or costs needed to move units against the resistance (forces opposing the movement of the firms offering into the market) or potential gradient in an industry. This COS includes wages, raw materials, Capex, and all expenditures associated with selling units. An interesting accounting application is fixed and variable costing and physics relationships which we will not consider here, as these can be related to operational cycles, and Carnot efficiencies.

From the relationship described above, Wd = ΔKe = $\frac{1}{2}mv^2$ = Fd = ΔPe – ΔKe……, and we can develop these relationships further to analyse the interrelationships in an industry. Thus the work done (Wd) links vector analysis, competitive theory and other measures of relationships within firms, in industries and between industries. A firm must do work to move units internally, in the industry where it directly competes, and within the local and global economy. The basis of Work is the energy or expenditure to create a product or service (unit), and sell it within a market. The lower the work or energy or money, a firm utilizes to move units compared to its competitors, the more competitive it can become provided it is moving the volumes and the better a firms conversion of units to revenue (sales = units multiplied by price) the more competitive its position. Whatever makes a company more sustainably energy (money) efficient than its competitors, will in the long term lead to higher revenues, lower costs and higher than average profits. Hence the better the firms value proposition, and the more efficiently it uses money and conserves it the better it should fare in a competitive environment.

The more efficiently a firm can produce and sell units, the better its value proposition, hence the higher its potential Pe, and money generated from movement Ke, and the better it can maintain momentum, the better it can do work. As it moves down the experience and learning curves, the more efficient a firm becomes, because more units produced for lower costs improves efficiencies. The higher a firms work rate per unit time, the greater its power, and the better it can withstand external and internal forces working against its thrust.

Thermodynamics considers the increase of internal energy of a system, in business we need to maximize profit as efficiently as possible. The energy (money) and mass (units) cycle of a firm must be optimized to maximize profits. We can use thermodynamics or the movement of energy (money) to determine the most efficient ways of doing work in value chains to move units along the channels of distribution as efficiently as possible, by conserving money, and minimizing expenditure.

To examine an economy, an industry, or firm's best competitive position, we need to look at the value it adds and its area of specialization. We need to compare its value proposition against that of other firms, industries and economies. We need to examine its strategies, and what the firm is trying to achieve. We look at the velocity or rate of change of its market share. Is the share increasing faster or slower than other players? Is the overall market growing, slowing or dead? What position does the firm hold in the pecking order is it competitive with respect to product, price, quality, promotions and channels. There are many factors to consider, and their relative importance in the value proposition can change over time. Their relative importance can be ranked and the competitive positioning of the firm measured and changed to suit conditions. Is the firm accelerating, or slowing in comparison to the industry, and its closest competitors? The force a company can exert, the weight it has in the industry, and the resultant force less frictional forces can be calculated. This force multiplied by the change in market share gives an indication of the work, or costs associated with competing at that position in the industry. The firm that can increase its market share with a minimal expenditure or work has a competitive advantage in that industry. A firm with a lower cost to market share ratio should be examined to determine its competitive advantages in operations and sales.

To gain the best operational advantage from synergies within a firm, revenue generating activities (sales or Q) must be linked as efficiently as possible to work generating activities. The aim is to maximize revenue and minimize costs. To make work more efficient need to minimize the effects of forces acting against the company whether these are internal or external. A starting point in analysis is to quantify all the costs affecting work done by the firm. Then use lean principles and eliminate unnecessary costs, and minimize unavoidable cost. Taking this one step further the time value of money must be considered, and all conservation or savings utilised. A simple way to economize is to take the ratio of all costs to the total cost of moving units. These ratios are then compared and likely candidates for elimination examined. Steps that can be safely eliminated from the process are analysed and the effects of their elimination measured. Should there be negligible or no effect after their elimination, they should be made redundant.
Adding all the costs, and noting the effect of the force driving the cost (positive or negative cost drivers) and their sum is the cost of selling product in that market.

The proposed models based on kinematics and thermodynamics prove that the underlying operations of a firm are a subset of physics laws. The study around competitive positioning of a firm based on improving momentum and potential energy, while minimizing work done by a firm to move units is derived from the velocity relationship. As the models are equivalent (based on averages – however for different products and prices they differ) it follows that:

$Profit_{max} = Revenue_{max} – Costs_{min}$

Profit = f (revenue generating activities – cost generating activities)

To maximize the value chain we need to maximize the unit sales of a company, at a minimum cost.

n = f (Internal Factors + External Factors) affecting a company. To optimize this we need to find the best fit of strategy to the capabilities of the company.

n = f (Industry Effect + Competitors Effect + Vector Field (Force Field) Effects (Global) + Entropy Loss+ Government Forces + Tax Optimization (1-T)) $_{External}$ + ((Internal Value Mix-Marketing and Service Mix (7Ps) + Internal Energy (f (Finance, HR, R&D….Internal Functions) + Entropy loss)*Synergy (Efficiency of operations)) $_{Internal}$ + other factors i.e. community, environmental etc.

$W_{net} = W_g + W_N + W_p + W_{friction}$ Or force, velocity, or units sold.

$W_{internal} = \Sigma W_{purchase\ materials} + \Sigma W_{conversion} + \Sigma W_{distribute} + \Sigma W_{sales} + \Sigma W_{other} = COPS$

These are all the costs associated with the manufacture and sale of goods and services. The internal work is proportional to the money expended to carry out the operations.

$W_{external} = \Sigma W_{suppliers} + \Sigma W_{competition} + \Sigma W_{customers} + \Sigma W_{entropy} + \Sigma W_{other} = COE$

$$Wd = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 .... + \beta_n x_n + \beta_{error} X_{error} = COS$$
$$\left(\frac{Revenue}{Unit}\right)_{\max} - \left(\frac{COS}{Unit}\right)_{\min} = \left(\frac{Profit}{Unit}\right)_{Optimum}$$
$$\Rightarrow \Delta Q - \Delta Wd = \Delta U ....1stLawThermo$$
$$where \Delta Q / T = \Delta S_{internal} ....2ndLawThermo$$
$$\Delta U = (Gross\ Profit_{internal} - Expenses_{internal}) = Net\ Profit_{internal}$$
$$NPAT = (Net\ Profit_{internal} - Tax_{external})$$
$$3rdLawThermo........no 100\%\ Recovery of Efficiencies$$
$$Profit = \Delta U$$
$$Revenue = n \times price = \Delta Q$$
$$COS = Wd = \Delta Pe + \Delta Ke = Fd$$
$$COS = Wd = \Delta Ke = nad$$
$$Where \Delta Pe = 0$$

However we are interested for this paper on competition only.

We need to optimise as follows: maximize velocity (increase market share) and momentum gain, minimize Kinetic Energy or Work done during a competitive collision

$$Wd_{actual} = Wd_{company} + Wd_{overcomeCompetition}$$

This is included in the COS, of a company and is not always obvious. However it costs money to move units internally and into the external environment of the firm.

Consider the following:

n = f (Industry Effect + Competitors Effect +Vector Fields + Entropy changes) External + (Changes in internal Energy + Value Mix + f (functions in firm) + Changes in Entropy)* Synergy Internal + Other Effects.

This is a highly complex model, and the scope thereof is beyond this paper.

W_d = f (n, v, profit, revenue, Cost per Unit, Kinetic Energy, Friction Losses, Forces, Vectors, Capabilities, Time value of money, ……) = COS

The proposed models are equivalent, if working with averages within an industry. To differentiate firm offerings and calculate the effects of proposed competitive positioning there is a need to be able to discern deeper than the normal financial accounting equations. The time based accounting model proposed allows a deeper insight into the mass (units) and energy (money) balances of a company or an industry and can also use the time cost of money. The model allows for a deeper insight into the conversion cycle of money to units (manufacture and purchasing) and units to mass (sales), on a real time based operational cycle. Using basic kinematics (movement of units), and thermodynamic equations (money) and conversions it becomes possible to study the underlying operations of a company, to determine competitive advantage from a number of functions within and external to the company.

By using one of the suggested models (depending on the data available), a constructive strategic model is possible, for competitive positioning within an industry.

4.17 Conclusions

This report uses modified physics and the basic business relationship equations as an analogy of the business system. Physics - business equations are derived using basic units and conformal mapping, while kinematic and thermodynamic relationships are further developed then related before being applied to a business situation. The system developed has general applicability to business and can be used for strategic positioning, amongst other applications.

This project builds on existing work in the area of process modeling and strategy formulation to define a quantitative management tool that effectively enables the formulation of a generic framework, to measure the effects of various strategic options using the derived time based financial management and physics models.

This research project provides an evaluative summary of existing literature on the applications of process modeling and physics to business limited in scope to competitive strategic planning through a literature review of existing business models and the subsequent development of a mathematical model based on kinematics, thermodynamics and business modeling.

From the literature review a mathematical framework was derived relating business and physics based on an indirect relationship of physical laws and business models. The derived model has applications to business, in the fields of value chains, competitive advantage and GAP analysis, amongst other uses. The reported model can be utilised as a tool to assist in strategy formulation. Statistical proof that the model is applicable to a set of competitors is calculated. An example is utilised to show how to determine optimal strategies using the model.

The derived quantitative tool is used to determine where a company is, and where it should position itself in future to optimise its competitive position. Further, the tool was developed into a strategic tool that allows for the fast turnaround in the implementation of strategy, and the ability to quickly predict necessary changes in direction.

From the derived equations a mathematical model to determine strategic options for a firm using time based financial accounting principles and physics equations can be formulated and used to find profitable options for a firm. By implication the model can be applied to strategic positioning of the firm. Unfortunately there is no work in the literature reviews to build this study on and much of it is built from first principles. This leads to complex mathematical relationships, which may prove difficult to follow. Due to this complexity the report is limited in scope to the postulation and mathematical poof of some aspects of the main relational equation, and then analysis of competitive positioning in detail. It then proposes a method of analysis of industries and a means of competitively positioning firms therein.

To differentiate a firms offering and calculate the effects of proposed competitive positioning there is a need to be able to discern deeper than the normal financial accounting equations. The time based accounting model proposed allows a deeper insight into the mass (units) and energy (money) balances of a company or an industry and can also use the time cost of money. The model allows for a deeper insight into the conversion cycle of money to units (manufacture and purchasing) and units to money (sales), on a real time based operational cycle. Using basic kinematics (movement of units), and thermodynamic equations (energy/money) and conversions it becomes possible to study the underlying operations of a company and to determine competitive advantage from a number of functions within and external to the company.

Hence it is possible to relate the laws of physics to business and use the resultant mathematical framework to analyse a firm's competitive position in an industry and position it accordingly.

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6.1 Appendix 1 Data Tables

Tables

The examples in the text are based on the following tables from http://www.smmt.com/Accessed on 2007/06/03

Table 27: Top Ten Unit Sales

New Cars Sold			Group	
MARQUE	2003	2004	2005	2006
BMW	134,332	145,860	156,436	153,634
DAIMLER	121,653	110,037	107,406	106,561
FIAT	85,130	80,897	42,224	64,080
FORD	488,783	481,735	457,820	444,211
GM	341,895	345,816	345,057	328,641
HONDA	81,858	91,241	98,344	97,728
HYUNDAI	53,415	71,030	76,389	71,403
MAZDA	37,854	47,739	45,706	49,631
MG	95,848	76,768	29,091	4,805
MITSUB	18,074	22,573	24,972	19,713
NISSAN	105,798	90,223	86,727	69,157
PSA	302,542	273,418	239,907	243,708
RENAULT	189,427	189,342	174,743	138,094
TOYOTA	131,533	135,269	137,106	136,785
VW	320,888	329,186	339,343	346,939
Total	**2,509,030**	**2,491,134**	**2,361,271**	**2,275,090**

	Make	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	Nissan	215	232	272	289	271	327	296	297	332	320	315	301
2	Toyota	88	117	105	172	179	171	155	212	211	245	263	282
3	BMW	0	0	0	0	0	0	42	160	174	189	200	185
4	Honda	91	106	108	112	114	75	112	177	185	193	187	184
5	Land Rov	100	97	107	149	154	160	139	155	148	150	176	176
6	Vauxhall	262	297	284	277	339	290	193	125	124	147	189	144
7	Peugeot	78	85	85	71	162	186	186	198	207	173	127	75
8	Jaguar	41	39	44	50	86	89	122	123	126	106	84	70
9	MG Rover	374	376	395	329	226	175	163	147	133	106	29	0
	others	274	328	302	298	255	155	84	35	18	18	26	25
	TOTAL	**1,523**	**1,677**	**1,702**	**1,747**	**1,786**	**1,628**	**1,492**	**1,630**	**1,658**	**1,647**	**1,596**	**1,442**

Table 28: Marque Unit Sales

6.2 Appendix 2 Goal Setting and Strategy

Goal Setting and Strategy

Heuristic

Start Heuristic

Set quantitatively defined goal.
Calculate Sales units needed to Achieve Goals
Calculate COS/Unit, and Revenue/unit for that product or product mix.
Calculate velocity (change in market share based on extra units to be sold). For this might have to estimate total industry sales.
Calculate Ke, using expected interactions with competitors. $Ke = 1/2m\ v^2 \rightarrow KeR/n = 1/2Rv^2$
Where R is the Cost/Unit. Hence the cost of the Ke (work done to move the extra units is known)
This is compared to the internal resources of the firm. Can the firm finance this increase, is their enough machine, and man hours. Does the firm have the capacity to produce the extra units?

Calculate Wd = Ke against Total Industry to achieve goal.
From the Energy Balance Wd = Sum of all work needed to achieve goals. This includes internal and external forces etc.
Or for an approximation let Ke = Wd = COS
If company has the capabilities e.g. finance, people etc to meet these commitments implement plan.
If not Repeat until best fit is achieved.

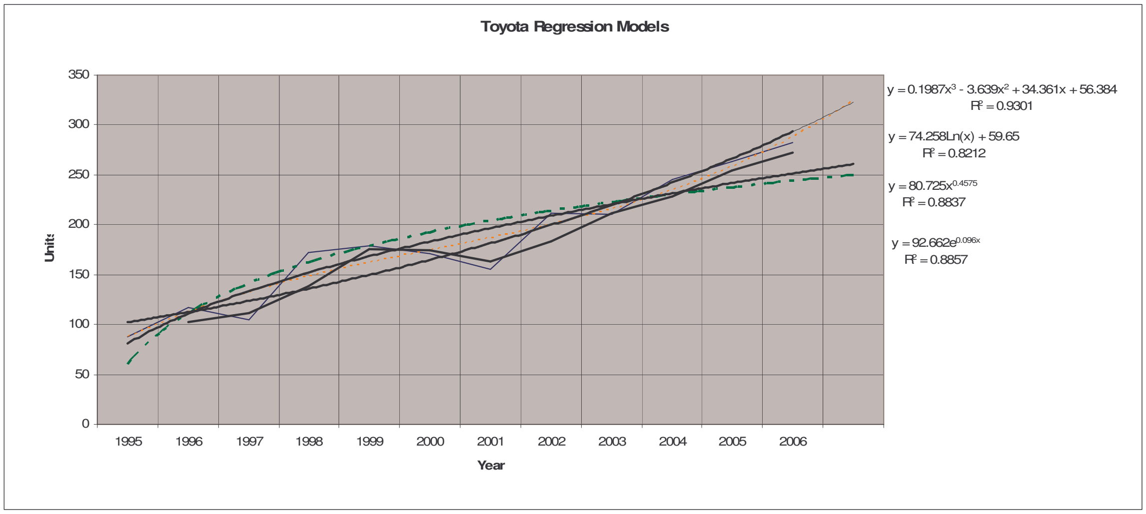
End Heuristic,

Based on this we need to examine which segment to compete in, the value mix (7Ps) and other factors as well.

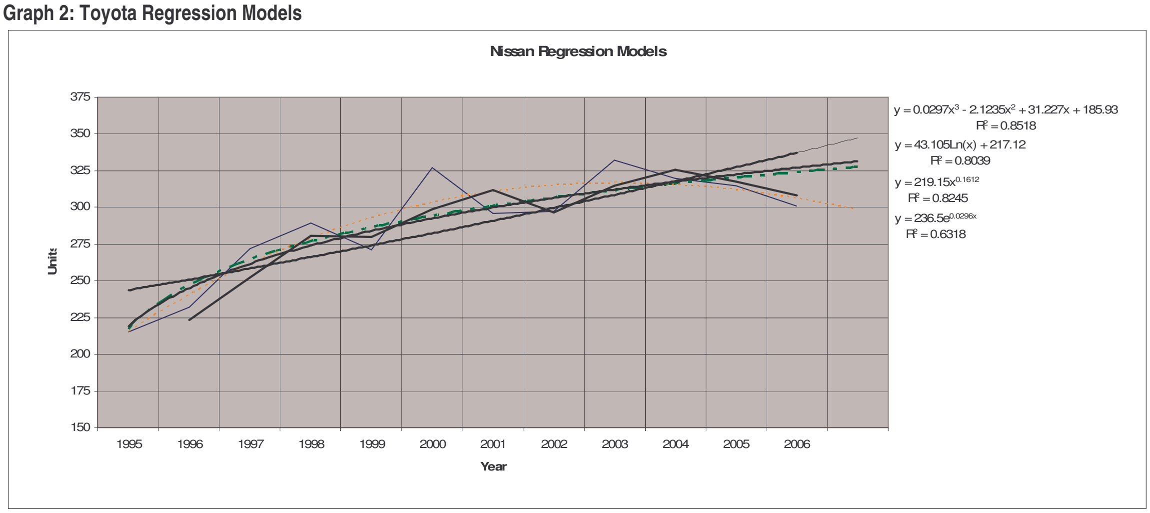
We can also use the Ontology model as derived above and other models not considered here.

6.3 Appendix 3 Regression Graphs, Equations and R

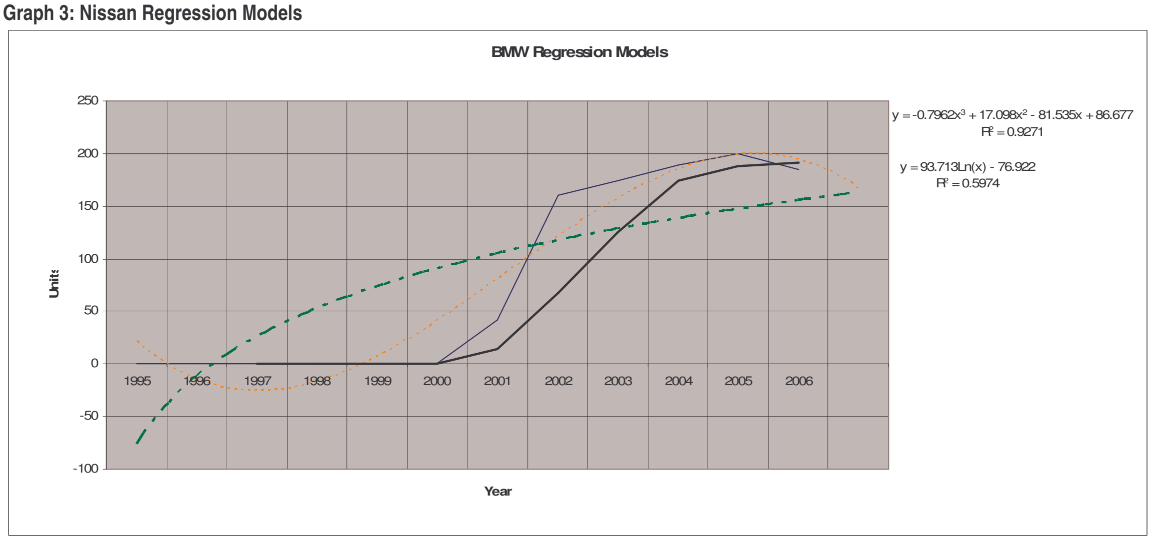
Regression Graphs, Equations and R



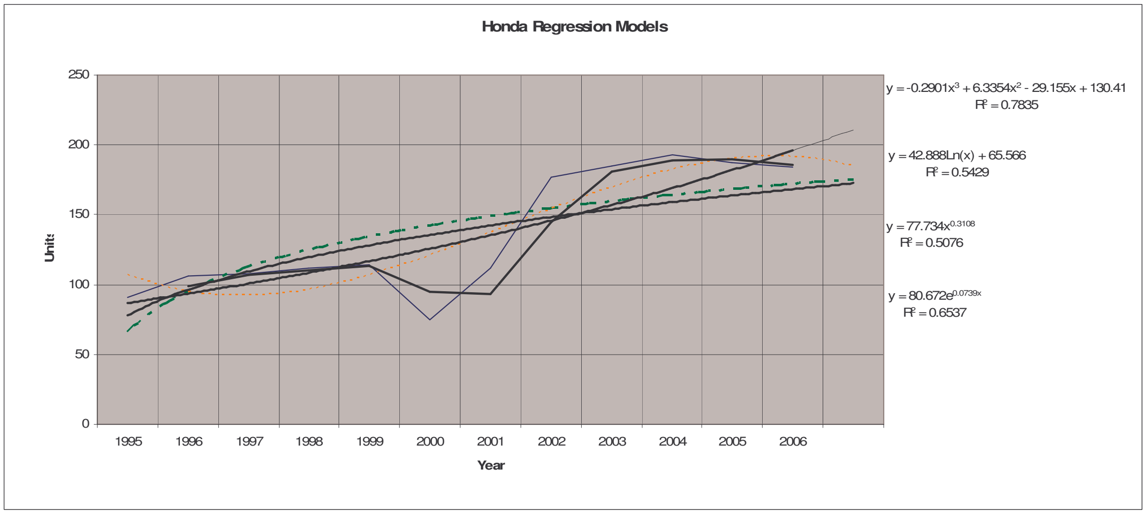
Graph 2: Toyota Regression Models



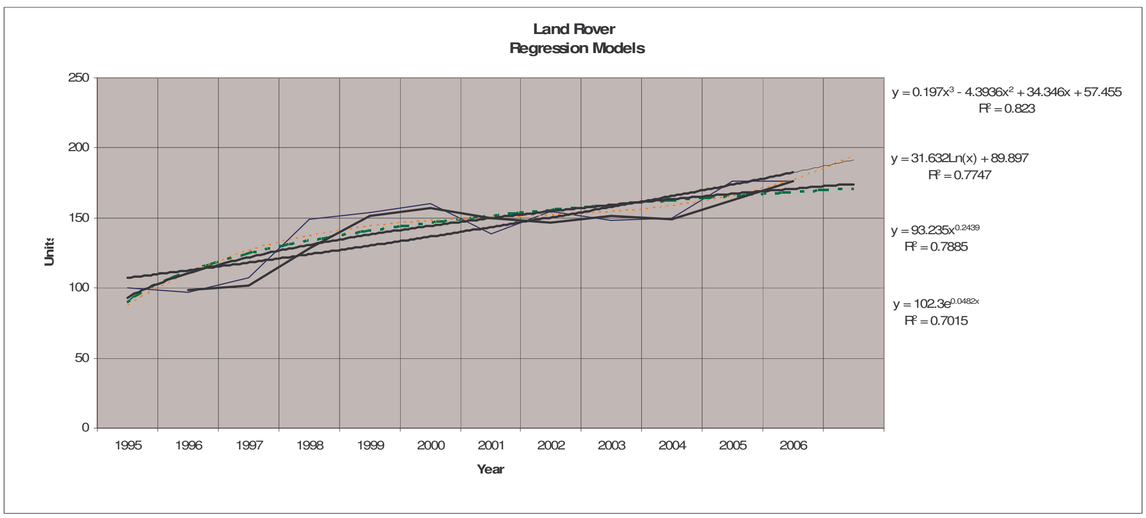
Graph 3: Nissan Regression Models



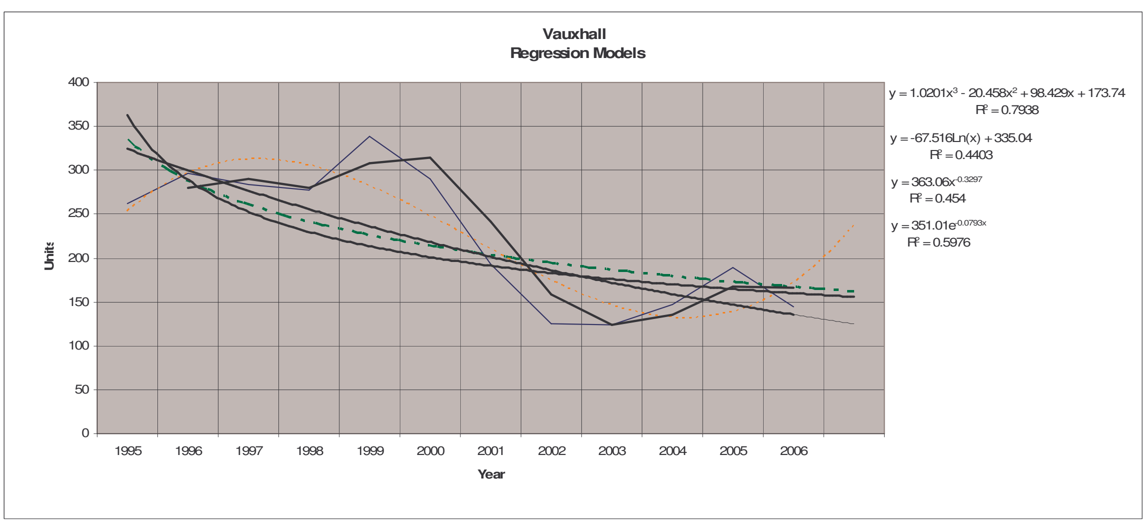
Graph 4: BMW Regression Models



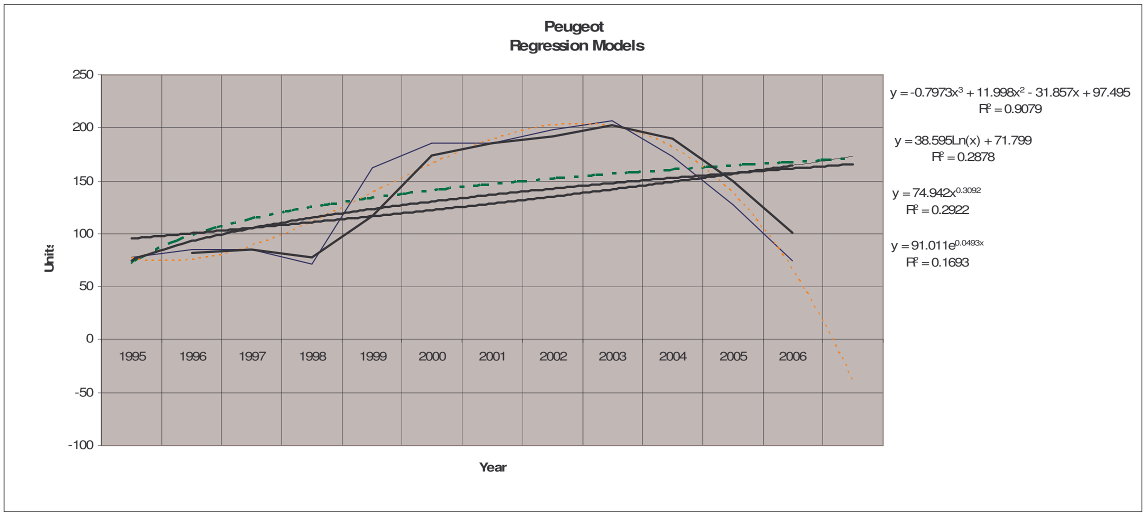
Graph 5: Honda Regression Models



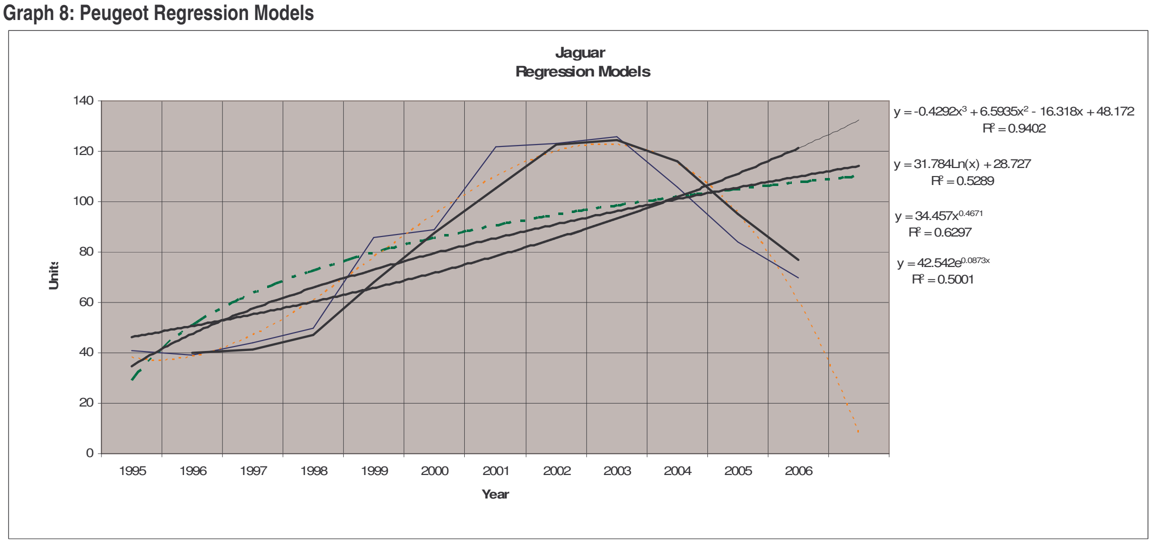
Graph 6: Land Rover Regression Models



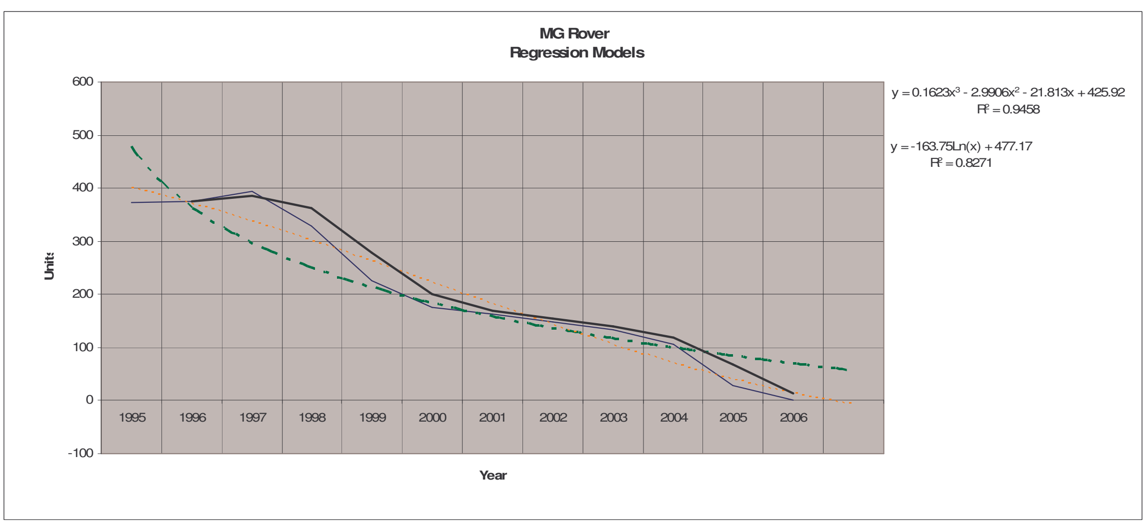
Graph 7: Vauxhall Regression Models



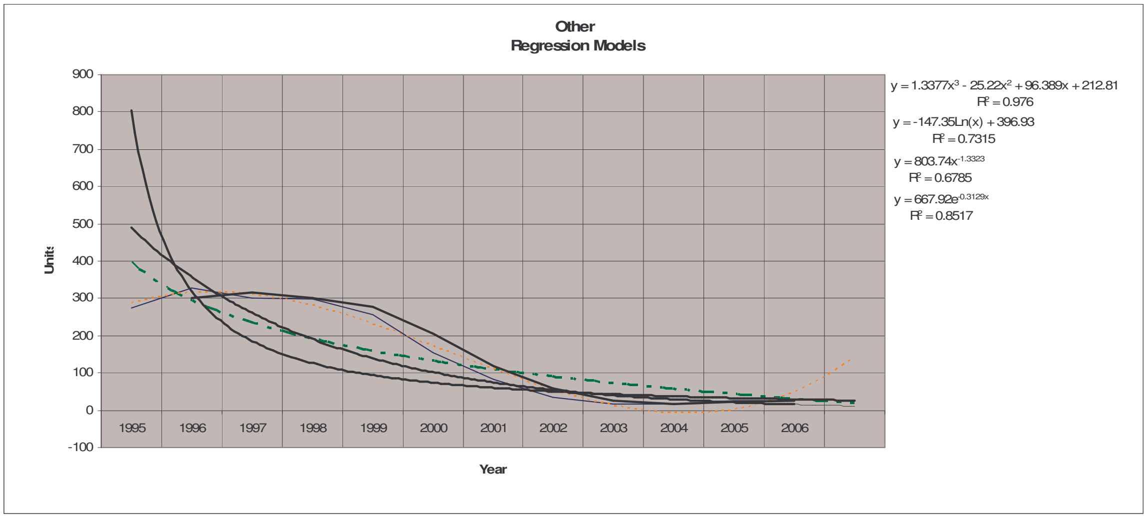
Graph 8: Peugeot Regression Models



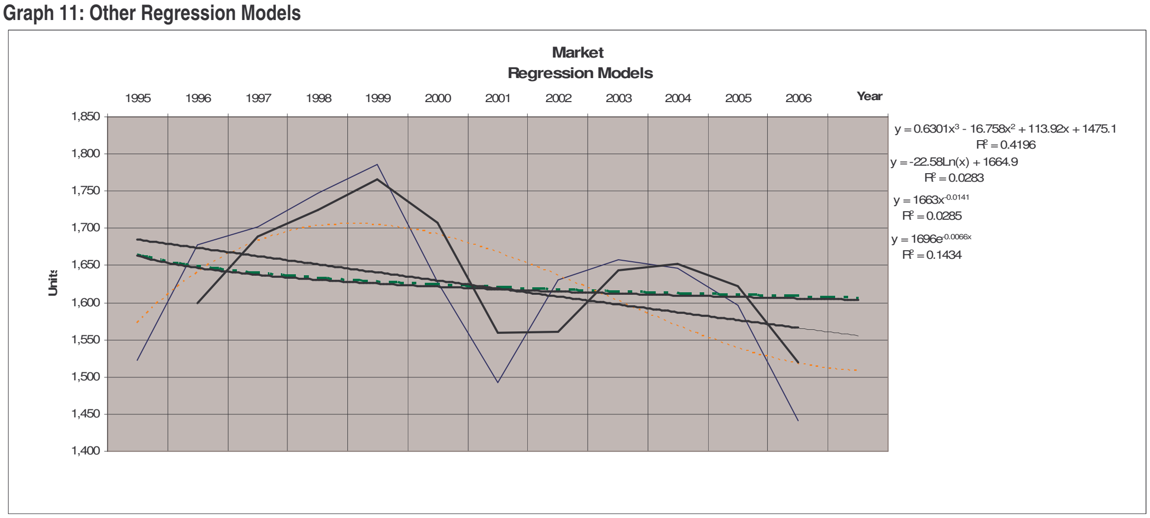
Graph 9: Jaguar Regression Models



Graph 10: MG Rover Regression Models



Graph 11: Other Regression Models

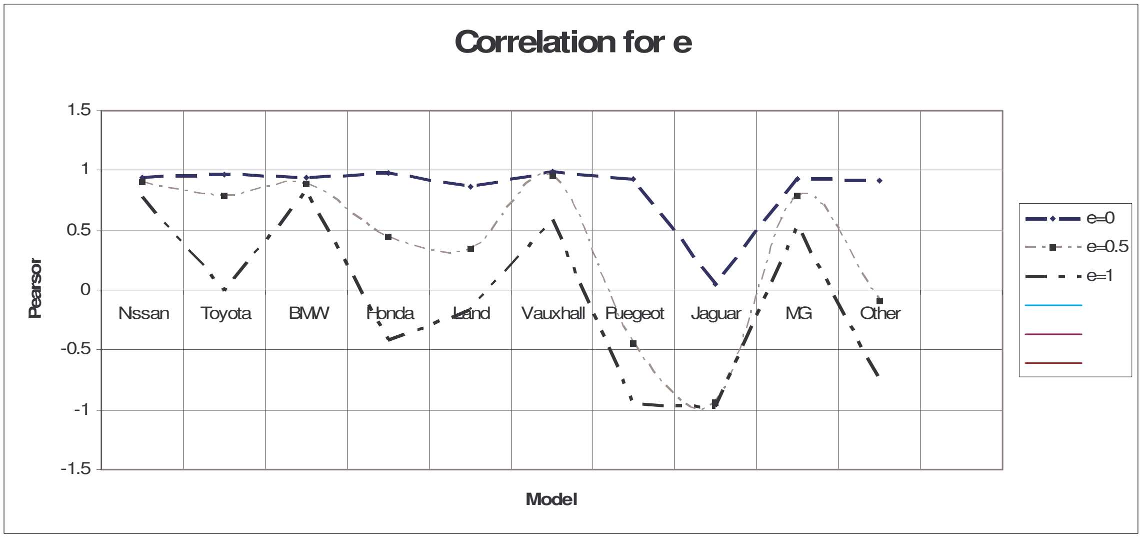


Graph12: Market Regression Models

It is apparent that the moving average (2 – 3 periods) could be a good estimator in this case as the other equations based on R, cannot estimate units sold. It is also apparent that using a conversion of the average calculated velocity and applying this to convert the calculate velocity (divide calc by average) we see that the velocity calc closely resembles the velocity actual.

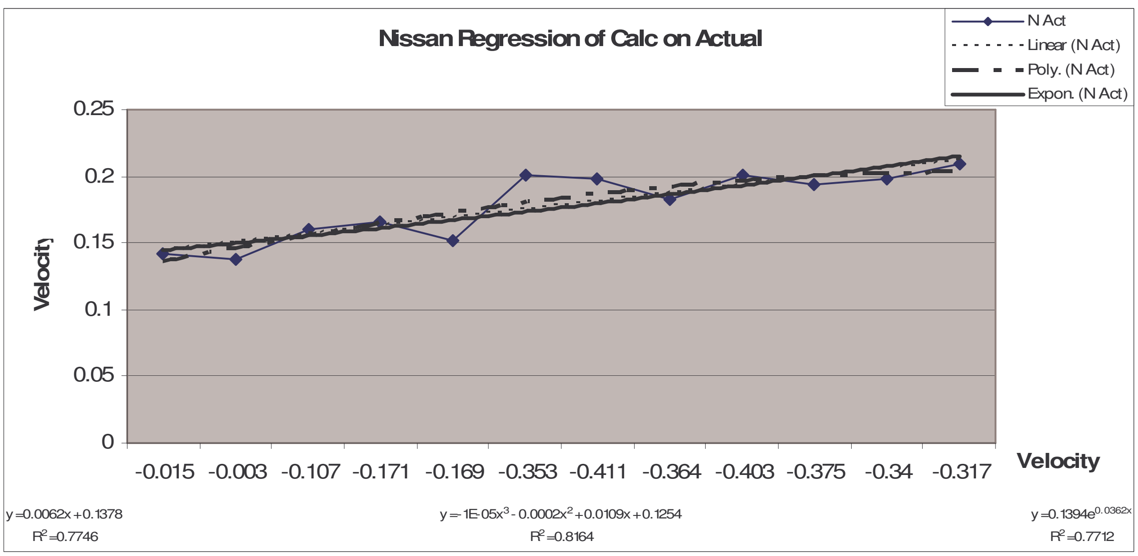
However we need to consider the regression of v actual vs v calculated, as the underlying equations are non-linear.

Correlation of Actual Velocity vs Calculated Velocity

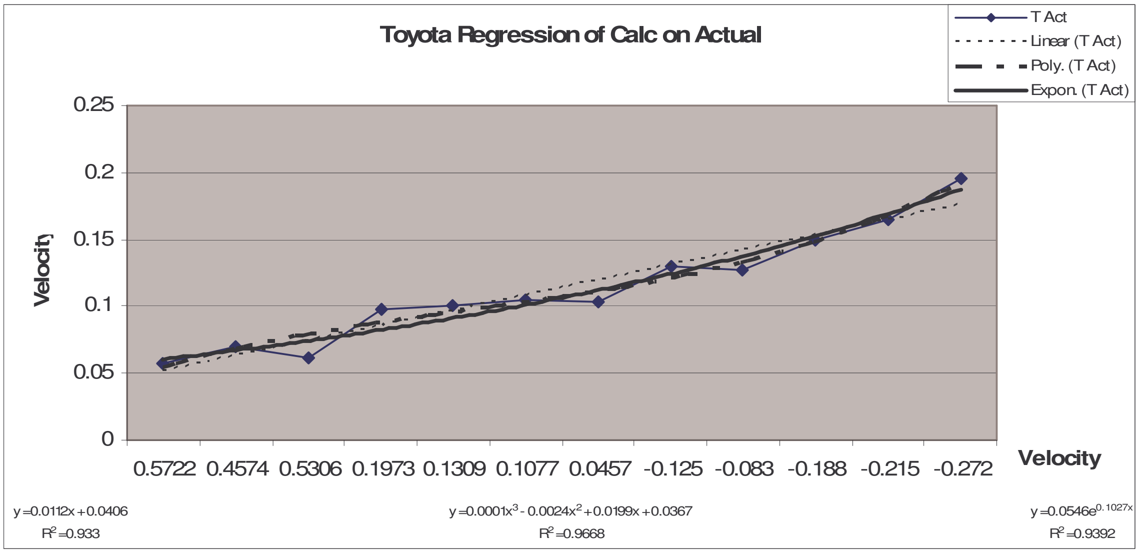


Graph13: Correlation of e

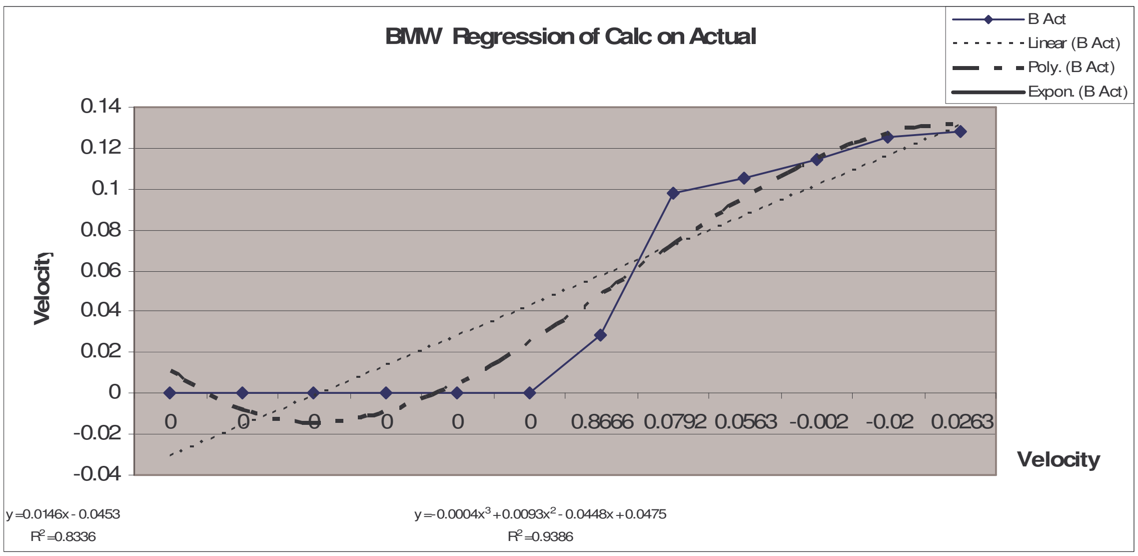
Hence we can use e = 0 for comparative purposes, as it has the highest correlation.



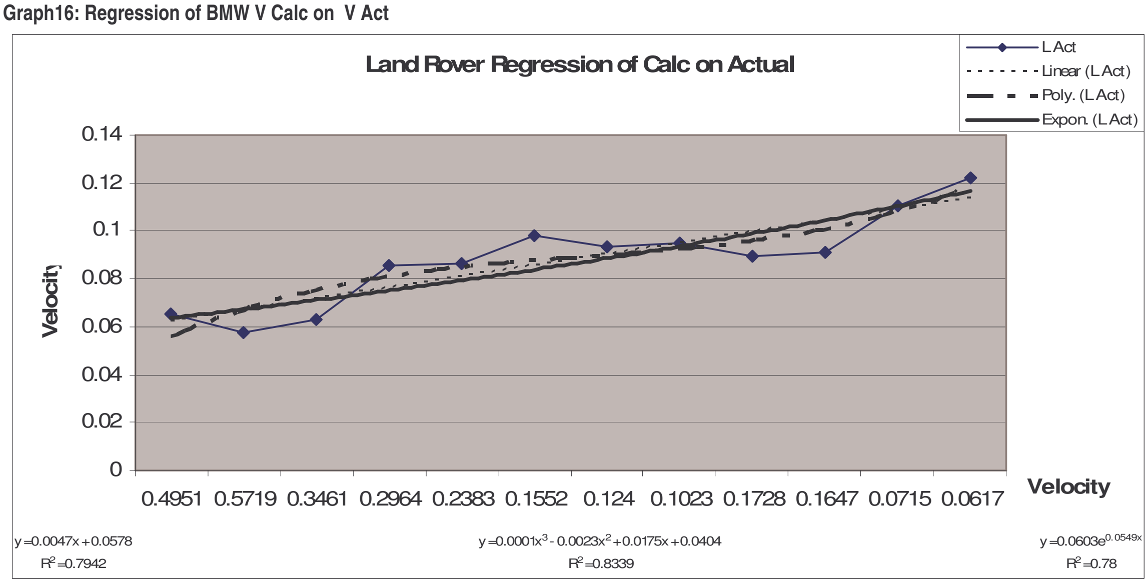
Graph14: Regression of Nissan V Calc on V Act



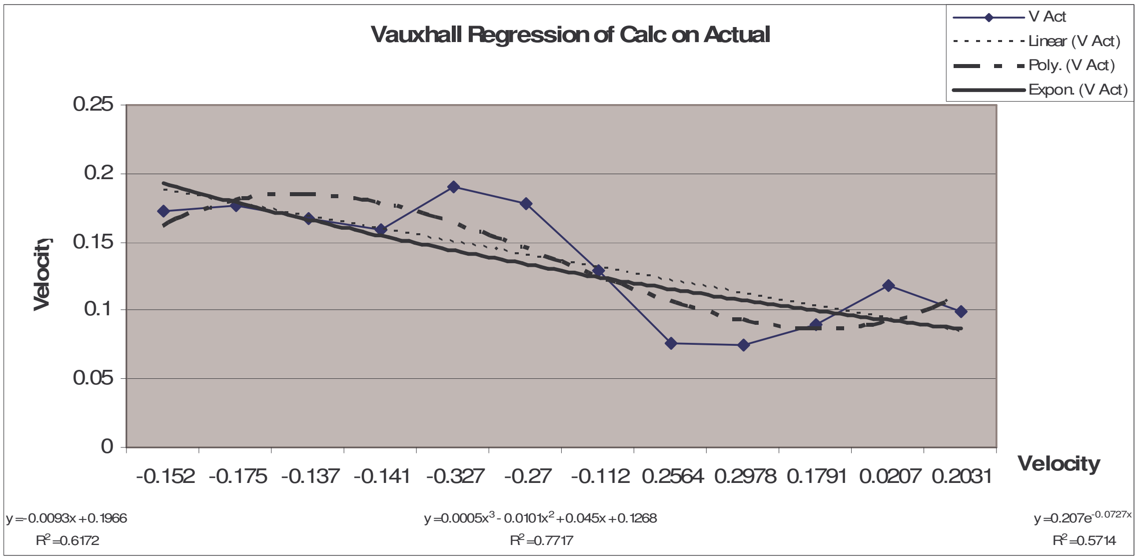
Graph15: Regression of Toyota V Calc on V Act



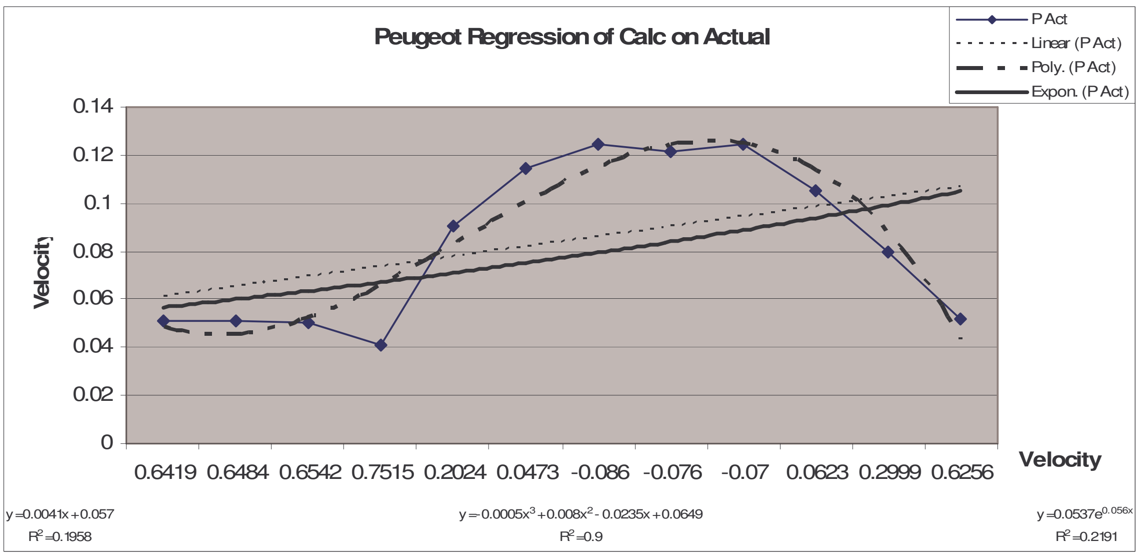
Graph16: Regression of BMW V Calc on V Act



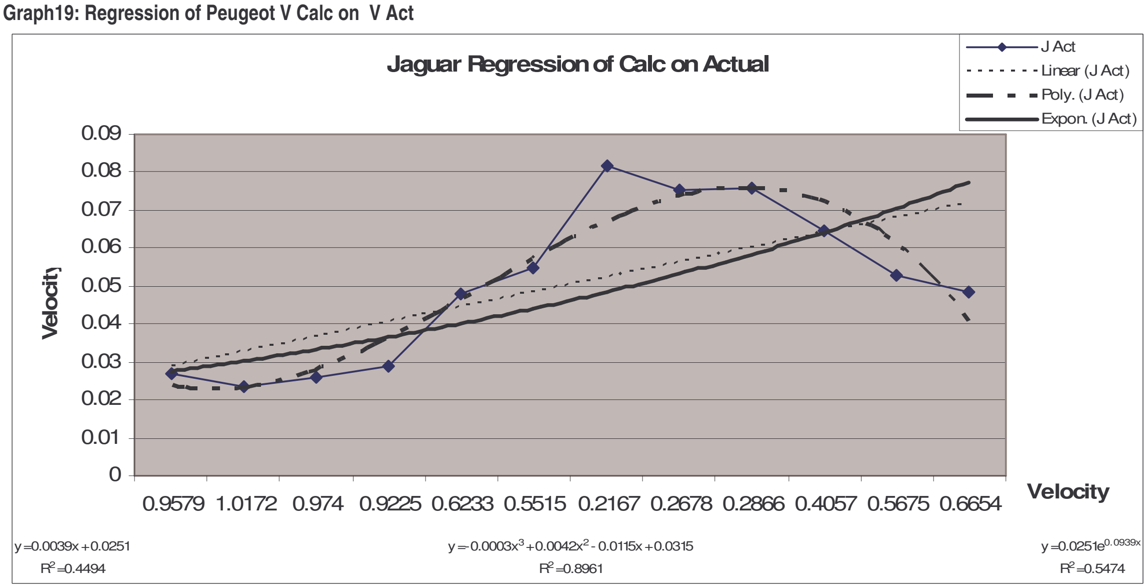
Graph17: Regression of Land Rover V Calc on V Act



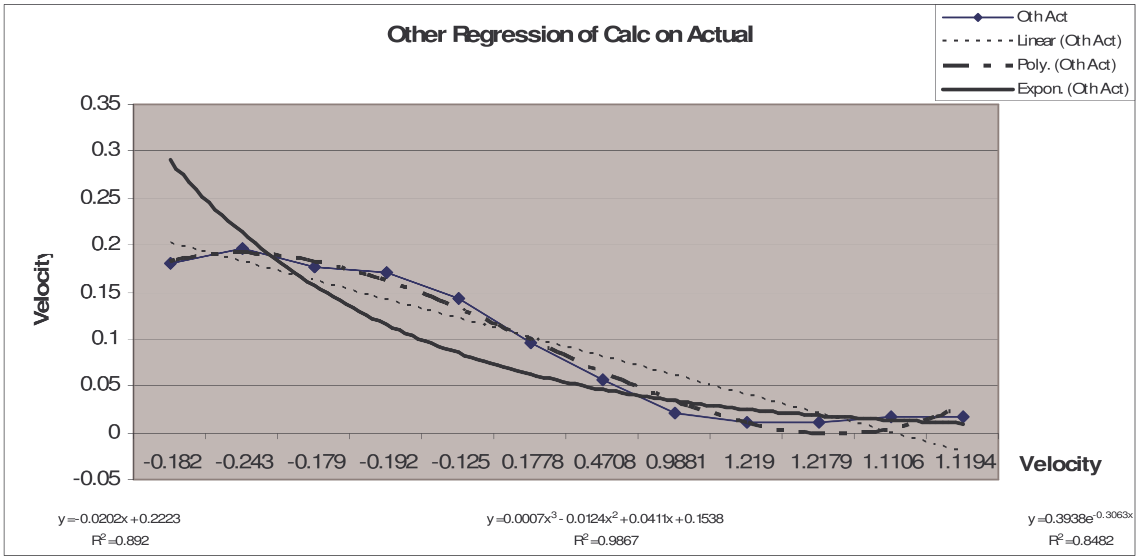
Graph18: Regression of Vauxhall V Calc on V Act



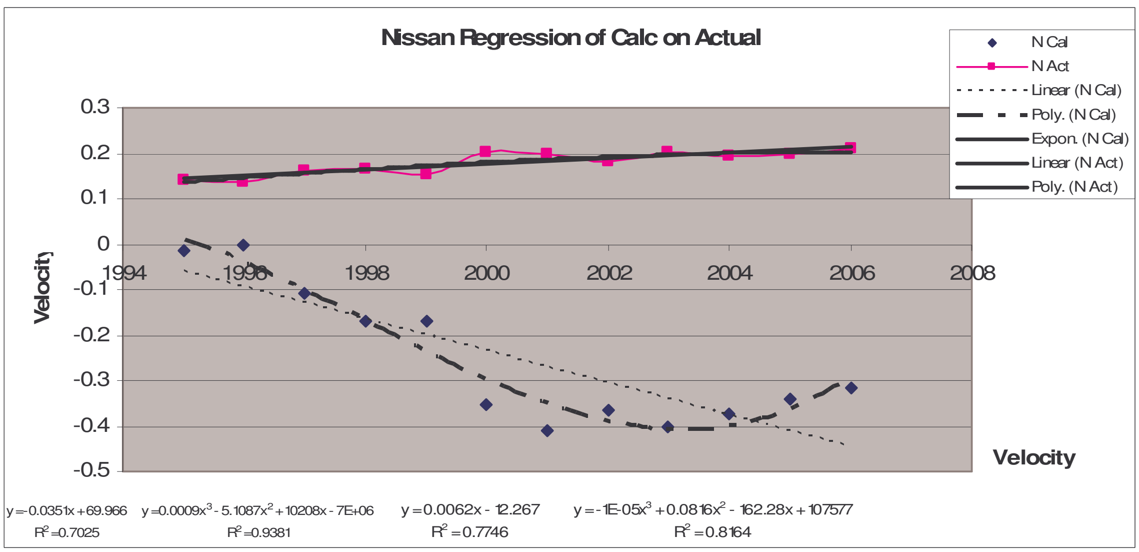
Graph19: Regression of Peugeot V Calc on V Act



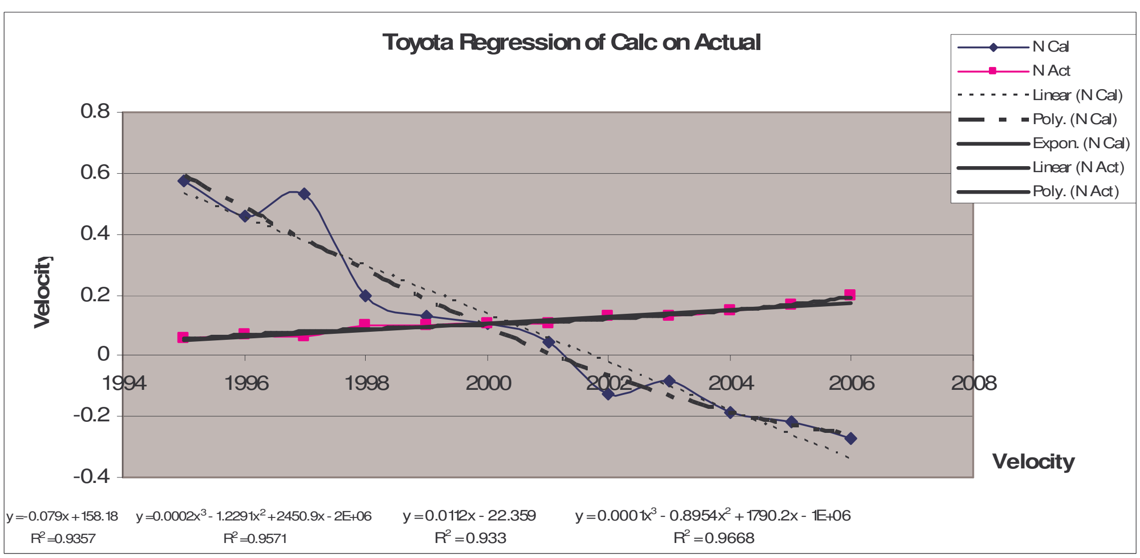
Graph20: Regression of Jaguar V Calc on V Act



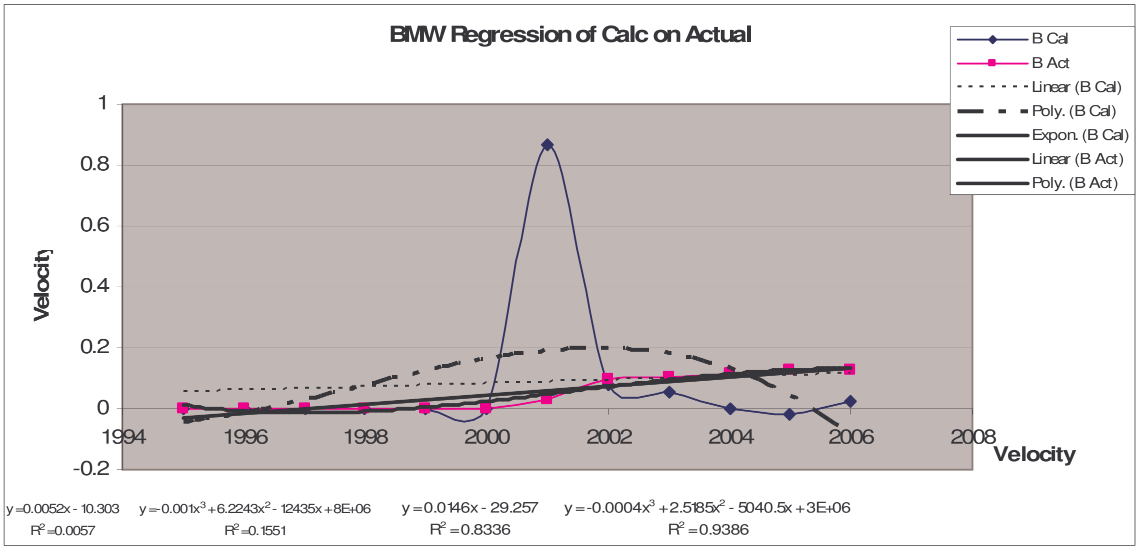
Graph21: Regression of Other V Calc on V Act



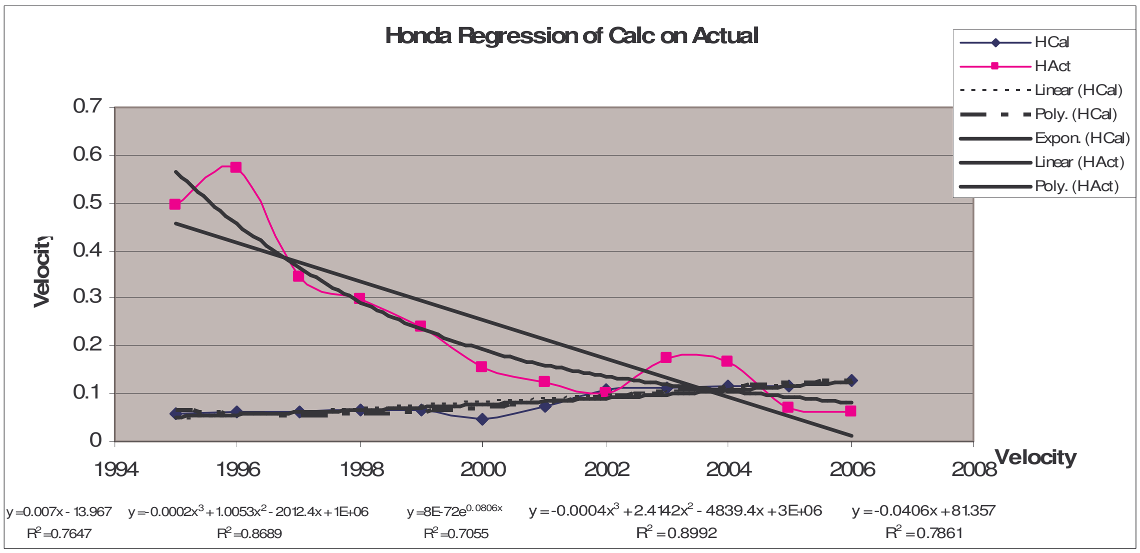
Graph22: Regression of Nissan V Calc on V Act



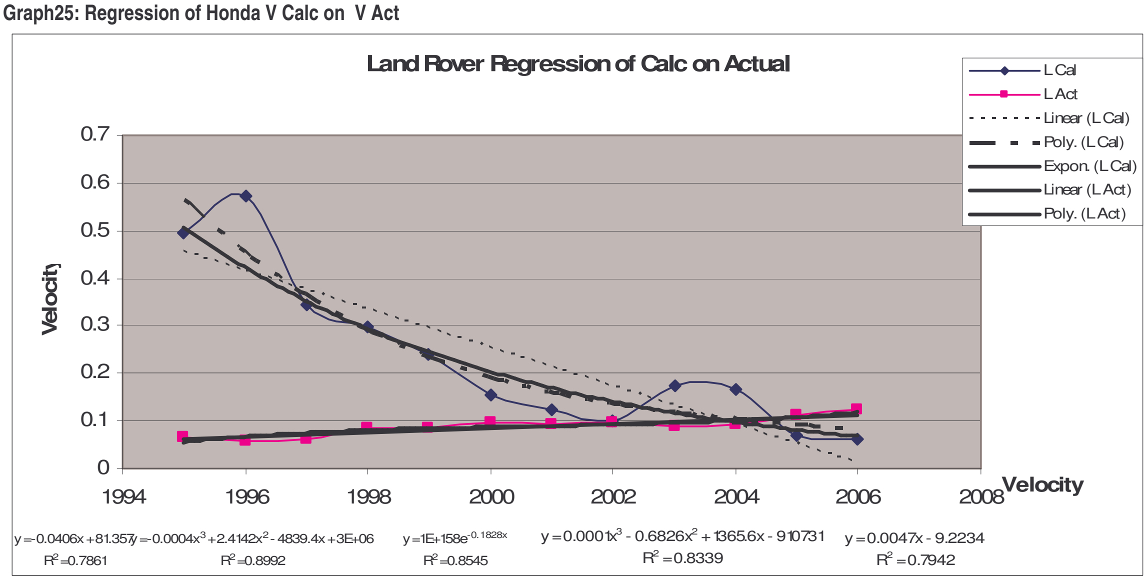
Graph23: Regression of Toyota V Calc on V Act



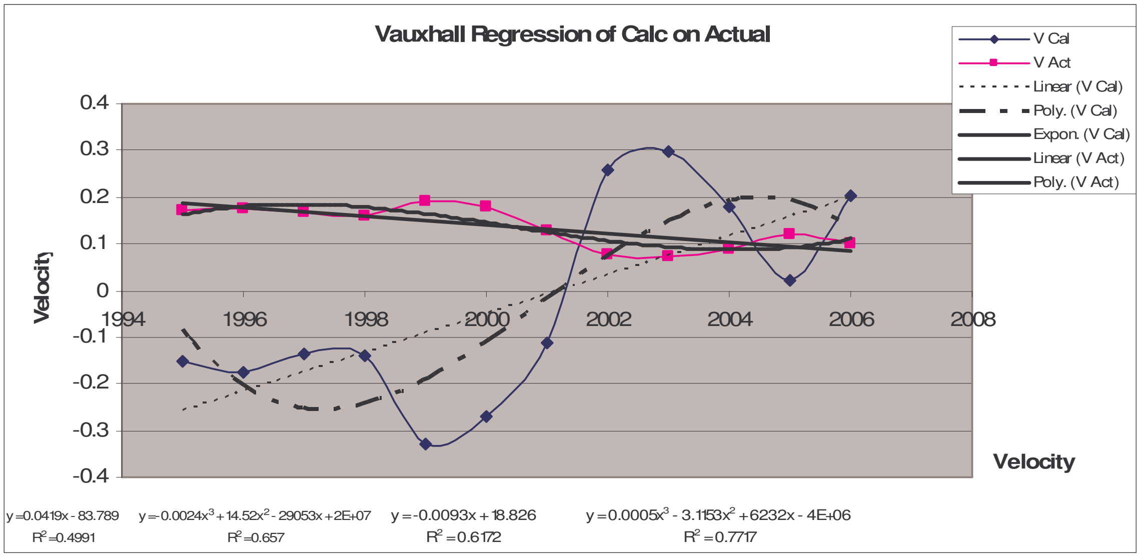
Graph24: Regression of BMW V Calc on V Act



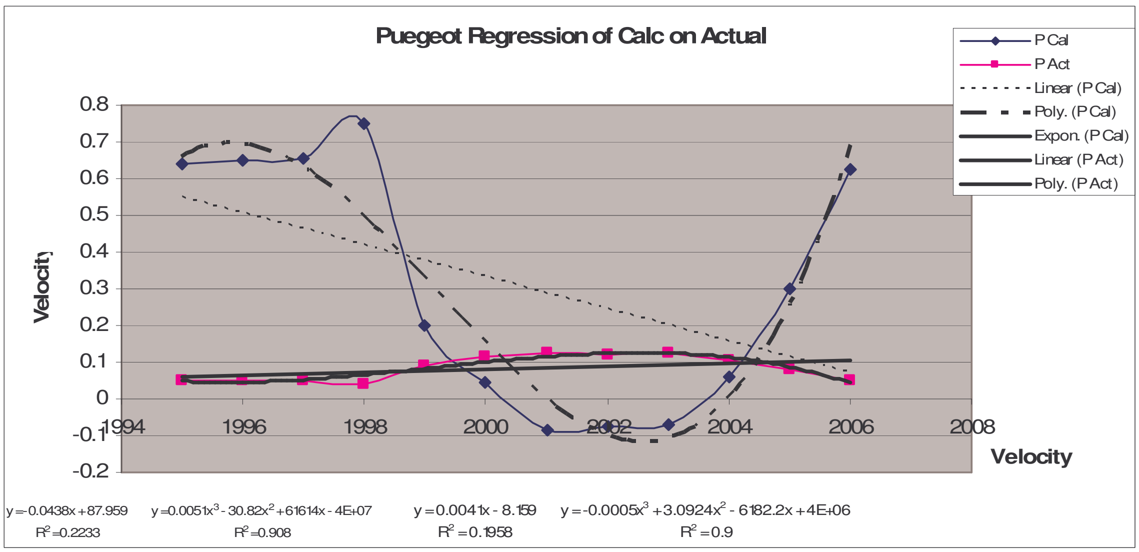
Graph25: Regression of Honda V Calc on V Act



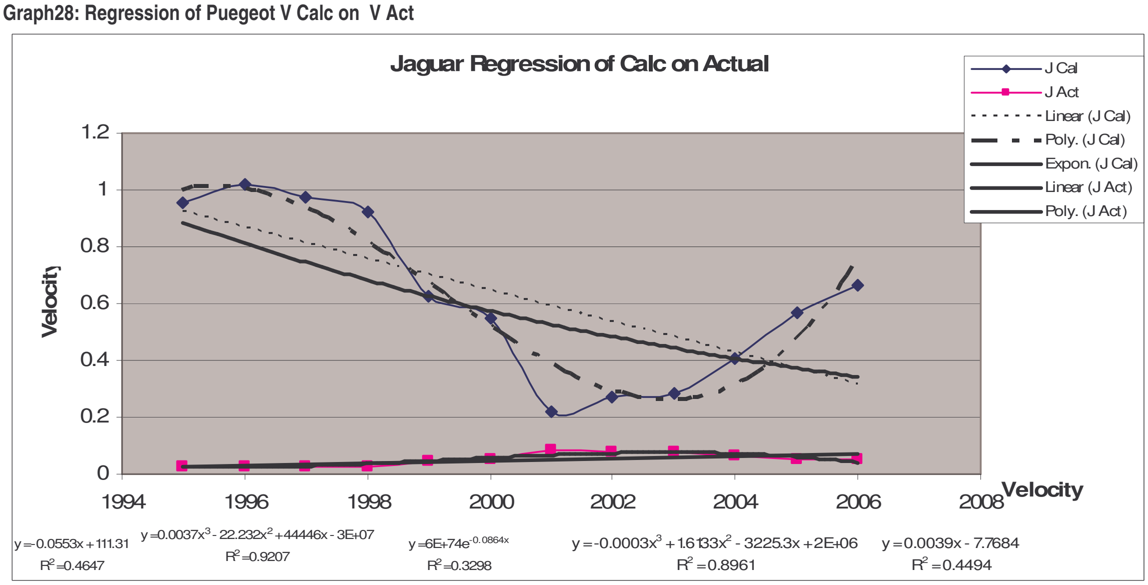
Graph26: Regression of Land Rover V Calc on V Act



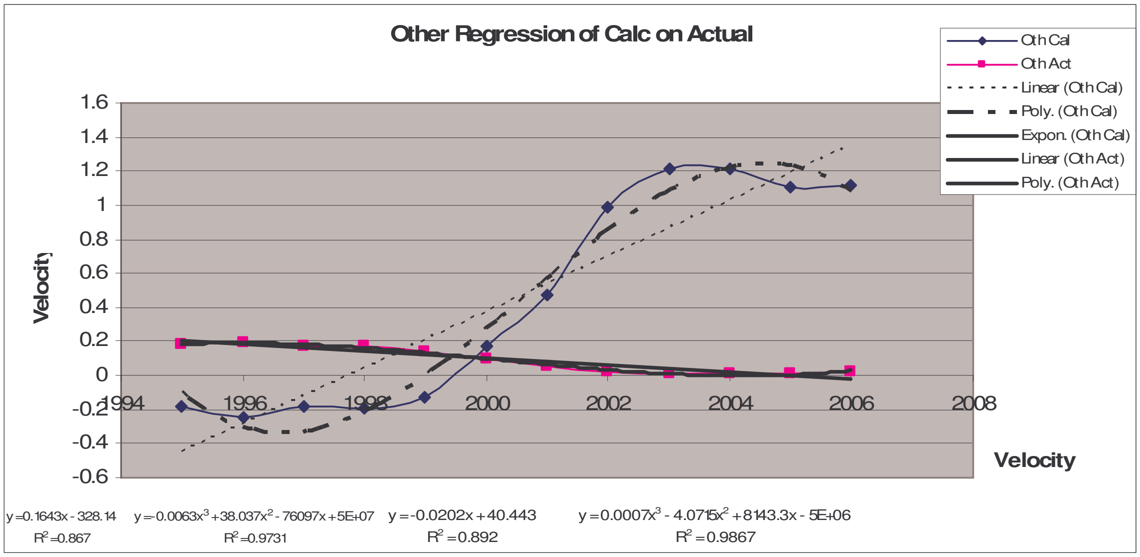
Graph27: Regression of Vauxhall V Calc on V Act



Graph28: Regression of Puegeot V Calc on V Act

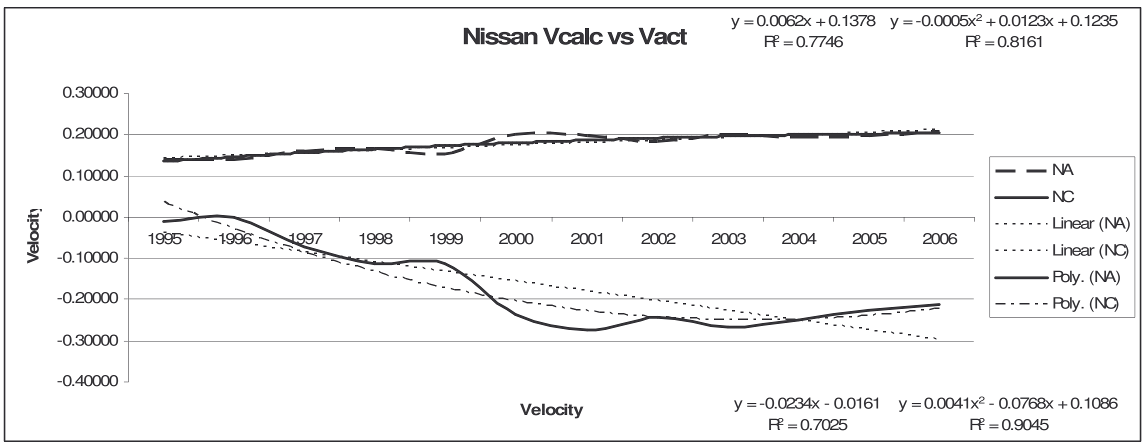


Graph29: Regression of Jaguar V Calc on V Act

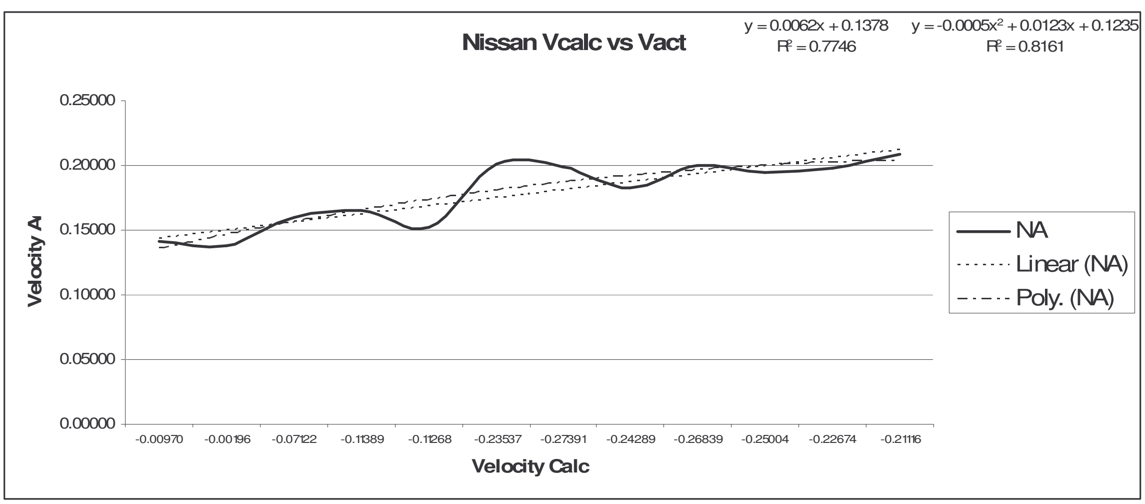


Graph30: Regression of Other V Calc on V Act

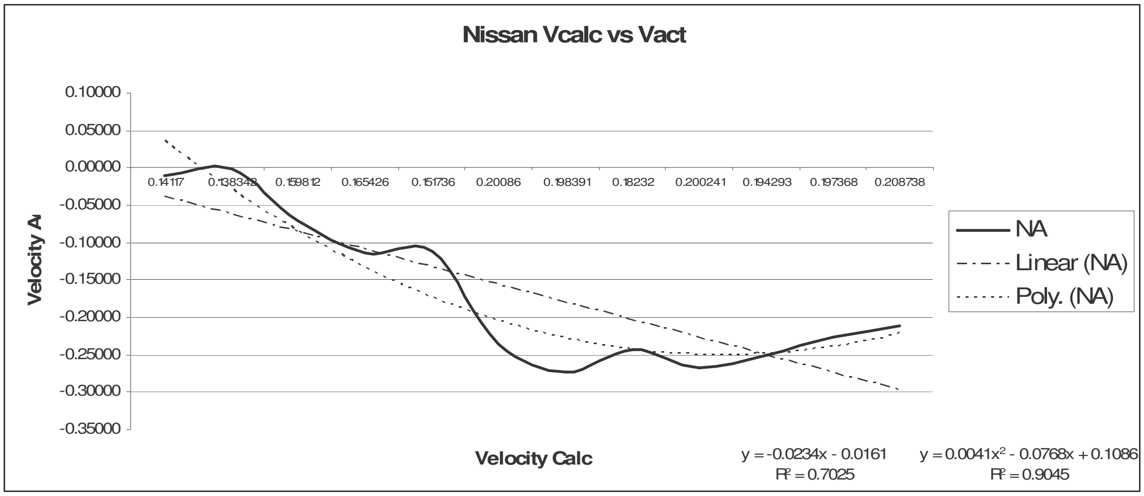
We now check the Regression of V calc vs V act.



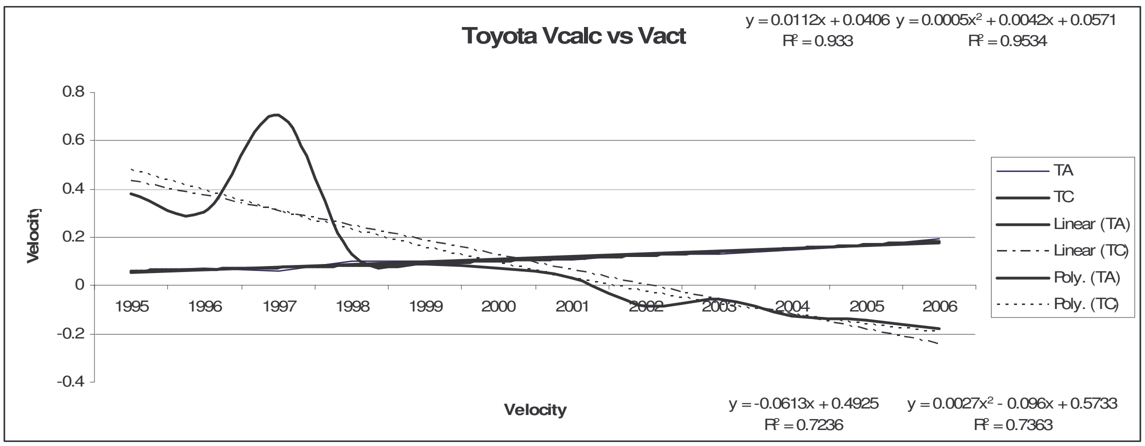
Graph31: Regression of Nissan V Calc on V Act



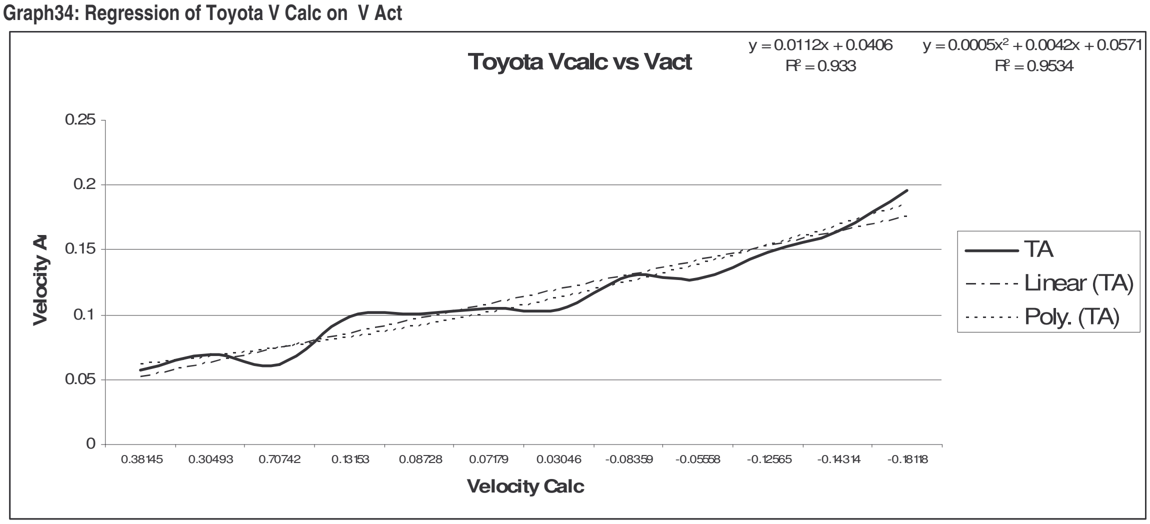
Graph32: Regression of Nissan V Calc on V Act



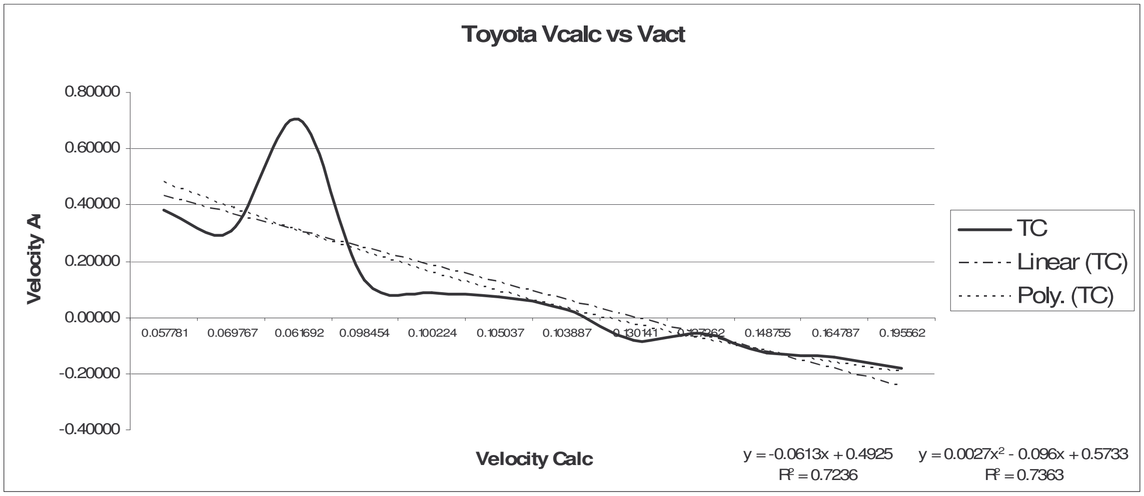
Graph33: Regression of Nissan V Calc on V Act



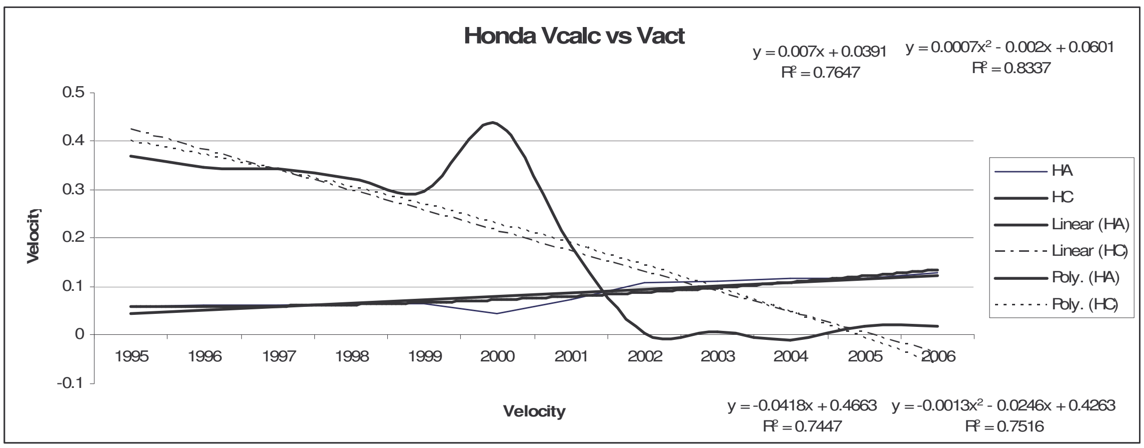
Graph34: Regression of Toyota V Calc on V Act



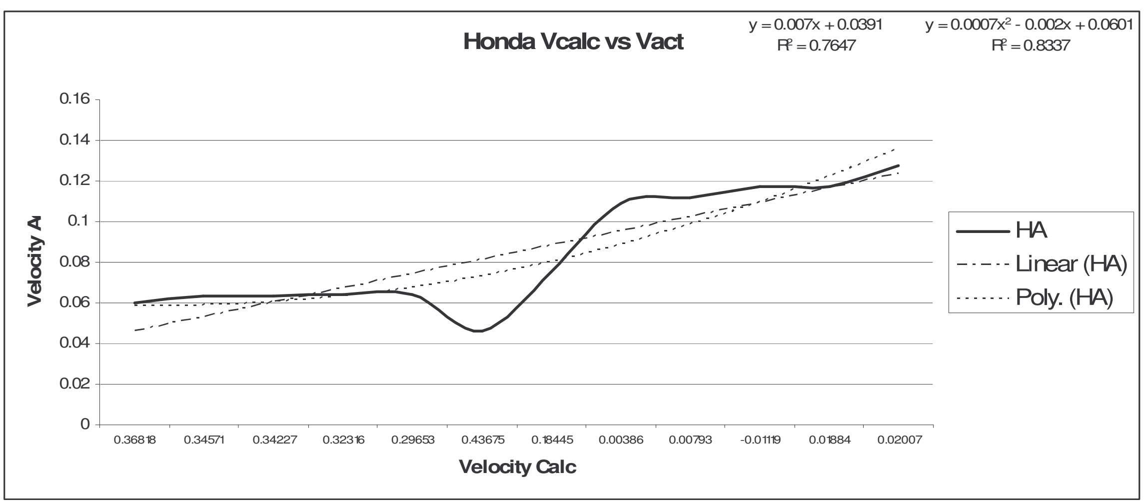
Graph35: Regression of Toyota V Calc on V Act



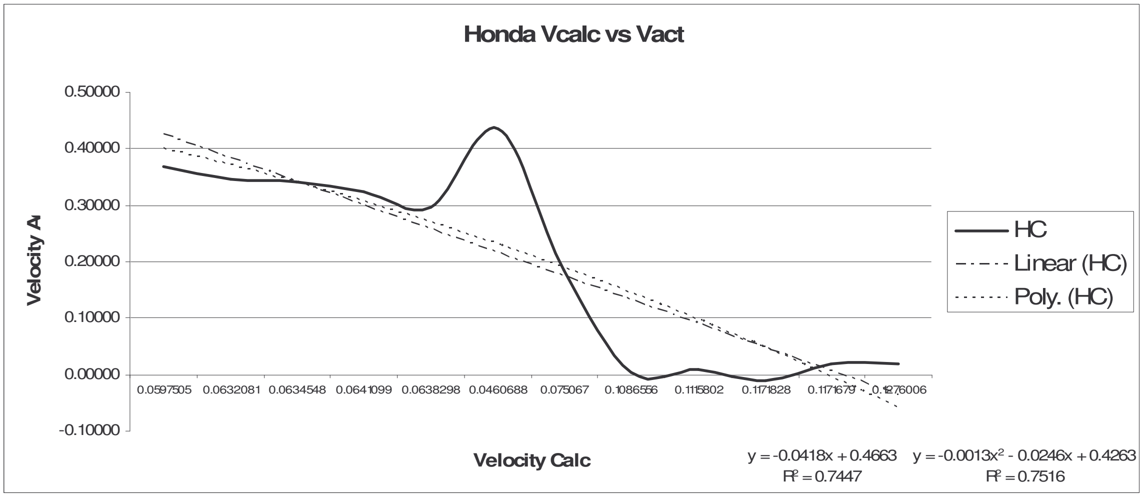
Graph36: Regression of Toyota V Calc on V Act



Graph37: Regression of Honda V Calc on V Act



Graph38: Regression of Honda V Calc on V Act



Graph39: Regression of Honda V Calc on V Act

Mirror Images

Where the firms' velocity is increasing the competitions velocity effect on it is decreasing proportionately. Hence this mirror image or inverse proportionality explains the effects of competition. If the competition on a firm at e = 0, (same markets) increases the sales or velocity of the firm decreases – this is to be expected. We need to analyse more in depth why this is happening.

Hence it is apparent that there is an inverse relationship between the effects of the cumulative competitive velocity of competitors and actual velocity of the firm.

6.4 Appendix 4 Data Analysis Summary

Data Analysis Summary											
ANOVA	**Nissan**	**Toyota**	**BMW**	**Honda**	**Land R**	**Vauxhall**	**Peugeot**	**Jaguar**	**MG**	**Other**	
Single Factor	H1	HO	HO	H1	H1	H1	H1	H1	HO	H1	
Single Factor	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	ANOVA Actual vs Calculated
Two-Factor no Replication	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	ANOVA Actual vs Calculated
	H1	HO	H1	H1	H1	H1	H1	H1	H1	H1	
F-Test Two-Sample for Variances	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	**HO**	No significant Difference of variances
Regression Statistics											
Multiple R	**0.9343**	**0.9304**	***0.7904***	**0.9615**	**0.9017**	**0.9731**	**0.9818**	**0.9919**	**0.9227**	**0.9754**	Good Multiple Regression except BMW
R Square	0.8729	0.8656	*0.6248*	0.9244	0.8131	0.9469	0.964	0.9839	0.8513	0.9514	
Adjusted R Square	0.8601	0.8521	*0.4997*	0.916	0.7923	0.941	0.96	0.9821	0.8348	0.9466	
Standard Error	**0.0095**	**0.0161**	***0.0091***	**0.0085**	**0.0083**	**0.0105**	**0.0067**	**0.0028**	**0.0308**	**0.0178**	
Intercept	H1	H1	H1	H1	H1	H1	H1	H1	H1	H1	Significant difference for intercept and slope
NC	H1	H1	H1	H1	H1	H1	H1	H1	H1	H1	
t Tests											
Paired Two Sample for Means	H1	HO	HO	HO	HO	H1	HO	HO	HO	HO	Only Toyota and Vauxhall significant difference
Two-Sample - Equal Variances	H1	HO	HO	HO	HO	H1	HO	HO	HO	HO	Hence something more than competition.
Two-Sample - Unequal Variances	H1	HO	HO	HO	HO	H1	HO	HO	HO	HO	

Table 28: Data Analysis Summary

From the data presented above there is no significant difference between the actual velocity and the sum of the interactions between the firms for ANOVA single factor and without replication. This means they are substantively a representation of two models in different forms. There is a difference across the years, as expected. The multiple regression statistics imply a good fit of data, but there is a significant difference between actual and calculated slope and intercept, which is expected as the data is not linear. The t tests for means and variances pick up a significant difference between Toyota and Vauxhall which means data cannot be attributed to the effects of competitive behaviour only.

6.5 Appendix 5 Correlation Models

ACT - CALC												
e=0												
Pearson	**-0.934**	**-0.869**	**-0.971**	**-0.975**	**-0.822**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.974**	**Act vs Calc**	**-0.9415**
Covariance	-0.002	-0.009	-0.007	-0.005	-0.003	-0.005	-0.007	-0.004	-0.018	-0.029		
Pearson	-0.997	-0.998	-0.999	-0.999	-0.999	-0.998	-1.000	-1.000	-0.997	-0.999	Matrix vs Cal	-0.9987
Pearson	0.958	0.901	0.978	0.981	0.851	0.983	0.987	0.994	0.951	0.982	Matrix vs Act	0.9567
e=0.5												-0.0420
Pearson	**-0.934**	**-0.930**	**-0.971**	**-0.963**	**-0.914**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.975**	**Act vs Calc**	-0.9557
Covariance	-0.003	-0.011	-0.010	-0.006	-0.003	-0.008	-0.010	-0.006	-0.027	-0.043		
Pearson	-0.999	-0.999	-1.000	-1.000	-0.999	-0.999	-1.000	-1.000	-0.998	-1.000	Matrix vs Cal	-0.9994
Pearson	0.952	0.945	0.976	0.970	0.927	0.980	0.986	0.994	0.944	0.980	Matrix vs Act	0.9654
e=1												-0.0340
Pearson	**-0.934**	**-0.948**	**-0.971**	**-0.943**	**-0.939**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.975**	**Act vs Calc**	-0.9580
Covariance	-0.004	-0.014	-0.014	-0.008	-0.004	-0.011	-0.014	-0.007	-0.036	-0.057		
Pearson	-0.999	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-0.999	-1.000	Matrix vs Cal	-0.9996
Pearson	0.948	0.957	0.975	0.951	0.948	0.978	0.986	0.994	0.939	0.979	Matrix vs Act	0.9654
												-0.0342
ACT + CALC												
e=0												
Pearson	**-0.934**	**-0.869**	**-0.971**	**-0.975**	**-0.822**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.974**	**Act vs Calc**	**-0.9415**
Covariance	-0.002	-0.009	-0.007	-0.005	-0.003	-0.005	-0.007	-0.004	-0.018	-0.029		
Pearson	0.993	0.996	0.999	0.999	0.998	0.995	1.000	1.000	0.991	0.999	Matrix vs Cal	0.9969
Pearson	-0.886	-0.819	-0.959	-0.964	-0.786	-0.941	-0.977	-0.991	-0.862	-0.962	Matrix vs Act	**-0.9148**
e=0.5												0.0821
Pearson	**-0.934**	**-0.930**	**-0.971**	**-0.963**	**-0.914**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.975**	**Act vs Calc**	
Covariance	-0.003	-0.011	-0.010	-0.006	-0.003	-0.008	-0.010	-0.006	-0.027	-0.043		

Pearson	0.997	0.999	1.000	0.999	0.999	0.998	1.000	1.000	0.997	1.000	Matrix vs Cal	0.9988
Pearson	-0.906	-0.909	-0.964	-0.953	-0.898	-0.954	-0.980	-0.992	-0.888	-0.968	Matrix vs Act	**-0.9412**
e=1												0.0577
Pearson	**-0.934**	**-0.948**	**-0.971**	**-0.943**	**-0.939**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.975**	**Act vs Calc**	
Covariance	-0.004	-0.014	-0.014	-0.008	-0.004	-0.011	-0.014	-0.007	-0.036	-0.057		
Pearson	0.999	0.999	1.000	1.000	1.000	0.999	1.000	1.000	0.998	1.000	Matrix vs Cal	0.9994
Pearson	-0.915	-0.935	-0.966	-0.932	-0.929	-0.960	-0.981	-0.992	-0.899	-0.970	Matrix vs Act	**-0.9477**
												0.0517
ACT * CALC												
e=0												
Pearson	**-0.934**	**-0.869**	**-0.971**	**-0.975**	**-0.822**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.974**	**Act vs Calc**	-0.9415
Covariance	-0.002	-0.009	-0.007	-0.005	-0.003	-0.005	-0.007	-0.004	-0.018	-0.029		
Pearson	0.995	0.945	0.955	0.978	0.992	0.976	0.966	0.391	0.786	0.759	Matrix vs Cal	0.8744
Pearson	-0.957	-0.964	-0.964	-0.957	-0.803	-0.956	-0.968	-0.428	-0.953	-0.798	Matrix vs Act	-0.8747
e=0.5												-0.0003
Pearson	**-0.934**	**-0.930**	**-0.971**	**-0.963**	**-0.914**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.975**	**Act vs Calc**	
Covariance	-0.003	-0.011	-0.010	-0.006	-0.003	-0.008	-0.010	-0.006	-0.027	-0.043		
Pearson	0.995	0.942	0.955	0.977	0.987	0.976	0.966	0.391	0.786	0.750	Matrix vs Cal	0.8724
Pearson	-0.957	-0.987	-0.964	-0.949	-0.907	-0.956	-0.968	-0.428	-0.953	-0.813	Matrix vs Act	-0.8882
e=1												-0.0158
Pearson	**-0.934**	**-0.869**	**-0.971**	**-0.975**	**-0.822**	**-0.971**	**-0.983**	**-0.993**	**-0.923**	**-0.974**	**Act vs Calc**	
Covariance	-0.002	-0.009	-0.007	-0.005	-0.003	-0.005	-0.007	-0.004	-0.018	-0.029		
Pearson	0.995	0.945	0.955	0.978	0.992	0.976	0.966	0.391	0.786	0.759	Matrix vs Cal	0.8744
Pearson	-0.957	-0.964	-0.964	-0.957	-0.803	-0.956	-0.968	-0.428	-0.953	-0.798	Matrix vs Act	-0.8747
												-0.000307926

Table 29: Correlation Models

Using correlation/Pearson coefficient to determine model type

Using the correlation coefficient it is apparent that the model is additive as this gives the closest correlation to the actual.

6.6 Appendix 6 Vector Fields

Vector Fields

Vector fields are vector functions of a firm's physical position in space and time. The forces experienced by firms are dependent on interactions with other firms. Unit flows and forces acting on competing firms can be represented by vector fields. At each point in the space time continuum a field has size and direction, in three dimensions. These dimensions for firms are geographical areas, multiplied by the sales volume $_{firm}$/ sales volume $_{industry}$. In the competition model in the text we only considered two dimensions. However:

$$\frac{dv}{dt} = -wr^2$$

$$Components$$

$$F_x = Cxr^{-3}, Fy = Cyr^{-3}, F_z = Czr^{-3}$$

$$MagnitudeF = (F_x^2 + F_y^2 + F_z^2)^{\frac{1}{2}} \Rightarrow r^2 = x^2 + y^2 + z^2$$

Fx falls of by x $^{-2}$: This means that the effects of other companies falls of rapidly the further the physical distance between competing firms, to disappear completely as the distance = infinity, Fx disappears completely. In practice there will always be an effect, as a minimal distance is possible, but never nil.

An interesting effect is the stopping distance for a firm, which we will not derive here. Vector field analysis revolves around the movement of units into competitive areas, and ways to overcoming resistance to these moves. It is a 3 dimensional representation i.e. geographical area x Sales Revenue of a Firm / Sales Revenue of all competitive firms. It is a volume positioning tool, based on physical units moved into a competitive area.

The momentum and Kinetic Energy models proposed above can be extended to 3 dimensions but we have only considered 2 for simplification. The momentum model is a strategic representation unlike the tactical vector fields approach. There are n vector models of a firm depending on the magnitude and direction of the vectors (forces) acting on it. For simplicity vector directions can be considered as + or – on a straight line. This is not a true representation, it is a simplification.

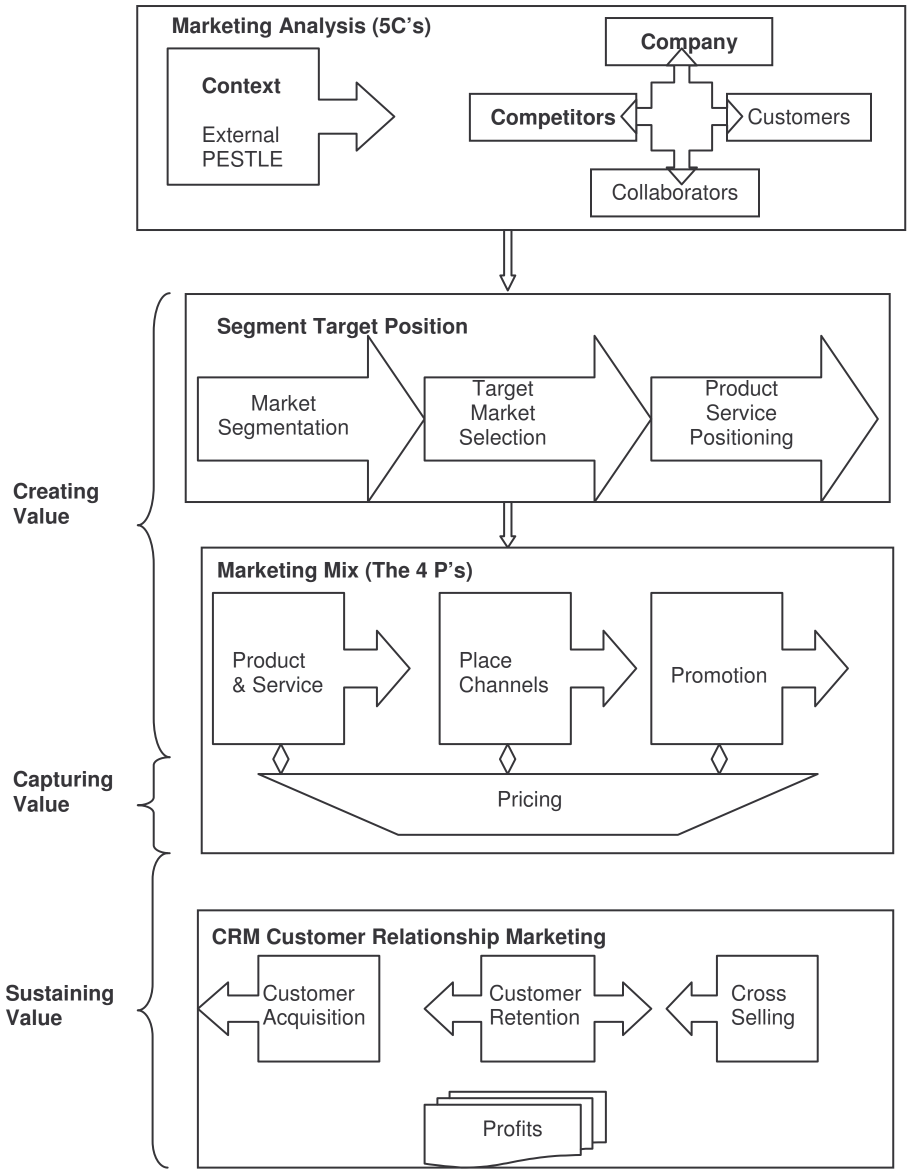
6.7 Appendix 7 Value Chain Applications

Value Chain Applications: The mathematical model proposed above is part of the value chain of the firm and leads to the value proposition. Further applications will be considered at a later stage.
We need to develop a model based on minimizing the work done to sell the product/service. This means simply that we minimize the COS for each step in moving a product from development (innovation cycle) to production (operations cycle) to finance cycle. We minimize the cost of value adding steps, and eliminate steps as far as possible that add no value. (Lean Processes) This has already been done by M.E. Porter. We need to consider a mass and energy balance for each step in the processes at a firm. We are considering internal forces and these are determined by using value chains, and COS.

6.8 Appendix 8 Market Strategy

Market Strategy: This is considered part of the model proposed above, and will be examined in more detail at a later stage. The revenue and cost generation ability of each of the contributors to the value mix must be considered in detail, and their net effect on the value proposition of the firm, as related to its ability to do work and move units into the market must be considered. Each factor must be analysed and its contribution to the total competitiveness of the firm determined, and then the factors are analysed based on their ability to add value. If the contribution of the variables is minimal they may be ignored, but must be measured periodically to ensure that their position does not change.

Marketing Planning



In the paper we considered competitor analysis. However it is possible to determine a quantitative model for the entire value proposition of a firm. This will not be considered further in this paper.

6.9 Appendix 9 Positioning

Positioning will be considered in detail in future papers as the proof is beyond the scope of this paper. However it follows from the proposed model outlined above and consists of using the models above and extensions of other models.

6.10 Appendix 10 Economics Models

Economics Models

Applications to economics include micro and macro applications. For brevity these will not be considered at this stage.