On Self Organising Cyberdynamic Policy

Mark R. Evans

A thesis submitted in partial fulfilment of the requirements of

Liverpool John Moores University

for the degree of Doctor of Philosophy

November 2016

To Mum and to the memory of my Dad

Abstract

The de facto model of what it means to be effectively organised, hence cybernetically viable, is Stafford Beer's Viable System Model (VSM). Many studies attest to the efficacy of what the VSM proposes, however, these appear to be largely confined to human based organisations of particular types e.g. businesses of assorted sizes and governmental matters.

The original contribution to the body of knowledge that this work makes, in contrast, has come from an unconventional source i.e. football (soccer) teams. The unique opportunity identified was to use the vast amounts of football player spatial data, as captured by match scanning technology, to obtain simultaneously the multi-recursive policy characteristics of a real viable system operating in real time under highly dynamical load (threat/opportunity) conditions.

It accomplishes this by considering player movement as being representative of the output of the policy function of the viable system model that they, hence their whole team, are each mapped to. As each player decides what they must do at any moment, or might need to do in the immediate future, this is set against their capabilities to deliver against that. This can be said of every player during every stage of any match. As such, their actions (their policies as viable systems) inform, and are informed by, the actions of others. This results in the teams of players behaving in a self-organising manner. Accordingly, in spatially varying player location, one has a single metric that characterises player, hence team function, and ultimately whole team policy as the policy of a viable system, that is amenable to analysis.

A key behavioural characteristic of a self-organising system is a power law. Accordingly, by searching for, and obtaining, a power law associated with player movement one thereby obtains the output of the policy function of that whole team as a viable system, and hence the viable system model that the team maps to. At the heart of such activity is communication between the players as they proceed to do what they need to do at any given time during a match. This has offered another unique opportunity to measure the amount of spatially underpinned Information exhibited by the opposing teams in their entirety and to set those in juxtaposition with their respective power law characteristics and associated match outcomes.

This meant that the power law characteristic that represents the policy of the viable system, and the amount of Information associated with that could be, and was, examined in the context of success or failure outcomes (as criteria of viability) to discern if some combinations of both were more profitable than not. This was accomplished in this work by using player position data from an anonymous member of the English Premier Football League playing in an unknown season to provide a quantitative analysis accordingly.

Acknowledgements

I would like to express my profuse thanks to my supervisory team, Mr. Andy Laws and Dr. Henry Forsyth. I am indebted to them for their unfailing help, patience, advice and assistance throughout the course of my research.

Especial thanks must go to Andy, however, for the life-changing introduction to the subject of cybernetics and in particular the work of Stafford Beer, for guiding my journey through it, for putting up with my random and lengthy visits to his office concerning it and for listening to me talk for hours about it.

I am extremely grateful to Prozone Sports Ltd, Leeds, United Kingdom, for their kind generosity, help and assistance in providing copious amounts of data from their own commercial work with the English Premiership Football League.

I have also had the valuable involvement of Dr. Eric Hayman (Head of Image Analysis) of ChyronHego AB (formerly Tracab), Stockholm, Sweden, in the provision of data sets from their commercial work with the various Scandinavian Football Leagues that allowed me to develop this work at its proof of concept stage.

None of my studies in cybernetics would have taken place if it was not for the existence of Stafford Beer and his work in managerial cybernetics. I cannot really express what the importance of this man's work represents to me since I do not possess requisite variety to do so.

I can only say that it is (and will remain) genuinely the biggest regret of my academic career that I did not have the honour and privilege to meet him and discuss his work. I do hope that what I have attempted to achieve with the viable system model herein causes him no offence wherever he may be.

Additionally, I am very grateful to have had the involvement of a very high profile English Premier League football club (unnamed herein for prevailing and on-going legal reasons) who have taken an interest in this work.

Finally, but certainly by no means least, thanks must go to my Mum for her years of totally relentless support in every single respect. In fact, 'thanks' is too small a word. I genuinely cannot express in words how much this means and how grateful I am for everything that you have done for me; to do so would take a text of a size far in excess of this volume and would take another lifetime to write.

Notes

It must be very clearly noted that the data analysed and presented herein does not belong to the football club referred to in the acknowledgements section, but relates to a team whose identification data were removed at source, and who were selected at random by Prozone Sports Ltd before issue.

Every effort has been made to credit all references as far as possible in the creation of this work and the associated software. For those who have been inadvertently omitted such contribution is herewith fully acknowledged and the author apologises for any such omission.

Contents

Glossary of Terms / List of abbreviations

Term	Meaning
Algedonic	Pleasure/ Pain.
Ashbean phase space	Proposed by British Cybernetician, W.Ross Ashby. It is a hypothetical space where every state that a target system can exhibit inhabits.
Autopoiesis	Self production
Beer's Regulatory Aphorisms:	**1)** It is not necessary to enter the black box to understand the nature of the function it performs. **2)** It is not necessary to enter the black box to calculate the variety it can potentially generate.
Bits	A construction of Binary and Digits i.e. 'Bi' (from Binary) and 'ts' from (Digits).
Black Box	Term used to describe a device or system whose inner workings are unknown either by accident or design and whose behaviour can only be discerned by reference to the behaviour of the device in terms of its range of output in correspondence to a range of inputs received by it.
Complex Adaptive System	A variation of a complex system in that either the components, the connections between them, or both adapt in some way for some reason. This serves to increase the complexity of the inter-connected parts and the relationships that subsist between them due to the amount of variability present. Accordingly, as the system adapts as required the traceability of specific behaviours exhibited by the system back to specific cause becomes even more difficult than before.

Term	Meaning
Complex probabilistic System	In many respects the complex adaptive system alluded to above feature such levels of complexity that the behaviour of the total system becomes difficult to predict. The reason for this is that the myriad of interactions between the components and the types of those interactions (especially in human social systems) introduces subtleties in total system behaviour that no designer of such systems could ever specify, or predict, at the outset. Accordingly, the whole system can behave in an entirely unpredictable, hence probabilistic, manner.
Complex System	These are systems that are comprised either of a few components with many forms of interaction, many components with a few forms of interaction, or a combination of either of these configurations. The relationships between the connected components determines the complexity of the system in that it very much depends on what those connections are, how many there are, what information they convey between the parts, how often they do this. The other aspect that determines the complexity of the system of components is that which depends on how each component system reacts to the inputs they receive and process and what output they issue as a result that may then, in their turn, have an affect upon other connected components. The number and type of connections and the responses alluded to can very quickly result in a system that is difficult to analyse the behaviour of in terms of the specific cause of it, even when the components involved and the connections between them are fixed in nature.
Conant Ashby Theorem	Every regulator must contain a sufficiently accurate model of that which it regulates.

Term	Meaning
Cyberfolk	Part of Beer's work in Chile during the time of the Allende Government (1971-1973). Beer envisaged each person could respond to televised coverage of government proceedings and respond to it in real time by turning a dial on a control box to accord with their personal level of agreement or disagreement with what they were witnessing. The readings from each person were consolidated and converted, in real time, to a meter arrangement that would rotate by an appropriate amount in accordance with the consolidated value computed. This meter was positioned behind the government ministers who were addressing the nation and formed part of the television broadcast. In this respect the ministers could discern the degree of well being that was being expressed by the electorate in correspondence to what they were proposing, and were naturally aware that this was being televised back to electorate so that they too could discern the general consensus amongst the rest of the population regards the matter under discussion. In this respect Cyberfolk established a real-time reciprocal control loop between the people and the government.
Cybernetically viable complex adaptive system	A system that is both viable, hence maps to the viable system model, but simultaneously behaves as a complex adaptive system when interacting with similar systems. A person in a cybernetically viable system, by definition, yet when two or more people interact, the collection of those people produces an output that no single individual can imbue that collection with. The interaction of the participants is an emergent property (see above) of the collective and that is underpinned by the complex behaviour (the myriad interactions) between them. Each participant is adaptive both to each other and the overall situation that the collection of participants faces. Those adaptations affect, and are affected by, each other and that contributes further to their mode of interaction and hence what the emergent behaviour of the collective will be. If that emergent behaviour is explicitly aligned with the purpose of the viable system that the collective represents, then the collective can be said to be a cybernetically viable complex adaptive system.

Term	**Meaning**
Cybernetics	The science of communication and control in the animal or the machine. A useful addendum to this definition is that Cybernetics relates to systems that can appropriately respond to a world that can always surprise them.
Cybersyn	Cybernetic Synergy: part of Beer's work in Chile at the request of the Allende government. It was a project to fully connect the people of Chile with the Social, Economic and Political agenda of their government in real time using computer technology, real time data processing via high speed telecommunication links, to encourage their participation in their country's future.
Emergent Properties	The effects of interaction between two or more components in a system to produce an outcome for the system that those components belong to that is greater than either one of them alone could provide the system with. In many respects, the emergent properties of a system are a by product of the suitably coordinated efforts / contributions of each component involved to create desired outcomes.
Endemically	Related to people; a characteristic in a particular field.
Entropy	The amount of disorder in a system i.e. the extent to which a system is disorganised. More entropy corresponds to greater disorganisation; less entropy corresponds to less disorganisation i.e. greater organisation – hence greater order.
Eudemony	The Aristotelian term for 'well-being'.
graddiff	The difference between gradmax and gradmin.
gradmax	The maximum value in the series of the gradient values for the linear regression lines plotted for each match.
gradmin	The minimum value in the series of the gradient values for the linear regression lines plotted for each match.
Homeostasis	The process of keeping a target system within prescribed control limits (often physiologically defined in terms of a human being e.g. body core temperature).

Term	Meaning
Homeostat	A device that describes and implements the process of Homeostasis.
icdiff	The difference between icmax and icmin.
icmax	The minimum value in the series of Shannon Information values computed for each match.
icmin	The minimum value in the series of Shannon Information values computed for each match.
Incipient Instability	Instability in a system that is just beginning or becoming apparent.
Information	The unit of communication across a communication channel (expressed in Bits). Also considered as the average amount of surprise that a system can exhibit and calculable using Shannon's equation for the Information content of an Information source.
Inside and Now	The term used to describe the internal environment of a viable system i.e. what is currently happening within itself in the name of it achieving the stated purpose of that viable system.
Isomorphic	Maps to.
Managerial Cybernetics	A field within Cybernetics in that it focuses upon management. It is the science of effective organisation.
Maxwell's Demon	A thought experiment developed by James Clerk Maxwell to investigate the prospect of whether or not it is possible to lower the amount of disorder (entropy) in a system without doing any work.
Metasystem	That part of the Viable System Model that contains System 5 (Policy), System 4 (Intelligence), System 3 (Delivery Management) and System 2 (Coordination) functions. The Metasystem describes what manages the activity of a viable system in general whereas, in contrast, System 1 describes what the viable system actually does whilst operating to the requirements of that management on a mutually agreeable and reciprocal basis.

Term	Meaning
Negentropy	The information based equivalent of Entropy. Maximal Entropy (Maximum Disorder in a system) represents minimal Information and Minimal Entropy (Minimum Disorder = Maximal Order) represents maximal Information.
Outside and Then	The term used to describe the external environment of a viable system and the probability of different types of future conditions therein.
Pathology	The science of disease diagnosis. Organisations suffer from common problems associated with how disorganised they are i.e. the extent of their maladjustment to what it means to be effectively organised. If what it means to be effectively organised is described by the Viable System Model, then a departure from the provisions of that model represent organisational pathologies. An example of this is the case of those inside an organisation who operate at board level proactively getting involved in minor administrative matters (e.g. the ordering of office stationery). They disconnect themselves from the external focus of their organisation that a person in their role demands. Whilst this is happening, the implications are that opportunities could be missed or threats may manifest themselves and the organisation suffers either way – it is less viable than would have otherwise been the case (subject to other factors).
Performative milieu	A physical or social space where an appropriate level of action is undertaken taken by a person to accomplish a desired objective whilst under the variable constraints of the prevailing circumstances.
Power Law	A mathematical relationship between two variables where one variable (say y) varies in proportion to another variable (say x) for some number k in accordance with an equation of the type $y = 1/x^{-k}$ where k is usually a number between 1 and 2. A power law that is discernable in a target system is an indicator of the presence of self organising behaviour for that system.

Term	Meaning
Recursion	A mathematical term that, when used in the context of the Viable System Model, essentially means that the provisions of the model are replicated within itself. If a viable system is a football team, then that follows the provisions of the viable system model. Each function that causes that team to do what it does (e.g. Attack, Midfield and Defence) is itself a viable system that is encapsulated by the team. Each of those functions contains players that are in turn viable systems. They behave in a manner to cause what each function does to become manifested in reality. Each of those functions then interacts in a manner to produce what the team as a whole actually does. Recursion in the Viable System Model decrees that the team, the functions and the players are all described by the viable system model. As such, in this case, the recursion denotes the team encapsulating the functions and the functions encapsulating the players. Each encapsulation follows the same systemic provisions of the viable system model, hence he football team can be considered to some extent as a nested structure of such encapsulations.
Redundancy of Potential Command	If there are many decision makers that can possibly take a decision that affects the outcome for the collection of decision makers, then each one of those decision makers can be called a 'Centre of Potential Command' since they can each assume command of the prevailing situation, make a decision about it and then take appropriate action. The decision making is not centralised, it is distributed throughout the system of decision makers i.e. there is redundancy in the centres of potential command. Accordingly, the redundancy of potential command is an essential prerequisite for any self organising system.
regdiff	The difference between regmax and regmin.
regmax	The minimum value in the series of the linear regression coefficient R^2 for the linear regression lines plotted for each match.
regmin	The minimum value in the series of the linear regression coefficient R^2 for the linear regression lines plotted for each match.

Term	Meaning
Resource Bargain	Part of the System 3 (Delivery Management) function in the Viable System Model. The System 3 holds the resources that are available to the whole system that are available for use in producing what the total system actually exists to do. Those viable systems that comprise System 1 (Operations) receive the resources they request to do what they need to do on behalf of the total system from System 3. They obtain these resources in exchange for the performance reporting information they supply to System 3 that is underpinned by what they have each done in terms of productive output and the resources they have already used to deliver that.

Term	Meaning
Self Organisation	The behaviour associated with the interaction of autonomous agents within a system in response to each other and their respective localised conditions. The behaviour of each individual agent informs, and is informed by, the behaviour of the other agents present and this causes the collection of agents to exhibit certain patterns of coherent behaviour. A notable example of this is the flocking behaviour of Starlings. Each Starling is an autonomous agent in a flock (group of Starlings) and its behaviour is its own concern. Yet, when that behaviour is influenced by the presence of other Starlings that surround them in the flock, that behaviour is in turn reciprocated back to them. This establishes continual circularity in the interaction between each Starling in accordance with each Starlings autonomous application of a rule set that they each apply to avoid each other. When one examines the entire flock of Starlings, one can discern that the flock behaves in a coherent manner in flight. Such patterns are often very complex, hard to predict and seem to form for no readily apparent reason aside from flock behaviour when it takes action to avoid the interest of airborne predators. Indeed, perhaps the difficulty in prediction is the strength of such self organising behaviour when avoiding a predator since that is obviously to the flock's advantage under such circumstances. The behaviour of the flock, i.e. the total system of interacting participants, exhibits behaviour that no one participant involved can impart upon it. By that rationale, the behaviour alluded to is emergent, but this is only the case due to the components (individual Starlings) each behaving the way that they do locally with respect to each other, and that is distributed throughout the flock, to create the global patterns associated with the whole flock. The behaviour of the flock is not under the guidance of a centralised control function in the form of a Starling that has been appointed its leader.

Term	Meaning
Spatiotemporal	Relating to both time and space.
Synergy	An advantageous combination of elements (e.g. resources or efforts).
Syntegration	A consensus based human decision making protocol for policy formation within viable systems and hence that which can be mapped to the viable system model.
System 1	That which encapsulates the functions of a viable system that serve to produce what the total system actually does.
System 2	The function of a viable system that describes how the components of System 1 are coordinated such that the total System 1 output is coherent and that no component predominates in a manner to compromise that.
System 3	The delivery management function of a viable system. It describes how the resources that the viable system has at its disposal are allocated and provided to System 1 and its associated components in return for performance reporting data being received from them concerning current performance levels with resources that have already been allocated.
System 3*	The audit function of a viable system. It represents the mechanism that allows System 3 to bypass the localised management of System 1 components so that the facts that they report concerning their performance can be objectively verified.
System 4	The intelligence function of a viable system. It describes how the total system engages with its environment and how both opportunities to be pursued and threats to be avoided can be anticipated and action formulated in advance as appropriate. Intelligence holds a model of both the total systems external environment as well as a model of the whole viable system and its capabilities in order to make informed judgements of the external environment in context of what the system is capable of accomplishing.

Term	Meaning
System 5	The policy function of a viable system. It handles the competing requirements of the externally focused and future oriented System 4 with those of System 3 and its internally focused agenda and what is currently happening inside the viable system.
System in Focus	Given that the Viable System Model describes a system in terms of a series of embedded recursions, the System in Focus refers to a particular recursion that is under consideration. In the case of a football team, that is a viable system that can be resolved into three recursions. The team is represented by Recursion 0 (the all encompassing viable system). Recursion 1 represents that team resolved into the various performative functions of Attack, Midfield and Defence. These are each viable systems that are encapsulated inside Recursion 0.Recursion 2 represents the players that are viable systems that are encapsulated inside each Recursion 1 (Attack, Midfield and Defence function) as applicable. If interest is held about, say, the Midfield function of the team then that is the System in Focus i.e. the recursion within the overall viable system that the team can be described as that is currently under examination.
Variety	The number of states that a system can exhibit.
Viability	The ability of a system to continually operate within its environment to the extent that it can pursue its stated purpose, despite the conditions in that environment possibly conspiring to counter that aim.
VSM	Viable System Model.
ydiff	The difference between ymax and ymin.
ymax	The maximum value in the series of the Y intercept values with the Y axis for the linear regression lines plotted for each match.
ymin	The minimum value in the series of the Y intercept values with the Y axis for the linear regression lines plotted for each match.

Term	Meaning
Zipf's Law	Relates to the word frequencies found in various sources of text irrespective of the language they are written in. On examining a text and listing every unique word within that text, one may evaluate how many times each of those words appears. This results in a table that features the most frequently used word on the first line and the least frequently used word on the last line. The former would be assigned the highest rank number i.e. 1, and the latter would be assigned the lowest rank number. Zipf discovered that a power law relates the word frequency to the rank number.

VSM Overview and Examples

This section is provided as a highly abridged overview of what the Viable System Model is and does to a reader who is unfamiliar with it, and does so in advance of the detailed description given later. Essentially the Viable System Model is divided into two parts:

1) The Metasystem – the functions that manage what the whole system does

This is comprised of:

System 5 – Policy: The balance between the systems external focus (goals, aspirations etc) and its abilities to deliver against those by its internalised efforts.

System 4 Intelligence: The external focus of the system i.e. the current conditions within its operating environment, the potential conditions within that environment, the results it wants to achieve and the incursions it seeks to avoid (both actual and anticipated).

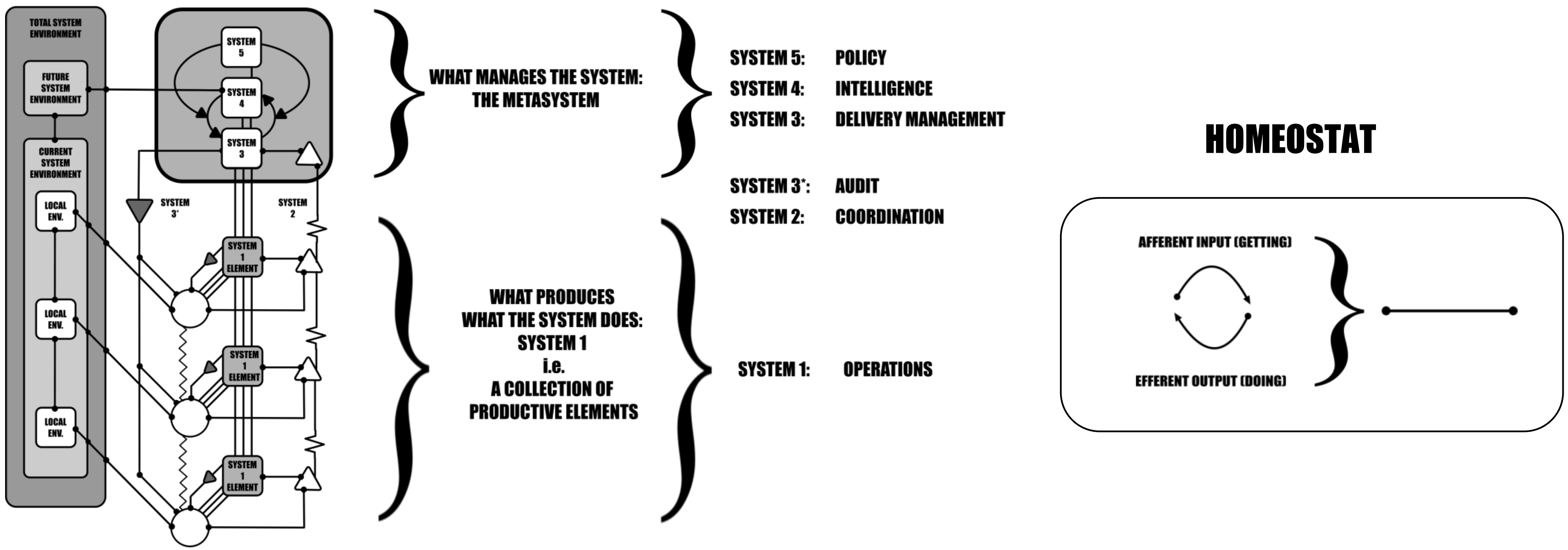
System 3 – Delivery Management: The internal focus of the system in terms of the management of its ability to produce what the whole system exists to actually do. Its emphasis is upon the allocation of available resources to the agents of production that accomplish that work with them in exchange for performance reporting data from them.

System 3* - Audit: This operates intermittently to verify the data being received from System 1 is as it should be.

System 2 – Coordination: Serves to ensure that all of the agents of production operate in harmony to the benefit of the total system and none of them do so unilaterally to its detriment.

2) System 1 – Operations: the agents of production that does the work that the whole system exists to produce.

The integration of these functions (as per Figs. 1-4) cause a synergy to emerge between them that serves to characterise the whole collection of them as a coherent, self contained, entity that has a relationship with its operating environment. As the conditions in that environment change, the synergy amongst the component systems changes in accordance with that to the extent that the total system (that collection of functions) continues to exist to do what it does. In other words the total system acts to continually sustain its coherent operation in the face of that which might seek to thwart that aim.



SYSTEM 5: **POLICY** = THE BALANCE BETWEEN THE WHOLE SYSTEMS INTERNAL AND EXTERNAL ENVIRONMENT

SYSTEM 4: **INTELLIGENCE** = PERCEPTION, JUDGEMENT, RECOMMENDATION AND ANTICIPATION OF FACTORS IN EXTERNAL ENVIRONMENT

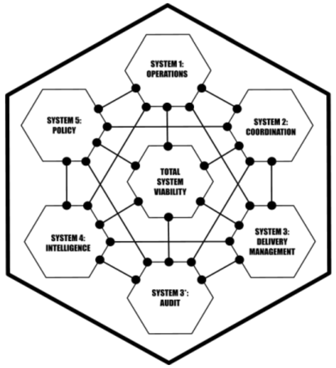
SYSTEM 3: **DELIVERY MANAGEMENT** = PERCEPTION AND ACTIVE CONTROL OF PERFORMANCE FACTORS IN INTERNAL ENVIRONMENT

SYSTEM 3*: **AUDIT** = INTERMITTENT MONITORING OF INTERNAL PERFORMANCE FACTORS

SYSTEM 2: **COORDINATION** = COORDINATION OF AND BETWEEN INTERNAL PERFORMANCE FACTORS

SYSTEM 1: **OPERATIONS** = INTERNAL PERFORMANCE FACTORS THAT UNDERTAKE THE WORK THE WHOLE SYSTEM EXISTS TO DO

Fig. 1 Viable System Model (VSM) (Stylised)

	Examples			
Viable System Model Component System	**Human being**	**Business**	**Football Team**	**All connected systems Per VSM resulting in Total System Viability**
System 5 – Policy	Brain	Chairperson	Self Organising aggregated team movement.	
System 4 – Intelligence	Senses	Directors (e.g. Sales, Production, Finance, Logistics)	Self Organising aggregated individual observations.	
System 3 – Delivery Management	Autonomic Nervous System (ANS)	Line Managers	Autonomous self allocation to a situation undertaken by each player.	
System 3* - Audit	ANS (Parasympathetic System: looks after the body's need to 'rest and digest' i.e. the bodily activities that occur when body at rest)	Work Checking (e.g. quality assurance)	Autonomous peer checking undertaken by each player.	
System 2 - Coordination	ANS (Sympathetic System: looks after the body's fight or flight responses)	Work plans and schedules (e.g. production and delivery schedules, shift rotas)	Self Organising effective interaction between individual players.	
System 1 – Operations	Muscles, Heart, Kidneys etc.	People involved in Sales, Manufacturing, Procurement. Depends on organisation type and what it exists to produce. For example, an accountant working in a firm of surveyors is not a System 1 element of that practice, but a surveyor would be since that is what the practice exists to do. The accountant does not operate to produce what the practice does.	Players involved in the team's Attack, Midfield and Defence functions.	

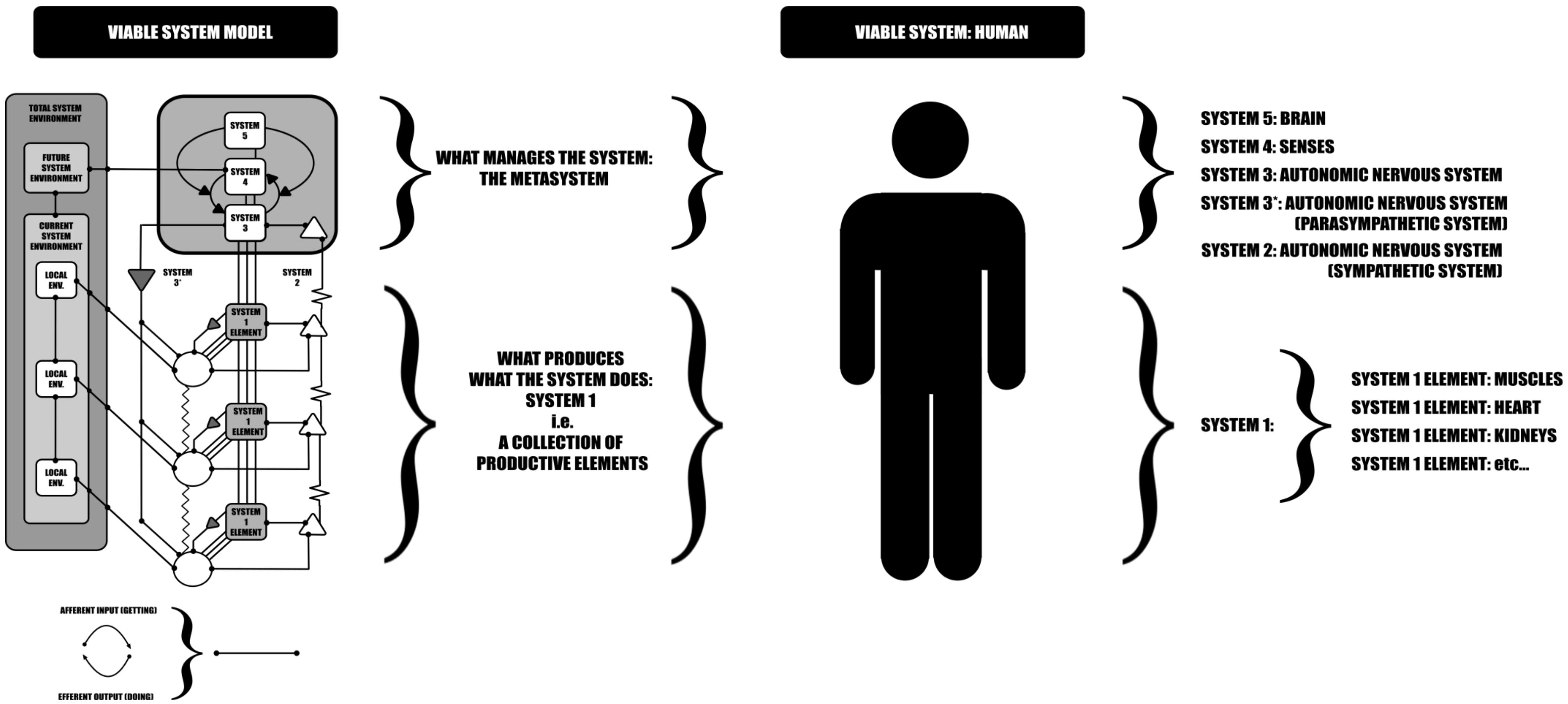


Fig. 2 Relationship of Viable System Model (VSM) and a Human being

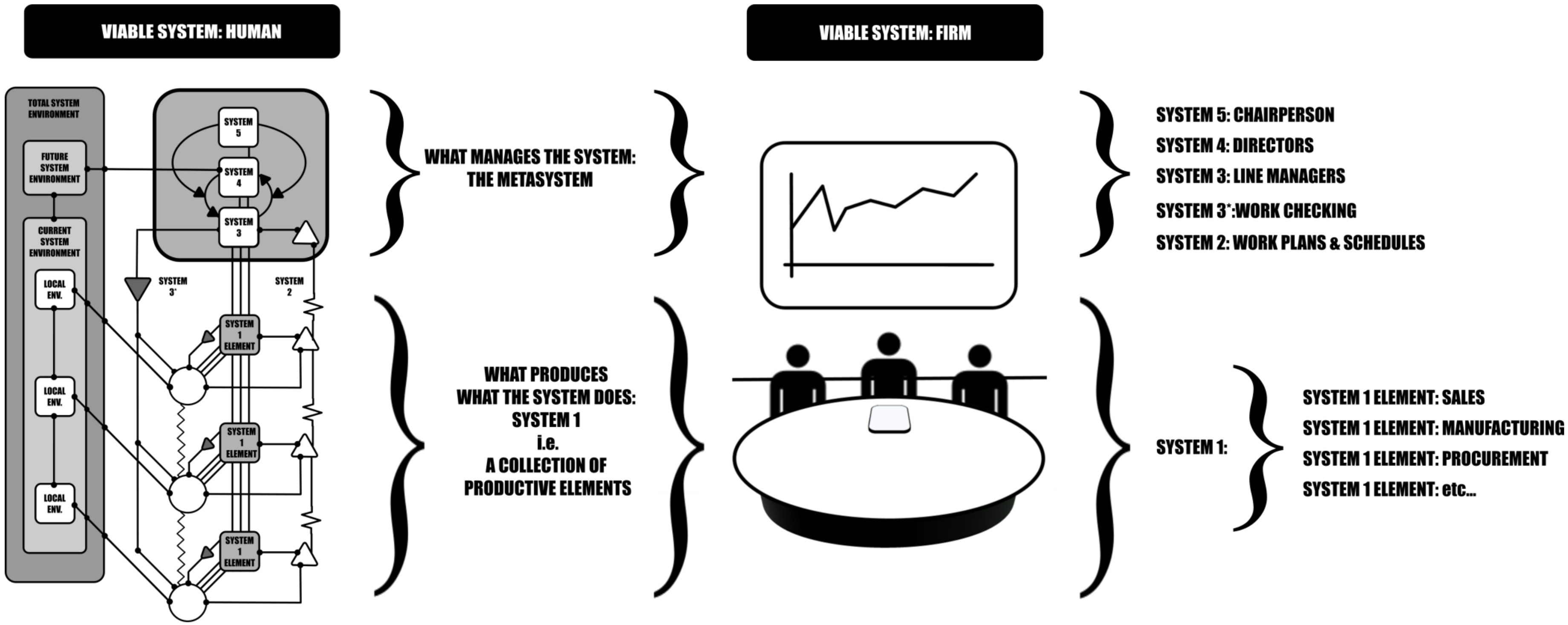


Fig. 3 Relationship of Viable System Model (VSM) and a business organisation

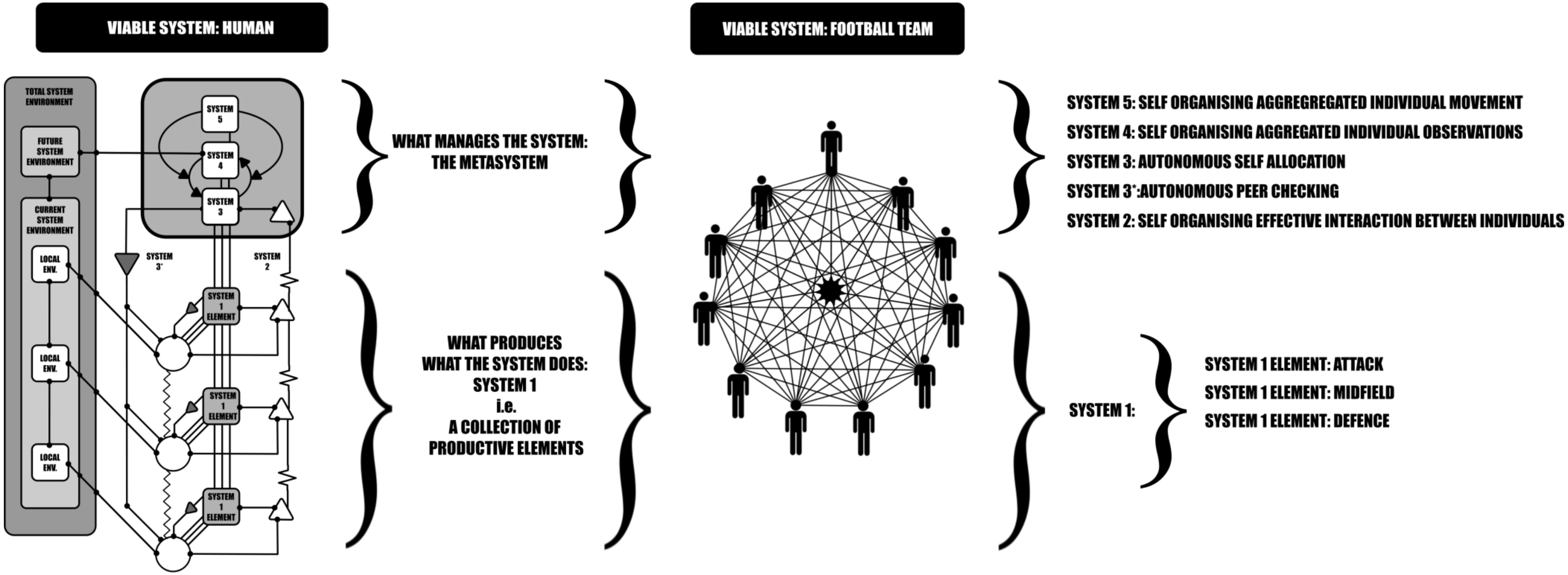


Fig. 4 Relationship of Viable System Model (VSM) and a football team

Chapter 1 – Why this work?

1.0 Introduction

This is a work in applied managerial cybernetics that specifically focuses upon the work of Stafford Beer in the development of his Viable System Model (VSM).Beer's model defines what it means to be viable i.e. what functionality a system must possess and interoperate internally to create a relationship with its external environment. This being to the extent that it survives in that environment to the point that it may achieve its purpose within it.

Often, the purpose of a viable system is pursuit of success and the avoidance of failure that it defines for itself. This depends upon the system involved. A business, considered as a system, may be cybernetically viable to the extent that it ultimately enjoys large profit margins. It may actually sustain losses, but in both cases it may be discerned that it is cybernetically viable to a greater or lesser extent. This means it may still exist to a point that it can continue to attempt to achieve those profits and avoid those losses. Sustaining a loss in one year may not necessarily destroy the organization, nor does it necessarily mean that it will not be able to earn a profit in the following year.

The organization survives since it is cybernetically viable to do so. The financial performance may, however, give owners of the organization concerns over the financial viability of it, which is a completely separate issue on the face of things. Yet what if that financial viability is explicitly linked to the purpose of the organization and hence to the mode in which it is organized to achieve it? Its purpose may well be to actively pursue the profit and avoid the loss and it is expressly organized and operated accordingly. This means that there is a quantifiable criterion of success that indicates the degree to which the organization fulfils its purpose.

Managerial cybernetics is, according to Beer (Beer, 1985, p.ix), the "*science of effective organization*". Accordingly, if what it means to be successful in the context of a system's stated purpose and how it is organized to accomplish it, then one can relate the degree of effective organisation to those success levels. Yet many organizations are more than just about money. A person is a viable system in just the same way as a business or government is. Their purposes and criteria of success or failure to accord with that are perhaps different, but as viable systems they share the common systemic provisions that make them so as per Beer's VSM. As such, this work is an exploration into that domain. It is a study in what cybernetic viability is and how various degrees of it are correlated with the success or failure of a nominated target system, and the following Research & Development Activity Matrix outlines the stages undertaken accordingly.

1.1 Research & Development Activity Matrix

STAGE	OBJECTIVES	KEY TASKS	METHODOLOGY
Stage 1 Requirements Research	Examine the current position in Viable Systems Research for quantified analysis of the Viable System Model (VSM)	Exploration of VSM & Complex Systems literature. Provide a step by step analysis of the isomorphy between a football team and its VSM representation. Relate what the VSM is and does to the operation of a football team to justify use of a football team as a suitable proxy for the model. Formally state the research objective to find a characteristic output signature of a viable system under load and how does that relate to the system's success or failure.	Literature Review. Case Study. Cybernetic Intervention and isomorphic analysis of football team compared to the VSM.
Stage 2 Technology Research	Investigation of technologies and associated data sources that characterise viable systems in action	Investigation of sources of data capture systems for viable systems under load. Assess programming languages pending software construction. Assess report writing tools to assist in analysis. Employ the techniques of Complex Systems to characterise Viable Systems.	Literature Review. Case Study.
Stage 3 Software Construction	Design and build software to play back football matches from data files provided	With reference to the supplied data file format, iteratively construct and test match playback software using the Java programming language via the Processing Integrated Development Environment.	Iterative rapid application development method for software construction.
Stage 3 Data Analysis	Analyse each match data file before playback in software (actual dynamics) and after playback (emergent dynamics)	Produce regression analyses as policies of viable systems under load to characterise the VSM in operation; also produce Shannon Information computations and juxtapose the two. Compare and contrast these and assess for statistical significance as a means of quantifying degree to which target football team were well organised hence isomorphic with their VSM representation.	Zipfian ranked frequency distribution production Linear regression treatment of the above Juxtaposition of both and run tests for statistical significance.

STAGE	OBJECTIVES	KEY TASKS	METHODOLOGY
Stage 4 Evaluation of Analysis Conclusions & Future Work	Comment upon the analysis undertaken as a new means of quantifying the degree of isomorphy the target team had with its Viable System Model representation based upon derived metrics and corresponding match outcomes.	Compare and contrast the calculations made with reference to match outcome type in terms of team success or failure and the corresponding juxtaposed metrics. Conclude findings based upon statistical significance figures and how that relates to the null hypothesis formulated for the research. Explore possible future areas of application of the work undertaken.	Objective analysis and evaluation of the findings as a conclusion to the work. Determination of possible future directions the work could take and provision of some recommendations accordingly.

1.2 Why has the work been undertaken?

This work has been embarked upon since, although what it means to be cybernetically viable is understood, there is an absence of supporting evidence to characterize what that actually looks like.

The VSM defines how a system that it represents balances the demands of its external environment with its ability to deliver against them. Only people can do anything about anything, and what they do is underpinned by a decision to do something that is then enacted i.e. their policy. What that policy is may be myriad in its nature and hence in its effect, but it is nevertheless their policy as a viable system.

They have perceived what they must or need to do, considered this in the context of their ability to do it and then enacted a policy to achieve it.

Yet, the whole organization that they belong to is doing this. Everybody involved has a policy at every point in time, and that means that if they are aggregated in some way then this is argued to characterize that entire organization at that moment.

At that moment, the organization will be more or less viable i.e. more or less organised to achieve its purpose. Problems may arise that may cause different policies to be enacted which causes attention to be diverted away from more strategically important matters e.g. sales directors reacting to problems in office stationery shortages whilst a competitor has just identified and won a lucrative contract.

Such situations represent an inconvenient truth when pointed out to those who undertake such practices, and this is exacerbated when it is pointed out that such behaviour is symptomatic of being badly organised. Some may argue that such action was necessary, yet the VSM would hotly dispute that.

The policies involved in the example offered above make the organization less than it could have otherwise been. This may manifest itself in real terms e.g. financially. Yet, systemically there is a problem and the two, in this case, are linked. Departure from the provisions of the VSM that renders an organization to be effectively organized has caused it not to achieve, in this case, the stated purpose of maximizing sales revenue – the contract was lost.

In this case, matters are quantified in terms of money, but what quantifies and characterises the degree of alignment with the VSM that caused this situation to be the case i.e. to what extent was this system less than effectively organized for what happened to happen?

A system in the real world may well be closely aligned with the provisions of the VSM, or it may not. It is argued that the net behavioural characteristics of that system in the pursuit of its purpose will therefore vary according to that degree of alignment.

Accordingly, if a net behavioural state of a nominated target system could be quantified, captured and continually monitored in real time, then this would be amenable to analysis, and hence perhaps reveal the degree of that alignment in some way.

Moreover, if that analysis could be associated with an accessible, intuitively sensible and commonly acknowledged criteria of success for that target system, then one might be able to differentiate less beneficial behavioural states from more advantageous ones.

If those more advantageous outcomes are associated with particularly strong behavioural characteristics that are exhibited by the target system, then it is argued that this is indicative of a closer alignment of the system to the VSM than not. It would hence provide a measure of how effectively organized the target system was.

This work is unusual since it attempts to explore this without having to resort to historical financial or business process centric data. This is on the grounds that this is periodically produced and does not represent the true dynamics of a real cybernetically viable system as it balances its relationship with its environment. That can only be truly described by the policy characteristics of the system as a whole, hence that is what is investigated.

1.3 The VSM contrasted with other paradigms of Self Organisation

The viable system model is underpinned by the cybernetic mechanisms that are to be found in the human body. Indeed, the viable system model was inspired by, and actually follows, the principles of human neurophysiology.

Accordingly, a human being is regarded as being a de facto viable system not only on the basis of shared neurophysiology with the model, but also in a literal sense in that a human being is capable of forming and following their own survival imperative under a wide variety of circumstances and environmental conditions.

If a human's neurophysiology describes the viable system model and its operation, then it is argued that the viable system model representation of them represents the wiring of the black box that they are. By reference to the input received by them and analysis of the output issued by them, one can discern the behaviour of the wiring of that viable system that relates the two together.

If the output is more or less aligned to the purpose that the human has at a particular time or over a particular duration of time, and that can be associated with a degree of success or failure in the pursuit of that, then it provides a measurement of how well organised that person was with respect to achieving their objective.

If one considers the human in terms of just their viable system model representation, one can therefore obtain insight into what extent, if any, certain distortions in the model may be present. The rationale being that if the human was less than effectively organised with respect to their objective then this would correspond to a distortion in the wiring of their viable system model representation in some way. This might perhaps indicate the absence of a function essential to ongoing viability or some sort of compromise in its output capacity that has served to compromise the whole system (human) accordingly.

This concept may be extended to groups of people who function to pursue a common goal in a manner that is effectively organised. Their behaviour qualifies as a self organising system by virtue of an application of localised rules on an autonomous basis.

The behaviour of each person involved affects, and is affected by, each other and the net output of that behaviour characterises what that group does. Yet, each participant is a viable system. As such, by virtue of their essential need to be organised with respect to their common objective, the emergent behaviour of that self organising collective is argued to equivalent in construction and operation of the viable system model that can be used to describe that collective.

It is via this line of argument that it is contended that analysis of the spatiotemporal activity of a football team facilitates an opportunity to study the multi-recursive policy of the recursions of the viable system model that can be used to describe the team concerned. From this one might then characterise the output dynamics of the viable system model itself in general terms via that proxy.

This is the focus of the work. It is to obtain a hitherto unobserved characteristic of the viable system model under load conditions since there are copious amounts of data available to make this possible, yet appear to have been unused in this manner thus far.

Although other paradigms exist that describe the self organising behaviour patterns observed in purposeful systems, it is of vital importance to draw the distinction here between those that do not explicitly refer to how the people involved actually operate and those that do.

The viable system model describes the latter. The former includes studies in the fields of Cognitive maps, Genetic Algorithms, Particle Swarm Optimisation, the Kuramoto Model and Kohonen neural networks.

Each of these is now compared and contrasted with the viable system model in terms of their salient features in an attempt to justify selection of the viable system model as the most appropriate foundation for the research undertaken from the range of possible options available in advance of the literature review carried out.

1.4 Comparison Matrix for VSM to other paradigms of self organisation

Paradigm	What it is	Relevant to the VSM	Equivalent to the entire VSM	Explanation	The case for its use	The case against its use
Cognitive Maps	A type of mental model representation which serves an individual to acquire, code, store, recall and decode information about relative locations in their everyday spatial environment. The concept seems to have some neural correlates with the human brain in that cognitive maps are allegedly located in the place cell system of the hippocampus, although this is speculated. Definition with appropriate acknowledgement to: https://en.wikipedia.org/wiki/Cognitive_map under Creative Commons Attribution-ShareAlike License: https://creativecommons.org/licenses/by-sa/3.0/	Yes - partial	No	The concept only seems to refer to the model of that which the viable system holds about that which it seeks to control and that is held (or should be held) by System 4 (Intelligence) i.e. the model of its environment and the self referential model it holds about itself (Conant Ashby Theorem). It does not explicitly relate input received to output issued as per the System 5 Policy function of the VSM, nor any other neurophysiologically underpinned paradigm essential to systemic viability.	An essential concept related to System 4 Intelligence if the viable system is to adhere to the Conant Ashby Theorem. Neural correlates allude to the strength of the connections between place cells and how that is equivalent to distances between objects in a subject's environment. This suggests that the spatiotemporal behaviour of players on a football team could potentially describe a cognitive map for the whole team.	Only partially representative of what Viability is. Does not explicitly relate input to output as policy for the system since it only relates to a model of the environment held by the subject. Does not describe how the model relates to survival of the subject as it pursues its purpose. Does not feature the concept of cybernetic variety explicitly in any control strategy that it might be associated with, which is an essential prerequisite, let alone how it may be homeostatically regulated.

Paradigm	What it is	Relevant to the VSM	Equivalent to the entire VSM	Explanation	The case for its use	The case against its use
Genetic Algorithms (GA)	A technique used in computer science inspired by the process of Darwinian natural selection in the evolution of life forms. The technique was developed to solve problems that occupy large solution spaces (myriad possible solutions of varying degree of suitability hence efficacy) where traditional algorithmic techniques would take far too much time. Definition with appropriate acknowledgement to: https://en.wikipedia.org/wiki/Genetic_algorithm under Creative Commons Attribution-ShareAlike License: https://creativecommons.org/licenses/by-sa/3.0/ also: p.391 Shiffman, D., 2012. *The Nature of Code*. New York: Self Published Book.	Yes - partial	No	The technique requires specific encoding of environmental conditions and the generation and manipulation of a population of candidate solutions to the problems present therein (e.g. obstacles to be avoided) in accordance with a scale of fitness being ascribed to those solutions. Although a strategy in the form of connections between system input and system output could be generated by such means for a given purpose, the time taken for the algorithm to run and make its recommendations might present an issue since the pace of the environment might change too rapidly, and too often, for it to keep up.	An excellent choice for optimising the connections between system input and system output to form a policy for the system. Natural selection process will offer solutions that may initially seem contradictory to a human designer of a policy, but are capable of showing that such solutions are more than capable e.g. through the subtleties they introduce to how the system will behave if its recommendations are implemented.	Does not describe fully what viability is. Rate of evolution may be pedestrian in comparison to the pace of the environment and the need for solutions to problems therein that are rapidly altering. The time lag between what the system needs and what the system proposes to do in response may well cause the Genetic algorithm to do precisely the right thing (fully optimised, best possible policy) at precisely the wrong time. Dissemination of recommendations to the players may be difficult in practice.

Paradigm	What it is	Relevant to the VSM	Equivalent to the entire VSM	Explanation	The case for its use	The case against its use
Particle Swarm Optimisation (PSO)	An optimisation technique inspired by social behaviours e.g. bird flocking. The technique is similar to Genetic Algorithms but does not use evolution operators such as crossover or mutation. In PSO, potential solutions to a problem are conceptualised as particles that fly through a space that describes the problem to be solved. Those potential solutions follow the current best solution (particle).For each iteration of the algorithm, all particles are updated with two "best" values. Its own personal best and the best value that any particle in the swarm possesses (a global best). The update determines the velocity and position of all particles. The information sharing in PSO is different to that in GAs i.e. it is one way since only the current global best updates every other particle – it is not a case of each particle updating each other.	Yes - partial	No	This has the advantage over GAs in that the solutions that it proposes can be expedited more rapidly. The method seems initially to have more intuitive alignment with the behaviour of the football team used in this work, but the fact that a particular player has possession of the ball does not necessarily equate to them being representative of the best policy (local or global) at that time. Similarly, if their possession of the ball does represent the best possible policy currently, this may soon be demoted in accordance with a player's autonomously formed action to, say, pass, the ball to a colleague and that may result in a situation that currently represents a less than optimal policy in overall terms. As such, there is no guarantee in actuality that the each player (equivalent to a candidate solution in a small scale particle swarm) would be updated with the best policy since what works for one, might not work for another under different circumstances.	PSO represents an excellent choice for describing how a policy for a system might be optimised rapidly. The strength of the approach is its speed over the GA approach and its similarity with how a team actually works on the pitch. This is to say that at the level of the whole team, each player can conceivably be considered to be a particle (candidate solution) in that system of particles. Moreover, that the other players involved do, in many respects literally, follow their colleague who has possession of the ball to support them. As such, the behaviour of PSO could be used to describe the policy formation of the collective and that could then be correlated with team success or failure. A comparison could then be made between what the algorithmic version of the PSO recommended and what the 'particles' on the pitch did at every time step. This could be mined for aspects appertaining to potential tactical advantage.	PSO is representative only of the policy aspects of a viable system and a fully optimised version of that. Often management can be too deterministic, hence rigid in its approach to solving a problem. If the PSO approach was used to provide an optimal policy at all times for the team, quite how that could be disseminated and enforced amongst the players in a real situation at all times remains an open question. The technique does not factor in the other essential prerequisites of what it means to be a viable system. One of the grounds for this is that there is no provision for negotiation between the components of the system, homeostatically or otherwise. The data being reported back from the ostensibly current global best is not objectively verifiable at all times in a real situation without an explicit mechanism to assure integrity. For sure, an algorithmic approach can implement this, but PSO as it stands does not. Moreover, no particle features a homeostatic relationship with its environment which defines its control strategy and dynamics with respect to it.

Paradigm	What it is	Relevant to the VSM	Equivalent to the entire VSM	Explanation	The case for its use	The case against its use
Kuramoto Model	Describes how a series of oscillating systems that are coupled together can either be synchronised or desynchronised with each other. Definition with appropriate acknowledgement to: http://tutorials.siam.org/dsweb/cotutorial/index.php?s=1&p=1	Yes – partial	No	The technique demonstrates that synchronisation of disparate, yet globally coupled, oscillating systems can be synchronised (coordinated) to describe a system that has an output that can be described in terms of a single sinusoidal curve.	Coordination is a vital part of what it means to be a viable system. If an individual player and their behaviour is conceptualised as an oscillating system, then a collection of such players (team) could have their coordination with each other described and modified by application of the Kuramoto model. If, for instance, their individual behaviour was such that the whole team was becoming uncoordinated, then the application of what the Kuramoto model proposes would serve to restore that coordination.	Coordination is only one aspect of what a viable system must possess to instantiate its viability and the Kuramoto model only deals with that aspect. Moreover, it relies on treating the behaviour of a player, and that of the whole team of players as oscillating systems. The model does not explicitly cover why any oscillator would behave with the periodicity it does (e.g. by reference to how it is connected to its environment) i.e. no policy aspect, let alone any other attribute essential to system viability.

Paradigm	What it is	Relevant to the VSM	Equivalent to the entire VSM	Explanation	The case for its use	The case against its use
Kohonen Neural Networks (KNN)	A type of neural network that performs clustering and also known as a Self Organising Map, that are trained using competitive learning (i.e. nodes in the network compete for rights so that they can respond to input data) that works in a manner to increase the specialisation of each node in the network. KNN can be used to cluster data into groups where the groups are not known at the outset i.e. for a given set of input data, a KNN will finish with a small set of specific units that relate to many observations, and many more units that do not relate to some observations. When the KNN is trained each input node competes with all the others to win each output node. KNN's feature two layers (input and output), where all input nodes are connected to all output nodes and those connections have different (random) weights.	Yes - partially	No	The paradigm represents how unsupervised learning may be used to cluster similar data together into clusters using competitive forces between the nodes in the input layer and the records in the output layer by updating the weights of the connections between them as the training of the KNN iterates over time. The output of the process being records in the output layer that are disconnected from each other in that layer that will exhibit a comparatively stronger response to the inputs received than others, thus 'winning' by being the answer the KNN gives for the input it has received.	KNNs could conceivably be used to imbue a viable system with a learning function by being introduced as the coupling between System 4 (Intelligence) and System 3 (Delivery Management) functional aspects of it. In this respect, System 5 (Policy) could potentially be described by the action of a KNN. That could then serve to guide a viable system (comprised of viable systems) such as a football team about the pitch and make appropriate recommendations to the team as to the best course of action it should take based upon the inputs currently being received and the KNN being configured the way that it currently is.	KNNs are only representative of how one might implement a learning policy function for a viable system. They do not feature any other aspect that is essential to systemic viability that is contributed by the necessary components to that end as described in the viable system model, and their affects upon the policy dynamic of the total system. As such KNNs are considered incomplete in comparison to the provisions of the VSM. This being the case since a KNN serves to only partially characterise a truly viable system. Moreover, how the recommendations of the KNN would be disseminated to each player involved in a football team for them to consider and/or abide by remains an open question.

Paradigm	What it is	Relevant to the VSM	Equivalent to the entire VSM	Explanation	The case for its use	The case against its use
Kohonen Neural Networks (KNN) (continued)	When a node competes and wins, during training for the KNN, the weights between input and output nodes are adjusted to match the pattern of predicted values for an output record. Over time the adjustments become small. The result is similar output nodes should be close together; in contrast, dissimilar nodes are broadly dispersed thus producing the clustering alluded to above.					This being in addition to whether or not the KNN could be configured to learn and make its recommendations in time for them to possibly be acted upon, rather than be received and an attempt to act upon them being carried out after the point when they might have been most useful to the team.

Definition and explanation with appropriate acknowledgement to: https://en.wikipedia.org/wiki/Self-organizing_map under Creative Commons Attribution-ShareAlike License: https://creativecommons.org/licenses/by-sa/3.0/ also https://www.ibm.com/support/knowledgecenter/en/SS3RA7_15.0.0/com.ibm.spss.modeler.help/kohonennode_general.htm and http://mnemstudio.org/neural-networks-kohonen-self-organizing-maps.htm

1.5 Literature review

Viable systems are systems that survive in their environment, the classic example of this being a human being. Yet, according to viable systems theory (Beer, 1981, 1984, 1985, 1994d, 1994e) such survival is predicated by the presence and effective and efficient interoperation of certain fundamental sub-systems that synergise to produce that property. This is to say that the viability of a viable system is autopoietic i.e. it produces itself via its own effective and efficient organisation to sustain its own survival in accordance with its purpose.

Beer (1959, p.15-16) considered organisations as, "*exceedingly complex probabilistic systems…* (where)… *making a change scatters influences in all directions*". Moreover, Beer (1959, p.16) opined that "*what those influences encounter and how the whole system settles down into a new balance cannot be exactly predicted*". This is to say that as the number of participants within an organisation and their interconnections increases then the less accurate the prediction of organisational balance will become.

As a general example, if one has a situation where two people are in a room and a fire breaks out there, then they will follow the prescribed evacuation plan by leaving the room by the nearest exit. As much is obvious, but what if the situation is desperate and the exit door is blocked? Some may argue that the people involved represent a comparatively deterministic system. Yet, each participant is, intrinsically, an exceedingly complex probabilistic system and the modes of interaction between them are myriad.

This means that the system as a whole (the interacting participants) will exhibit the emergent properties (Johnson, 2001) of their interactions. This is an attribute of their interaction that no single participant can instantiate alone – there is mutual self-reliance to cause the total system to do what it does for the common good of all concerned.

The plan to deal with that emergency situation (deterministic in its nature) assumes that the door will not be blocked should the anticipated emergency (fire in the room) arise. Yet, there is still a need to evacuate the room despite the obstacle. The people in the room have to escape but they cannot via the official plan of action. One of them determines that they can climb up and reach a window and, once up on the ledge with the window open, then give their colleague a hand up to escape from the room also.

The point being here is that the two people involved adapted to their environment in accordance with their survival imperative for sure. Yet, on a subtle level, the pair did behave as a unified system of two components with a common aim that organised themselves both with respect to each other and their common situation to bypass an ineffective plan by creating and enacting something ultimately better than that under those circumstances.

The official plan did not have requisite variety (Ashby, 1957) over the situation that arose, so the unofficial plan synthesised variety to deal with it as it arose, thus illustrating the advocacy of adaptation and cautioning against the stoic belief that a static plan will always be best.

Yet the plan (as a system to prescribe a means of escape) nevertheless accorded with the Conant-Ashby theorem (Conant and Ashby, 1970) in that it possessed a regulatory model of the anticipated situation that was deemed to be sufficient to assure requisite control over it. The plan (as systematic means of escape) was deemed adequate and fit for anticipated purpose as the designer of the plan (system for escaping) saw fit.

Moreover, and despite this, it is clear that the anticipatory nature of the plan was in some way deficient since there was no provision within it to deal with the blocked door at the initial threat assessment stage, nor did subsequent evaluation and any possible alterations that took place account for the situation where the exit was blocked. It nevertheless did become blocked, the situation changed, and the plan to deal with its ilk became instantly redundant – in some respects echoing Beer's notion of '*Absolutum, Obsoletum*' (if it works, it's out of date) (Beer, 1981).

Although the arrangement of the two people in the room described does not perhaps at first blush adhere to Beer's notion of an "*exceedingly complex probabilistic system*" (Beer, 1959, p.17), it is nevertheless contended to do so. This is on the grounds that if it is scaled up to include many participants with many interconnections (or perhaps comparatively few participants but with the many interconnections between them varying in a highly dynamical manner), then that denotes such complex (many connections of varying weight, direction and duration) and probabilistic (uncertainty in the output produced by interactions across those connections) behaviour..

Moreover, it is intriguing to note that Beer explains that such systems though "*not alive… has to behave very much like a living organism*" citing a company as a prime example of this.

This is illustrated by the example offered above, in that the unified system of two components was dependent upon each of those working in suitable harmony towards the outcome that was desired by both of them, yet was not achievable by one of them in isolation, either at all or not without some considerable difficulty.

Although both participants are alive, the effects of the cooperative agenda of the components betokens a characteristic of the total system that they belong to with the output characteristic of that total system being its survival (both participants, hence the entire system, escaped the room). The emergent behaviour of the total system is indicative of the "aliveness", not only of the participants individually, but also that of the pair of them classified as a self-contained system. The "aliveness" is characteristic of the emergent system. It is the common policy of the participants and how it varied as they, jointly and severally, did what they needed to do for themselves and each other whilst their dynamically adaptive escape plan unfolded.

From that contention, one may ascribe that attribute as the net performative output state (the net output variety of the system of two interacting people) and its behaviour. Moreover, it establishes the foundation of the notion that if such an attribute could be analysed on that basis and compared with a self-contained and natural instantiation of a viable system (e.g. a person), then the emergent and actual characteristics of viable systems that feature "aliveness" could be compared and contrasted.

It is a short step from considering the scenario of people in the room having to organise themselves as a unit with respect to a common survival objective, and its analogy to groups of people that similarly have to organise themselves with respect to their own survival imperative i.e. a football team and its need to win.

Commercial (see Beer, 1959; 1967; 1974b, 1976, 1981, 1985) and governmental (see Beer, 1974a and, specifically, Beer, 1981) concerns seem to be most prevalent in Beer's corpus of work. There is no specific mention of the cybernetics of football teams (or competitive field sports in general) in the role of an exceedingly complex probabilistic system that exhibits the attributes of aliveness, and what specifically quantified property denotes that (although see Beer, 1959, p.27 in respect of football team captaincy and Beer, 1994a, p.277 concerning rugby teams).

This may be attributed to the main focus of Beer's work lying elsewhere and possibly symptomatic of an absence of data pertaining to such viable systems that precluded dynamical analysis of them. It is easy to envisage, for example, the difficulties of coding, quantifying, measuring and analysing data for a manufacturing company, or the Health Service (Beer, 1985, p.76-77) as the viable dynamical systems that they are.

Yet, in the case of competitive systems, they are contended to exhibit the aliveness that Beer alludes to. They are federated viable systems of viable systems that adhere to a common teleological (purposeful) imperative that can be equated to their survival criterion i.e. their success in winning a game.

They are also contended to represent a direct (albeit in microcosm) analogy with two firms that compete for a single scarce resource (e.g. one client who has narrowed their choice of suppliers for a £20M computer system to two possible vendors). Both firms are exceedingly complex probabilistic systems, and the net output variety (the output state produced by them) of both competing firms will dynamically vary through Ashbean phase space (the conceptual space where all states that can be exhibited by such systems can exist) as they each make efforts to succeed in their objective at the expense of their respective competitor.

As such not only is a football team a viable system by Beer's definition, it is also an exceedingly complex probabilistic one that adapts to its environment continuously in just the same way as a firm.

Although firms feature management, and provision is made for this within the VSM in the form of the Metasystem at each level of recursion, it is interesting to consider that whilst a football team is in play, the manager of the team is disconnected from what is actually happening in a performative sense.

The team operates in a manner to self-regulate itself with respect to the opposition, thereby providing themselves with an advantage whilst placing the opponent at a disadvantage. Beer (Beer, 1967) opined that "*such a mechanism that arranges its own stability is of interest to management*", but there is nothing within Beer's work that explores this aspect in a sports context.

Yet it is clear that how a team self-organises in its capacity as a viable system to regulate itself with respect to its opponents really is an important consideration in that domain.

In the case of a football team, there are 11 players involved (usually). Given the pace of decision making in anticipation and response to their individual and collective environmental conditions (the pace and actual dynamic content of the game), this corresponds to much spatial reconfiguration whether a particular player on a particular team has possession of the ball or not.

Indeed, most of the activity that exists within the game is spatiotemporal with a view to controlling the opposing teams' activities, and a considerable amount of that is generated even though only one of their numbers has possession of the ball at any time.

If one considers each player as a viable system, then they will each have isomorphy with the provisions of the viable system model. The spatiotemporal activity displayed by them is contended to be the enactment of their policy as that viable system, and that is based upon their assessment of the conditions of their environment (See Kim, 1993).

The player's intelligence function is coupled to their delivery management function and dynamically varied as conditions dictate. The coupling is the player's policy as a viable system and this manifests itself as its own continually changing trajectory about the football pitch.

Accordingly, position is equivalent to policy in this scenario and the characteristics of that policy correspond to the instantiation of the viable system model that the player is isomorphic with.

As such, this means that by analysing player trajectory (in its role as the policy of a de facto viable system), then one may thereby discern the policy attribute of the de facto organisational template that it is aligned with. Moreover, one may do this without having to entertain the prospect of entering the varietal black box that the player and their neuronal configurations (i.e. the configurations of the connections between a players senses and motor responses formed by connections in the brain that defines the policy they enact) represent.

This is contended to address not only an analytical difficulty whilst obeying Beer's first regulatory aphorism ("*it is not necessary to enter the black box to understand the nature of the function it performs*") (Beer, 1985). On the contrary, it is also contended to address the absence of how, in the context of a firm, say, it's policy (as a viable system with a trajectory through its own varietal phase space (Ashby, 1957) can be determined). Moreover, how this may be quantified, monitored and compared over time in the absence of prescriptive methods of doing so, other than perhaps adoption of Beer's performance index scheme (Beer, 1981).

To be sure, this would require significant overhead on the part of the firm to migrate to the scheme, despite the advantages of doing so, and that itself may well be a barrier to analysis of it. Indeed, it is difficult to envisage how one might otherwise codify, quantify, capture, analyse and characterise viable system policy data for other, ostensibly viable systems such as a firm, university or government in the round.

Yet, the data relating to the policy of multiple viable systems of viable systems for which high volume objective data is, in contrast, available and does bypass such barrier to analysis. Accordingly, it lends itself to extraction of the dynamical characteristics of what it means to be effectively organised in concert with the provisions of the viable system model and, thereby, provide insight into the dynamical characteristics of that.

Examination of Beer's myriad books and papers held in the Special Collections Archive at Liverpool John Moores University has revealed that there is an absence of specific evidence to support how a viable system may be characterised as it navigates Ashbean phase space in real time. Yet, they most definitely reveal the scope of how this might be achieved provided that appropriate data in sufficient volume were available.

Indeed, this situation persists amongst others who have closely examined Beer's work in both a theoretical and conventionally practical sense (see Azadeh et al, 2012; Burgess et al, 2013; Hilder, 1995; Hoverstadt et al, 2007; Hoverstadt, 2008; Jackson, 2000; Leonard, 1992; Piffner, 2010; Yolles, 1999 and Vidgen, 1998).

The viable system model is advanced as the de facto master template of effective organisation of any organisation and, as such, enshrines the common laws that all organisations follow (to a lesser or greater extent). As such, one would expect a feature that betokens what the viable system model prescribes to feature a common characteristic of operation across a diversity of ostensibly different types of organisation.

Yet the literature does not feature any aspect of what the policy that causes the system to do what it does actually looks like, let alone how it varies over time and, it is admittedly inferred from this, that this is due to an absence of data to at least attempt an analysis.

This is despite such literature describing very novel use of the Viable System Model outside of its usual target area in a computing sense (in particular see Laws et al, 2006 and Thompson et al, 2010 but also Amcoff Nyström, 2006, Leonard, 1993 and Herring et al, 2000), and also in an information systems sense (Richter et al, 2014).

Accordingly, it begs the question of how one might approach an organisation that follows the precepts of the viable system model and then request how the overall net varietal state of the organisation (its viability) is expressed, without resort to financial metrics (say). Moreover, if it was available, then how might one readily, and entirely objectively, compare and contrast such organisations on that basis with others operating in the same environmental domain simultaneously.

Perusal of video footage of Beer (Falcondale Lecture Series Sessions 1-9, 1994; WOSCORG, 2012a-f;) does not refer to what is proposed by this author in terms of the pursuit of an operational characteristic that betokens a viable system, thereby that of the Viable System Model, by reference to its net performative (hence varietal) output.

Specifically, Session 9 in the Falcondale series relates to Syntegration (a consensus based decision making protocol for use by a policy making unit within a viable system to balance the 'inside and now' with the 'outside and then').

The account refers to the principles of how and why the protocol operates as it does, with the output of the various iterations of it being the consensually approved policies of the viable system into which it is embedded.

As such, if those policies were codified and quantified into a form into which they could be analysed over time then one would be able to discern the policy characteristic of the associated viable system develop with respect to its environment, despite the protocol receiving criticism from some quarters (Jackson, 2000).

Yet despite the efficacy of the protocol, it takes a number of days to iterate each stage of it, which, for a cybernetically viable complex adaptive system that needs to expedite policy decisions continuously in real time since the highly dynamical nature of its operational environment demands it, may be too pedestrian.

It is interesting to note, however, that the nearest equivalent to what this authors work has sought to address (on a real time basis) was proposed and described by Beer (see Espejo and Harnden (eds), 1989). This was in terms of the measurement of Eudemony (well-being of the population – Beer, 1974a) as part of the Cyberfolk (see Beer, 1972a, 1972e also Pickering, 2010, p.269-273) component initiative of the Chilean Cybersyn experiment 1971-73 (See Beer, 1981 also Medina, 2011).

It may be argued here that aggregation of national eudemony amongst the population of Chile in response to government broadcasts relating to issues of concern, provided a single algedonic (pleasure / pain) metric. The proposed system would have done this as the government navigated a trajectory through Ashbean phase space (in a eudemic context) whilst the people and the government operated under consensually approved reciprocal level of homeostatic control in real time via local and national telecommunication links.

The rationale being that the algedonic signals as represented by the level of eudemony was expressed by government to people and by people to government and both parties came to a consensus.

As such the single eudemic metric would have perhaps corresponded to the characteristics of the balance between the 'inside and now' (the Chilean people) and the 'outside and then' the government as the interface of the people to the environment the country operated in as a viable system in matters to do with national eudemony. Accordingly, the scheme as depicted in the literature does have a parallel within respect to the contribution to the body of knowledge offered by this author i.e. that the single metric that betokens system policy is spatiotemporally, rather than endemically, defined.

Despite this though, and at some level, the spatiotemporal aspect could nevertheless cause an algedonic response from the players involved in a football match. They might either be very satisfied with their own actions and those of their team mates in those terms (e.g. an impressive spatiotemporally coordinated effort prior to scoring a goal). Conversely, they express gross dissatisfaction with something that somebody should have, and could have, been in position to take advantage of a clear opportunity and was very conspicuous by their absence from that location.

It is argued that this has a repercussive effect upon morale, but also upon the continued use or otherwise of particular spatiotemporal configurations that betoken enacted tactics, colloquially referred to as ‘set pieces’ usually invoked under particular circumstances.

Although a football team is a viable system i.e. an organisation that can survive in its environment (Beer, 1985, p.1) (team), of viable systems (team functions) of viable systems (team players), it is also a self-organising complex adaptive system (see Miller, et al 2007) in its own right.

There are accounts in the literature of such self organising systems in nature such as colonies of ants (Bonabeau et al, 1997; Detrain et al, 2006, Jackson et al, 2006) and bees (Camazine et al, 1991; O’Malley, 2010) that also qualify as similarly structured and populated viable systems.

Accordingly, it is clear that if one can suitably analyse the behavioural patterns of such systems, whilst under environmental load conditions, then one actually discerns their net policy output of the viable system that they are and, thereby, the viable system model that they map to (are isomorphic with).

As each ant, say, undertakes its duties they each inform (and are informed by) other ants in their colony mostly, although not always, via evaporative pheromone trails. Such trails serve to mediate localised, and ultimately global, action by the colony with respect to a common objective (e.g. foraging for food – an essential prerequisite to their survival as a viable system).

The rate of evaporation of these pheromone trails identifies to each ant the most profitable trail; with more currently profitable ones pheremonally reinforced whilst the less profitable others remain un-reinforced and are left to evaporate.

As each ant moves in cognisance of the pheromone trail, say, one may witness their policy as an individual viable system being enacted, but it is contented that when one views the policy of all of the ants on the same basis then the policy characteristics of the viable system that the entire colony is may similarly be discerned.

The behaviour (enacted policy) of the self-organising system in the pursuit of its purpose in response to an entirely emergent (Johnson, 2001) agent of common coordination (the pheromone trails and their relative strength) serves to enable characterisation of the viable system that it is. Indeed, the pheromone trail could be construed as a continually adaptive coordinative function for the ant colony concerned, which is an essential prerequisite in a systems cybernetic viability (please see Section 3.2.3 p.100)

Moreover, it is contended to be an intuitive notion that a concept such as this could be scaled back to groups of people with a common goal in their own environment that is similarly defined in two-dimensional space. This aspect also features the added benefit that a comparative handful of people are more easily measured and their data captured, than the machinations of a million plus ants (an exercise in variety engineering itself).

A counterpoint to that argument may be that one might take a sample of ants and analyse them. This would be agreeable at some level if considering that sample as a self-contained system, but the system under study might need to be the whole colony and hence what that does. To analyse a sample, and make inferences about it, could possibly weaken the analysis since it exposes the system being studied to the perils of the reductionist approach i.e. some essence of the system is lost in the process of its dissection. Moreover, if a technology exists to capture the data of the system as a whole for subsequent analysis, then it would make sense to use it for the entire system and not just a part of it.

In respect of the human based viable system, the individual people (viable systems) can be envisaged to use visual cues of each other’s position and other real time communicative means (see LeCouteur et al, 2011) as a means of how they spatially organise themselves continuously as analogous with the movement of the ants.

Yet what has not been discussed here thus far is the fact that the ants operate in a comparatively static environment whilst foraging for food, thus limiting the scope of analysis to examining its behaviour whilst perhaps not under threat conditions. This is an important consideration in people based organisations such as businesses and teams since they operate in a competitive milieu and hence implicit threat.

Moreover, this aspect is crucial in viable systems theory, since for viability to be sustained the viable system has to keep pace with and respond to environmental conditions otherwise its viability will be compromised.

Accordingly, by analysing the machinations of two opposing viable systems that interact competitively with each other in real time, one may reveal insight into the viable system policy formation characteristics of them under load conditions.

As teams, like the ants, qualify as viable systems but also as self-organising complex adaptive systems (see Mitchell, 2009) then they will feature the acknowledged characteristics of such systems i.e. a power law.

According to both Mitchell (2009) and Newman (2013), power laws are ubiquitous in nature and indicate the presence of systems that self-organise (i.e. those systems that feature no source of centralised control, the activities of which emerge through the interaction of participatory factors e.g. earthquakes and their frequency of occurrence).

Both references highlighted Zipf's law as a power law that is exhibited by various text-based material that appears to have ubiquity across different language barriers. Additionally, this was also identified and reported by Ausloos (Ausloos, 2008) in the comparison of natural languages (English) and (intriguingly) artificial languages (Esperanto).

Moreover, authors based at the Santa Fe Institute for Complexity studies have commented upon the universality of Zipf's Law in communication (Corominas-Murta, 2010a; 2010b). This is in some way endorsed by the work of Galbaix (Galbaix, 1999) in the applicability of Zipf's law to the growth of cities (see also Gómez-Liévano et al, 2012), despite the work of Kuninaka (Kuninaka et al, 2008) reporting a break down in Zipf's Law in Rank-Size distributions of Cities.

What has been, and is, especially compelling is the universality of Zipf's law especially in the context of artificial languages. Indeed, as will be covered later in this work, one can legitimately equate movement of a viable system (football player) with their policy. Yet, such policy serves to inform, and be informed by, the policy of other players in the absence (for the most part) of direct verbal (effectively articulated text) communication amongst them.

Rather, the communicative language between the football players is mostly confined to responses to each other's activities in the positions on the pitch that they take place at.

Since pitch position is policy for such viable systems, then that also represents the information that precipitates suitable change in other viable systems. From that, it is reasonable to consider pitch position as the equivalent of the words in a conversation between the two.

Moreover, such policy manifestations are argued to represent the spatiotemporally based variety of each player but also, if such values are measured for all players simultaneously, then one can capture the variety of the whole team and analyse it accordingly.

This proposition of pitch position as viable system policy has direct analogy with the printed word on the page and the reader of it – all of which lend themselves to Zipfian lexical analysis. Moreover, it opens up consideration of how much information each interacting system generates with respect to each other on that basis, to imbue the necessary changes in the conversing systems involved and how that corresponds to outcomes for them.

This is not only founded on information being classified as "*that which changes us*" (Beer, 1994e, p.283) and that corresponds to the amount of negentropy (Beer, 1994a p.347) that it betokens but also, as Mitchell (Mitchell, 2009, p.54) observes "*the average amount of surprise*" it represents to a recipient of it – an important consideration in competitive sports since such surprise represents a tactical advantage.

Yet review of viable systems literature reveals that power-law like behaviour exhibited by individual viable systems within encapsulating viable systems has not been sought and, as such, there appears to have been no attempt to correlate performative policy characteristics with a target viable system's criterion of viability operating in real time under dynamical load conditions.

Moreover, in complex systems literature such viable systems (albeit not explicitly classified as such) are the subject of analysis (insect colonies as described but also in rat pups (May et al, 2006) and people (Arrow et al. 2000; Duarte et al, 2012; Duarte et al, 2013; Goldstone et al, 2006; Kelso, 1995).

As such, in this respect, there seems to be something of a disconnection between viable systems theory and complex systems theory, yet both are clearly related, A possible exception to this being the work of Haggerty (Haggerty, 1988). Indeed, it is interesting to note Haggerty's work in contextualising the viable system model in a footballing domain, but such work does not relate to the focus of this author's work or the approach to analysis and actual results that underpins it.

As this work deals with human beings as viable systems and how what they actually do in the world is the manifestation of their respective policies as viable systems, it was essential that consultation was undertaken with cyberneticians operating in that particular area.

Personal communication (Adams, 2014; Leonard, 2014; Malik, 2014 and Piffner, 2014) was entered into concerning real time policy formation in viable systems (as being the total output characteristic of what such systems actually do). This provided valuable insight concerning the knowledge of whether or not a real time policy characteristic for the viable system model had ever been attempted or actually extracted.

All of this correspondence revealed that, as far as each respondent was aware, no such work had ever been carried out before. Moreover, despite the fact that little mention of football in the context of the viable system model and cybernetics in general is given in Beer's work, Allenna Leonard has commented in some personal correspondence with the author that such an investigative topic would nevertheless be interesting to carry out (Leonard, 2014).

Accordingly, this work has sought to address that to the extent that what it advances might be of practical use to those dealing with groups of people in highly dynamic competitive environments.

There is a huge volume of literature relating to the VSM. Most of it, unsurprisingly enough, relates to the function of management of various types of organisations that are populated, hence instantiated, by humans.

Despite this, there are a few notable exceptions that have taken Beer's perhaps most famous work and have applied it within a diversity of novel and interesting fields of endeavour, such as attempted fusion of the VSM with the notion of algorithmic hot swapping in the field of adaptive software systems (Laws et al, 2006; Thompson et al, 2010).

The former category of application areas speaks profusely of organisations as dynamical systemic entities that seek to survive in their environment; such survival being in accordance with a given or stated survival criterion that is then equated with what, for the system in focus, it actually means to be viable for that particular system. Yet there is little if any data to support any actual findings that relate to that dynamical nature, let alone the characteristics of the VSM that such systems can be represented by. In terms of the latter category of application areas, the example pertaining to software engineering alludes to the systemic dynamism as advocated by the model but is not human based.

Yet, the fact remains that the majority of case studies that are in the public domain, and are accessible to the body of knowledge, relate to the mechanisms and organisational provisions that Beer proposed should be present and suitably interoperable. They seldom, if ever, relate to a real organisation operating in a real environment that is confronted with real situations that could, and often do, conspire to compromise its survival within that milieu on a truly continuous and dynamically varying basis.

Accordingly, the literature review undertaken has highlighted that there is a paucity of research relating to the real time dynamical characteristics of systems that are, or have been, explicitly and fully isomorphically aligned with the VSM in theoretical terms where there are large volumes of data that can be mined to discern the characteristics of viability. Beer (Beer, 1984) states that "*other scientists around the world have confirmed the VSM in various modes and situations; most but not all of these being managerial in nature*". The literature review has revealed that this state of affairs persists to this day. That fact simultaneously defines the motivation to address this situation; it also raises the challenges of doing so.

1.6 Motivation

There are myriad texts that cover what a viable system is and what it should do. There are also many such publications that describe what the VSM is and does. Yet there appears to be a small gap in the body of knowledge, since in terms of the degree to which a real cybernetically viable system is aligned to the provisions of the VSM to a greater or lesser extent, there appears to be nothing that characterizes or measures it.

The literature reveals that direct cybernetic intervention of an organization, say, will reveal aspects that cause it to deviate from what the VSM recommends for it to be genuinely viable. From this, appropriate corrective action may be taken.

Yet, there appears to be a small gap in the body of knowledge in the form of an absence of studies that specifically relate to the actual dynamics of the balance that real viable systems, hence the VSM that represents them, maintains with their environment whilst under dynamical load conditions.

The pre-intervention version of the organization will have had a net relationship with its environment that was defined by the extent to which it was effectively organized to instantiate and operate it. This is relationship will therefore have the hallmarks of the extent of that effective organization.

The post intervention version of the organisation will also have a net relationship with its environment, but this will now be different in its characteristics. The reason for this is that since it has been more closely aligned with the VSM, it has become more effectively organized to do what it exists to do.

Yet how can the difference be measured i.e. how can the organizations degree of isomorphy with the VSM be quantified such that one may say that it is more or less effectively organized, hence more or less viable.

In many respects, the problem is intractable since hitherto the necessary mechanisms and data seem to be unavailable to undertake a study. This was considered to be something of an analytical barrier that the VSM was concealed behind in many respects, and it was speculated that this was the reason for the gap in the body of knowledge.

Yet, an opportunity was identified that suggested that it would be possible to break that barrier by considering viable systems, hence the viable system model, differently.

In this respect, and as will be seen, cybernetic theory itself was re-applied to the viable system model and a research hypothesis formed from there that rendered it amenable to analysis. This was by virtue of the copious amounts of data available that was available for the target systems studied, and how they could be thought about in terms of cybernetically viable systems.

Accordingly, the motivation of this work was to address the small gap in the body of knowledge identified by taking a novel approach to VSM theory and placing it firmly in real viable systems practice. Moreover, this was enhanced by having the opportunity to provide copious amounts of data to support any findings made, that perhaps would have been otherwise unused in this context.

1.7 Research Questions

This work fundamentally seeks to answer two questions:

1) What does the policy dynamics of a real viable system look like whilst under varying dynamic load conditions and is it a common characteristic that can be ascribed to the VSM?

2) How does (1) relate to its degree of success or failure as defined by the extent of how well organized it is to accomplish its objectives i.e. what is the systems degree of isomorphy with the VSM that represents it as it achieves success or sustains failure as defined by its purpose?

1.8 Research Approach

This work has taken an arguably unusual approach in attempting to answer the research questions, by considering the activities of football teams. Justification for this is that a football team is a systemic structure that is comprised of component parts that are de facto viable systems i.e. players.

Yet, a football team considered in systemic terms is a viable system in its own right. It is a viable system that manifests itself as a result of the presence and interaction of the players. The purpose of each player is aligned with the purpose of every other player on their team. This defines the aggregated unity of purpose that defines what the team as a whole exists to achieve. The team may be regarded as an abstract systemic construct that nevertheless has a tangible purpose.

Although a football player is analytically intractable in viable systems terms, what data is available about them is their policy. This is argued to be their position on the pitch from which point they take, or are taking, appropriate action.

The rationale for this being that each player has autonomy to be where they are on the pitch in order to do what they need to do to ultimately fulfil their purpose, and that of their team, in that particular match.

Yet a football team can also be, and usually is, demarcated into sub-groups of players and each of those groups have specific functions within the team e.g. Attack, Midfield and Defence. As such, each group is a smaller version of the whole team that is, and operates as, a viable system within it.

Accordingly, in this example a whole team is a viable system that is comprised of three component viable systems (Attack, Midfield and Defence) and each of those viable systems are themselves comprised of viable systems in the form of players.

As such, not only does a player have a policy, so too does the function they are a member of and ultimately they aggregate to form the purpose of the whole team. This means that there is an opportunity to characterize the policies of such viable systems via player tracking technology.

Here, by tracking the individual movements of each player, one may also compute policies for their allocated group and for the whole team. This can nominate a particular target team and then monitor its policy dynamics, and those of its various opponents, simultaneously and in real time for every match they played in one or more football seasons.

This is a particularly important aspect since the environment of one team is defined by the presence and operation of the other as they each simultaneously act in a manner to advance their own interests at the expense of the other.

By considering movement as policy at all levels within the team, one is effectively treating the viable system model that each level can be represented by as a black box (Ashby, 1957, p.86). That is to say, the movement is a result of input being translated into output in the form of motion without specific knowledge of the connections between the two that are responsible. Indeed, Beer (Beer, 1973b) stated that "*However complicated a system may be, there is one output state that defines it"*.

In taking this view, the viable system model itself becomes the wiring of the black box that connects input to output. It is here that if an organization is less than effectively organized (comparatively less viable) then the wiring would have been in some way deficient, and this would manifest itself as the policy (movement in this case) that was outputted. Conversely, if the wiring was in full compliance with the VSM then the organization would be effectively organized to accomplish its purpose as possible and this too should manifest itself as policy.

Prozone Sports Ltd is a vendor of football match data capture and analysis systems that have prominent use worldwide, but also within the English Premier Football League. An industrial partnership was established with Prozone which provided player movement data for an anonymous, randomly selected football team and all of their opponents for a full football season that was also unknown and randomly selected.

Software was written (please see Appendix 7 commencing on p.527) to enable the data files for each match to be read and to carry out the necessary policy computations for the Attack, Midfield and Defence subgroups of the target team, as well as that for the whole team. The results produced were then manipulated and analysed to attempt to discern any useful characteristics that could be correlated to success or failure in each match played and findings were then evaluated.

1.9 Research Scope

This work is specifically confined to the Viable System Model and hence what it means to be cybernetically viable.

Although it has used football as a means of analysis, the work is not a study in football as such.

As has been stated, a football team is a viable system and it maps to Beer's VSM, but it also has a myriad of data available as it acts to regulate its activity under highly dynamical threat conditions. Moreover, that data is captured in copious amounts in real time with high accuracy.

The data describes how a viable system is organizing itself in real time with respect to another and where both have a diametrically opposing purpose to each other. This is something that further differentiates this work, since it is very sobering to consider how one might capture the same or similar data for other types of viable systems as they compete in their environments e.g. Businesses of various size, or perhaps Universities.

Both are, ostensibly at least, viable systems in their own environments, but what is the net output state that defines either of them as a result of their respective policies? This difficulty is not only just in terms of the varying scale of operation of such organizations, but also in what data, if any, is available and how that might be captured. Yet both are viable systems that map to the VSM so would be amenable to analysis if the similar real time data was available that characterized the true essence of what they actually do.

This is the strength of the football data since what is done is what is captured. Although the approach to research has, by nature of the systems associated with the data, apparently focused upon football, this is not strictly the case.

Indeed, the focus of the work is to determine how effectively organized a target system is in consonance with Beer's VSM in general terms, and hence what might characterize viability in general. It does this in the context of a specific and measurable success criterion.

Football is a means of analysis to that end since it abstracts the investigation from the problems of undertaking the same study for other types of organization that are nonetheless viable, as alluded to above.

1.10 Research Aims and Objectives

To capture the policy dynamics of truly cybernetically viable systems that aligns to a greater or lesser extent with the provisions of the VSM and to characterize that. This is to then be aligned with that system's nominated criteria of success (as defined by its purpose).

This is with a view to discerning how the degree of alignment that the target system has with the VSM is translated into its policy. From there exploration of how that policy is correlated to either its success or failure (its viability) in its environment is to be undertaken. Accordingly, the aim is to expedite a measure of how effectively organized the system is to accomplish what it does, and to compare and contrast this between opposing systems.

1.11 Contribution to the body of knowledge

The contribution that this work makes to the body of knowledge is to use the self-organising spatial dynamics of a football team operating under load conditions to search for and obtain a power law that describes that activity and hence characterises the output of the policy function of the VSM that it maps to.

In this respect, the work seeks to extract a policy feature of the model itself as it balances its external demands with its internal resources to deliver against them, and it uses a football team as a proxy to accomplish this.

Since a football team is fully isomorphic with the VSM it is an eminently suitable candidate to study how the balance alluded to corresponds to a fixed criterion of viability i.e. the success enjoyed by the team in terms of goals scored and the failure it sustains in the form of goals conceded.

Yet such teams are self-organising systems that either exert or subvert control over a match as it unfolds, such that the prevailing match situation becomes regulated to either team's advantage.

The movement of each player serves to inform, and be informed by, the movement of every other player.

This corresponds to self-organising behaviour underpinned by changes in player position and that is communicated to every other player, with each of them taking largely autonomous action in response to, or in anticipation of that.

Accordingly, there is an amount of Information that is associated with such communication that is continually generated and consumed by the players involved, and hence is associated with their respective teams as a whole, as they attempt to regulate their situation to their advantage. Yet, this

Information also serves to characterise the degree of order (hence Organisedness) associated with what a team actually does.

As such, by analysing a football team in this way, one can descend directly into how a viable system regulates itself (hence is dynamically organised and re-organised) with respect to its environment in real time, with the environment of one team defined by the presence and activity of the other.

The diametrically opposing efforts in this respect are readily quantifiable in terms of the number of goals scored or conceded by a target team.

Hence this study facilitates a quantitative analysis of not only how the parameters of the power law sought may be associated with either outcome type, but also how much Information is present as they attempt reciprocal control over each other.

The balance of this control is argued to correspond to target team success or failure as applicable, and hence to its cybernetic viability, and the work explores this aspect.

1.12 Thesis Structure

The remainder of this work is organised into seven chapters.

Chapter 2 deals with the notion of systems, complex adaptive systems, emergence and self-organisation and the hallmarks thereof. This is to establish the case for the study of complex adaptive systems in the context of the VSM.

Chapter 3 covers what a viable system is, how the VSM is used in relation to the very concept of viability. It examines how the provisions of the VSM relate to the structure and operation of a football team in a function specific and data interchange manner and, how those explanations can be fused together. This is with a view to providing an illustrative example that makes the case for a football team being considered as a system that is fully isomorphic with the VSM. It makes the case for the self-organising characteristics of football teams being equivalent to the operational characteristic of the VSM that can be used to describe them.

Chapter 4 deals with how the necessary experimentation work was undertaken. It also reveals the background to the data capture technology and system used to collate the data used in this work.

Chapter 5 presents what findings were obtained.

Chapter 6 provides an evaluation of the work undertaken and a conclusion in respect of the findings.

Chapter 7 provides an illustration of what the future developments in the work could be in both sports specific and other areas.

Seven appendices are included:

Appendix 1 – Actual policy characteristics and results:

Appendix 2 – Emergent policy characteristics and results:

Appendix 3 – Amount of data underpinning policy characteristics graphs

Appendix 4 – Regression line parameters for each team in each match.

Appendix 5 – Actual Dynamics and Match Outcomes

Appendix 6 – Emergent Dynamics and Match Outcomes

Appendix 7 – Match replay Software

1.13 Summary

This chapter provides an overview of what this work is and is not. It relates specifically to the Viable System Model, what characterises viability and how a quantitative analysis of the attributes of that might reveal in terms of them being possibly correlated to system success or failure. It has also illustrated that absence of quantitative case studies relating to the Viable System operating under load conditions exists, hence a unique opportunity to address that.

The work has employed a suitable candidate system to assist with this aim for which a considerable amount of fully quality assured, commercial grade data is available i.e. a football team. Although a sport centric system has been employed, the work is not about such matters. Use of a football team has been made because of its nature as a viable system that is composed of viable systems that self organise to produce its own outcomes in terms of its own success or failure. In other words, the viable system that the team is, hence its viable system model representation, has a fixed purpose to win and not lose that is based upon an agreed scale of success (more viability) or failure (less viability). More viability here being representative of closer alignment of the team in action with the provisions of the viable system model, and less viability representing a departure from it.

Chapter 2 - Quantifying the Organised

2.0 Introduction

This chapter examines what systems are and how the quantification of their behaviour provides a measure of how well organised (or not, as the case may be) they are. It accomplishes by considering what systems are, how they can and do adapt depending on their nature and mode of operation and what the combined efforts of the components of such systems cause the whole system to be characterised in a particular way.

The chapter then covers how the nature of systems can be related to theoretical physics and its relationship with Information theory and how such aspects can be expressed mathematically. Accordingly, it illustrates both the theoretical and the practical underpinnings of much of the rest of this work in terms of how what Beer's Viable System Model is and does seeks to assure that a target system is an effectively organised one with respect to its purpose.

As such it provides an account of the means used in this work to quantify, compare and contrast what that actually is, what it looks like and how that can be correlated to such purpose when that is defined in terms of a football team's success or failure.

2.1 Systems

Beer (Beer, 1994e, p.7) defines a system as that which "*consists of a group of elements dynamically related in time according some coherent plan*".

This is congruent with Bogdanov's (Bogdanov, 1996, p.xxxv) view of 'Complexes' that are the result of organization i.e. "*compositions of elements organized into specific complexes by virtue of their specific inter-relationships*".

If one considers a football team one can discern from this that it is the very essence of what a system is. The players are the elements and these are dynamically related to each other in time in terms of what they actually do on the pitch at any time. Moreover, that this activity is undertaken in accordance with a plan for any particular match that they are to work within the scope of, as set out by their manager.

The system (team) produces something that characterizes the essence of what it actually exists to do. A football team is comprised of groups of people arranged in one particular configuration that is defined by a plan to produce a system designed to win and not lose. Each of them may specialise in certain skills and hence roles, but this is underpinned by the role of a generalist i.e. they are footballers first and specialists second. Those same players could be (and often are) reconfigured to produce essentially a completely team in the context of its performance i.e. some configurations of which player plays in what position and when will affect how they interact with each other and their objective. That will then serve to translate into different outcomes for that team.

In other words, the introduction of new or different players, or the same players in new or different roles, and how they interact with what is already there, does alter the characteristics of what the team actually does.

The football transfer market can be highly lucrative since a player that a team signs up will have its performance characteristics fundamentally altered by that person. The new signing may well have a very high profile and enviable international reputation as an excellent player.

Accordingly, the team they are joining may have high expectations of them and are prepared to pay the price to have that player join them. When that particular player arrives, they will doubtlessly be expected by all concerned to integrate into current and future plans for the team and how they perform.

This may go smoothly or it may not. The new signing may find it difficult to change playing style or position as required since they are temperamentally unsuited to that, or that their strengths lie elsewhere. An example of this is a newly signed former striker being required to play in midfield as their career advances and as new strikers become employed by the team.

The point being here is that not only does the performance of each component (player) intrinsically differ, the collection of those components available coupled with how they are related has a direct effect upon what is produced by the whole arrangement.

A team may well be composed of some of the most highly regarded players in the world. If, however, they are related in some way that renders the production of what they do to be somewhat deficient then this could spell disaster. One can cite many examples of this, but a notable one is the decline in the fortunes of Manchester United after the departure of Sir Alex Ferguson. To say that Manchester United were a successful team at the point of his departure is something of an understatement. They arguably had the best balance of skilled players in the world.

When Mr. David Moyes replaced him, it was then that Manchester United’s performance started to decline. This is despite the broadly acknowledged success that he was considered to have in his previous role over 11 years. Although, despite this, many Everton fans still lament the absence of any trophy acquisitions during that time.

Yet it is intriguing to note from a systems perspective that Manchester United still retained the players that they had before and were still an impressively resourced team in terms of money and facilities.

There are many speculative reasons as to why they saw that evaporation in their success, but it is hypothesized that it may have been attributed to how the new manager rearranged how the players related to each other. This may have been due to for example, changes in tactics formulated by the new incumbent, or changes made in the roles that certain players were asked to adopt.

In doing this, the essence of what the team produced was fundamentally and systemically, altered. Yet, the composition of the component players was the same: yet it started to fail to translate action into desired outcomes. Moreover, over the season concerned they lost comparatively more than they won to the point that their position in the English Premier League declined alarmingly.

One may argue that Manchester United was comparatively less well organized to accomplish their objectives than they had previously been. This is despite the fact that on face value perhaps what they were doing with the same resources as before should have been successful, at least in theory.

Yet it is interesting to note Bogdanov's view of 'Organisedness' (Bogdanov, xxxvii) here in that this was contended to have been "*dependent on the point of view of the observer*". Here, "*actions or outcomes which were organizationally positive under one set of circumstances could, equally, be organizationally negative under another*".

Indeed, in the context of football it is especially interesting to note that Bogdanov (Bogdanov, 1996, p.1) states that "*All human activities are essentially either organizational or de-organisational*", where 'to organise' is to "*collect people for some purpose, to regulate and coordinate their efforts in the light of some rational unity*".

For sure, a team manager is ostensibly in the position to accomplish this. The intentions and requirements of the manager are then represented by the team captain on the pitch. The captain then directs the activities of the players, to a greater or lesser extent, in accordance with the game plan that is, prima facie at least, coherent enough to achieve team objectives.

Although the team manager has responsibility for team composition and performance, control of that as it translates into performance minute by minute is divorced from them. The exception to that being the captain's presence on the pitch; they provide and relay managerial instructions to the players. Yet, when the players in the team (those components in that system) autonomously reconfigure their actions as the situation demands from their perspective, then the team makes a transition from something that is perhaps considered deterministic, to a complex system - and has to be treated as such.

2.2 Complex Adaptive Systems

According to Page (Page, 2011, p.24) there are many definitions and measures of what complexity is. There does appear to be, however, characteristics of such systems that are nevertheless broadly agreed upon amongst the research community.

The acknowledged world leader in complex systems research is the Santa Fe Institute (SFI) (New Mexico, USA). According to the work of Mitchell of SFI (Mitchell, 2009, pp.12-15), a complex system can be described as:

"*A network of individual components, where each component follows relatively simple rules with no central control or leader. In so doing, those components serve to produce and use information and signals from both their internal and external environments and hence adapt by changing their behaviour to improve their chances of survival. Moreover, it is the collective actions of many such components that give rise to complex, hard to predict, changing patterns of behaviour*".

2.3 Emergence

Miller and Page (Miller & Page, 2007, p.46), define emergence is a "*phenomenon whereby well-formulated aggregate behaviour arises from localized, individual behaviour*", yet this does not suggest how such aggregate behaviour represents success or failure for a system that exhibits it.

In the context of a football team, the players work individually and collectively on accomplishing their team's objective. Each player shares a common aim on behalf of their team and this defines their unity of purpose. Yet some teams are more or less successful than other teams. Various teams differ in their composition and hence the skill sets of their players.

Accordingly, the conventional view taken is that a team that perhaps has the most money can attract the best players. This can (although does not always) lead to success for that team and hence to attractive amounts of prize money.

Yet some teams fall into this category and are defeated by comparatively less well-resourced teams despite their prima facie advantages over them. The players in both teams work amongst themselves to promote their agenda whilst conspiring to defeat that of their opponent. It is very much the case that no single player can accomplish the same effect as a whole team. Accordingly, success or failure is only, and can only, be attributed to the whole team. Yet if that collective effort is superior to that of the collective effort of the opposition, then one would expect the former to be successful with respect to the latter.

This leads to the notion of one team that is perhaps less well-resourced than its opponent, working in a manner that produces that superior collective effort and that corresponding to victory over them. Bogdanov (Bogdanov, 1996, pp.68-71) considered how effective collective effort like this might manifest itself and how it might correspond to a more or less successful outcome.

Bogdanov observed that two people working together may produce more than any one of them could produce alone, but also that they could equally produce less, and, as such, what was produced was "*dependent upon the combination of their efforts*". Where a collective effort produced more than the effort of any single participant to that, Bogdanov defined this as "*the outcome was greater than the sum of the parts*" and equated this combined effort to being "o*rganized*".

Similarly, when combined effort was less than it could have been, then this referred to a less than effective combination of individual efforts that Bogdanov described as "*disorganized*", since the efforts of each individual effectively resist each other. Accordingly, it may be inferred from this that a more successful team may well be able to overcome the efforts of an ostensibly better resourced opponent if the efforts of its players are more effectively coordinated than theirs.

There are many cases of football teams that have comparatively little difficulty in defeating opponents that have far more resources at their disposal. The most recent example being the success of Leicester City Football Club in winning the English Premier League Championship for the 2015-2016 season.

Leicester was a rank outsider to win the competition at the start of the season (Stanton and Jackson, 2016), yet evidently did so, and with comparatively modest resources applied with highly potent effect. It is argued that the collective efforts of their players were far more effectively combined and consistently so, in contrast to their many opponents, and that was instrumental in what was effectively their emergent success.

2.4 Self Organisation and its Hallmarks

The emergent properties of complex systems are aggregates of the behaviours of the component systems within that structure that synergise together to produce a net total system output that no component, or set of sub components, could produce in isolation.

The work of Miller and Page (Miller & Page, 2007, p.165), contends that the aggregation referred to can be categorised by generic patterns that betoken the global behavioural activity of both natural and artificial systems and, in particular, their work highlights that one such pattern is a distribution of activity characterised by a power law.

2.5 Power Laws

According to Freiberger and Thomas (Freiberger and Thomas, 2016, p.74) whenever a variable y varies in proportion to $1/x^{-k}$, for some number k, then y is said to follow a power law. Networked structures, such as friendship networks can be shown to follow such laws. Here people in the network represent nodes with a number of edges (links) between them.

It is interesting to observe that in some respects such friendship networks can qualify as organizations. Indeed, as people convene into such networks it may be with a view to sharing common interests.

Similarly, such networks may materialize when a particular company, say, has an excellent reputation for treating its employees well. This is suggested on the grounds that this aspect causes people who learn of this from people who already work at the company to apply for jobs there.

Indeed, in terms of friendship networks, if one evaluates the number of y nodes that are linked to x other nodes, it can be shown that the relationship between them approximates to $y = 1/x^{-k}$ where k is usually a number between 2 and 4.

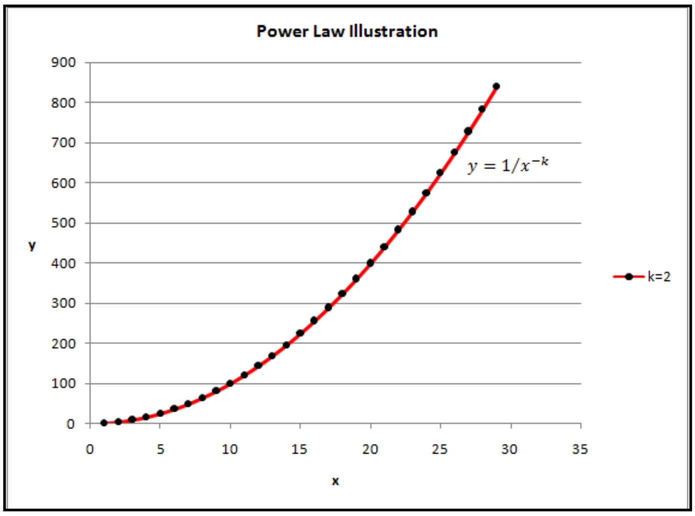


Fig. 5 Power Law Illustration

If one has the equation $y = 1/x^{-k}$ and k = 2, then $y = 1/x^{-2}$. Taking logarithms to base 2 (chosen arbitrarily at this point) then$\log_2 y = 2\log_2 x$. If values of $\log_2 y$ and $\log_2 x$ are plotted on a log-log scale then the plot describes a perfectly linear relationship. This features a linear correlation coefficient R^2 of 1 accordingly as shown below.

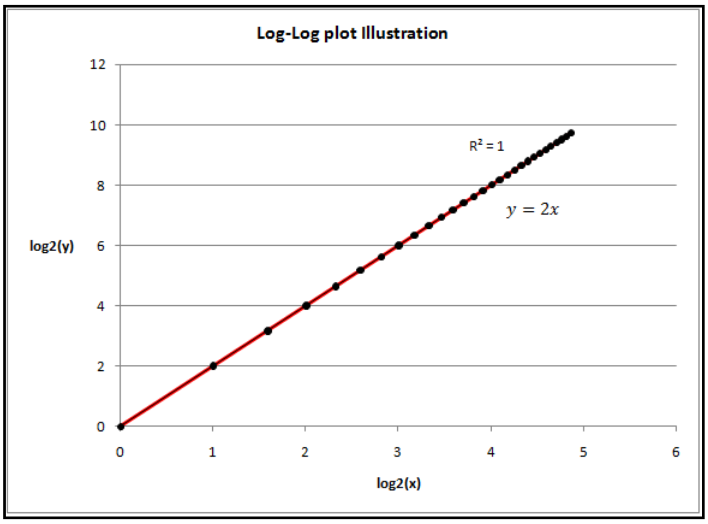


Fig. 6 Log-Log plot illustration

An interesting further illustration of the ubiquity of power laws is presented by Freiberger and Thomas (Freiberger and Thomas, 2016, p.74). This is in the form of the concept of ‘the rich get richer’, where a network of rich people (say) grows via new entrant nodes always choosing to connect with nodes that already possess many connections.

From a cybernetic point of view, this is a type of reinforcing behaviour i.e. positive feedback to reinforce action towards a result, as opposed to error-controlled negative feedback that would subtract action from an input to the system until an outcome that is acceptable to it is obtained. In both cases feedback referring to “*the return of a signal, indicating the result of an action, in order to determine further actions*” (Pask, 1968, p.114)

Systems that exhibit Power Law distributions in their signature characteristics are ubiquitous. Indeed, according to Newman (Newman, 2013, p.255) power laws are found in: city populations, earthquakes, moon craters, solar flares, computer files, and wars. They are also observable in the frequency of use of words in human languages, the frequency of occurrence of personal names in most cultures, the number of papers scientists write, and the number of hits on web pages, Moreover, they also arise in the sales of books, music recordings, and almost every other branded commodity.

The notion of a power law being present in human languages is of particular interest in this work. This is on the basis that when the players on one team move, they communicate with each other in terms of that movement i.e. movement is the language of the match. In considering motion on this basis, then one may use known lexical analysis techniques to characterize that language in much the same way as one can do this with a natural spoken language.

One of the most famous methods of lexical analysis is that developed by Harvard linguist, George Kingsley Zipf i.e. Zipf's law (Mitchell, 2009). Moreover, it is interesting to note the work of Eliazar and Cohen (Eliazar and Cohen, 2011, pp.4294-4301) who advance that Zipf's law "*seems to be a hallmark of complex systems based upon collective human efforts*".

Zipf's law describes the relationship between word frequencies in a source of text with the rank given to that frequency. Here the frequency with which each particular word in a source of text is evaluated and tabulated in descending numerical order. The most frequently occurring word is ranked with the highest value (represented by 1) and the least frequently occurring word being ranked last.

What is intriguing about this is that if one plots the word frequency value with the corresponding rank value, then one can discern power law-like behaviour. This behaviour follows the form:

$$Frequency = Rank^{-1}$$

Based upon the above, one may say that if a target system exhibits behaviour that follows a power law more closely than not, then this might correspond to the degree to which that system self organizes. The rationale being that a more effectively self-organized system would have a closer approximation to the power law than a less effectively organized system. Accordingly, when that power law following data is plotted on a log-log scale, it will have a degree of linearity that is argued to correspond to how well organised or not the system was.

Despite the presence of power laws in many self-organising systems, Clauset et al (Clauset et al, 2009) report that "*the detection and characterisation of power laws is complicated by large fluctuations that occur in the tail of the distribution i.e. the part of the distribution that contains the large but rare events and by identifying the range over which power law behaviour holds*". Moreover, they opine that "*commonly used methods for analysing power law data such as least square fitting can produce substantially inaccurate estimates for power law distributions"*.

Given the opinion of Clauset et al (Clauset et al, 2009) above, it is interesting to note the work of Chow et al (Chow et al, 2011, p.194), who reveal that studies have been undertaken that illustrate the presence of power laws that describe the behaviour of some variables that can be observed in the field of rugby union games as they evolve.

Accordingly, despite the contention of Clauset et al above, and bolstered by the work of Chow et al, this work nevertheless uses the method of least squares to determine the extent to which the variables under study have a resemblance to a power law. The reason for this is that this work does not necessarily seek to isolate and advance a power law that describes all football teams as self-organising systems.

On the contrary, what is specifically sought is the extent to which player movement approximates to a power law and how that is correlated to team success or failure as a viable system.

The rationale for this being that the nearer the self-organising behaviour of a football team approximates to a power law then the more self-organised the system is. If the team is more effectively self-organized then one would expect that to be reflected in its level of success.

Yet, if the team is effectively organized then it must abide by the provisions of the viable system model (VSM), so the measure of how well organized it is may provide an indication of how well mapped it is to the VSM. This is to say that if one could capture a football's teams self-organizing behaviour then one could subject it to a least squares regression analysis.

From this a measure of the degree of linear correlation could be produced i.e. R^2 - the correlation coefficient. This would serve to indicate the degree to which the self-organizing behaviour corresponded to a power law (the hallmark of a truly self-organizing system).

If there was a high degree of correlation then R^2 may well approach its maximum of 1, say, 0.92. Moreover, if there were a lower degree of correlation then R^2 would be comparatively less e.g. approaching its minimum, say, of 0.3.

The former is contended to closely behave as a truly self-organizing system than the latter and this may well manifest itself in terms of team success or failure defined by goals scored or conceded.

On this basis, least squares regression is considered a suitable test, especially when one considers the number of data sets and the number of data points within each that have been used to underpin the results produced in this work (please see Chapter 5 – Analysis and Results, p.163). The notion of using R^2 is not the only means of assessing how well organized or not a system is. The next section examines the alternatives.

2.6 Thermodynamics

Despite the proposals made in the last section, there are other measures that can be used to measure how well organized a system is to accomplish its objectives namely, thermodynamics and its link to information theory.

Yet for conventional organizations such as businesses and universities (cybernetically viable systems), how might such techniques be used when data to directly support that approach is not available since it cannot really be captured? This lends further weight to the use of football teams in this work. Justification for this being their intrinsic behaviour in the domain i.e. there are very close analogies between the movements of a player on a pitch with the thermodynamics of gas particles, as will be seen below.

The work of Southern & Sparrow (Southern and Sparrow, 2016, pp.59-60) defines thermodynamics as the study of heat in motion and explain that Heat is a form of energy, and Entropy is the amount of thermal energy in a system that cannot be used for doing work.

If a person has to push a rock along the ground, then they convert their potential energy into the kinetic energy of themselves and the rock, but not all of it is fully transferred into motion.

The person perspires through exertion and loses energy in the form of heat to the environment. This is the percentage of energy that is not converted by the person into moving the rock along the ground i.e. work done, and as such represents entropy.

Southern and Sparrow (Southern and Sparrow, 2016, pp.74-75) also convey that "*entropy is often considered as an indicator of the disorder in a system*", moreover that *"entropy has a tendency to increase, meaning that neatly ordered systems do not tend to occur of their own accord*" and that such systems "*can only be created by using energy from the surrounding environment, thereby increasing* (their) *entropy*".

This means that if you increase the amount of energy in a system in the name of rendering it to a neatly ordered condition then, by definition a percentage of the energy introduced cannot be used for doing useful work.

Accordingly, by adding energy to accomplish the objective of orderliness, a percentage of it is lost as entropy. This work considers the orderliness referred to as being equivalent to the degree to which a target system is effectively organized.

2.7 Maxwell's Demon and Information

James Clerk Maxwell developed an experiment, Maxwell's demon, to investigate the 2nd Law of Thermodynamics. This was in an attempt to answer the question of whether it is possible to lower the amount of entropy (disorder) in a system without doing any work. In this, a box was divided into two, with the dividing wall containing a door that was operated by a Demon, and the box was filled with a gas of a given temperature.

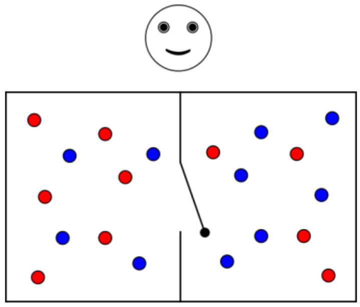


Fig. 7 Maxwell's Demon: Red (Hot) moving from L-R & Blue (Cold) from R-L

Yet, since the temperature of the gas represents only the average molecular energy, there would be molecules of gas that are warmer and colder than each other. This means that the warmer ones had a higher speed due to more energy than the cooler ones.

Maxwell hypothesized that the Demon would operate the door in the dividing wall in accordance with the particle type that approached it. If a hot particle approached from left to right, the Demon would open the door, let it through and then close the door behind it blocking its return.

It would do the same for the cold particles moving from right to left. Over time gas inside the box would become unbalanced i.e. the hot gas particles would all be on the right hand side and the cold gas particles would be on the left.

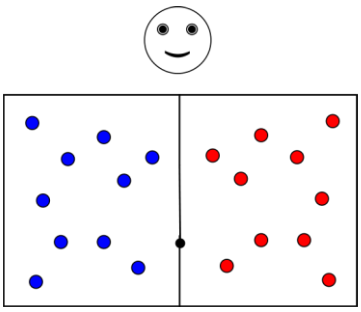


Fig. 8 Maxwell's Demon: Box of gas some time later and now ordered

The system (box of gas) has become unbalanced (hot on right, cold on left), but one may consider that it is nevertheless neatly ordered into two. The question here was has entropy (disorder) been lowered i.e. has the total system become more ordered if the gas separated as described, without any work being done?

The argument is that the answer is no, since the demon has actively done work by operating the door. This means that the demon has introduced work into the system in the name of making it orderly. In other words, it has done work to neatly divide (hence organize as required) the box into hot and cold gas. In doing this, the thermal energy within the system has increased and this has had the effect of actually introducing entropy into the system.

Accordingly, the act of organizing the system introduces further disorder (entropy) into the system thus setting off a continuously operating circularity of reinforcing events. This is because by introducing that additional energy, by definition a percentage of it will not be converted into useful work.

Beer (Beer, 1981, p.402) describes entropy as "*the measure of a systems inexorable tendency to move from a less to a more probable state… this entails an evening-out of the energy available to the system, which reaches a stand still at unit entropy (= maximal probability)*". Moreover, Beer stated that, for a viable system, unit entropy equalled death.

Indeed, from this one may conclude that, from the perspective of an organization, if it is maximally disordered (has maximal entropy) then it is minimally ordered i.e. organized in what it does to do what it exists to do. Conversely, if that organization is maximally ordered then it has minimal disorder (entropy). This means that the organization is effectively organized to accomplish its purpose.

Beer (Beer, 1981, p.402) also refers to the notion of Negentropy and stated that this is the "*measure of negative entropy equalling the active information content of a system*", and highlighted that a system gaining in entropy (disorder) are equivalently losing in information and vice versa.

From the above account this can be summarized as:

- Entropy increasing (more disorder and less order = less well organised) corresponds to decreasing Negentropy (Information).
- Entropy decreasing(less disorder and more order = more well organised) corresponds to increasing Negentropy (Information)

In the case of Maxwell's demon, one may consider the box of gas to represent a single football team. That is, it is an organization that is more or less organized.

In the case of a football match one would have two opposing Maxwell's demon arrangements where the degree of organization in one may differ to that in the other. Given their diametrically opposing objectives, this may represent a weakness in the less well-organized team that the more organized team can discern and exploit, and this is conveyed by how one signals their behaviour to each. Such communication can be quantified in terms of information.

2.8 Information

According to Beer (Beer, 1994e, p.283), "*information is that which changes us*". When information is received, and we are in some way changed, then our state implicitly changes.

In the case of a football team, these changes in state are directly discernible. The movement of one or more players in a particular manner elicits a suitable motor response from the others. This means that, in spatial terms at least, the player's state has changed.

Yet, it must be remembered that this work has equated player position to player policy when regarding that player as a viable system. Moreover, that the same principle applies to whole teams and sub groups of players in those teams.

Accordingly, the activities of all players at all times inform, and are informed by, each other irrespective of how one may demarcate any particular team. Their behaviour (change of state) is signalled to those who are observing it and this changes their state as appropriate.

That communication has an amount of information associated with it that may indicate to a recipient either an opportunity to be pursued, an incursion to be avoided or that the situation is unchanged.

The same applies to groups of players, with the exception being that what is signalled between opposing groups (e.g. one teams attack function to another teams' defence) is information that is associated with the aggregated behaviour of that group.

What one team acknowledges to itself as the strength in its own attack, may be perceived to have weaknesses that can be taken advantage of by the opposing team's defence, and they may act accordingly.

If there is such a disparity in one teams' ability to attack to overcome another teams defence, then the characteristics of the aggregated behaviour that are based upon how well they were organized to create that performance, should be reflected in the characteristics of that behaviour in some way.

If that aggregated behaviour can be enumerated and monitored over time, then this may provide an opportunity to correlate performance or failure to such characteristics. Recalling from the section on Thermodynamics (2.6, p.67) that: Beer (Beer, 1981, p.402) describes Entropy as "*the* *measure of a systems inexorable tendency to move from a less to a more probable state…*", and recalling from Section 2.7 (p.68) that:

- Entropy increasing (more disorder and less order = less well organised) corresponds to decreasing Negentropy (Information).

- Entropy decreasing (less disorder and more order = more well organised) corresponds to increasing Negentropy (Information)

It follows that as Entropy increases in a system it becomes more (or increasingly) predictable.

Similarly, that as Entropy decreases in a system it becomes less (or decreasingly) predictable.

This means that one may conclude that a system becomes less predictable as the amount of information it expresses increases. Moreover, that a system becomes more predictable as the amount of information it expresses decreases.

Indeed, according to Mitchell, (Mitchell, 2009, p.54) Shannon's definition of information content has been described as the "*average amount of surprise*" a recipient experiences when they receive a message from a source.

In a competitive scenario between two viable systems such as two football teams, this element of surprise is of vital importance. If two teams (A and X, say) oppose each other, then each may have an advantage of comparative surprise over the other at any time as indicated by the amount of information they generate due to their current mode of self-organization to do so. This may represent the edge that they need in a match to win it.

If A is more predictable from X's perspective than X is from A's perspective then the tactical advantage is argued to belong to X, since X possesses an element of surprise over A. As this is underpinned by how effectively organized and re-organised (adaptive) either team is as a viable system under load conditions, it is variable during a match.

If the balance of that situation is more often than not in favour of one team over another, then it is argued that the team that has the bias in its favour will be more likely to be victorious. The rationale for this being that it self-organises in such a manner to create and apply itself as an adaptive controller over its opponents and does so with greater efficacy than its opponent can muster.

In doing this, the team with the greater chance of success has presented more surprise to its opponent than its opponent has presented to it. The opponent appears to be the more predictable of the two teams and the other team perceives and takes advantage of that.

It is contended that the bias can fall back into the opponent's favour to the extent that it can rapidly reorganise itself as an effective adaptive controller that serves to counter the effects of the surprise it has suffered from.

It is speculated that it accomplishes this by operating it in a manner to create and impart a greater level of surprise upon its adversary. If the movement of all players within a team causes that team to possess an amount of entropy via the forces of self-organization that are present, then this also has an amount of Negentropy,

Moreover, that Negentropy can be directly measured by reference to the motion of the players, sub groups of players and whole teams involved and hence be related to corresponding levels of tactical advantage or disadvantage. From there, one may correlate the metrics with metrics of success or failure of the team in terms of goals scored or conceded.

As the activity involved is spatially based, it may be argued that the position vectors one team expresses to another defines their whole repertoire of action. This is argued to be the equivalent of the language of communication between the two teams, where particular position vectors of one team have particular meaning to another. As much is obvious in football, but the subtle point here is that if movement is considered to be language, then it lends itself to the techniques of lexical analysis. Indeed, as Bogdanov (Bogdanov, 1996, pp.60-61) observed: "*Speech is an essentially organisational process and, besides of a universal nature. By means of it, all the practices of people in their co-operation are organised: the spoken word establishes common goals and common means, determines the place and function of each collaborator, outlines the sequence of activities, etc*".

In cybernetics, such changes in state are described in terms of Variety, where variety is a term defined by Ashby (Ashby, 1957, p.126) as being "*the number of distinguishable elements (states) of a system or the logarithm to the base 2 of the number of those elements (states)*".

For example, if a player is given 20 options to take action that can only be answered 'yes' or 'no' then the variety is 2^{20} = 1,048,576. This illustrates that for a very simple system of decision making, the variety involved can be considerable, although it may be constrained by the purpose that one ascribes to a particular system and hence, in so doing, constrain its variety.

Yet, the example poses the question of how many distinguishable states other more complicated systems may exhibit. The exponents involved in the calculations may be large and as such, the calculations may be made easier by using logarithms.

If a system is a source of communication then, according to Ashby (Ashby, 1957, pp.123-124), "*the act of 'communication' necessarily implies the existence of a set of possibilities*" and "*the information carried by a particular message depends on the set it comes from*".

As such, given that information is measured in bits (the binary number scheme using base 2) then it follows that variety calculations using base 2 is appropriate.

In the case of the football team, the positions that it occupies on the pitch is its variety in spatial terms i.e. it is the number of distinguishable states it exhibits from a universe of possibilities defined by the pitch area. Yet, that also represents information that is communicated to the opposing team and hence can be calculated in bits also.

In this work it is the pitch that is considered to represent that which Ashby (Ashby, 1957, p.37) defines as the "*phase space*" of the system since it is the environment where all of the state transformations can be represented (literally in this case) by the coordinate vectors of the players.

Indeed, if taking a given point on Cartesian axes such that we may have a vector of, say, (8, 4), then the x coordinate of that point is 8 and the y coordinate of that point is 4, but the state of that point is (8, 4) since it is a *"…well defined condition or property that can be recognised if it occurs again*" (Ashby, 1957, p.25).

Accordingly, a change in state in a given system, such as the positions of players, can be described and expressed in informational terms; indeed, Pask (Pask, 1968, p.115) observed that "*Variety can also be shown to be a measure of uncertainty of the amount of selection needed to remove the uncertainty*"

Pask neatly encapsulates the cybernetic notion that in order to remove the uncertainty expressed by one system (Team A, say) to another (Team X, say), it must engineer its variety to do so i.e. increase or decrease it.

In this respect Team X must select from its available repertoire, of states (player positions in this case) to bring Team A within Team X's definition of what it means to effectively control Team A. It may also do this by being given or provided with resources that can cause it to create new states. By doing this, and succeeding, Team A is made more predictable i.e. the uncertainty that it had is reduced or eliminated. If this happens then one would expect Team A to express less Negentropy (information) than before it fell under Team X's control

According to Mitchell (Mitchell, 2009, pp.52-54) Shannon's definition of information ignores the meaning of the messages sent and received across a communication channel, and only shows how often an information source sends each of the possible different messages to the receiver. As such, in Shannon's theory a message can be any unit of communication.

Moreover, by considering how often particular messages are sent, it makes the connection with thermodynamic theory. It is differentiated from the probabilities associated with the statistical mechanics of thermodynamics, by considering message probabilities instead.

The position vectors that a team exhibits can therefore be used to calculate how much information one team expresses to another. Those vectors are underpinned by the self-organizing behaviour of those teams operating as adaptive, cybernetically viable systems.

This means that they are more-or-less effectively organized to do what they need to do, and this is expressed by their level of information associated with what is actually done. If one considers the position vectors expressed by one team as the information that it conveys to another in the conversation of action that exists between them, then one can apply the techniques of lexical analysis and information theory to that data.

In the case of lexical analysis, the vocabulary of position vectors that a team has may be subjected to Zipf's law in just the same manner as it may be applied to a text source such as a book. In this respect, one may observe a power law in the data. Similarly, those position vectors convey information to an opponent and they then act upon that.

Accordingly, if one undertakes a Zipfian ranked frequency analysis of the position vectors, then one may discern a power law in the data (the hallmark of a self-organizing system). From there one may also then applies Shannon's Information equations to that in order quantify the associated amount of Shannon Information.

Mitchell (Mitchell, 2009, pp.49-54) reports that this has been "*characterised in some quarters as the average amount of surprise a receiver experiences upon receipt of a message and where surprise is equivalent to the degree of uncertainty the receiver has about what would be sent next*".

In other words, if a system (a football team in this case) has less entropy then the amount of disorder within that system (football team) is less, hence there is more order in the system (if there is more entropy then there is more disorder and hence less order in the football team).

If, however, the system has more order (less disorder) then it presents more surprise to an observer by way of how it behaves.

In information theory, information is equivalent to thermodynamic entropy (more information being equivalent to less entropy and less entropy (disorder) implies more order in the system.

Similarly, if there is more entropy (more disorder) then the system (football team in this case) is less orderly and hence more predictable which implies it is a lesser source of surprise to an observer. This can be depicted as follows.

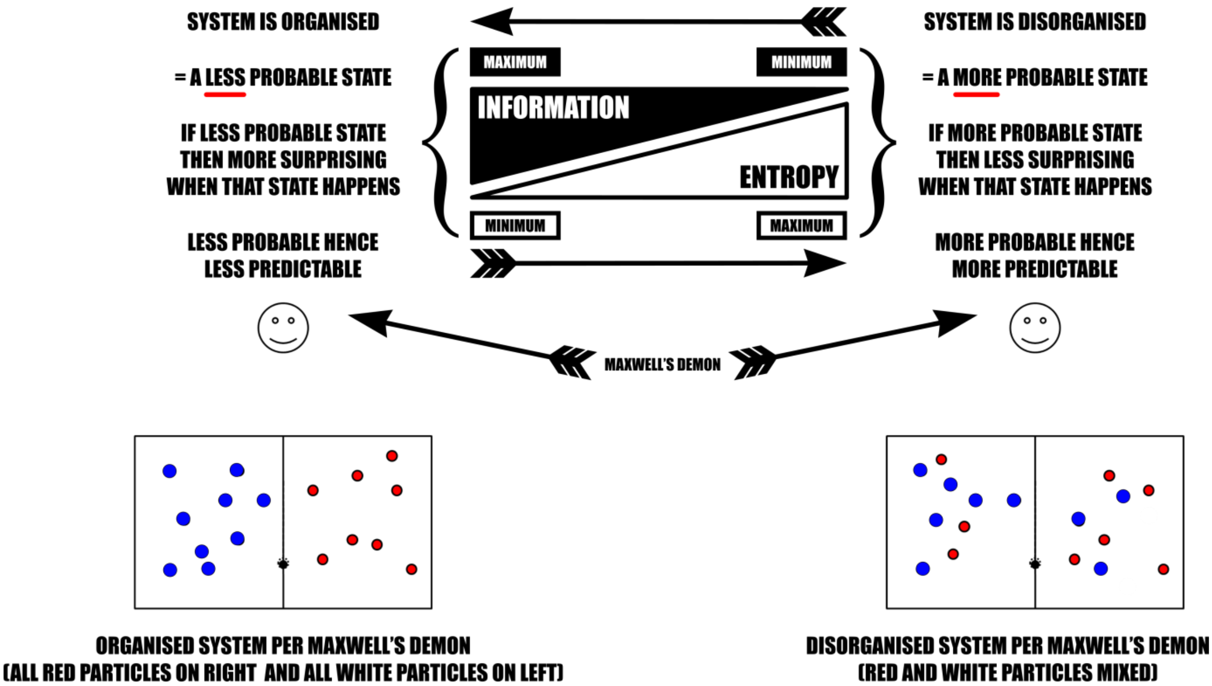


Fig. 9 Relationship of Shannon Information and Entropy in terms of Maxwell's Demon

Fig. 9 above illustrates the relationship between Entropy and Shannon Information (Negentropy). It employs the concept of Maxwell's Demon to convey the extent to which a given system can be described as being ordered (organised) and disordered (disorganised), purely as a visual metaphor, to assist with the following explanation.

In the case of system that is in need of effective organisation to meet its objectives (a viable system) such as a football team, the expectation is that the more organised (less disorganised) it is, then the more Information it will be associated with when that is evaluated for it in the context of what it is actually doing.

This is to day that if a football team's players have policy vectors (their positions on the pitch) that continually change, then so too will the policy vector of the tactical function they have been allocated to (Attack, Midfield and Defence team groupings) and, thereby, so too will the policy vector of the whole team.

The vectors involved at a per player level are messages that each player sends to each other, irrespective of which team they are playing for. Those messages are a result of a player informing, and being informed by, the messages of the other players involved and them each taking appropriate action in anticipation or response to those as they see fit.

Accordingly, each message expressed has a probability of being sent or not i.e. what position a player takes upon the pitch (their policy as a viable system) has a likelihood of occurrence. Statistically, some messages will occur with greater frequency than others and it is this aspect in particular that permits one to directly equate such frequencies to Shannon's work related to information transmission across a communications channel.

It is from here that one is able to directly measure the degree of organisation present within the football team by reference to the relationship between Shannon Information (Negentropy) and Entropy (disorder).

If a football team (Team A) exhibits less information than their opponent (Team X), then this corresponds to more entropy (disorder) within Team A than is present in Team X. Such disorder in Team A corresponds to being more disorganised than Team X; hence Team A is at a disadvantage to Team X at that point.

Conversely, if a football team (Team A) exhibits more information than their opponent (Team X), then this corresponds to less entropy (less disorder) within Team A than in Team X. This means that Team A is less disorganised than Team X; hence Team A is at an advantage to Team X at that point.

Yet, that information in both cases is an expression of the players own output in their capacity as a cybernetically viable system. Here, a viable system has accepted input, processed it, and issued an output defined for the most part by a change in that system's position on the football pitch.

Indeed, the same rationale can be applied to various consolidations of such movements e.g. the emergent policy of all of the players in the Midfield function as computed by their respective changes in position making contributions to the movement of nodes in the polygon that describes that function, and hence to its ever changing centroid (equivalent to the consolidated policy).

One may also apply that rationale to the behaviour of the whole team i.e. its centroid. Consequently, one is able to dynamically re-compute the various policies for the Attack, Midfield and Defence function within the team as well as that for the whole team itself. The implication of this is that one is able to capture all of the policy outputs of the various recursions of that team in its capacity as a cybernetically viable system. It is from this point that one may then say that those signatures represent the output characteristics of their various viable system model representations.

Justification for this being that not only do the players accept input, process it and issue a response that is spatiotemporal in its nature, but also that the viable systems that the various sub groups they belong to inside the team do the same thing. This is a very subtle point that, if discussed with a player, they might find at best oddly counterintuitive. It refers to how each of their behaviours are effectively being consolidated via how individual activity on the pitch informs, and is informed by, each of their team mates in a self organising manner. A player sees what they need to do and so do their colleagues. They interact with each other, but that interaction imbues that collective of players with its own spatiotemporal signature i.e. that collectives emergent policy not only as an operational unit of that team, but also as a recursion of its own viable system model representation.

Yet it is nevertheless from here that one may calculate how well organised a team is in order to produce those policies for itself via its own self organising behaviour. The frequencies of the positions (hence policies) the team expresses can be used with Shannon's equation for the amount of information an information source sends across a communication channel. It is from this point that one may obtain insight into the amount of order (or disorder) present in the team by reference to the relationship between Shannon Information (Negentropy) and Entropy (disorder in a system).

If one confines ones attention to just one team, their policy functions at player, function and team level will all continuously alter. As such within the confines of the football pitch, and under the prevailing circumstances and how they change during a match, some policies will occur more frequently than others and some less so. Accordingly, one may isolate the behaviour of that team and make an assessment of how well organised it is with respect to its objectives. One may also carry this out for the opposing team involved. Once both sets of readings are obtained, they may be compared to discern which of them was perhaps the more well organised of the two, hence which perhaps stood the best chance of success in that match. This is conceptualised in the illustration on the next page (Fig. 10).

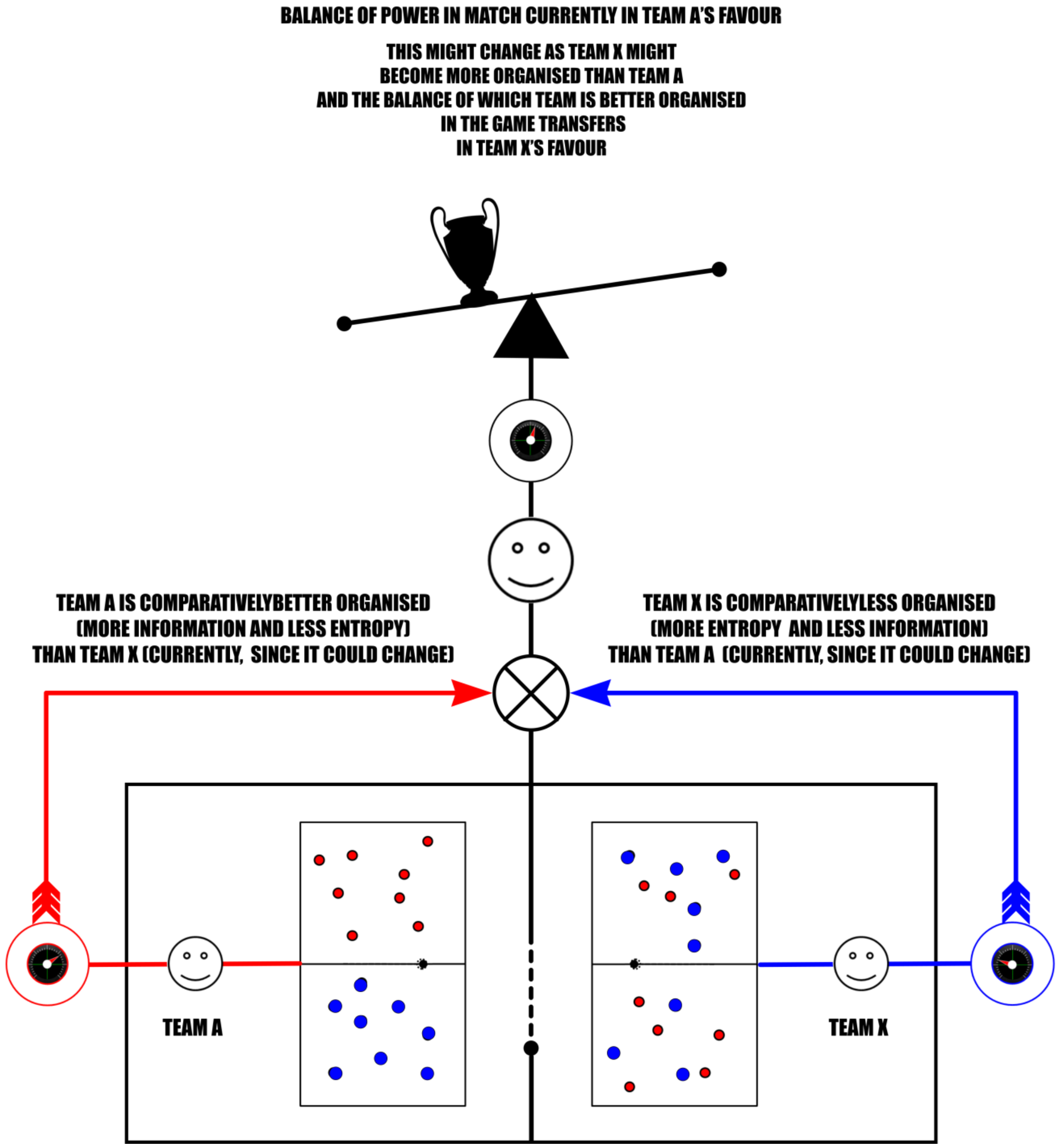


Fig. 10 Opposing Teams as opposing Maxwell's Demons and the varying balance of success or failure for either

In Fig. 10 above, each team is conceptualised as two Maxwell's Demon arrangements that represent an ordered, (organised) system (Team A) and a disordered (disorganised) system (Team X). Both teams are themselves encapsulated in a depiction of Maxwell's Demon that illustrates that, in terms of orderliness present in that match, Team A is the most organised part of the arrangement at the moment in contrast to Team X. As such, for that Maxwell's Demon depiction of the match, the balance of success currently favours Team A.

Given that the activities of both teams continually vary, then this bias to Team A may well change at any moment e.g. if Team X becomes comparatively more organised than Team A, or if Team X remains the same as before and Team A starts to become disorganised for some reason (a less than effective choice in a player substitution for example).

The point here is to illustrate that each of the teams attempt to organise themselves effectively enough so as to counter the affects of their respective opponent. Team A tries to organise, and adaptively reorganise, itself with respect to Team X and Team X will experience the effects of that. Team X will reciprocate and Team A will feel the effects of Team X's organisational prowess in the same way.

The balance between the two is argued to rapidly alternate and that this represents how the balance of success or failure for either of them in a given match oscillates in general. If one team can maintain itself at a higher threshold of effective organisation and for longer than their opponent (both as viable systems) then it is argued that victory in the match will be in that team's favour. Fig. 11 below illustrates the provisions of Fig. 10, but this time in terms of how various levels of Information and Entropy are involved, and what the implications of that are for each team.

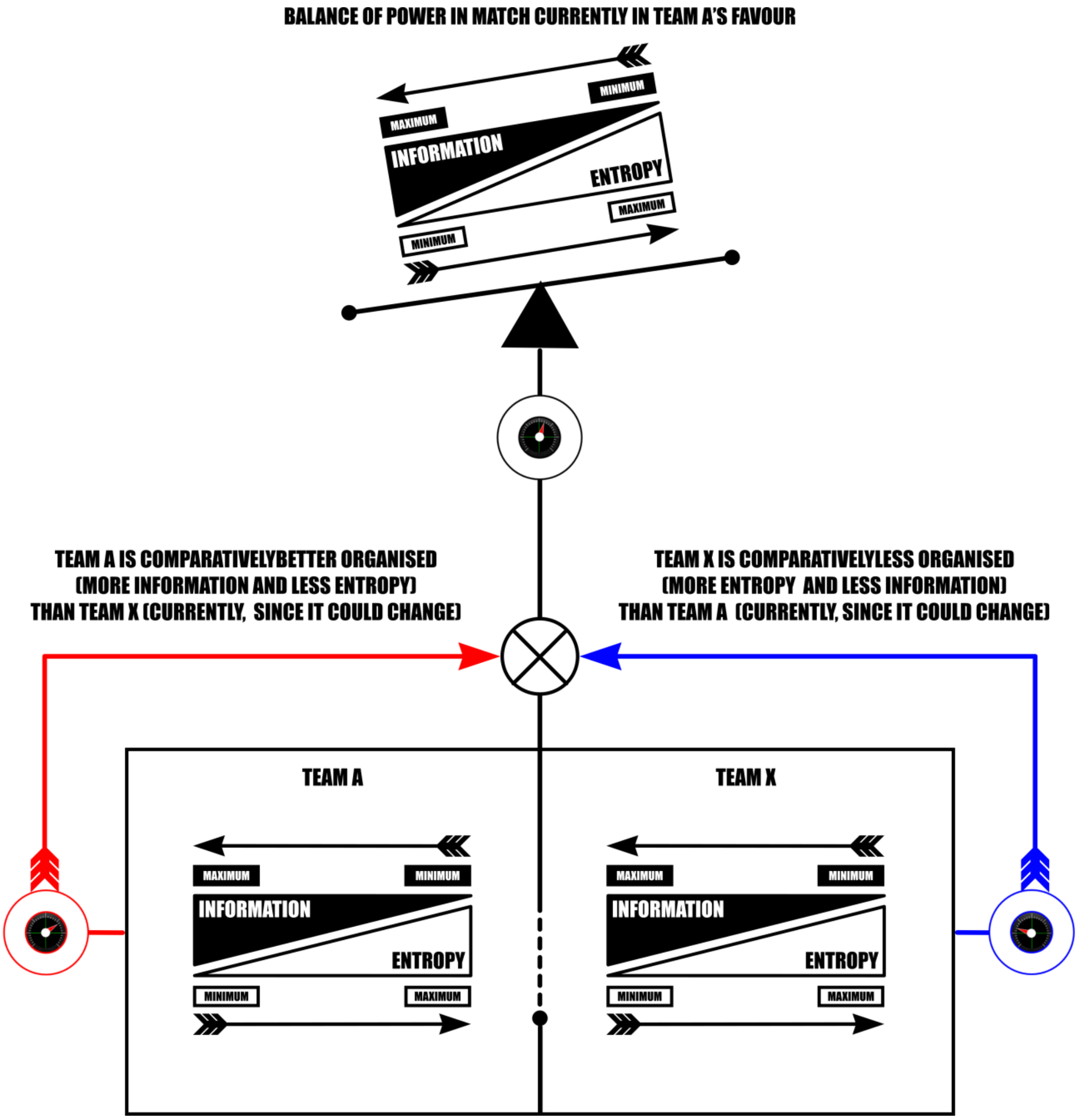


Fig. 11 As per Fig.10 but now in terms of relationship between Shannon Information and Entropy

Accordingly, what follows below is an example of how Shannon Information has been calculated for each team, and hence how insight into how well organised they are (or not as the case may be) can be obtained.

This notion can be described by the following equation:

$$H(message\ source) = -\sum_{i=1}^{M} p_i \log_2 p_i$$

Equation 1 – Shannon Information content of an Information source

Where M is the number of possible messages and p_i is the probability of message i.

Coordinates (System Policy (Spatial) Enacted)	Frequency of Occurrence (Descending Order)	Rank (Ascending Order)
(44.6,4.5)	326	1
(34.3,-14.1)	208	2
(18.1,23.7)	201	3
.	.	.
.	.	.
.	.	.
(4.1,12.2)	4	31,998
(4.1,13.4)	4	31,999
(4.1,14.4)	4	32,000

Table 1 Zipfian Ranked Frequency Distribution

In terms of the content of Table 1 and the treatment of its data by the equation presented above, then, as an illustrative example in the computation of the data we may say that:

H(Policy) = -[(326/$alpha$)* $\log_2(\frac{326}{alpha})$+[(208/ $alpha$)* $\log_2(\frac{208}{alpha})$+….+ [(4/ $alpha$)* $\log_2(\frac{4}{alpha})$]

…where $alpha$ is the maximum rank value in the table above.

In other words, the relative frequencies of those policies tabulated in Table 1 are computed and treated as probabilities. The sum of all those probabilities is equated to the amount of information that the set of policies represents i.e. that which is conveyed by one team to another and vice versa. It is this calculation that underpins the IC (Information Content) used in this work.

Yet, that corresponds to the amount of predictability of a target system, and the tactical implications for opposing football teams and the outcome of a match. Accordingly, it was deemed that a suitable analysis should be undertaken to discern the presence of any correlation of it to the extent to which the target team was self-organising and how many goals it accrued in the process.

This chapter has outlined two means of quantifying how well organized or not a system is. If a system is effectively well organized to accomplish its purpose than not, then this is argued to be indicative of the target system's isomorphy with the VSM that can be shown to represent it actually is.

The work of Beer (Beer, 1974, pp.1-2) contends that:

> *"…the pattern of information exclusively defines whatever regulation exists…the laws that govern such regulation are general laws and that the output of a complex probabilistic system is a function of a self-regulating organisation with high input variety in which the regulatory power is not vested in a 'controller' but in a structure of that organisation itself".*

2.9 Summary

Football competitive by its very nature and as such it is a zero sum game i.e. one team seeks to win at the expense of the opposing side losing and vice versa. The imperative for a team is to win, not necessarily by a margin of a given value, but simply that the number of goals that one team scores is greater than that scored by the other. If a team loses then it has not fulfilled its purpose of winning despite its efforts to do so.

Yet, it is intriguing to note, however, that a zero sum outcome in a football match is underpinned by non-zero sum activity within each team. In this respect, one may take a systemic perspective of the machinations of a football team. It is comprised of sub systems, players, who are convened into sub groups of players to defined key team functions. The players in a team must work together in an effective and efficient manner to produce a mutually beneficial outcome for all of them in that team.

In so doing, their respective activities with respect to all of the other players in their team and with regards to those on the opposing team represents the self organising behaviour of the team as a whole. The activities of the players imbue the systemic structure (the team) with an emergent property that characterises what that system actually does. Such self organising behaviour represents the amount of synergy between the players involved in a team i.e. the amount of mutually advantageous combined action present. If the whole team has an amount of synergy associated with it, then notional groupings of players within that team (e.g. players allocated to Attack, Midfield and Defence) will also.

Since the characteristics of a team's self organising behaviour can be obtained (via the link between player policy, player position and Shannon Information via Zipf's Law as shown in this Chapter), then the amount of synergy amongst the players can be quantitatively related to team outcomes for a host of football matches. Consequently, by reference to a match score line for a team one can relate the characteristics of its self organising behaviour to a degree of potency that can be directly related to how many goals a team either scores or concedes.

The balance between success and failure varies rapidly during a football match. In a given moment one team may be likely to be more successful than another since they have possession of the ball, say, and are very near their opponent's undefended goal. Yet, the player in possession may have that seized from them by an opposing player tackling them. It may be the case that a few moments later the situation is somewhat reversed. How the balance between success and failure oscillates for a team is indicative of how well organised it is (or not, as the case may be) to be the controller of its own situation. In many respects the team is what Pask (Pask, 1968, p.114) described as an "*Adaptive Controller*" i.e. a controller that can modify its programme of action.

Yet, as the team adapts the effectiveness of that emergent control over its opponent will vary and it is contended that such effectiveness is related to the characteristics of the teams self organising behaviour. At any point in the game one team will be attempting to control the overall match situation to its advantage by being organised to produce what it intends to do. It will seek to do this with greater proficiency than the opposing team and will expect results to follow if it can do so. Yet, the opposing team is, simultaneously, doing the same thing. The potency of their respective self organising behaviour, in diametric opposition to each other, represents the balance of success or failure in the match. This is continuously variable not only for each team involved, but also for the entire match concerned.

If a team's behaviour is correlated to its purpose, that purpose can be legitimately equated to the survival requirement of that team when that team is regarded as a system. The rationale for this is that often a team must succeed in its objectives since failure could mean its dissolution. A football team could become disbanded if it does not enjoy its expected levels of success. Similarly, if it does attain its objectives then it may be able to sustain itself by signing up more high profile players. These people may be attracted to successful teams playing at higher levels that can pay correspondingly high salaries, and also offer the chance of boosting their profiles further.

According to Beer (Beer, 1985, pp.x-1), "*an organisation is viable if it can survive in a particular sort of environment*". This means that it must be properly organised to be in that position. As such it is legitimate to equate a football team's imperative to win with its survival requirement since they are both dependent on how well organised they are. Since the self organising activities of football teams can be measured as outlined in this chapter, and hence monitored over time, then one can obtain how those characteristics can be associated with success or failure i.e. the survival requirement of that team as a system. Football teams are therefore systems that are cybernetically viable and that viability can be measured. Accordingly, since such viable systems are fully described by Stafford Beer's Viable System Model (VSM), the focus of this work will now turn to that.

Chapter 3 - Cybernetic Viability

3.0 Introduction

This chapter introduces and examines Stafford Beer's Viable System Model (VSM) in detail. It describes both how the VSM prescribes what attributes an effectively organised system must feature and operate if it is to hope to attain the purpose of its very existence. It also covers this in the context of the continually adaptive control strategy it creates to ensure that is the case, provides justification for selection of the model in addressing the research questions presented in this work and how one can characterise the model using a football team as a proxy for it.

The chapter accomplishes this by reference to, and illustration of, the model's isomorphy with how a football team is constructed and operated as a federated system of parts that are brought together to achieve a given purpose. It explains this whilst acknowledging the requirement of the football team to continually adapt to its situation (a situation that can always surprise them) in the control of it and to its advantage.

If a system is designed, constructed and operated to accomplish a specific purpose, then the expectation is that when that system is in operation that purpose will be attained. Yet, especially in the case of human based systems, this can often not be the case.

Examples of this abound in organisations that are defined by what people do, or do not do, across a diversity of fields of endeavour. These include, aside from football teams business, government and educational establishments for example. In all cases, each has an objective and they are constructed and operated in a systemic way to accomplish that. That objective defines what the relevant system exists to do and, as it seeks to accomplish that, what its associated operational characteristics are. Often organisations will adhere to their purpose by operating in a suitable manner to do so, yet it is also often the case that they do not.

The former represents a system that is effectively organised with respect to its objective and as such it is in a position to at least attempt to achieve it. From that position it may subsequently either succeed or fail, but in either case the system remains coherent enough to continue to attempt attainment moving forwards. In this respect the system is regarded as a viable system.

It is fully aligned and operated along the principles enshrined the Viable System Model. In contrast, the latter is either a viable system that is coherent in just the same way as the successful system, but it has just been unlucky; or it could be the case that its failure might be attributable to something a little more insidious. This latter aspect is of particular interest since it represents a departure of the system from the provisions of the Viable System Model in either a structural sense, an operational sense or some combination of the two.

In other words, it is this aspect that causes the system to be unable to attain its purpose since it is not, at a fundamental level, structured and operated in a manner to do so. It may be the case that this situation prevails due to either accident or design, but if the system is to continue to accomplish what it exists to do then its necessary shortcomings in terms of its current state of less than effective organisation will require remedying. That remedy will be to align the actual system to the provisions of the Viable System Model in its structure, operation and possibly both and this is examined in what follows also.

3.1 What is a Viable System?

Stafford Beer stated (Beer, 1973b 15m: 41s – 15m: 48s) that "*we must perceive the nature of dynamic surviving systems and the conditions they must meet to remain stable yet adaptive*". Such systems, according to Beer (Beer, 1994a, p.256) have the "*ability to respond to a stimulus that was not included in the list of anticipated stimuli when the system was designed*". Moreover, "*they can learn from repeated experience what is the optimal response to that stimulus and are robust against internal breakdown and error*".

A viable system is a system that has and continually generates its own capacity to maintain its survival whilst operating in its environment and being subject to the vagaries of that environment that may or may not act to threaten that survival. A viable system accepts input from its environment, processes it and issues an appropriate response in both a reactive manner, but also, and crucially, in an anticipatory manner. In doing this it forms and implements a control strategy for itself with respect to its operational environment that it continually operated by reference to the balance between what it seeks to accomplish or avoid in that environment and its ability and the resources available to it to deliver against that. This balance is accomplished via the data that circulates about the system from both within it (performance reporting data) and without it (data from the environment) directly, but also with reference to how that data builds into a model that the system has of both its environment and of itself. In this latter respect, the model is self referential.

Taking inspiration for its design from human neurophysiology (as representing a de facto viable system), Beer spent approximately 30 years in the development of his Viable System Model (VSM) (Beer, 1984, p.7) to describe the necessary functions and operation of any system that was regarded as viable i.e. one that was effectively organised. In essence, the VSM is a synthesis of six systems that are interconnected in a particular way to yield the emergent property of viability (the control strategy and the characteristics of its implementation) when considered as one self-contained holistic system. As will be seen, a viable system is a recursive (nested) structure.

There are many texts that cover the VSM (Beer, 1981; 1985; 1994a; Hoverstadt, 2008; Jackson, 2000; Espejo & Harnden, 1989 for example) and such detail is not replicated in the overview that follows, since that is not the purpose of this work. Nevertheless, coverage, albeit somewhat abridged, is essential given the nature of this current work and is provided next.

The diagram below depicts the definitive version of Beer's VSM (Beer, 1985, p.136)

The diagram of Beer's Viable System Model originally presented here cannot be made freely available via LJMU E-Theses Collection because of copyright. The diagram was sourced at Beer, S., 1985. *Diagnosing The System For Organisations*. Chichester: John Wiley & Sons Ltd (per p.136).

Fig. 12 Beer's Viable System Model (VSM)

From this point in the work, a stylised version of Beer's Viable System Model is used to perhaps more easily convey the key concepts involved and how they are specifically related to this work, and this is presented below.

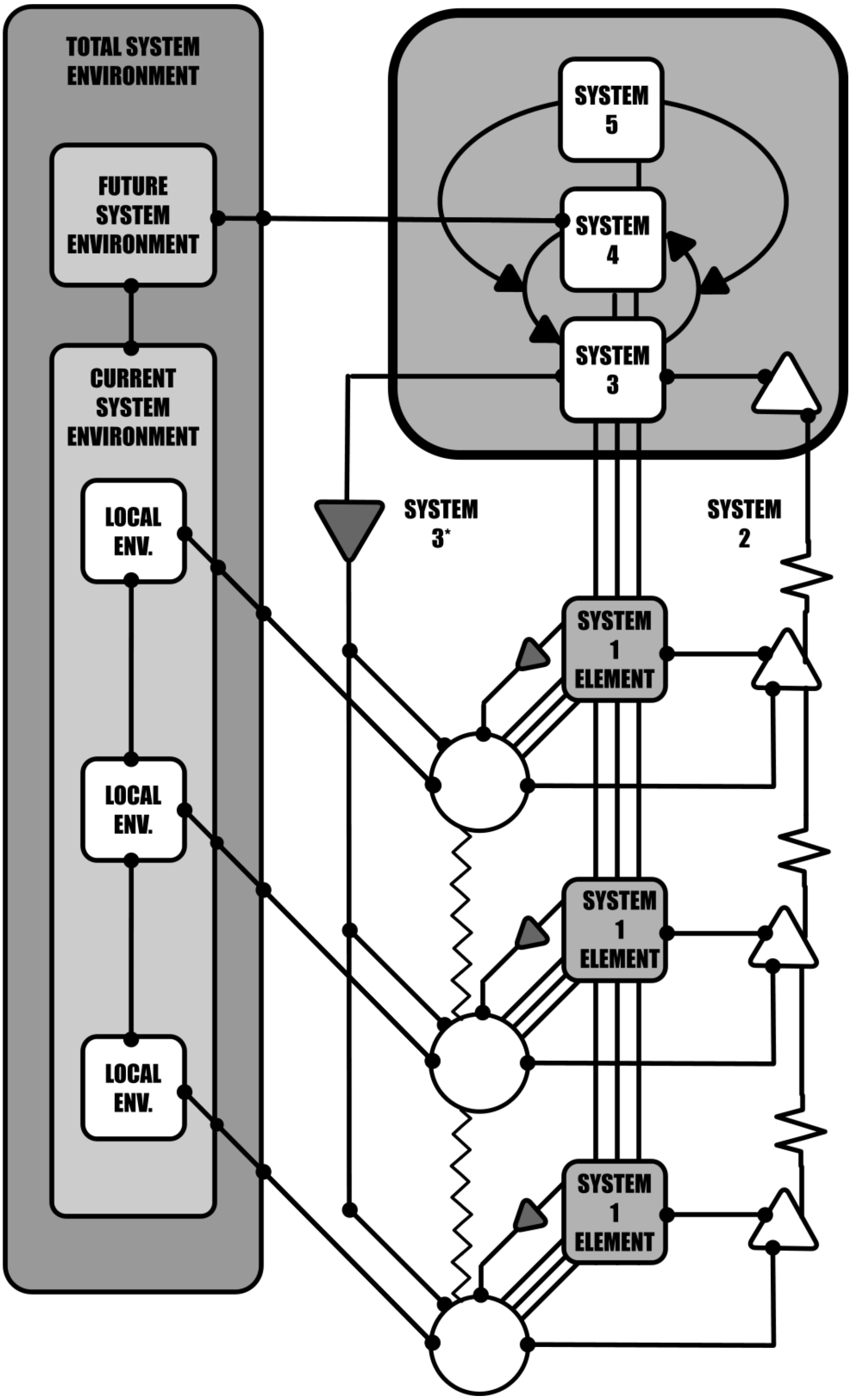


Fig. 13 Stylised version of Fig. 12

3.2 Variety and the Viable System Model

Beer (Beer, 1959, p.50) in citing Ashby's Law of Requisite Variety states that "*only variety in the control mechanism can deal successfully with the variety in the system controlled*". In other words, for every perturbation that a system encounters it must have an action to counter it if the system has requisite variety over that perturbation.

An example of requisite variety in a football context would be, say, a player that has 10 and only 10 possible ways of preventing their loss of possession of the ball in a given situation. Yet if the player only has knowledge of what must be done to retain possession of the ball in that situation in 5 and only 5 of the 10 possible scenarios the threat state can manifest itself as (in the form of the skill and knowledge of the opposing player), then the player currently in possession does not have requisite variety over the situation. They do not have the capacity to exhibit variety (a state that they can express) to counter the variety of the situation (the state of threat as expressed by what the opposing player has at their disposal to take the ball e.g. better fitness levels, technical insight, better training etc.).

Admittedly, the threat may present itself in the form of one of the situations that the player in possession knows how to overcome and hence remedy, but this might not be the case. Therefore, the player in possession does not have control over the situation overall i.e. they do not have requisite variety with respect to the opposing player (threat) as a system that they can lose control of in any one of those 10 ways since they can only fix 5 of them.

The player would have to amplify (increase) what variety they have to deal with that situation. This would be to the extent that the varietal balance between themselves and the threat situation is restored such that their control of it is restored. For example, they may have to go on a training course, obtain better technical insight, boost their level of fitness etc.). In doing this they have attenuated (reduced) the variety of the situation they face by obtaining a remedy to it.

This also applies to groups of players within a football team and also to the entire team.

Both are acting in a manner to control their respective situations yet if that control is critically balanced (as is most definitely the case in a football match) then this is indicative of homeostasis in action (i.e. the capability of a system to hold its critical variables within physiological limits in the face of unexpected disturbance or perturbation (Beer, 1981, p.402)). Justification for this being that control of the situation is the critical variable that must be held by a player or team within limits that are acceptable to it – whilst dealing with forces that conspire to thwart that aim in an unpredictable way.

A homeostat is a device or means of facilitating and implementing homeostasis of a target system with regards to their respective situations, and these are represented by the lines in the depiction of the VSM shown as:

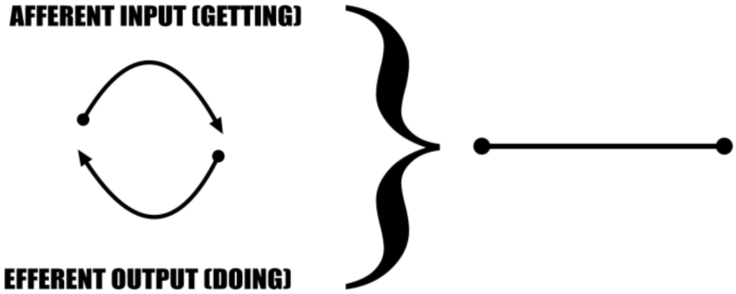


Fig. 14 Stylised depiction of homeostat per Fig.12 & Fig.13

This is a conceptualised means of showing the presence and operation of the necessary homeostatic relationships between the subsystems featured within the VSM both amongst themselves, but also between themselves and their external environments. It should also be taken to mean that these are the connections between what is to be controlled and what attempts to exert control over such coupled systems. In the case of a player being controlled by their situation (since they have less variety than it), then the player needs to restore their control of that situation to their acceptable limits by amplifying (increasing) their variety with respect to it (e.g. better training etc.), thereby attenuating (reducing) the variety of that situation and its affect upon them –thus restoring their control of it.

As such the viable system model is an architecture that embodies the concept of effective organisation to the point that the whole system it describes is fully homeostatically mediated with its environment. It is constructed in a manner that this is simultaneously the case across every connection it has with it, and operates continually in that manner to ensure that this is preserved whilst the system pursues its stated purpose under far from uncertain conditions. As such, the Viable System Model is the very embodiment of Ashby’s Law of Requisite Variety, which is an essential principle of control.

It is this principle, coupled with the self organising behaviour of a football team, which has allowed what such teams do to describe its viable system model representation under load conditions by reference to the movement of the players and the various functions of the team. As such, the proxy of a viable system (a football team) can be legitimately used to characterise the Viable System Model itself. Justification for this being that the work does this by reference to how that team controls its variety with respect to its situation in a manner that has variable effectiveness, as evidenced by how that is related to match outcomes (the by product of the overall control effort).

3.2.1 Recursion

The VSM is a fully recursive structure. This means that it contains multiple copies of what it proposes within itself. Yet, if one takes a viable system that contains such copies, it can often be discerned that it is itself part of a system that is also viable.

In other words, when dealing with a viable system, hence the VSM, there are often multiple copies of its provisions both above and below the system being currently examined. Above and below suggests hierarchy, but this is not the case.

The terms are used here to mean containment within containment of the same systemic principles. The containment is applicable across the spectrum of the finest level that one may resolve a viable system to, up to its broadest level of abstraction.

The following two diagrams (Fig. 15 and Fig. 16) are colorized versions of Fig. 12 (p.78) & Fig. 13 (p.79) to illustrate how one recursion relates to the other, in this case at two levels: the all-encompassing system and one recursion within that.

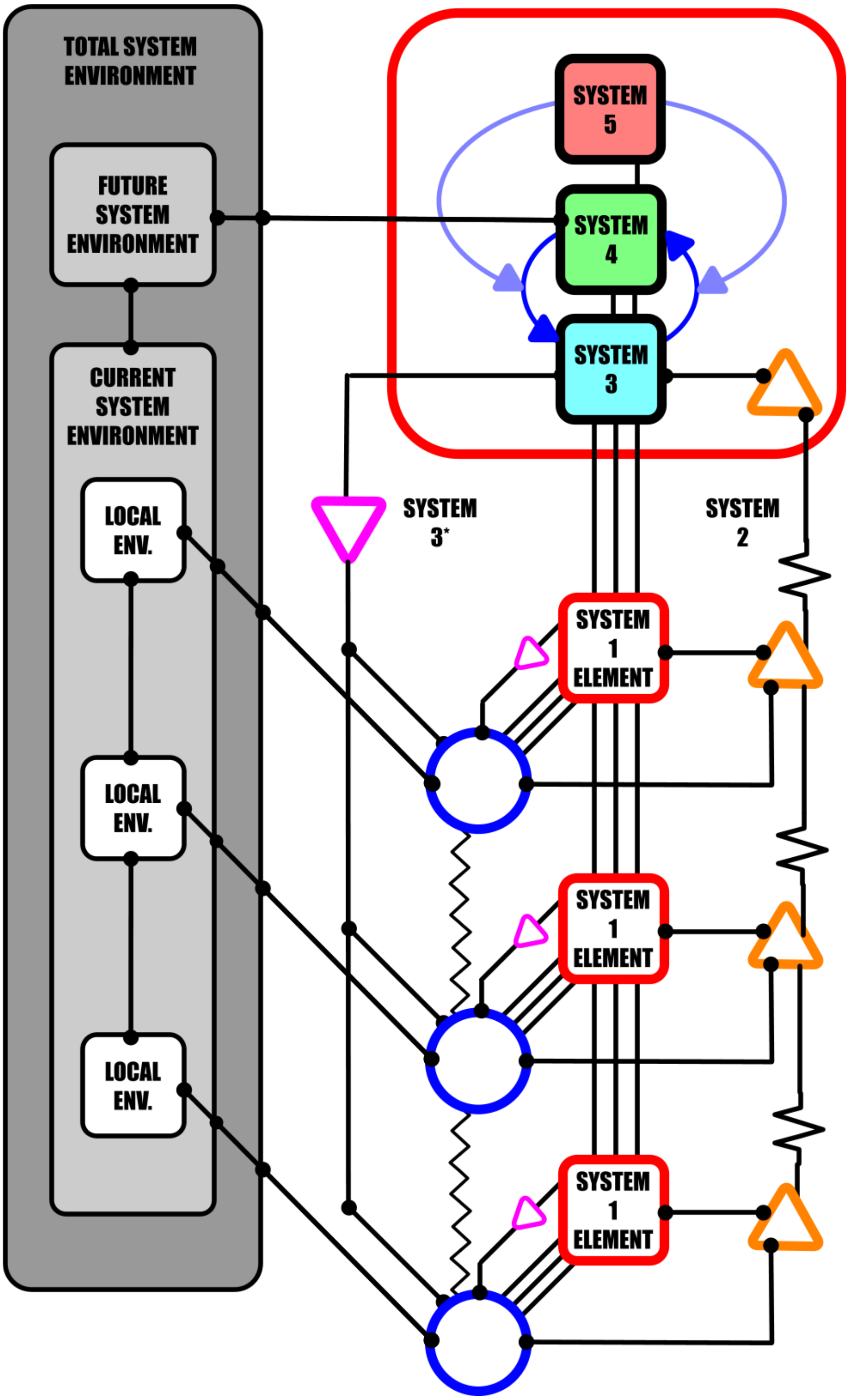


Fig. 15 Beer's VSM (recursions highlighted)

This diagram depicts a complete viable system. All of the necessary functions are present and interconnected. The large red box is the Metasystem for the whole structure and what is delivered by the system (what it actually does) is produced in part by the interaction of the smaller red boxes interacting with their respective blue circle. This is recursion 0.

It is only when each set of ‘small red box with blue circle’ commence interacting with each other that the system starts to produce what it sets out to do. Those agents of production also contain further recursions i.e. copies of the systemic provisions of the VSM that they are embedded in are also within themselves as containing systems.

This means that ‘small red box with blue circle’ contains further ‘small red boxes with blue circles’ and so on – as indicated by the colour scheme. Those embedded systems then become recursion 1.

All of these may perform different functions, but organizationally speaking they still possess what the VSM prescribes at every level.

This similarity is illustrated by the next diagram.

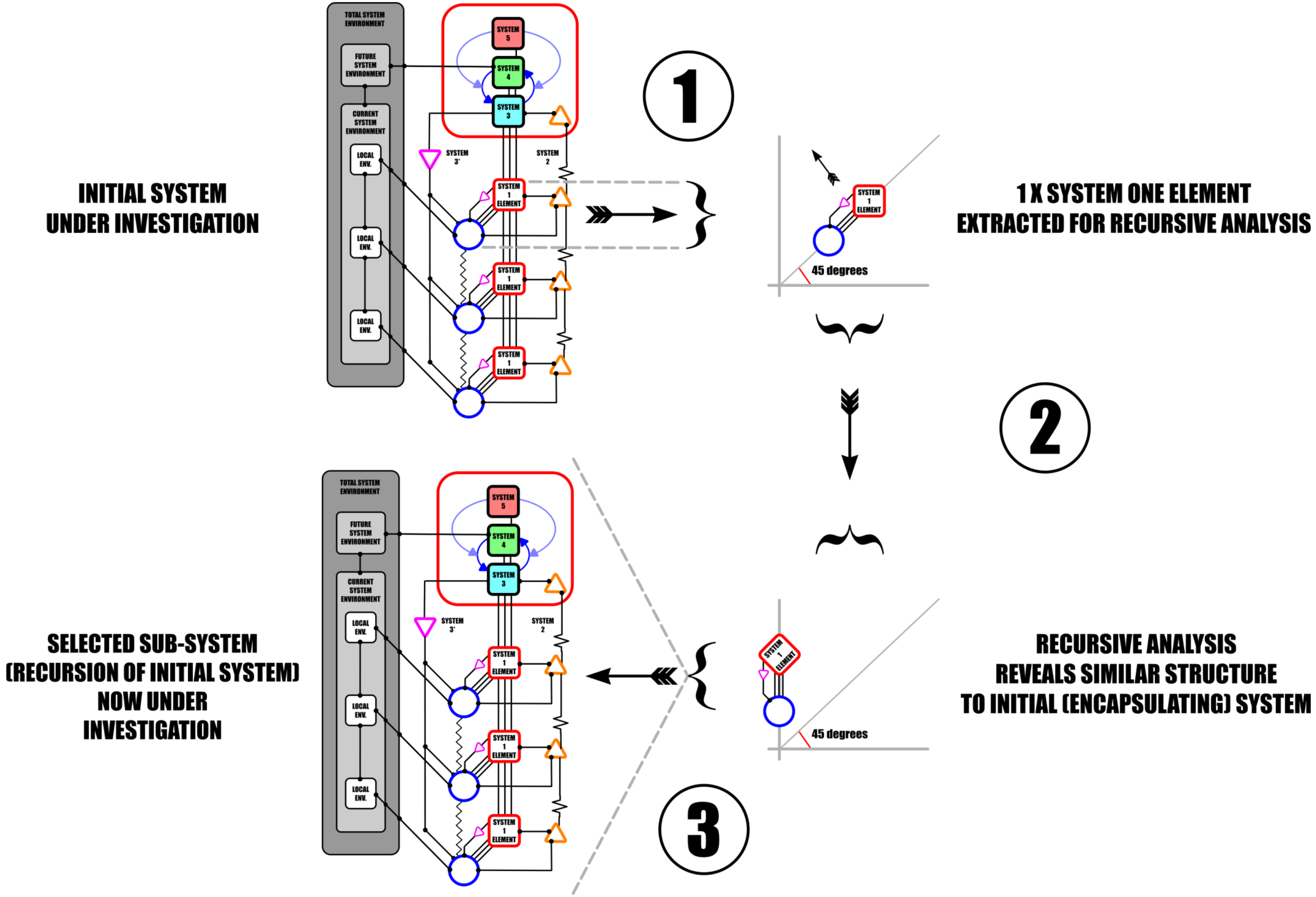


Fig. 16 Resolving the total system into recursions of interest

Accordingly, the VSM is comprised of the following six systems.

- System 1 (Operations)
- System 2 (Coordination)
- System 3 (Delivery Management)
- System 3* (Audit)
- System 4 (Intelligence)
- System 5 (Policy)

3.2.2 System 1 (Operations)

The System 1 function of the VSM contains those activities that produce what the system the VSM is modelling actually does. In other words, System 1 is the home of those functions that cause an organisation (of any description) to undertake the actual work that causes the organisation to be able to at least attempt to achieve its stated purpose. This, in turn, is the purpose for which the organisation exists.

An illustrative example of this in footballing terms is a football player. A person is a natural, hence entirely useful, instantiation of a viable system by definition. Accordingly, they are fully isomorphic with the VSM that can be shown to represent them (please see below):

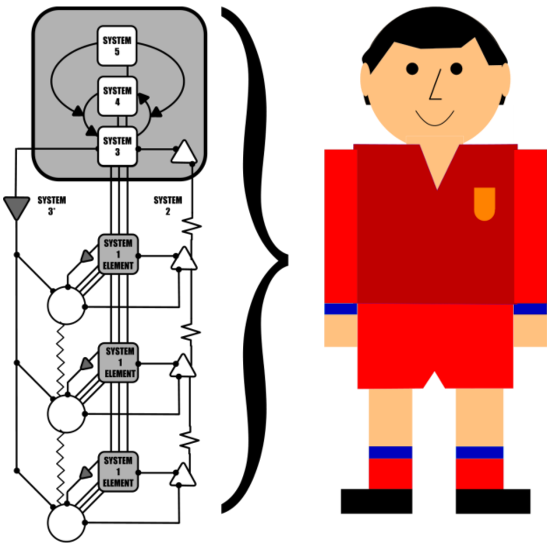


Fig. 17 Football Player and their stylised VSM representation

If an individual player is considered as a self-contained system then one can state that this system features many variables (heart rate, blood pressure, rate of digestion and so forth) at many levels.

In many respects, the player as a human being exhibits what Ashby (Ashby, 1957, pp.39-40) described as "*an infinity of variables*", stating, "*any suggestion that all of the facts pertaining to such variables be studied is unrealistic and, as such, an attempt at that should not be made*".

Yet, given the nature of this work and its focus on examining the dynamics of the viable system model that a player can be shown to be isomorphic with, then what attribute of the system should be studied? The answer to that dilemma is the most prevalent aspect of each player's performative agenda i.e. their motion about the pitch. This not only applies to the players, however. Indeed, the motion of the players serves to imbue the motion of various performative functions present in the team (Attack, Midfield and Defence, for instance) is also of relevance. Moreover, this concept can be extended to include the motion of the whole team also. Accordingly, a conceptualisation of a football team as a nested (recursive) structure of viable systems is now presented in Fig. 18 below.

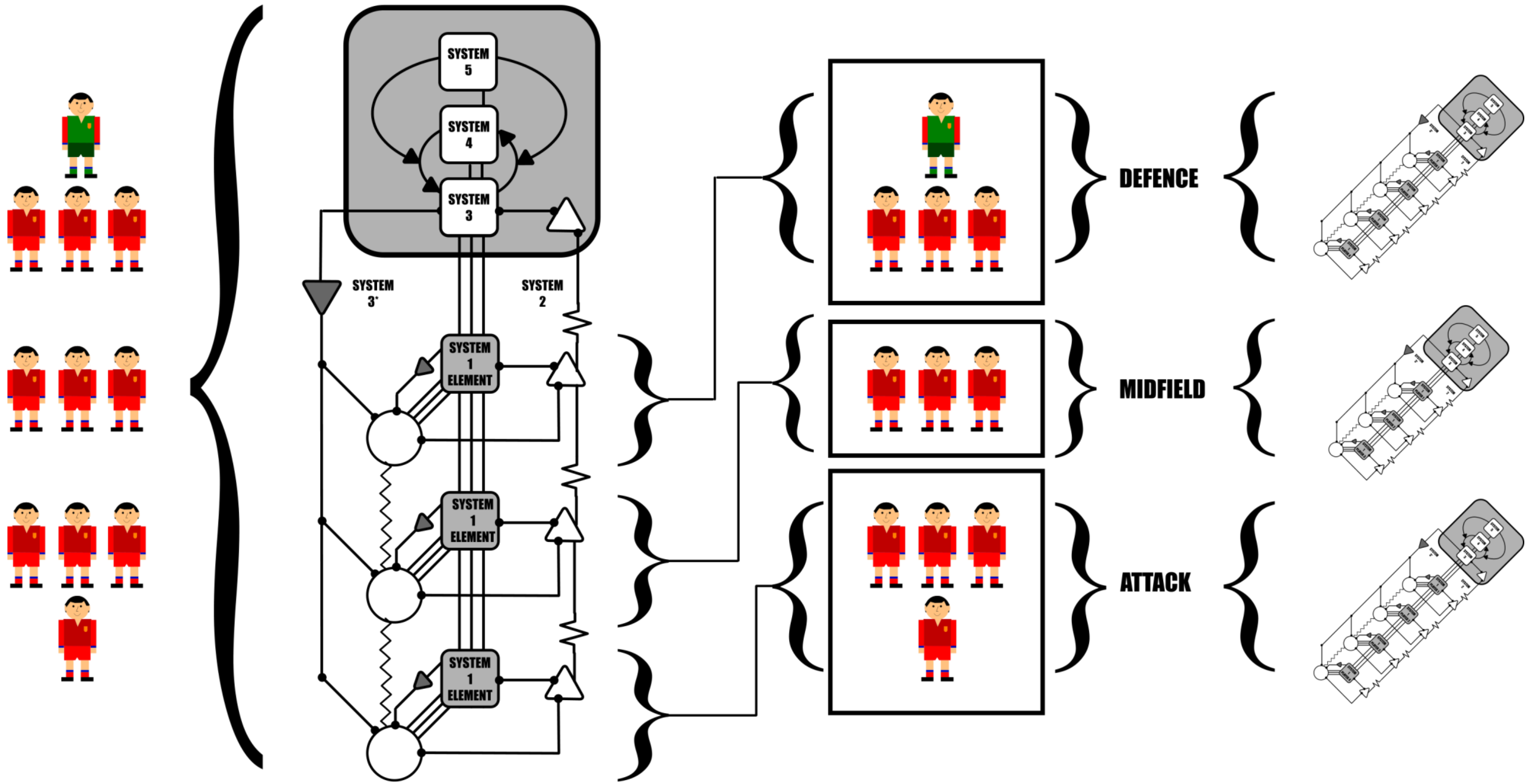


Fig. 18 Football team resolved into viable functions

What the players do produces an outcome for each of them that also makes a contribution to the whole that defines and represents that group of players however so defined. In this respect, one may be considering just four,say, players that comprise, say the Attack.

Similarly, one may consider the whole team perspective and state that all players involved make a contribution to that. Nevertheless, football teams are traditionally divided up into functions that perform particular roles for the whole team.

As such, and in acknowledgement of the concept of recursion, each player as a viable system is an embedment to either one of the Attack, Midfield or Defence tactical functions that comprise the team. Each one of those functions are themselves viable systems that can be depicted in terms of the viable system model as shown in Fig. 18 above.

So we have an arrangement of viable systems (players) that interact with each other inside their respective tactical functions in a way to produce what that tactical function actually does. This is depicted in Fig. 19 below.

On the left hand side of Fig. 19, a player is shown as a viable system That player is embedded into a tactical function called Midfield, and that has been allocated three players by the team manager.

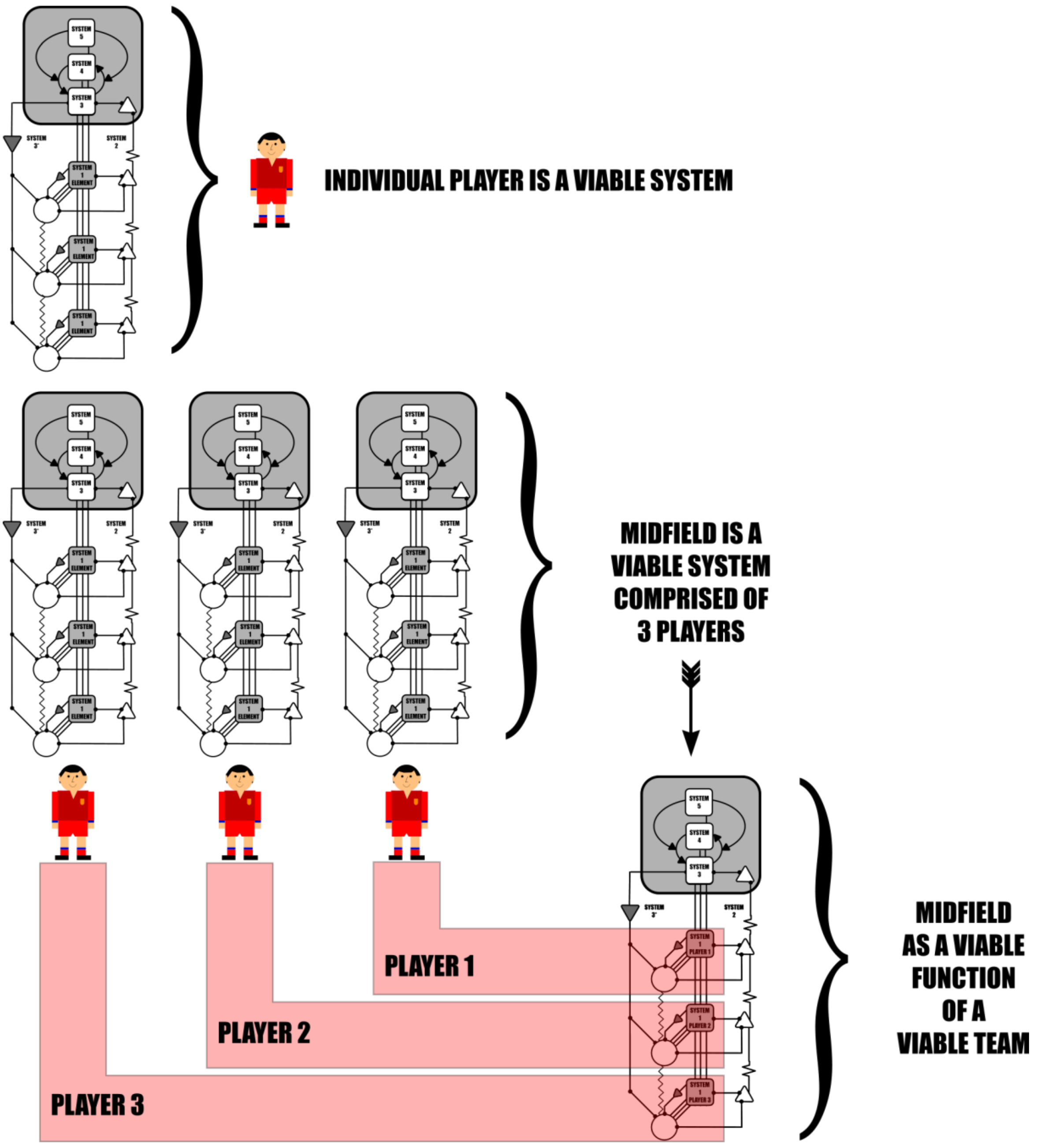


Fig. 19 Recursion: Players as a viable system within a viable system

That Midfield function is a viable system that is embedded as a System 1 element of the whole team when that whole team is depicted as a viable system.

Fig. 20 below illlustrates the juxtaposition of the Team's Attack, Midfield and Defence functions in situ within the VSM scheme that depicts the whole team.

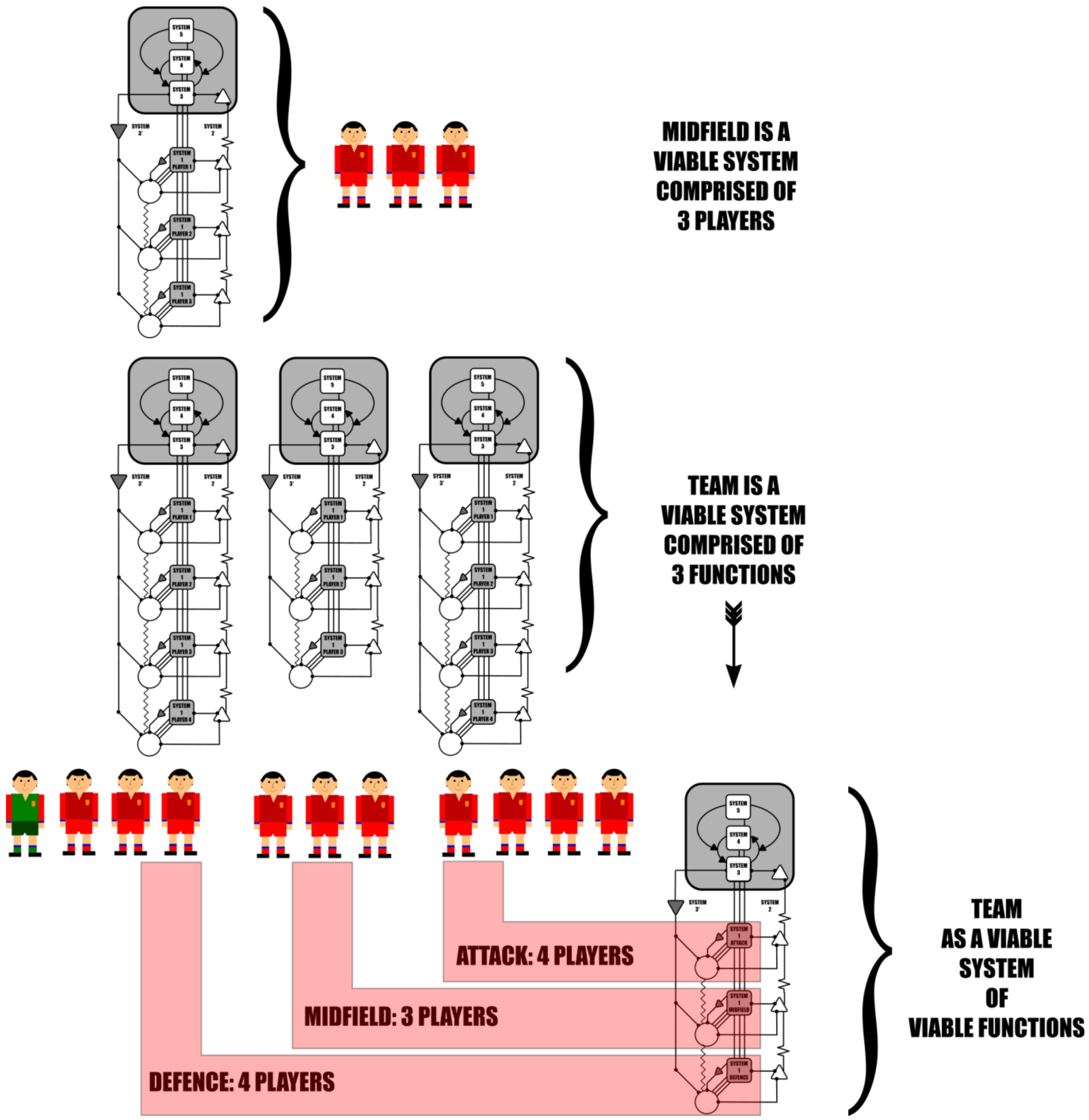


Fig. 20 Recursion: Functions as viable systems within a viable system

Fig. 20 contrasts with the case of Fig. 19 (that illustrated that 3 players had been assigned to the Midfield) and serves to illustrate the number of players assigned to the remaining attack and defence functions not depicted in Fig. 19.

It is also necessary to observe from Fig. 20 that the numbers of players involved in each function would accord with the familiar '3-4-4' configuration i.e. 3 attackers, 4 midfielders and 4 defenders, the initial formation concept used by most football teams. The activities of these functions are then similarly synergised in a manner that is identical to the behaviour of players within functions as depicted in Fig. 19.

This is to say that the functions illustrated in Fig. 20 synergise together to create a supra-emergent policy that produces what the team as a whole actually does and what the emergent output characteristic of that is that can be discerned by an external observer of it. This is the emergent, all encompassing viable system commonly referred to as 'the team'. The two opposing teams, being comprised of opposing functions and, in their turn, those being comprised of opposing players work as viable systems at all levels to synergise what that all encompassing system actually does. In terms of the Viable System Model, the situation between them during a football match can be despicted as per Fig. 21 below.

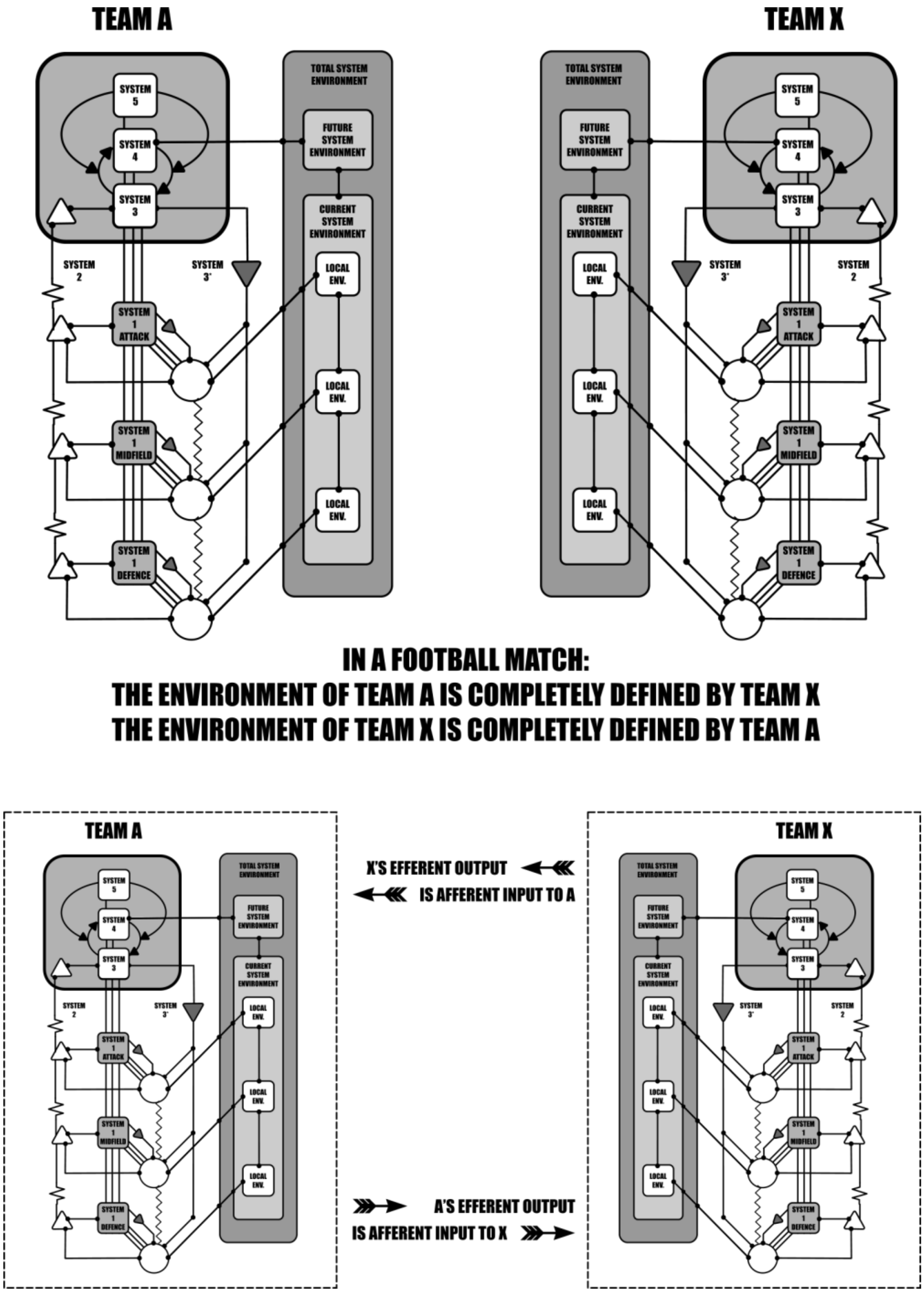


Fig. 21 Two opposing Viable Systems (Teams) in a football match

3.2.3 System 2 (Coordination)

The System 2 function of the VSM is defined as that which ensures that there is an absence of conflict and a state of harmony that subsists between each entity that produces what the organisation as a whole actually does i.e. each System 1 element.

It serves to balance the interplay between each element that is present in System 1 (Operations) within each recursion of the total system. This is such that the behaviour of those elements, and their emergent effects, do not serve to compromise what the organisation as a whole actually does.

In doing this, System 2 essentially acts as a brake on the autopoiesis (the self-production) of each System 1 element individually and collectively within each identified recursion. It does this to the extent that it does not become systemically pathological i.e. become detrimental to the performance of that recursion and, thereby, to the entire organisation.

In the overarching notion of systemic viability, it is vital to note Beer's work (Beer, 1994a, p.257) here in that, in an industrial context, "*there are managers who are responsible for their own area of a company and operate in a manner regardless of the rest, and that it is often said that if all managers succeed in this then their success represents the success of the whole.*"

Yet, it is characteristic of a viable system that all its parts may interact, and must interact, in a manner that is conducive to causing that viability to become manifest. If one considers a footballing analogy to this situation, the managers mentioned above could be considered to be the players who have responsibility to deliver for and on behalf of the team as a whole as determined by the team manager in advance of a match.

If any one of them (or a sub group of them) fails to subscribe to the collaborative agenda and undertake to do something of their own accord, and that is something the other players plainly disapprove of via a consensus of their opinions, it will undoubtedly cause much consternation within that group. If they disconnect themselves from the collaborative effort in the pursuit of their own scheme, the whole team (system) may very well suffer the consequences of that.

What has been agreed upon as to what should be done, that was either planned for in advance or manifested dynamically through circumstances, has clearly not manifested itself as intended.

In behaving autopoietically to the extent that it becomes pathological, the inter-relatedness of the parts that betokens a viable system breaks down. The emergent effect of what that inter-relatedness could deliver (and was delivering) is diminished and hence the viability of the team is diminished.

This means that the System 2 Coordination function of the emergent viable system known as 'the team' is less than it could have been in performative terms. This being since it did not have the capacity to prevent that pathological autopoiesis or mitigate is when it arose.

Evidence of this situation may be observed by watching a football match closely and noting that football players seem to naturally coordinate their actions. They do this in order to achieve both their individual and collective objectives and, by doing so, it is clearly a case of the manifestation of self-organising performative behaviour that is attributed to the team as a whole.

For example, a player on a team may win possession of the ball from an opponent and commence an attack run. Due to that player's skills and abilities they may successfully negotiate themselves and the ball around the various opponents, but there often comes a point whereby the threat to their possession of the ball becomes too great.

At this point, or in anticipation of it, the player will seek an opportunity to relinquish possession to one of their team mates who may be better placed to continue with the attack run at best, or at least take receipt of the ball such that their team does not relinquish possession of it.

It may be a case that a player observing this situation takes the view that the attack run that was commenced by their colleague can be seen to be able to continue if they got involved and got to an appropriate location on the pitch in time. They may conclude that their intervention would get their colleague out of their predicament of having their (hence the teams) possession of the ball being seized.

If the player in possession of the ball notices their colleague taking appropriate action to attempt to assist them by changing their location with necessary speed, the player can make a revised judgment call and autonomously decide whether or not to complete the pass to their colleague.

Via the signal they receive of their colleague's movement, the player in possession will need to expedite a decision as to what to do here within an epoch that is defined in microseconds for the most part due to the prevailing pace of the match. Accordingly, there is little time available for comparatively prolonged, strategic debate via the signalling between them.

The point being is that the player in possession of the ball needs to be able to successfully coordinate themselves with the player to whom they intend to safely and promptly pass the ball, in good time and with best effectiveness. It is incumbent upon them, and all the players involved on their team, to observe the situation they currently face and make the right decision in the face of the many alternatives that may (or may not) be open to them.

This is contended to be via the continually redefined interaction relationship network that they create for the team as a whole by their very actions. That is, the one that largely manifests itself as what each participant might be able to contribute to a situation via their spatial location with respect to it and that they each use as a means to signal each other appropriately.

Such signalling is the information that changes the state of each player, as referred to in Chapter 2, and serves to mediate their respective actions, thus providing a means of coordination. Each player on their team is doing this, continuously and simultaneously, and the effects of this emerges in the aggregate as the coordinative power of the whole team – the System 2 coordination function of the team as a viable system.

3.2.4 System 3 (Delivery Management)

System 3 (Delivery Management) represents what Stafford Beer referred to as the 'inside and now' (Beer, 1994e, p. 263) of the VSM that describes any viable system. It represents the highest management level that the elements of System 1 report to, and from which such elements obtain their resources to produce and accomplish what they are required to do on behalf of the organisation (the system) as a whole.

In the context of a football example, this could be the players of a football team (System 1 (Operations) elements that produce what the system (team) does) reporting to their team manager (System 3 Delivery Management).

Indeed, the work of Hoverstadt (Hoverstadt, 2008, p.30) states that System 3 has to do with those management processes that build the primary activities (as per System 1) into a greater whole. Accordingly, by that contention, it is clear that one may equate the relationship of the team manager and the collective of players in such terms since it is the manager that adjusts the composition and performative interaction relationships between the players.

That is to say, the manager picks and chooses from the transfer market who they can afford to have on their team. They then select from those whomsoever they want to play in a particular match and position them on the pitch such that they interoperate with each other in a manner to create the required synergy to attempt to defeat the opposing team.

Therefore, the team manager is argued to embody and perform the System 3 function for the organised system i.e. Team as a viable system.

It is, however, important to note that when that viable system is in performative mode, it is only the players themselves (to include the team captain) that can, and do, synergise the sum total of the viability that corresponds to their performance.

The manager is absent from that since they are not directly part of the viable system whilst it is under load conditions. It is argued that if the players synergise to produce the team's viability as a performative force, then it is they, and only they, when in that mode and by their actions, that must instantiate the System 3 functionality of that viable system.

In this respect, if a given player on a particular team is in possession of the ball, then their team mates are each operating in a manner such that they autonomously allocate themselves to particular places, hence situations, on the pitch. This in accordance with both their observation of that team mate with the ball, but also of their own respective environments with regards to the opposition in general.

In the performative milieu that they are operating in, there is no centralised source continuously determining which of the players should be where and why (although many would argue that this is what the manager does and, indeed, actually attempts to do in many respects).

Admittedly, there may be a tactical plan in place that notionally resides in the head of each player as has been formulated by the team manager and their support personnel in advance of the current match and that the players have taken cognisance of. Yet, a plan such as this does not have requisite variety for the situation it is intended to deal with.

It is an attempt to utilise a fixed notion of what is expected as being likely to happen actually happening. Yet it is intuitive that the dynamics of any football match are far from static and continuously evolve in actuality, thus warranting the continuous self-allocation of the players involved on a team to the situations that they feel they can make the best contribution to on a moment-by-moment basis.

Indeed, a notional model of the capabilities of both their own team and that of the opposition may be held by that manager and they design a control strategy for their team based upon that. Yet, that opposing team does have autonomy to vary from that as it sees fit i.e. it can become, via its own autonomy, unpredictable with respect to the model of it held by that manager.

In this respect, the opposing team can synergise in such a manner as to exhibit a net performative output state that the manager's team might not be able to synergise and provide an effectively countermeasure to.

The manager allocates their team to a, perhaps comparatively, static representation of a fixed situation in theory. The players, most definitely allocate themselves dynamically to a dynamical situation in practice as the circumstances warrant.

Thereby, when such action is considered in the aggregate, it is that which is contended to instantiate the emergent System 3 function of the emergent viable system (team) that they operate within. Their emergent System 3 functionality is contributory to the effects of the team's net performative output in just the same way as the emergent System 2 functionality is a contributor to it also.

Within viable systems theory, System 3 has an entirely pivotal nature. The reason for this is that System 3 also defines the linkage between the collective of System 1 elements and the Metasystem of the organisation (please see later).

System 3 looks within the overall system towards the activities of System 1 and the collective of productive units therein that are responsible for what the organisation actually does i.e. actually produces (analogous to the team manager looking at the collective of players). The System 1 elements report their performance to System 3 and they each receive (from the sum total of the resources available to, and in possession of, the total system) what they need to accomplish their roles via a negotiated resource bargain with it.

The players within the football team, by their actions, are reporting to each other continuously i.e. they can, for the most part and at most times, each see what each of the others are doing and thereby what everybody involved is doing with respect to the opposition. It is a case of what was contended earlier in terms of System 2 (Coordination) i.e. they signal their situational need to each other by virtue of where they are and what they are (or are not) doing with respect to the situation at that location.

The players individually allocate themselves to where they feel they need to be by virtue of their own autonomy that they have been imbued with to do so and under the rules of the game. This is a crucially important point, since such activity (or not as the case may be) is not only a vital input to the coordinative capacity of the system as a whole as covered in Section 3.2.3, but also one that is entirely self-managing – when the team is in performative mode.

The emergent aggregation of each individual's decisions that pertain to whether or not they allocate themselves to the prevailing situation in an appropriate way is not subject to a centralised controller that formulates and disseminates instructions to all parties to that affect, but is perhaps the case when one considers football teams from a more conventional managerial perspective.

In terms of role allocation, each player allocates themselves to roles as they see fit and hence as they believe as circumstances warrant.

Taken collectively, it may be argued that, in an abstract sense, the net emergent effect of all of them doing that simultaneously and being aggregated, directly replicates the effects of a single embodiment of such a function, such as a team manager and what they actually do.

The team on the pitch effectively forms an emergent collective intelligence that forms and executes that resource allocation function on behalf of itself. It is the collection of players that is an instantiation of System 3 in the viable system that they are a part of, and it is also they who hold and operate the resource bargaining channel of that viable system as well.

3.2.5 Resource Bargaining and its Channel

In viable systems theory, the resource bargaining channel is that which is held by System 3 (Delivery Management) on behalf of the total viable system. The resources that the viable system has available to help it achieve its purpose are allocated by System 3 to the elements of System 1 (Operations) that actually undertake the required work on behalf of the whole system. Those System 1 elements may require resources to help them accomplish their task or they may not.

Yet, those resources are economically scarce as far as the total system is concerned i.e. they are finite and hence need to be allocated fairly, with maximal effectiveness with the minimum of waste such that the resources can be economically conserved.

Accordingly, System 3 will allocate resources appropriately to the operational elements of System 1 in exchange for performance reporting data from them that provide insight into how those resources are being deployed and effectively organised. In other words, there is a mutual expectation that exists within both System 3 and System 1 that they will each honour the needs of the other.

As has been argued earlier, in the case of an example of a football team, System 3 (Delivery Management) is the collective of players; but there is duality here since those players are also operational elements of System 1 (Operations) that actually produce the work that the total system requires should be done. Moreover, a case has been made that the System 2 coordinative aspect of those System 1 elements is also an emergent property of the team as a viable system that is founded upon how the players actually perform on the pitch.

The Resource Bargaining function and its communicative channel is considered to be no exception to this emergent agenda. Although it is not physically tangible, it is tangible in a performative way. The reason for this is contended to be that the role allocation mechanism (System 3

(Delivery Management) as argued) perceives the needs of the System 1 elements as a collective intelligence with respect to its own configuration.

This is on the grounds of the systemic duality referred to earlier. The players each see what is happening with each other and autonomously dispatch themselves as resources of assistance to particular situations as they see fit.

They are all doing this simultaneously, therefore when such behaviour is aggregated then it may be equated to the resource bargaining channel of the collective intelligence that is System 3.

This is in operation with respect to itself in its own capacity as the total system's System 1 functionality, and in a manner that is identical to that System 3's role allocation function.

It is admitted that such self-referential behaviour is somewhat abstract, but it is nevertheless claimed to be present and operational in the manner described. If it were not, then how else could the resource bargaining channel of the team as a viable system become manifest in the face of such duality and in a self-organising manner?

The role allocations are made by System 3 in consonance with what is needed in System 1. For example, a striker may be needed at a particular point further down the pitch towards an opponent's goal so they autonomously position themselves there in anticipation of receiving a pass from their midfield.

The midfielder will likely have witnessed this signal that the ball is required at the position where the striker from the attack function has positioned themselves and pass the ball if they can from that point, or perhaps advance towards that point and pass the ball at a more opportune time.

In terms of System 1, the midfielder has signalled their position to their team mates (the remainder of the team's System 3 that is not in possession of the ball) as to their current situation. Those members of System 3, i.e. the collection of players that are not in possession of the ball, each autonomously makes a decision as to what they can or must do in response to that signal they are receiving from that midfielder and they adjust their activities accordingly.

This reconfiguration is the response of those in System 3 that are not in possession of the ball to the midfielder as to what that System 3 can allocate to them in terms of total system resources. This change in configuration is communicated to the midfielder and they make a judgement as to what action to take with respect to that. That is to say, appropriate information (that which changes the state of each player) is continually broadcast between them via the continually reconfiguring relationship interaction network that they create for themselves and communicate across by their actions and the observation of those.

It is this mechanism that is contended to be the equivalent of the resource bargain between any single System 1 element (player) and the collective that is System 3 (remaining collective of players on the team) that defines the total systemic resource bargain that operates between them. Accordingly, this is contended to be an emergent performative property of the team that is contributory to the effects of the team's net performative output as a viable system.

3.2.6 System 3* (Audit)

Within the VSM, there is a need for verification that what is being reported as happening by the various mechanisms designed to deliver such information actually is happening. It is prudent to verify the facts relating to what has been reported, since if there is any reason as to why this might be incorrect then this could have major repercussions for the organisation as a whole.

Accordingly, System 3* (Audit) represents the mechanism within the viable system that facilitates a check on the activities of each System 1 element directly, thus bypassing the localised management of that element. The management involved in the supervision of various System 1 activities that they are allocated to may well be reporting the facts as they receive them from their System 1 functionaries and interpret them in good faith. They will often consolidate these facts and escalate them to others who, in turn, they report to with no reason to withhold or distort them.

Yet, there may be a reason as to why this is not the case. There may be a situation where the manager is acting in good faith but data emanating from their associated System 1 is not as indicative of reality as it should or could be. Accordingly, it is prudent for the benefit of the whole system that verification of what is reported as being the case actually is the case.

If the mechanism is not in place, then whatever data is actually relayed to the higher management may or may not be a true reflection of the inside and now of the total system i.e. the true nature of things as experienced by the System 1 (Operations) elements. Similarly, this mechanism might very well reveal something that is being kept from the localised management deliberately by the System 1 elements involved, and of which the management function governing their overall activity are entirely and innocently unaware.

System 3* (Audit) then acts as a double check from a different systemic perspective to ensure that what the system actually produces (or should not be producing) is acceptable or not in the context of what it should be doing locally and hence in the overall scheme of things.

Accounts of the audit channel advocate that such investigation should be carried out intermittently and to the appropriate extent required. To behave in a manner that is counter to this advocacy may well be interpreted by those who are subjected to it as being symptomatic of entirely autocratic and oppressive behaviour. This may precipitate undesirably deleterious repercussions to cascade about the system in focus due to disaffection with the way things are. This may well serve to fuel the case that the system actually becomes significantly less than what it could have otherwise been in a performative manner.

In the context of a football team, the operation of the audit channel is different to that described above only in context and most certainly not in operation. In this respect the System 3* (Audit) mechanism of the emergent viable system that the team is, is instantiated by the self-organising activity of the players involved.

It is the case that the manager is traditionally responsible for this activity, but again it must be noted once more that, in this context, the manager is not part of the performative system under load conditions. They therefore make no moment-by-moment contribution to it on the same self-organising basis as a player does, due to their physical disconnection from it. In much the same way as the other functions of the team as a viable system have been contended to become instantiated and operated on a self-organising basis amongst the players, System 3* (Audit) is no exception.

In making their observations of each other, they are undertaking an audit of each other both individually, but also when considered as a collective. The defence function of the team, for example, may comprise three players, and the rest of the team can each visually observe this unit (or part thereof) and make an appraisal of its efficacy that is either explicit or intuitive. This may (or may not) be reported by someone to the team captain for them to take action, or, indeed, they may have a discreet word with those causing offence by their actions (or inactions as the case may be) to resolve matters.

Although an appraisal such as this may be a subjective one, this is more than sufficiently offset in an objective manner since what each player does is for the most part represented by their position about the pitch and what they might (or might not) enact there if they have possession of the ball or otherwise.

The behaviour is there for all to see either in the moment or afterwards and serves as a more than adequate audit mechanism. Approval or disapproval of a particular player's (or small group of player's) action (or inaction) may be forthcoming from others on their team. This since they have directly observed what has (or has not) happened and will, likely as not, be subject to necessary levels of peer pressure as a by-product of the audit channel having achieved its purpose.

3.2.7 Algedonics and its Channel

The term Algedonics is given to the notions of pleasure and pain as experienced by the system in focus. In the context of the VSM it is used to provide an alert of either type by System 1 (Operations) to System 5 (Policy) (please see Section 3.2.9, p.113) directly, thus bypassing System 3 (Delivery Management) and System 4 (Intelligence) in the process.

This is used to bring to the attention of the normative management of the total system (System 5 – Policy) that something requires its attention and that might not otherwise reach it via the interplay of System 3 (the inside and now of the team) with System 4 (the outside and then of the team – please see Section 3.2.8, p.110) that it serves to balance.

In the context of a football team then if a player has a problem they can raise it directly with the team captain whilst on the pitch should they need to in a conventional sense.

In an emergent viable systems sense, this appeal is contended to be to the collective sense of justice of their colleagues taking a view of any injustice that might befall a particular player in their team whether from within or without of the team. Indeed, witness arguments on the pitch between aggrieved players where one has plainly been done a disservice by an opponent and how other players from both teams congregate around such arguments and vocalise their opinions.

In their collective capacity as that which instantiates and operates in a manner to regulate itself with respect to its current situation i.e. to produce a self-organising adaptive controller of it, then it is implicit that such an arrangement balances its internal capabilities with external obligations. In this respect their behaviour instantiates an emergent capacity to behave in a manner to represent what System 5 (Policy) actually does on behalf of it as a viable system.

The localised management of a given situation on a pitch during a match is undertaken by a player that interfaces with that situation and attempts to control it. As each player is a viable system by definition, then what they do is the outcome of their policy in that capacity and the implementation of that.

Those policies are aggregated to form what the team as a whole is discerned to be doing at a given time. As such the output of that aggregation is the operational characteristics of the whole team with respect to its total situation and hence its policy as the emergent viable system that the team is.

It is argued that when each System 1 element issues a signal (which may mean they issue no signal –which represents a signal in itself) that all is well as far as they are concerned. Under such circumstances, it will be likely that they may be winning the match.

Accordingly, the aggregation of such signals represents the extent to which the pleasure aspect of the algedonic signal is currently alerting, hence pervading, the team as a whole, and is hence serving to influence its policy function.

Similarly, if all were not well with each System 1 element, say because of poor morale due to losing the match with little time remaining to recover the situation then this would correspond to the pain aspect of the algedonic signal.

Here the System 5 Policy of the whole team may be adjusted due to its influence and may well become manifested as the team resigning themselves to defeat. This may be evidenced by it exhibiting less coherence or a reduction in their intensity of play due to apathy concerning the current situation.

By the rationale presented, the algedonic-signalling amongst the players is therefore present. It is operating in emergent form and it is conveyed amongst them, individually and hence collectively, by the relationship interaction network that subsists between the players as alluded to earlier.

3.2.8 System 4 (Intelligence)

System 4 (Intelligence) represents what Stafford Beer referred to as 'the 'Outside and Then' (Beer, 1994e, p.263) of a viable system. In other words, this is the function of the viable system that scans the environment that the whole system operates in, and does so at a scale of what is colloquially termed 'the bigger picture'.

System 4 is therefore the interface between the organisation as a system as a whole and its external environment i.e. its environment beyond its systemic boundary. It functions to observe the environmental conditions, as they currently exist and attempts to predict what they might be.

The former ensures that there is a direct linkage between the system and its environment in terms of what is happening right now, so that it may be suitably reacted to, with the latter operating in an attempt to anticipate environmental conditions in advance. This being such that the whole system may avoid or pursue the threats or opportunities it faces respectively, and organise itself in readiness to do so in advance.

Both are vital functions of System 4 but it is submitted that the anticipatory function is especially important since it is far easier to identify a potential problem in advance and take action to avoid it rather than attempt to fire fight it whilst in the midst of it.

In operating in this specific respect, the function thereby seeks to ensure that scarce organisational resources are not unduly wasted. It does this by mitigating the effects upon the organisation of an unanticipated or unforeseen set of environmental conditions. Consequently, such scarce organisational resources are more productively and more profitably utilised to the organisation's overall benefit.

During a football match, the football team as a whole is directly connected to the environment of concern via the players who are responsible for what the organisation actually does on a per-second basis. As such, the players and what they can accomplish represents the reactive capacity of the team and responsibility for this is devolved to them by the manager both individually and collectively.

The players also possess an anticipatory function that they can employ to attempt to predict ahead in the short term how a particular situation that they and their team are experiencing might unfold and pre-formulate, albeit on an extremely short epochal scale, a suitable plan to perhaps deal with that. This is part of their innate apparatus as an inherently valid, natural, instantiation of the VSM and its precepts; but since this is essentially being aggregated in the name of making the total system (team) viable then they are forming the total system's version of that functionality.

Their individual observations are essentially aggregated to form the System 4 functionality of the team as a whole as a viable system. This representing what is essentially the perception and anticipation circuit of the team considered as a multi-perspective collective intelligence.

In terms of making use of the data that it receives about its own situation within its environment, the team as a viable system has to make sense of it in the context of what it is and what its capabilities are to do something appropriate about that.

In the case of individual players as viable systems, they interpret their individual situations as they observe them; but they also do this in the context of the model that they hold in their heads about what they can do about that - since only they know their true abilities that they can muster to deal with that.

All players in the team are contended to be doing this continuously and at such a pace that for the most part the players seem to behave in an entirely reactive manner when they are observed. This suggests that they are processing their environmental intelligence and developing a response to it at a rate that matches the rate of environmental perturbation they receive as a viable system. This means that they appear to have very little opportunity for them to apply an anticipatory aspect of their System 4 Intelligence function. This being due to the dynamic pace of their situation and that not offering much opportunity for internalised deliberative strategy formation - even given the massive parallel computation ability of the human brain to attempt this.

There may be enough time for a player to observe, assess, design and implement a response to their situation (as per Kim's single loop learning model (see Kim, 1993)) and thereby engage in the internalised deliberative process as to what they should do at each moment during a match. Nevertheless, the efficacy of the outcome of that process is submitted to be directly proportional to the amount of time allowed by the pace and pressure of the prevailing environmental conditions to do so.

The assessment and design may well be executed with impressive effectiveness and efficiency. It may well be the very best course of action for that player to take in that moment based upon their own sense of their own abilities and limitations at that particular time. Yet, the situation that the response was designed to deal with will have since changed in some way by the time it was physically implemented; and this will probably diminish the fitness of its purpose accordingly.

The designed response related to a situation that changed before that response could be fully implemented. It may still be useful to an extent, but it nonetheless relates to a situation that is no more. This is exacerbated by the fact that such conditions seldom slow to such a pace that deliberation may take place in advance of appropriate action.

Occasionally, the pace of a game may slow down in this way. For example, in the event of a penalty, corner or free kick being set up, or as a player has an opportunity to stop for a few seconds on the pitch whilst in possession of the ball to consider their options. Nevertheless, for the majority of the time, football matches operate at a much accelerated pace and, therefore there is little opportunity for excessive anticipatory functionality to operate.

Despite this contention, the fact remains that only the players involved know what they are thinking at the time they are thinking it, so there may be a degree of anticipatory behaviour that is present that is difficult to isolate and quantify in terms of how it translates into spatiotemporally based performance terms.

Since the player is a natural instantiation of a viable system, then the anticipatory aspect of their System 4 functionality is inferred as being present and in operation. This being such that it fully influences the behaviour of that player to the extent that the player’s own will and desire to do so will permit it, since they do have a thought-based veto over it.

This serves to influence the debate between the player’s external situation and their internalised capabilities to deal with that i.e. their policy as a viable system. Since this applies to each of them, then when their behaviour is aggregated it is contended that this imbues the system as a whole with its anticipatory function. This is accomplished via the relationship interaction network that operates between each player, and the whole team’s anticipatory function is operated and aggregated over that network.

3.2.9 System 5 (Policy)

The purpose of System 4 (Intelligence) essentially reduces to dealing with the ‘outside and then’ of what the whole system is in existence to deal with in the first place. Similarly, we have observed that the purpose of System 3 (Delivery Management) is to handle the ‘inside and now’ of what the whole system is undertaking.

Both System 3 and System 4 deal with an enormous amount of variety (states of the systems that they have to contend with) respectively and by virtue of their unique perspectives.

Yet they also have to interact with each other to the extent that the whole system effectively and efficiently balances the external environmental factors that are of interest to it, with the internal factors that are reporting upon how they are attempting to deal with those factors on behalf of the whole system.

Hoverstadt (Hoverstadt, 2008, p. 35) refers to the interplay of System 3 and System 4 balance between ‘where we are now’ and ‘’where we want to be in the future” respectively. In other words, for a system to be viable, the variety it confronts in its environment and the variety that it generates internally must be considered.

There are many organisations where these two aspects are conducive to the system’s viability, but occasionally one may exceed the other and thereby serves to compromise the organisations concerned. This may be to the extent that they devote too much attention to their external situation and do not have enough awareness of their internal capabilities to deal with that. Similarly, too much attention may be devoted by the organisation to its internalised requirements and they may not have enough cognisance and anticipatory awareness of their external situation.

The differences (the biases in favour of either System 3 or System 4) between such varieties needs to be restored to equality, and the design of the VSM features a function to undertake this balancing i.e. System 5 (Policy). In achieving balance between the demands of both functions (Systems 3 and 4), the whole system has closure through the systemic coherence that the balancing mechanism provides.

Recalling that Beer (Beer, 1959, p.50) in citing Ashby’s Law of Requisite Variety states that “*only variety in the control mechanism can deal successfully with the variety in the system controlled*”, this means that, for every perturbation that a system encounters it must have an action to counter it if the system has requisite variety over that perturbation.

Accordingly, the variety of System 3 and System 4 is engineered by each and with respect to each other to the extent that the internal and external demands upon the system are balanced via an Ashbean self-vetoing homeostat i.e. a mechanism for holding some (critical) variable between desired limits (Beer, 1959, pp. 22-23).

This is such that if that variable wanders away from its acceptable value (or outside a range of acceptable values) then a mechanism is present that brings that back to within the range of acceptability to the system.

In other words, the homeostat embodies the principle of self-regulation – the action of one half of the homeostat causes the other half to act in a way to bring that errant half back under acceptable control limits and vice versa. This represents how the externally focused System 4 is regulated with respect to the internally focused System 3 in a viable system, such that what the system as a whole perceives what it perhaps seeks to pursue or avoid is balanced (hence controlled) with its own abilities and resources to deliver against such requirements as applicable.

There are occasions whereby the variety engineering that is undertaken by both System 3 and System 4 is not balanced via the self-vetoing homeostat between them. This means that there is residual variety (biased in favour of either System 3 or System 4 as the occasion dictates) that needs to be dealt with by the system as a whole.

System 5 (Policy) is that which deals with such residual variety such that the balance between System 3 and System 4 can be restored and the total system they are a part of has stability with respect to the control it exerts over its current situation in its total environment.

The output of the whole football team is determined by how the input it receives is accepted by it, processed within it, and what results of that processing are issued by it. The policy of the system (System 5's output) mediates the activity between the inside and the outside of the system to ensure that overall balance is maintained between them. The activity of that arrangement determines the overall control characteristics formulated and issued by the system as a whole. As has been contended earlier in this Chapter, System 3 and System 4 in the viable system that can be, and is, exemplified by a football team, is due to the self-organising synergy of the players involved to produce the net total performative output, hence implemented control characteristics, of the team as a viable system. This is examined in detail below.

3.3 Players as Self Organising Metasystem of Football Team

The structure within the Viable System Model that contains System 3 (Delivery Management), System 4 (Intelligence) and System 5 (Policy) is referred to as the Metasystem. It is this set of functions that supervises the activities produced by System 1 (Operations). As such it is the Metasystem that manages the total system, and it is System 1 that produces what it does.

If a football team is considered in conventional terms, one might expect the team manager and their associated support staff to occupy this Metasystem. After all, it is they who are, ostensibly, responsible for the management and performance of the team. Yet, the paradox is that when the team are on the pitch doing what they are there to do, the management and support staff are, for all practical purposes, disconnected from what those players are actually doing. Despite this, it is agreed that the manager can signal instructions verbally and visually from the sidelines to their players, perhaps to advise and guide them, but it is submitted that, in a performative sense, this is an effort in vain most of the time. By definition, the game is such that it is the players that either produces the required result for the team or they do not. The manager *et al* have no direct input into, nor control over, every circumstance that either one player individually, the tactical functions that they belong to, or that of the team as a whole on a per second basis

Despite this, a football team playing under load conditions in a match is nominally hierarchical in terms of its management due to the presence of a team captain, however this aspect is considered to be something of a token gesture.

The justification for this is that just as the manager is disconnected in direct control terms from all aspects of the performative agenda of the team in play, then so too is the captain. The exception to this being they are involved in the action on the pitch – they are members of the interaction network.

Ostensibly, they represent the totality of the Metasystem of that performative agency (they are most definitely members of it), but they alone cannot serve to regulate the performance of the total system directly. The captain may well be involved in what is going on, but they do not possess requisite variety to anticipate environmental conditions, formulate and disseminate a plan and then regulate performance of the team accordingly.

In the context of the Viable System Model, this aspect is especially intriguing since Stafford Beer (Beer, 1981, p.201) considered that the policy making function within a viable system should be a Multinode.

This means that the Metasystem of the VSM is underpinned by essentially a nucleus of debate. It is a place where the representatives of System 4 (Intelligence) and System 3 (Delivery

Management) would interact and debate their points of view about what the total system should be doing in accordance with its external perspective of the total system environment and its internal conditions to deliver against that. The group of players would (and do) form what Börner et al (Börner et al, 2005, p.57) term a "*global brain*", as alluded to earlier.

Yet, in Viable Systems terms there is something of a paradox here. The players produce the results for the team acting both as individual people and as a collective with a common objective, and as such they produce what the team does in every second of every match. Yet, it is those same players that individually and collectively contribute to the management of that team whilst it is under real load conditions. As such there is a duality in the role of each player i.e. they are both members of System 1 (Operations), since they produce what the team as a viable system does, but they are, simultaneously, members of the Metasystem of that viable system. Their behaviour is self organising and so too is their own management of it. They literally and figuratively become the multinode that Beer advocated.

According to the work of Correia et al (Correia et al, 2011, p.663), networks of this type represent social neurobiological systems that are important to study since:

"*The movement of each individual may be considered an emergent property of the continuous interactions of biological animated system in the context of goal directed behaviour with respect to their operational environments*".

In this respect, the collective of players self-organise to produce a collective mental model held by the emergent system that informs, and is informed by, their individual actions. It is enacted upon, dynamically error adjusted and immediately implemented based on multiple perspectives and hence a diversity of knowledge. It is dynamically error adjusted in terms of its effects via the process of error-controlled negative feedback

It is argued that by virtue of the comparatively large numbers involved, the group of players (as an emergent collective intelligence) holds, a far superior mental model of the total situation than any single intelligence (an individual manager, or perhaps a small group of managers and their close advisers) could ever hope to aspire to, let alone continually implement.

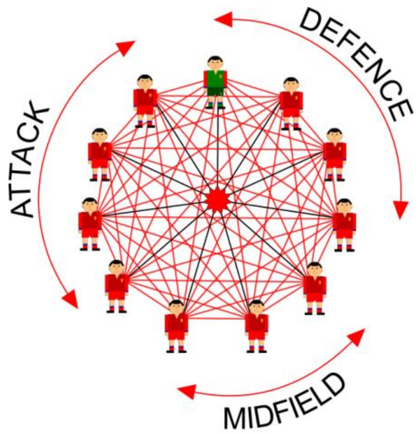


Fig. 22 Football team as self-organising system operating over a network of interaction

Given the preceding account, and noting Beer's contentions in particular, Fig. 22 illustrates the social network that the collection of players that comprise Team A represents. This is a fully connected network of interaction that represents how each player not only inter-regulates their respective interactions with all of their counterparts but also with respect to the emergent synergy property of that total arrangement (red star in the centre of the network).

Fig. 22 depicts how each player in each function of the viable system that is the Team influences, and is influenced by, each other. The connections between them are reciprocal and represent Ashbean self-vetoing homeostats that facilitate the error adjustments alluded to above. These are submitted to represent how players coordinate their activities with respect to each other, and that vary in strength as the occasion warrants. Some will be more active than others, and some may lie dormant until needed. Fig. 23 illustrates the duality in the role of each player i.e. both as a member of System 1, but also as a member of the team's Metasystem

.

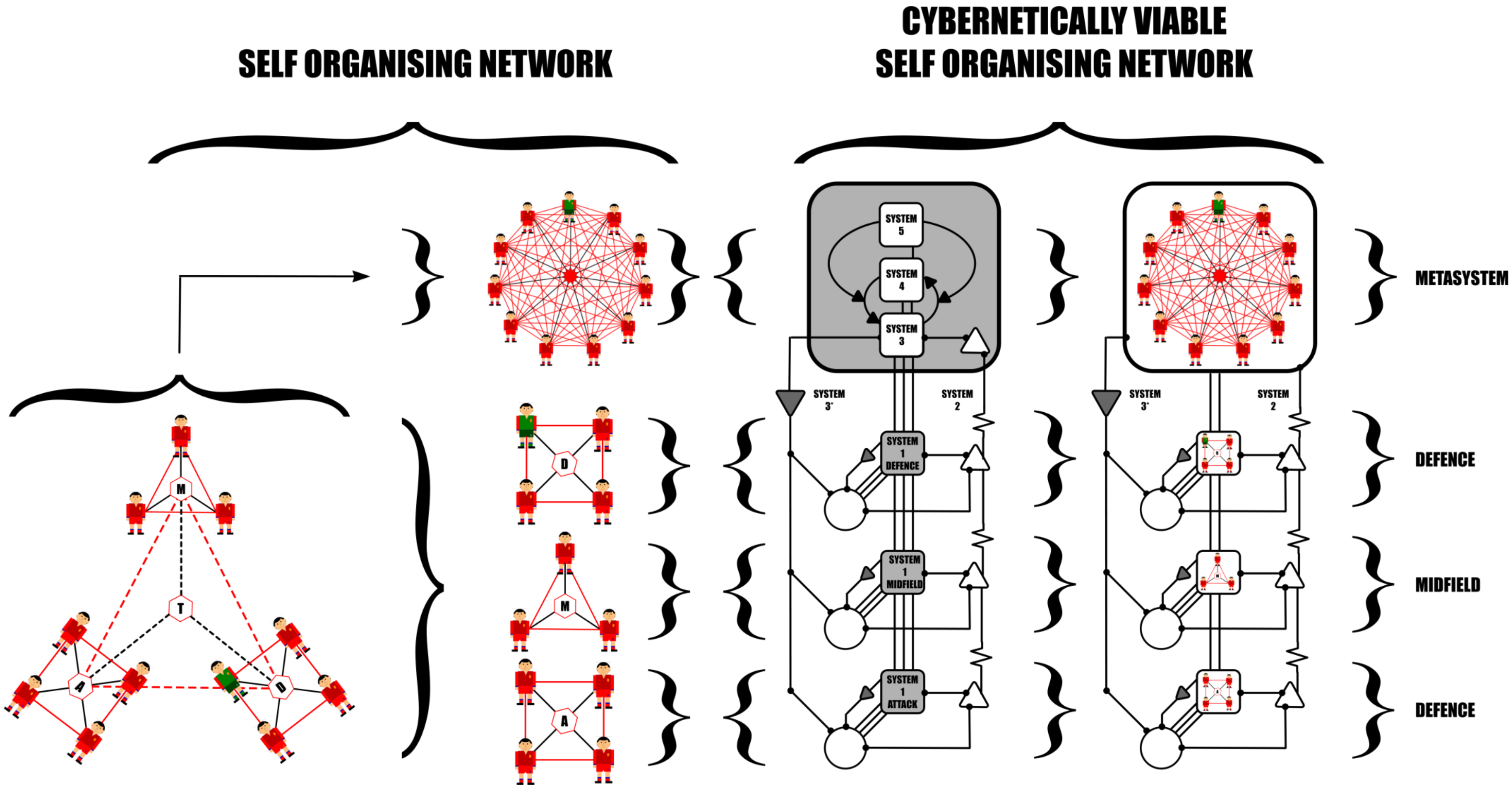


Fig. 23 Football team as viable system with self-organising Metasystem

3.4 Inter-Viable System via Intra-Viable System Policy Aggregation

Team A exerts itself upon Team X (Red and Blue respectively in Fig. 24 below) in an attempt to pursue its aims and objectives by regulating itself with respect to the environment that they are faced with i.e. the activities of Team X. In doing this, Team A engineers its variety to control Team X- such that the behaviour of Team X falls within acceptable control limits to Team A. Team A does not have its own way here, since Team X is applying a similar control strategy upon it.

A point was made earlier that if a team is victorious over another (e.g. Team A victorious over Team X), then it (Team A in this case) is contended to produce sufficient variety to contain the activities of Team X as described above. Importantly, this renders Team A far more effective than Team X and this is enhanced since Team A also possesses sufficient variety engineering capacity to execute that effectiveness with requisite efficiency.

In short, Team A self-organises to produce a more effective controller where the control it asserts is more efficiently implemented consistently, in contrast to the same properties emanating from Team X.

It is this that regulates the balance of success and failure for either team during a football match and hence the balance of the varieties between two viable systems in dynamical terms.

During that match, the more often that a team (e.g. Team A) can self-organise to cause an effective control function that they can efficiently execute in contrast to their opponent's ability to do the same thing (e.g. Team X), then the chances of success for the former are greater than those of the latter on the whole.

Indeed, as Beer (Beer, 1994a, p.279) stated specifically "*if the system can be trained to proliferate its variety a little more quickly, or to pattern it within the system a little less uncertainly, the control is likely to succeed for most of the time*".

It is the balance of that varietal proliferation, or suitable patterning as the case may be, which is contended to oscillate backwards and forwards in either team's favour during the match under consideration, as their respective variety is engineered by them in response to each other.

This is illustrated by the concept of a comparator function determining this difference and controlling the angle of the balance containing the coveted trophy in either team's favour in Fig. 24. The inclusion of the meters is intended to convey that this work has captured the Attack, Midfield and Defence tactical function emergent policy property of each as this is produced during each of the matches, and this process is also undertaken for the whole team.

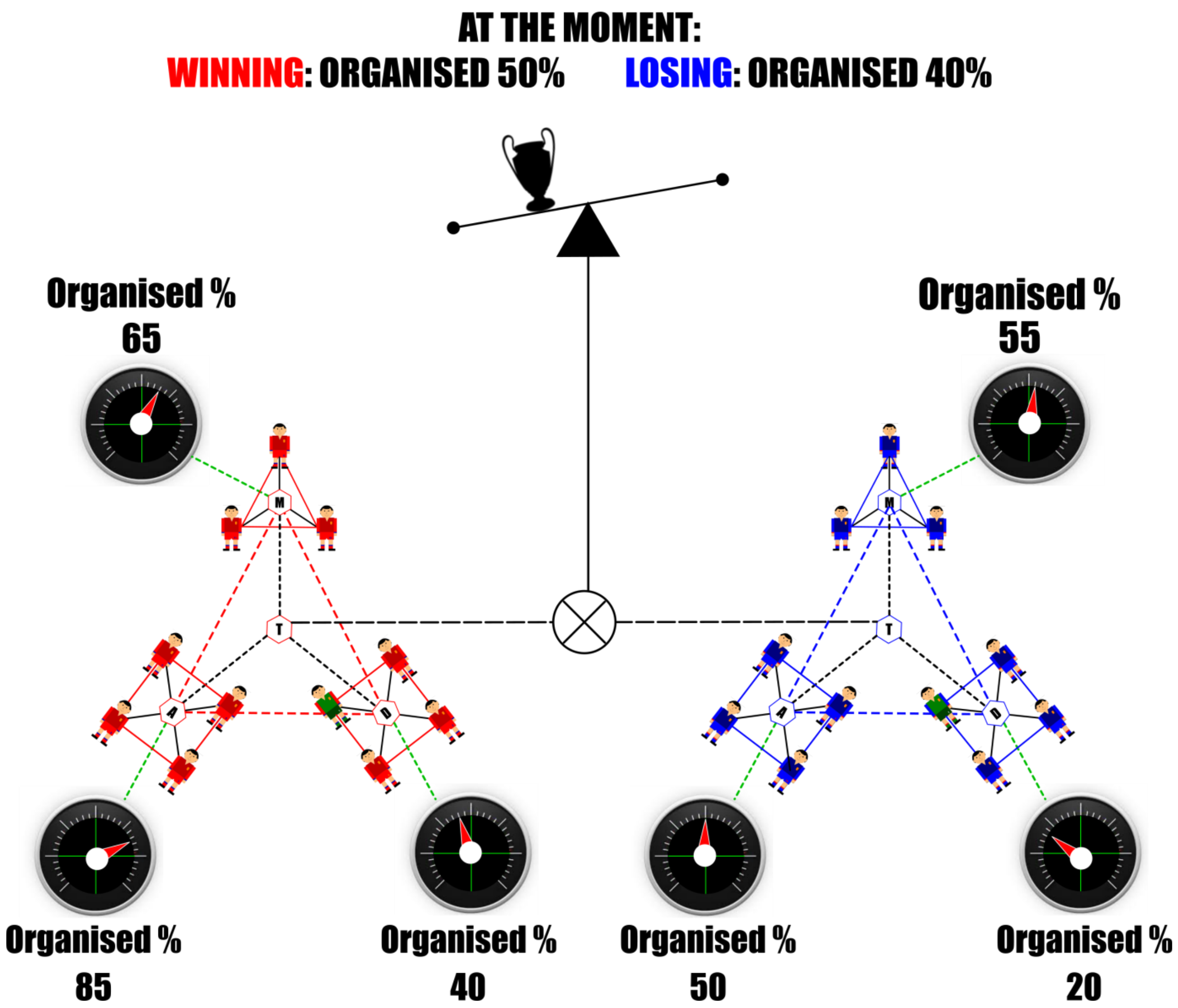


Fig. 24 The battle of the varieties

Fig. 24 may also be depicted as Fig. 25 shown on the next page, where each of the fully connected social networks that represent each team is reciprocally coupled to each other via their respective collective perception circuits (pink circle) and their respective collective motor circuits (green circle).

The scheme presented in Fig. 24 is used as a device to describe how the balance of success and failure in the match (for either side) may be, in essence, homeostatically regulated in wholesale terms. Each team regulates themselves with respect to each other externally (i.e. inter systemically), but is also where each one of them wants or needs to be with respect to each other internally (i.e. intra-systemically). Indeed, as Beer conveys (Beer, 1974, p.10) "*in a football team the power transfer needs to occur where the people themselves are located since at that point they share perceptions of the world and of purpose.*"

This is with a view to them then making the necessary operational corrections to reduce the disparity between the two via the feedback circuit that subsists between them. Such feedback suffers little in terms of lag since the dynamics of the occasion warrants it and it can actually be implemented since all aspects of the system operate at the same rate.

The teams self-organise to the extent that the collective feedback controller that they instantiate is that which is effective to deal with the time lags that exist between what it perceives and what it does to the extent that it is stable (See Beer, 1994e, pp.61-62). Indeed, the work of Pask (Pask, 1968, p.82) states that, "*when a control system achieves stability it solves the problem posed by not being stable*".

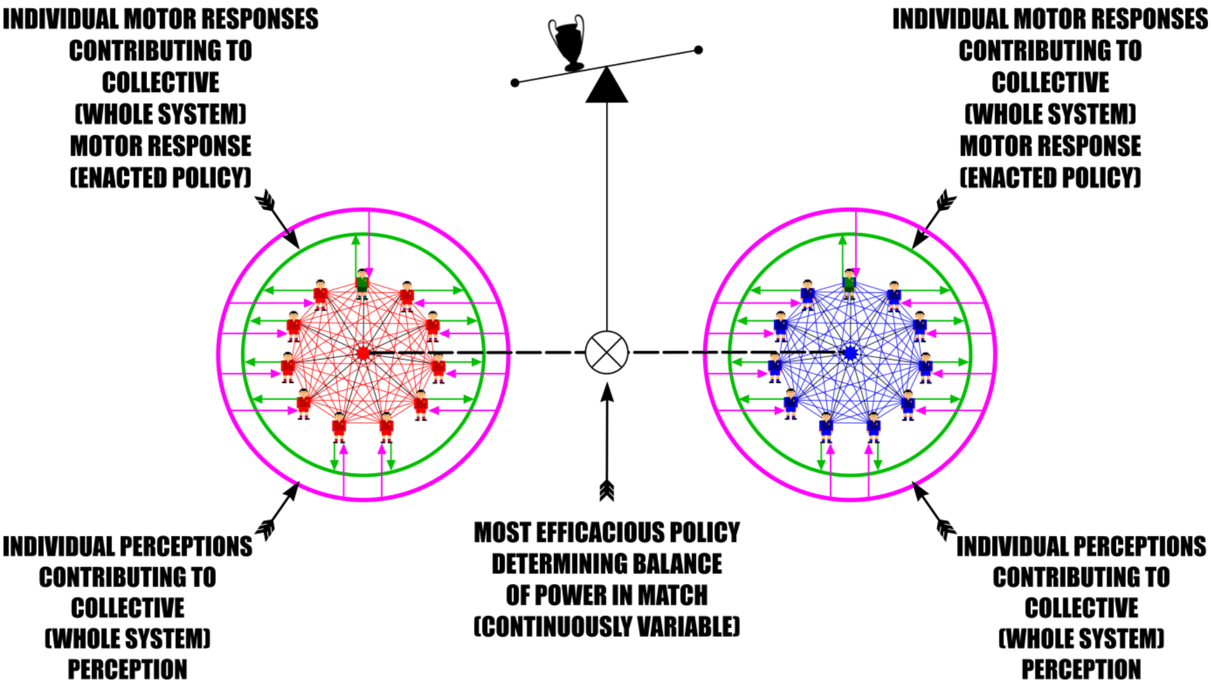


Fig. 25 Teams as opposing homeostatically regulated self organising networks

Fig. 25 illustrates that each team involved is what Espejo (Espejo, 2004, p.671) reports as being "*an example of a collective that is under pressure that evolves into a social system that has a capacity to maintain its stability far from equilibrium*".

Each player has their own policy as to what they need and want to do with respect to what they believe they can do at a particular moment in time with respect to the overarching purpose of the team they are a part of as it exists at that point. This is the result of the relationship between what they have perceived and what they have enacted being in accordance with a particular network of neuronal connections in their respective brains that facilitates that.

Yet, in the sense of ‘the team’ taken as a whole, by their respective actions, those players are similarly configuring what is in essence the neuronal connections within the global brain that they instantiate. Here, their collective perception being related to their collective motor action on an entirely self-organising basis. Accordingly, that is the policy of the emergent viable system that they instantiate and cause to become operational.

To expand on this point a little further, the individual policies of each player are predominately manifested as a continually updated sequence of discrete changes in their location about the pitch. From this, it may be inferred that their policy is their position at any point in the trajectory that sequence of discrete pitch positions describes.

The position that they exhibit as a result of their own policy is a change in their state, since not only they have literally changed location, but also their change in location changes the state of the team in a spatial context.

Moreover, a change in state is also present in a performative sense, since the relocation of player against opposing player is a realistic attempt to control the opposing team via such spatiotemporal variety.

The skill to actually seize control once in an appropriate location is of vital importance, but it is secondary to it since if one is not in position to attempt to take control then one never will i.e. succeeding in a tackle is predicated by first being in a position to actually execute it.

This means that the collective position of all of the players (the location of the team as a whole) can be considered to be the policy of the global brain that they are a part of. It is the output characteristic of each player’s policy as a viable system considered in the aggregate that denotes the policy of the viable system that they are all a part of i.e. the team. It is its net output state.

The policy of the team changes in aggregated spatiotemporal terms due to the contributions made to it by the policies of each player in spatiotemporal terms also. It is here that the input to the team in that global brain capacity is related to its output via the configuration of the relationship interaction network that is in continuously reconfiguring operation between the players as contributories to it.

That interaction network is intangible in physical terms but it is not in informational terms. It is the amount of information that represents the essence of the team’s policy, and it is this that has analogy with the physical connections between the sensor (afferent input) and motor plates (efferent output) in Beer’s anasotomotic reticulum concept (a branching and reconnecting network of connections in which unique pathways may or may not be specifiable (see Beer, 1981, pp.402-403 and Beer, 1981, Fig. 9, p.47). The information referred to in this represents the function that transforms net system input to net system output.

This may be further justified when one views such configuration of a particular team in the round (i.e. holistically) since, when one is observing a football match very carefully, its general trajectory will reveal how the movement of the team considered in its totality ebbs and flows in unison about the pitch.

This concept can be illustrated in the following example. This only considers the Attack function of a given football team, but the principle applies to the whole team as well as the remaining team functions: Midfield and Defence.

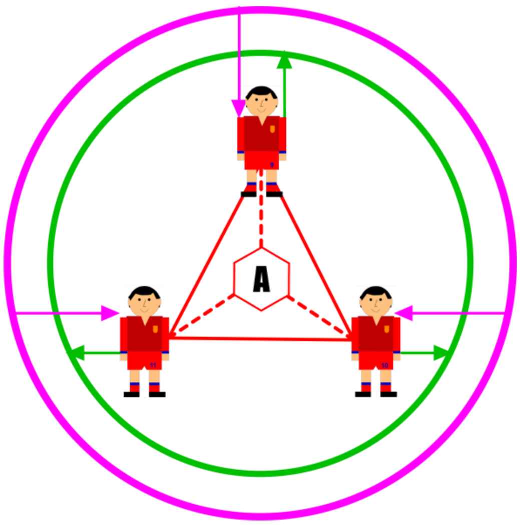


Fig. 26 Team A Attack function comprising 3 players

The pink circle represents each players own link with their own immediate environment and, thereby the collective environment of the whole attack function. The green circle represents the motor output of each player. It is this mechanism that defines how the connections between them vary, hence the shape of the polygon that connects each player as a node in that networked unit.

As each player moves and the polygon varies in shape, then the centroid of that polygon varies also i.e. it has its own trajectory about the pitch. This can be considered to be equivalent to how the collective effort of the players involved emerges, and does so as they organize themselves with respect to both each other and their individual environmental circumstances.

Yet, that collective effort is a change in motion vector, and especially in the game of football, that implies policy. This is to say that position (and its alteration) is the manifestation of the policy to transition from one position to another on the pitch for various reasons.

As a result of this, the location of the centroid of the attack unit (and its alteration) is regarded as being equivalent to a change in group policy. No single player imposes this upon the whole unit; it is an emergent property of how they interact. The interaction witnessed is a result of each player coordinating themselves with respect to their own local environmental conditions, and taking action (predominately defined in motor terms).

Simultaneously, they need to be cognizant to the extent required that the attack unit is a coherent force. There must be no conflict between the participants of the unit since if that were the case then its capability to produce its outcome would likely be diminished. Not only is each player aware of their personal 'outside and then' with respect to their personal 'inside and now', they are also aware of both aspects for the unit that they belong to. These demands need to be kept in reconciliation so that the actions of the individuals do not exceed the purpose of the unit, hence its requirements at any given time.

As such the whole unit maintains its own total balance between its 'outside and then' and its 'inside and now', and on a self-organizing basis. By using this method, one may similarly determine the emergent policy characteristics of other key functions within a team e.g. defence and midfield. Moreover, this may be extended to represent the policy of the whole team and also for each team involved.

As the attack function of the red team traverses the pitch between any two nominated points, the configuration, hence shape, of the polygon that links them will likely have changed. This changes the position of its centroid, and hence by such means dynamically varying emergent policy for the unit can be discerned. Moreover, since this is emergent then there is no physically tangible node present on the pitch for match scanning technologies to lock on to and hence continuously track for updated positions. Accordingly, for the emergent policy to be discerned, the coordinates of the unit's centroid needs to be dynamically recomputed and recorded.

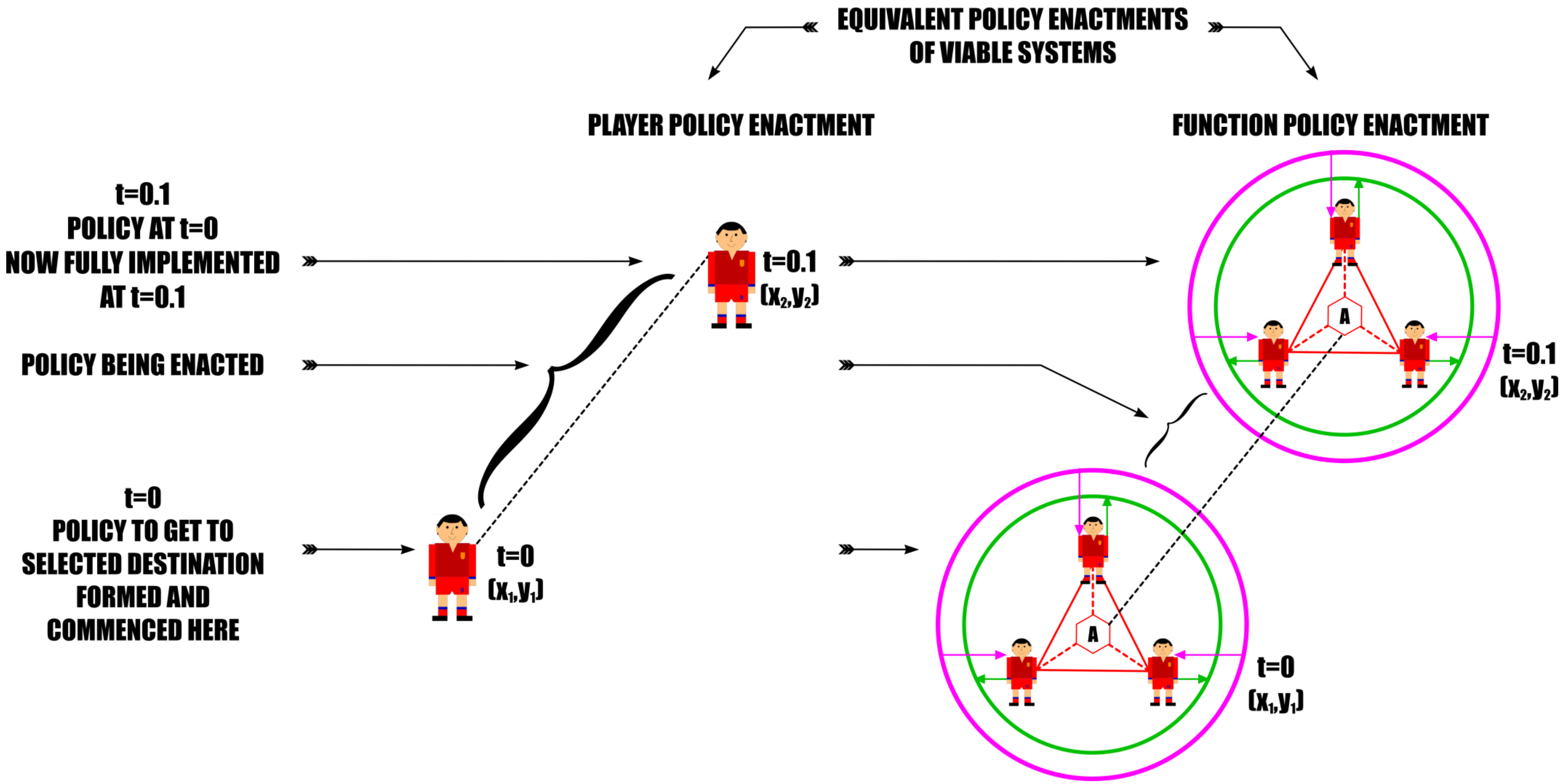


Fig. 27 Function movement analogous to player movement

The trajectory of an individual player is defined as a manifestation of their policy when defined as a cybernetically viable system. The same rationale applied to the three players that comprise the attack function, but the collective motion also describes the policy of that unit when it too is considered as a cybernetically viable system in its own right. In policy terms, both sides of the figure above are considered equivalent.

During an attack run, the Team A (red) are in possession of the ball. This will cause the defence function of the opposing team (Team X (blue)) to muster and take appropriate counter action.

In just the same manner as Team A's attack function, the defence function of Team X will have a policy that is underpinned by the policies of the individuals involved that comprise it. From Team A's perspective, Team X's defence is an obstacle to its efforts to score a goal. Team A needs to develop its own countermeasure to Team X's efforts so that the attack run can continue on a successful path.

Accordingly, the players in Team A's attack take individual action that underpins the wholesale action of that function. Individual policies interact and create a collective, emergent policy for the unit. This policy may, or may not be successful. Team A's attack function may be operating in isolation since perhaps it is some distance ahead of their own midfield who could help.

This means that they must work together in a manner that effectively counters the threat presented by Team X's defence. If they do not, and they do not obtain assistance in time, then they may well lose possession of the ball.

Although Team A's attack function is, ostensibly, well organized to accomplish its objectives this may not have sufficient potency to counteract Team X's defensive efforts. One may argue ad infinitum that this depends entirely on how many defenders are present and in action against Team A's attackers.

On the face of things, Team X's defence may contain more players than Team A's attack (please see Fig. 28 on the next page). Yet, what if those defenders are poorly self-organized to carry out that objective in contrast to the potency of the self-organizing attack of Team A? What the former has in terms of numbers could be effectively countered by the latter's ability to be better organized to perform its role in comparison.

This situation is depicted below:

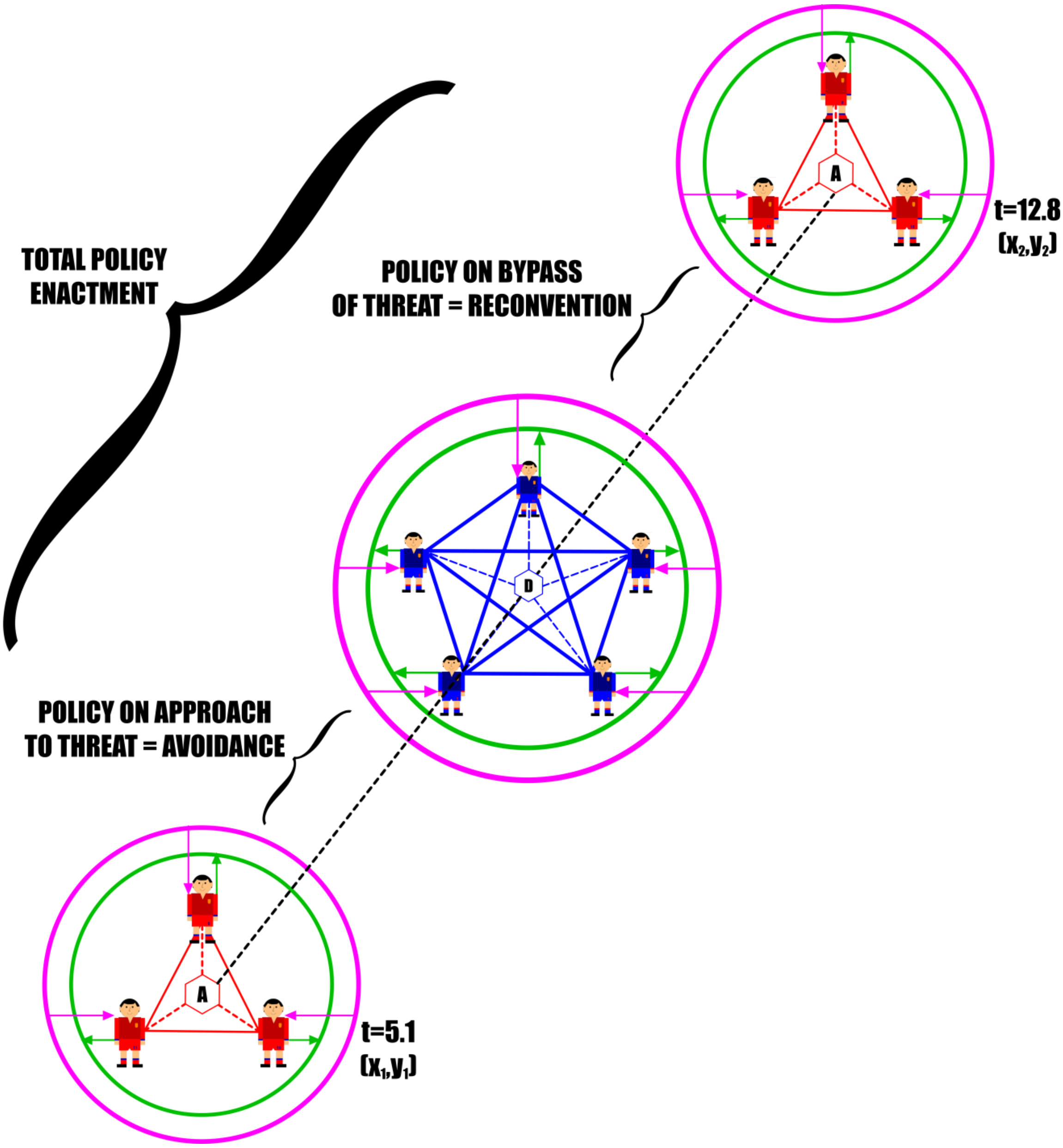


Fig. 28 Team A Attack (red) dealing with Team X Defence.

This takes it a period of time of 12.8 – 5.1 seconds and results in a transition of the unit from (x1, y1) to (x2, y2). The threat has been countered and the attack unit has reconvened beyond the threat to continue pursuing its purpose. Team A's attack would have had to respond individually, hence collectively, to the threat presented by Team X's defence.

Yet, it can be noticed that the latter had 5 players present in contrast to that of the former i.e. 3. The fact that Team A's attack surmounted its opposition, even though it was outnumbered, does suggest that it literally did more with less. In terms of the number of players involved in each opposing function, Team X's defence outnumbers Team A's attack. On that basis, one may argue that the former can easily nullify the activity of the latter.

The number of players involved in both functions, the actions taken by each of them and the interactions of those defines what characterizes it as a performative unit. By consolidating all of these various attributes, one may ascribe the notion of a specific performative unit as exhibiting a particular state at any given time.

Given that the numbers within Team A's attack and Team X's defence differ, then the range of states that either of them are capable of producing is determined by that. Yet those states correspond to what they are doing at any point, and hence to what they are achieving. This raises the question of what state a group would exhibit that corresponds to more success and less failure for it.

For sure, each player in both functions may have similar skill sets, but some may be better defenders on a like for like basis than some of the opposition as attackers. Moreover, when the players in each function interact then, since there is a difference in the numbers, the number of states that can arise to describe that group varies accordingly.

The intriguing aspect here is that the states generated by each function are ultimately designed and manifested to negate each other at the very least, and subsume each other to one particular team's advantage at best. In this way, the purpose of either team is pursued under the prevailing rules of the game. One team will operate in a manner to nullify the effects of their opponent's state and vice versa. This can be illustrated as follows.

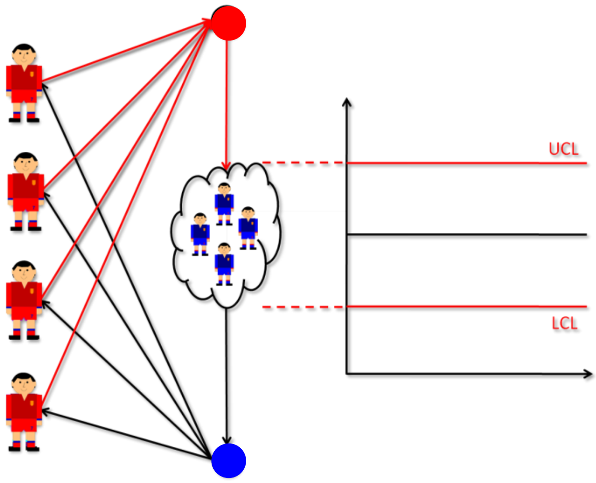


Fig. 29 Team A (Red) Attack vs Team X Defence (Upper and Lower Control Limits)

In Fig. 29 the Team A Attack Function confronts the Team X Defence function i.e. the latter defines the environment of the former in what Pickering (Pickering, 2010, p. 20) termed the dance of agency. The interaction between the teams is that based upon their diametrically opposed objectives and represents what either one of them must control to an acceptable level.

Each participant within the Team A Attack function will autonomously act on behalf of that function in accordance with what the team needs to do at a particular point in the match. In doing this, the individual actions consolidate into what the whole function actually does. This aggregation is not simply the sum of every participant's contribution nor is it the average. It is synergistic in nature since the performative effects of that consolidation are greater than any single participant to that group could create for it when working in isolation.

In order for the Team A Attack to control any threat presented by the Team X Defence, that synergy has to be greater in its performative effect than that emanating from the Team X Defence and applied by them to that Team A Attack function. This can be discerned in Fig. 29 by the activities of the Team X Defence causing to aggregate and form an emergent effect upon the Team A Attack via the Black lines in the figure (the aggregation is depicted by the Blue circle).

The aggregated activity of the Team X Defence has an effect upon each player in the Team A's Attack. By their actions, the Team A's Attack form an aggregated countermeasure to (depicted by the red coloured circle) via the Red lines in Fig. 29. This has a net effect upon the Team X Defence that precipitates the next action that they take in response to what the Team A Attack has done.

Accordingly, a homeostat is established and operated between the two functions i.e. the Team A Attack and the Team X Defence.

One function seeks collective control over another and vice versa to the extent that either one side defines as acceptable to itself. The degree of control will reside within a range of values that represents the upper and lower control limits that have been defined by the Team A Attack function's level of acceptability of the situation.

It is contended that this value will vary dynamically as the required level of control that the Team A Attack exerts over the Team X Defence modulates. This is argued to happen as circumstances within the football match concerned vary, and as the degree of separation of the upper (UCL) and lower (LCL) control limits also vary accordingly.

This is conceptualised as follows:

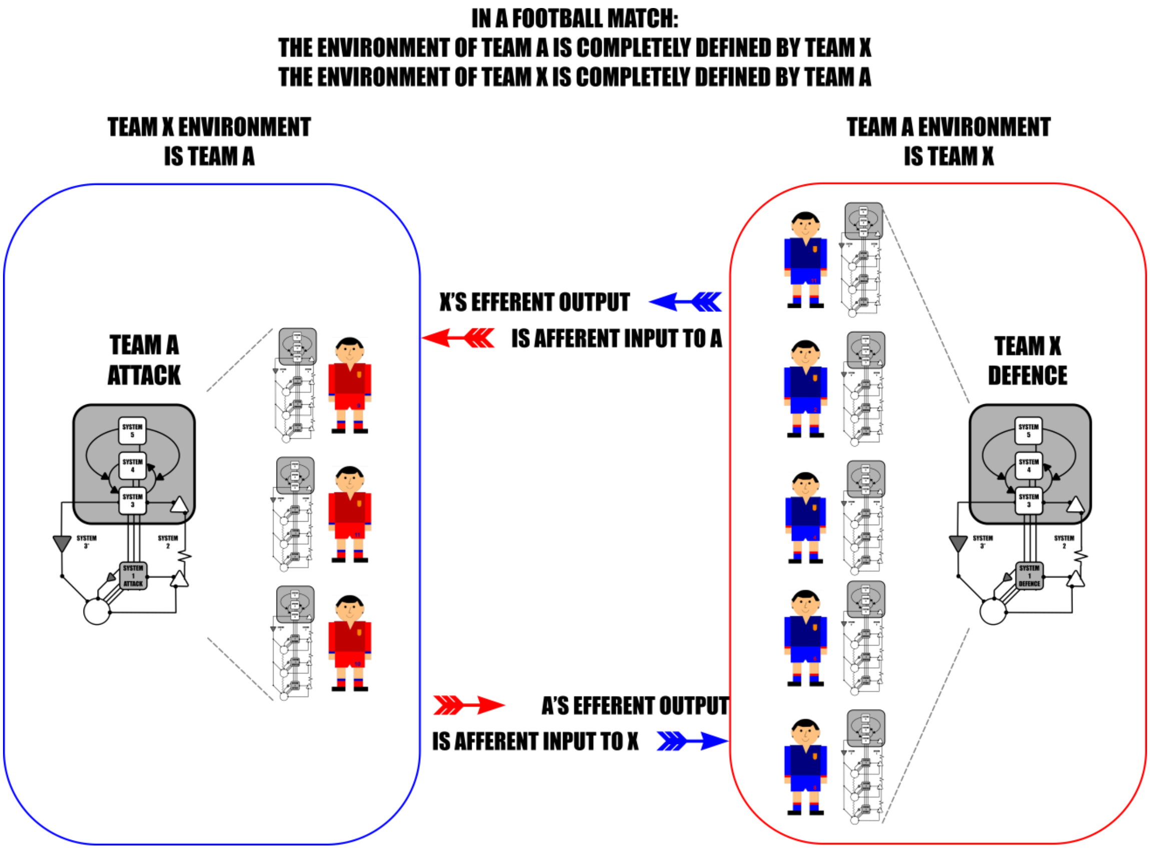


Fig. 30 Fig.29 depicted as two opposing viable systems (functions) of viable systems (players)

With this in mind, Fig. 31 and Fig. 32 below conceptually (not derived from match data, but could be) illustrates this situation via a dynamical characteristic for a, currently fixed, range of acceptable control (distance between upper and lower control limits). This is represented by the function depicted in each that oscillates between UCL and LCL control limits. In Fig. 31 Team A 's Attack function currently has a consensus about Team X's defence in terms of the threat that their activities represents to its objectives and this is represented by the red trace i.e. it is the emergent policy characteristic of Team A's Attack function as it varies over time. The same is true of Fig. 32 i.e. Team X's Defence function has a consensus about Team A's Attack function and they form and apply a continuously varying emergent policy to it as shown by the blue trace.

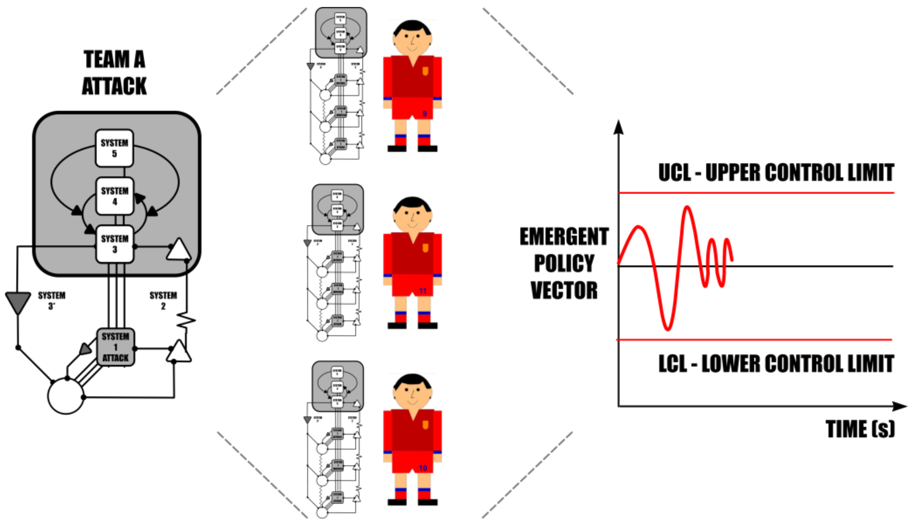


Fig. 31 The activity of the red attack function (its net output as a viable system = its policy)

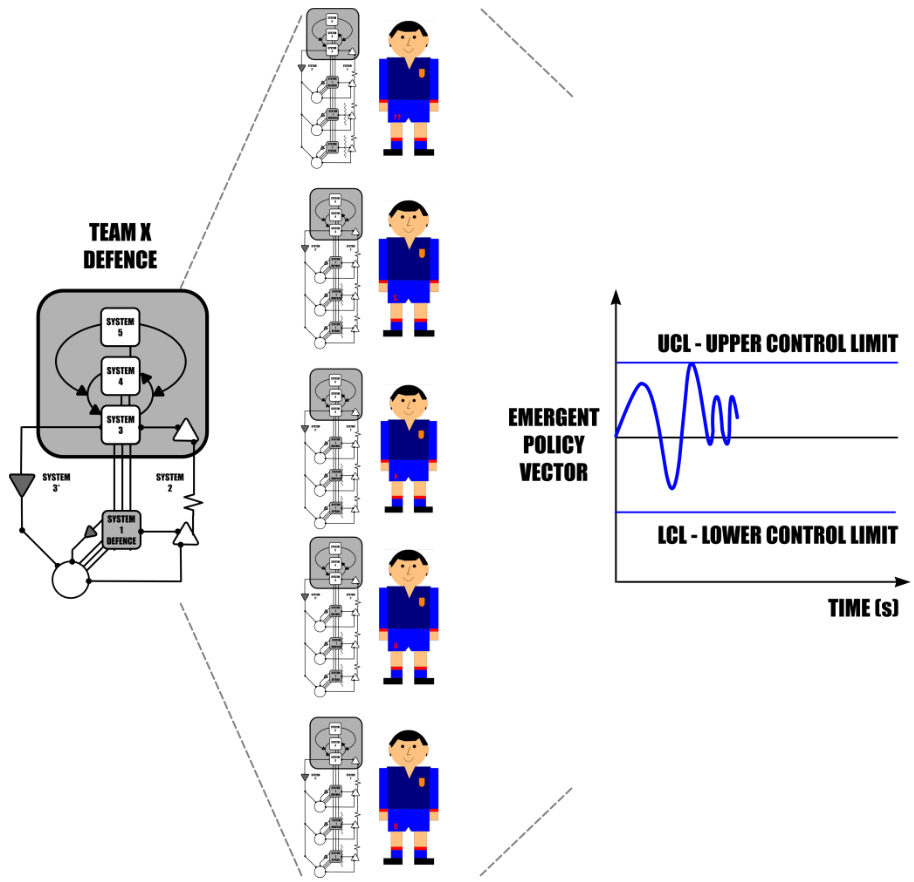


Fig. 32 The activity of the blue defence function (its net output as a viable system = its policy)

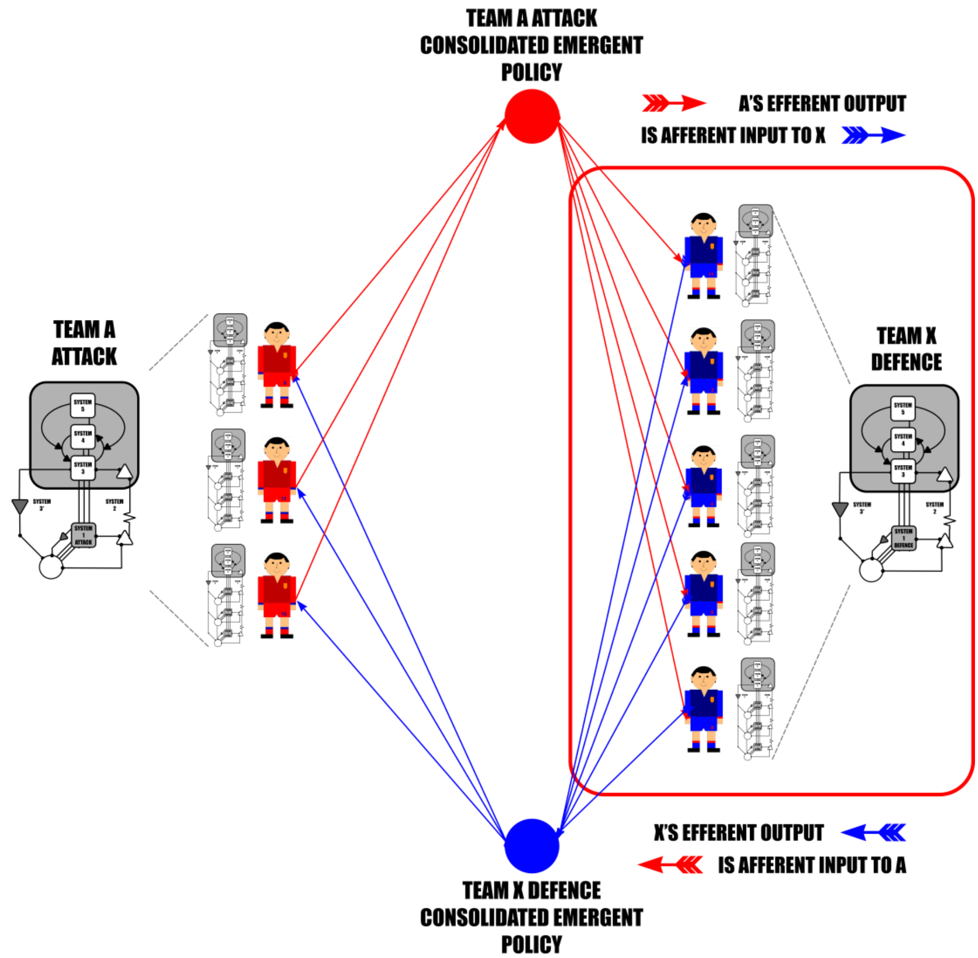


Fig. 33 Conceptual: Coupled consolidated policies of opposing viable systems

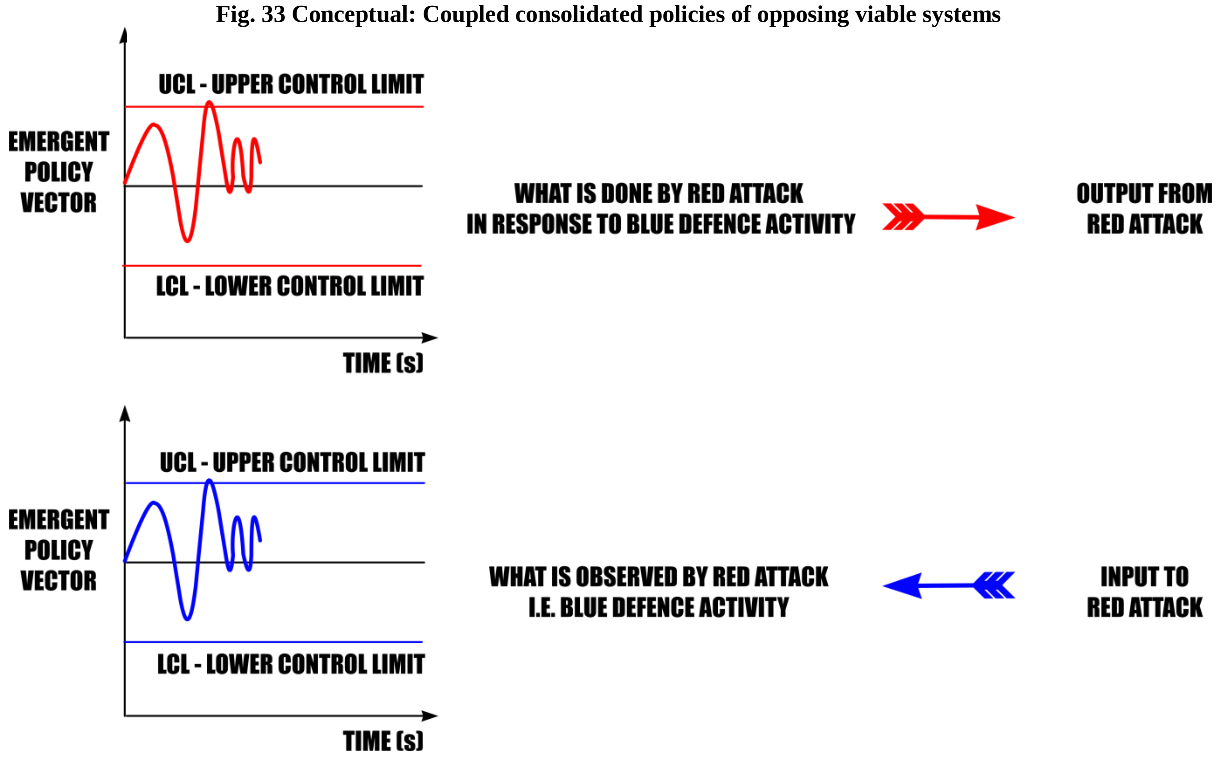


Fig. 34 Conceptual: Policies of Viable Systems related to control limits

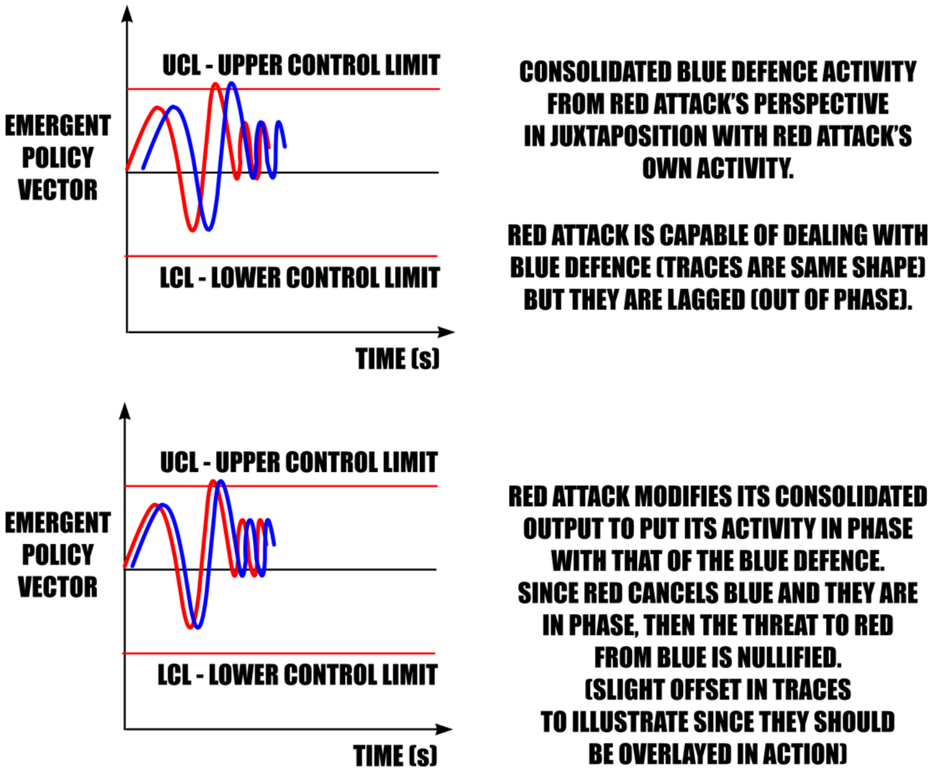


Fig. 35 Conceptual: cancellation of policies (red upon blue and blue upon red)

In general terms, this concept can be depicted as follows:

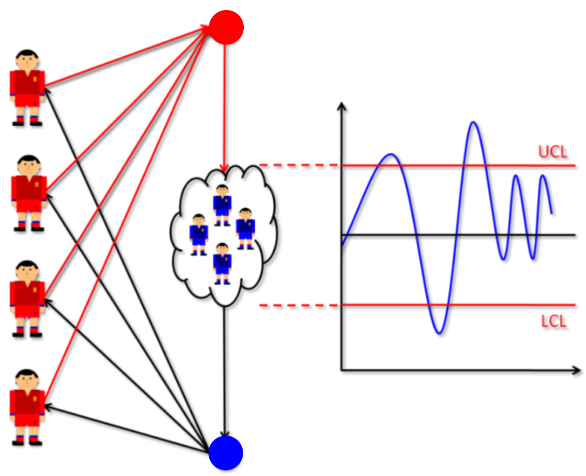


Fig. 36 Conceptual depiction of Team X Defence policy characteristics from Team A's Attack perspective

Fig. 37 below describes how the Team A Attack synergises their respective individual activities to overcome the effects of the Team X Defence upon it. Their aggregated emergent response and the implementation of it upon the Team X Defence are depicted in the figure via the function shown in Red that oscillates between the UCL and LCL control limits.

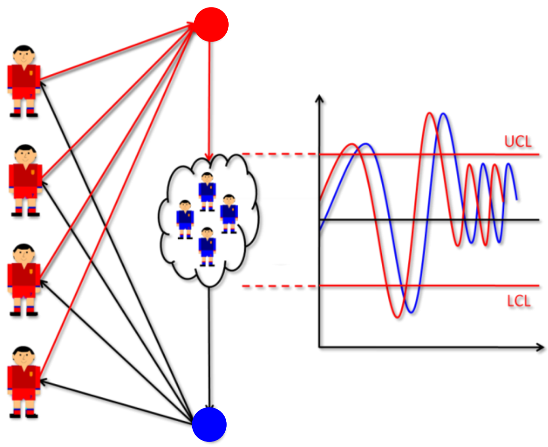


Fig. 37 Team A aggregated policy response to Team X (slightly out of phase)

Taking inspiration from Beer (WOSCORG, 2012b 4m:11s-5m:30s), Fig. 37 shows that the policy of Team A's Attack (illustrated by the Red trace) has aggregated and is currently attempting to impart upon the Team X Defence. This does shows the promise that it may serve to cancel out the effects of the Team X Defence upon it (illustrated by the Blue trace).

This is not unreasonable since it can be seen that both the Red and Blue traces are similar in shape (in this instance). Indeed, the participants of Team A Attack would engineer their variety (state) in such a way that their state (position) best places them to counter the threat to them that the Team X Defence presents.

As has been argued, this change in state is also their individual policies as viable systems (i.e. their System 5 function), but it is also that of the emergent viable system that they form to create and operate. This variety engineering is expected to counter the effects of the variety present in the threat, so the Team A Attack have to produce a varietal trace that nullifies the varietal trace of the Blue Defence, hence the depiction given.

Yet, crucially, the Red and Blue traces in Fig. 37 are lagged i.e. they are out of phase with one another. Moreover, the activities of the Team X Defence are still such that they fall outside of the acceptable control limits that Team A Attack possesses. Accordingly, despite its best efforts, Team A Attack is synergising to create an effective response that only appears to be an effective countermeasure to the activities of Team X's Defence.

This is indicated by the red and blue traces being practically identical. What is important here is that the red team is doing precisely the right thing at the wrong time.

The Red trace is an agent of cancellation upon the effects represented by the Blue trace, so if they were both identical in shape and applied to each other such that they were in phase, then one trace would cancel the other. This is illustrated by Fig. 38 below.

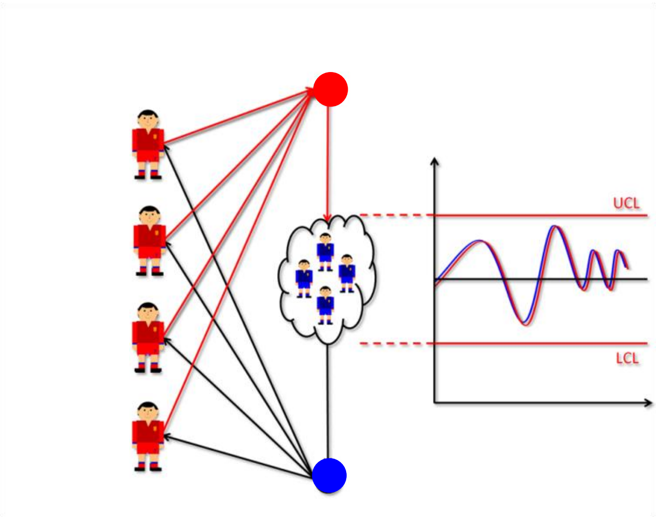


Fig. 38 Team A aggregated policy in phase with Team X's (Blue now under control from Red's perspective (Blue's activity inside Red's control limits for it)

If the balance is in either team's favour for long enough, then it is argued that they are more likely to succeed in contrast to their opposition. Yet, in football, the state that a team, or a sub group of it, expresses at any given time is for the most part spatiotemporally defined.

Players take action appropriate to their situation, and this may or may not be successful. Yet, to take that particular action at that moment they first have to be where they need to be to undertake it.

Their position on the pitch predicates the action taken there. It may be analytically impenetrable to quantify and analyse the specific rationale and mechanics of a particular action taken by a player at a given point, but it is comparatively easy to capture their position.

The former may result in not being able to accurately determine the states referred to above, but the latter means that spatiotemporally defined states can be quantified. On the face of things, Team X's defence was more than capable of dealing with A's attack – yet did not stop it. This suggests that the state expressed by Team X lacked the effect of nullifying the effect of Team A in this situation.

As has been discussed, Team X's defence had more players, and each of them may well have been terrific defenders in their own right. Yet, when working together there may have been less than optimal interactions that caused a less effective emergent performance to arise under the circumstance.

The corresponding state did not correspond with a performance to stop Team A's attack, despite having greater numbers to do so. Team A's attack may well have been comparatively more organized in the production of its state. Their perception will have been of five opposing defenders, but their mode of interaction coupled with, and underpinned by what each of them can do, resulted in a state that corresponded to success.

Yet on paper, Team X's defenders were not only greater in number; they were also perhaps officially rated as better players. This last point is important since, ostensibly, better players and more of them would lead one to intuitively conclude that they would produce a state that would counter the efforts of Team A's attack. Yet they did not.

Similarly, on paper Team A's attack may well be composed of players that are broadly acknowledged as being less skilful players in contrast to Team X's defenders. Nevertheless, Team A succeeded in its particular objective at that time. The state that they created through personal efforts being coupled through effective interaction being efficiently executed was more potent that Team X's efforts in performative terms.

Accordingly, either Team A's attack was superior in its individual and collective policy formation and the implementation of that against a greater number of opponents or conversely, it may be that this was actually modest in reality and Team X's defence was in comparative disarray.

The reasons for that may be myriad. If Team X's defence was less than it could, or should, have been, then one reason for this could have been that one particular 'star' player took it upon themselves to act unilaterally. Although this is speculated here, it is argued that it is at least possible for such situations to arise.

In light of this, it is important to consider other factors. For example, this situation may or may not have arisen on the grounds that the individual player is a highly performing individual who has, essentially, been left to carry a poorly performing defence to success. It may well be the case that if a particular player had not acted unilaterally, and worked effectively together with their colleagues, then they may well have been successful and stopped Team A's attack.

By acting unilaterally, the Team X's defence function in total was less than it could have otherwise been in performance terms. The synergy between the players was diminished, if not broken, and the emergent effects of their action lost. This is especially sobering since such emergent effects are greater than the sum of their parts by definition.

In this respect, in acting unilaterally then at some level the outcome for the team is automatically less than it should have been – it is by definition less than any one individual can create and apply. The unilateral action damaged the coordination of the players in Team X's defence and this caused that functional unit to lose coordination with its externally defined objective: defeat Team A's attack.

Indeed, as Arthur (Arthur, 2011, p.302) opines "*Star players often try to outshine each other, leading to conflict, not collaboration*" yet also advances that "*the best motivator may be impending doom or a fierce competitor".*

This highlights the dichotomy between the actual actions of an individual that is counter to the requirements and purpose of their colleagues. Moreover, that such matters are particularly relevant in a time pressured competitive context.

There is evidence to suggest that an outnumbered or under resourced force can still be successful. An illustration of this in terms of football is Leicester City FC during the 2015-16 English Premier League campaign. A recent article (Stanton and Jackson, 2016) reported that some pundits were quoting odds of 5000 to 1 against Leicester City winning the Premier League champions title at the start of the 2015-16 football season.

As the season unfolded, it became clear that Leicester City were undoubtedly successful. Yet the fact remained that they were comparatively under resourced in terms of money and players of high profile. Indeed, Stanton and Jackson (Stanton and Jackson, 2016) highlight that Leicester City's player salary payments transitioned from £36 Million in 2013-14 to £57 million by the end of the 2015-16 season (cf. Deloitte Sports Business Annual Review). They also observe that this represents only 25% of what Manchester United's player salary obligations were from two seasons prior. It is also interesting to note that Stanton and Jackson's article also opines that much of Leicester City's success is owed to striker, Jamie Vardy.

It is also very compelling to note that the article concedes that Vardy's efforts in collaboration with Riyad Matirez "*forged a deadly combination*" when it came to scoring goals.

Although observation of Leicester City's football matches during 2015-16 may well cause one to agree with the views of Stanton and Jackson, it is argued that Leicester's performance cannot be attributed entirely to two people. If Vardy and Matirez, as separate individuals, each represent optimized striking performance, then the optimized synergy of those two optima would represent the net effect of their unified action.

If they could not work together optimally, then this may well cause the effects that both of them actually do produce in unison to be much less than it could have otherwise been. Moreover, and by the same rationale, the optimized strike force that they did materialize to be would have had to have been assisted and supported.

It is argued that this was accomplished by similarly optimized synergies between other players and functions that comprise the team. If less than effective assistance is made available to an optimally operating strike force, then the latter's optimality could qualify as a waste of time. Those strikers, individually and collectively, cannot produce the required outcomes for the team. As such one may possess the world’s best strike force but they are let down by indifferent levels of support.

In the overall scheme of things, Leicester City was less well-resourced than their competing teams in terms of money and players of high profile with formidable reputations as footballers both domestically and internationally. Yet, Leicester was successful to say the least. It is argued that they were better organized so that they could accomplish much more with significantly less and far more consistently, in contrast to their opponents.

Indeed, if their success cannot necessarily be attributed to money and players of certain standing then what else is left? Of course, one may point to tactics and that is a legitimate answer. Yet, tactics formulated before and during a match provide a framework of how players do what they do.

If they see an opportunity to score a goal, then it is argued that they are not going to ignore and forsake it for the sake of adhering to any form of tactical plan. Indeed, what action they take at any moment is directly coupled to what is currently happening.

It is contended that no amount of planning can necessarily take account of every scenario that manifests itself, and players organize themselves and each other by their actions when an unforeseen opportunity arises. Preplanning cannot fully account for how a match will develop on a second by second or minute by minute basis. It can at best only speculate. Anticipation of one team’s state may be the objective, but the states are formed in real time continually.

Notwithstanding, it is acknowledged that certain states manifest themselves in accordance with certain styles of play in the form of set pieces (routines applicable to particular situations such as taking a corner). Yet, even within such supposedly routine scenarios, the random activity implicit in that situation can cause a particular state to manifest itself in an instant.

Set pieces do not always have the desired affect despite a team incessantly practicing them. Actual circumstances can arise that can negate their acknowledged efficacy under idealized training circumstances.

Another instance of this line of argument is the case of Liverpool Football Club's formidable recovery during the 2005 European Champions League final against AC Milan in Istanbul, Turkey.

Liverpool was being heavily defeated at the half time point by three goals to nil. When the players returned to the pitch, the transformation in Liverpool’s fortunes was impressive to say the least. Liverpool scored three goals in six minutes.

According to Winter (Winter, 2009) this aspect "*broke the spirit of AC Milan*", apparently causing them to "*fold completely*" during the penalty shoot-out. Liverpool won the Champions League for the fifth time in the face of overwhelming odds against doing so.

This may or may not have been attributable to a weakness that manifested itself in the opposition, but equally it may well have been as a result of Liverpool behaving in a different manner to synergise a better outcome for itself. Indeed, Winter (Winter, 2009) opines that Rafa Benitez, Liverpool's manager, made a rousing speech to boost morale and reports that he also made tactical changes in team composition.

It is argued that Liverpool were ultimately more adaptively and effectively organized, perhaps augmented but certainly influenced by the change in team composition, during that time pressured window of six minutes, and this translated into the outcome that they enjoyed.

The case of Liverpool does illustrate the power of effective organization since what was accomplished can only be manifested by such means. The rationale here is that if you are disorganized from the outset then you have little chance of achieving your stated objective.

In particular, Liverpool's performance highlights what can be accomplished in a short time frame that is allowed to do so. One could argue from that point that perhaps such levels of effectiveness should, and could, have manifested themselves earlier in the match to the extent that they put themselves ahead of AC Milan and then acted to preserve that.

The intriguing aspect is that AC Milan appeared to do this in the first half and presumably felt that the goal difference represented a comfortable buffer. The impact to morale within AC Milan as Liverpool scored goals are argued to be the soft factors that manifested themselves into a performance defined in terms of hard systems.

What happened is speculated to have caused their capacity to organize themselves to prevent Liverpool from doing what they were doing. It is contended from that perspective that they could have maintained their capacity to organize themselves to deal with Liverpool.

They could have then just grudgingly conceded the first goal and then re-established control of the match in their favour. Instead, AC Milan's control started to deteriorate as Liverpool's organized itself to take control of that match to their own benefit.

It must be noticed that the case of Liverpool is not an isolated one. Many people watch football matches played in many leagues of varying prominence. Some matches are more important than others irrespective of this. Poor performance in a particular match may result in relegation to a lower league, for example.

In an amateur league this may be disappointing but in the overall scheme of things of little consequence. In a professional football club operating at the highest level, however, relegation is not just disappointing; it usually has huge financial implications.

For example, if a premier league club fails to qualify for the European Champions League, then it is less able to attract new signings since they are unable to offer the chance of playing in that competition. This then has consequential impact upon gate receipts and so forth.

Success is vital and is argued to be correlated to the potency of how a team self organizes its performative capacity with respect to its opponent's capacity to do the same. If the bias is in one teams favour, then successes, and gate receipts, are speculated to follow.

In this respect, the observation is often made that when particular teams return to the pitch at half time that they are in some way fundamentally different in how they perform. Moreover, such differences often correspond to more success in the last half of the match than was enjoyed during the first half.

It is contended that this may be discerned from the self-organizing policy dynamics of such teams and how the characteristics of that might correlate with match outcomes. As has been stated, this work seeks to characterise the characteristics of the self-organizing policies of cybernetically viable complex adaptive systems. It also seeks to discern patterns within those characterizations that might reveal any particular pattern(s) that may be specifically associated with success or failure with respect to its objectives.

For a cybernetically viable system, the objective of the target system is to survive in its operating environment to the extent that it can at least achieve its stated purpose. Yet, as has already been covered, cybernetically viable systems are often analytically impenetrable. Those that may be analysed and diagnosed against the provisions of Stafford Beer's VSM often have data that is defined in purely financial terms.

From what has been stated above, it is clear that employment of a football team is justified.

Each player is a cybernetically viable system.

Sub groups of players within a team are convened to perform particular roles (attack, midfield and defence, say).

The players in those sub-groups interact in a manner to produce what that function does. They organize themselves as individuals with respect to the situations that they confront.

This is defined by their relationship with the opposing team, the members of their own team and, in particular, and the members of their own functional unit within that team.

Each functional unit within a team interacts with each other, directly or indirectly, in order to produce what the whole team does. Each functional unit is emergent since it only manifests itself when the players that populate it organize themselves as described to synergise what the unit as a whole actually does.

In just the same way that an individual player has a trajectory about the pitch that represents their policy as a viable system, then so too does the unit that they belong to. The trajectory of the unit is the policy of that unit, and the trajectory of the whole team is the policy of the whole team.

By using appropriate data capture technologies and computer based techniques, the emergent policies of each function, and that of the whole team, can be dynamically computed from the movements of each player that aggregate together to form them. Moreover, such techniques can capture the relevant data and do the necessary computations in real time as two teams oppose each other in a match.

This means that not only does this provide a means to characterize the policy dynamics of such viable systems, and hence the VSM that they map to. Indeed, it also permits one to examine this whilst both systems are under highly dynamic, time pressured load conditions whilst both have a quantified criterion of viability i.e. success over an opponent by the widest possible margin.

This is on the grounds that a football match is a competitive game and the environment of one team (A) is entirely defined by the presence and operation of another team (X) and vice versa. Accordingly, this is explored in the next chapter: Chapter 4 – Experimentation.

3.5 Summary

This chapter has made the case for how a football team is fully isomorphic with the provisions of the Viable System Model in its structure and operation, and set this in context of how such teams have duality as complex adaptive systems. It has examined how the output of one team might control the other and vice versa during a match both in terms of variety engineering and how that may be conceptualised in terms of acceptable control boundaries. It has also illustrated how ostensibly well resourced teams (viable systems) can be overcome by less well resourced teams due to their ability to self organise more effectively.

Chapter 4 - Experimentation

4.0 Introduction

This chapter provides an account of the experimentation work undertaken to test the hypothesis that underpins this thesis. This includes the nature of the necessary football match data files provided by the author's football industry partners and how they were initially processed as supplied (the actual policy dynamics of the players) using a report writing tool to produce Zipfian ranked frequency distributions for that data.

An overview of the software written to handle those files is provided that explains how that was written in such a manner that those matches could be played back inside a virtual stadium and how certain attributes associated with team policy, and various functional sub policies, were dynamically recomputed from there (the emergent policy dynamics of the Attack, Midfield Defence functions of the team concerned as well as its overall policy – all considered as viable systems operating under load).

Once played back the same Zipfian analysis was repeated for the dynamically recomputed policy data produced by that process.

Linear regression analysis was then undertaken of the Zipfian analyses for both sets of data (actual and emergent) and amounts of Shannon Information associated with each were computed in readiness for the post match playback analysis that features in Chapter 5 – Analysis and Results.

A number of different technologies were investigated and subsequently employed in the experimentation stage of the research and an overview of what was considered and selected for use is presented below in summary form and expanded upon immediately afterwards..

4.1 Overview of Technologies Used

Technology Used	Reason for Use
Java and the Processing Integrated Development Environment (IDE)	Facilitated rapid application software development in a highly visual context whilst providing direct access to all of the Java programming language's features.
Tracab Match Scanning System	Used in the work to underpin the results of the paper Self Organisation characteristics in Football Teams as opposing agent-based Viable Systems (Evans & Laws, 2014).
Prozone3 Player Scanning System	Initially selected as an alternative to the Tracab system to provide data for the analysis presented in this thesis in order to compare and contrast it, but used subsequently due the ready availability of the required number of data sets needed.
Minitab 17 Statistical Software	To bypass the upper limit of Microsoft Excel's graphical output of 32,000 data points in a regression line plot. Minitab 17 was able to handle all of the data points that were to be included in the analysis, plot them, compute the necessary regression coefficients and linear regression line equations in one process. As such represented a good alternative to Microsoft Excel.
Microsoft Excel 2007 Spreadsheet Software	Predominately used for the production of the pivot tables to produce the juxtaposed tabular analysis of Match Regression Line coefficients as well as the amount of Shannon Information associated with each value (also calculated with Excel). Excel was also used to produce the bar charts presented in the analysis section of the thesis.
Seagate Crystal Reports v10 Professional	A dedicated software report writing tool available from SAP (Systems, Applications & Products in Data Processing). It features the ability to connect to a variety of different data sources (SQL (Structured Query Language), CSV (Comma Separated Value), XLS (Microsoft Excel), MDB (Microsoft Access), TXT (plain text) file types for instance and amongst others) and unify them and/or manipulate that data as required to produce meaningful information. It features full relational database functionality, its own programming language and graphics engine and is mostly used in a business environment to provide information to key stakeholders but can handle any data type from any domain. It was programmed to produce the Zipfian ranked frequency distributions of the policy vectors in all aspects of this work using the CSV type data files for each match provided by Prozone Sports UK Ltd.

4.2 Details of Technologies Used

4.2.1 Tracab Player Tracking System

The initial investigative work undertaken involved the use of a football match scanning technology developed by for that purpose by ChyronHego AB (formerly Tracab), Stockholm, Sweden. The system employs patented optical image processing techniques that were originally developed by SAAB for military purposes and records the exact position of all players for both teams playing in a football match at all times, in addition to the position of the ball and the referee in three dimensional Cartesian space (x,y,z coordinates). It also undertakes calculations related to player performance such as the average speed of the players, player distance run, player acceleration, team formations and set plays.

The match data is captured in near true real time (maximum delay is three image frames) at the rate of 25 readings per second via two arrays of TRACAB super-HD cameras. These employ stereo technology to ensure that the whole of the playing surface is covered without any technology intruding upon the match, and features machine learning algorithms that make the distinction between the various target types e.g. the players and the ball. The system is currently deployed in the English Premier League, Swedish Premier League, German Bundesliga, Spanish La Liga, Danish NordicBet Liagen, Dutch Erdivisie, including the Japanese J.League and features the capability to be connected to a variety of data visualisation platforms with a view to assisting team decision makers.

The photograph of the Stadium mounted super HD camera array originally presented here cannot be made freely available via LJMU E-Theses Collection because of copyright. The photograph was sourced at Chyron Hego AB – TRACAB Optical Tracking Product Information Sheet - http://192.241.161.41/documents/support_files/Product%20Information%20Sheets/TRACAB-PI-sheet.pdf	The photograph of the pitch side equivalent of the Stadium mounted super HD camera array originally presented here cannot be made freely available via LJMU E-Theses Collection because of copyright. The photograph was sourced at Medeiros, J., 2011. *Football's Panopticon*. Wired Magazine, Aug. p.38a.

Fig. 39 Stadium mounted Super HD Camera array providing aerial perspective and data capture for football match (Left) and pitch side equivalent (right)

Source: Chyron Hego AB and Medeiros, J., 2011 (respectively)

The photographs of (A) Player Distance Monitoring, (B) Player Speed Monitoring, (C) Player Position Monitoring and (D) TRACAB operators working during a football match originally presented here cannot be made freely available via LJMU E-Theses Collection because of copyright. The photographs were sourced at Chyron Hego AB – TRACAB Player Tracking Case Study - http://info.chyronhego.com/playertracking_casestudy#

Fig. 40 (A) - Player Distance Monitoring; (B) - Player Speed Monitoring; (C) - Player Position Monitoring; (D) - TRACAB Operators working during a football match

Source: Chyron Hego AB

4.2.2 Prozone3 Player Tracking System

Two different candidate match scanning systems were identified: the laser scanning based tracking system from Tracab and the video capture based system from Prozone. Early work was undertaken with anonymised data provided by Tracab.

This data related to a team that operated in the Scandinavian football league and it permitted exploration of the concepts proposed in this work. The findings obtained from that found acceptance in the research community and were published (Evans and Laws, 2014).

A decision was made to approach Prozone Sports Limited as a means of comparing the technologies and to explore opportunities for data access captured by a different type of system.

This was done in an attempt to discern if there was some consistency in the findings between data provided by two different systems in some way.

Although the Tracab system provided copious amounts of data per match, the Prozone system provided slightly less. The laser scanning involved in the Tracab system placed a laser-net over the pitch and could resolve player position to an accuracy of 0.01m (1cm) at a sampling rate of 25 readings per second.

In contrast, the Prozone system featured a resolution of 0.1m (10 cm) at a sampling rate of 10 readings per second. Although the former had greater resolution per match, more match data sets for a specific team could be readily supplied by Prozone.

Accordingly, a decision was made to use Prozone data and an appropriate non-disclosure agreement was signed and remains in force.

The Prozone3 Football Analysis System is a highly sophisticated commercial football analytics offering that has many high profile client users. The system features prominently in televised football punditry and, in particular, during post match analysis during episodes of BBC television's

‘Match of the Day’ programme. This is in addition to its main purpose of providing client football clubs with insight into their performance and tactics.

The Prozone3 system (Jones, 2014) utilises a configuration of 8 remotely controlled Sony digital IP cameras, each of which is located at roof level in each of the four corners of the client stadium thereby obtaining 100% pitch coverage.

This data is captured simultaneously from all cameras at the rate of 10Hz from the cameras and is fed to and held on a dedicated server located on the stadium premises. This is carried out via dedicated video capture software and is accessed post match using a 2MB Symmetric Digital Subscriber Line (SDSL) for download to Prozone. Prozone analyses the data then in conjunction with an outside broadcast video feed that is captured on the same server.

There are specific requirements for the location of the outside broadcast video cameras. These are to ensure accuracy, quality and efficiency of the system. As such, they need to be at an optimum height of between 15-20m above the pitch, and be with an optimum distance of 5m from the edge of it at the half way line.

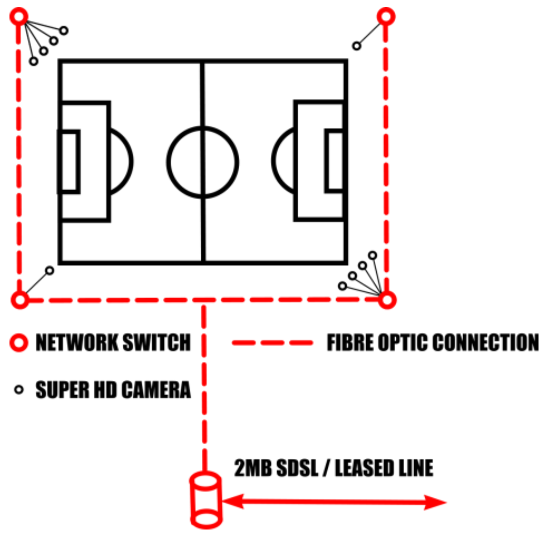


Fig. 41 The Prozone Data Capture Process

The data captured by the system is coded in the form:

<Match Event><Player ID><PitchPosition (of the action)>

The system uses 55 event classifications such as Cross, Pass etc.

Once the event classification process has been completed, the data undergoes a four stage quality control procedure. It is here that each analysis team involved at Prozone checks their match event inputs (home and away teams) inside the Prozone system environment and with reference to the outside broadcast video footage.

This is augmented by an additional check undertaken by two specialist quality control teams. It is here that any errors found in the first pass are identified and corrected before a final check is carried out by a third quality control team prior to distribution. The checks involved are 1) player tracking against all cameras and 2) match events against all available cameras.

Post match player tracking is conducted via semi-automatic image processing with manual player ID. Each video is also tracked independently to determine image coordinates and continuous trajectories for each player every 0.1s. Once such tracking is complete, the output from the stadium cameras are automatically combined to produce a single data set and the image coordinates are converted into real world pitch coordinates.

This is done via use of a calibration process and proprietary algorithm that eliminates visual distortion and non-two-dimensional playing surfaces. Proprietary software is then used to synergise player tracking data with the notated events.

4.2.3 Java and the Processing IDE

Java is a high level, fully object oriented computer programming language developed by Sun Microsystems (now acquired by Oracle). It runs on millions of devices around the world to undertake a huge diversity of computer based tasks such as applications for mobile telephones to embedded systems such as television set top boxes and high end commercial applications.

The Java platform is essentially split into two components: the Java Application Programming Interface (API) and the Java Virtual Machine (JVM).The former is a collection of Java commands that can be used to undertake programming work. The API features a compiler which converts the human readable code into a form that is interpretable by the latter i.e. Java byte code that is capable of being executed by the target machine. Versions of the Java Virtual Machine exist for many hardware platforms e.g. Microsoft Windows, Apple Mac OS X, Linux and so forth.

Consequently, the JVM’s for the various platforms make any code written using the Java API portable across a range of diversity of devices i.e. the programs written are independent from the underlying hardware.

The software developed to test the hypothesis advances in this work required a rapid application development approach to software development with very short iteration cycles. This was such that visual feedback of the constructed software’s performance could be very readily tested and modified in accordance with the requirements of the problem domain.

The intention from the outset was to create a non-commercial grade piece of software to test the thesis hypothesis that could possibly be used as a foundation for future development after some refinements. Nevertheless, the software had to be sufficiently accurate and robust to allow the necessary work to take place.

A Java based, open source integrated development was identified in the form of Processing. This facilitates very rapid software construction and is highly focused towards graphical output so as to readily discern program performance to program requirements.

This is in contrast to constructing Java based software using a command line tool. Processing was initially developed as a programming learning tool within a visual context by graduate students Casey Reas and Ben Fry of the Massachusetts Institute of Technology Media Lab (MIT) in 2001.

Since that time it has morphed into a tool for use by professional level programmers also. It features a deceptively simple user interface, but the environment can invoke the full power of the Java platform from there to produce sophisticated software. Processing has received, and continues to receive, continual development at Fathom Information Design (Boston, USA), UCLA Arts Software Studio (Los Angeles, USA) and the Interactive Telecommunications Program (ITP) at New York University (New York, USA) and the software has a world wide user base.

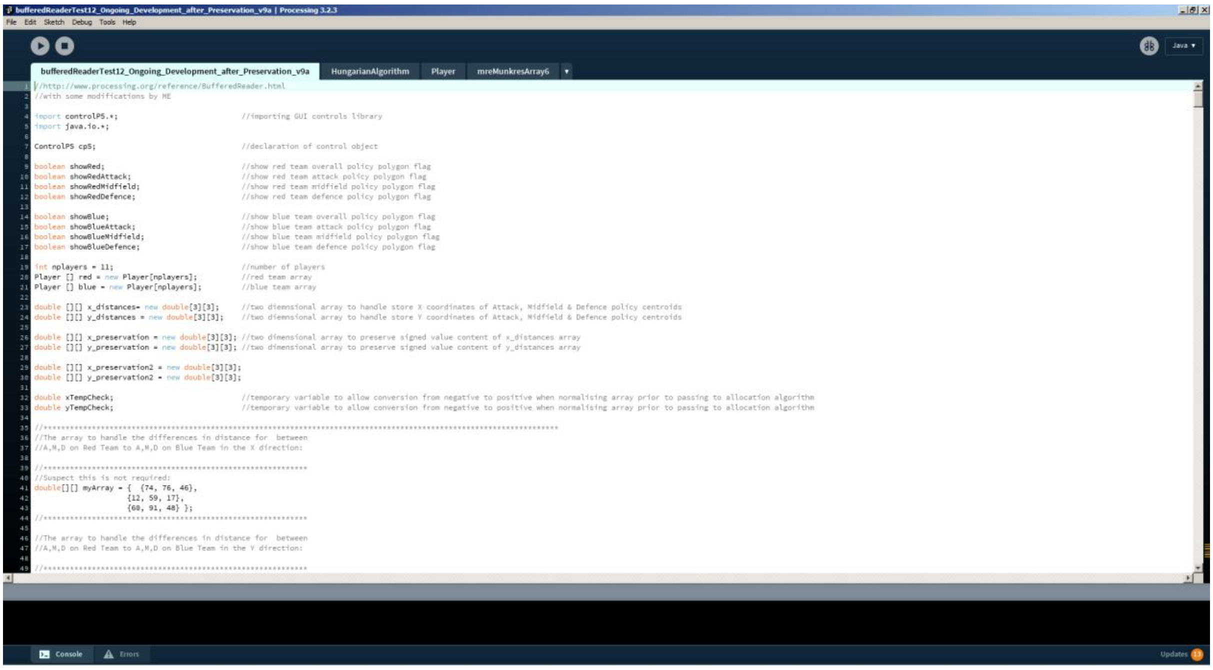


Fig. 42 Processing Integrated Development Environment (Shown in Java mode with software written for this thesis)

The software written was designed to take a match data file supplied by Prozone and to parse that such that the match it related to could be played back inside a virtual representation of the stadium concerned.

By suitably configuring the software, centroids could be computed, and dynamically recomputed for specific groups of players that represented attack, midfield and defence team functions. Moreover, the centroid of the whole team could also be treated in the same way. This facilitated capture of a team’s whole emergent policy (in spatiotemporal terms) in addition to that for the team’s attack, midfield and defence functions. These were written to a file for post match analysis as the target match was played back in software.

Once the complete set of files for all matches had been played back, the data produced for the centroids (emergent policies) was computed in the same manner as that undertaken for the actual dynamics of the team i.e. using the same calculations of R^2R^2 and Information as already described.

Initial work carried out in for the thesis included proposal to include an implementation of the Hungarian Algorithm (also known as the Munkres Algorithm) with a view to making recommendations as to how attack, midfield and defence could be assigned to those functions in the opposing team in each match. This made recommendations of what should be allocated where on a one to one basis thus representing a perfect coordination function (System 2) in the viable system model. The Hungarian Algorithm guarantees that such allocations are made at the total lease cost to the overall system of allocations it represents, hence is representative of a cost optimal resource bargaining function (System 3) in the viable system model.

This was deployed for all matches and data captured for the recommendations it made during each match examined. These results were not included in the final thesis since it was determined that the work required further refinement.

Despite this the code to implement the algorithm was left inside the code when the software was run for the match data that appears in the thesis and operated without interference with what the remaining code needed to accomplish to produce the metrics, hence results, presented herein.

4.2.4 Minitab 17

In all cases the output data was processed using Minitab 17 Statistical Software to provide the necessary linear regression analyses required. Although Minitab retains a focus on the learning of statistics, many household business names use it in their day to day activities. Examples include Apple, Google, Nike, Amazon, Samsung and Toyota.

The software features a whole range of statistical capabilities from Basic Statistics (Descriptive Statistics, for example) and Graphics (may types of scatter plots, histogram, time series plots and so forth) to Statistical Processing Control techniques (Run Charts, Pareto Charts for example), Measurement Systems Analysis (ANOVA (Analysis of Variation) and Xbar-R methods) to Time Series and Forecasting aspects (Time series plots, Trend Analysis, Exponential Smoothing etc) (see http://www.minitab.com/en-us/products/minitab/features-list/)

4.2.5 Excel 2007

An almost universally popular spreadsheet based data manipulation offering from Microsoft that provides a gamut of tools from Basic number manipulation to highly sophisticated statistical tests. Excel features enough flexibility to produce the majority of the numerical manipulation and summarisation in this work. The only (surprising) limitation encountered was the upper limit to its graphical output capabilities in terms of scatter plot production i.e. being limited to 32,000 data points. It was at this juncture that an alternative to Excel had to be sought to handle a greater number of points since the target files exceeded that number, hence the selection of Minitab17. To have persisted with Excel here would have introduced distortions into the analysis that were obviously not required. Minitab handled all of the data points involved in all cases, plotted them and produced the necessary regression line functions and the degree of fit calculations in a single process for each file. Given the number of files involved this did not only serve to preserve the accuracy of the results produced, but also represented something of an administrative economy since the work could be expedited more quickly

4.2.6 Seagate Crystal Reports v10 Professional

An established, corporate level, report writing tool that provides a host of data manipulation functionality. The only limitation encountered with the software was its ability to only evaluate logarithms to base 10. Accordingly, the ranked frequency data produced by the reports had to be exported to Excel for conversion to logarithms to base 2 as required to carry out the necessary Shannon Information calculations (despite attempts to program the report in advance to produce this at run time).

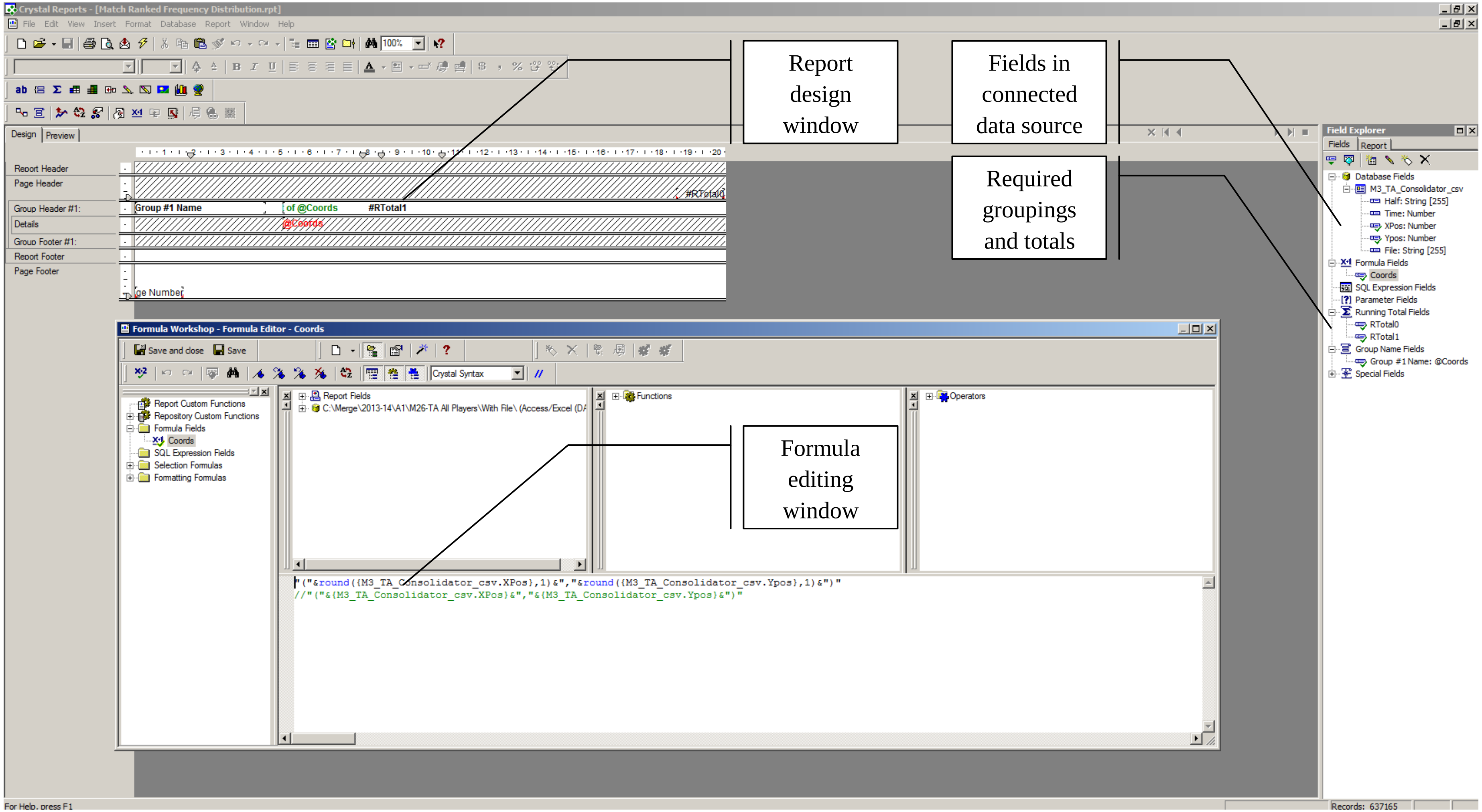


Fig. 43 Crystal Reports V10 Professional Report Design and Editing window featuring formula editing programming window

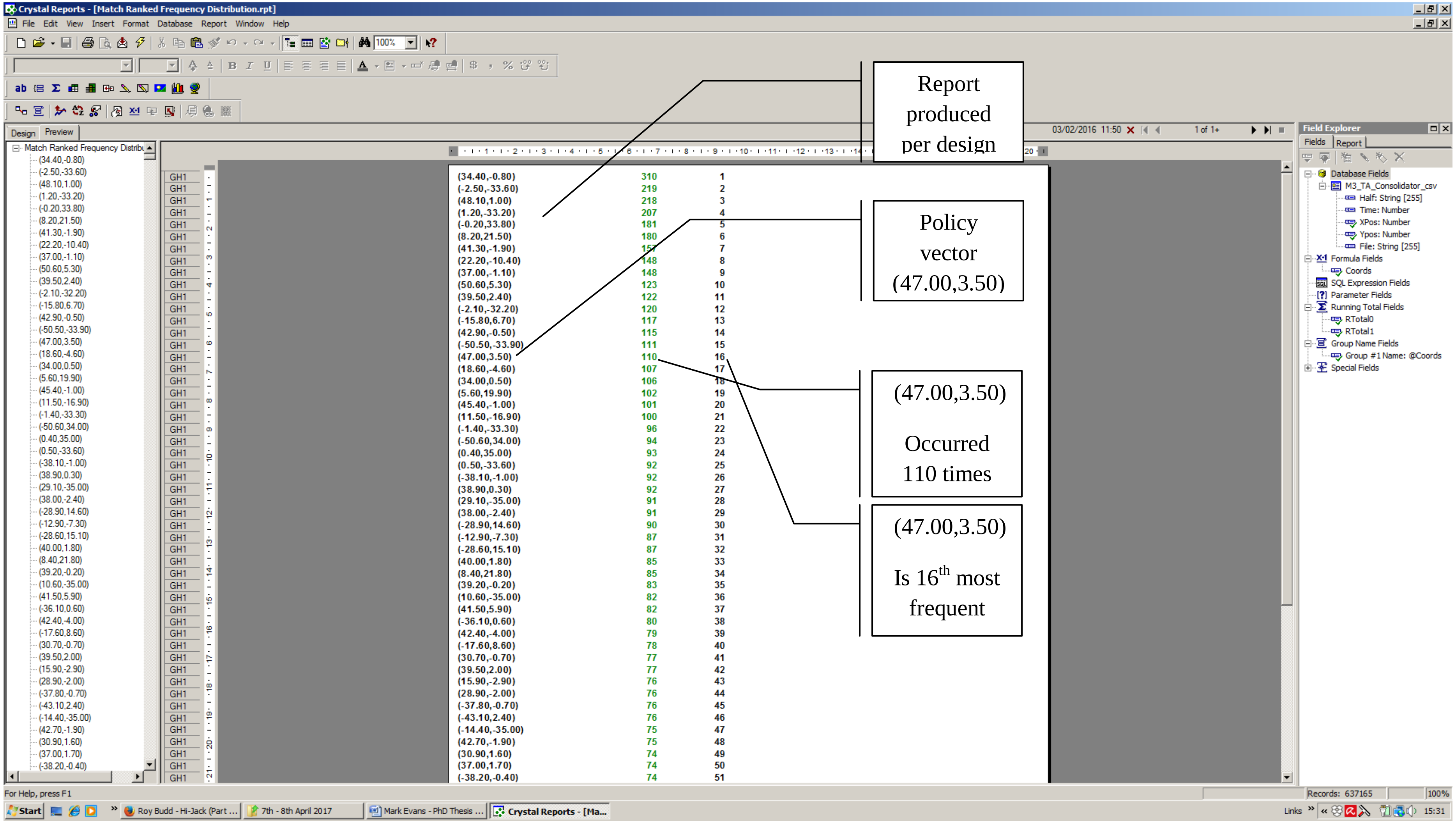


Fig. 44 Crystal Reports V10 Professional Report Output Window (as after derived report design run against nominated data target file)

4.3 The experimental process undertaken

A request was made to Prozone to supply anonymous match data for one complete football season of their selection and for one particular team playing in that season. Moreover, it was requested that Prozone select their data in a manner that did not feature any distinctive score lines that may permit inference of the identity of the team. This was kindly provided by Prozone and the only known identification fact about the club involved was that they were a member of the English Premier League for the season selected.

Prozone were requested to supply the requested data in the following format:

<Match Number><Team Number><Player Number><Match Half><Time Stamp><XPosition><YPosition>

Where:

- The Match Number was an identifier ranging from 1 to 37.
- The Team Number was an identifier ranging from 1 to 19, but included ‘A’ as the ‘Target Team’ being monitored with respect to each of their opponents.
- The Player Number was the codified shirt number of the players on each team.
- The Match Half was an identifier of either ‘First’ or ‘Second’
- The Time Stamp was the time that the reading of the position of a player was taken from the starting point of the match (measured in milliseconds)
- The XPosition and the YPosition was the location of the players measured from the centre of the pitch in metres. The centre of the pitch represented the origin of the coordinate system (0,0) and both XPosition and YPosition were captured simultaneously for each player every 10 milliseconds (0.1 seconds)

Each match file contained the data for both teams involved. The opposing teams’ data was initially set aside for later use, and just the data for the target team, Team A, used.

A report was written using Seagate Crystal Reports v8. This took the XPosition and YPosition of each player from separate data fields to produce a corresponding Cartesian coordinate pair (XPosition, YPosition).

Recalling that player position is equivalent to player policy in this work, those ordered pairs were then used by the report to produce a ranked frequency of the whole match file concerned. Accordingly, by taking each ordered pair and counting how many times each one was visited by any team player, a frequency table of the player policies for Team A was constructed.

This was sorted in descending order of frequency, with the most frequently occurring policy value being assigned the highest rank i.e. 1, and the least frequently occurring being assigned the lowest as determined by the report. This was with a view to determining the extent to which player policy might be related to policy rank by a power law (e.g. $Policy\ Frequency = (Policy\ Rank)^{-1}$).

The contents of each report was then exported to Microsoft Excel 2007. This was done in order to calculate logarithms (to base 2) for the policy frequency and the policy rank values for each match, and these were saved separately. The files were then used in conjunction with Minitab 17 to produce scatter plots of the data they contained on a log-log scale.

This was done to discern if there was any linearity present in the scatter plot. This was an important consideration since the strength of any linearity present, as measured by Pearson's Correlation Coefficient (R^2), determines the data's degree of approximation to a power law.

The reason for this is that studies in complexity science reveal that the behaviour of many self-organizing systems in nature follows a power law distribution, as described earlier. When such relationships are plotted on a log-log scale, they feature a degree of linearity that can be measured using linear regression.

Accordingly, Minitab was used to compute a linear regression line of the data in the scatter plot that related to each match. This took the general form of: $y = mx + c$. In the case of the match data, y was represented by $Policy\ Frequency$ and x was represented by $Policy\ Rank$. The value of m represented the gradient of the straight line, and c its intercept with the y axis of the graph.

From examination of the various scatter plots and associated regression lines, there was very strong evidence to support the notion that:

$$log_2(Policy\ Frequency) = c - mlog_2(Policy\ Rank)$$

Hence:

$$Policy\ Frequency = 2^{(c - mlog_2(Policy\ \ Rank))}$$

Equation 2 – Policy Frequency related to Policy Rank via power law

The strength in the linearity of data, that has had the process of linear regression applied to it, is measured by R^2 , where $R^2 = 0$ indicates no linearity present, and $R^2 = 1$ indicating that a purely linear relationship is present.

With specific regards to this, this work considers $R^2 = 0$ to represent a self-organizing system in complete disarray (entirely disorganized), in contrast to $R^2 = 1$ representing a perfectly self-organizing system.

A value for R^2 was computed for $log_2(Policy\ Frequency) = c - mlog_2(Policy\ Rank)$ i.e. the linear regression line plotted for each match. This revealed in many individual cases (please see Appendix 1 on p.245) highly impressive degrees of linearity, with values of R^2 being in excess of 0.8 not being untypical (e.g. Match 1 for Team A (m1-ta-H1+H2) (please see p.248).

This process provided insight into the self-organising manner in which the team accomplished what it did based upon the data supplied for complete matches. Yet it was recognized that what teams do and what results they achieve can vary by match half and match fixture. Accordingly, each set of match data was split by those criteria and the process explained above repeated for each of them.

As the work is focused upon the viable system model (VSM), it was also necessary to attempt to extract the policy characteristics of sub-groups of players in the target team. The subgroups of Attack, Midfield and Defence were identified as being those functions that serve to produce what a team actually does.

Accordingly, in VSM terms, each of Attack (A), Midfield (M) and Defence (D) subgroups are viable systems that are embedded as recursions within the all-encompassing viable system model that represents the team. Moreover, the players involved in each sub group are the agents of production within it that causes that group to do what it does.

This means that a football team is a viable system (recursion 0 of the VSM that models the team), that contains subgroups that are themselves viable systems (recursion 1 of the VSM that models the team). This arrangement is illustrated below in Fig. 45 (with randomly allocated player shirt numbers to each functional subgroup).

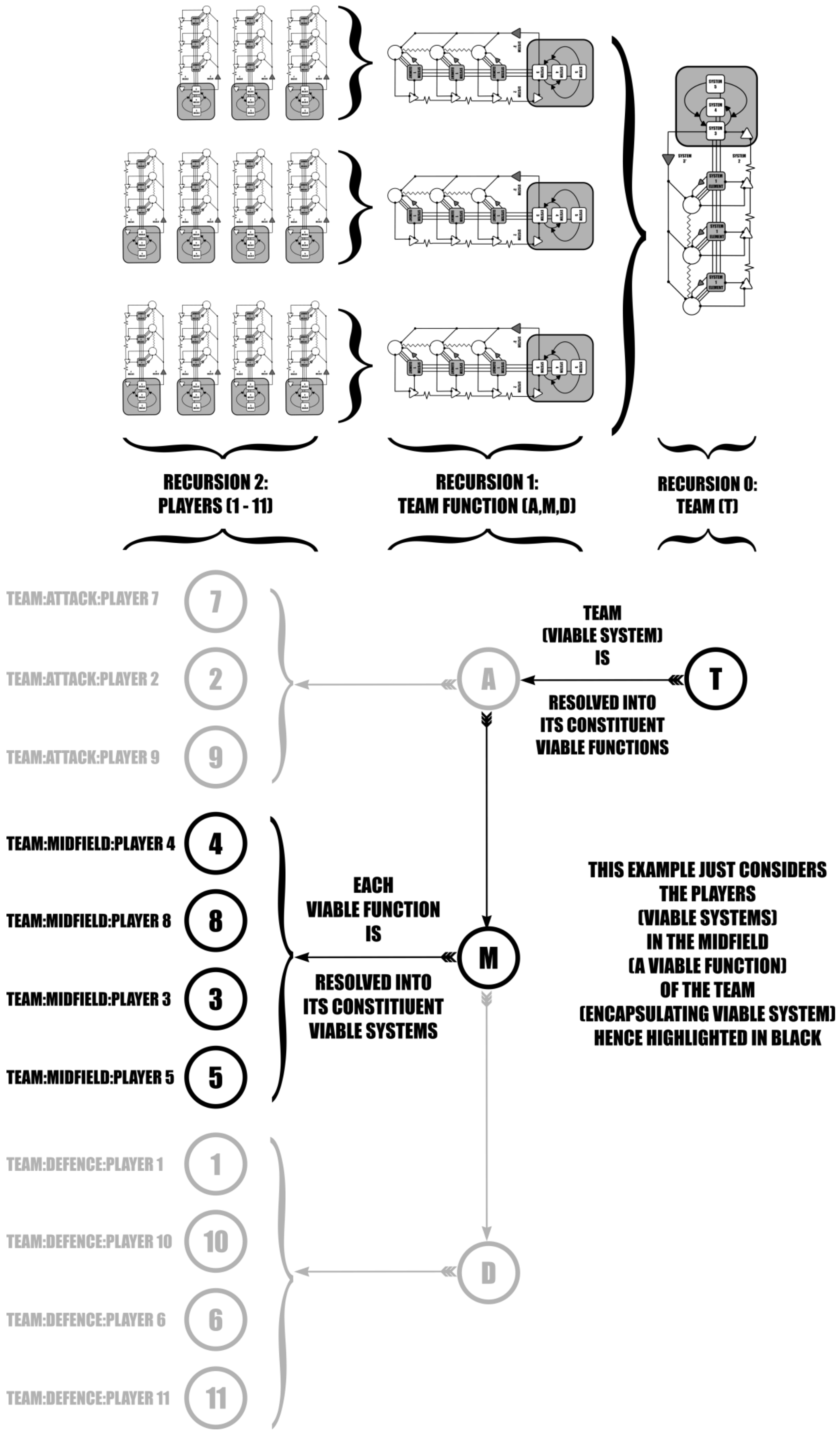


Fig. 45 VSM recursive breakdown of football team

As the subgroups are the players involved in them, then those players are the viable systems that form recursion 2 of the VSM that models the team.

Each recursion follows the precepts of the VSM in terms of the functionality that must be present for each recursion, hence the whole system, to be viable. From this, one can conceptualise a subgroup as having its own policy. This being equivalent to the position of that subgroup on the pitch.

Yet, this is underpinned by the largely autonomous activities of each player as they each interact with their environment i.e. interaction with their team mates both within their subgroup and with those players in others, in addition to opposition players.

Similarly, those players also make individual contributions to the motion of their whole team and hence its policy. In neither case is that motion (policy) under the direct influence of a central controller that tells everybody what to do and when at all times.

Although it is acknowledged that the team manager and its captain will have requirements for what a team does and how it does it, the players have this as a frame of reference to work with. As such, it does not represent explicit second-by-second instruction as to who should move where.

Two or more players may have to dynamically coordinate (and re-coordinate) their positions on the pitch with respect to what they are confronted with at any time. This is done largely by visual cues until coordination is achieved and they are able to do what they have essentially agreed by consensus.

Yet what is actually done is an emergent effect of their interaction i.e. it is an outcome that is greater than the sum of its parts (See Bogdanov, 1996). With this concept in mind, it became clear that if the collective motion of the subgroups within a team could be captured, then one would obtain the policy characteristic of it as a recursion within the VSM representing the team i.e. the policy of recursion 1.

Similarly, if one could capture the collective motion of the whole team, then one would have the emergent policy of the whole team as a viable system i.e. the policy of recursion 0. Indeed, the policy dynamics for recursion 2 (players) have already been dealt with.

Accordingly, the use of the football team presented a unique opportunity to obtain simultaneously the multi-recursive policy for a real viable system operating in real time under dynamical load (threat/opportunity) conditions. The notion of what collective attribute of any subgroup, or the whole team, needed to be answered; and it was found in the form of the geometric centroid of the relevant subgroup.

In this respect, if the players involved in a subgroup / team represented nodes of a polygon, the linear distances between them could conceivably act as its edges. This meant that the centroid of the polygon that represented the group could be re-computed dynamically as the participants moved.

Essentially the centroid of the polygon would be representative of the consensus of opinion that underpinned subgroup movement (policy) at any point. In an attempt to address this aspect, a computer program was written in Java using the Processing Integrated Development Environment (please see Appendix 7 commencing on p.527).

This in essence played back each match by taking the data in each file provided by Prozone for each match and creating software versions of both opposing teams as they interacted inside a virtual stadium and with the players observed from directly above. The software was written to include the dynamic re-computation of the centroid coordinates for both teams in their entirety and for each subgroup in each team. It also featured the ability to toggle visibility the colour of the polygons representing the various subgroups of players in both teams, so that they could be easily differentiated.

The software also incorporated the location of each centroid in each polygon as it updated as well as an on screen depiction of its coordinates i.e. in the same manner as that applied to each player in each team (please see screenshot 4 on p.161 as an example).

The player shirt numbers belonging to the various subgroups within Team A were unknown, and, as such, these were assigned to them by reference to their initial position on the pitch at the start of each match. Those coordinates were then transferred to graph paper worksheets that were suitably scaled to represent the dimensions of a football pitch that complied with FIFA regulations (Fédération Internationale de Football Association, 2014). These pitch dimensions were also used in the creation of the virtual stadium in software.

The most likely membership of the relevant subgroup for each player in each match for Team A was determined based upon those worksheets. The different player roles were then allocated in the software prior to match playback, albeit on this perhaps somewhat subjective basis.

The last step in file preparation before this, however, was that the match file contained so much data i.e. one reading for every 0.1s of each game. Initial tests on playback showed that this presented a problem with playback speed. To overcome this problem, the data file was condensed by a factor of 10 to obtain one reading per second.

This was tested and the playback of each match then took place in real time and not at the pace dictated by the read rate of the Prozone data capture system. The dynamically re-computed centroid for each polygon was written to a file as an ordered Cartesian coordinate pair. This was pending post-match policy analysis using the ranked frequency distribution method covered earlier.

In terms of the construction and operation of the software, the following images (Screenshots 1-5) are presented below to illustrate a typical match being replayed from the source file for it provided by Prozone. Please also refer to the Nassi-Shneiderman diagram below for insight into how the software written parsed the target data files, computed the relevant policy centroids dynamically and wrote them to the various target files for post-match analysis.

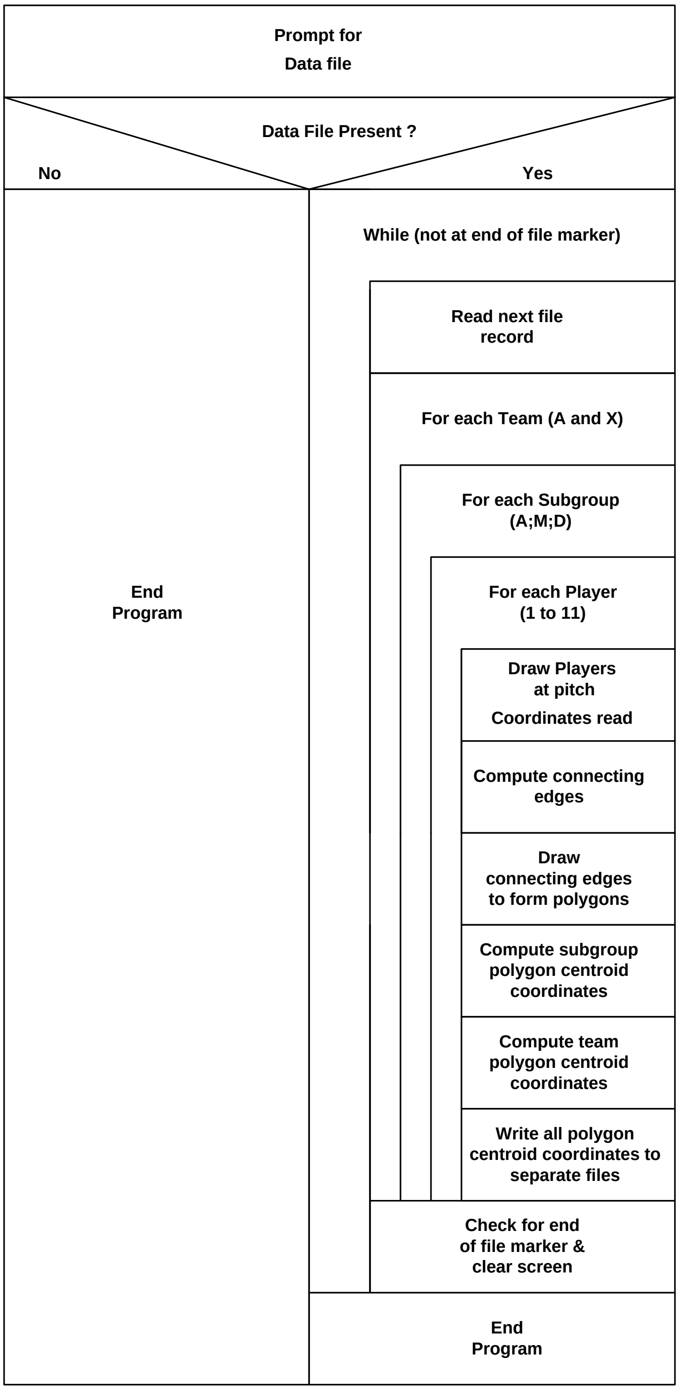
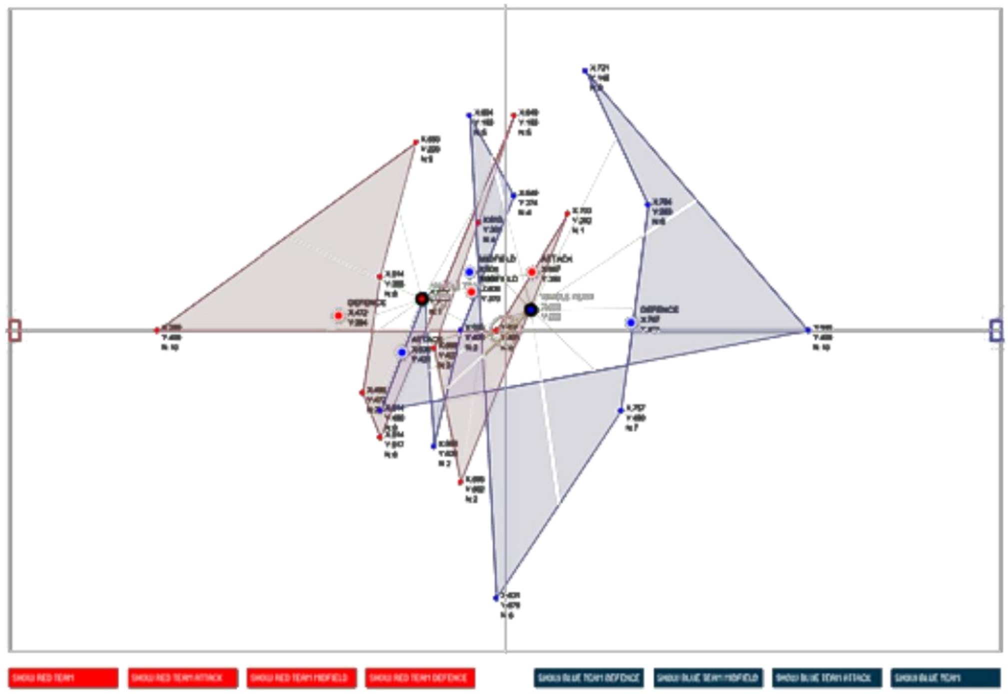
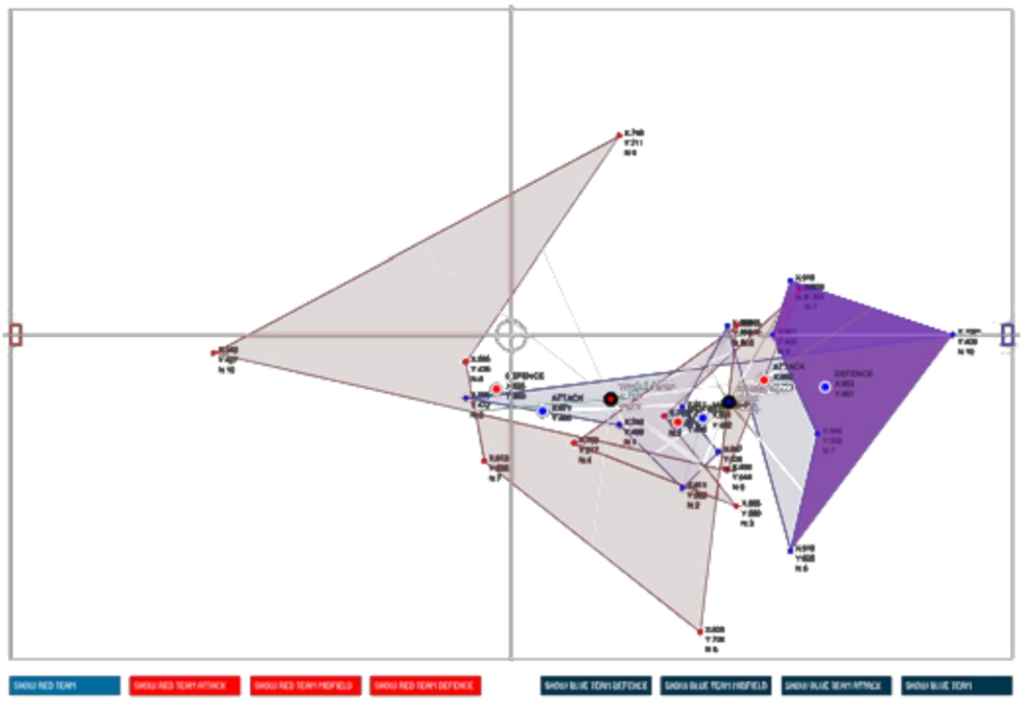


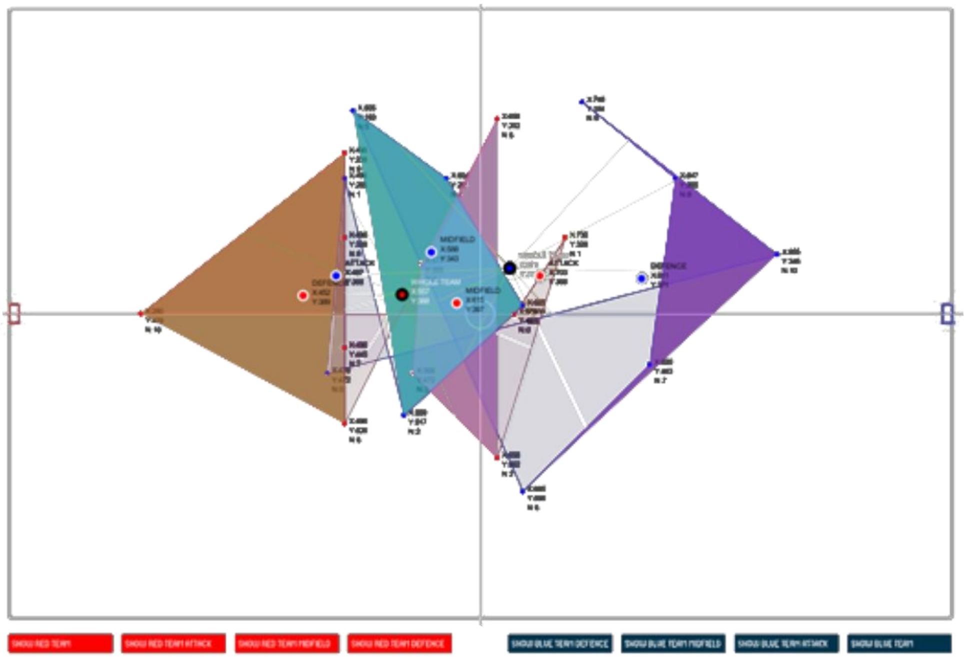
Fig. 46 Nassi-Shneiderman diagram of match replay software written



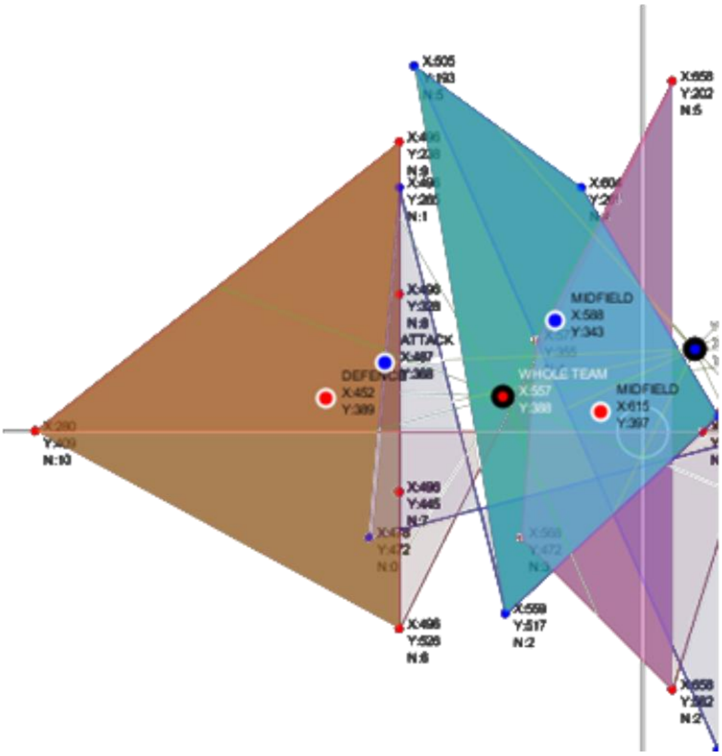
Screenshot 1 Team A and Team X as opposing polygons



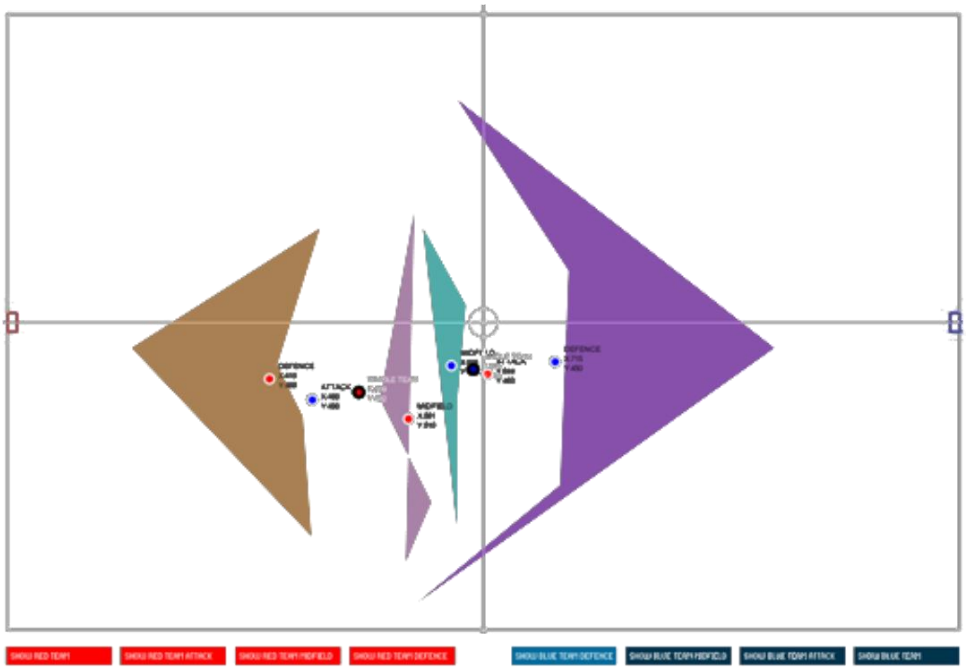
Screenshot 2 As per Screenshot 1 but with Team X's Defence highlighted in purple



Screenshot 3 As Screenshot 2 with Team A’s Defence (orange) & Midfield (pink), plus Team X’s Midfield (light blue)



Screenshot 4 as Screenshot 3 (magnified)



Screenshot 5 Team Polygons removed and just indicating Team A and Team X functional polygons

4.4 Summary

Having reviewed appropriate match scanning technologies, obtained the necessary industrial involvement for the supply of data and written software to manipulate it and analyse it, this chapter has highlighted if a player's position is that player's policy as a viable system, then the data files provided by Prozone allowed one to produce a Zipfian ranked policy distribution for that, and every other, player playing for the target football team. This was undertaken for all of the players in that team for each match over a complete football season, such that a suitable distribution could be produced for that team that characterised its actual self organising behaviour. Yet, the data files provided by Prozone did not provide any direct insight into how the various functions of the team (Attack, Midfield and Defence) were behaving in their own right based upon the spatially based policy contributions of the players allocated to those functions. The same need was identified at the level of the whole team also. In this respect, the emergent policies of each recursion of the viable system that represented the team: Recursion 0 – whole team ; Recursion 1 – Attack, Midfield, Defence function were missing from the analysis since that had already been carried out for recursion 2 (the players) based upon the data files as supplied. Therefore to complete the whole analysis required, the emergent effects of those involved in recursion 2 (players) as per how they had been allocated to recursion 1(function) needed to be dynamically recomputed in policy terms (the policies of the players informing, and being informed by the emergent policy of their allocated function). This was necessary since not to have carried this out would have constrained the work in this thesis to only a partial analysis of the VSM under load instead of the complete one presented as per Chapter 5.

Chapter 5 - Analysis and Results

5.0 Introduction

This chapter presents a detailed analysis of the data produced as a result of the experimentation process. It refers to both the actual and emergent dynamics of each team in each match for which data has been supplied. The actual dynamics refers specifically to the data as it has been supplied i.e. it has not been manipulated in the match replay software. The emergent dynamics refers specifically to the manipulated version of that data i.e. the dynamically recomputed subgroup centroids that are dependent upon the movement of each player allocated to those subgroups produced by the match replay software.

In both cases, a whole series of computations has been carried out to determine the parameters of the power law-like behaviour of each team in each match. This process has also included measurements of the strength of the linear regression line (R^2) as well as the amount of Shannon Information (Negentropy) present.

Appendix 1 (commencing on p.245) includes the graphical analyses, regression line equations and their respective R^2 values for the actual dynamics measured. Appendix 2 (commencing on p.354) contains the same thing but for the emergent dynamics examined. Accordingly, the analysis is split into two sections to cover each category.

5.1 Actual Dynamics

Graphs 1 and 2 below are extracts from Appendix 1 to illustrate the relationship between the policy rank and the policy frequency in terms of a scatter plot with a fitted linear regression line.

Each scatter plot contains a not inconsiderable number of data points (please see Appendix 3 commencing on p.495). It may be noticed from these graphs that there are very high values of R^2 present indicating high degrees of fit between the plot and the computed linear regression line.

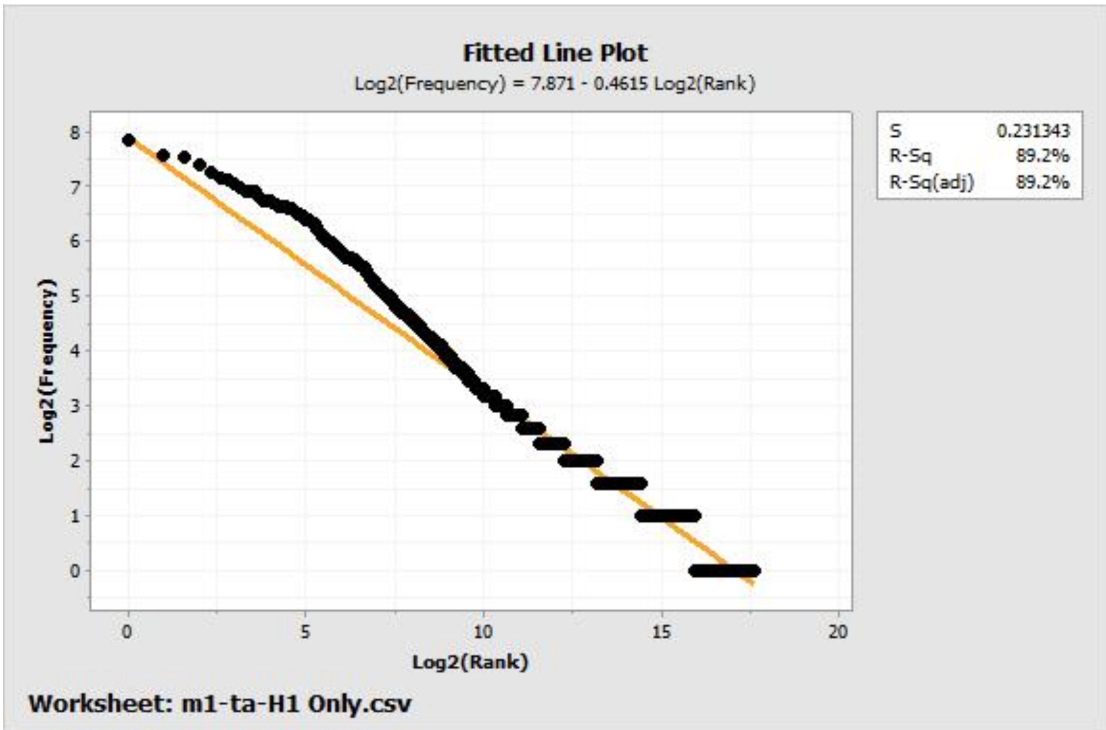
Accordingly, in the case of graph 1:

$$log_2(Policy\ Frequency) = 7.871 - 0.4615\ log_2(Policy\ Rank) \text{ and } R^2 = 0.892$$

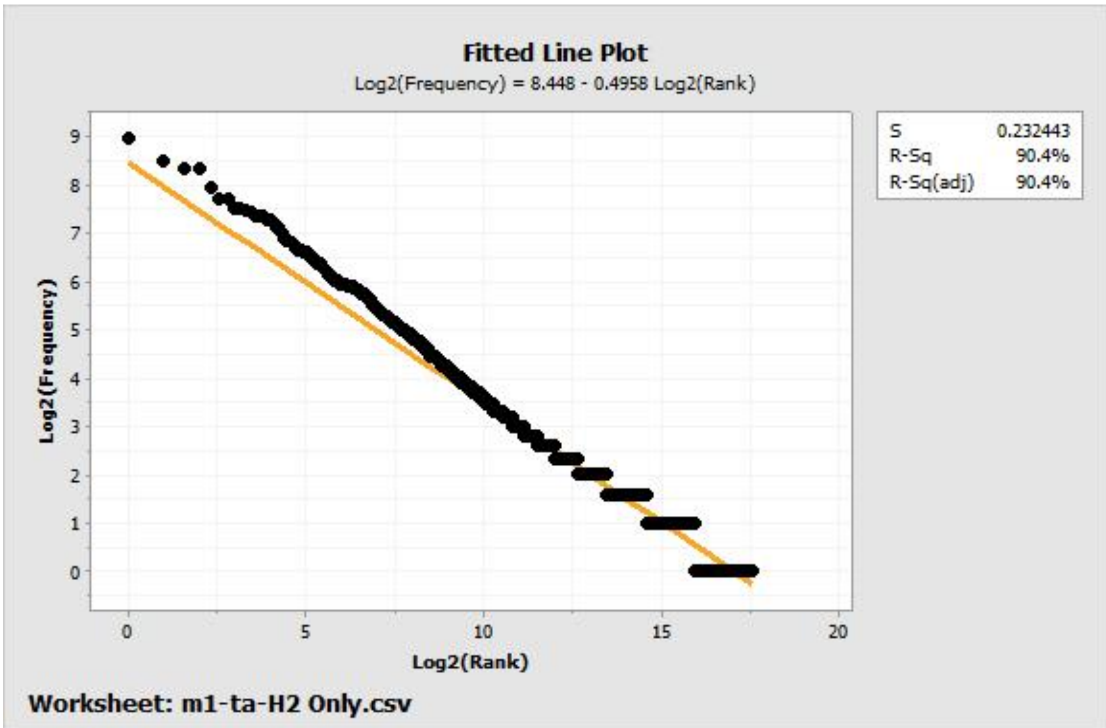
In the case of graph 2:

$$log_2(Policy\ Frequency) = 8.448 - 0.4958\ log_2(Policy\ Rank) \text{ and } R^2 = 0.904$$

These equations are common in their form and their values of R^2 for both halves of each match played by Team A and their respective opponents, as may be seen in Appendix 1 (specifically, in this example, p.246-7).



Graph 1 Linear Regression Line fit with plot of Team A Policy Frequency vs Policy Rank (match 1, 1st half)



Graph 2 as Graph 1 but for Team A (match 1, 2nd half)

The regression equations, their R^2 values, their corresponding amount of Shannon Information (Negentropy) (please see Section 2.8, p.70) and the outcome of each stage of each match were then tabulated as shown below in extract form (please see Appendix 4 commencing on p.500 for the full version).

TEAM A														
Match File	Team	Half	Y Intercept	Gradient	Regression Coefficient	Goals Scored	Goals Conceded	Goal Difference	TEAM A WIN	TEAM A LOSE	TEAM A DRAW	TEAM A OUTCOME	Information Content	Team A Home or Away?
m1	ta	1	7.87	0.46	89.20	2	0	2	WIN			WIN	26.41	1
m1	ta	2	8.45	0.50	90.40	1	0	1	WIN			WIN	27.66	1
m1	ta	3	10.06	0.56	91.40	3	0	3	WIN			WIN	33.54	1
m2	ta	1	7.79	0.46	89.00	1	0	1	WIN			WIN	26.38	1
m2	ta	2	8.42	0.49	90.50	0	1	-1		LOSE		LOSE	27.68	1
m2	ta	3	9.84	0.54	89.90	1	1	0			DRAW	DRAW	33.44	1
m3	ta	1	8.21	0.48	89.60	0	0	0			DRAW	DRAW	27.48	2
m3	ta	2	8.90	0.52	91.30	0	0	0			DRAW	DRAW	28.94	2
m3	ta	3	9.87	0.55	90.20	0	0	0			DRAW	DRAW	33.41	2

Table 2 Linear Regression Line parameters for each team in each match (extract)

It will be noticed from Table 2 that the Match file column that the relevant target data file name follows the scheme:

Match Number-Team-Match Half (e.g. m1-ta-H1 being match 1, Team A, first half).

The use of H1+H2 relates specifically to the case when both H1 and H2 match data sets were fused together to construct a contiguous data set for each match.

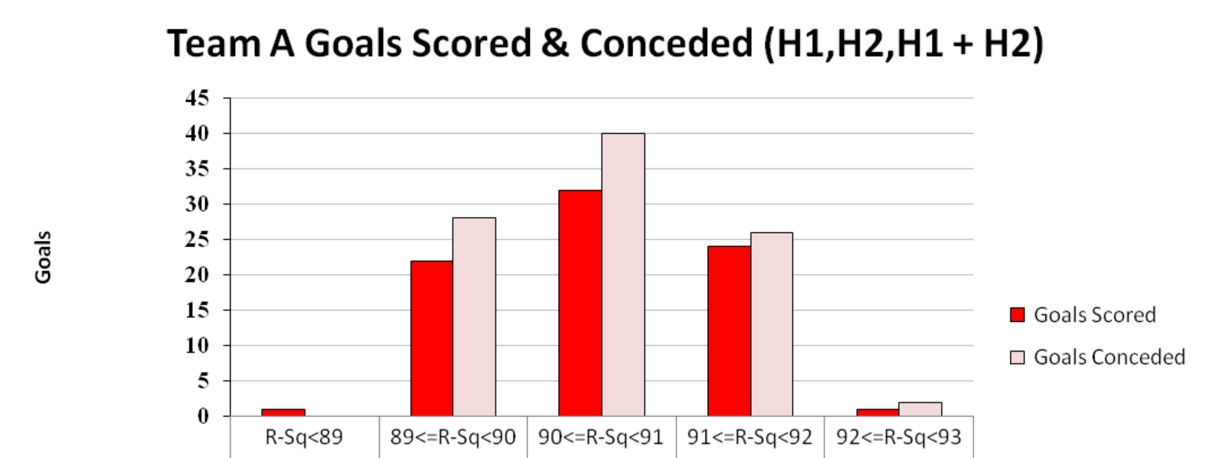
The purpose of this was to permit playback of the whole match in software and carry out the centroid computations referred to earlier.

In the first instance, the strength of the linear regression line (R^2) as well as the amount of Shannon Information (Negentropy) present was of particular interest when considered in juxtaposition with match outcome. Accordingly, a general survey of these values for each match played by Team A per Table 2 was undertaken.

This was done to discern what values of either parameter might be more closely associated with varying degrees of team success (goals scored) or failure (goals conceded).The linear regression line (R^2) values for each line in table 2 were considered firstly on this basis, as follows:

H1, H2 and H1+H2 considered together as per table 2 to discern general trends.

H1, H2 and H1+H2 per table 2 taken as separate files (segmentation of table 2) to discern if any general trend was half-specific.



	R-Sq<89	89<=R-Sq<90	90<=R-Sq<91	91<=R-Sq<92	92<=R-Sq<93
Goals Scored	1	22	32	24	1
Goals Conceded	0	28	40	26	2

Chart 1 Team A banded regression coefficient ranges by match goal type

From Chart 1, it can be discerned that very few goals were accrued by Team A when they performed in a manner that they exhibited a measure of self-organisation that was less than 89% (i.e. R^2 = 0.89). Moreover, this was also the case where $92 \leq R^2 < 93$.

One might expect that for a team to be less effectively organised (under organised) than it could otherwise have been, then that would correlate with a comparatively poor goal yield. Similarly, the more effectively organised that team is then the goal yield should increase.

The case where $92 \leq R^2 < 93$ appears to hotly dispute this. It suggests that if the team is organised to this extent then it becomes over-organised to the point that it experiences diminishing returns. It could be argued that Team A may be perhaps too deterministic in its approach, hence is less adaptable than the prevailing match situations warrant.

It is interesting to note from Chart 1 that three central categories for R^2 which seems to define a region where Team A appears to be sensibly organised i.e. operating such that the number of goals accrued by it is drastically increased, in contrast to the two outlier categories for R^2 just discussed.

The goals accrued and conceded by Team A when it exhibited R^2 category values over the ranges $89 \leq R^2 < 90$ and $91 \leq R^2 < 92$ are very similar in total. Nevertheless, the former could be considered to represent a comparatively laissez faire approach to the self-organising behaviour of Team A in contrast to, perhaps, the more autocratic style associated with the latter.

What is very compelling is the central category on the bar chart i.e. where $90 \leq R^2 < 91$. In comparison to the categories either side of it (laissez faire and autocratic, say) the increased number of goals accrued and conceded is, quite discernibly, more.

This suggests that there is a natural point of balance for Team A in terms of it behaving in such a manner that it is sensibly organised, i.e. it precludes a propensity to behave in a laissez faire or an autocratic manner in a self-organising sense.

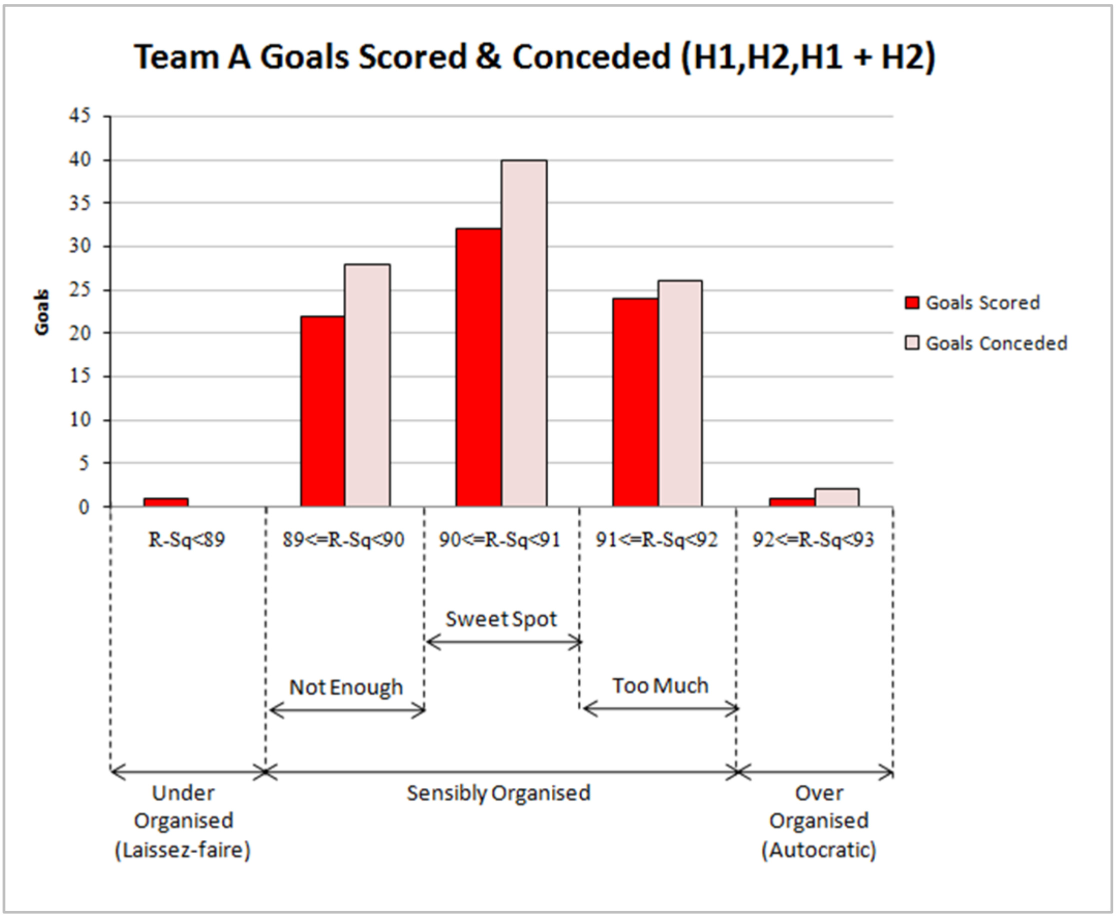
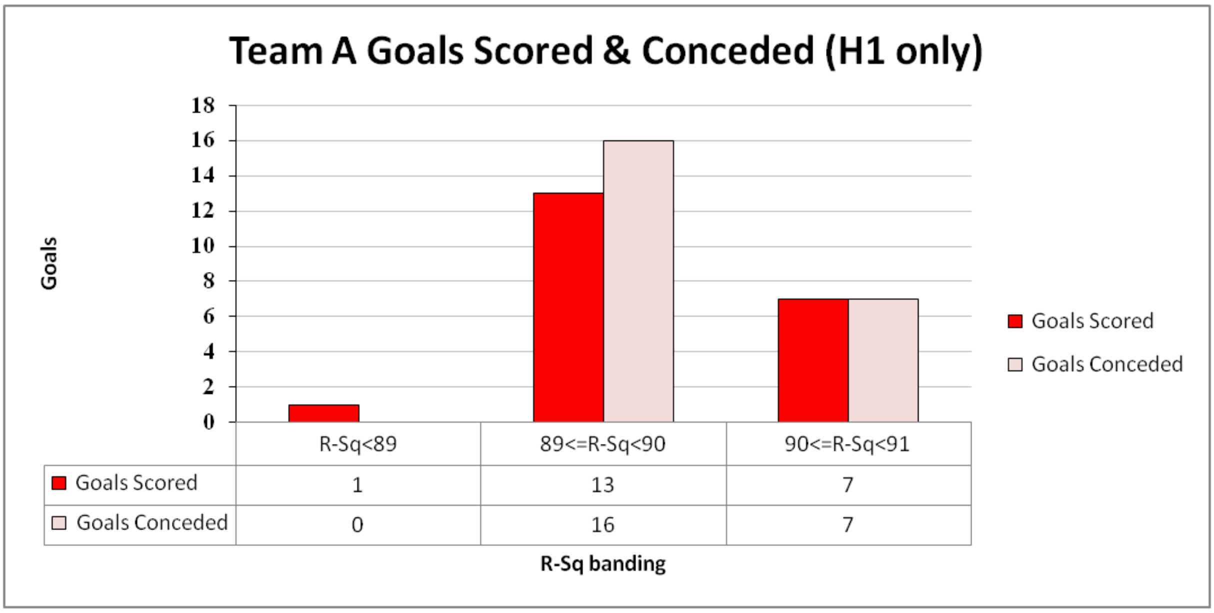


Chart 2 Team A and its degrees of Organisation

The remaining half configurations were then considered as follows:



	R-Sq<89	89<=R-Sq<90	90<=R-Sq<91
Goals Scored	1	13	7
Goals Conceded	0	16	7

Chart 3 As per Chart 1 but first half of each match only

Chart 3 seems to follow Chart 2 in that there is one central R^2 category that is associated with most goal activity, i.e. $89 \leq R^2 < 90$. This can also be said of the Chart 4 below. It is also interesting to note that both the previous Chart 3 (h1) and the Chart 4 below (h2) indicate parity between goals scored and goals conceded in the case of $90 \leq R^2 < 91$, echoing the notion of the "sweet spot" point of balance per H1,H2, H1+H2 i.e. Chart 1.

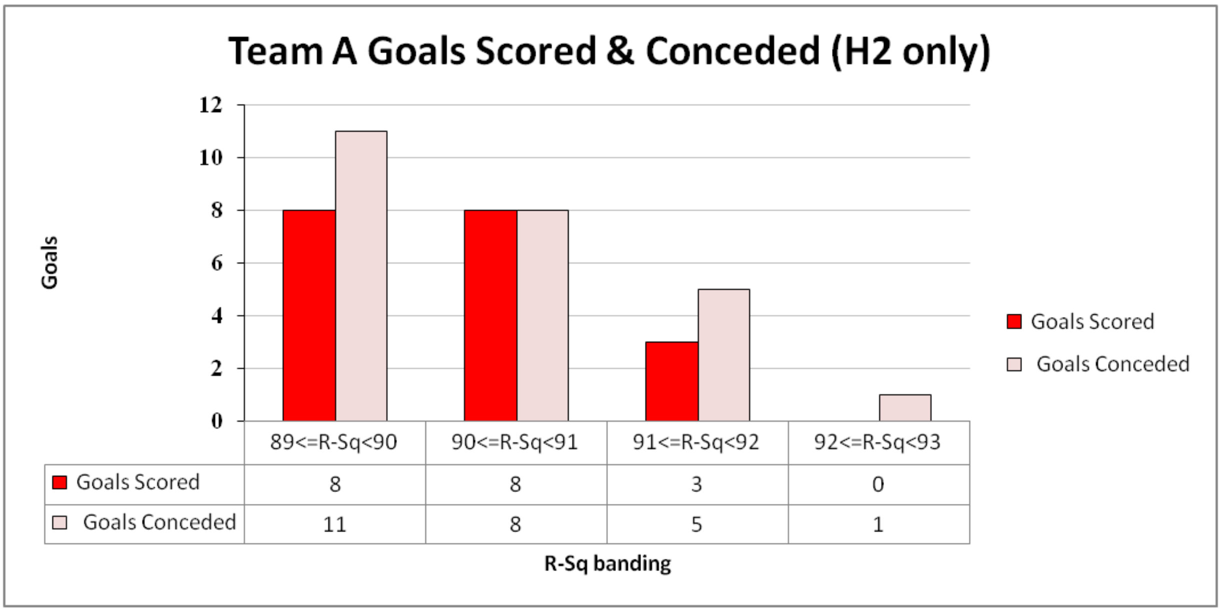


Chart 4 as per Chart 1 but second half of each match only

Chart 5 below relates to the case of H1 and H2 separate data sets being fused together to provide a data source to playback a whole match, without a half time break, via software written specifically for that purpose. Each R^2 category has parity in terms of goals scored and conceded with the exception of $90 \leq R^2 < 91$ which has a bias towards goals conceded. Accordingly, it does seem that $90 \leq R^2 < 91$ not only represents a tightly defined range of balance point values, but it is one that holds the critical balance between team success and failure on the whole.

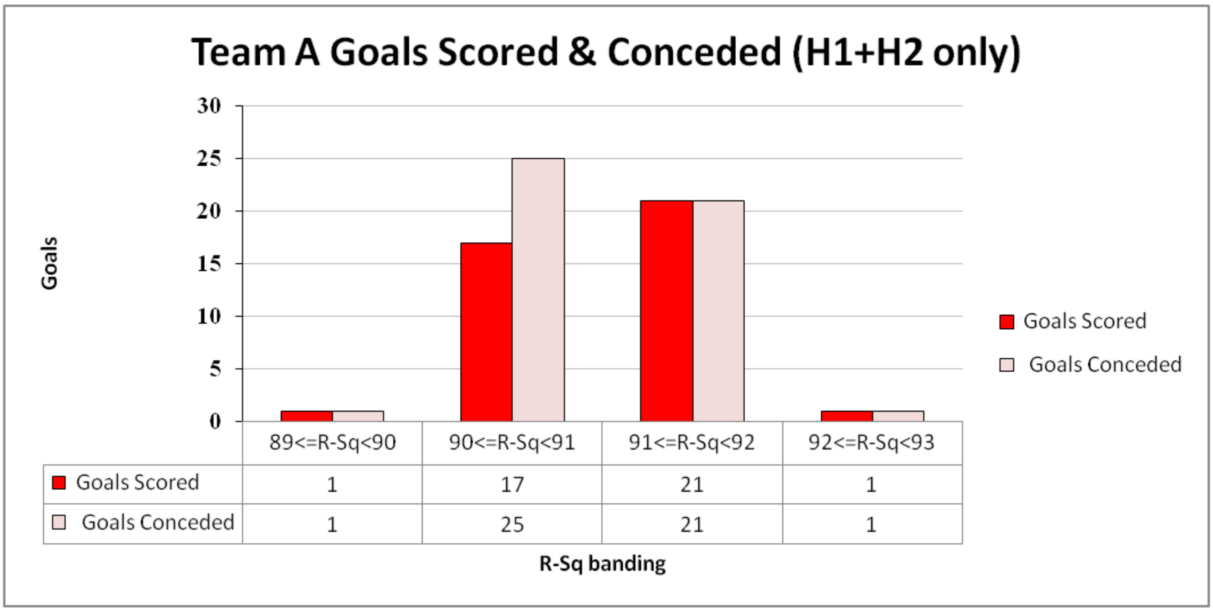


Chart 5 As per Chart 1 but first and second half data sets made contiguous

The second stage of the initial analysis examined how goals scored and conceded were related to the amount of Shannon Information (Negentropy) that each team exhibited in all match half scenarios, and the results are presented below.

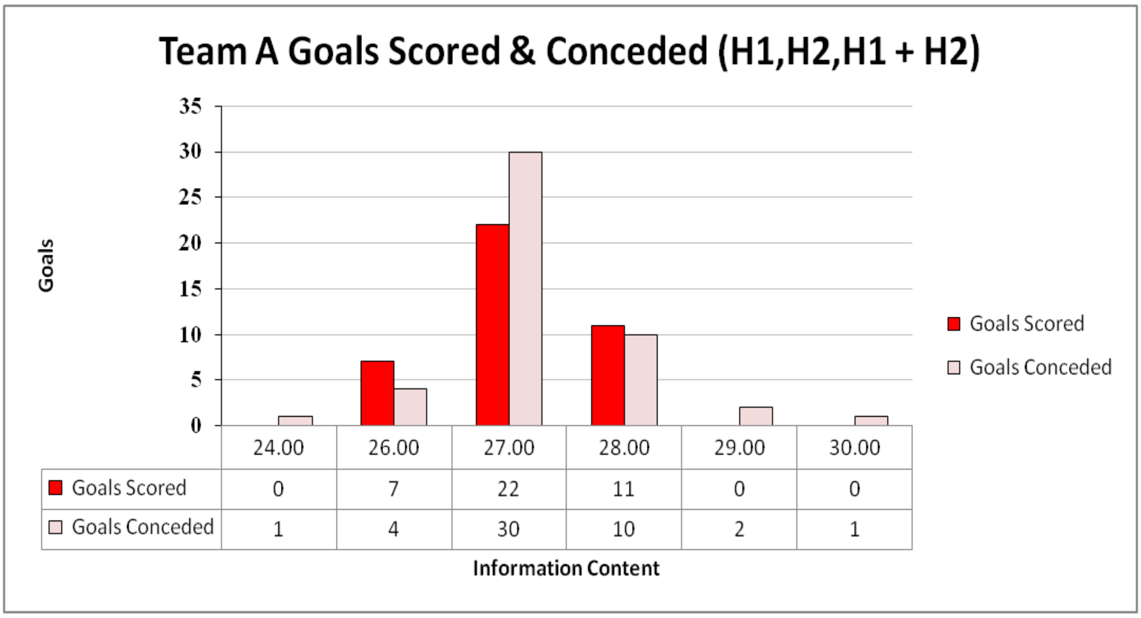


Chart 6 as per Chart 1 but for Shannon Information (Negentropy)

In the case of Chart 6 above, it can be discerned that there is a "sweet spot" balance point of 27 bits, and this, along with the 26 and 28-bit values defines the region of "sensibly organised". Here, the 26-bit category would be "Not Enough" and the 28-bit category being "Too Much" as per the scheme proposed earlier. The 24 and 29 & 30 bit values would be classified as "Under Organised (Laissez-faire)" and "Over Organised (Autocratic)" respectively.

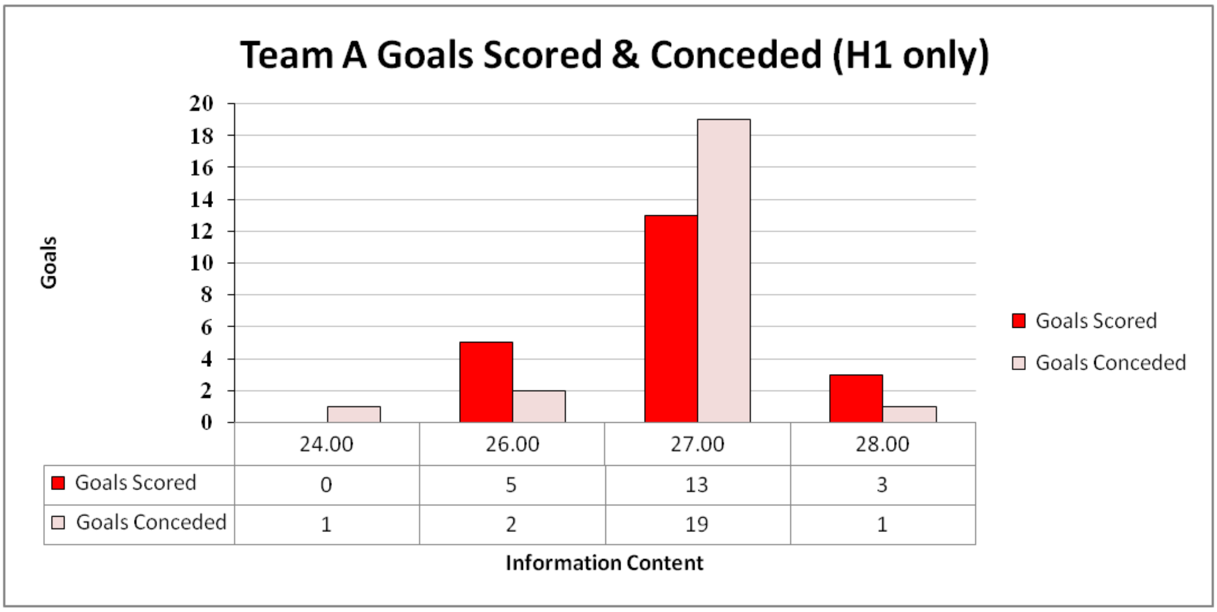


Chart 7 as per Chart 3 but for Shannon Information (Negentropy)

In terms of H1 considered in isolation, as per Chart 7 above, the 27-bit category still predominates the overall goal activity and continues to lend itself as a candidate for the "sweet spot" balance point.

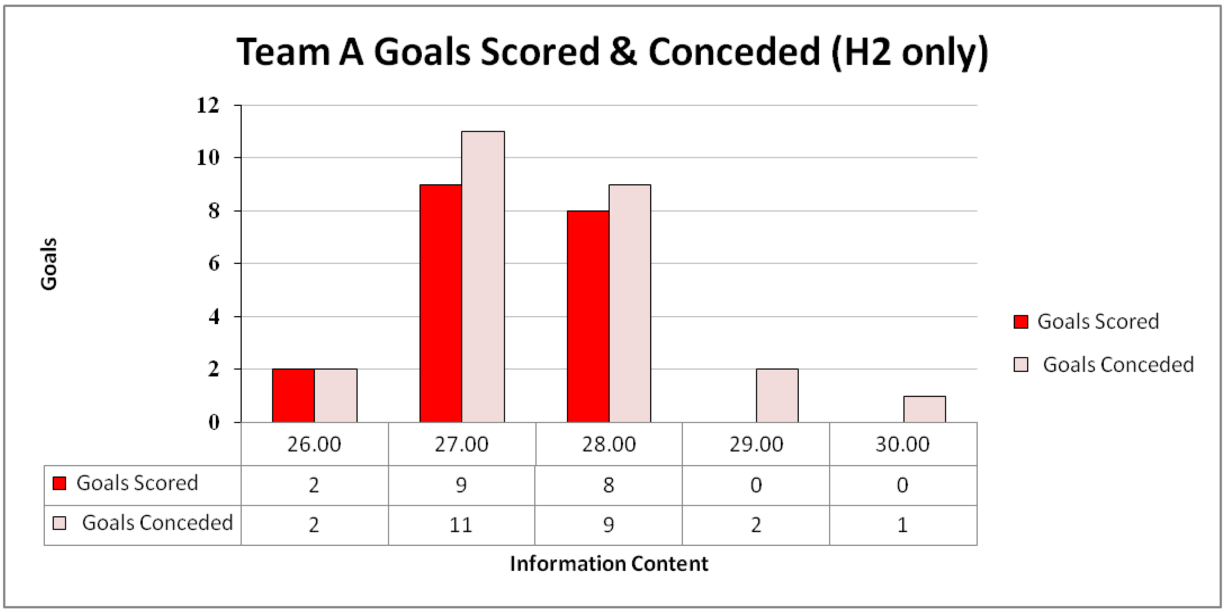


Chart 8 as per Chart 4 but for Shannon Information (Entropy)

In terms of H2 alone, as per Chart 8 above, the 27-bit category continues to represent the majority of goal related activity. This provides evidence that the importance of the 27-bit category in terms of the barrier between team success and failure is not match half-specific.

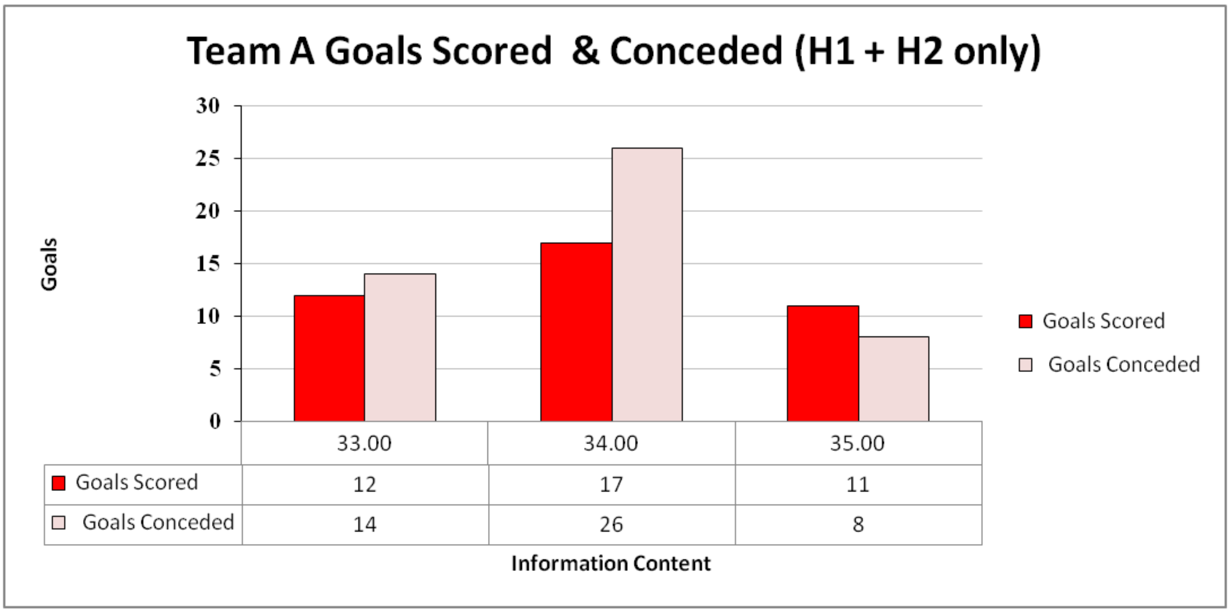


Chart 9 as per Chart 5 but for Shannon Information (Negentropy)

In terms of the fusion of the H1 and H2 data sets as outlined earlier, Chart 9 above reveals that the range of information values is different to the specific match half analysis undertaken thus far.

Nevertheless, there does appear to be a “sweet spot” balance point present at the 34-bit value, and this is flanked by the 33 and 35-bit values that correspond to “Not Enough” and “Too Much” sensible organisation respectively in continuous whole match terms.

The balance points alluded to for both R^2 and Shannon Information (Negentropy) were extremely thought provoking since they did seem to point to the range of values over which the demarcation between team success and failure for the team was especially sensitive.

Subsequent research into this aspect revealed that these findings are perhaps far from anomalous. Indeed, exploration of the work of Kaufmann (Kaufmann, 1991, p.22), Page (Page, 2011, p.32) and Beer (Beer, 1994a, p.256) all essentially refer to a notional point of balance between order and chaos, and this is covered further in the evaluation section of this work (please see Chapter 6 commencing on p.203).

The next stage was to split Table 2 (the whole table per Appendix 4 commencing on p.500, not just the extract depicted on p.165) into sections and analyse each separately.

Team A:

Half 1 at Home fixture

Half 2 at Home fixture

Half 1 at Away fixture

Half 2 at Away fixture

The results for each are contained in Appendix 5 (commencing on p.507), but for illustration purposes, 'Half 1 at Home fixture' is shown below:

Match File	Team	Half	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Goals Scored	Goals Conceded	Goal Difference	TEAM A WIN	TEAM A LOSE	TEAM A DRAW	Information Content	Team A Home or Away?
m1	ta	1	7.87	0.46	89.20	10.80	2	0	2	WIN			26.41	1
m2	ta	1	7.79	0.46	89.00	11.00	1	0	1	WIN			26.38	1
m5	ta	1	7.91	0.46	89.40	10.60	0	1	-1		LOSE		26.46	1
m10	ta	1	8.15	0.48	89.90	10.10	0	1	-1		LOSE		26.92	1
m11	ta	1	8.12	0.48	89.90	10.10	0	0	0			DRAW	26.84	1
m12	ta	1	8.42	0.50	90.30	9.70	1	1	0			DRAW	27.42	1
m16	ta	1	8.23	0.48	90.10	9.90	0	2	-2		LOSE		27.08	1
m17	ta	1	8.28	0.49	90.10	9.90	0	2	-2		LOSE		27.31	1
m18	ta	1	7.98	0.47	89.60	10.40	0	0	0			DRAW	26.56	1
m21	ta	1	7.95	0.47	89.50	10.50	1	2	-1		LOSE		26.56	1
m23	ta	1	8.31	0.49	90.30	9.70	0	0	0			DRAW	27.30	1
m25	ta	1	8.03	0.47	89.60	10.40	1	0	1	WIN			26.76	1
m26	ta	1	7.94	0.47	89.50	10.50	0	0	0			DRAW	26.50	1
m27	ta	1	8.331	0.4916	90.2	9.80	1	0	1	WIN			27.34	1
m30	ta	1	8.15	0.48	89.90	10.10	0	0	0			DRAW	26.90	1
m33	ta	1	7.80	0.46	89.40	10.60	0	1	-1		LOSE		24.50	1
m35	ta	1	7.65	0.45	88.70	11.30	1	0	1	WIN			26.07	1
m36	ta	1	7.76	0.46	89.10	10.90	0	0	0			DRAW	26.08	1
m38	ta	1	8.00	0.47	89.60	10.40	0	1	-1		LOSE		26.62	1

Min	7.65	0.45	88.70								24.50
Max	8.42	0.50	90.30								27.42
Diff	0.77	0.05	1.60								2.93
Goals Scored					8						
Goals Conceded						11					
Goal Difference							-3				

Table 3 Team A: all regression line parameters (all home matches, 1st half, complete season)

It can be seen from the table above that the values for the Y intercept, gradient and regression coefficient of the linear regression line all occupy a very narrow range. The same can be said of the amount of Shannon Information associated with each performance.

Before considering the results presented from this point forwards, please recall that the regression lines associated with each match as described take the form $y = mx + c$ where m is the gradient of the regression line and c is its intercept with the y axis.

The work above shows that survey of such regression lines has been taken for the target team under a variety of scenarios i.e. goals scored and conceded in both first and second match halves at both home and away fixtures.

Within each scenario, the regression line parameters were each found to be spread across quite a narrow range of values, with each featuring a minimum and a maximum, with difference between them defining the range

Accordingly, ymin and ymax represents the least and highest values respectively of c (intercept with the y axis) for the regression lines obtained, permitting one to compute ydiff as the difference between them.

Similarly, gradmin, gradmax and graddiff are the equivalent quantities for m (the gradient of the regression line); regmin, regmax and regdiff are the equivalent values for the strength of the linearity in the regression line measured by R^2 and icmin, icmax and icdiff are the equivalent values for the amount of Shannon Information (Negentropy) involved.

This approach was taken since there did not seem to be a particular value of either m, c, R^2 or information content (ic) directly associated with team success or failure. It was considered that since the differences in the parameter values was so narrow then this might hold some promise and reveal some insight.

As such, the tables produced for Half 1 at Home fixture, Half 1 at Away fixture, Half 2 at Home fixture and Half 2 at Away fixture were then combined.

For example, the summary table at the foot of Table 3 represents the first line of Table 4 (combined results table) that follows on the next page. This was to discern if the change in fixture corresponded to any change in the parameters of the regression lines concerned.

Team	Half	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scor	Goals Conceded	Goal Difference
A	1	1	7.65	8.42	0.77	0.45	0.50	0.05	88.70	90.30	1.60	24.50	27.42	2.93	8	11	-3
A	2	1	7.91	8.70	0.79	0.46	0.51	0.05	89.30	91.00	1.70	26.43	28.26	1.83	12	8	4
A	1	2	7.84	8.48	0.64	0.46	0.49	0.03	89.20	90.50	1.30	26.31	27.80	1.48	13	12	1
A	2	2	7.87	9.30	1.44	0.46	0.55	0.09	89.20	92.10	2.90	26.23	29.71	3.48	7	17	-10

Table 4 Team A min/max regression line parameters by match half and fixture

The variables in this table were then correlated using Microsoft Excel's 'toolpak' feature and this is shown below:

	Half	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scored	Goals Conceded	Goal Difference
Half	1.00																
Fixture	0.00	1.00															
ymin	0.71	0.37	1.00														
ymax	0.79	0.47	0.50	1.00													
ydiff	0.66	0.41	0.24	0.96	1.00												
grad min	0.64	0.47	0.99	0.49	0.24	1.00											
grad max	0.79	0.40	0.43	0.99	0.98	0.42	1.00										
grad diff	0.67	0.29	0.17	0.93	0.99	0.15	0.96	1.00									
reg min	0.64	0.43	1.00	0.46	0.20	1.00	0.38	0.11	1.00								
reg max	0.82	0.47	0.56	1.00	0.94	0.55	0.99	0.91	0.52	1.00							
reg diff	0.70	0.37	0.26	0.96	1.00	0.25	0.98	0.99	0.21	0.94	1.00						
ic min	0.58	0.51	0.98	0.46	0.20	1.00	0.37	0.10	0.99	0.51	0.20	1.00					
ic max	0.79	0.53	0.57	1.00	0.94	0.56	0.98	0.89	0.53	1.00	0.94	0.53	1.00				
ic diff	0.28	0.06	-0.36	0.62	0.81	-0.37	0.69	0.86	-0.41	0.57	0.81	-0.41	0.55	1.00			
Goals Scored	-0.20	0.00	0.45	-0.53	-0.74	0.47	-0.61	-0.80	0.50	-0.48	-0.74	0.51	-0.46	-0.99	1.00		
Goals Conceded	0.15	0.77	0.02	0.73	0.81	0.08	0.72	0.75	0.03	0.69	0.77	0.09	0.72	0.68	-0.64	1.00	
Goal Difference	-0.19	-0.48	0.21	-0.71	-0.86	0.18	-0.74	-0.86	0.22	-0.66	-0.84	0.19	-0.67	-0.91	0.88	-0.93	1.00

Table 5 correlation matrix for Table 4

It was observed from the above that there were some very high values of correlation between certain variables. What was of particular interest was the strength in the relationships between the goals scored and conceded by the team, as well as the margin between them i.e. goal difference.

It was discerned that goals scored by the team were strongly negatively correlated with the difference in the y intercept of the linear regression lines (y diff) i.e. -0.74 (-74%). It was noticed also that this applied in particular to the difference in the gradients of the regression lines (grad diff) and the difference in the amounts of Shannon Information involved (ic diff (ic=information content) i.e. -0.80 (-80%) and -.99(-99%) respectively.

In terms of goals conceded, intriguingly, very high positive correlations were present for ydiff (0.81 (81%)), graddiff (0.75 (75%)) and icdiff (0.68(68%)). Goal difference revealed a -0.86 (-86%) correlation with ydiff and graddiff, yet this was surpassed by -0.91(91%) with icdiff.

The process outlined above was then repeated for the whole collection of various opponent teams that Team A confronted during the season. The intention here was to compare and contrast the scope of the linear regression parameters produced by the various opponents with that of Team A's corresponding range of values.

Accordingly, for the purpose of comparative analysis, the regression line parameters of each opposing team that Team A faced during the season, was notionally ascribed to the repertoire of action of a single, hypothetical opponent team i.e. Team X. It must be clearly noted that this does not represent any form of amalgamation resulting in the averaging of data and hence the distortion of results.

On the contrary, by taking a survey of the various opponents regression line parameters, a discovery was made that revealed that, irrespective of the opposing team, the range of their respective regression line parameters (e.g. gradmax-gradmin=graddiff) was extremely narrow (please see Table 6, p.176).

This was despite the diversity in the inherent performative capabilities of so many fundamentally different teams. With this specifically in mind, it was considered a legitimate approach to ascribe such tightly focused and highly similar behaviour to the hypothetically derived Team X. At no point was any data averaged. The contents of table 6 represent a survey of the opposing teams that is directly equivalent to that undertaken for Team A, purely so that they may be directly compared to reveal some insight.

Accordingly, the whole collection of opposition regression line parameters then represented, hypothetically at least, the various tactics that a single resourceful and experimental opponent applied to Team A. The range of regression line parameters that Team X exhibited over the season is presented below and the corresponding correlation matrix for Team X that relates each variable to each variable is presented on the next page.

Team	Half	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scor	Goals Cond	Goal Difference
X	1	1	7.51	8.36	0.85	0.44	0.49	0.05	88.40	90.30	1.90	25.74	27.71	1.97	12	13	-1
X	2	1	7.62	9.00	1.38	0.45	0.53	0.08	88.70	91.50	2.80	25.97	29.16	3.19	17	7	10
X	1	2	7.44	8.45	1.01	0.44	0.50	0.06	88.20	90.20	2.00	25.51	27.45	1.94	11	8	3
X	2	2	7.54	8.83	1.30	0.44	0.52	0.08	88.40	91.30	2.90	25.88	28.37	2.49	8	12	-4

Table 6 Team X min/max regression line parameters by half and fixture

	Half	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Score	Goals Conceded	Goal Difference
Half	1.00																
Fixture	0.00	1.00															
ymin	0.80	-0.61	1.00														
ymax	0.97	-0.07	0.82	1.00													
ydiff	0.95	0.09	0.71	0.99	1.00												
grad min	0.66	-0.75	0.98	0.71	0.59	1.00											
grad max	0.97	0.11	0.70	0.98	1.00	0.57	1.00										
grad diff	0.92	0.31	0.55	0.93	0.98	0.40	0.98	1.00									
reg min	0.70	-0.70	0.98	0.76	0.64	1.00	0.63	0.46	1.00								
reg max	0.99	-0.13	0.87	0.98	0.94	0.75	0.95	0.88	0.79	1.00							
reg diff	0.99	0.11	0.72	0.95	0.96	0.57	0.97	0.95	0.62	0.97	1.00						
ic min	0.86	-0.46	0.96	0.82	0.72	0.89	0.73	0.61	0.90	0.91	0.81	1.00					
ic max	0.90	-0.40	0.96	0.94	0.87	0.91	0.87	0.75	0.93	0.95	0.85	0.92	1.00				
ic diff	0.87	-0.36	0.92	0.95	0.89	0.88	0.88	0.77	0.91	0.92	0.83	0.85	0.99	1.00			
Goals Scored	0.15	-0.77	0.60	0.35	0.25	0.74	0.20	0.05	0.73	0.28	0.07	0.36	0.57	0.62	1.00		
Goals Conceded	-0.20	0.00	-0.17	-0.42	-0.47	-0.22	-0.42	-0.41	-0.27	-0.24	-0.19	0.03	-0.37	-0.49	-0.64	1.00	
Goal Difference	0.19	-0.48	0.45	0.42	0.38	0.56	0.33	0.23	0.59	0.29	0.14	0.21	0.53	0.62	0.93	-0.88	1.00

Table 7 Correlation matrix for Table 6

It was observed from the above that there were some strong correlations present, despite the fact that Team X is an ‘amalgamation’ of the parameters of many teams. Indeed, it was interesting to note that this hybrid team had a 47% negative correlation between ydiff and the number of goals conceded, and that goals scored was positively correlated with the value for gradmin i.e.74%. The information difference (icdiff) also seems to have a strong relationship with both the goals scored and the goals conceded by Team X i.e. both 62% positively correlated. The value of regmin seems to have a strong correlation (73% positive) with goals scored by Team X also.

These values prompted the undertaking of both separate regression and correlation analyses for each of the following in terms of goals scored, goals conceded and goal difference.

Half 1 at Home fixture

Half 2 at Home fixture

Half 1 at Away fixture

Half 2 at Away fixture

	All Matches			
	Half 1		Half 2	
	Home	Away	Home	Away
Goals Scored	A1	B1	A4	B4
Goals Conceded	A2	B2	A5	B5
Goal Difference	A3	B3	A6	B6

Table 8 Test Plan

The results for each are presented in Appendix 5 (commencing on p.507). All of these, with two exceptions, indicated low levels of correlation and regression.

Test A1 corresponded to Team A during the first half of all home fixture matches.

Test B1 relates to Team A during the first half of all away fixture matches.

Both of these tests highlighted some interesting findings and these are reported upon separately below.

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
1.00	1.00	7.87	0.46	89.20	26.41	2
1.00	1.00	7.79	0.46	89.00	26.38	1
1.00	1.00	7.91	0.46	89.40	26.46	0
1.00	1.00	8.15	0.48	89.90	26.92	0
1.00	1.00	8.12	0.48	89.90	26.84	0
1.00	1.00	8.42	0.50	90.30	27.42	1
1.00	1.00	8.23	0.48	90.10	27.08	0
1.00	1.00	8.28	0.49	90.10	27.31	0
1.00	1.00	7.98	0.47	89.60	26.56	0
1.00	1.00	7.95	0.47	89.50	26.56	1
1.00	1.00	8.31	0.49	90.30	27.30	0
1.00	1.00	8.03	0.47	89.60	26.76	1
1.00	1.00	7.94	0.47	89.50	26.50	0
1.00	1.00	8.33	0.49	90.2	27.34	1
1.00	1.00	8.15	0.48	89.90	26.90	0
1.00	1.00	7.80	0.46	89.40	24.50	0
1.00	1.00	7.65	0.45	88.70	26.07	1
1.00	1.00	7.76	0.46	89.10	26.08	0
1.00	1.00	8.00	0.47	89.60	26.62	0

Table 9 Test A1 - Team A's 1st half regression line parameters (home fixture)

The table below indicates the correlation of each variable in the table above with each other. As can be discerned, the strongest correlation with Goals scored in this scenario is with the Regression Coefficient value i.e. -0.30 (-30%)

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	0.98	0.97	1.00		
Information Content	0.80	0.82	0.69	1.00	
Goals Scored	-0.16	-0.15	-0.30	0.04	1.00

Table 10 Correlation matrix for Table 9

A regression analysis was also carried out on Test A1 table above and this is reported below.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.747
R Square	0.559
Adjusted R Square	0.433
Standard Error	0.457
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	3.705	0.926	4.431	0.016
Residual	14.000	2.927	0.209		
Total	18.000	6.632			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*er.*	*Lower 95.0%*	*Upper 95.0%*
Intercept	441.779	119.428	3.699	0.002	185.632	#	185.632	697.927
Y Intercept	11.521	8.692	1.326	0.206	-7.121	#	-7.121	30.164
Gradient	27.059	143.385	0.189	0.853	-280.471	#	-280.471	334.589
Regression Coefficient	-5.921	1.584	-3.738	0.002	-9.317	#	-9.317	-2.524
Information Content	-0.599	0.435	-1.375	0.191	-1.532	#	-1.532	0.335

Table 11 Regression analysis for Table 9

The R Square value (R^2) indicates the amount of variance in the dependent variable (in this case Goals Scored) that was accounted for by the independendent variables (in this case Y intercept, Gradient, Regression Coefficient and Information content).

The regression statistics above indicate that, taken as a set, the independent variables account for 55.9% of the variation in the dependent variable, but this does not mean that they each account for an equal apportionment of that 55.9%.

Taking an alpha value of 0.05, the Significance F value in the ANOVA (Analysis of Variation) section reveals that this is less than alpha i.e. 0.016 < 0.05. This indicates that the value for R^2 is significantly greater than zero, and hence means that the independent variables predict a significant amount of variance in the value of Goals Scored.

The section of the table below ANOVA examines the individual independent variables, and does not consider them as a set. As such, it serves to reveal if any individual independent variable uniquely accounts for a significant amount of variance in the dependent (Goals Scored) variable.

This has been achieved in this case by assessing the p value in the table for each independent variable against an alpha value of 0.05. In this particular test, the p value of the 'Regression Coefficient' variable is 0.002. This is less than alpha i.e. 0.002 < 0.05.

Accordingly, it can be concluded that the overall regression model was significant F (4, 14) =4.431, p<0.05, R^2=0.559.The same process was repeated for Test B1 (Team A during the first half of all away fixture matches) as shown below.

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
1.00	2.00	8.21	0.48	89.60	27.48	0
1.00	2.00	8.48	0.49	90.50	27.80	2
1.00	2.00	7.97	0.47	89.50	26.64	1
1.00	2.00	7.99	0.47	89.70	26.59	0
1.00	2.00	8.32	0.49	90.20	27.38	1
1.00	2.00	8.20	0.48	90.00	27.08	0
1.00	2.00	8.36	0.49	90.30	27.57	1
1.00	2.00	8.38	0.49	90.30	27.49	1
1.00	2.00	8.04	0.47	89.70	26.68	0
1.00	2.00	7.84	0.46	89.20	26.31	0
1.00	2.00	8.09	0.47	89.80	26.86	3
1.00	2.00	8.18	0.48	89.90	27.28	0
1.00	2.00	7.85	0.46	89.30	26.35	1
1.00	2.00	8.07	0.47	89.80	26.74	1
1.00	2.00	8.07	0.47	89.50	26.97	0
1.00	2.00	7.96	0.47	89.50	26.51	1
1.00	2.00	7.99	0.47	89.50	26.72	1
1.00	2.00	8.02	0.47	89.70	26.73	0

Table 12 Test B1 – Team A's 1st half regression line parameters (away fixture)

The table below indicates the correlation of each variable in the table above with each other. As can be discerned, the strongest correlation with Goals scored in this scenario is with the Regression Coefficient value i.e. 0.33 (333%).

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.94	0.95	1.00		
Information Content	0.97	0.96	0.86	1.00	
Goals Scored	0.26	0.20	0.33	0.19	1.00

Table 13 Correlation matrix for Table 12

A regression analysis was also carried out on Test B1 table above and this is reported below

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.753
R Square	0.566
Adjusted R Square	0.433
Standard Error	0.622
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	6.578	1.644	4.247	0.020
Residual	13.000	5.033	0.387		
Total	17.000	11.611			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-238.215	189.865	-1.255	0.232	-648.394	171.964	-648.394	171.964
Y Intercept	24.286	11.538	2.105	0.055	-0.640	49.212	-0.640	49.212
Gradient	-519.577	146.879	-3.537	0.004	-836.889	-202.265	-836.889	-202.265
Regression Coefficient	3.273	2.338	1.400	0.185	-1.777	8.323	-1.777	8.323
Information Content	-0.171	2.616	-0.065	0.949	-5.823	5.481	-5.823	5.481

Table 14 Regression analysis for Table 12

In a similar manner to the Test A1 table, the above indicates that the regression statistics indicate that, taken as a set, the independent variables account for 56.6% of the variation in the dependent variable, but this does not mean that they each account for an equal apportionment of that 56.6%.

Taking an alpha value of 0.05, the Significance F value in the ANOVA (Analysis of Variation) section reveals that this is less than alpha i.e. $0.02 < 0.05$. This indicates that the value for R^2 is significantly greater than zero, and hence means that the independent variables predict a significant amount of variance in the value of Goals Scored. The p values for each independent variable have been assessed against an alpha value of 0.05. In this particular test, the p value of the 'Gradient' variable is 0.004 and is less than alpha i.e. $0.004 < 0.05$.

Accordingly, it can be concluded that the overall regression model was significant F (4, 13) =4.247, p<0.05, R^2=0.566.

Team A’s table of regression line parameters was also used in an attempt to derive an equation that could be used to predict a particular match outcome for that team, irrespective of fixture type or game half.

The rationale for doing this was that one might be able to obtain an equation that relates to overall team viability in a cybernetic sense in the context of its success (win), failure (lose) or balance (draw).

Team	Half	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scor	Goals Conceded	Goal Difference
A	1	1	7.65	8.42	0.77	0.45	0.50	0.05	88.70	90.30	1.60	24.50	27.42	2.93	8	11	-3
A	2	1	7.91	8.70	0.79	0.46	0.51	0.05	89.30	91.00	1.70	26.43	28.26	1.83	12	8	4
A	1	2	7.84	8.48	0.64	0.46	0.49	0.03	89.20	90.50	1.30	26.31	27.80	1.48	13	12	1
A	2	2	7.87	9.30	1.44	0.46	0.55	0.09	89.20	92.10	2.90	26.23	29.71	3.48	7	17	-10

Table 15 Team A min/max regression line parameters by match half and fixture

In football:

Success = goals scored > goals conceded = a positive goal difference

Failure = goals scored < goals conceded = a negative goal difference

Balance = goals scored = goals conceded

The maximization of success and the minimization of failure is the purpose of the game.

It is intuitively obvious that no team will turn up to a match with the specific intention of losing. The team’s efforts are therefore specifically defined by the purpose. This means that it can be legitimately argued that, in the context of any match, the team’s purpose as a cybernetically viable system is the same thing i.e. its success is its criterion of viability.

If a team sustains failure, then it has failed in its purpose as a cybernetically viable system in that operational context i.e. that particular match. The exception to the above is where success and failure are perhaps the same and the team experiences a draw situation.

From the cybernetic point of view, this may be regarded as homeostatic balance.

	Half	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scored	Goals Conceded	Goal Difference
Half	1.00																
Fixture	0.00	1.00															
ymin	0.71	0.37	1.00														
ymax	0.79	0.47	0.50	1.00													
ydiff	0.66	0.41	0.24	0.96	1.00												
grad min	0.64	0.47	0.99	0.49	0.24	1.00											
grad max	0.79	0.40	0.43	0.99	0.98	0.42	1.00										
grad diff	0.67	0.29	0.17	0.93	0.99	0.15	0.96	1.00									
reg min	0.64	0.43	1.00	0.46	0.20	1.00	0.38	0.11	1.00								
reg max	0.82	0.47	0.56	1.00	0.94	0.55	0.99	0.91	0.52	1.00							
reg diff	0.70	0.37	0.26	0.96	1.00	0.25	0.98	0.99	0.21	0.94	1.00						
ic min	0.58	0.51	0.98	0.46	0.20	1.00	0.37	0.10	0.99	0.51	0.20	1.00					
ic max	0.79	0.53	0.57	1.00	0.94	0.56	0.98	0.89	0.53	1.00	0.94	0.53	1.00				
ic diff	0.28	0.06	-0.36	0.62	0.81	-0.37	0.69	0.86	-0.41	0.57	0.81	-0.41	0.55	1.00			
Goals Scored	-0.20	0.00	0.45	-0.53	-0.74	0.47	-0.61	-0.80	0.50	-0.48	-0.74	0.51	-0.46	-0.99	1.00		
Goals Conceded	0.15	0.77	0.02	0.73	0.81	0.08	0.72	0.75	0.03	0.69	0.77	0.09	0.72	0.68	-0.64	1.00	
Goal Difference	-0.19	-0.48	0.21	-0.71	-0.86	0.18	-0.74	-0.86	0.22	-0.66	-0.84	0.19	-0.67	-0.91	0.88	-0.93	1.00

Table 16 Team A Correlation matrix for Table 15

Examination of the correlation matrix above reveals that the variables with the highest correlation values relating to goals scored, goals conceded and goal difference are the 'ydiff', 'graddiff' and 'icdiff' variables.

Accordingly, these variables and their corresponding degrees of success or failure in goal terms were extracted from the table on the previous page and are presented below.

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goals Scored
0.77	0.05	2.93	8
0.79	0.05	1.83	12
0.64	0.03	1.48	13
1.44	0.09	3.48	7

Independent Variables			**Dependent Variable**
ydiff	**grad diff**	**ic diff**	**Goals Conceded**
0.77	**0.05**	**2.93**	**11**
0.79	**0.05**	**1.83**	**8**
0.64	**0.03**	**1.48**	**12**
1.44	**0.09**	**3.48**	**17**

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goal Difference
0.77	0.05	2.93	-3
0.79	0.05	1.83	4
0.64	0.03	1.48	1
1.44	0.09	3.48	-10

Table 17 Team A regression line parameters per Table 16 with highest correlation levels

In considering 'ydiff', 'graddiff' and 'icdiff' as independent variables that may serve to predict an outcome for a dependent variable (scored, conceded or difference as applicable), then there may be an equation that one could derive to relate the two with an amount of predictive accuracy.

In this respect, it was determined that for this type of situation an equation of the following form can be used for this purpose:

$$y = a_n x_n + a_{n-1} x_{n-1} + \cdots a_1 x_{n1} + a_0$$

Equation 3

Where y is the dependent variable, a_n is the gradient of the independent variable, x_n, is the independent variable and a_0 is the y intercept.

Microsoft Excel 2007's LINEST function calculates the statistics for a line by using the least squares method to calculate a straight line that best fits the data, and then returns an array that describes the line.

The array produced contains:

a_n	a_3	a_2	a_1	a_0
Standard Error of a_n	SEa_3	SEa_2	SEa_1	SEa_0
R^2, Standard Error of y	R^2	SEy		
F, degrees of freedom	F	df		
Sum of Squares	$SS_{regression}$	$SS_{residuals}$		

Table 18 LINEST array interpretation

In the case of goals scored:

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goals Scored
0.77	0.05	2.93	8
0.79	0.05	1.83	12
0.64	0.03	1.48	13
1.44	0.09	3.48	7

LINEST Array			
ic diff-A	grad diff-A	ydiff-A	Goals Scored
-3.63	5.58	1.20	17.43
0	0	0	0
1	0		
	0		
26	0		

Table 19 LINEST computations (Goals Scored)

This resulted in a predictive equation (irrespective of half or fixture) of:

$$y = -3.63(icdiff) + 5.58(graddiff) + 1.2(ydiff) + 17.43$$

Using the values of the independent variables as input to the above equation resulted in the following predictions being made by the equation.

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goals Scored
0.77	0.05	2.93	8
0.79	0.05	1.83	12
0.64	0.03	1.48	13
1.44	0.09	3.48	7

Prediction	Residuals(Goals Observed-Prediction)
8	0.00
12	0.00
13	0.00
7	0.00
Sum of Squares	0.00

LINEST Array			
ic diff-A	grad diff-A	ydiff-A	Goals Scored
-3.63	5.58	1.20	17.43
0	0	0	0
1	0		
	0		
26	0		

Table 20 Outcome predicted for Goals Scored

The prediction column contains the value returned by the above equation when using the independent variables for that row. The residuals column is the difference computed in the actual goals scored (Goals observed) and the prediction made.

As can be seen, the equation predicts the number of goals scored with some degree of accuracy, albeit for four sets of independent variables.

In the case of goals conceded:

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goals Conceded
0.77	0.05	2.93	11
0.79	0.05	1.83	8
0.64	0.03	1.48	12
1.44	0.09	3.48	17

LINEST Array			
ic diff	grad diff	ydiff	Goals Conceded
4.95	-1110.38	66.65	-0.82
0	0	0	0
1	0		
	0		
42	0		

Table 21 LINEST computations (Goals Conceded)

This resulted in a predictive equation (irrespective of half or fixture) of:

$$y = 4.95(icdiff) - 1110.38(graddiff) + 66.5(ydiff) - 0.82$$

Using the values of the independent variables as input to the above equation resulted in the following predictions being made by the equation.

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goals Conceded
0.77	0.05	2.93	11
0.79	0.05	1.83	8
0.64	0.03	1.48	12
1.44	0.09	3.48	17

Prediction	Residuals(Goals Observed-Prediction)
11	0.00
8	0.00
12	0.00
17	0.00
Sum of Squares	0.00

LINEST Array			
ic diff	grad diff	ydiff	Goals Conceded
4.95	-1110.38	66.65	-0.82
0	0	0	0
1	0		
	0		
42	0		

Table 22 Outcome predicted for Goals Conceded

Once more, the equation seems to provide a useful degree of accuracy.

In the case of goal difference:

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goal Difference
0.77	0.05	2.93	-3
0.79	0.05	1.83	4
0.64	0.03	1.48	1
1.44	0.09	3.48	-10

LINEST Array			
ic diff	grad diff	ydiff	Goal Difference
-8.57	1115.97	-65.45	18.24
0	0	0	0
1	0		
	0		
110	0		

Table 23 LINEST computations (Goal Difference)

This resulted in a predictive equation (irrespective of half, fixture losses or gains) of:

$$y = -8.57(icdiff) + 1115.96(graddiff) + 65.77(ydiff) + 18.24$$

Using the values of the independent variables as input to the above equation resulted in the following predictions being made by the equation.

Independent Variables			Dependent Variable
ydiff	grad diff	ic diff	Goal Difference
0.77	0.05	2.93	-3
0.79	0.05	1.83	4
0.64	0.03	1.48	1
1.44	0.09	3.48	-10

Prediction	Residuals(Goals Observed-Prediction)
-3	0.00
4	0.00
1	0.00
-10	0.00
Sum of Squares	0.00

LINEST Array			
ic diff	grad diff	ydiff	Goal Difference
-8.57	1115.97	-65.45	18.24
0	0	0	0
1	0		
	0		
110	0		

Table 24 Outcome predicted for Goal Difference

This too seems to provide a useful degree of prediction.

Given the equations proposed, anything that is outside of those predictions is suggested to be classified as a draw, since that situation does not represent success, failure or difference. It represents homeostatic balance.

Given the spectrum of regression line parameters for both teams as per table 5 (Team A) and table 7 (Team X) earlier, it was deemed appropriate to place these in juxtaposition to discern how they might be correlated

		Team A																
		Half	Fixture	ymin-A	ymax-A	ydiff-A	grad min-A	grad max-A	grad diff-A	reg min-A	reg max-A	reg diff-A	ic min-A	ic max-A	ic diff-A	Goals Scored-A	Goals Conceded-A	Goal Difference-A
	Half	1.00																
	Fixture	0.00	1.00															
	ymin-A	0.71	0.37	1.00														
Team A	ymax-A	0.79	0.47	0.50	1.00													
	ydiff-A	0.66	0.41	0.24	0.96	1.00												
	grad min-A	0.64	0.47	0.99	0.49	0.24	1.00											
	grad max-A	0.79	0.40	0.43	0.99	0.98	0.42	1.00										
	grad diff-A	0.67	0.29	0.17	0.93	0.99	0.15	0.96	1.00									
	reg min-A	0.64	0.43	1.00	0.46	0.20	1.00	0.38	0.11	1.00								
	reg max-A	0.82	0.47	0.56	1.00	0.94	0.55	0.99	0.91	0.52	1.00							
	reg diff-A	0.70	0.37	0.26	0.96	1.00	0.25	0.98	0.99	0.21	0.94	1.00						
	ic min-A	0.58	0.51	0.98	0.46	0.20	1.00	0.37	0.10	0.99	0.51	0.20	1.00					
	ic max-A	0.79	0.53	0.57	1.00	0.94	0.56	0.98	0.89	0.53	1.00	0.94	0.53	1.00				
	ic diff-A	0.28	0.06	-0.36	0.62	0.81	-0.37	0.69	0.86	-0.41	0.57	0.81	-0.41	0.55	1.00			
	Goals Scored-A	-0.20	0.00	0.45	-0.53	-0.74	0.47	-0.61	-0.80	0.50	-0.48	-0.74	0.51	-0.46	-0.99	1.00		
	Goals Conceded-A	0.15	0.77	0.02	0.73	0.81	0.08	0.72	0.75	0.03	0.69	0.77	0.09	0.72	0.68	-0.64	1.00	
	Goal Difference-A	-0.19	-0.48	0.21	-0.71	-0.86	0.18	-0.74	-0.86	0.22	-0.66	-0.84	0.19	-0.67	-0.91	0.88	-0.93	1.00
Team X	ymin-X	0.80	-0.61	0.35	0.34	0.27	0.24	0.38	0.34	0.26	0.37	0.32	0.16	0.31	0.17	-0.14	-0.35	0.15
	ymax-X	0.97	-0.07	0.80	0.64	0.46	0.73	0.63	0.46	0.74	0.69	0.50	0.68	0.66	0.04	0.04	-0.05	0.05
	ydiff-X	0.95	0.09	0.88	0.69	0.49	0.83	0.66	0.46	0.83	0.74	0.52	0.78	0.71	0.00	0.09	0.04	0.02
	grad min-X	0.66	-0.75	0.25	0.13	0.07	0.13	0.18	0.15	0.16	0.16	0.12	0.06	0.10	0.04	-0.03	-0.53	0.31
	grad max-X	0.97	0.11	0.87	0.73	0.54	0.81	0.71	0.52	0.81	0.77	0.57	0.77	0.75	0.06	0.04	0.09	-0.04
	grad diff-X	0.92	0.31	0.91	0.79	0.59	0.88	0.75	0.54	0.87	0.83	0.61	0.84	0.82	0.05	0.05	0.23	-0.12
	reg min-X	0.70	-0.70	0.32	0.17	0.09	0.21	0.21	0.16	0.24	0.21	0.14	0.14	0.14	0.02	0.00	-0.52	0.32
	reg max-X	0.99	-0.13	0.68	0.71	0.58	0.60	0.71	0.59	0.61	0.74	0.62	0.54	0.70	0.23	-0.15	0.03	-0.09
	reg diff-X	0.99	0.11	0.75	0.84	0.70	0.69	0.83	0.69	0.68	0.87	0.73	0.63	0.85	0.28	-0.19	0.24	-0.24
	ic min-X	0.86	-0.46	0.32	0.54	0.51	0.21	0.59	0.58	0.22	0.56	0.56	0.13	0.51	0.41	-0.37	-0.10	-0.12
	ic max-X	0.90	-0.40	0.61	0.44	0.30	0.51	0.46	0.34	0.53	0.49	0.35	0.44	0.44	0.03	0.02	-0.29	0.19
	ic diff-X	0.87	-0.36	0.68	0.39	0.22	0.59	0.39	0.25	0.61	0.44	0.27	0.53	0.40	-0.10	0.15	-0.35	0.29
	Goals Scored-X	0.15	-0.77	0.20	-0.48	-0.60	0.12	-0.47	-0.55	0.16	-0.43	-0.56	0.09	-0.47	-0.60	0.57	-0.95	0.87
	Goals Conceded-X	-0.20	0.00	-0.73	0.22	0.48	-0.72	0.30	0.54	-0.75	0.15	0.47	-0.74	0.15	0.88	-0.92	0.57	-0.80
	Goal Difference-X	0.19	-0.48	0.48	-0.41	-0.61	0.42	-0.43	-0.60	0.47	-0.34	-0.57	0.41	-0.37	-0.80	0.80	-0.87	0.93

		Team X														
		ymin-X	ymax-X	ydiff-X	grad min-X	grad max-X	grad diff-X	reg min-X	reg max-X	reg diff-X	ic min-X	ic max-X	ic diff-X	Goals Scored-X	Goals Conceded-X	Goal Difference-X
Team X	ymin-X	1.00														
	ymax-X	0.82	1.00													
	ydiff-X	0.71	0.99	1.00												
	grad min-X	0.98	0.71	0.59	1.00											
	grad max-X	0.70	0.98	1.00	0.57	1.00										
	grad diff-X	0.55	0.93	0.98	0.40	0.98	1.00									
	reg min-X	0.98	0.76	0.64	1.00	0.63	0.46	1.00								
	reg max-X	0.87	0.98	0.94	0.75	0.95	0.88	0.79	1.00							
	reg diff-X	0.72	0.95	0.96	0.57	0.97	0.95	0.62	0.97	1.00						
	ic min-X	0.96	0.82	0.72	0.89	0.73	0.61	0.90	0.91	0.81	1.00					
	ic max-X	0.96	0.94	0.87	0.91	0.87	0.75	0.93	0.95	0.85	0.92	1.00				
	ic diff-X	0.92	0.95	0.89	0.88	0.88	0.77	0.91	0.92	0.83	0.85	0.99	1.00			
	Goals Scored-X	0.60	0.35	0.25	0.74	0.20	0.05	0.73	0.28	0.07	0.36	0.57	0.62	1.00		
	Goals Conceded-X	-0.17	-0.42	-0.47	-0.22	-0.42	-0.41	-0.27	-0.24	-0.19	0.03	-0.37	-0.49	-0.64	1.00	
	Goal Difference-X	0.45	0.42	0.38	0.56	0.33	0.23	0.59	0.29	0.14	0.21	0.53	0.62	0.93	-0.88	1.00

Table 25 Team A correlation matrix correlated with Team X's

As may be noticed from Table 25 each of Team A's regression line parameters have been correlated with those expressed by Team X, and the overlap between them is indicated in various shades of purple.

Recalling that Team X represents an amalgamation of the data for a diversity of different teams that Team A played against, it is interesting to note some of the high degrees of correlation present.

In particular, the relationship of the number of goals that Team A conceded throughout the season was 53% and 52% negatively correlated with Team X's gradmin and regmin values respectively.

The goals scored by Team X were 48% and 60% negatively correlated with Team A's ymax and ydiff parameters respectively.

A similar situation related to both Team A's gradmax and graddiff parameters.

In the case of the former, this was 47% negatively correlated with Team X's goals scored; and in the case of the latter, it was 55% negatively correlated.

Moreover, it was also observed that the strength in the correlations also seemed to relate to Team A's parameter values for icmax and icdiff i.e. 47% and 60% negatively correlated with Team X's goals scored respectively.

In terms of goals conceded by Team X, this is highly negatively correlated with Team A's ymin value i.e. 73%.

Team A's ydiff parameter seems to have a bearing here in much the same way as in the case of goals scored, except to say that it is much less well correlated (48%) with Team X's concessions and it is positively correlated.

Team A's gradmin parameter seems to have a strong relationship with Team X's goals conceded, being 72% negatively correlated with it. This seems to be in contrast to how it was related to Team X's goals scored (positive correlation of 12%).

Team X's goals conceded also seems to have a strong relationship with Team A's graddiff and regmin values of 54% positive and 75% negative correlations respectively.

What is very interesting to note also is the very high degree of positive correlation between Team X's goals conceded and Team A's icdiff parameter i.e. 88%. Indeed, recalling from Section 2.7 (p.68), if the entropy of a system decreases, it exhibits less disorder and hence more order and is as such, comparatively more organised. Yet, a decrease in entropy corresponds to an increase in

Negentropy (Information) and that corresponds to a system becoming less predictable. Accordingly, the positive correlation between Team X's goals conceded and Team A's icdiff parameter suggests that perhaps as a broadening range of icdiff for Team A makes it less predictive (and better self-organised) from the perspective of an opponent (Team X) and that this corresponds to the opponent conceding more goals.

The figures from the correlation matrix (Table 5, p.174) seemed to point to critically important parameters in the regression line that was fitted to Team A's ranked policy frequencies.

This prompted examination of the regression lines in the context of success and failure (goals scored and conceded) to attempt to find particular parameter values that were associated with success. This was an effort in vain as substantiated by the separate correlation and regression tests carried out.

As such it appears that it is not specific values of specific regression line parameters that are perhaps associated with Team A's propensity towards success or failure, but the differences between them as defined by a very small range of values for each.

The fact remained that the 88% correlation of Team A's icdiff and Team X's goals conceded was present, and this demanded further investigation.

This was accomplished by placing Team A's R-Sq values and their corresponding amounts of Shannon Information into juxtaposition with the number of goals scored and the number of goals conceded by it. The rationale for this was to determine if what this work proposes about information and R-Sq had a bearing on the frequency of goals in either case.

The following tables were produced:

	Sum of Goals Scored	Information Content									
	R-Sq Group	**24.00**	**26.00**	**27.00**	**28.00**	**29.00**	**30.00**	**33.00**	**34.00**	**35.00**	**Grand Total**
Half	**1.00**	**0**	**5**	**13**	**3**						**21**
Home	**1.00**	**0**	**4**	**4**							**8**
	R-Sq<89	0	4	2							6
	90<=R-Sq<91			2							2
Away	**2.00**		**1**	**9**	**3**						**13**
	R-Sq<89		1	7							8
	90<=R-Sq<91			2	3						5
Half	**2.00**		**2**	**9**	**8**	**0**	**0**				**19**
Home	**1.00**		**1**	**8**	**3**						**12**
	R-Sq<89		1	5							6
	90<=R-Sq<91			3	2						5
	91<=R-Sq<92				1						1
Away	**2.00**		**1**	**1**	**5**	**0**	**0**				**7**
	R-Sq<89		1	1							2
	90<=R-Sq<91			0	3						3
	91<=R-Sq<92				2	0					2
	92<R-Sq<93						0				0
Half	**3.00**							**12**	**17**	**11**	**40**
Home	**1.00**							**7**	**12**	**1**	**20**
	R-Sq<89							1			1
	90<=R-Sq<91							2	3		5
	91<=R-Sq<92							4	8	1	13
	92<R-Sq<93								1		1
Away	**2.00**							**5**	**5**	**10**	**20**
	90<=R-Sq<91							4	5	3	12
	91<=R-Sq<92							1	0	7	8
	Grand Total	**0**	**7**	**22**	**11**	**0**	**0**	**12**	**17**	**11**	**80**

Table 26 Goals Scored by R-Sq and Information Content for Team A

		Sum of Goals Conceded	Information Content									
		R-Sq Group	**24.00**	**26.00**	**27.00**	**28.00**	**29.00**	**30.00**	**33.00**	**34.00**	**35.00**	**Grand Total**
Half		**1.00**	**1**	**2**	**19**	**1**						**23**
	Home	**1.00**	**1**	**1**	**9**							**11**
		R-Sq<89	1	1	4							6
		90<=R-Sq<91			5							5
	Away	**2.00**		**1**	**10**	**1**						**12**
		R-Sq<89		1	9							10
		90<=R-Sq<91			1	1						2
Half		**2.00**		**2**	**11**	**9**	**2**	**1**				**25**
	Home	**1.00**		**0**	**7**	**1**						**8**
		R-Sq<89		0	7							7
		90<=R-Sq<91			0	1						1
		91<=R-Sq<92				0						0
	Away	**2.00**		**2**	**4**	**8**	**2**	**1**				**17**
		R-Sq<89		2	2							4
		90<=R-Sq<91			2	5						7
		91<=R-Sq<92				3	2					5
		92<R-Sq<93						1				1
Half		**3.00**							**14**	**26**	**8**	**48**
	Home	**1.00**							**5**	**13**	**1**	**19**
		R-Sq<89							1			1
		90<=R-Sq<91							3	4		7
		91<=R-Sq<92							1	8	1	10
		92<R-Sq<93								1		1
	Away	**2.00**							**9**	**13**	**7**	**29**
		90<=R-Sq<91							7	10	1	18
		91<=R-Sq<92							2	3	6	11
		Grand Total	**1**	**4**	**30**	**10**	**2**	**1**	**14**	**26**	**8**	**96**

Table 27 Goals Conceded by R-Sq and Information Content for Team A

In both tables, Half 3 was the case that the data for both halves of each match had been fused in order to compute the emergent dynamics (described in Section 5.2, p.196), but these were not analysed further. Accordingly, both of the tables above were examined on a Half 1 and Half 2 basis.

In the case of goals scored:

Sum of Goals Scored	Information Content						
R-Sq Group	**24.00**	**26.00**	**27.00**	**28.00**	**29.00**	**30.00**	**Grand Total**
R-Sq<89	0	7	15	0	0	0	22
90<=R-Sq<91	0	0	7	8	0	0	15
91<=R-Sq<92	0	0	0	3	0	0	3
92<R-Sq<93	0	0	0	0	0	0	0
Grand Total	**0**	**7**	**22**	**11**	**0**	**0**	**40**

Table 28 Goals Scored by Team A (half 1 and half 2 - all fixtures)

In the case of goals conceded:

Sum of Goals Conceded	Information Content						
R-Sq Group	**24.00**	**26.00**	**27.00**	**28.00**	**29.00**	**30.00**	**Grand Total**
R-Sq<89	**1**	**4**	**22**	**0**	**0**	**0**	**27**
90<=R-Sq<91	**0**	**0**	**8**	**7**	**0**	**0**	**15**
91<=R-Sq<92	**0**	**0**	**0**	**3**	**2**	**0**	**5**
92<R-Sq<93	**0**	**0**	**0**	**0**	**0**	**1**	**1**
Grand Total	**1**	**4**	**30**	**10**	**2**	**1**	**48**

Table 29 Goals Conceded by Team A (half 1 and half 2 - all fixtures)

The null hypothesis (H_o) is that the goals scored or conceded per the juxtaposition of Information Exhibited (bits) and their associated R-Sq values are attributable to randomness (i.e. R-Sq has no dependence on Information Exhibited).

Accordingly, the alternate Hypothesis (H_A) is that those same figures are not attributable to randomness. That is to say, that R-Sq has a degree of dependence on Information Exhibited and that the relationship between them is somewhat deterministic, despite the inherent randomness exhibited by the actions of the players in the various teams.

Both of these matrices were then subjected to a Chi-Squared test for the purposes of statistical significance assessment as follows.

Observed

Sum of Goals Scored	Information Content			
R-Sq Group	26.00	27.00	28.00	Observed Total Frequency of Occurrence of R-Sq banding per Info. Category
R-Sq<89	7	15	0	22
90<=R-Sq<91	0	7	8	15
91<=R-Sq<92	0	0	3	3
Grand Total	**7**	**22**	**11**	**40**

Expected

Sum of Goals Scored	Information Content			
R-Sq Group	26.00	27.00	28.00	Expected Total Frequency of Occurrence of R-Sq banding per Info. Category
R-Sq<89	3.85000	12.10000	6.05000	22
90<=R-Sq<91	2.62500	8.25000	4.12500	15
91<=R-Sq<92	0.52500	1.65000	0.82500	3
Grand Total	**7**	**22**	**11**	**40**

Observed - Expected

Sum of Goals Scored	Information Content		
R-Sq Group	26.00	27.00	28.00
R-Sq<89	3.15000	2.90000	-6.05000
90<=R-Sq<91	-2.62500	-1.25000	3.87500
91<=R-Sq<92	-0.52500	-1.65000	2.17500

(Observed - Expected)^2

Sum of Goals Scored	Information Content		
R-Sq Group	26.00	27.00	28.00
R-Sq<89	9.92250	8.41000	36.60250
90<=R-Sq<91	6.89063	1.56250	15.01563
91<=R-Sq<92	0.27563	2.72250	4.73063

Sum of ((Observed - Expected)^2/Expected)

Sum of Goals Scored	Information Content			
R-Sq Group	26.00	27.00	28.00	Total
R-Sq<89	2.57727	0.69504	6.05000	9.32231
90<=R-Sq<91	2.62500	0.18939	3.64015	6.45455
91<=R-Sq<92	0.52500	1.65000	5.73409	7.90909
Chi-Squared	5.72727	2.53444	15.42424	**23.68595**

Table 30 Chi-Squared test - Goals Scored

Chi-Squared is 23.68595 and the degrees of freedom is 4 ((number of rows-1)*(number of cols-1).

Taking a value for alpha (not the same value of alpha used in information calculations given earlier) of 0.001, then for 4 degrees of freedom this provides a critical value of 18.467 (See https://www.medcalc.org/manual/chi-square-table.php).

As Chi-Squared is greater than the critical value then the null hypothesis can be rejected. Indeed, using Microsoft Excel's Chi Test function the probability that the null hypothesis is correct is 9.23266E-05, i.e. 1 in 10,831

Sum of Goals Conceded	Information Content						
R-Sq Group	24.00	26.00	27.00	28.00	29.00	30.00	Observed Total Frequency of Occurrence of R-Sq banding per Info. Category
R-Sq<89	1	4	22	0	0	0	27
90<=R-Sq<91	0	0	8	7	0	0	15
91<=R-Sq<92	0	0	0	3	2	0	5
92<R-Sq<93	0	0	0	0	0	1	1
Grand Total	**1**	**4**	**30**	**10**	**2**	**1**	**48**

Expected

Sum of Goals Conceded	Information Content						
R-Sq Group	24.00	26.00	27.00	28.00	29.00	30.00	Observed Total Frequency of Occurrence of R-Sq banding per Info. Category
R-Sq<89	0.56250	2.25000	16.87500	5.62500	1.12500	0.56250	27
90<=R-Sq<91	0.31250	1.25000	9.37500	3.12500	0.62500	0.31250	15
91<=R-Sq<92	0.10417	0.41667	3.12500	1.04167	0.20833	0.10417	5
92<R-Sq<93	0.02083	0.08333	0.62500	0.20833	0.04167	0.02083	1
Grand Total	**1**	**4**	**30**	**10**	**2**	**1**	**48**

Observed - Expected

Sum of Goals Conceded	Information Content					
R-Sq Group	24.00	26.00	27.00	28.00	29.00	30.00
R-Sq<89	0.43750	1.75000	5.12500	-5.62500	-1.12500	-0.56250
90<=R-Sq<91	-0.31250	-1.25000	-1.37500	3.87500	-0.62500	-0.31250
91<=R-Sq<92	-0.10417	-0.41667	-3.12500	1.95833	1.79167	-0.10417
92<R-Sq<93	-0.02083	-0.08333	-0.62500	-0.20833	-0.04167	0.97917

(Observed - Expected)^2

Sum of Goals Conceded	Information Content					
R-Sq Group	24.00	26.00	27.00	28.00	29.00	30.00
R-Sq<89	0.19141	3.06250	26.26563	31.64063	1.26563	0.31641
90<=R-Sq<91	0.09766	1.56250	1.89063	15.01563	0.39063	0.09766
91<=R-Sq<92	0.01085	0.17361	9.76563	3.83507	3.21007	0.01085
92<R-Sq<93	0.00043	0.00694	0.39063	0.04340	0.00174	0.95877

Sum of((Observed - Expected)^2/Expected)

Sum of Goals Conceded	Information Content						
R-Sq Group	24.00	26.00	27.00	28.00	29.00	30.00	Total
R-Sq<89	0.34028	1.36111	1.55648	5.62500	1.12500	0.56250	10.57037
90<=R-Sq<91	0.31250	1.25000	0.20167	4.80500	0.62500	0.31250	7.50667
91<=R-Sq<92	0.10417	0.41667	3.12500	3.68167	15.40833	0.10417	22.84000
92<R-Sq<93	0.02083	0.08333	0.62500	0.20833	0.04167	46.02083	47.00000
Chi-Squared	0.77778	3.11111	5.50815	14.32000	17.20000	47.00000	87.91704

Table 31 Chi-Squared test – Goals Conceded

Chi-Squared is 87.91704 and the degrees of freedom is 15 ((number of rows-1)*(number of cols-1).

Taking a value for alpha (not the same value of alpha used in information calculations given earlier) of 0.001, then for 15 degrees of freedom this provides a critical value of 37.697 (See https://www.medcalc.org/manual/chi-square-table.php).

As Chi-Squared is greater than the critical value then the null hypothesis can be rejected. Indeed, using Microsoft Excel's Chi Test function the probability that the null hypothesis is correct is 2.42273E-12, i.e. 1 in 4.128E+11.

From both sets of Chi-Squared tests, it can be discerned that the relationship between R-Sq and Information content in the cases of number of goals scored and conceded appears to be statistically significant.

5.2 Emergent Dynamics

The approach to analysis for the emergent dynamics has largely taken the same form as that for the actual dynamics of each team as described in the last section. The difference between the data for the actual dynamics and the emergent dynamics is that the latter is not demarcated into match halves, but it was in terms of the different functional subgroups in each team.

Accordingly, Team A's Emergent Dynamics were analysed in the following way:

	Subgroup (VSM Recursion) Centroid			
	Attack	Midfield	Defence	Whole Team
Fixture	Home	Home	Home	Home
	Away	Away	Away	Away

Table 32 VSM recursion centroids by fixture

From this schedule, a set of results for each subgroup in each fixture type was created. All of these can be found in Appendix 6 (commencing on p.514), but an example is presented below.

Match File	Team	Type	Y Intercept	Gradient	Regression Coefficient	Goals Scored	Goals Conceded	Goal Difference	Information Content	Team A Home or Away?
m1	ta	a	9.67	0.50	93.90	3	0	3	153.18	1.00
m2	ta	a	12.04	0.74	70.90	1	1	0	152.63	1.00
m5	ta	a	9.68	0.50	93.10	0	1	-1	154.34	1.00
m10	ta	a	11.56	0.69	80.20	1	1	0	153.66	1.00
m11	ta	a	13.46	0.89	72.80	1	0	1	106.65	1.00
m12	ta	a	9.96	0.53	96.00	1	1	0	151.92	1.00
m16	ta	a	12.59	0.79	68.10	2	4	-2	151.21	1.00
m17	ta	a	9.65	0.50	94.00	1	3	-2	152.75	1.00
m18	ta	a	11.61	0.70	73.20	1	0	1	147.93	1.00
m21	ta	a	11.19	0.65	66.00	2	2	0	154.73	1.00
m23	ta	a	12.53	0.79	67.50	0	0	0	146.60	1.00
m25	ta	a	10.38	0.60	84.60	1	2	-1	109.71	1.00
m26	ta	a	9.84	0.52	92.10	0	0	0	152.61	1.00
m27	ta	a	10.41	0.58	84.30	1	0	1	150.04	1.00
m30	ta	a	10.13	0.54	85.70	0	1	-1	158.28	1.00
m33	ta	a	12.15	0.75	70.80	0	1	-1	156.46	1.00
m36	ta	a	9.68	0.51	91.30	1	1	0	148.14	1.00
m38	ta	a	11.25	0.66	78.60	1	1	0	148.88	1.00

Min	9.65	0.50	66.00				106.65
Max	13.46	0.89	96.00				158.28
Diff	3.81	0.39	30.00				51.63
Goals Scored				17			
Goals Conceded					19		
Goal Difference						-2	

Table 33 Min/Max regression line parameter analysis by match outcome type (Team A's Attack, Home fixture)

The summary matrix (illustrated at the foot of the example) for each type of analysis was then combined to produce the following matrix:

Key	
Type	Fixture
1=a	1=Home
2=m	2=Away
3=d	
4=c	

Type	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scored	Goals Conceded	Goal Difference
1	1	9.65	13.46	3.81	0.50	0.89	0.39	66.00	96.00	30	106.65	158.28	51.63	17	19	-2
1	2	9.47	15.79	6.32	0.49	1.13	0.64	53.00	93.50	40.5	87.27	263.74	176.47	20	26	-6
2	1	9.46	14.93	5.47	0.53	1.03	0.49	61.90	90.80	28.9	82.86	110.33	27.47	17	19	-2
2	2	0.96	14.08	13.12	0.51	0.95	0.44	55.70	94.30	38.6	71.30	152.41	81.11	20	26	-6
3	1	10.51	14.82	4.31	0.64	1.02	0.38	67.90	86.40	18.5	52.33	82.22	29.90	17	19	-2
3	2	9.62	15.31	5.69	0.56	1.06	0.51	70.30	88.20	17.9	74.33	92.64	18.31	20	26	-6
4	1	9.19	12.09	2.90	0.06	0.80	0.74	81.50	90.00	8.5	40.44	44.05	3.62	17	19	-2
4	2	9.17	12.78	3.61	0.56	0.86	0.30	81.30	87.70	6.4	40.41	43.88	3.47	20	26	-6

Table 34 Matrix of Min/Max regression parameters (various analysis types and fixtures)

This table was then used to produce the following correlation matrix to discern how each variable related to each other.

	Type	Fixture	ymin	ymax	ydiff	grad min	grad max	grad diff	reg min	reg max	reg diff	ic min	ic max	ic diff	Goals Scored	Goals Conceded	Goal Difference
Type	1.00																
Fixture	0.00	1.00															
ymin	0.14	-0.42	1.00														
ymax	-0.56	0.28	0.08	1.00													
ydiff	-0.36	0.51	-0.92	0.32	1.00												
grad min	-0.32	0.29	0.01	0.61	0.24	1.00											
grad max	-0.52	0.32	0.12	0.99	0.28	0.57	1.00										
grad diff	-0.01	-0.11	0.08	0.02	-0.07	-0.77	0.07	1.00									
reg min	0.86	-0.22	0.40	-0.74	-0.68	-0.40	-0.71	-0.07	1.00								
reg max	-0.80	0.02	-0.43	0.02	0.42	-0.14	-0.02	0.15	-0.60	1.00							
reg diff	-0.92	0.18	-0.44	0.61	0.66	0.29	0.58	0.09	-0.98	0.75	1.00						
ic min	-0.93	-0.05	-0.02	0.50	0.22	0.31	0.45	-0.03	-0.70	0.75	0.77	1.00					
ic max	-0.90	0.29	-0.18	0.61	0.42	0.22	0.62	0.21	-0.87	0.71	0.90	0.74	1.00				
ic diff	-0.75	0.39	-0.22	0.57	0.43	0.15	0.60	0.29	-0.82	0.59	0.82	0.52	0.96	1.00			
Goals Scored	0.00	1.00	-0.42	0.28	0.51	0.29	0.32	-0.11	-0.22	0.02	0.18	-0.05	0.29	0.39	1.00		
Goals Conceded	0.00	1.00	-0.42	0.28	0.51	0.29	0.32	-0.11	-0.22	0.02	0.18	-0.05	0.29	0.39	1.00	1.00	
Goal Difference	0.00	-1.00	0.42	-0.28	-0.51	-0.29	-0.32	0.11	0.22	-0.02	-0.18	0.05	-0.29	-0.39	-1.00	-1.00	1.00

Table 35 Correlation matrix for Table 34

The values of specific interest were those that featured the highest correlation with goals scored, goals conceded and goal difference. Despite there being a number of weak correlations present, one in particular indicated a correlation of - 0.506 i.e. the goal difference was negatively correlated with the ydiff variable

From this matrix, separate tests for correlation and regression were carried out for each sub group at both fixture types where the team scored goals, conceded them or experienced a net goal difference. This was done in accordance with the test plan presented below

	Subgroup (VSM Recursion) Centroid							
	Attack		Midfield		Defence		Whole Team	
	Home	Away	Home	Away	Home	Away	Home	Away
Goals Scored	D1	D4	E1	E4	F1	F4	G1	G4
Goals Conceded	D2	D5	E2	E5	F2	F5	G2	G5
Goal Difference	D3	D6	E3	E6	F3	F6	G3	G6

Table 36 VSM recursion Test Plan

The letters D1, D2 etc refer to the relevant test number in the appendix.

These were not particularly revelatory; however, one in particular was i.e. test number F2, as shown below.

Match File	Team	Type	Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m1	ta	d	1.00	10.86	0.67	72.40	75.13	0
m2	ta	d	1.00	11.55	0.73	73.00	75.42	1
m5	ta	d	1.00	10.61	0.64	79.70	78.98	1
m10	ta	d	1.00	12.12	0.78	80.00	76.62	1
m11	ta	d	1.00	14.82	1.02	78.70	76.19	0
m12	ta	d	1.00	12.98	0.85	80.10	76.89	1
m16	ta	d	1.00	11.63	0.73	73.30	78.72	4
m17	ta	d	1.00	12.34	0.79	74.00	77.81	3
m18	ta	d	1.00	11.50	0.74	86.40	52.33	0
m21	ta	d	1.00	11.24	0.70	82.50	77.45	2
m23	ta	d	1.00	10.77	0.65	77.70	82.22	0
m25	ta	d	1.00	14.77	1.01	78.40	73.15	2
m26	ta	d	1.00	10.51	0.64	86.40	77.74	0
m27	ta	d	1.00	11.13	0.69	74.10	76.95	0
m30	ta	d	1.00	14.82	1.02	73.60	76.51	1
m33	ta	d	1.00	11.54	0.73	71.90	77.12	1
m36	ta	d	1.00	11.30	0.71	79.10	74.46	1
m38	ta	d	1.00	12.17	0.78	67.90	81.16	1

Table 37 Test F2 from Test Plan

Test F2 describes Team A's emergent defence regression line parameters for a home fixture match where goals were conceded.

The table below indicates the correlation of each variable in the table above with each other. As can be discerned, the strongest correlation with Goals scored in this scenario is with the Regression Coefficient value i.e. -0.254 (-25.4%).

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.13	-0.11	1.00		
Information Content	-0.05	-0.08	-0.47	1.00	
Goals Conceded	0.15	0.13	-0.25	0.22	1.00

Table 38 Correlation matrix for Table 37

A regression analysis was also carried out on Test F2 table above and this is reported below

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.8442
R Square	0.7127
Adjusted R Square	0.6243
Standard Error	0.6804
Observations	18.0000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.0000	14.9268	3.7317	8.0616	0.0017
Residual	13.0000	6.0177	0.4629		
Total	17.0000	20.9444			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*er.*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-119.9544	23.3305	-5.1415	0.0002	-170.3569	#	-170.3569	-69.5518
Y Intercept	42.8119	8.0745	5.3021	0.0001	25.3680	#	25.3680	60.2558
Gradient	-482.4898	91.2110	-5.2898	0.0001	-679.5393	#	-679.5393	-285.4403
Regression Coefficient	-0.0089	0.0382	-0.2319	0.8202	-0.0913	#	-0.0913	0.0736
Information Content	-0.2933	0.0675	-4.3432	0.0008	-0.4392	#	-0.4392	-0.1474

Table 39 Regression Analysis for Table 38

The R Square value (R^2) indicates the amount of variance in the dependent variable (in this case Goals Scored) that was accounted for by the independent variables (in this case Y intercept, Gradient, Regression Coefficient and Information content).

The regression statistics above indicate that, taken as a set, the independent variables account for 71.27% of the variation in the dependent variable, but this does not mean that they each account for an equal apportionment of that 71.27%.

Taking an alpha value of 0.05, the Significance F value in the ANOVA (Analysis of Variation) section reveals that this is less than alpha i.e. 0.0017 < 0.05. This indicates that the value for R^2 is significantly greater than zero, and hence means that the independent variables predict a significant amount of variance in the value of Goals Scored. The section of the table below ANOVA examines the individual independent variables, and does not consider them as a set.

As such, it serves to reveal if any individual independent variable uniquely accounts for a significant amount of variance in the dependent (Goals Scored) variable. This has been achieved in this case by assessing the p value in the table for each independent variable against an alpha value of 0.05.

In this particular test:

The p value of the ‘Y intercept’ variable is 0.0001.

The p value of the ‘Gradient’ variable is 0.0001 and

The p value of the ‘Information Content’ variable is 0.001

All of the above are considerably less than alpha i.e. < 0.05.

Accordingly, it can be concluded that the overall regression model was significant F (4, 13) =8.0616, p<0.05, R^2=0. 7127. It is inferred from these results that the model of using the regression line parameters of the emergent defence’s centroid i.e. Y intercept, Gradient and Information Content provides insight into how the defence subgroup is implicated when Team A concedes goals at home fixtures in particular.

5.3 Summary

This chapter has explored how the Zipfian ranked policy frequency distributions for the target team were treated logarithmically in order to produce a linear regression analysis of each of those. It has covered how the degree of fit of those, as represented by Pearson’s correlation coefficient (R^2), has been used as a measurement of how well organised the target team was in order to produce those particular distributions. Moreover, the chapter has covered the degree of disorder (entropy) (hence absence of order) present within the team at any time by reference to how such disorder can be expressed in terms of its inverse relationship with Shannon’s theory relating to information and its transmission across a communications channel. The work has then taken this and proposed the juxtaposition of both at multiple levels of team operation i.e. those that correspond to the team’s Attach, Midfield and Defence functions, as well as the whole team. This has been with view to providing a means of evaluating how well organised multiple recursions of the viable system model that the team can be represented by were via direct reference to the policy output of each of them i.e. their position about the pitch. Tests for statistical significance have been undertaken and indicate evidence that the approach employed holds some promise in this respect. Indeed, correlations of the regression line parameters produced for each match and the amount of Shannon Information associated with that, for example, features some interesting aspects when considered in the context of goals scored, goals conceded and the fine balance between the two that the viable system that the team seems to occupy.

Chapter 6 - Evaluation and Conclusion

6.0 Introduction

This chapter provides closure to the main body of this work by presenting an evaluation of what it has achieved and what conclusions can be drawn from that and what contribution it makes to the body of knowledge. It does this, both as a self contained piece of research, but also how what has been concluded provides contexts for the possible future work that might result from this as a foundation step as covered in Chapter 7 – Future Work.

6.1 Research Outcome

An organization that is fully aligned with the provisions of the VSM is considered to be effectively organized to fulfil its stated purpose i.e. it is cybernetically viable. If there is any departure away from those aspects, then the organization is correspondingly less well organized with respect to that aim.

An example of this is all or certain vital parts of an organization being badly coordinated with respect to each other. This, in VSM terms, represents diminished System 2 functionality. If this situation remains unchecked then it is possible that certain uncoordinated factions (sales and production, say) will pursue their own agenda.

This is a dangerous situation for the organization since this may effectively result in those factions working against the aims of each other. This may lead to intervention by operational or strategic level management (System 3 and System 4 in VSM terms) to remedy matters, or attempt to do so.

Yet, that may mean that System 4 strategic management is micromanaging the situation when System 3 operational management is more than capable. Conversely, System 3 operational management may have been judged unfit for that position, and System 4 involvement is needed to correct the matter. In either case, System 4's attention is diverted from the outward agenda of the organization towards the internal agenda of it. This creates a disconnection between the total organization and its' environment.

Yet, System 3 may well be more than capable of handling the situation between production and sales, but is pushed aside by System 4. This creates a waste in organisational resources, since effort is duplicated and perhaps two managers are dealing with the same problem at the same time.

This is a coordination problem (System 2) in itself. Paradoxically, the original coordination problem between sales and production is exacerbated to the detriment of the whole organization i.e. by the very fact that effort is doubled to remedy it.

The example cited above is only one of a myriad of organizational pathologies that can befall an organization if it departs from the provisions of Beer's VSM. All organizations accept input from their environment, process those in some way and then produce an output that then influences the environment accordingly.

The VSM may be regarded as the wiring in between the input and the output. As such, if that wiring is optimally configured then the output will be such that the organization is cybernetically viable. If this is not the case, and the wiring is in some way deficient, then the organization will be correspondingly less viable. Moreover, if the wiring is not present, then the whole concern will be completely disorganized.

The output that organizations issue is the enactment of their policies to do so. The policy of a viable system is that it acts in a manner to be viable and then operates in a manner to sustain that in accordance with its purpose. This means that the attributes of the enacted policies can be correlated with organizational output and hence to what extent the organization does, or does not, succeed in achieving its purpose.

In many respects, large and small human organizations are either fully or partially viable. If a university is a viable system and operates as such, then how might one quantify how its relationship between its total input and its total output is transformed by its internal wiring as per the VSM?

It is argued that unless there is specific data capture and data relay mechanisms in place and in operation at all times then the answer to that question is intractable. Notwithstanding a cybernetic intervention into the machinations of the university to discern its degree of alignment with the VSM (no small undertaking in itself), the problem of necessary data capture and relay persists.

It would require everybody involved to quantify, capture and submit data on all aspects of their activity at all times. It would also require, as a prerequisite to that, a significant degree of business process reengineering to facilitate it.

If this is the case then so be it, but what of the policy that manifests itself as a result of that and that causes the organization to do what it does and, thereby, manifest its viability? Moreover, what does that look like whilst the viable system has its viability threatened by another viable system?

This work has fundamentally sought to answer two questions:

1) What does the policy dynamics of a real viable system look like whilst under varying dynamic load conditions and is it a common characteristic that can be ascribed to the VSM?

2) How does (1) relate to its degree of success or failure as defined by the extent of how well organized it is to accomplish its objectives i.e. what is the systems degree of isomorphy with the VSM that represents it as it achieves success or sustains failure as defined by its purpose?

Given the intractability alluded to, the notion of a football team provides some insight.

A player is a viable system. They participate in subgroups of a football team that are themselves, thereby, viable systems. Those viable subgroups convene and synergise their respective performance to produce what the team actually does.

What the team actually does is seek to win and not to lose football games, with perhaps modest concession to sustaining a draw result. This means that their operational characteristics are quantitatively defined in terms of goals.

Yet, the policies of all of the player, the subgroups and the team as viable systems can be similarly quantified. This is on the basis that, in this specific context, their respective movement represents the manifestation of their policy.

Moreover, those policies are what they are due to the prevailing forces of self-organization in operation. These are those between the players in each team with respect to their own colleagues on that team, and on an individual and collective basis with all of the players on the opposing team.

This work has sought to characterize what it means to be more, or less, effectively organized by reference to player, subgroup and team position being equated to their policies as viable systems. It has accomplished this using a professional grade football match data capture system and associated data sets for a target football team over a period of one football season.

This has been used to discern that for every team, in every half of every match and at every fixture, player, subgroup and team policy can be described by the power law:

$$Policy\ Frequency = 2^{(c - m\log_2(Policy\ \ Rank))}$$

As the data follows this power law to a lesser or greater extent, then the degree to which this happens is argued to be equivalent to the degree to which the target system (players, subgroup or team) is effectively organized. The rationale for this is that a power law relationship between characteristic operational data for a system indicates the presence of a self-organizing system.

As such, if that relationship is of particularly close alignment with a particular power law, then one may infer that the system is more self-organizing than not. If the target system was perfectly self-organising, then it is argued that the data would follow the power law perfectly. If it were less than perfectly self-organizing, then the alignment would be suitably approximate.

Indeed, if the data related to a system that was completely disorganized, then there would be no alignment with a power law whatsoever. If what is means to be more or less effectively organized is to be more, or less aligned with the VSM, then the power law is contended to provide a means to measure the extent of that alignment.

This is to say that if a target system behaves in a way where its policy as a viable system follows a power law, then degree to which it follows it is an indicator of how well organized the system was in order to produce and enact it in the first place. If position is policy, as argued for a football team, then the power law will provide a measure of that team's alignment with the provisions of the VSM.

In the case of a football team, the purpose (its criterion of viability) of the team is clear and its success or failure in achieving its purpose is quantified in terms of goals scored or conceded. Accordingly, the degree of success or failure experienced by the team is attributable to the degree to which it effectively organizes and operates itself to achieve that.

As this has been argued to be represented by the power law, then one may equate it to varying degrees of team success or failure. Indeed, analysis has revealed that certain values of the variables in the exponent of the power law are associated with particular match outcomes.

When the power law is plotted on a log-log scale, then one may discern a linear relationship.

In the case of the power law above this has the form:

$$log_2(Policy\ Frequency) = c - mlog_2(Policy\ Rank)$$

In this work, the data for policy frequency and policy rank was scatter plotted on a log-log scale and found to be linear. This was verified by applying linear regression to the scatter plot an obtaining a regression line that had an associated regression coefficient R^2that indicated the strength in the linearity present.

If the value of R^2 was nearer to 1 (its maximum) then this was interpreted as the data having a very good approximation with a power law. Similarly, if the value of R^2 was nearer to 0 (its minimum) then this would signify poor approximation (if any) with a power law.

The former being indicative of a system that was for more potent in its capacity to self-organise to produce its outcomes and the latter far less. Moreover, the data that underpinning the scatter plot for each match had an amount of Shannon Information associated with it (Negentropy), that serve to indicate the degree to which the team involved was predictable in its behaviour. As such, a series of values for R^2 and Shannon Information, as well as the power law and the degree of team success or failure in different half and fixture configurations was available.

These were then manipulated as per the analysis section (Chapter 5 commencing on p.163) to reveal the insight that is summarized below. The policy of a viable system operating in two-dimensional phase space (e.g. a team of players on a pitch) can be characterized by

$$log_2(Policy\ Frequency) = c - mlog_2(Policy\ Rank)$$

Where c is the y intercept and m is the gradient of the line.

For the team (Team A) under study, the range of values for c, m, R^2 and Shannon Information was very narrow.

The range of values for c for Team A ranged from an absolute minimum of ymin =7.65 to an absolute maximum of ymax = 9.30, a difference of just 1.65 across the whole season examined (See Table 5, p.174).

In terms of m , this featured an even smaller range of values i.e. from an absolute minimum of gradmin = 0.45 to an absolute maximum of ymax=0.55, a difference of precisely 1 over the same period examined (See Table 5, p.174).

Indeed, the absolute minimum value recorded for R^2 was regmin=88.70, with the maximum value regmax of 92.10 resulting in a difference of only 3.4 bits in the face of such a diversity of opponents confronted examined (See Table 5, p.174).

Moreover, certain of these parameters were strongly correlated with team performance. It was observed that in the case of both goals being scored and conceded, irrespective of match half or fixture, the information content associated with Team A seemed to gravitate to a value of 27 bits.

Indeed, for goals scored, the number of goals associated with 27 bits was 22 from a total of 40 scored in the whole season. 15 of that 22 corresponded to R^2<89, and 7 to $90 \leq R^2 < 91$ examined (See Table 26, p.190).

This was followed by a value for information content of 28 bits, where a total of 11 goals were scored, 8 of those being associated with $90 \leq R^2 < 91$ and 3 with $91 \leq R^2 < 92$.

Taken together, the information content values of 27 and 28 bits accounted for a total of 33 of the 40 goals scored in total, with 7 being associated with a value of 26 bits and that corresponding to $R^2 < 89$.

For goals conceded, the picture was similar. An information content value of 27 bits was associated with 30 of the total of 48 goals conceded by Team A. 22 of that 30 were associated with $R^2 < 89$, with the remaining 8 being associated with $91 \leq R^2 < 92$ examined (See Table 27, p.191).

Once more, an information content value of 28 bits seems to have a bearing on team failure in just the same way as that when it enjoys success. 10 of the 48 goals conceded in total were associated with 28 bits. 7 of those corresponded to $90 \leq R^2 < 91$ and 3 to $91 \leq R^2 < 92$.

The remaining goals conceded were associated with the information content values that were not seen when the team were victorious i.e. 24, 29 and 30 bits corresponding to 1, 2, and 1 goal(s) conceded respectively over a mixture of R^2 values. It is hypothesised that this might be associated with the team using experimental styles of play that have unfortunately failed in their desired effect.

It was also noted that banded ranges of values for R^2 in juxtaposition with values of Shannon Information had a statistically significant relationship with the number of goals scored and goals conceded by the target team.

Chi-Squared tests revealed high degrees of statistical significance in the relationship between R^2 (banded ranges), information content and match outcomes that were remarkably similar when one considers the different fixture, different opponents and different compositions of players with different skill sets in Team A at any time. Certainly, such ostensible variability has surprising consistency as the team behaves as a cybernetically viable complex adaptive system.

The figures obtained and presented do seem to indicate a very strong critical point that defines the boundary between team success and failure. This is largely confined to a difference of 1 bit (28-27), but also the range $90 \leq R^2 < 91$.

Indeed, one would expect that a comparatively well self-organised team, as a complex adaptive system, would have a higher degree of R^2 i.e. approaching 100% as it was effectively organised, hence had a stronger isomorphy with Beer's VSM. One would also expect R^2 to fall in concert with comparative disorganisation and lesser isomorphy with the VSM.

Yet, the figures suggest that the higher R^2 is, in this scenario, then one encounters diminishing returns. In all cases of goals scored or conceded, the higher values of R^2 are associated with less goals in either scenario. Better organised does not necessarily correspond to more goals scored or less goals conceded. At a level below the maximum observed value for R^2 i.e. at $90 \leq R^2 < 91$, outcomes of either type seem to be closely associated with that. Moreover, many goals are associated with $R^2 < 89$ and it must be recalled that the absolute minimum for R^2 observed was

$R^2 = 88.70$ a difference of only 0.30 also, thus defining a window of success or failure, for the most part, of $88.70 \leq R^2 < 91$, a difference of 2.30.

Accordingly, the work has revealed that if a football team behaves on the pitch in a manner that causes the parameters of ranked policy frequency distributions, and their corresponding values of Shannon Information, to fall within certain tightly defined ranges, then they may enjoy more success and less failure. They would be correspondingly more or less cybernetically viable, hence more or less aligned with Beer's VSM accordingly on the scale that their range of values defines.

In Chapter 5 (commencing on p.163) mention was made of the work of Kaufmann (Kaufmann, 1991, p.22), Page (Page, 2011, p.32) and Beer (Beer, 1994a, p.256) concerning the notional boundary between order and chaos.

Kaufmann (Kaufmann, 1991, p.22) states that communities of agents will co-evolve to an "*edge of chaos*" between over rigid and over fluid behaviour. Whereas the work of Page (Page, 2011, p.32) suggests, "*complexity lies between order and randomness*".

Yet, it is maintained that what they refer to has a relationship with cybernetic viability, and hence this work, in that, as Beer (Beer, 1994a, p.256) has observed: "*cybernetics has demonstrated that for a system to have the attributes of viability they only do so if they have high complexity i.e. they must exist beyond a certain 'complexity barrier' to be viable*".

Given that this work has undertaken an analysis of the viable system model via the use of a football team (that qualifies as a community of agents) that behave in a self-organising manner, it was interesting to discover how this cybernetically focused work had further ties with complexity studies that are not, explicitly at least, cybernetically defined.

Since the work presented here has used Zipf's law applied to player movement data to penetrate the analytical barrier that the VSM, under load conditions, is concealed behind, it was interesting to note a further parallel with this work that seems to add to the legitimacy of the approach to analysis it takes.

This took the form of the comparatively recent investigations of Eliazar and Cohen (Eliazar and Cohen, 2011, pp.4294-4301) who advance that Zipf's law "*seems to be a hallmark of complex systems based upon collective human efforts*", contending that "*the Lorenzian Limit Law asserts that complex systems displaying Zipf's law are in a state of self-organized criticality, balancing themselves on the critical boundary between totalitarianism and egalitarianism*".

Moreover, it was interesting to note the work of Correia et al (Correia et al, 2011, p.667) who reports of studies of space-time patterns in team sports that have demonstrated moments of stability and instability over time within particular subsystem of games analysed (cf. Bourbousson, Seve, & McGarry, 2010a, 2010b; Frencken & Lemmink, 2008; McGarry, 2006).

The VSM is a master template for effective organisation that has been examined in the context of complexity science by equating the collective human effort of a football team. This effort is, for the most part, spatially defined but has been considered here in terms of a language of action between the two teams.

Yet that language is also the activity that corresponds to a team controlling itself whilst it attempts to control, their opponents, or to subvert the control of their opponents over them. It is the externalised manifestation of how each player, hence each functional subgroup and team balances what they feel needs to be done with their ability and resources to deliver against that i.e. their policy as a viable system.

Once defined in language terms, it became clear that the techniques of lexical analysis could be applied to the spatial data to reveal insight into the behaviour of the team as a complex adaptive system but also a cybernetically viable one.

This meant that the behaviour of the former could be used to characterise the latter in policy terms (i.e. what the target system actually enacts: changes in position). It also meant that the VSM, considered as a black box, did not have to be investigated internally i.e. the VSM could be treated as a black box that could be characterised entirely by reference to how its inputs (what must be done, say) corresponded to its outputs (what was done about it, say).

Moreover, using the techniques employed and placing them in juxtaposition with fixed criteria of viability has not only provided insight into the VSM under load conditions, it has also indicated the model’s legitimate relationship with other fields of study, providing a contribution to the body of knowledge on both counts.

6.2 Summary

The research has undertaken to both characterise what it means to be a viable system as espoused by the provisions enshrined in Beer’s Viable System Model. Moreover, it has done this in the context of a known and accepted scale of success or failure for the type of system selected for use in the study i.e. goals scored or conceded by a football team. Specifically, in this respect, the work has directly equated such success or failure to the purpose of that team in its capacity as a viable system. Using a variety of techniques, the work has provided a quantitative analysis associated with those characteristics that could then be correlated with that scale of success or failure; this being in an attempt to discern if one or more were associated with either outcome type for the team concerned.

Here, the quantified attributes alluded to was the Pearson correlation coefficient (R^2) of the regression line produced when the policy vectors (actual and emergent dynamics) of the team were subjected to a Zipfian ranked frequency distribution (power law based) analysis. Moreover, the amount of Shannon Information associated with the same analysis was then computed and, by virtue of its relationship with the concept of entropy (systemic disorder). Both of these metrics were then used in cross tabulated juxtaposition for the case of goals scored and for goals conceded by the team and the results for both outcome types were then compared and contrasted.

It was discovered that no instance of the juxtaposed metrics specifically corresponded to either success or failure for the team as a viable system. What was determined, however, was what appears to be a particular value of the juxtaposed metrics that represents the critical balance between the two, and that the range of metrics obtained occupied a surprisingly narrow range of values. In this respect the viability barrier that the viable system holds itself at by how well organised it is with respect to its own success or failure, as underpinned by its self organising behaviour, seems to have been found, at least for the case of a football team for the moment. The rationale for this is that the most predominant category of juxtaposed metrics was common in both success and failure scenarios for the team studied. Moreover, this was the case for that team over a complete football season, in the face of a diversity of opponents confronting it and irrespective of play being at their home and a range of away match fixtures. This seems to point to the essence of what viability, as espoused by what the viable system model is and serves to do and as such the work is contended to fully characterise that model under load conditions.

Chapter 7 - Future Work

7.0 Introduction

This chapter considered what future work might be undertaken as a result of what has been proposed and has been discovered during the course of it. It speculates how it might be used in other fields such as the military and how well organised military personnel, the battalions formed by those, the regiments formed by those or, perhaps how they in turn form whole armies, might be assessed for organisational effectiveness with respect to their objectives. Moreover, although the context of the work has chosen a field sport for analysis, this was deliberate due to the high volume of fully quality controlled data being available and the fact that a football team is a viable system and hence maps to the viable system model. Yet, although the work undertaken has been in a sports arena and as such may be considered narrow in its scope, there is much depth within that scope e.g. other types of highly dynamic team, sports could be assessed for how well organised they are. This would then serve to add to the initial work presented in this thesis. This is since it could provide further evidence of how the viable system model operates in different organisation types under different kinds of pressures. Once done these could be assessed against this football study for comparison and assessment of possible consistency in the results obtained.

The chapter concludes by offering a matrix of topics where the nature of this work could be applied in future by either a post graduate masters student or a post graduate research student.

7.1 Overview of possible extensions to this work

What has become apparent in this work is in many respects symptomatic of a classical problem in management in general i.e. analysis after the fact. Management in a football sense is considered to be no different to perhaps more conventional management roles in other areas of industry. In both domains, the order of the day is to decide what needs to be done and then ensure that it is done.

A football team manager will decide who plays and in what playing position based upon player skill and ability. Occasionally, these factors are permuted to provide some differentiation to team performance in the face of various opponents and an assessment of their tactics.

This will cause the same group of players to work together in slightly different ways. Some will work more effectively with others. This might be disrupted by changes made by the manager and, as such, may ultimately be either to the benefit or to the detriment of the team.

In either case, the self-organising dynamics of the team will alter, and the measured and calculated attributes of this can be, and has been, correlated with match outcome. This aspect is the key differentiator between this study and those that focus more upon conventional areas of application of viable systems theory.

The approach to analysis in this work does not frame the viable organisation in terms of, say, simple deterministic processes that suffer from an absence of data to support analysis. On the contrary, it considers the football team not only as a cybernetically viable system but also, simultaneously, as a complex adaptive and self-organising one for which much data can be captured.

In many respects, this is both the strength and the weakness of the work. On the one hand, the approach to analysis facilitates penetration of the analytical barrier that most conventionally based studies pertaining to the viable system model seem to suffer from. Yet, on the other hand, most organisations in practice do not behave in the same manner as a football team in an everyday operational sense. This is despite the fact that both the football team and organisations such as, say, businesses, governments or educational establishments do adhere (whether they are aware of it or not) with the provisions of the same model of effective organisation (the VSM) to a lesser or greater extent.

Studies relating to Beer's VSM refer to cases of essential sub-systems that it proposes perhaps being missing from a target organisation e.g. an absence of an adequate coordination function (System 2) where, say the sales manager and the production manager do not speak to each other to coordinate their respective efforts.

Yet, in the case of a football team, the presence of such functionality is implicitly present since it has to be during the match played. The players have to coordinate with each other sufficiently well enough otherwise the passing of the ball from one to another, say, would continually fail.

In the case of a football match, such factors can be readily quantified and continually monitored in real time. In a more conventional organisation, the fact that two managers do not adequately communicate with each other might only be discovered by, say, the managing director, after it is too late to extricate the organisation from the consequences of that. Although mechanisms can be put in place to ensure that meetings take place between such managers to ostensibly ensure coordination between them takes place, this is nevertheless no guarantee of transparency in effective coordination.

The point here is that when one considers a football team as a viable system, it is literally exposed to analysis by match scanning technologies. The interaction between players and how they are allocated to their roles by the manager and how they self-allocate in real time as that evolves, is exposed as they pursue their criteria of viability.

The data supporting this is available in large amounts in real time and represents the actual organisational mechanics of what it means to be a viable system. In the case of a conventional approach to, say a business, the essence of what the organisation actually is and does is concealed by administrative systems that have indifferent levels of objectively verifiable data that often fail to describe that same essence for that organisation. The only exception to this is perhaps financial records, but even that is only partly representative of what the organisation actually is and does.

Accordingly, this work stands at something of a cross roads between the conventional practical and theoretical application of managerial cybernetics in the form of the VSM and the unconventional area of self-organising complex adaptive systems.

The former facilitates very wide application to human based organisations of every type, yet suffers from having to resort to administrative systems that provide data that distorts what the essence of the organisation actually is. The latter does not suffer from this, but most organisations are literally not operated in the same way as a football team since the demands of their operational environment often do not require them to do so – certainly perhaps not at the same pace.

Accordingly, the practical scope of application of the techniques used in this work is comparatively limited despite the universality of the principles of information theory, viable systems theory and the concept of variety engineering that underpin it.

Despite this narrow scope, football is the most popular team sport on the planet and anything that might be useful in providing a team with a competitive edge would, doubtless, be considered welcome, or at least be of interest. This means that the scope of application of the work may be narrow, but this is more than offset by the depth offered within that scope.

Moreover, this work has only been possible to the depth that it offers by having access to team spatial data. It is considered that if other field sport team data were made available, e.g. for hockey, ice hockey or perhaps rugby or basketball, then what it proposes would have equal applicability.

Irrespective of target team used, as a vehicle to explore this work further, one key factor remains that is of vital cybernetic importance. Specifically, this is that team performance analysis is usually undertaken after the conclusion of the match. It is not done in real time at least and certainly does not employ real time forecasting techniques to pre-empt any problems or opportunities and provide a plan to either avoid or pursue them respectively in advance at best. This position has been verified by the Head of Performance Analysis at the English Premier League football club that the author has established a collaborative association with, and who have expressed an interest in how this aspect might be developed.

The proposals made in this work can theoretically be computed in real time and be forecasted for both opposing teams. As such, this represents an interesting area for future work to take place.

Specifically, the system used to capture the player movement data in this work was the Prozone3 tracking system. This allows highly accurate and fully quality controlled post-match analysis, but it is only available to managers to examine after the applicable match has finished.

Yet, the data, albeit not fully quality controlled, is captured during the match and is a live data feed that could potentially be utilised to provide match intelligence in real time. Moreover, using appropriate forecasting algorithms such data streams could be examined for signals of incipient instability in the readings of the target team and their opponents.

This could cause decisions to be made and taken a few minutes in advance of when the system announces that an event predicted is likely to occur. The rationale here is that a manager, in the absence of using the Prozone3 system would be using imperfect information anyway and would be reliant upon predominately visual observation to inform their decisions.

The Prozone3 system facilitates accuracy in reporting terms, but it is nevertheless only available in processed form after the fact i.e. after the conclusion of the match and a few days later once processed. The situation that they are trying to control has elapsed into history by the time they receive the data they needed to help them at the time that matters needed addressing.

In this respect, there is a continual post mortem of what has happened and perhaps consideration of what should have happened and hence might have happened. The information provided by the Prozone system is valuable. It can serve to provide input into future tactical planning in many respects, but it has nevertheless arrived after the situation where it would have been even more useful has long since passed.

In other words, to control the situation then at the very least the data relating to it should arrive at the rate at which the situation changes. If a compromise could be agreed upon whereby a manager agrees to use something better than the imperfect information they directly observe, then this might be a promising start.

If the manager is prepared (and allowed) to tap into the data for their team as it is captured by the Prozone3 system, then that data could be used in real time to provide better information than they are currently getting. Perhaps the only trade off in that scenario being that the data captured has not been subjected to stringent quality assurance checks.

Yet the compromise might be enough to give such a team an edge to its performance and hence to its cybernetic viability. From the data received by the system, it is theoretically possible to compute the viability signatures presented in this work dynamically. The attributes of those for the team's various tactical functions could form the basis of their own times series that could be forecasted against. This could be such that the actual propensity to viability of those functions may be discerned before they actually happen. This would allow a manager to rapidly formulate their desired plan of action and have it more readily disseminated to the players in advance.

Admittedly, the time scales involved may be very small, but if such forecasts could be expedited even just a few minutes in advance, then that may afford sufficient time for appropriate instructions to be issued to the players involved.

This aspect is of real interest to the premier league football club that has been involved in some aspects of the work to date. Indeed, exploratory discussion with the Head of Applied Mathematics at Liverpool John Moores University, Professor Paulo Lisboa, has already taken place regarding the technique of Alternating Least Squares to explore this matter further.

In the spirit of this, some work was undertaken to attempt to predict match outcomes from the data sets provided by Prozone that underpin the results presented in this work. As the hypothesis in this work was being worked upon, Prozone were requested to supply their data as agreed, but were requested to withhold the final score lines until notified that they were needed. Once the power law based signatures had been obtained, the associated parameters were used in conjunction with other techniques (unpublished) to develop a means of predicting match outcome.

The predictions made were given to the author's Director of Studies, Mr. Andy Laws, and Prozone were then requested to supply the match score lines. They were then compared with the predictions made.

This essentially meant that a blind test of the predictive efficacy of such initial proposals was undertaken. Interestingly, these showed some early promise with a 52% predictive accuracy based upon the initial method. Although this is only a small amount away from an outcome with even odds, it is contended that the method used could be refined and the results improved upon. Accordingly, this is something that will be investigated in more depth in the future.

Another possible avenue of exploration for this work may be that of fraud detection in player movements. The policies exhibited either by a player acting unilaterally or in collusion with one or more others to commit fraud during a match might be revealed in the self-organizing dynamics in some way. This may possibly be as a readily discernable, but perhaps small, transient in the policy data distributions. Certainly, such aspects would be of considerable interest to the authorities and to the gambling industry. Accordingly, some work (unpublished but lodged with Mr. Laws and to be developed further) has already taken place in this respect using the same data sets that underpin the results presented in this work, and the initial results indicate some promise. The next step will be to obtain further sets of test data if Prozone will permit this.

The work presented in this document deals fundamentally with the question of how viable systems are organized to instantiate and sustain their viability in the face of factors that might conspire to prevent that from within its environment.

Although football has been used as a device to test the hypothesis advanced, the work is contended to have equal applicability to other team sports. This is on the proviso that the dynamics of the participants are similar and suitable amounts of data are available for analysis. In particular, hockey or basketball might be a candidate, but sports with many pauses in play, however brief, might not be suitable e.g. American football. Despite what has been said about the work in a sports context, it is nevertheless considered to have applicability to other domains.

One interesting avenue is application of the work to battlefield dynamics either in terms of troop movements, tank movements or both. Indeed, this situation is very similar to the football field scenario. Two opposing viable systems (armies) of viable systems (troops) diametrically oppose each other for some reason, and the outcome is essentially a zero sum game in either side's favour.

Tactical advantage is obviously of the keenest interest to the military and they deploy a variety of techniques to that end. One of these is use of satellite intelligence. Accordingly, if the necessary data is being supplied already, then, in principle at least, that could be used to underpin an analysis similar to that undertaken in this work.

Moreover, if this could be developed in conjunction with the forecasting aspect mentioned then this might be somewhat compelling and hence worthy of further exploration.

Certainly, in a football context at least, such proposals are certainly in contrast with the more conventional post-match post mortem analysis so currently prevalent.

7.2 Specifics for future research by an MSc. or PhD student

The nature of the work presented in this document is contended to provide a number of opportunities to further investigate the nature of what characterises cybernetic viability and how that can be associated with target system success, failure or the critical balance between the two and some suggested examples are presented below.

7.2.1 Prediction work

The nature of the work undertaken thus far is argued to lend itself to how the future performance of a team might be predicted based upon a historical record of the metrics proposed in this work having been produced for that team.

This would involve retrospective analysis of team performance and production of the juxtaposed metrics proposed in this work for the applicable matches. This would be used to develop a historical record of metrics for one or more suitable forecasting techniques to employ in making predictions relating to the likelihood of team success or failure on the epochal scale of annual football seasons. This may include techniques such as exponential smoothing, alternating least squares and/or those based upon the work of Bayes.

The completeness of the work would, subject to the necessary data being made available and the relevant legal agreements being in place, be applied to football teams operating in leagues of differing national and international profile e.g. the Premier League, Championship League , League 1 in England, the Prem, Champ, League 1 and League 2 in Scotland (Domestically) and the German Bundesliga, Italian Serie A, French Ligue 1, Dutch Eredivisie, Portuguese Primeira, Spanish La Liga (Internationally).

The MSc. work would involve the construction of software that would parse the target files and compute the necessary metrics needed from the data to complete the analysis. Initially, this would involve basic forecasting algorithms and then gradual progression in the sophistication of the algorithms to determine the most suitable for a small set of data files for one team in one league over a specified period of time. The work would involve an initial investigation, by the student of how new technologies such as Microsoft's Hololens , Oculus Rift and other virtual reality systems might be used in conjunction with real time forecasting during matches. The work would likely involve some initial prototyping of a system to handle this aspect in both software and hardware to assess the feasibility of in game real time match analysis and outcome prediction, as opposed to a post mortem approach to analysis of the work they have already undertaken thus far, so as to provide contrast.

The PhD work would involve extending the foundation established in the MSc work by broadening the scope of the work to one target team operating in each of the named domestic and international leagues over a period of at least four football seasons. The work would involve designing, building and testing a real time prediction engine designed specifically for in game use on a 'heads up display' basis for decision makers in football matches to use and to assist them. The work would feature pattern recognition aspects that can then be used to make recommendations based upon short term forecasting. This aspect would be implemented as an initial prototype and this would require the student to invite and secure interest from representatives of the football world to witness demonstrations of the work and possibly be involved in its development. This would be with a view to perhaps assisting the student in the pursuit of any aspect that would be to their commercial advantage such as the future development of a product or service that they could then market.

Note: the work alluded to could potentially be applied to team sports other than football, e.g. Rugby, Basketball, Ice Hockey and so forth. Tactical advantage is of the keenest interest to sports analysts and anything that might facilitate this does hold interest. This would serve to substantiate whether or not the work presented in this document is just confined to one type of competitive team sport or has applicability and relevance to more. It is envisaged that, given that teams are organisations that pursue a purpose, then they qualify as viable systems and hence have a viable system model representation. Accordingly, the characteristics obtained for other team types, based on this work, could be used to provide further evidence of a signature of viability that is ubiquitous in a sports sense.

7.2.2 Fraud Detection work

Given that the work proposes consideration of the self organising dynamics of a football team, it is considered that it might be possible to detect suspicious activity from such metrics that relate to unilateral or multilateral fraudulent activity. The rationale for this is that if the self organising dynamics of one team over another are representative of a control strategy, then anomalies in the control signal associated with that strategy might indicate that something is amiss. In this respect, fraudulent activity would be akin to a control strategy for the whole team involved being deliberately taken out of control due to the actions of one or more individuals with criminal intent. The proposals are similar to the case of Benford's Law being used as admissible test against financial fraud (via the distribution of digits in the numbers reported) in the Federal Courts of the United States of America.

The MSc work would involve investigation of how the metrics produced in this work could be described as a control signal that one team expresses to another during a football match. Specifically, this would require a survey of a target team, in a nominated league, to be investigated over a number of seasons. This may serve to provide some evidence that the work presented in this current document does have general applicability to football teams. Once the data has been captured, processed and the necessary metrics produced, those metrics will be used as data for a series of control charts, or pattern recognition techniques and an examination of these will be undertaken to discern if any transients in the data are present and, if so, question whether they might be indicative of potential fraud or not.

The PhD work would take the work produced at the MSc level and broaden its scope to a target team in each league mentioned above over at least four football seasons. Work would be undertaken to construct a prototype system that would read live data streams of player data during a match, compute the metrics proposed in this work in real time and then analyse the data stream using either the control chart or pattern recognition techniques so as to potentially provide an alert to possible fraud as it happens, or even beforehand if a forecasting element is incorporated to that.

Note: the work alluded to could potentially be applied to team sports other than football, e.g. Rugby, Basketball, Ice Hockey and so forth. Fraudulent activity is of the keenest interest to the authorities and to the gambling industry. As such, any countermeasure to detect and or prevent fraud that is shown to be effective would be of interest to them. This has already been verified with a senior industry representative of a sports technology company that is unrelated to Prozone but operates in a similar domain (identity undisclosed due to commercial confidentiality).

7.2.3 Organisations operating in Virtual Worlds

If a team of mutually reliant participants is focused upon a particular task under particular circumstances with fixed resources at their disposal, then that describes a viable system of viable systems operating under load – especially if their activity is equated to the survival of that organisational unit.

Accordingly, to test the work presented in this document in a non-sports context, it is proposed to employ the vehicle of multi-player computer games to create either 2 dimensional or immersive (virtual reality based) operational scenarios for teams to organise themselves with respect to.

This may involve completion of a practical task, moving from one location to another over varying types of terrain whilst possibly being pursued by another team participating in that multi-player arena. The location of a given player's avatar can be tracked from a specified set of coordinates in side the virtual environment, and that means that the distance between them can also be computed as per the proposals in this work. Consequently similar metrics may be extracted for a team of players in that environment to those produced in this work. The crucial difference is that in the virtual environment the nature of the problem is readily changed and can be made to change with the same level of dynamism as the football match e.g. virtual weather conditions, the size of objects, the measure of threats and opportunities.

Moreover, the constraints that a team in a virtual environment can be more controlled and hence more readily quantified. This would permit variation of team resources whilst completing the same or different tasks and thus facilitate how they viability metrics vary accordingly.

Those metrics could then be recorded and predictions made about team efficacy as individual and collective viable systems operating under a variety of circumstances.

The MSc. work would involve an investigation of suitable multi-player game environment and the development of a small game to involve a few participants with respect to simple objectives to be accomplished in a specific time frame. The work would track the progress of the players as they work together to overcome problems and seek to attain their collective goal. The data produced would then be used to provide a scale of viability similar to that proposed in this work for football teams, but would be related to specifically to the situation(s) created inside the virtual environment.

The PhD work would extend the MSc. work to involve greater numbers of participants on multiple teams under a diversity of 'in-world' scenarios. Metrics would one more be taken that relate to the viability of each team and these would be compared and contrasted. Forecasting may be used to determine if team success or failure could be predicted from the viability metrics produced. This would further serve t characterise the Viable System Model under load conditions and und a variety of circumstances such that the scope of this work may be broadened beyond its initial test using the proxy of football. This is summarised on the next page.

Student Type	Proposed Work	Short Term Extension	Long Term Extension
MSc.	Prediction	Incorporation of basic forecasting algorithms to predict future team behaviour based on metrics proposed in this work and using different (and more) data sets for one target team in a different league to the EPL.	Investigation of forecasting techniques developed in the context of 'heads-up' display for in match prediction and/or decision making.
	Fraud Detection	Investigation into the conceptualisation of metrics produced in this work as a control signal and the conduct of initial experiments as a proof of concept for one team over a couple of seasons.	Relation of any transients in the control signals analysed to real world events via reference to recorded television broadcasts of the relevant matches. Liaison with the necessary football club(s) for an assessment of player(s) activity at the timestamp the transient was reported in the data.
	Virtual Worlds	Development of a small multiplayer game to involve a few participants organising themselves with respect to completion of simple objectives in a set time period whilst computing the viability metrics proposed in this work. Basic analysis of results required and interpretation thereof.	Repetition of the work but using different scenario types and differing numbers of participants with different resource constraints and time pressures. Analysis of viability metrics produced and recommendations for team performance improvement required where found to be less than viable.

Student Type	Proposed Work	Short Term Extension	Long Term Extension
PhD.	Prediction	Extension to scope of MSc by considering multiple teams in multiple leagues. Design and build of real time visualisation and prediction engine based upon in game data as captured.	Incorporation of existing or new pattern recognition techniques to act as real time recommender systems to decision makers. Possible incorporation of Particle Swarm Optimisation to that end.
	Fraud Detection	Broadening the scope of the MSc. work to include one or more teams operating over multiple football seasons. Investigation of the feasibility of producing a system that would read live streams of player data in the context of a control chart to alert to potential fraud as it happens or, via forecasting, beforehand	Application of the work to other team types such as Rugby, Ice Hockey with a view to providing the authorities with a test to categorically detect fraudulent activity from player spatial dynamics (as viable systems) and to mitigate financial losses in the gaming industry.
	Virtual Worlds	Broadening of the scope of the MSc. to incorporate forecasting / real time recommender systems against an opponent and against own performance under a single scenario type to discern if success or failure is likely for either so as to inform team actions with a view to taking appropriate action. Analysis of viability data produced with a full assessment of the statistical significance of the same.	Investigation into differing scenario types and hence different load conditions. Examination of situation where resources provided to a team ‘in world’ are critically low, how they cope whilst monitoring how the viability metrics vary. Analysis of the data produced plus assessment of the statistical significance of the same. Scenarios include the battlefield dynamics as alluded to earlier in this work.

7.3 Summary

The nature of cybernetics, and the viable system model in particular, lends itself to novel application within, and across, a diversity of disparate fields of endeavour. In many respects, this is both the strength and the weakness of cybernetics. On the one hand it does not suffer from being constrained by subject specific boundaries. In other words, cyberneticians may freely traverse the necessary subjects that can provide them with what tools and techniques that they need to accomplish their work and study them to the require scope and depth accordingly. In this respect the contributions sought and obtained by the Cybernetician in addressing a problem or theoretical question serve to underpin an outcome that is greater than the sum of those parts. This is certainly the spirit in which the work in this thesis has been approached and carried out and in which the suggested paths for continuation based upon it is offered.

Yet, despite the strength alluded to above, there are weaknesses present in the cybernetic approach that can confound its intent. It is contended that the main cause of this is, paradoxically, that strength – since the scope of the solution sought can encompass so many aspects of so many fields, the focus of the work can become diluted or lost as a result. A common analogy to this is the concept of ‘feature creep’ in software development where the scope of the project broadens to incorporate somewhat unnecessary features to the point that the original purpose of the software is lost and it becomes something else entirely. As such the future work proposed would have to bear this caveat in mind and their scope carefully constrained accordingly. Notwithstanding, the suggestions made above are considered to be suitably constrained and provide a path for some interesting work to be undertaken in extending the quantitative approach to viable systems theory by actually illustrating it in applied practice.

In Chapter 1 of this thesis a matrix was presented in relation to the research and development activity that underpins it. In this concluding chapter, a matrix is presented below that corresponds to how the aims and objectives documented in Chapter 1 have translated into specific accomplishments as a result of the work being carried out.

OBJECTIVES	CHAPTERS	ACCOMPLISHMENTS
Examine the current position in Viable Systems Research for quantified analysis of the Viable System Model	Ch.1 Ch.2 Ch.3	• Determined an absence of case studies relating to the Viable System operating under load conditions. • Identified a unique opportunity to address this using data that can accomplish this but was currently unused for that purpose. • Established the link between player policy and player position and Shannon Information via Zipf's Law. • Identified Zipf's Law as a power law as a means to quantify degree of self organisation present in team via linear regression analysis. • Hypothesised juxtaposition of Shannon Information to regression line parameters in juxtaposition and in alignment with match outcomes as a measure of cybernetic viability i.e. degree of alignment of team with its VSM representation as a means of assessing its degree of effective organisation with respect to its stated purpose. • Made the case for how a football team is fully isomorphic with the provisions of the Viable System Model in its structure and operation, and set this in context of how such teams have duality as complex adaptive systems. Examined how the output of one team might control the other and vice versa during a match.
Investigation of technologies and associated data sources that characterise viable systems in action Design and build software to play back football matches from data files provided	Ch.4	• Reviewed available team data capture systems relating to football teams. • Approached and obtained industrial involvement of system vendors for the supply of data files for analysis. • Iterative rapid application development method for software construction.
Analyse each match data file before playback in software (actual dynamics) and after playback (emergent dynamics)	Ch.5	• Compared derived metrics to match outcomes by match fixture type. • Identified patterns and relationships in the data to indicate barrier of complexity between team success and failure. • Undertook tests for statistical significance of findings obtained.
Comment upon the analysis undertaken as a new means of quantifying the degree of isomorphy the target team had with its Viable System Model representation based upon derived metrics and corresponding match outcomes.	Ch.6 Ch.7	• Reported that policy output of the Viable System Model operating under real time load conditions against an opposing viable system follows a power law that characterises the system under a diversity of circumstances, irrespective of opponent or match fixture. • Reported that the amount of Shannon Information present in each match is remarkably consistent and occupies a very narrow range of values. • Offered suggestions in respect of how the research undertaken might be extended and/or applied in other fields of endeavour whilst serving to extend the corpus of viable systems research on a quantitative rather than qualitative basis.

References & Bibliography

Abbott, R., 2007. Putting Complex Systems to Work. *Complexity*, 13(2), pp.30-49.

Abbott, R., 2009. The Reductionist Blind Spot. *Complexity*, 14(5), pp.10-22.

Adams, D., *Questions*. [email] (Personal communication, 27 November 2014).

Adeagbo-Sheikh, A.G., 1987. An attempt at a control-theoretic solution to stability problems in management. *Kybernetes*, 16, pp.161-167.

Adelman, L., Miller, S.L. and Yeo, C., 2004. Testing the Effectiveness of Icons for Supporting Distributed Team Decision Making Under Time Pressure. *IEEE Transactions on Systems, Man, and Cybernetics*, 34(2/ Part A: Systems and Humans), pp.179-189.

Agre, P.E., 1991. Principled design for Sociable Agency. In: *IEE Colloquium on Intelligent Agents*. London, UK. 25 Feb 1991. pp.2/1 - 2/3.

Aidt, T.S., Leong, B., Sgroi, D. and Saslaw, W.C., 2006. *A power Law Distribution for Tenure Lengths of Sports Managers*. [online] Available at <http://www2.warwick.ac.uk/fac/soc/economics/staff/dsgroi/papers/2006_finalversion_managers.pdf> [Accessed 26 Oct 2014].

Aldashev, G. and Carletti, T., 2009. Benefits of Diversity, Communication Costs and Public Opinion Dynamics. *Complexity*, 15(2), pp.54-63.

Alderson, D.L. and Doyle, J.C., 2010. Contrasting views of Complexity and their implications for Network-Centric Infrastructures. *IEEE Transactions on Systems, Man, and Cybernetics*, 40(4/ Part A: Systems and Humans), pp.839-852.

Alexsander, I., 1982. Mind, Brain, Structure and Function. *Kybernetes,* 11, pp.249-253.

Amcoff Nyström, C., 2006. Demands on Intranets - Viable System Model as a Foundation for Intranet Design. In: Computing Anticipatory Systems: *CASYS'05 - Seventh International Conference (ed. D.M. Dubois)*. American Institute of Physics.

Andrew, A.M., 1996. The challenge of Daisyworld. *Kybernetes*, 25(7/8), pp.94-99.

Anthony, R.J., 2004. Emergence: a Paradigm for Robust and Scalable Distributed Applications. In: *Proceedings of the International Conference on Autonomic Computing*, IEEE 2004.

Arrow, H., McGrath, J.E. and Berdahl, J.L., 2000. *Small Groups as Complex Systems*. London: Sage Publications Ltd.

Arthur, J., 2011. *Lean Six Sigma Demystified.* 2nd ed. New York: McGraw-Hill.

Ashby, W.R., 1957. *An Introduction to Cybernetics*. London: Chapman & Hall.

Atay, F.M. and Jost, J., 2004. On the Emergence of Complex Systems on the Basis of the Coordination of Complex Behaviors of Their Elements. *Complexity*, 10(1), pp.17-22.

Ausloos, M., 2008. Equilibrium (Zipf) and Dynamic (Grasseberg-Procaccia) method based analyses of human texts. A comparison of natural (english) and artificial (esperanto) languages. *Physica A*, 387 (25), pp.6411-6420.

Axelrod, R., 1984. *The Evolution of Cooperation*. Revised ed. Cambridge: Perseus Books Group.

Axelrod, R., 1997. *The Complexity of Cooperation*. Princeton: Princeton University Press.

Ay, N. and Zahedi, K., 2011. *Causal Effects for Prediction and Deliberative Decision Making of Embodied Systems*. [online] Available at <http://www.santafe.edu/media/workingpapers/11-11-055.pdf> [Accessed 26 Oct 2014].

Azadeh, A., Darivandi, K. and Fathi, E., 2012. Diagnosing, Simulating and Improving Business Process Using Cybernetic Laws and the Viable System Model: The Case of a Purchasing Process. *Systems Research and Behavioral Science Syst. Res.*, 29, pp.66-86.

Baas, N.A. and Emmeche, C., 1997. *On Emergence and Explanation*. [online] Available at <http://www.santafe.edu/media/workingpapers/97-02-008.pdf> [Accessed 26 Oct 2014].

Babcock, D.L., 1972. Assumptions in Forrester's Urban Dynamics Model and their Implications. *IEEE Transactions on Systems, Man and Cybernetics*, 2(2), pp.144-149.

Badre, A.N., 1982. Selecting and Representing Information Structures for Visual Presentation. *IEEE Transactions on Systems, Man, and Cybernetics*, 12(4), pp.495-503.

Bahr, F.R., 1972. Man-Machine Symbiosis. *Kybernetes*, 1, pp.169-174.

Bai, G. and Lindberg, L-A., 1999. A sociocybernetic approach to information systems development. *Kybernetes*, 28(6/7), pp.792-809.

Bainbridge, L., 1997. The Change in Concepts Needed to Account for Human Behavior in Complex Dynamic Tasks. *IEEE Transactions on Systems, Man, and Cybernetics*, 27(3), pp.351-359.

Bak, P., Christensen, K., Danon, L. and Scanlon, T., 2002. Unified Scaling Law for Earthquakes. *Physical Review Letters*, 88(17), pp.178501-1 - 178501-4.

Bang, D., Fusaroli, R., Tylén, K., Olsen, K., Latham, P.E., Lau, J.Y.F., Roepstorff, A., Rees, G., Frith, C.D. and Bahrami, B., 2014. Does interaction matter? Testing whether a confidence heuristic can replace interaction in collective decision-making. *Consciousness and Cognition*, 26, pp.13-23.

Bar-Yam, Y. 2004. Multiscale Variety in Complex Systems. *Complexity*, 9(4), pp.37-45.

Baskin, K., 2000. Corporate DNA: Organizational Learning, Corporate Co-Evolution. *Emergence*, 2(1), pp.34-49.

Bechler, R., 2002. *Stafford Beer: the man who could have ran the world*. [online] openDemocracy.net. Available at <https://www.opendemocracy.net/node/611> [Accessed 5 October 2014].

Beek, P.J., Peper, C.E. and Stegeman, D.F., 1995. Dynamical models of movement coordination. *Human Movement Science*, 14, pp.573-608.

Beer, S., 1957. *The Development of Our Work on Control Systems (United Steel - Department of Operational Research and Cybernetics)*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412517211535~415&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1958. *The organisation of certain Management Service at the Branches (United Steel - Department of Operational Research and Cybernetics)*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412517355390~89&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1959. *Cybernetics and Management*. Chichester: John Wiley & Sons Ltd.

Beer, S., 1967. *Management Science*. London: Aldus Books.

Beer, S., 197.n.d. *Variety & its control*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412531508584~302&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014]

Beer, S., 1970a. *Automation - The First Epoch (for the Dominion Bureau of Statistics Canada)*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412517000332~690&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1970b. Managing Modern Complexity. *Futures*, June Issue, pp.114-122.

Beer, S., 1970c. Managing Modern Complexity. *Futures*, September Issue, pp.245-257.

Beer, S., 1971a. *Cybernetic Notes on The Effective Organisation of The State with particular reference to industrial control*. [online] Stafford Beer. Available at: <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412516121803~391&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1971b. The Liberty Machine. *Futures*, December Issue, pp.338-348.

Beer, S., 1972a. *5 Principles for the People towards good Government*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412519737317~369&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014]

Beer, S., 1972b. Cybernetics - A Systems Approach to Management. *Personnel Review*, 1(2), pp, 28-39.

Beer, S., 1972c. *Cyberstride: Preparations*. [online] Stafford Beer. Available at : <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412515929918~171&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1972d. *Cybersyn - A description of the Recursive Structure, Types of Reporting, & Algedonic Feedback*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412516495842~693&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1972e. *Project Cyberfolk*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412516245286~229&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1973a. *Response to Chilean Coup - Interview with Roger Cook*, [Download]. Available at <http://www.cybsoc.org/StaffordCoup.wma> [Accessed October 2014]

Beer, S., 1973b. *The 1973 CBC Massey Lectures, "Designing Freedom" Part 1: The Threat to All We Hold Most Dear*. [online] Available at <http://www.cbc.ca/video/news/audioplayer.html?clipid=2146142317> [Accessed 24 Oct 2014].

Beer, S., 1973c. *The 1973 CBC Massey Lectures, "Designing Freedom" Part 2: The Discarded Tools of Modern Man*. [online] Available at <http://www.cbc.ca/video/news/audioplayer.html?clipid=2146142318> [Accessed 24 Oct 2014].

Beer, S., 1973d. *The 1973 CBC Massey Lectures, "Designing Freedom" Part 3: A Liberty Machine in Prototype"*. [online] Available at <http://www.cbc.ca/video/news/audioplayer.html?clipid=2146142319> [Accessed 24 Oct 2014].

Beer, S., 1973e. *The 1973 CBC Massey Lectures, "Designing Freedom" Part 4: Science in the Service of Man"*. [online] Available at <http://www.cbc.ca/video/news/audioplayer.html?clipid=2146142320> [Accessed 24 Oct 2014].

Beer, S., 1973f. *The 1973 CBC Massey Lectures, "Designing Freedom" Part 5: The Future That Can Be Demanded Now"*. [online] Available at <http://www.cbc.ca/video/news/audioplayer.html?clipid=2146142321> [Accessed 24 Oct 2014].

Beer, S., 1973g. *The 1973 CBC Massey Lectures, "Designing Freedom" Part 6: The Free Man in a Cybernetic World"*. [online] Available at <http://www.cbc.ca/video/news/audioplayer.html?clipid=2146142322> [Accessed 24 Oct 2014].

Beer, S., 1974a. Cybernetics of National Development Evolved From Work in Chile. *The Zaheer Lecture*, 5th December 1974.

Beer, S., 1974b. *Warburton Cybernetics - 2nd Instalment: Group Diagnostic Model*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412517497267~186&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1975. *Platform for Change*. Chichester: John Wiley & Sons Ltd.

Beer, S., 1976. *Warburton Cybernetics - 4th Instalment: A Divisional Model with Algedonic control*. [online] Stafford Beer. Available at <http://digitool.jmu.ac.uk:1801/view/action/singleViewer.do?dvs=1412517622717~514&locale=en_US&VIEWER_URL=/view/action/singleViewer.do?&DELIVERY_RULE_ID=4&application=DIGITOOL-3&forebear_coll=1234&frameId=1&usePid1=true&usePid2=true&COPYRIGHTS_DISPLAY_FILE=copyrights_sb> [Accessed 5th October 2014].

Beer, S., 1981. *The Brain of the Firm*. 2nd ed. Chichester: John Wiley & Sons Ltd.

Beer, S., 1983. The Will of the People. *The Journal of the Operational Research Society*, 34(8), pp.797-810.

Beer, S., 1984. The Viable System Model: Its Provenance, Development, Methodology and Pathology. *The Journal of the Operational Research Society*, 35(1), pp.7-25.

Beer, S., 1985. *Diagnosing The System For Organisations*. Chichester: John Wiley & Sons Ltd.

Beer, S., 1990. *Forty years of Cybernetics*, [Download]. Available at: <http://www.cybsoc.org/Stafford Beer.wma> [Accessed October 2014]

Beer, S., 1994a. *Decision and Control*. Chichester: John Wiley & Sons.

Beer, S., 1994b. Knowing Norbert. *Kybernetes*, 23(6/7), pp.17-20.

Beer, S., 1994c. May the Whole Earth Be Happy: Loka Samastat Sukhino Bhavantu. *Interfaces*, 24(4), pp.83-93.

Beer, S., 1994d. *The Falcondale Collection (video series transcript)*. Liverpool: Liverpool John Moores University.

Beer, S., 1994e. *The Heart of Enterprise*. Chichester: John Wiley & Sons Ltd.

Beer, S., 2002. What is cybernetics? *Kybernetes*, 31(2), pp.209-219.

Beer, S., 2004. What is cybernetics? *Kybernetes*, 33(3/4), pp.853-863.

Benbasat, I. and Taylor, R.N., 1982. Behavioral Aspects of Information Processing for the Design of Management Information Systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 12(4), pp.439-450.

Beroggi, G.E.G. and Wallace, W.A., 1997. The Effect of Reasoning Logics on Real-Time Decision Making. *IEEE Transactions on Systems, Man, and Cybernetics*, 26(6/Part A: Systems and Humans), pp.743-749.

Berrien, F.K., 1968. *General and Social Systems*. New Brunswick: Rutgers University Press.

Bhavnani, R., Backer, D. and Riolo, R., 2008. Simulating Closed Regimes with Agent Based Models. *Complexity*, 14(1), pp.36-44.

Bisantz, A.M., Kirlik, A., Gay, P., Phipps, D.A., Walker, N. and Fisk A.D., 2000. Modeling and Analysis of a Dynamic Judgement Task using a Lens Model Approach. *IEEE Transactions on Systems, Man, and Cybernetics*, 30(6/ Part A: Systems and Humans), pp.605-616.

Boettcher, K.L. and Levis, A.H., 1982. Modeling the Interacting Decisionmaker with Bounded Rationality. *IEEE Transactions on Systems, Man, and Cybernetics*, 12(3), pp.334-344.

Boettcher, K.L. and Tenney, R.R., 1986. Distributed Decisionmaking with Constrained Decisionmakers: A Case Study. *IEEE Transactions on Systems, Man, and Cybernetics*, 16(6), pp.813-823.

Bogdanov, A.A., Dudley, P. (editor), Bogdanov's Tektology, Centre for Systems Studies Press ,Hull, United Kingdom, 1996. ISBN 0-85958-876-9

Boguta, K., 2005. Complexity and the Paradigm of Wolfram's A New Kind of Science. *Complexity*, 10(4), pp.15-21.

Boisot, M., 2000. Is there a Complexity beyond the reach of Strategy?, *Emergence*, 2(1), pp.114-134.

Bonabeau, E., Dorigo, M. and Theraulaz, G., 2000. Inspiration for Optimization from Social Insect Behavior. *Nature*, 406 (July Issue), pp.39-42.

Bonabeau, E., Henaux, F., Guérin, Syners, D. and Kuntz, P., 1998. *Routing in Telecommunications Networks with "Smart" Ant-Like Agents*. [online] Available at <http://www.santafe.edu/media/workingpapers/98-01-003.pdf> [Accessed 26 Oct 2014].

Bonabeau, E., Theraulaz, G., Deneubourg, J-L., Aron, S. and Camazine, C., 1997. Self-organization in social insects. *Tree*, 12(5), pp.188-193.

Börner, Dall'Asta, L., Weimao, K. and Vespignani, A., 2005. *Complexity*, 10(4), pp.57-67.

Boschetti, F., McDonald, D. and Gray, R., 2008. Complexity of a Modelling Exercise: A Discussion of the Role of Computer Simulation in Complex System Science. *Complexity*, 13(6), pp.21-27.

Braitenberg, V., 1984. *Vehicles: Experiments in Synthetic Psychology*. Cambridge: MIT Press

Brewis, S., 2004. The role of information and models in regulating complex commercial systems. *Kybernetes*, 33(3/4), pp.577-589.

Brocklesby, J. and Mongers, J., 2005. The Use and Concept of Autopoiesis in the Theory of Viable Systems. *Systems Research and Behavioral Science Syst. Res.*, 22, pp.3-9.

Brodu, N., 2008. A synthesis and a practical approach to Complex Systems. *Complexity*, 15(1), pp.36-60.

Brozyna, J., 1999. The Science of human and social processes: an introduction to vytvorology. *Kybernetes*, 28(2), pp.181-197.

Bugess, N. and Wake, N., 2013. The applicability of the Viable Systems Model as a diagnostic for small to medium sized enterprises. *International Journal of Productivity and Performance Management*, 62(1), pp.29-46.

Bula, G., and Espejo, R., 2012. Governance and inclusive democracy. *Kybernetes*, 41(3/4), pp.339-347.

Cadwallader, M.L., 1959. The Cybernetic Analysis of Change in Complex Social Organisations. *American Journal of Sociology*, 65(2), pp.154-157.

Camazine, S. and Sneyd, J., 1991. A method of collective Nectar Source selection by Honey Bees: Self-organization through simple rules. *Journal of theoretical Biology*, 149, pp.547-571.

Chan, K.P., Hui, P.M. and Johnson, N.F., 2005. *Decision Making, Strategy dynamics, and Crowd Formation in Agent-based models of Competing Populations*. [online] Available at <http://arxiv.org/pdf/cond-mat/0505581v2.pdf> [Accessed 26 Oct 2014].

Chandraskekaran, B., 1981. Natural and Social System Metaphors for Distributed Problem Solving: Introduction to the Issue. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(1), pp.1-5.

Changizi, M.A. and He, D., 2005. Four Correlates of Complex Behavioral Networks Differentiation, Behavior, Connectivity, and Comparmentalization. *Complexity*, 10(6), pp.13-40.

Chaudhury, A., 1998. Two Mechanisms for Distributed Problem Solving. *IEEE Transactions on Systems, Man, and Cybernetics*, 28(1/ Part A: Systems and Humans), pp.48-55.

Chaudhury, A., Deng, P-S. and Rathnam, S., 1996. A Computational Model of Coordination. *IEEE Transactions on Systems, Man, and Cybernetics*, 26(1), pp.132-141.

Chen, K., Mathes, J.C., Jarboe, K. and Wolfe, J., 1979. Value Oriented Social Decision Analysis: Enhancing Mutual Understanding to Resolve Policy Issues. *IEEE Transactions on Systems, Man, and Cybernetics*, 9(9), pp.567-580.

Chow, J.Y., Davids, K., Hristovski, R., Araújo, D. and Passos, P., 2011. Nonlinear pedagogy: Learning design for self-organizing neurobiological systems. *New Ideas in Psychology*, 29, pp. 189-200.

Christakis, A.N., 2004. Wisdom of the People. *Systems Research and Behavioral Science*, 21, pp.479-488.

Chu, Y-Y. and Rouse, W.B., 1979. Adaptive Allocation of Decision making Responsibility Between Human and Computer in Multitask Situations. *IEEE Transactions on Systems, Man, and Cybernetics*, 9(12), pp.769-778.

Cilliers, P., 2000. What can we learn from a Theory of Complexity?, *Emergence*, 2(1), pp.23-33.

Clauset, A., Shalizi, C. and Newman, M., 2007. *Power-Law Distributions in Empirical Data*. [online] Available at <http://www.santafe.edu/media/workingpapers/07-12-049.pdf> [Accessed 26 Oct 2014].

Clauset, A., Shalizi, C.R. and Newman, M.E.J., 2009. Power-Law distributions in empirical data. *SIAM Review*, 51(4), pp.661-703.

Coleman, H.J., 1999. What enables self-Organizing Behavior in Businesses. *Emergence*, 1(1), pp.33-48.

Colman, A.M., Pulford, B.D. and Rose, J., 2008. Collective rationality in interactive decisions: Evidence for team reasoning. *Acta Psychologica*, 128, pp.387-397.

Conant, R.C. and Ashby, W.R., 1970. Every Good Regulator of a System must be a Model of that System. *Int. J. Systems Sci*., 1(2), pp.89-97.

Conradt, L. and Roper, T.J., 2010. Deciding group movements: Where and when to go. *Behavioural Processes*, 84, pp.675-677.

Cooksey, R.W., 2000. Mapping the Texture of Managerial Decision Making: A Complex Dynamic Decision Perspective. *Emergence*, 2(2), pp.102-122.

Cornforth, D., Kirley, M. and Bossomaier, T., 2004. Agent heterogeneity and coalition formation: Investigating market-based cooperative problem solving. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems-Volume 2*. IEEE Computer Society, 2004.

Corning, P.A., 1996. Cybernetics and the Evolution of Politics. *International Political Science Review*, 17(1), pp.91-119.

Corning, P.A., 2002. The Re-emergence of "Emergence": A venerable concept in search of a theory. *Complexity*, 7(6), pp.18-30.

Corominas-Murtra, B. and Solé, R., 2010. *On the Universality of Zipf's Law*. [online] Available at

<http://www.santafe.edu/media/workingpapers/10-01-002.pdf> [Accessed 26 Oct 2014].

Corominas-Murtra, B., Andreu, J.F and Solé, R.V., 2010. *Emergence of Zipf's Law in the Evolution of Communication*. [online] Available at <http://www.santafe.edu/media/workingpapers/10-12-035.pdf> [Accessed 26 Oct 2014].

Correia, V., Araújo, D., Davids, K., Fernandes, O. and Fonesca, S., 2011. *Psychology of Sport and Exercise*, 12, pp.662-669.

Cuff, J.M., 2007. C.S.Peirce, G.W.F. Hegel and Stuart Kauffman's Complexity Theory: A Response. *Zygon*, 42(1), pp.249-255.

Dadelo, S., Turskis, Z., Zavadskas, E.K. and Dadeliene, R., 2014. Multi-criteria assessment and ranking system of sport team formation based on objective-measured values of criteria set. *Expert Systems with Applications*, 41, pp.6106-6113.

de Oca, M.A., and Stützle, T., 2008. Towards incremental social learning in optimization and multiagent systems. In: *Proceedings of the 2008 GECCO conference companion on Genetic and evolutionary computation*. ACM, 2008.

de Raadt, J.D.R., 1990. Information Transmission in Viable Systems. *Journal of The American Society for Information Science*, 41(2), pp.111-120.

de Zeeuw, G., 2004. Fighting for Science. *Kybernetes*, 33(3/4), pp.717-725.

Decugniere, A., Poulain, B., Campo, A., Pinciroli, C., Tartini, B., Osée, M and Birattari, M., 2008. Enhancing the cooperative transport of multiple objects. *Ant Colony Optimization and Swarm Intelligence*. Springer Berlin Heidelberg, 2008. pp.307-314.

Detrain, C. and Deneubourg, J-L., 2006. Self-organized structures in a superorganism: do ants "behave" like molecules? *Physics of Life Reviews*, 3, pp.162-187.

Dove, J., 2009. *Crystal Reports Formulas Explained*. Leicester: Matador.

Duarte, R., Araújo, D., Correia, V., Davids, K., Marques, P. and Richardson, M.J., 2013. Competing together: Assessing the dynamics of team-team and player-team synchrony in professional association football. *Human Movement Science*, 32, pp.555-566.

Duarte, R., Araújo, D., Correia, V., Freire, L., Folgado, H., Fernandes, O. and Davids, K., 2012. Intra- and inter-group coordination patterns reveal collective behaviors of football players near the scoring zone. *Human Movement Science*, 31, pp.1639-1651.

Dubberly, H. and Pangaro, P., 2007. Cybernetics and service-craft: language for behavior-focused design. *Kybernetes*, 36(9/10) pp.1301-1317.

Dubberly, H. and Pangaro, P., 2009. *What is conversation? How can we Design for effective conversation?*. [online] Dubberly and Pangaro. Available at <http://www.dubberly.com/wp-content/uploads/2009/07/ddo_article_whatisconversation.pdf> [Accessed 5 October 2014].

Dubberly, H., Haque, U. and Pangaro, P., 2009. *What is Interaction? Are there different types?*. [online] Dubberly and Pangaro. Available at <http://www.dubberly.com/wp-content/uploads/2009/01/ddo_article_whatisinteraction.pdf> [Accessed 5 October 2014].

Dubberly, H., Maupin, C.J., and Pangaro, P., 2009. *Bio-cost - An economics of human behavior*. [online] Dubberly and Pangaro. Available at <http://pangaro.com/published/Biocost_Dubberly_Maupin_Pangaro-2010.pdf> [Accessed 5 October 2014].

Ducatelle, F., Di Caro, G. A., and Gambardella, L. M., 2008. Robot navigation in a networked swarm. In: *Intelligent Robotics and Applications.* pp. 275-285. Springer Berlin Heidelberg.

Ducatelle, F., Di Caro, G. A., and Gambardella, L. M., 2010. Cooperative stigmergic navigation in a heterogeneous robotic swarm. In: *From Animals to Animats, 11*. pp. 607-617. Springer Berlin Heidelberg.

Ducatelle, F., Di Caro, G. A., Förster, A., and Gambardella, L.M., 2010. Mobile stigmergic markers for navigation in a heterogeneous robotic swarm. In: *Swarm Intelligence* (pp. 456-463). Springer Berlin Heidelberg.

Ducatelle, F., Di Caro, G.A., Pinciroli, C., and Gambardella, L.M., 2010. Self-organized Cooperation between Robotic Swarms. *Swarm Intelligence*, 5(2), pp.73-96.

Ducatelle, F., Di Caro, G.A., Pinciroli, C., Mondada, F. and Gambardella, L., 2011. Communication assisted navigation in robotic swarms: self-organization and cooperation. In: *IEEE/RSJ International Conference on Intelligent Robots and Systems*, San Francisco, CA, USA, September 25-30 2011.

Dyck, R.G., 2006. Fractal planning for integral economic development. *Kybernetes*, 35(7/8), pp.1037-1047.

Dyer, J.R.G., Ioannou, C.C., Morrell, L.J., Croft, D.P., Couzin, I.D., Waters, D.A. and Krause, J., 2008. Consensus decision making in human crowds. *Animal Behaviour*, 75, pp.461-470.

Eccles, D.W. and Groth, P.T., 2007. Wolves, bees and football: Enhancing coordination in sociotechnological problem solving systems through the study of human and animal groups. *Computers in Human Behaviour*, 23, pp.2778-2790.

Eliazar, I., Cohen, M.H., 2011. The universal macroscopic statistics and phase transitions of rank distributions. *Physica A*, 390, pp.4293-4303.

Entin, E.E. and Serfaty, D., 1997. Sequential Revision of Belief: An Application to Complex Decision Making Situations. *IEEE Transactions on Systems, Man, and Cybernetics*, 27(3/Part A: Systems and Humans), pp.289-301.

Ericson, R.F., 1972. Visions of Cybernetic Organisations. *The Academy of Management Journal*, 15(4), pp.427-443.

Espejo, R. and Kuropatwa, D., 2011. Appreciating the complexity of organizational processes. *Kybernetes*, 40(3/4), pp.454-476.

Espejo, R. and Schwaninger, M. eds, 1993. *Organisational Fitness*. Germany: Campus-Verlag.

Espejo, R., 1994. What is systemic thinking? *System Dynamics Review*, 10(2-3), pp.199-212

Espejo, R., 1996. Requirements for Effective Participation in Self-Constructed Organizations. *European Management Journal*, 14(4), pp.414-422.

Espejo, R., 1999. Aspects of identity, cohesion, citizenship and performance in recursive organisations. *Kybernetes*, 28(6/7), pp.640-658.

Espejo, R., 2004. The footprint of complexity: the embodiment of social systems. *Kybernetes*, 33(3/4), pp.671-700.

Espejo, R., 2009. Performance management, the nature of regulation and the Cybersyn project. *Kybernetes*, 38(1/2), pp.65-82.

Espejo, R., and Harnden, R. eds, 1989. *The Viable System Model - Interpretations and Applications of Stafford Beer's VSM*. Chichester: John Wiley & Sons Ltd.

Espejo, R., Bowling, D. and Hoverstadt, P., 1999. The viable system model and the Viplan software. *Kybernetes*, 28(6/7), pp.661-678.

Espinosa, A. and Porter, T., 2011. Sustainability, complexity and learning: insights from complex systems approaches. *The Learning Organization*, 18(1), pp.54-72.

Espinosa, A., Harnden, R. and Walker, J., 2007. Beyond hierarchy: a complexity management perspective. *Kybernetes*, 36(3/4), pp.333-347.

Evans, M. and Laws, A., 2014. Self Organisation characteristics in Football Teams as opposing agent-based Viable Systems. In: *IEEE Conference on Norbert Wiener in the 21st Century (21CW)*. Boston, Massachusetts, 24-26 June 2014. IEEE.

Evenson, S. and Dubberly, H., 2011. Design as Learning - or "Knowledge creation" - the SECI model. *Interactions Magazine*, XVIII (January - February issue).

Falcondale Lecture Series Session 1 - The History & Nature of Cybernetics: Part 1. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 2 - The History & Nature of Cybernetics: Part 2. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 3 - Complexity & the measure of Variety. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 4 - Homeostasis & Viability. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 5 - Elemental Organisational Unit. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 6 - The Horizontal & Vertical Variety Balance. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 7 - The Viable System Model: 'The Inside & Now'. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 8 - The Viable System Model: 'The Outside & Then'. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Falcondale Lecture Series Session 9 - Syntegration. 1994. [video] Liverpool: Liverpool John Moores University (Session presented by Stafford Beer)

Fédération Internationale de Football Association, 2014. *Rules of the Game*. [online] Available at <http://www.fifa.com/mm/document/footballdevelopment/refereeing/02/36/01/11/27_06_2014_new--lawsofthegameweben_neutral.pdf> [Accessed 30 October 2014].

Filk, T. and von Mϋller, A., 2007. Evolutionary Learning of Small Networks. *Complexity*, 13(3), pp. 43-54.

Fonesca, S., Milho, J., Travassos, B. and Araújo, D., 2012. Spatial dynamics of team sports exposed by Voroni diagrams. *Human Movement Science*, 31, pp.1652-1659.

Fox, M.S., 1981. An Organisational View of Distributed Systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(1), pp.70-80.

Franks, N.R., Richardson, T.O., Stroeymeyt, N., Kirby, R.W., Amos, W.M.D., Hogan, P.M., Marshall, J.A.R. and Schlegel, T., 2013. Speed-cohesion trade-offs in collective decision making in ants and the concept of precision in animal behaviour. *Animal Behaviour*, 85, pp.1233-1244.

Freiberger, M. and Thomas, R., 2016. *Maths Squared*. London: Apple Press.

Fuchs, C. and Hofkirchner, W., 2005.Self-organization, knowledge and responsibility. *Kybernetes*, 34(1/2), pp.241-260.

Fuller, T. and Moran, P., 2000. Moving Beyond Metaphor. *Emergence*, 2(1), pp.50-71.

Gabaix, X., 1999. Zipf's Law and the Growth of Cities. *The American Economic Review*, 89(2), pp.129-132.

Gasser, L. and Hill, R.W., 1990. Coordinated Problem Solvers. *Annual Review of Computer Science*, 4, pp.203-253.

Geoghegan, M.C. and Pangaro, P., 200.n.d. Design for a self-regenerating organization. *International Journal of General Systems*, X(X).

Gershenson, C., Csermely, P., Erdi, P., Knyazeva, H. and Laszlo, A., 2013. *The Past, Present and Future of Cybernetics and Systems Research*. [online] Available at <http://arxiv.org/pdf/1308.6317v3.pdf> [Accessed 6th October 2014].

Gershenson, C., Csermely, P., Érdi, P., Knyazeva, H. and Laszlo, A., 2013. *The Past, Present and Future of Cybernetics and Systems Research*. [online] Available at <http://arxiv.org/abs/1308.6317> [Accessed 23 Sept 2013].

Ghavamzadeh, M. and Mahadevan, S., 2004. Learning to communicate and act using hierarchical reinforcement learning. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems*. 3. pp. 1114-1121. IEEE Computer Society.

Ghosal, A., 1976. Applied Cybernetics: Its role in management problems. *Kybernetes*, 5, pp.165-171.

Giske, R., Benestad, B., Haralstad, K. and Høigaard, R., 2013. Decision-Making Styles Among Norwegian Soccer Coaches: An Analysis of Decision Making Style in Relation to Elite and Non-Elite Coaching and Level of Playing History. *International Journal of Sports Science & Coaching*, 8(4), 2013.

Glöckner, A., Heinen, T., Johnson J.G., Raab, M., 2012. Network approaches for expert decisions in sports. *Human Movement Science*, 31, pp.318-333.

Goldspink, C., 2000. Contrasting Linear and Nonlinear Perspectives in Contemporary Social Research. *Emergence*, 2(2), pp.72-101.

Goldstein, J., 1999. Emergence as a Construct: History and Issues. *Emergence*, 1(1), pp.49-72.

Goldstone, R.L. and Janssen, M.A., 2005. Computational models of collective behavior. *TRENDS in Cognitive Sciences*, 9(9), pp.424-430.

Goldstone, R.L. and Roberts, M.E., 2006. Self-organized Trail Systems in Groups of Humans. *Complexity*, 11(6), pp.43-50.

Gómez-Liévano, A., Youn, H. and Bettencourt, L.M.A., 2012. *The Statistics of Urban Scaling and Their Connection to Zipf's Law*. [online] Available at <http://www.santafe.edu/media/workingpapers/12-02-001.pdf> [Accessed 26 Oct 2014].

González-Víllora, S., García-López, L.M., Gutiérrez-Díaz, D. and Pastor-Vicedo, J.C., 2012. Tactical Awareness, decision making and skill in youth soccer players (under-14 years). *Journal of Human Sport & Exercise*, 8(2), 2013.

Govindaraj, T. and Rouse, W.B., 1981. Modeling the Human Controller in Environments that Include continuous and Discrete Tasks. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(6), pp.410-416.

Grabowski, M. and Roberts, K.H., 1996. Human and Organisational Error in Large Scale Systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 26(1/Part A: Systems and Humans), pp.2-16.

Granovetter, M., 1978. Threshold Models of Collective Behavior. *The American Journal of Sociology*, 83(6), pp.1420-1443.

Gray, J.N., Pessel, D. and Varaiya, P.P., 1972. A critique of Forrester's Model of an Urban Area. *IEEE Transactions on Systems, Man, and Cybernetics*, 2(2), pp.139-144.

Green, N., 2004. Axioms from interactions of actors theory. *Kybernetes*, 33(9/10), pp.1433-1462.

Greenstein, J.S. and Rouse, W.B., 1982. A Model of Human Decisionmaking in Multiple Process Monitoring Situations. *IEEE Transactions on Systems, Man, and Cybernetics*, 12(2), pp.182-192.

Gribbin, J., 2005. *Deep Simplicity: Chaos, Complexity and the emergence of life*. London: Penguin.

Griesinger, D.W., 1978. The Physics of Motivation and Choice. *IEEE Transactions on Systems, Man, and Cybernetics*, 8(12), pp.902-907.

Griffiths, N., 2005. Cooperative clans. *Kybernetes*, 34(9/10), pp.1384-1403.

Groß, R., Nouyan, S., Bonani, M., Mondada, F. and Dorigo, M., 2008. Division of labour in self-organised groups. In: *From Animals to Animats 10*, pp. 426-436. Springer Berlin Heidelberg, 2008.

Größler, A., Grϋbner, A. and Milling, P.M., 2006. Organisational adaptation process to external complexity. *International Journal of Operations & Production Management*, 26(3), pp.254-281.

Grund, T.U., 2012. Network structure and team performance: The case of English Premier League soccer teams. *Social Networks*, 34, pp.682-690.

Guimerá, R., Danon, L., Diaz-Guilera, A. and Arenas, A., 2002. Self-similar community structure in organisations. *Physical Review E* 68, p.065103 (2003)

Gutiérrez, Á., Campo, A., Santos, F.C., Pinciroli, C. and Dorigo, M., 2008. Social odometry in populations of autonomous robots. In: *Ant Colony Optimization and Swarm Intelligence*, pp. 371-378. Springer Berlin Heidelberg, 2008.

Haggerty, T.R., 1988. Designing Control and Information Systems in Sport Organizations: A Cybernetic Perspective. *Journal of Sport Management*, 2, pp.53-63.

Halley, J.A. and Winkler, D.A., 2008. Consistent Concepts of Self-organization and Self-assembly. *Complexity*, 14(2), pp.10-17.

Halley, J.D. and Winkler, D.A., 2008. Classification of Emergence and its relation to Self-organization. *Complexity*, 13(5), pp.10-21.

Hassan, Y. and Tazaki, E., 2003. Emergent phenomena in cellular automata modelling. *Kybernetes*, 32(3), pp.251-275.

Helsinger, A., Kleinmann, K. and Brinn, M., 2004. A Framework to Control Emergent Survivability of Multi Agent Systems. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems*. New York, USA. pp.28-35.

Henderson, A. and Harris, J. and Dubberly, H. (ed). Conversational Alignment. *Interactions Magazine*, XIX.1 (March - April issue).

Hennenman, R.L. and Rouse, W.B., 1986. On measuring the Complexity of Monitoring and Controlling Large-Scale Systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 16(2), pp.193-207.

Herring, C. and Kaplan, S., 2000. Viable components: a cybernetic organization for computing. In: *Proceedings. International Conference on Software Methods and Tools*. Woolongong, NSW, 6-9 September 2000. pp.67-74. IEEE.

Herring, C. and Kaplan, S., 2000. Viable Components: A Cybernetic Organization for Computing. In: *Proceedings of the International Conference on Software Methods and Tools*, 2000. pp.67-74.

Hilder, T., 1995. *Stafford Beer's Viable System Model - An Interpretation*. [online] Available at <http://www.flowmap.com/documents/vsm.pdf> {Accessed 21st October 2014].

Hoffman, R.R., Norman, D.O. and Vagners, J., 2009. Complex Sociotechnical Joint Cognitive Work Systems? *IEEE Intelligent Systems*, May/June Issue, pp.82-89.

Hogg, L.M.J. and Jennings, N.R., 2001. Socially Intelligent Reasoning for Autonomous Agents. *IEEE Transactions on Systems, Man, and Cybernetics*, 31(5/ Part A: Systems and Humans), pp.381-393.

Holland, J.H., 1993. *Echoing Emergence*. [online] Available at <http://www.santafe.edu/media/workingpapers/93-04-023.pdf> [Accessed 26 Oct 2014].

Holten, R. and Rosenkrantz, C., 2011. Designing viable social systems - The role of linguistic communication for self organization. *Kybernetes*, 40(3/4), pp.559-580.

Hommon, R.J., 1995. *Social Complex Adaptive Systems: Some Hawaiian Examples*. [online] Available at <http://www.santafe.edu/media/workingpapers/95-07-066.pdf> [Accessed 26 Oct 2014].

Hong, L. and Page, S.E., 1998. *Diversity and Optimality*. [online] Available at <http://www.santafe.edu/media/workingpapers/98-08-077.pdf> [Accessed 26 Oct 2014].

Hornby, G., 2007. Modularity, Reuse, and Hierarchy: Measuring Complexity by Measuring Structure and Organization.

Complexity, 13(2), pp.50-61.

Hoverstadt, P., 2008. *The Fractal Organisation*. Chichester: John Wiley & Sons Ltd.

Hoverstadt, P., Kendrick, I. and Morlidge, S., 2007. Viability as a basis for performance measurement. *Measuring Business Excellence*, 11(1), pp.27-32.

Huang, W., Raman, K.S. and Wei, K-K., 1997. Effects of Group Support System and Task Type on Social Influence in Small Groups. *IEEE Transactions on Systems, Man, and Cybernetics*, 25(5), pp.578-587.

Huaxia, Z., 2007. Exploring Dynamics of Emergence. *Systems Research and Behavioral Science*, 24, pp.431-443.

HungarianAlgorithm.com, 2013.Solve the assignment problem online - HungarianAlgorithm.com. [online] Available at: <http://www.hungarianalgorithm.com/solve.php> [Accessed October 2014]

Hunt, A., 2009. Relevance of Percolation Theory to Power-Law Behavior of Dynamic Processes Including Transport in Disordered Media. *Complexity*, 15(2), pp. 13-27.

Hübler, A.W., 2008. "Homeopathic" Dynamical Systems. *Complexity*, 13(3), pp.8-11.

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD1 Part1*. [video online] Available at <http://www.youtube.com/watch?v=obvzUj76eNo&list=PLB81F4FC0EDC4DECC&index=1> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD1 Part2*. [video online] Available at <http://www.youtube.com/watch?v=GfO0uaDKFZM&index=2&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD1 Part3*. [video online] Available at <http://www.youtube.com/watch?v=WxRryagIC4E&index=3&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD1 Part4*. [video online] Available at <http://www.youtube.com/watch?v=8d99orrkraI&index=4&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD1 Part5*. [video online] Available at <http://www.youtube.com/watch?v=f2LkQS8B75Y&index=5&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD1 Part6*. [video online] Available at <http://www.youtube.com/watch?v=Hsv7uF4GQio&list=PLB81F4FC0EDC4DECC&index=6> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part1*. [video online] Available at <http://www.youtube.com/watch?v=dIiQtqqrIfk&list=PLB81F4FC0EDC4DECC&index=7> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part2*. [video online] Available at <http://www.youtube.com/watch?v=uKENWP10M3E&index=8&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part3*. [video online] Available at <http://www.youtube.com/watch?v=qjUqrf85rXk&list=PLB81F4FC0EDC4DECC&index=9> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part4*. [video online] Available at <http://www.youtube.com/watch?v=_hndE3y8uGI&list=PLB81F4FC0EDC4DECC&index=10> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part5*. [video online] Available at <http://www.youtube.com/watch?v=dRh6PJyX0Eo&list=PLB81F4FC0EDC4DECC&index=11> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part6*. [video online] Available at <http://www.youtube.com/watch?v=2c7KDhsfOLo&index=12&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD2 Part7*. [video online] Available at <http://www.youtube.com/watch?v=bw0HxG3D5sk&list=PLB81F4FC0EDC4DECC&index=13> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD3 Part1*. [video online] Available at <http://www.youtube.com/watch?v=hHMY0NEbn2E&index=14&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD3 Part2*. [video online] Available at <http://www.youtube.com/watch?v=dRh6PJyX0Eo&list=PLB81F4FC0EDC4DECC&index=11> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD3 Part3*. [video online] Available at <http://www.youtube.com/watch?v=R9SggE9DCM0&list=PLB81F4FC0EDC4DECC&index=16> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD3 Part4*. [video online] Available at <http://www.youtube.com/watch?v=tLpmVUM2c5Q&list=PLB81F4FC0EDC4DECC&index=17> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD4 Part1*. [video online] Available at <http://www.youtube.com/watch?v=bHSNzAqxWy0&list=PLB81F4FC0EDC4DECC&index=18> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD4 Part2*. [video online] Available at <http://www.youtube.com/watch?v=3XlRbfhQvgA&list=PLB81F4FC0EDC4DECC&index=19> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD4 Part3*. [video online] Available at <http://www.youtube.com/watch?v=ohPSylG9lno&index=20&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD4 Part4*. [video online] Available at <http://www.youtube.com/watch?v=2w4c234NIMY&list=PLB81F4FC0EDC4DECC&index=21> [Accessed 25 Oct 2014].

IIISchannel, 2012. *6 Hours Tutorial Professor Umpleby delivered at WMSCI 2006 - DVD4 Part5*. [video online] Available at <http://www.youtube.com/watch?v=_QmKot1N2Ao&index=22&list=PLB81F4FC0EDC4DECC> [Accessed 25 Oct 2014].

Irmay, S., 1997. The relationship between Zipf's law and the distribution. *Journal of Applied Statistics*, 24(4), pp.383-393.

Irving, R.H. and Conrath, D.W., 1988. The Social Context of Multiperson, Multiattribute Decisionmaking. *IEEE Transactions on Systems, Man, and Cybernetics*, 18(3), pp.348-357.

Jackson, D.E. and Ratnieks, L.W., 2006. Communications in Ants. *Current Biology*, 16(15), pp.R570-R574.

Jackson, M.C., 2000. *Systems Approaches to Management*. New York: Plenum Publishers.

Javier Livas, 2009a. *Ashby's Law of Requisite Variety and Autonomy / Stafford Beer // Javier Livas*. [video online] Available at <http://www.youtube.com/watch?v=bDRudRhNgy4> [Accessed 5 Apr 2014].

Javier Livas, 2009b. *The Basis for the Viable System Model / Stafford Beer // Javier Livas*. [video online] Available at <http://www.youtube.com/watch?v=BaLHocBdG3A> [Accessed 5 Apr 2014].

Javier Livas, 2009c. *The Cybernetic Paradigm Part 2|2 Stafford Beer - Javier Livas*. [video online] Available at <http://www.youtube.com/watch?v=5yuLHUBuPzg> [Accessed 5 Apr 2014].

Javier Livas, 2009d. *The Cybernetic Paradigm, Part 1/2 Stafford Beer - Javier Livas*. [video online] Available at <http://www.youtube.com/watch?v=7O09FPHuCQQ> [Accessed 5 Apr 2014].

Javier Livas, 2011a. *The Intelligent Organization, PART 1 Stafford BEER // Javier Livas*. [video online] Available at <http://www.youtube.com/watch?v=7COX-b3HK50> [Accessed 5 Apr 20114].

Javier Livas, 2011b. *The Intelligent Organization, PART 2 Stafford BEER // Javier Livas*. [video online] Available at <http://www.youtube.com/watch?v=xxomXq-X1M0> [Accessed 5 Apr 2014].

Jenner, R.A., 1994. Changing Patterns of Power, Chaotic Dynamics and the Emergence of a Post-modern Organizational Paradigm. *Journal of Organizational Change Management*, 7(3), pp. 8-21.

Johnson, J. and Sugisaka, M., 2000. Complexity Science for the Design of Swarm Robot Control Systems. In: *26th Annual Conference of the IEEE Industrial Electronics Society*. Nagoya. 22-28 October 2000. IEEE.

Johnson, M. and Liber, O., 2008. The Personal Learning Environment and the human condition: from theory to teaching practice. *Interactive Learning Environments*, 16(1), pp.3-15.

Johnson, N.F., 2007. *Simply Complexity*. Oxford: Oneworld Publications.

Johnson, N.F., Choe, S.C., Gourley, S., Jarrett, T. and Hui, P.M., 2004. *Theory of Collective Dynamics in Multi-Agent Complex Systems*. [online] Available at <http://arxiv.org/pdf/cond-mat/0403158v1.pdf> [Accessed 26 Oct 2014].

Johnson, S., 2001. *Emergence*. London: Penguin Books.

Jones, W., 2014. *Question*. [email] (Personal communication, 13 November 2014).

Josephson, B.D. and Hauser, H.M., 1981. Multistage Acquisition of Intelligent Behaviour. *Kybernetes*, 10, pp.11-15.

Juan, L., Yaqi, D., Zhen, Z., Jin, L. and Qiping, H., 2012. Re-evaluation of Individual Performance in the 2012 UEFA Euro Cup Tournament. In: *2012 Eighth International Conference on Semantics, Knowledge and Grids*. 2012. IEEE.

Juarrero, A., 2000. Dynamics in Action: Intentional Behavior as a Complex System. *Emergence*, 2(2), pp.24-57.

Katare, S. and West, D.H., 2006. Optimal Complex Networks Spontaneously Emerge When Information Transfer is Maximised at Least Expense: A Design Perspective. *Complexit*y, 11(4), pp. 26-35.

Kauffman, S.A., 1991. *The Sciences of Complexity and "Origins of Order"*. [online] Available at <http://www.santafe.edu/media/workingpapers/91-04-021.pdf> [Accessed 26 Oct 2014].

Keller, E.F., 2005. Ecosystems, Organisms and Machines. *Bioscience*, 55(12), pp.1069-1074.

Kelso, J.A.S., 1995. *Dynamic Patterns: the Self Organisation of Brain and Behaviour.* Cambridge: MIT Press

Kennedy, F.D., 1979. A Model of Service Program Output Incorporating Behavioral Change. *IEEE Transactions on Systems, Man, and Cybernetics*, 9(9), pp.559-567.

Kim, D.H., 1993. The Link between Individual and Organisational Learning. *Sloan Management Review*, 35(1), pp.37-50.

Kincaid, R.K., Alexandrov, N. and Holroyd, M.J., 2008. An Investigation of Synchrony in Transport Networks. *Complexity*, 14(4), pp.34-43.

Kinser, W., 2008. Complexity and Its Measures in Cognitive and other Complex Systems. In: *Proceedings 7th IEEE Int. Conf. on Cognitive Informatics*.

Kitamura, Y. and Murao, T., 2004. Risk Management Methods for Speculative Actions. In: *Intelligent Agents and Multi-Agent Systems - 7th Pacific Rim International Workshop on Multi-Agents*, PRIMA 2004, Auckland, New Zealand, August 8-13, 2004, Revised Selected Papers, pp.92-103.

Klein, M., 1991. Supporting Conflict Resolution in Cooperative Design Systems. *IEEE Transactions on Systems, Man, and Cybernetics,* 21(6), pp-1379-1389.

Krause, J., Ruxton, G.D. and Krause, S., 2010. Swarm Intelligence in animals and humans. *Trends in Ecology & Evolution*, 25(1), pp.28-34.

Kreifeldt, J.G., 1972. A Dynamic Model of Behavior in a Discrete Open-Loop Self-Paced Motor Skill. *IEEE Transactions on Systems, Man, and Cybernetics*, 2(2), pp.262-273.

Kummamuru, S., 2012. Cybernetics Framework for addressing the people related challenges in an IT Services organization. In: *IEEE International Conference on Computational Intelligence and Cybernetics*. Bali, 12-14 July 2012. pp.103-107.

Kuninaka, H. and Matsushita, M., 2008. Why Does Zipf's Law Break Down in Rank-Size Distribution of Cities? *J. Phys. Soc. Jpn*. 77, 114801.

Labra, F., Marquet, P. and Bozinovic, F., 2007. *Scaling Metabolic Rate Fluctuations*. [online] Available at <http://www.santafe.edu/media/workingpapers/07-06-011.pdf> [Accessed 26 Oct 2014].

Laws, A.G., Taleb-Bendiab, A. and Wade, S.J., 2006. Genetically Modified Software: Realizing Viable Autonomic Agency. *Innovative Concepts for Autonomic and Agent-Based Systems Lecture Notes in Computer Science*, 3825, pp.184-196.

LeCouteur, A. and Feo, R., 2011. Real-time communications during play: Analysis of team-mate's talk and interaction. *Psychology of Sport and Exercise*, 12, pp.124-134.

Lee, C., 2004. Emergence and Universal Computation. *Metroeconomica* 55(2 & 3), pp.219-238.

Lee, S.M. and Pritchett, A., 2008. Predicting Interactions Between Agents in Agent-Based Modeling and Simulation of Sociotechnical Systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 38(6/ Part: A: Systems and Humans), pp.1210-1220.

Lefebvre, E. and Letiche, H., 1999. Managing Complexity from Chaos: Uncertainty, Knowledge and Skills. *Emergence,* 1(3), 7pp.7-15.

Lehner, P., Mir-Masood, S-S., O'Connor, M.F., Sak, S. and Mullin, T., 1997. Cognitive Biases and Time Stress in Team Decision Making. *IEEE Transactions on Systems, Man, and Cybernetics*, 20(5), pp.698-703.

Leonard, A, 20.n.d. *The VSM applied to Complex Organisations in Crisis*. [online] Allenna Leonard. Available at <http://allennaleonard.com/VSMCII.html> [Accessed 5 October 2014]

Leonard, A., 1992. Making Alphabet Soup: Blending VSM, STS and TQM. *Kybernetes*, 21(4), pp.33-42.

Leonard, A., 1993. Modelling Response to Catastrophe Using Beer's VSM: Viability for Effective Action. *Kybernetes,* 22(6), pp.79-90.

Leonard, A., 20.n.d. *To Change Ourselves: a Personal VSM Application*. [online] Allenna Leonard. Available at <http://allennaleonard.com/PersVSM.html> [Accessed 28 December 2011].

Leonard, A., 20.n.d. *Walking the Line: Making and Dissolving Distinctions with the Viable System Model and Team*

Syntegrity. [online] Allenna Leonard. Available at <http://allennaleonard.com/walking.html> [Accessed 28 December 2011].

Leonard, A., 2005. *Between Momentum and Control: a Dynamic of Democracy*. [online] Allenna Leonard. Available at <http://allennaleonard.com/Momentum%20and%20Control.html> [Accessed 28 December 2011].

Leonard, A., 2006. Momentum and control: a dynamic of democracy. *Kybernetes*, 35(1/2), pp.76-89.

Leonard, A., 2007. Symbiosis and the viable system model. *Kybernetes*, 36(5/6), pp.571-582.

Leonard, A., 2009. The Viable System Model and Its Application to Complex Organizations. *Syst Pract Res*, 22, pp.223-233.

Leonard, A., 2010. *Governance in the relative when*. [online] Allenna Leonard. Available at: <http://allennaleonard.com/GOVERNANCE%20IN%20THE%20RELATIVE%20WHEN.html> [Accessed 28 December 2011].

Leonard, A., 2014. *Syntegration*. [email] (Personal communication, 27 August 2014).

Letiche, H., 2000. Self-Organization, Action Theory, and Entrainment. *Emergence*, 2(2), pp.58-71.

Lewis, G.J. and Stewart, N., 2003. The Measurement of Environmental Performance: An Application of Ashby's Law. *Systems Research and Behavioral Science Syst. Res*. 20, pp.31-52.

Lewis, G.J., 1997. A Cybernetic view of Environmental Management: The Implications for Business Organisations. *Business Strategy and the Environment*, 6, pp.264-275.

Li, W., 1991. *Random Texts Exhibit Zip's Law-Like Word Frequency Distribution*. [online] Available at <http://www.santafe.edu/media/workingpapers/91-03-016.pdf> [Accessed 26 Oct 2014].

Lissack, M.R., 1999. Complexity: the Science, its Vocabulary, and its Relation to Organizations. *Emergence*, 1(1), pp.110-126.

Long, Y., Liu, K. and Huang, S., 2010. A control strategy for large-scale system based on the synergy among material flow, energy flow and information flow. In: *2nd International Conference on Computer Engineering and Technology (ICCET)*, 2010 , Volume: 4 Source: IEEE Xplore

Macedo, L. and Cardoso, A., 2004. Exploration of Unknown Environments with Motivational Agents. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems*. New York, NY, USA. 2004. AAMAS 2004.

Maes, P., 1995. Artificial Life Meets Entertainment: Lifelike Autonomous Agents. *Communications of the ACM*, 38(11), pp.108-114.

Malik, C., 2014. *Syntegration*. [email] (Personal communication, 27 August 2014).

Malik, D.S., 2010. *Java Programming: From Problem Analysis to Program Design*. International 4th ed. Boston: Course Technology, Cengage Learning.

Mallubhatla, R., Pattipati, K.R., Kleinman, D.L. and Tang, Z.B., 1991. A Model of Distributed Team Information Processing under Ambiguity. *IEEE Transactions on Systems, Man, and Cybernetics*, 21(4), pp.713-725.

Mansfield, J., 2010.*The Nature of Change or the Law of Unintended Consequences*. London: Imperial College Press.

Marion, R. and Bacon, J., 2000. Organizational Extinction and Complex Systems. *Emergence*, 1(4), pp.71-96.

Matsuno, K., 1978. Evolution and Stability of an Autonomous System Subjected to Interdependent Decisionmakers. *IEEE Transactions on Systems, Man, and Cybernetics*, 8(7), pp.534-539.

May, C.J., Schank, J.C., Joshi, S., Tran, J., Taylor, R.J., and Scott, I., 2006. Rat Pups and Random Robots Generate Similar Self-Organized and Intentional Behavior. *Complexity*, 12(1), pp.53-66.

Mayer-Kress, G., Liu, Y-T. and Newell, K.M., 2006. Complex Systems and Human Movement. *Complexity*, 12(2), pp. 40-51.

McClelland, K., 1994. Perceptual Control and Social Power. *Sociological Perspectives*, 37(4), pp.461-496.

McLurkin, J. and Yamins, D., 2004? *Dynamic Task Assignment in Robot Swarms*. [online] Available at <http://www.eecs.harvard.edu/~rad/courses/cs266-fall04/papers/rss05-mclurkin-yamins.pdf> [Accessed 7th October 2014].

Medeiros, J., 2011. *Football's Panopticon*. Wired Magazine, Aug. p.38a.

Medina, E., 2002a. *Designing Freedom, Regulating a Nation: Socialist Cybernetics in Allende's Chile*. [online] Available at <http://web.mit.edu/sts/pubs/pdfs/MIT_STS_WorkingPaper_34_Miller.pdf> [Accessed 6th October 2014].

Medina, E., 2002b. Designing Freedom, Regulating a Nation: Socialist Cybernetics in Allende's Chile. *Working Paper #34, Program in Science, Technology, and Society*, Massachusetts Institute of Technology.

Medina, E., 2011. *Cybernetic Revolutionaries*. Cambridge: The MIT Press.

Miller, J.H. and Moser, S., 2004. Communication and Coordination. *Complexity*, 9(5), pp.31-40.

Miller, J.H. and Page, S.E., 2004. The Standing Ovation Problem. *Complexity*, 9(5), pp.8-16.

Miller, J.H. and Page, S.E., 2007. *Complex Adaptive Systems*. Princeton: Princeton University Press.

Miller, P., 2010. *Smart Swarm: using Animal behaviour to change our world*. London: Collins.

Mitchell, M., 1998. *A Complex-Systems Perspective on the "Computation vs. Dynamics" Debate in Cognitive Science*. [online] Available at <http://www.santafe.edu/media/workingpapers/98-02-017.pdf> [Accessed 26 Oct 2014].

Mitchell, M., 2006a. *Complex Systems*. [online] Available <http://www.santafe.edu/media/workingpapers/06-10-036.pdf> [Accessed 26 Oct 2014].

Mitchell, M., 2006b. Complex Systems: Network thinking. *Artificial Intelligence*, 170, pp.1194-1212.

Mitchell, M., 2009. *Complexity: A Guided Tour*. New York: Oxford University Press.

Moffat, J. and Campbell, I., 2004. Intelligent Behavior is a Partly Emergent Process for Agents in Conflict. *IEEE Transactions on Systems, Man, and Cybernetics*, 34(3), pp.371-375.

Morlidge, S.P., 2009. Money, Time and Variety Engineering: The Application of Cybernetics to the Diagnosis and Design of Financial Performance Management Systems. *Syst Pract Res*, 22, pp.235-247.

Mouaddib, A-I, and Jeanpierre, L., 2011. Decentralized decision-making technique for dynamic coalition of resource-bounded autonomous agents. *International Journal of Intelligent Computing and Cybernetics*, 4(2), pp.228-242.

Mowles, C., Stacey, R. and Griffin, D., 2008. What contribution can insights from the Complexity Sciences make to the theory and practice of Development Management? *Journal of International Development*, 20, pp.804-820.

Nechansky, H., 2007. Elements of a cybernetic epistemology. *Kybernetes*, 36(2), pp.157-174.

NeuralOutlet, 2013. *Warren McCulloch Interview (1969)*. [video online] Available at <http://www.youtube.com/watch?v=MTmR6X2w8Tg&list=PL5mwE5MDZICs48phKale8qga2eDPjYB1Y> [Accessed 5 Apr 2014].

Nevitt, B., 1976. Anticipating Fate: Beyond Feedback to Feedforward by Process Pattern Recognition. *Kybernetes*. 5, pp-221-228.

Newman, M.E.J., 2011. *Complex Systems: A Survey*. [online] Available at <http://arxiv.org/pdf/1112.1440v1.pdf> [Accessed 26 Oct 2014].

Newman, M.E.J., 2013. *Networks - An Introduction*. Oxford: Oxford University Press.

Nicolis, S.C., Despland, E. and Dussutour, A., 2008. Collective decision-making and behavioral polymorphism in group living organisms. *Journal of Theoretical Biology*, 254, pp.580-586.

Nieves, J.M. and Sage, A.P., 1998. Human and Organizational Error as a Basis for Process Reengineering: With Applications to Systems Integration Planning and Marketing. *IEEE Transactions on Systems, Man, and Cybernetics*, 28(6), pp.742-762.

Nishimura, S.I. and Ikegami, T., 1997. Emergence of Collective Strategies in a Prey-Predator Game Model. *Artificial Life*, 3, pp.243-260.

Norrelykke, S.F. and Bak, P., 2000. Self-Organized Criticality in a Transient System. *Phys. Rev. E 65*, p.036147 (2002)

Olguin, D.O., Waber, B.N., Kim, T, Mohan, A., Ara, K. and Pentland, A., 2009. Sensible Organisations: Technology and Methodology for Automatically Measuring Organisational Behavior. *IEEE Transactions on Systems, Man, and Cybernetics*, 39(1), pp.43-55.

O'Malley, M., 2010. *The Wisdom of Bees*. London: Penguin Group.

Paczuski, M. and Bak, P., 1999. Self-Organization of Complex Systems. In: *Proceedings of 12th Chris Engelbrecht Summer*

School.

Page, S.E., 2007. *The Difference*. Princeton: Princeton University Press.

Page, S.E., 2011. *Diversity and Complexity*. Princeton: Princeton University Press.

Panait, L. and Luke, S., 2004. A Pheromone-Based Utility Model for Collaborative Foraging. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems*. Washington DC, USA. Pp.36-43, June 2004.

Pangaro, P., 2009. How can I put That? - Applying Cybernetics to "Conversational Media" (based on a presentation given). In: *American Society for Cybernetics (Annual Conference)*, Olympia, Washington, USA, March 2009. New York: Paul Pangaro.

Pankiw, T., 2005. The Honeybee Foraging Behavior Syndrome: Quantifying The Response Threshold Model of Division of Labor. In: *Swarm Intelligence Symposium*. Proceedings IEEE, 8-10 June 2005

Papagallis, 2010. *The Experimenters - Gordon Pask - 1974 BBC*. [video online] Available at <http://www.youtube.com/watch?v=yt-fXmzF9WQ > [Accessed 10 June 2014].

Pask, G., 1968. *An approach to Cybernetics*. London: Hutchinson & Co.

Pask, G., 1975. *The Cybernetics of Human Learning and Performance*. London: Hutchinson & Co.

Pask, G., 1976. *Conversation Theory: Applications in Education and Epistemology*. Amsterdam: Elsevier Scientific Publishing Company.

Pask, G., 1980. *The Limits of Togetherness*. Proceedings, Invited Keynote address to IFIP, World Congress in Tokyo and Melbourne, Editor, S. Lavington. Amsterdam, New York, Oxford: North Holland Pub. Co., 1980, 999-1012. [online] Available at <http://pangaro.com/pask/pask%20limits%20of%20togetherness.pdf> [Accessed 5th October 2014].

Patel, R., Mitchell, R.J. and Warwick, K., 2005. Intelligent agents and distributed models for cooperative support. *Kybernetes*, 34(9/10), pp.1456-1468.

Peck, G., 2004. *Crystal Reports 10: The Complete Reference*. California: McGraw-Hill.

Pentecost, A., 1999. *Analysing Environmental Data*. Essex: England.

Pérez Rios, J., 2010. Models of organizational cybernetics for diagnosis and design., *Kybernetes*, 39(9/10), pp.1529-1550.

Peroff, N.C., 1999. Is Management an Art of a Science? A Clue in Consilience. *Emergence*, 1(1), pp.92-109.

Pĕrse, M., Kristan, M., Kovačič, S., Vučkovič, G. and Perš, J., 2009. A trajectory-based analysis of coordinated team activity in a basketball game. *Computer Vision and Image Understanding*, 113, pp.612-621.

Petit, O. and Bon, R., 2010. Decision-making processes: The case of collective movements. *Behavioural Processes*, 84, pp.635-647.

Pfiffner, M., 2010. Five experiences with the viable system model. *Kybernetes*, 39(9/10), pp.1615-1626.

Pfiffner, M., 2014. *Syntegration*. [email] (Personal communication, 3 September 2014).

Pickering, A., 2002. Cybernetics and the Mangle: Ashby, Beer and Pask. *Social Studies of Science*, 32(3), pp.413-437.

Pickering, A., 2004. The science of the unknowable: Stafford Beer's cybernetic informatics. *Kybernetes*, 33(3/4), pp.499-521.

Pickering, A., 2009. Beyond Design: Cybernetics, Biological Computers and Hylozoism. *Synthese*, 168(3), pp.469-491.

Pickering, A., 2010. *The Cybernetic Brain: Sketches of another Future*. Chicago: The University of Chicago Press.

Prokopenko, M., Boschetti, F. and Ryan, A.J., 2008. An Information-Theoretic Primer on Complexity, Self-Organization, and Emergence. *Complexity*, 15(1), pp.11-28.

Rai, V.K., 2013. Systems Oriented Approach to Production Support - A Viable Framework. In: *2013 IEEE International Conference on Systems, Man, and Cybernetics*. IEEE Computer Society

Rapoport, A., 1950-51. Mathematical Biophysics, Cybernetics and Significs. *Synthese*, 8(3/5), pp.182-193.

Reas, C. and Fry, B., 2007. *Processing: A Programming Handbook for Visual Designers and Artists*. Cambridge: The MIT Press.

Regine, B. and Lewin, R., 2000. Leading at the Edge: How Leaders Influence Complex Systems. *Emergence*, 2(2), pp.5-23.

Richter, J. and Basten, D., 2014. Applications of the Viable Systems Model in IS Research - A comprehensive Overview and Analysis. In: *2014 47th Hawaii International Conference on System Science*. IEEE Computer Society.

Rose, J., 1969. *Progress of Cybernetics*. London: Gordon and Breach Science Publishers.

Rothman, M.A., 1972. *Cybernetics - Machines that make Decisions*. Great Britain: Collins Publishers.

Rulence-Pâques, Fruchart, E., Dru, V. and Mullet, E., 2005. Decision-making in soccer game: a developmental perspective. *Revue européenne de psychologie appliquée*, 55, pp.131-136.

Sabelli, H. and Kovacevic, L., 2007. Biotic Complexity of Population Dynamics. *Complexity*, 13(4), pp.47-55. March /April 2008.

Sage, A.P., 1981. Behavioral and Organizational Considerations in the Design of Information Systems and Processes for Planning and Decision Support. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(9), pp.640-678.

Saichev, A., Malevergne, Y. and Sornette, D., 2009. Theory of Zipf's Law and of General Power Law Distributions with Gibrat's law of Proportional Growth. *Lecture Notes in Economics and Mathematical Systems*, 632.

Sánchez-Escribano, M.G. and Sanz, R., 2014. Emotions and the Engineering of Adaptiveness in Complex Systems. In: *Conference on Systems Engineering Research (CSER 2014)*. Reondo Beach, CA, March 21-22, 2014. Elsevier.

Sanz, R., Sánchez-Escribano, G. and Herrera, C., 2013. A Model of Emotion as Patterned Metacontrol. *Biologically Inspired Cognitive Architectures*, 4, pp.79-97.

Schaurhofer, M. and Peschl, M.F., 2005. Autonomy: starting point and goal of personal and social change. *Kybernetes*, 34(1/2), pp.261-277.

Scherrer-Rathje, M., Arnscht, J., Egri, P., Braun, E., Csáji, B.S. and Schuh, G., 2009. A Genetic Model to Handle Complexity in Collaborative Networks. In: *PICMET 2009 Proceedings*. Portland, Oregon, USA. Aug 2-6 2009. PICMET.

Schmidt, A., 2012. Movement pattern recognition in basketball free-throw shooting. *Human Movement Science*, 31, pp.360-382.

Schroeder, W.W., 1972. System Dynamics: A Unique Tool for Analyzing Data-Deficient Social Systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 2(2), pp.217-220.

Schwager, M. McLurkin, J., Slotine, J-J.E. and Rus, D. *From Theory to Practice: Distributed Coverage Control Experiments with Groups of Robots*. [online] Available at <https://groups.csail.mit.edu/drl/wiki/images/5/5a/SchwagerISER08.pdf> [Accessed 7th October 2014]

Schwaninger, M. and Koerner, M., 2004. City Planning "Dissolving" urban problems insights from an application of management cybernetics. *Kybernetes*, 33(3/4), pp.557-576.

Schwaninger, M. and Pérez-Rios, J., 2008. System dynamics and cybernetics: a synergistic pair. *System Dynamics Review*, 24(2), pp.145-174.

Schwaninger, M., 2001. Intelligent Organizations: An Integrative Framework. *Systems Research and Behavioral Science Syst. Res.*, 18, pp.137-158.

Schwaninger, M., 2006. Theories of Viability: a Comparison. *Systems Research and Behavioral Science Syst. Res*. 23, pp.337-347.

Schwaninger, M., 2007. Optimal structures for social systems. *Kybernetes*, 36(3/4), pp.307-318.

Seminar - The Will of the People? 1982. [video] Middlesex: Middlesex Polytechnic (Seminar presented by Stafford Beer)

Seuront, L., 2013. Complex dynamics in the distribution of player's scoring performance in Rugby Union world cups. *Physica A*, 392, pp.3731-3740.

Shen, J., Zhang, X., and Lesser, V., 2004. Degree of local cooperation and its implication on global utility. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems-Volume 2 (pp. 546-553)*. IEEE Computer Society.

Shiffman, D., 2008. *Learning Processing*. Burlington: Morgan Kaufmann Publishers.

Shiffman, D., 2012. *The Nature of Code*. New York: Self Published Book.

Sice, P. and French, I., 2006. A holistic frame-of-reference for modelling social systems. *Kybernetes*, 35(6), pp.851-864.

Simon, T.W., 1976. A Cybernetic Analysis of Goal-Directedness. In: *Proceedings of the Biennial Meeting of the Philosophy of Science Association. Volume One: Contributed Papers (1976*), pp.56-67.

Singh, C.M. and Singh, M.G., 1978. An Exploratory Analysis of Organisational Hierarchies from an Engineering Point of View. *IEEE Transactions on Systems, Man, and Cybernetics*, 8(3), pp.205-208.

Sistemas Sociales, 2014. *Sketches of Another Future an Interview with Andrew Pickering*. [video online] Available at <http://www.youtube.com/watch?v=juGIXi6Lyek> [Accessed 10 June 2014].

Skyttner, L., 1998. Information Theory - a psychological study in old and new concepts. *Kybernetes*, 27(3), pp.284-311.

Smith, R.G, 1981. Frameworks for Cooperation in Distributed Problem Solving. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(1), pp.61-70.

Solé, R.V., Bonabeau, E., Garcia-Fernandez, J. Fernandez, P. and Marin, J., 1999. *Pattern Formation and Optimization in Army Ant Raids*. [online] Available at <http://www.santafe.edu/media/workingpapers/99-10-074.pdf> [Accessed 26 Oct 2014].

Southorn, G. and Sparrow, G., 2016. *Physics Squared*. London: Apple Press

Stanton, J. and Jackson, A.., Leicester City: Facts & figures behind Premier League title win [online] Available at < http://www.bbc.co.uk/sport/football/36166146 > [Accessed 10 May 2016].

Stassinopoulos, D. and Bak, P., 1996. *Democratic Reinforcement: Learning via Self-Organization*. [online] Available at <http://arxiv.org/pdf/cond-mat/9601113v1.pdf> [Accessed 7th October 2014].

Steeb, R. and Johnson, S.C., 1981. A Computer-Based Interactive System for Group Decisionmaking. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(8), pp.544-552.

Stern, K.L., 2012. HungarianAlgorithm.java. [computer program] Kevin Stern. Available at <//https://github.com/KevinStern/software-and-algorithms/blob/master/src/main/java/blogspot/software_and_algorithms/stern_library/optimization/HungarianAlgorithm.java> [Accessed 30 May 2014].

Student Seminar - What is Cybernetics? 1991. [video] Liverpool: Liverpool John Moores University (Seminar presented by Stafford Beer)

Sundarasaradula, D., Hasan, H., Walker, D.S. and Tobias, A.M., 2005. Self-organization, evolutionary and revolutionary change in organizations. *Strategic Change*, 14, pp.367-380.

Surowiecki, J., 2004. *The Wisdom of Crowds: Why the many are smarter than the few*. London: Little, Brown.

Szczerbicki, E., 1991. Information Flow Evaluation in Autonomous Groups Functioning. *IEEE Transactions on Systems, Man, and Cybernetics*, 21(2), pp.402-408.

Taha, H.A., 2006. *Operations Research: An Introduction* (8th Edition). London: Prentice Hall.

Takatsu, S., 1984. Organizational Equilibrium Under Uncertainty. *Kybernetes*, 13, pp.87-92.

Tarride, M.I., 2003. System's identity conservation requirements. *Kybernetes*, 32(9/10), pp.1464-1472.

Tasaka, H., 1999. Twenty-first-century Management and the Complexity Paradigm. *Emergence*, 1(4), pp.115-123.

Tenney, R.R. and Sandell, N.R., 1981. Structures for Distributed Decisionmaking. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(8), pp.517-527.

Terzidis, K.,2009. *Algorithms for Visual Design using the Processing Language*. Indianapolis: Wiley Publishing , Inc.

Theodoridis, G.C., 1973. On the Quantitative Formulation of the Human Reward Function. *Kybernetes*, 11(2), pp-101-105.

Thompson, R.J., Laws, A.G., Reilly, D.J. Taleb-Bediab, A. and Llewellyn-Jones, D., 2010. A Cybernetic Case Study of Viable Computing Systems: A Framework for Requisite Variety via Algorithmic Hot-Swapping. In: *IEEE 9th International Conference on Cybernetic Intelligent Systems*. Reading, 1-2 September 2010. pp.1-6. IEEE.

Thompson, R.J., Laws, A.G., Reilly, D.J. Taleb-Bediab, A. and Llewellyn-Jones, D., 2010. An Open-Bounded Cybernetic Case Study of Viable Computing Systems: Applying Directive Correlation to an Algorithmic Hot-Swapping Scenario. In: *IEEE 9th International Conference on Cybernetic Intelligent Systems*. Reading, 1-2 September 2010. pp.1-6. IEEE.

Tilebein, M., 2006. A complex adaptive systems approach to efficiency and innovation. *Kybernetes*, 35(7/8), pp.1087-1099.

Tivan, B.F., 2005. Coevolutionary Dynamics and Agent-Based Models in Organization Science. In: *Proceedings of the 2005 Winter Simulation Conference* eds. Kuhl, M., Armstrong, F.B. and Joines, J.A., 2005.

Trachtenberg, M., 1992. Why Failure Rates Observe Zipf's Law in Operational Software. *IEEE Transactions on Reliability*, 41(3), pp.386-389.

Travassos, B., Araújo, D., Davids, K., Vilar, L., Esteves, P. and Vanda, C., 2011. Informational constraints shape emergent functional behaviours during performance of interceptive actions in team sports. *Psychology of Sport and Exercise*, 13, pp. 216-223.

Travassos, B., Araújo, D., Duarte, R. and McGarry, T., 2012. Spatiotemporal coordination behaviors in futsal (indoor football) are guided by informational game constraints. *Human Movement Science*, 31, pp.932-945.

Travassos, B., Araújo, D., Vilar, L. and McGarry, T., 2011. Interpersonal coordination and ball dynamics in futsal (indoor football). *Human Movement Science*, 30, pp.1245-1259.

Trianni, V. and Nolfi, S., 2009. *Self-Organising Sync in a Robotic Swarm*. *IEEE Transactions on Evolutionary Computation*, 13(4), pp.722-741.

Trianni, V., Ampatzis, C., Christensen, A.L., Tuci, E., Dorigo, M. and Nolfi, S., 2007. *From Solitary to Collective Behaviours: Decision Making and Cooperation*. In: Proceedings Advances in Artificial Life (9th European Conference, ECAL 2007, Lisbon, Portugal, September 10-14, 2007). Pp.575-584.

Trianni, V., Nolfi, S. and Dorigo., M., 2008. *Evolution, Self-Organisation and Swarm Robotics*. In: Swarm Intelligence - Introduction and Applications (Part 2). pp.163-191.

Tuan, N-T., 2004. On the complex problem: a study of interactive management. *Kybernetes*, 33(1), pp.62-79.

Tϋrke, R-E., 2006. Towards productive and sustainable forms of interaction in governance. *Kybernetes*, 35(1/2), pp. 164-181.

Venkatasubramanian, V., 2006. A theory of design of Complex Teleological Systems: Unifying the Darwinian and Boltzmannian Perspectives. *Complexity*, 12(3), pp.14-21.

Vidgen, R., 1998. Cybernetics and Business Processes: Using the Viable System Model to Develop an Enterprise Process Architecture. *Knowledge and Process Management*, 4(2), pp.118-131.

Viroli, M. and Ricci, A., 2004. Instructions-Based Semantics of Agent Mediated Interaction. In: *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems.* New York, NY, USA. 2004. AAMAS 2004.

Von Foerster, H., 1974. *Cybernetics of Cybernetics*. The Cybernetician, No. 8. BCL Report No. 73.38

Wallace, J.L. and Norton, K.I., 2014. Evolution of World Cup soccer final games 1966-2010: Game structure, speed and play patterns. *Journal of Science and Medicine in Sport*, 17, pp.223-228.

Wallace, M.R., 1979. Applications of Ultrastability. *Kybernetes*, 8, pp.185-191.

Wang, C. and Mukhopadhyay, A., 2012. The Dynamics of Goal Revision: A Cybernetic Multiperiod Test-Operate-Test-Adjust-Loop (TOTAL) Model of Self-Regulation. *Journal of Consumer Research*, 38(5), pp.815-832.

Weick, K.E., 1987. Organizational Culture as a Source of High Reliability. *California Management Review*, XX1X (2), pp.112-127.

Wesson, R., Hayes-Roth, F., Burge, J.W., Stasz, C. and Sunshine, C.A., 1981. Network Structures for Distributed Situation Assessment. *IEEE Transactions on Systems, Man, and Cybernetics*, 11(1), pp.5-23.

West, B.J., 2006. Thoughts on Modeling Complexity. *Complexity*, 11(3), pp.33-43.

West, G.B., Brown, J.H. and Enquist, B.J., 1997. *A General Model for the Origin of Allometric Scaling Laws in Biology*. [online] Available at <http://www.santafe.edu/media/workingpapers/97-03-019.pdf> [Accessed 26 Oct 2014].

White, D., Owen-Smith, J., Moody, J. and Powell, W., 2004. *Networks, Fields, and Organizations: Micro-Dynamics, Scale and Cohesive Embeddings*. [online] Available at <http://www.santafe.edu/media/workingpapers/04-03-009.pdf> [Accessed 26 Oct 2014].

Whittaker, D. ed., 2009. *Think before you think*. Oxon: Wavestone Press.

Wiener, N., 1965. *Cybernetics: or control and communication in the Animal and the Machine*. 2nd ed. Cambridge: The MIT Press.

Winter, H., Top 20 sporting moments of the decade: Liverpool's 'Miracle of Istanbul'. [online] Available at <http:// http://www.telegraph.co.uk/sport/football/teams/liverpool/6653607/Top-20-sporting-moments-of-the-decade-Liverpools-Miracle-of-Istanbul.html> [Accessed 12 April 2016].

Wisbey, B., Montgomery, P.G., Pyne, D.B. and Rattray, B., 2010. Quantifying movement demands of AFL football using GPS tracking. *Journal of Science and Medicine in Sport*, 13, pp.531-536.

Wolpert, D.H. and MacReady, W., 2007. Using Self-dissimilarity to Quantify Complexity. *Complexity*, 12(3), pp.77-85.

Wooldridge, M., 1996. What Agents Aren't: A Discussion. In: *IEE Colloquium on Intelligent Agents and Their Applications*, (Digest No: 1996/101).

WOSCORG, 2012a. *StaffordBeer1*. [video online] Available at <http://www.youtube.com/watch?v=1IWXojPJdYg&list=UUGb3q0R00dU35Fem8WPI8fg> [Accessed 28 May 2014]

WOSCORG, 2012b. *StaffordBeer2*. [video online] Available at <http://www.youtube.com/watch?v=ftqLUqry63Y&list=PLk6K2ebGeTHxVTiBglBXJUXNLnHFwgMqn> [Accessed 28 May 2014]

WOSCORG, 2012c. *StaffordBeer3*. [video online] Available at <http://www.youtube.com/watch?v=DSYuoFZvvKA&list=UUGb3q0R00dU35Fem8WPI8fg> [Accessed 28 May 2014]

WOSCORG, 2012d. *StaffordBeer4*. [video online] Available at <http://www.youtube.com/watch?v=UH6nsMqeii0&list=UUGb3q0R00dU35Fem8WPI8fg> [Accessed 28 May 2014]

WOSCORG, 2012e. *StaffordBeer5*. [video online] Available at <http://www.youtube.com/watch?v=c2H_0_u1YtU&list=UUGb3q0R00dU35Fem8WPI8fg> [Accessed 28 May 2014]

WOSCORG, 2012f. *StaffordBeer6*. [video online] Available at <http://www.youtube.com/watch?v=afNm0FTCnyk&list=UUGb3q0R00dU35Fem8WPI8fg> [Accessed 28 May 2014]

Yijun, Z. and Xuejun, W., 2008. Study on Corporate Culture Evolution - From the view of Complexity Science. In: *4th International Conference on Wireless Communications Networking and Mobile Computing*. Dalian. 12-14 Oct. IEEE.

Yolles, M., 1999. *Management Systems : a viable approach*. London: Financial Times Management.

Yolles, M., 2000. Organisations, complexity, and viable knowledge management. *Kybernetes* 29(9/10), pp.1202-1222.

Yolles, M., 2001a. Implications for Beer's ontological system/metasystem dichotomy. *Kybernetes*, 33(3/4), pp.726-764.

Yolles, M., 2001b. Viable Boundary Critique. *The Journal of the Operational Research Society*. 52(1), pp.35-47.

Yolles, M., 2003. The political cybernetics of organisations. *Kybernetes*, 32(9/10). pp.1253-1282.

Yolles, M., 2006. Revisiting the political cybernetics of organisations. *Kybernetes*, 34(5), pp.617-636.

Youssefmir, M., and Huberman, B.A., 1995. *Clustered Volatility in Multiagent Dynamics*. [online] Available at <http://www.santafe.edu/media/workingpapers/95-05-051.pdf> [Accessed 26 Oct 2014].

Yu, E.S.K. and Mylopoulos, J., 1996. AI Models for Business Process Reengineering. *IEEE Expert*, 11(4), pp.16-23.

Zexian, Y., 2007. A New Approach to Studying Complex Systems. *Systems Research and Behavioral Science Syst. Res.*, 24, pp.403-416.

Appendix 1 – Actual Policy Characteristics

Each page depicts two such plots i.e. one for the first half of each football match and one for the second half such that the differences between them may be discerned. Moreover, each plot features an orange line that represents the Linear Regression line that was fitted to the plotted data (in black) by Minitab17.

Each plot is suitably coded. The coding scheme used is: **mX-ta-HZ Only**

Where:

X is the match number (1 to 37);

a is the Team identifier;

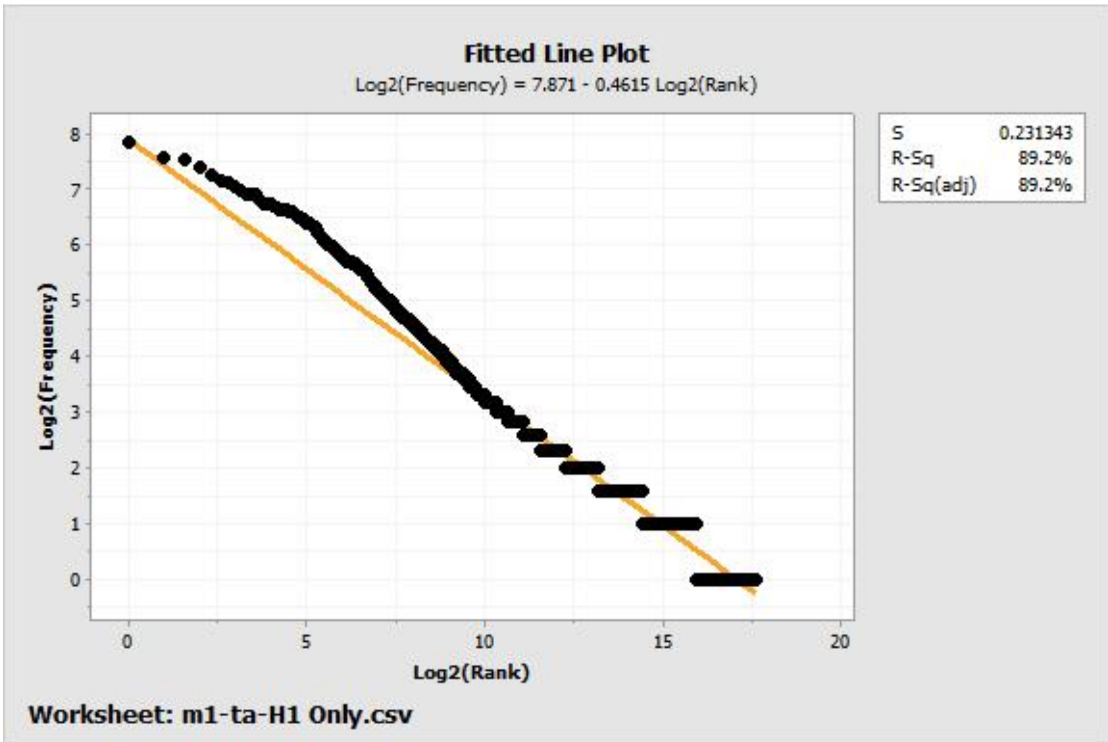
Z is the Half (1st (1) or 2nd (2))

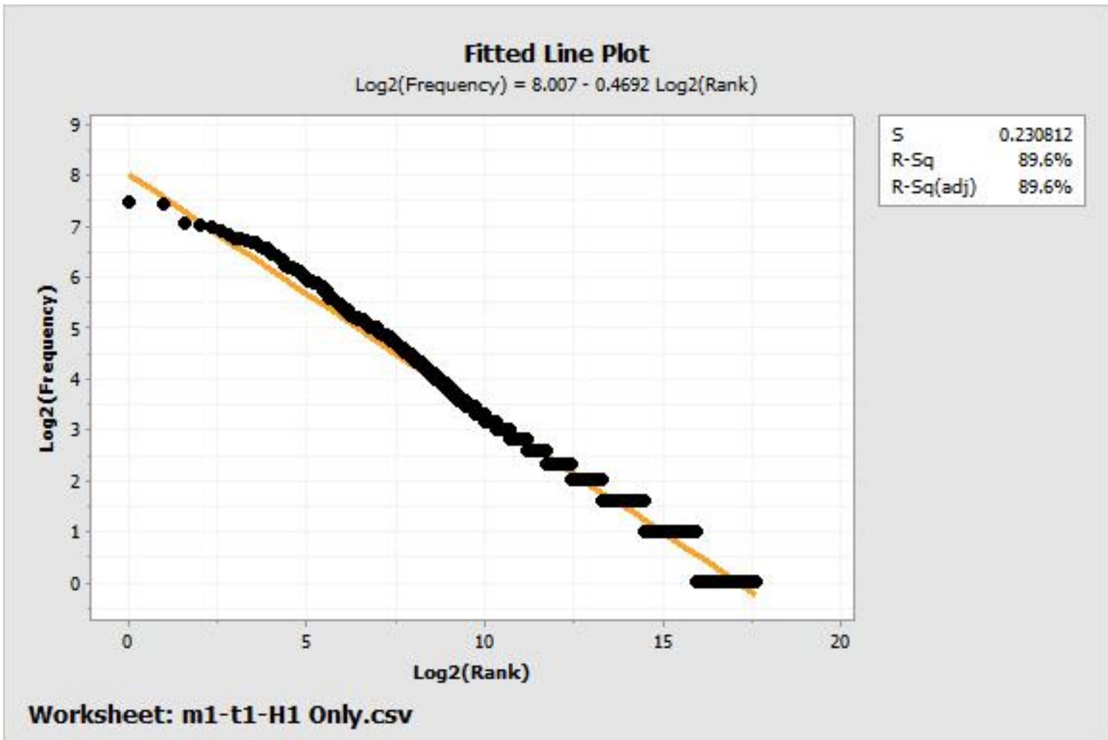
Example:

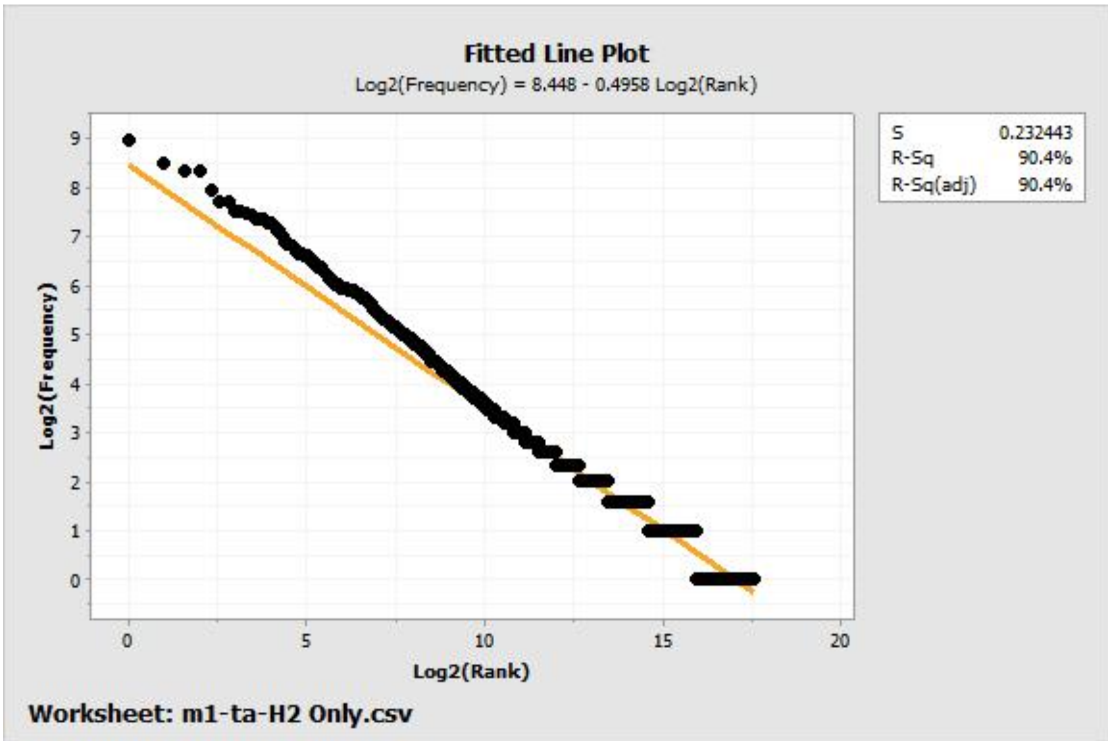
m1-ta-H1 Only

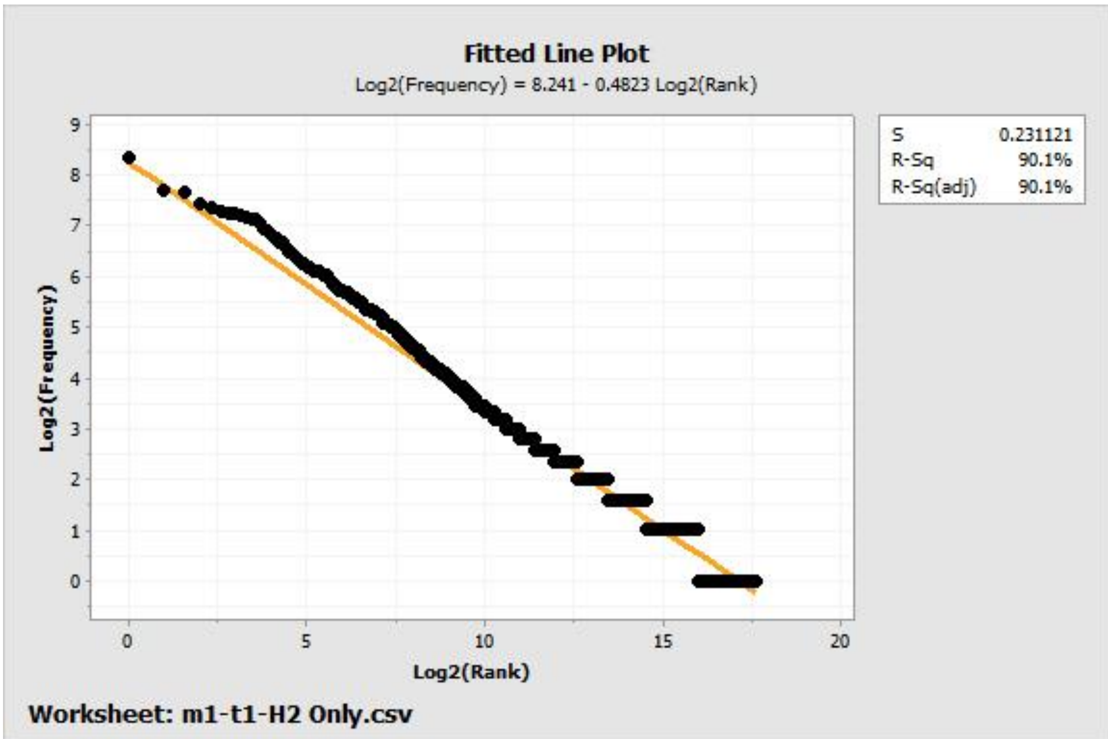
This means:

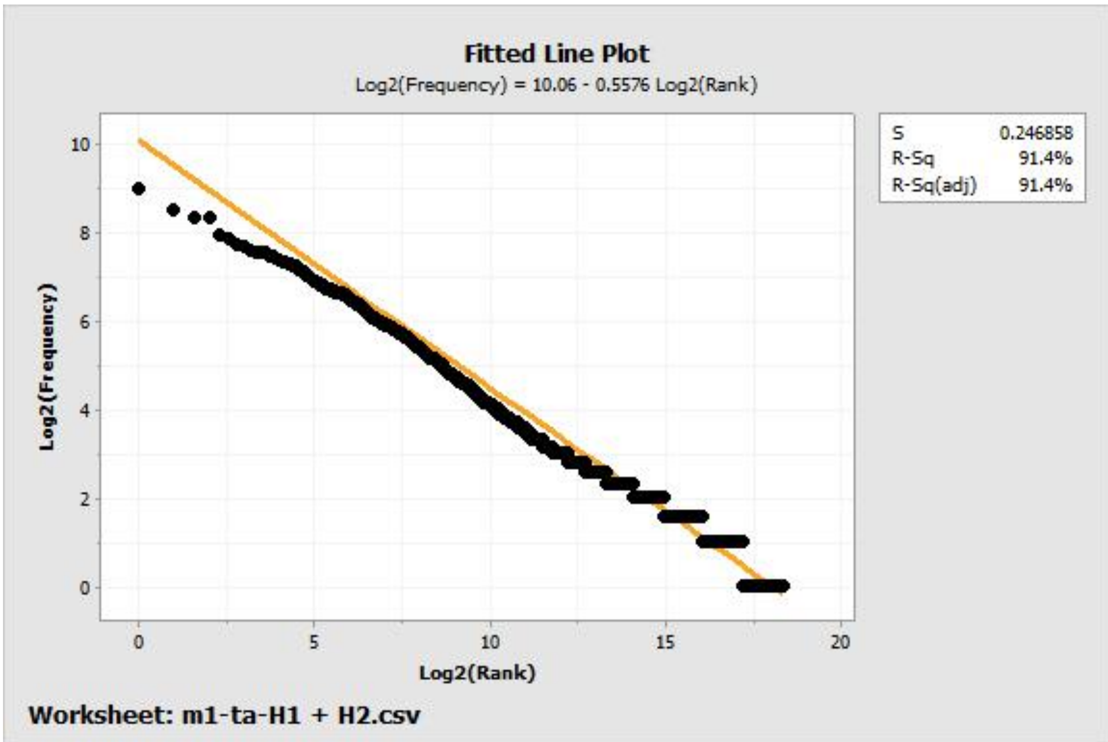
Match 1; Team A (a); Half 1 (1) Only

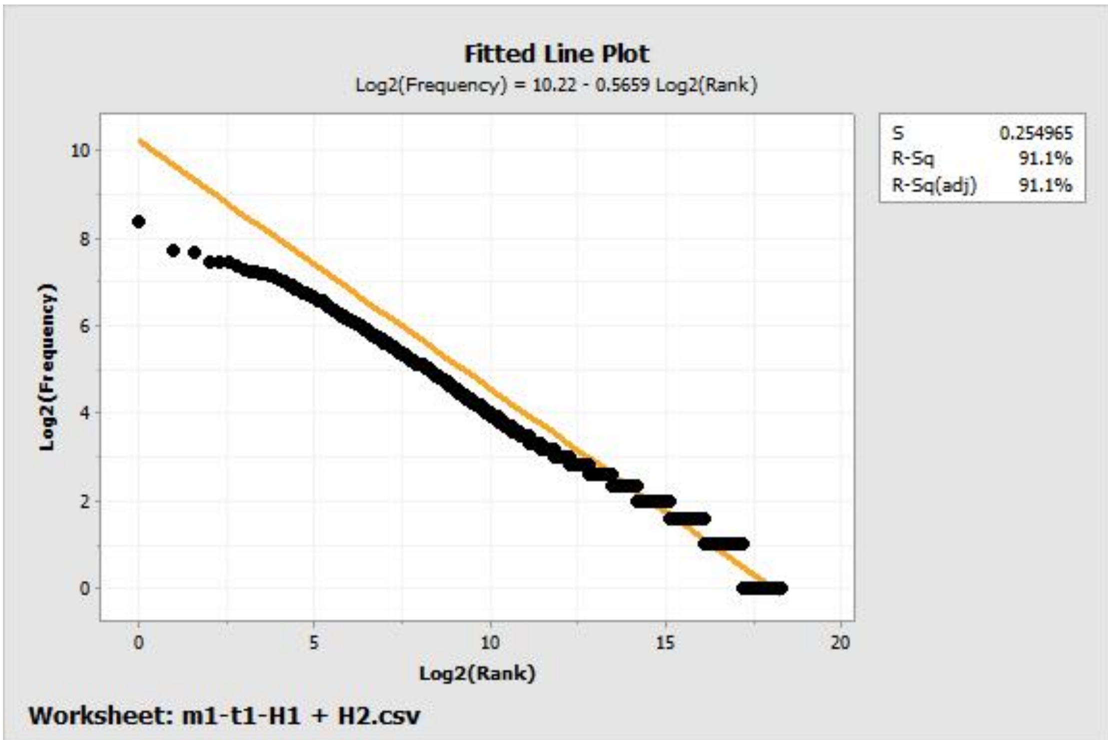

Fitted Line Plot
Log2(Frequency) = 7.871 - 0.4615 Log2(Rank)
S 0.231343
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
0
5
10
15
20
0
1
2
3
4
5
6
7
8
Worksheet: m1-ta-H1 Only.csv

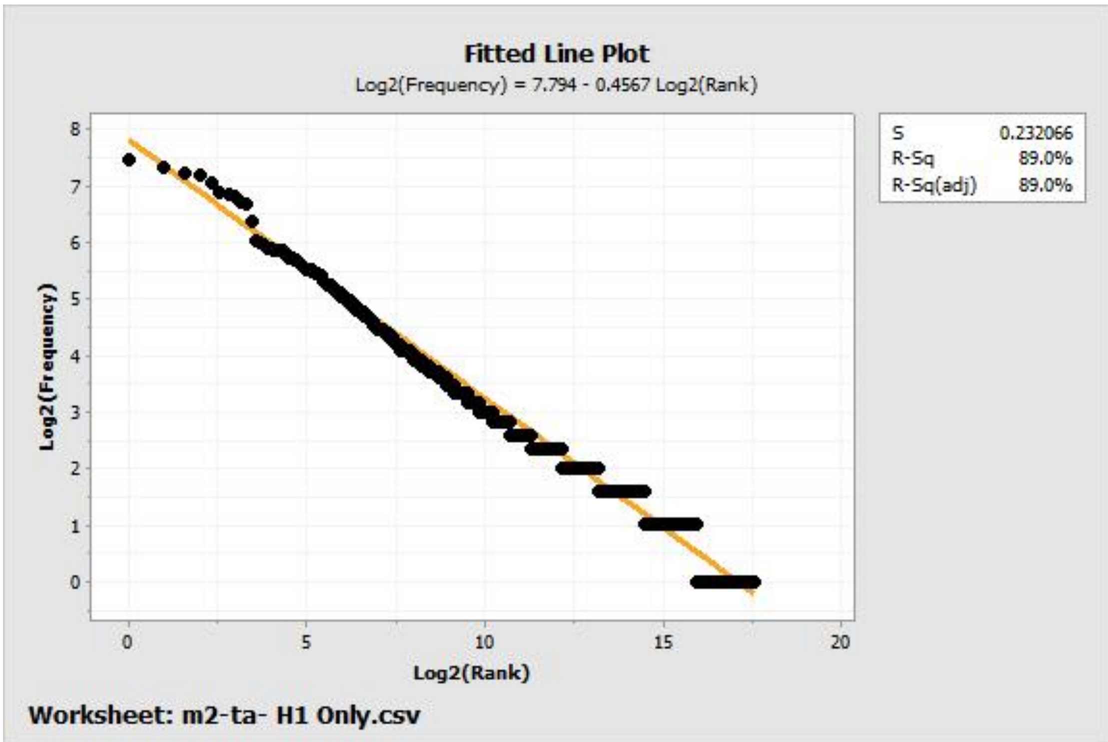

Fitted Line Plot
Log2(Frequency) = 8.007 - 0.4692 Log2(Rank)
S 0.230812
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
0
5
10
15
20
0
1
2
3
4
5
6
7
8
9
Worksheet: m1-t1-H1 Only.csv

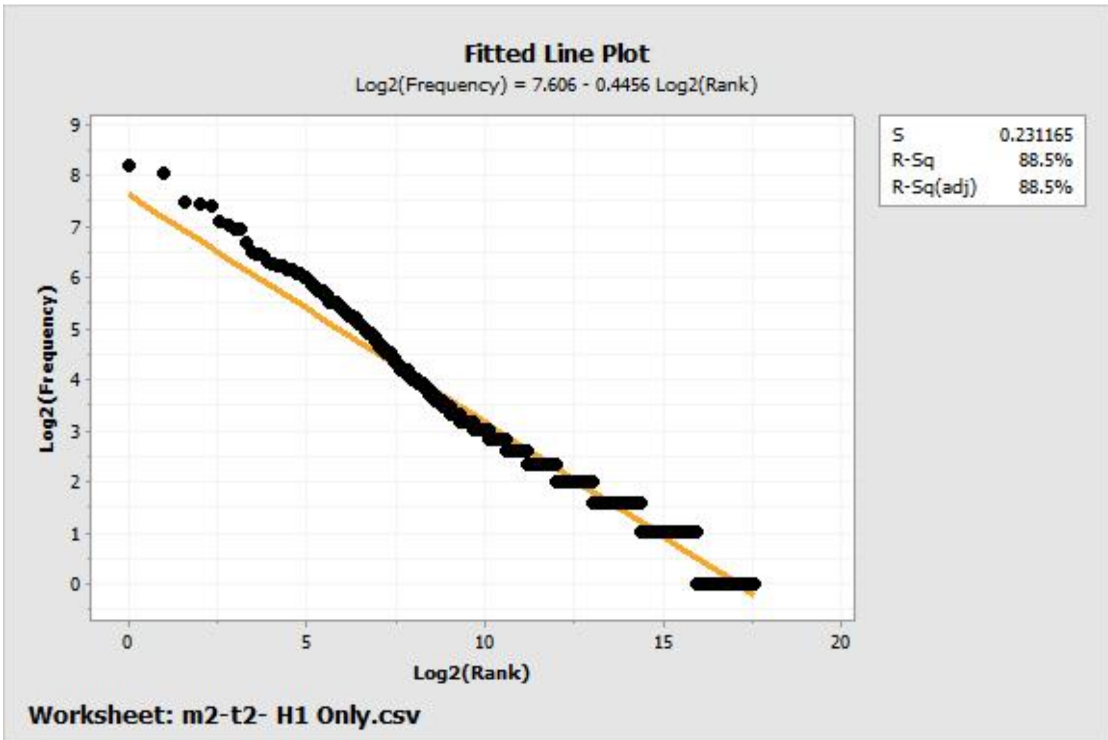

Fitted Line Plot
Log2(Frequency) = 8.448 - 0.4958 Log2(Rank)
S 0.232443
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-ta-H2 Only.csv

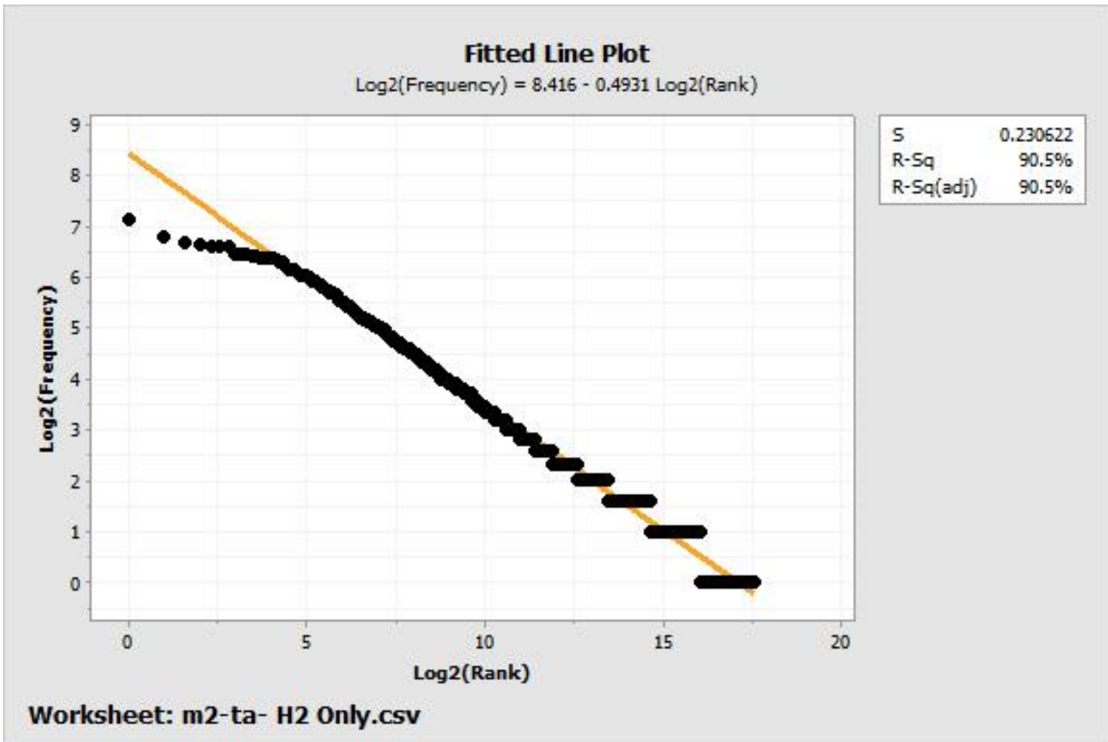

Fitted Line Plot
Log2(Frequency) = 8.241 - 0.4823 Log2(Rank)
S 0.231121
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-t1-H2 Only.csv

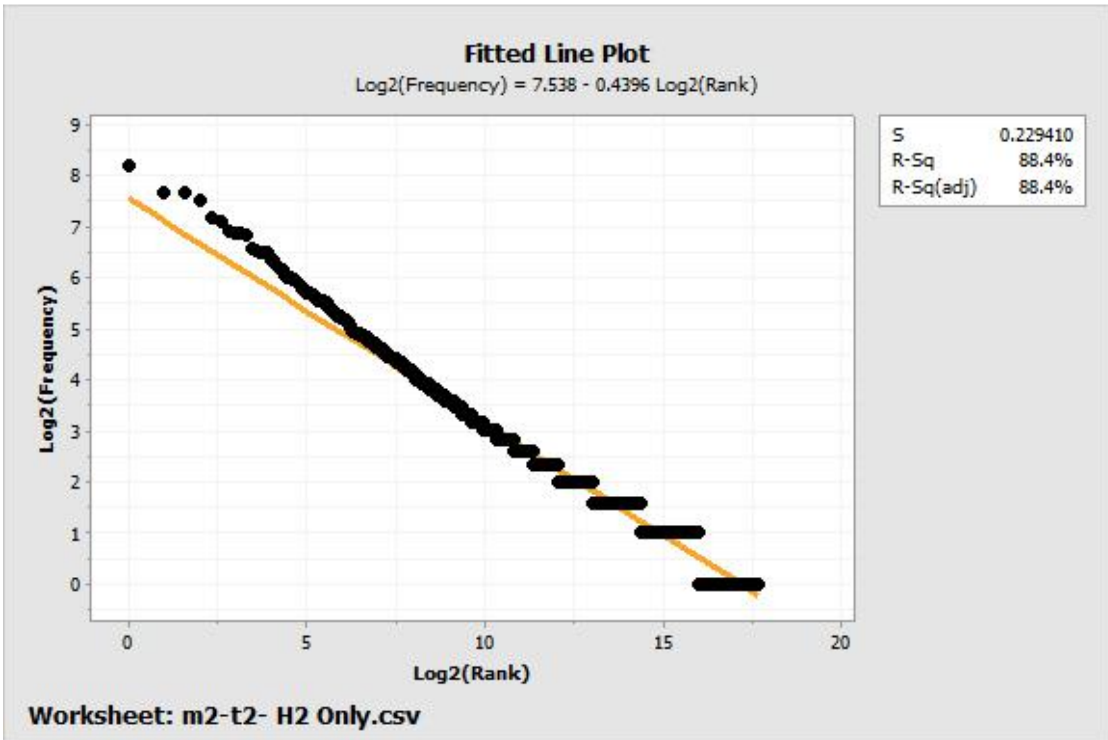

Fitted Line Plot
Log2(Frequency) = 10.06 - 0.5576 Log2(Rank)
S 0.246858
R-Sq 91.4%
R-Sq(adj) 91.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-ta-H1 + H2.csv

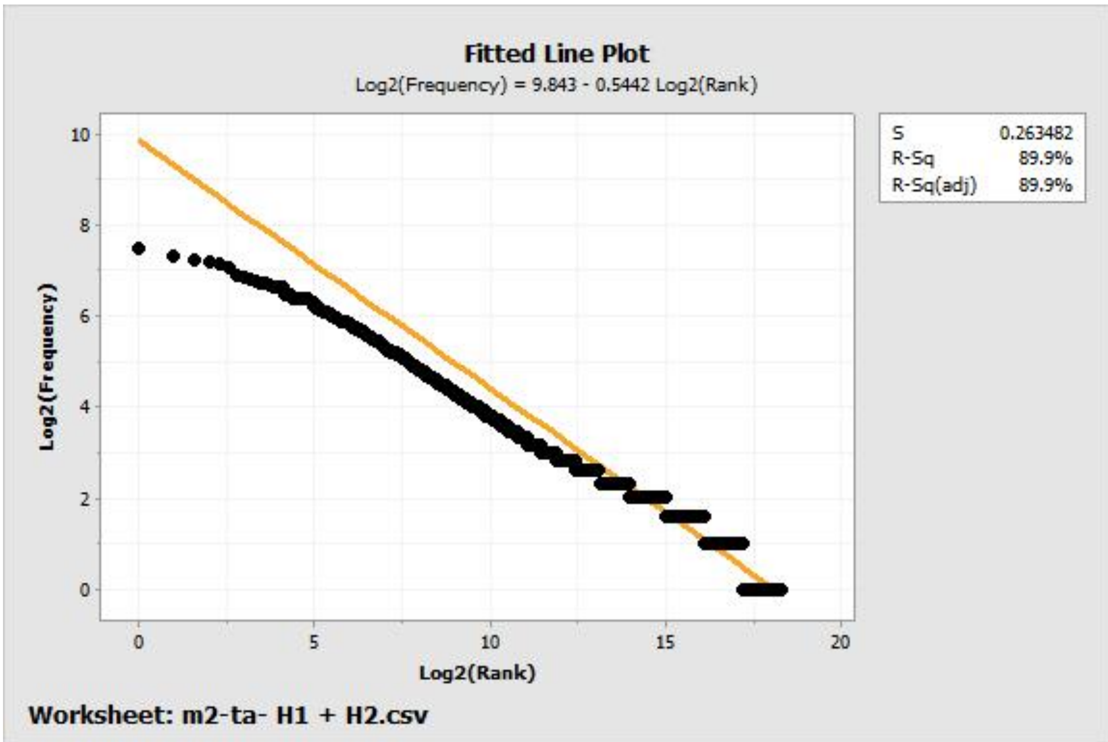

Fitted Line Plot
Log2(Frequency) = 10.22 - 0.5659 Log2(Rank)
S 0.254965
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-t1-H1 + H2.csv

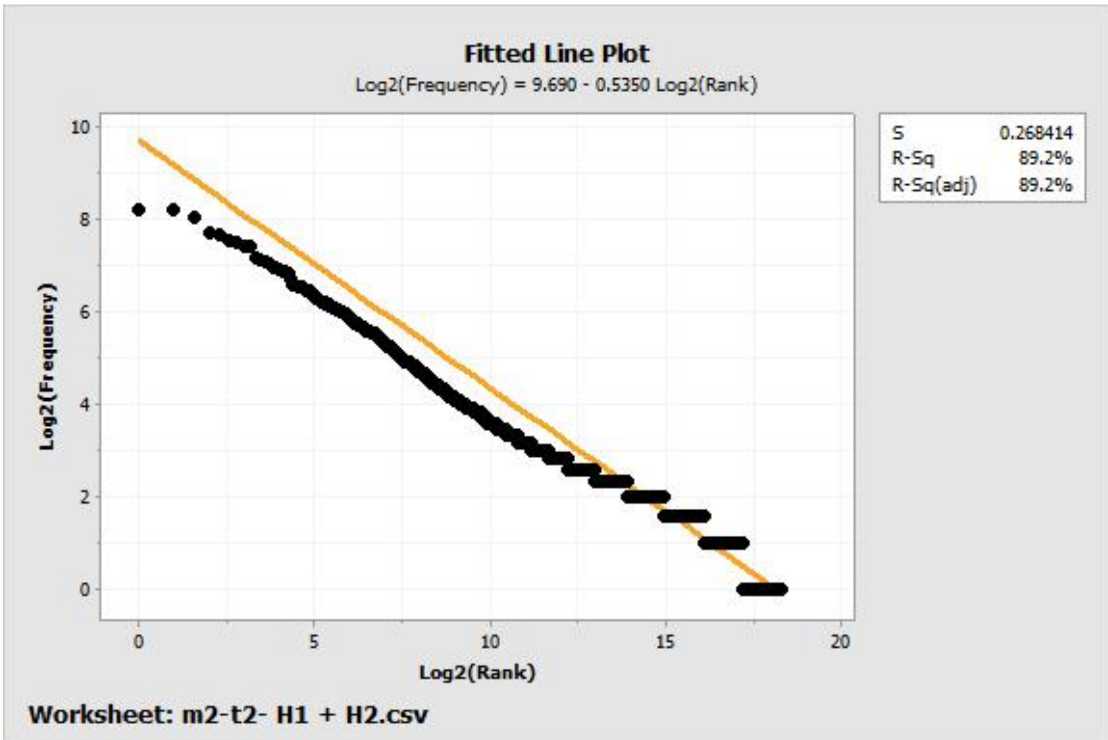

Fitted Line Plot
Log2(Frequency) = 7.794 - 0.4567 Log2(Rank)
S 0.232066
R-Sq 89.0%
R-Sq(adj) 89.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-ta- H1 Only.csv

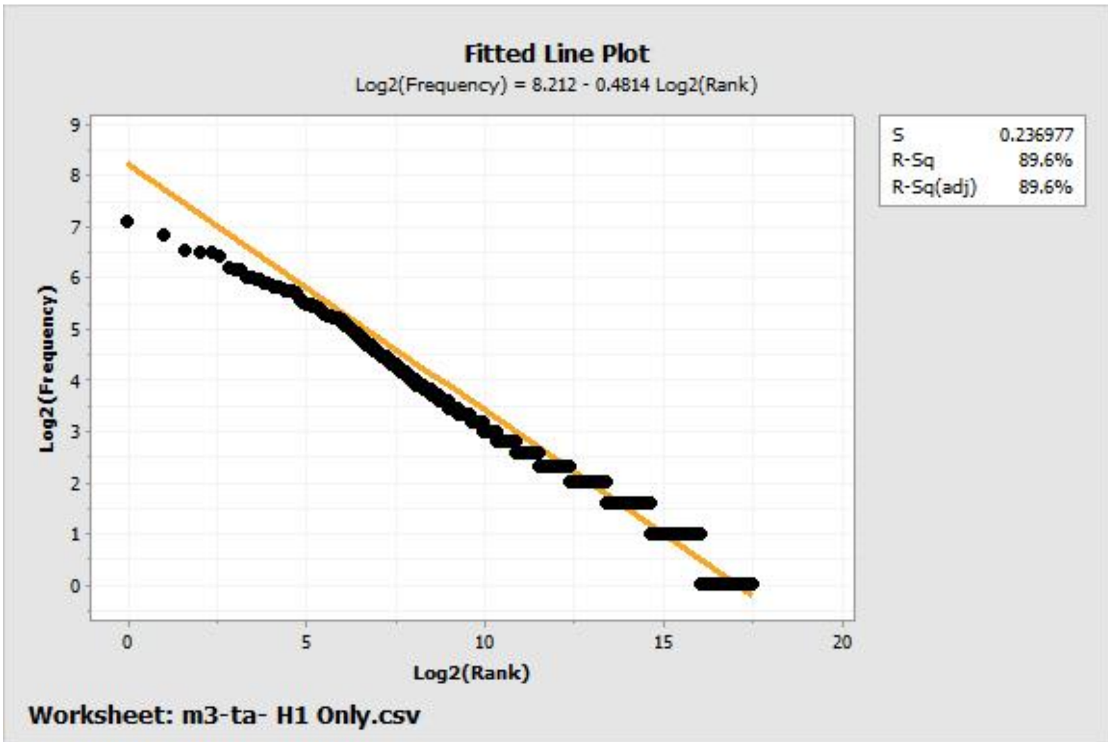

Fitted Line Plot
Log2(Frequency) = 7.606 - 0.4456 Log2(Rank)
S 0.231165
R-Sq 88.5%
R-Sq(adj) 88.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-t2- H1 Only.csv

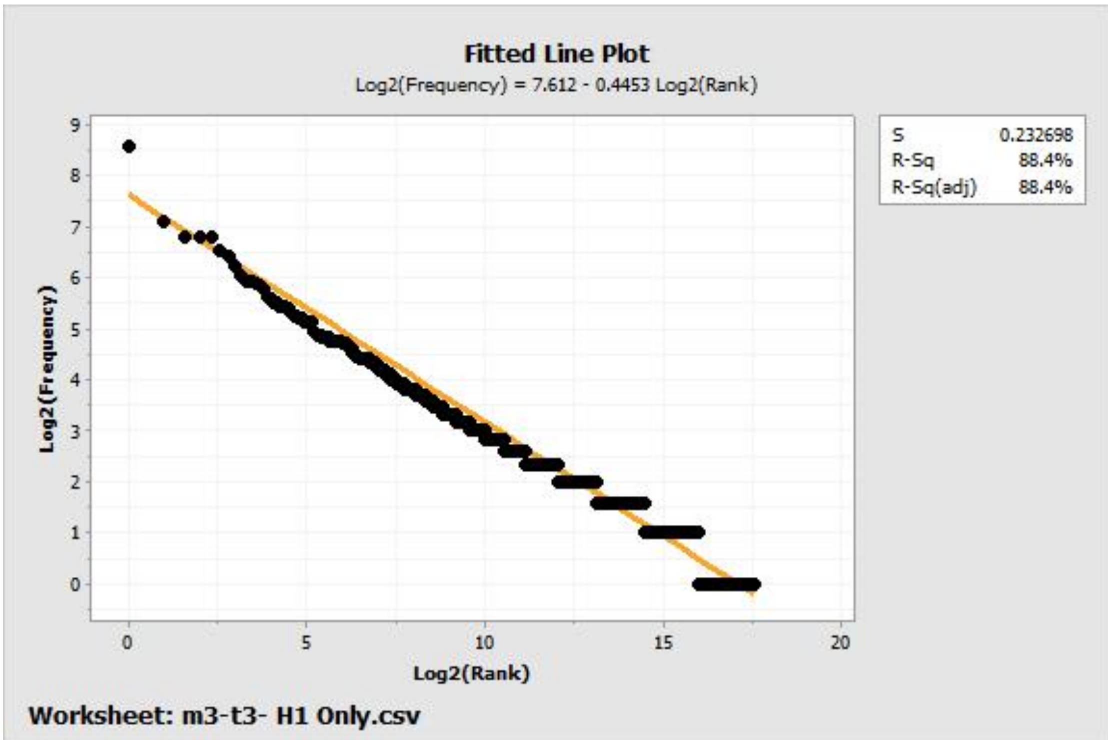

Fitted Line Plot
Log2(Frequency) = 8.416 - 0.4931 Log2(Rank)
S 0.230622
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m2-ta- H2 Only.csv

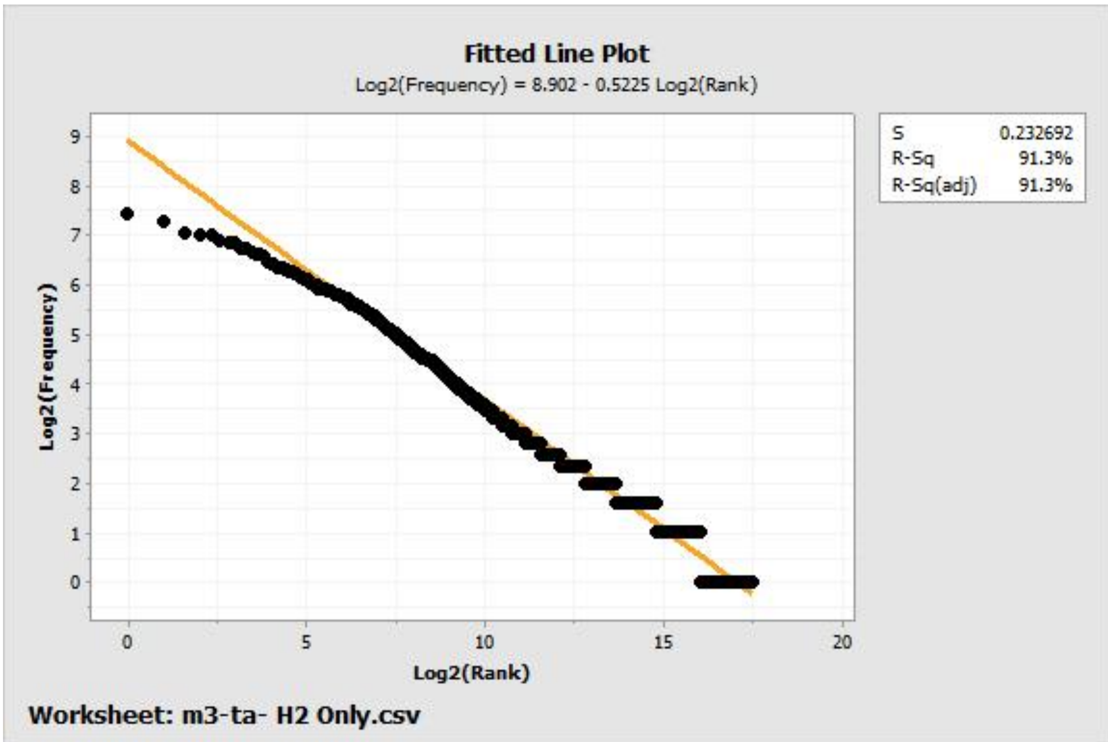

Fitted Line Plot
Log2(Frequency) = 7.538 - 0.4396 Log2(Rank)
S 0.229410
R-Sq 88.4%
R-Sq(adj) 88.4%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m2-t2- H2 Only.csv

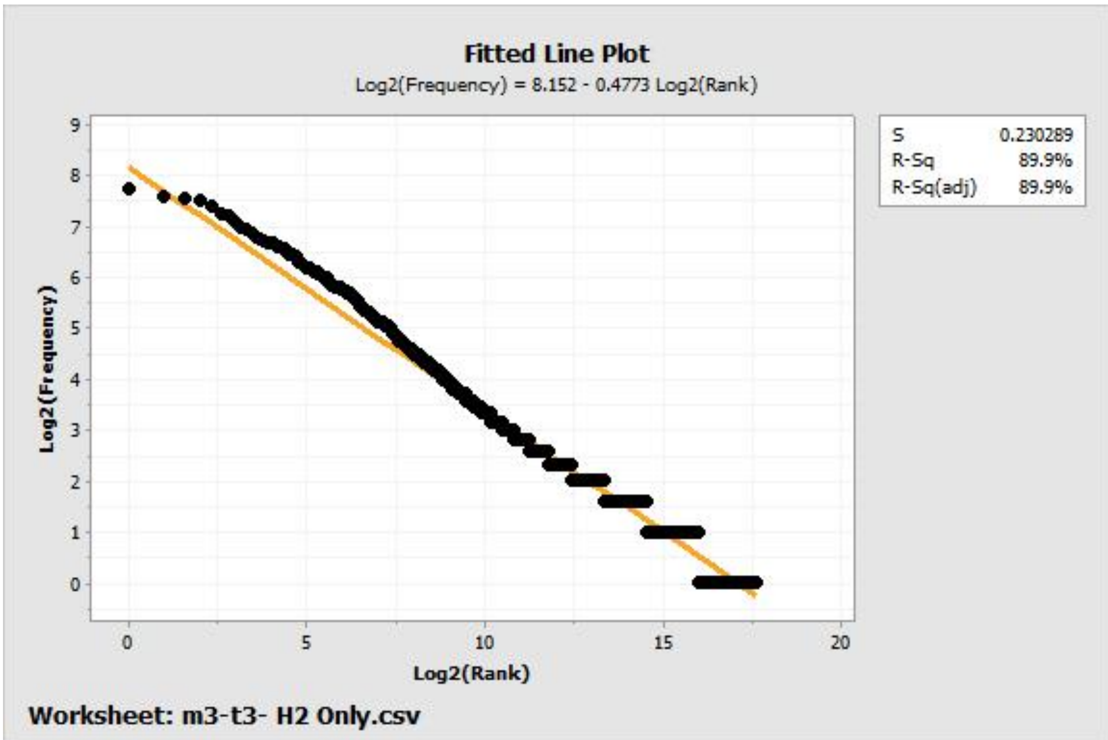

Fitted Line Plot
Log2(Frequency) = 9.843 - 0.5442 Log2(Rank)
S 0.263482
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m2-ta- H1 + H2.csv

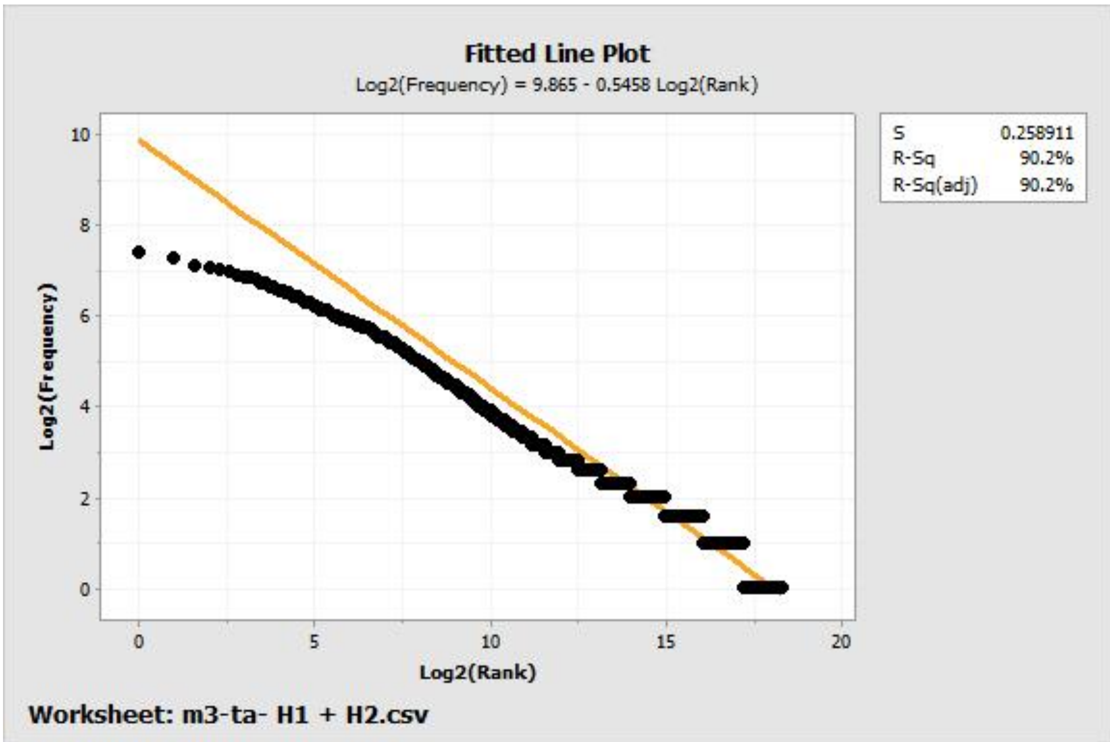

Fitted Line Plot
Log2(Frequency) = 9.690 - 0.5350 Log2(Rank)
S 0.268414
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m2-t2- H1 + H2.csv

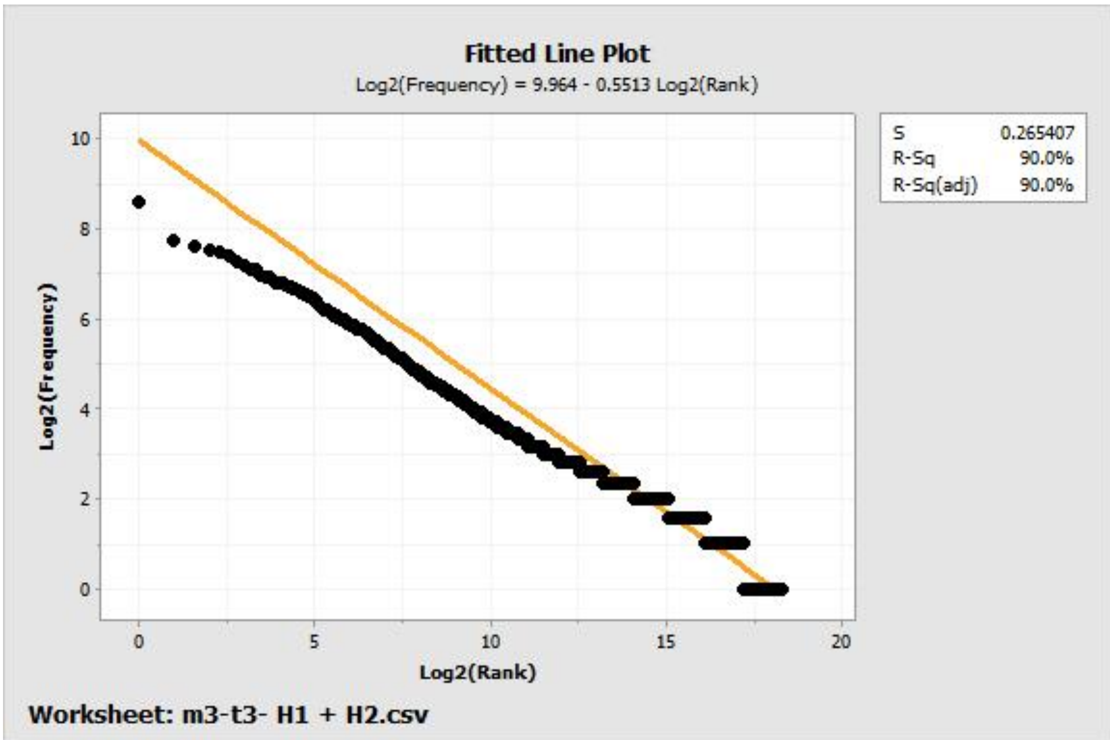

Fitted Line Plot
Log2(Frequency) = 8.212 - 0.4814 Log2(Rank)
S 0.236977
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-ta- H1 Only.csv

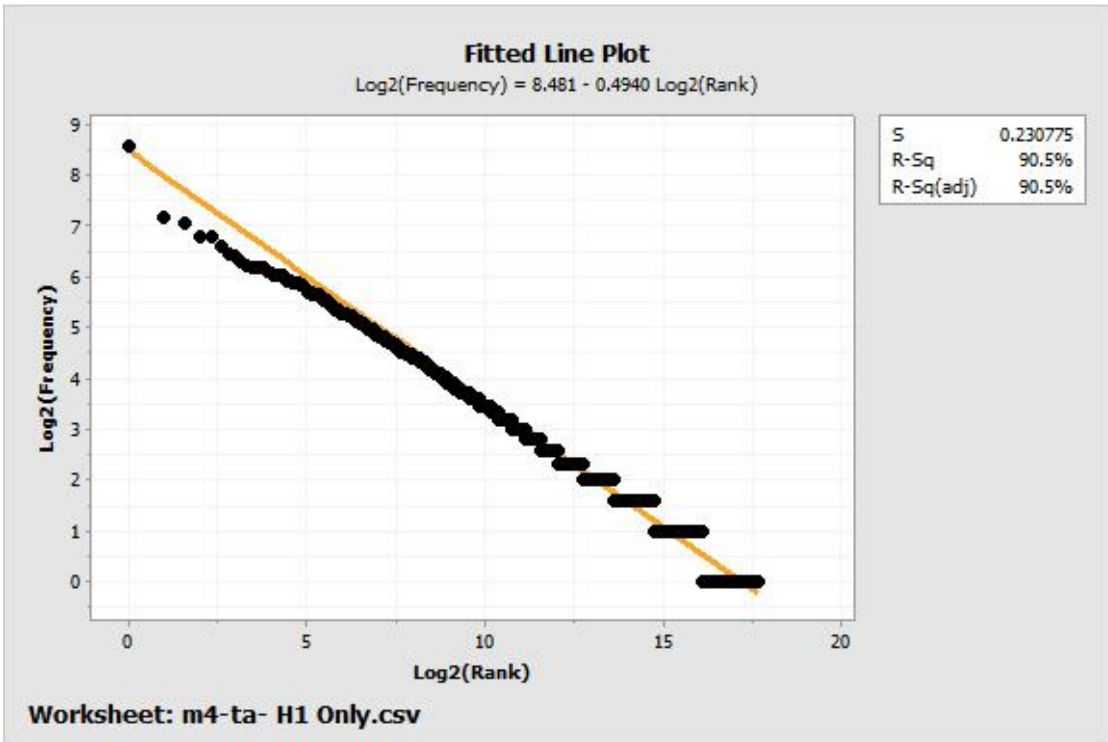

Fitted Line Plot
Log2(Frequency) = 7.612 - 0.4453 Log2(Rank)
S 0.232698
R-Sq 88.4%
R-Sq(adj) 88.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3- H1 Only.csv

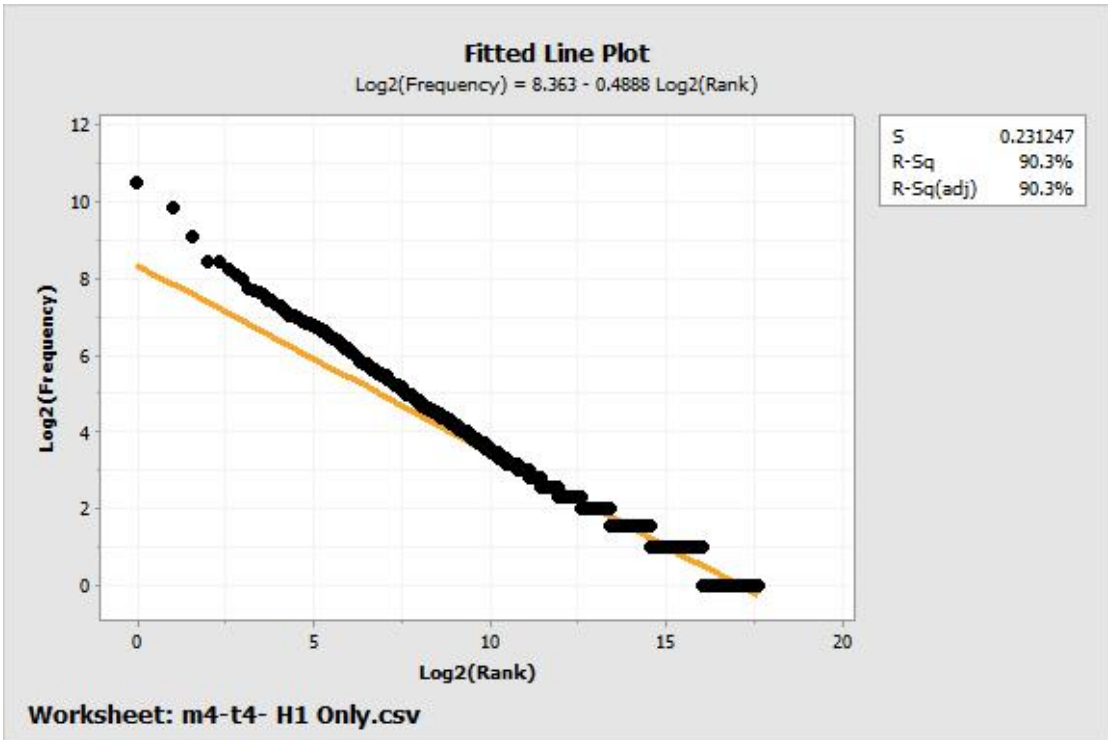

Fitted Line Plot
Log2(Frequency) = 8.902 - 0.5225 Log2(Rank)
S 0.232692
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-ta- H2 Only.csv

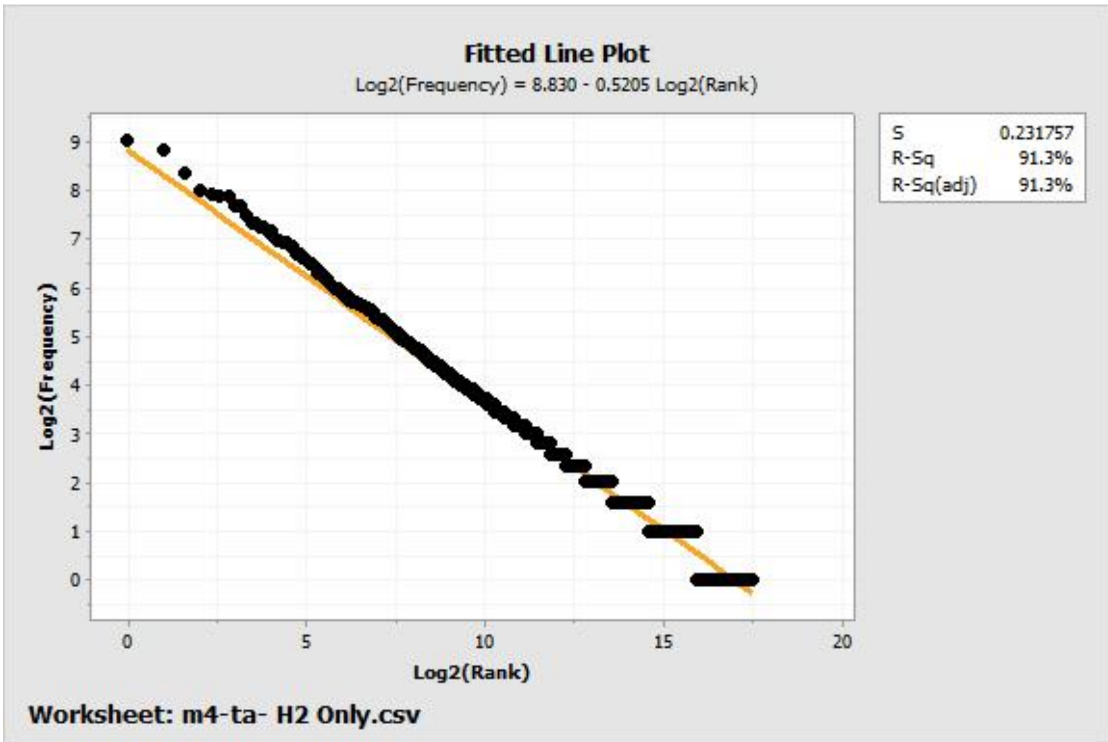

Fitted Line Plot
Log2(Frequency) = 8.152 - 0.4773 Log2(Rank)
S 0.230289
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3- H2 Only.csv

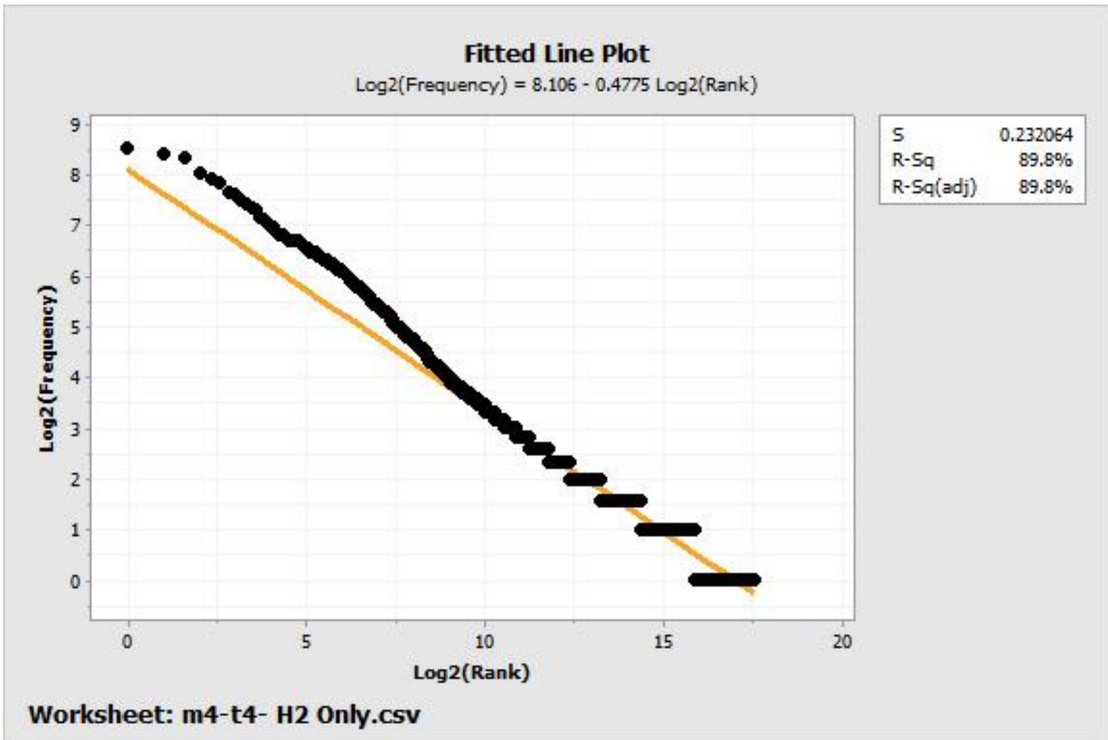

Fitted Line Plot
Log2(Frequency) = 9.865 - 0.5458 Log2(Rank)
S 0.258911
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-ta- H1 + H2.csv

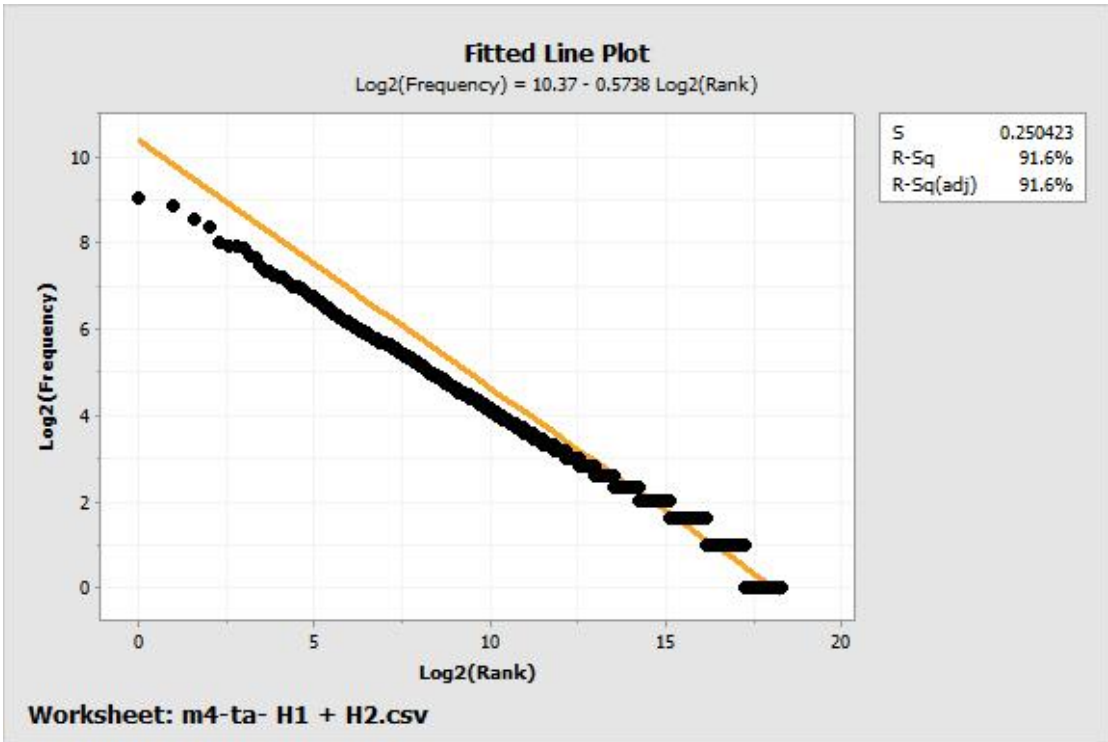

Fitted Line Plot
Log2(Frequency) = 9.964 - 0.5513 Log2(Rank)
S 0.265407
R-Sq 90.0%
R-Sq(adj) 90.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3- H1 + H2.csv

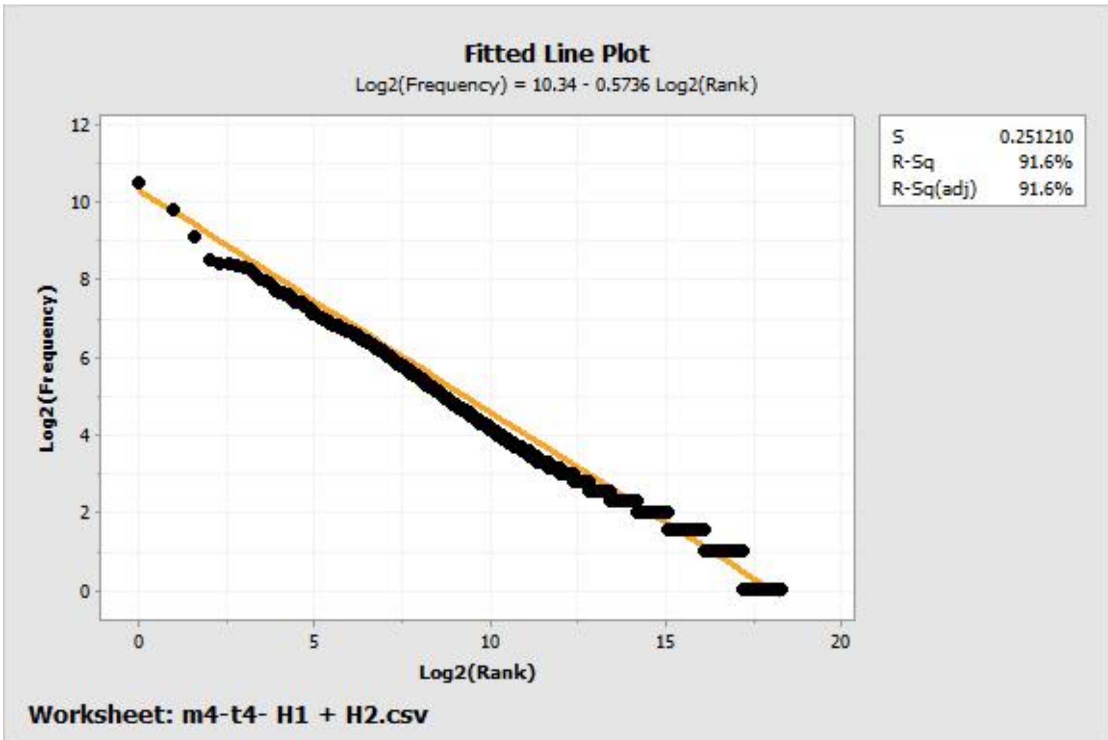

Fitted Line Plot
Log2(Frequency) = 8.481 - 0.4940 Log2(Rank)
S 0.230775
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-ta- H1 Only.csv

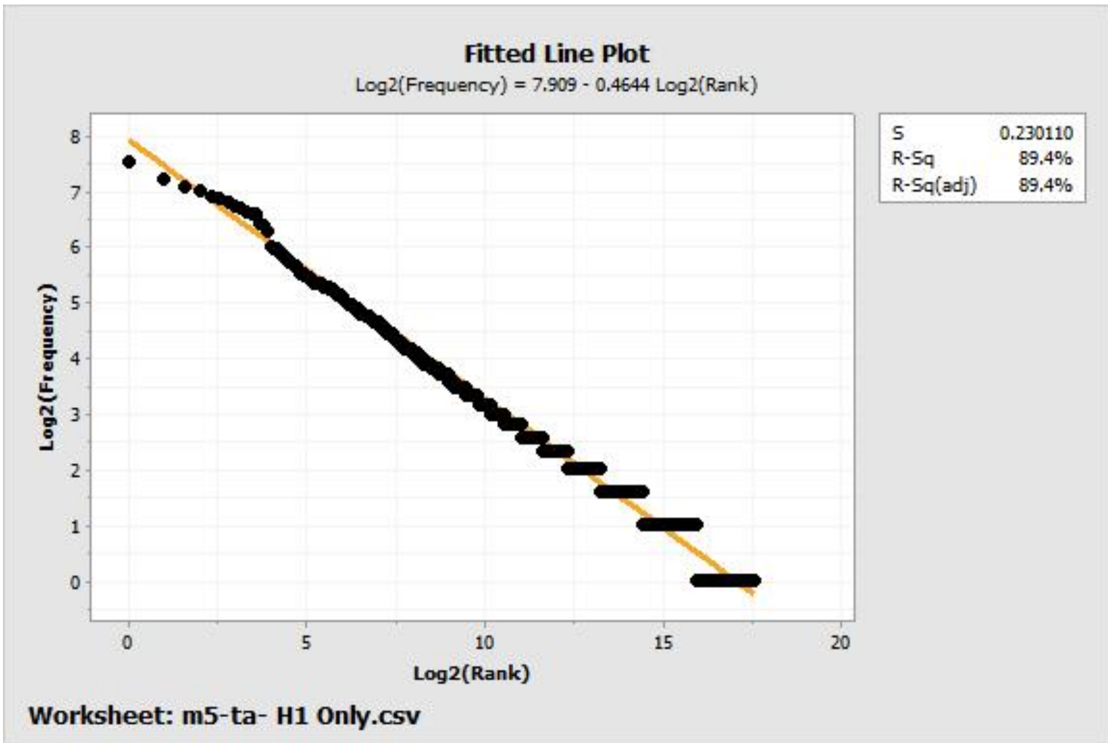

Fitted Line Plot
Log2(Frequency) = 8.363 - 0.4888 Log2(Rank)
S 0.231247
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-t4- H1 Only.csv


Fitted Line Plot
Log2(Frequency) = 8.830 - 0.5205 Log2(Rank)
S 0.231757
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-ta- H2 Only.csv

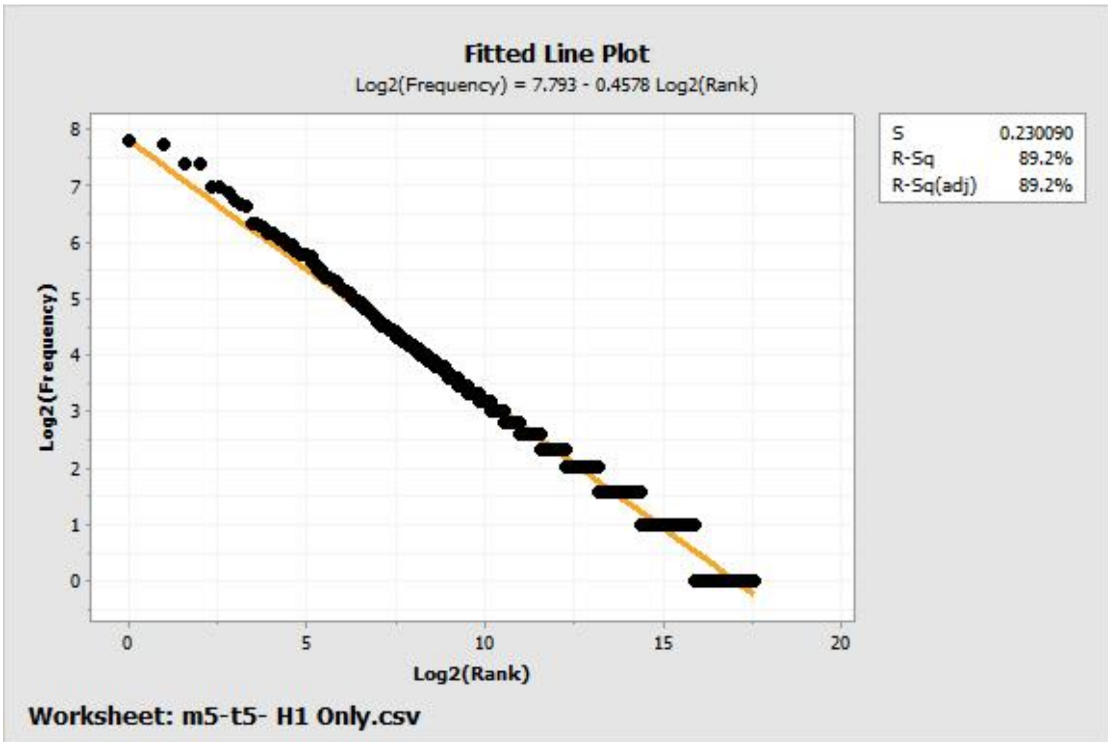

Fitted Line Plot
Log2(Frequency) = 8.106 - 0.4775 Log2(Rank)
S 0.232064
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-t4- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.37 - 0.5738 Log2(Rank)
S 0.250423
R-Sq 91.6%
R-Sq(adj) 91.6%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m4-ta- H1 + H2.csv

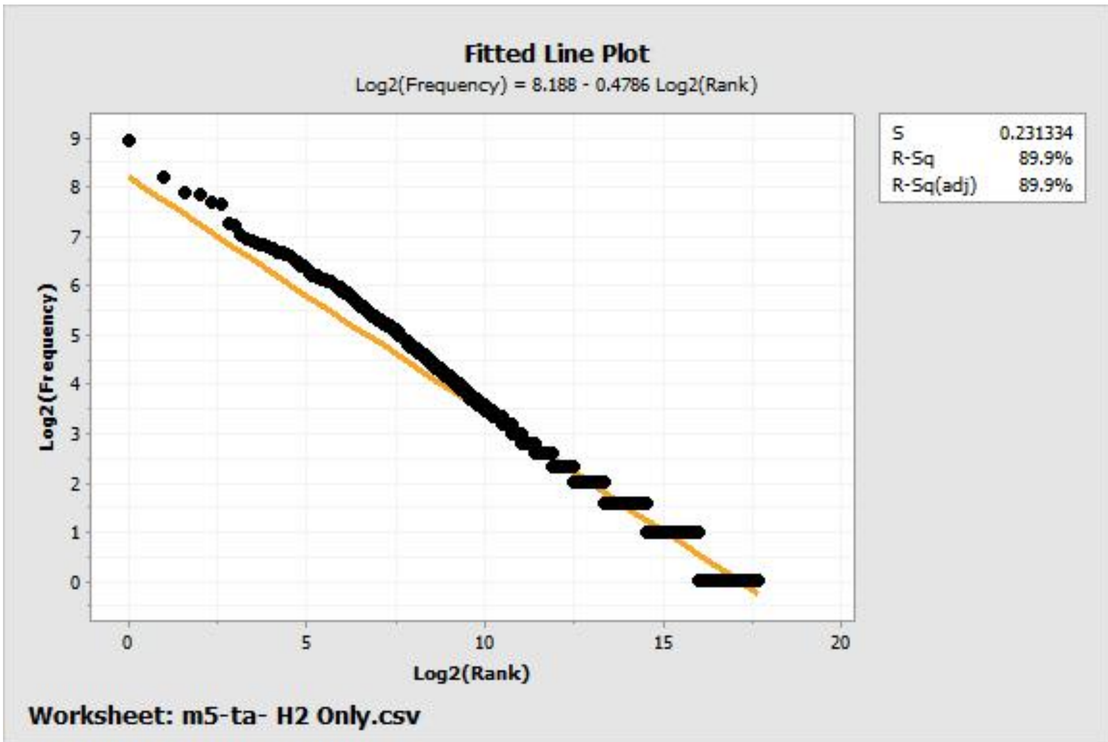

Fitted Line Plot
Log2(Frequency) = 10.34 - 0.5736 Log2(Rank)
S 0.251210
R-Sq 91.6%
R-Sq(adj) 91.6%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
0
5
10
15
20
Worksheet: m4-t4- H1 + H2.csv



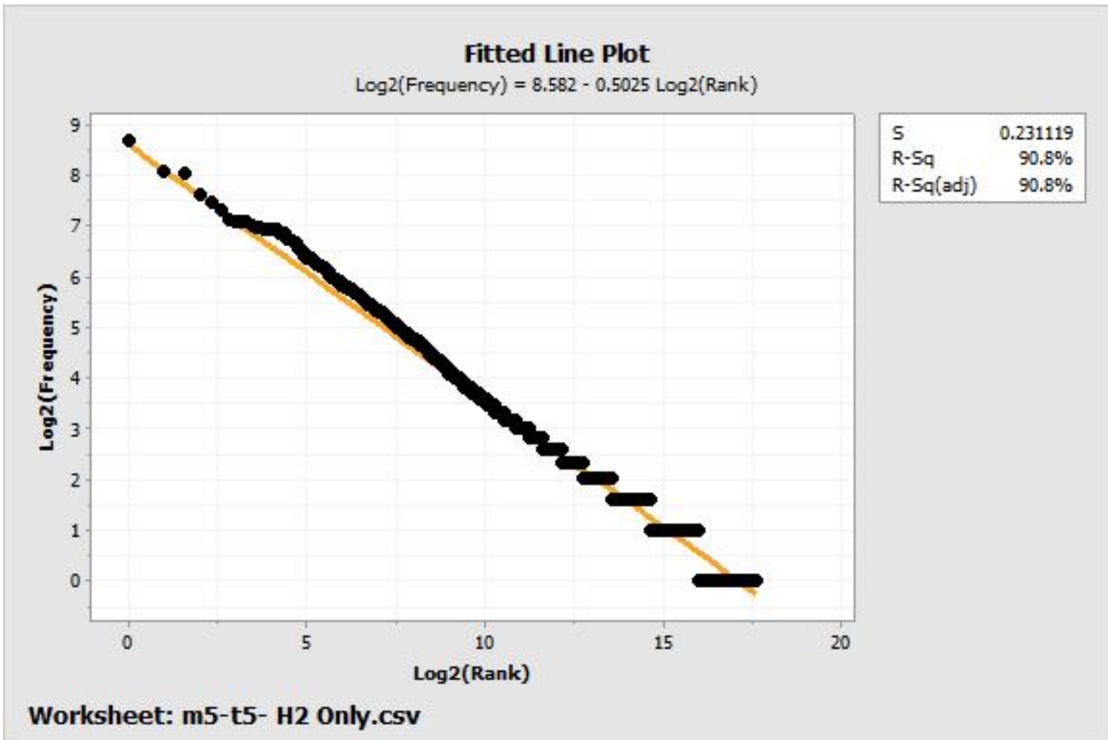
Fitted Line Plot
Log2(Frequency) = 7.909 - 0.4644 Log2(Rank)
S 0.230110
R-Sq 89.4%
R-Sq(adj) 89.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-ta- H1 Only.csv



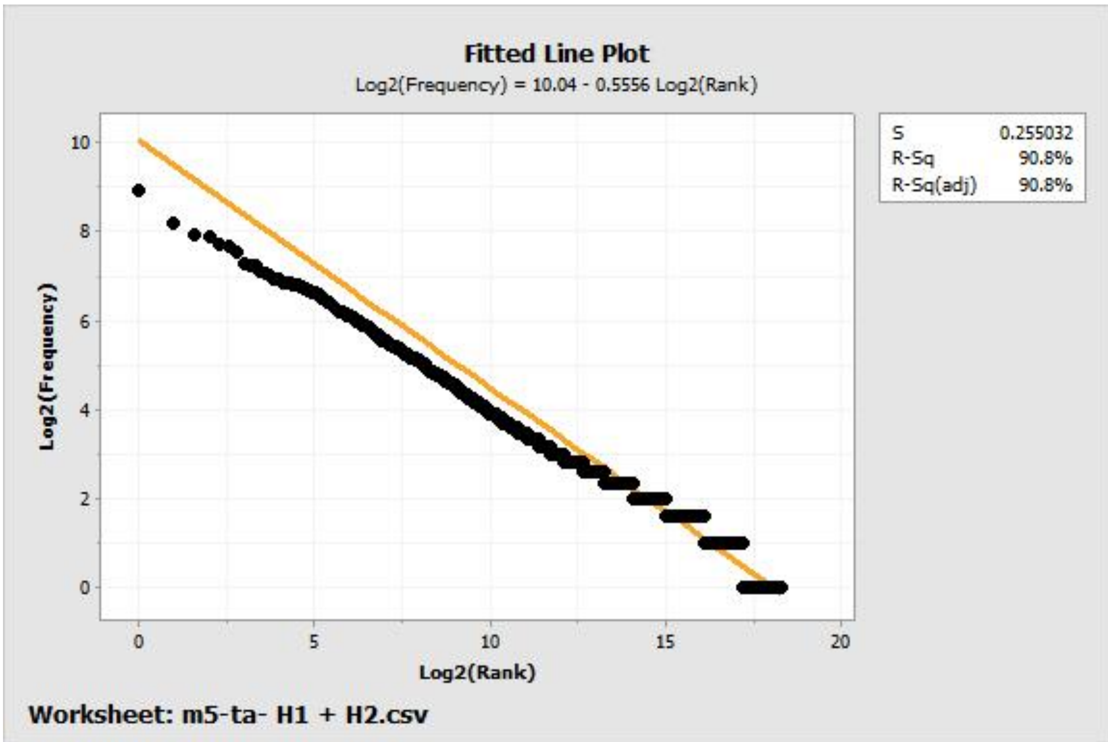
Fitted Line Plot
Log2(Frequency) = 7.793 - 0.4578 Log2(Rank)
S 0.230090
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-t5- H1 Only.csv

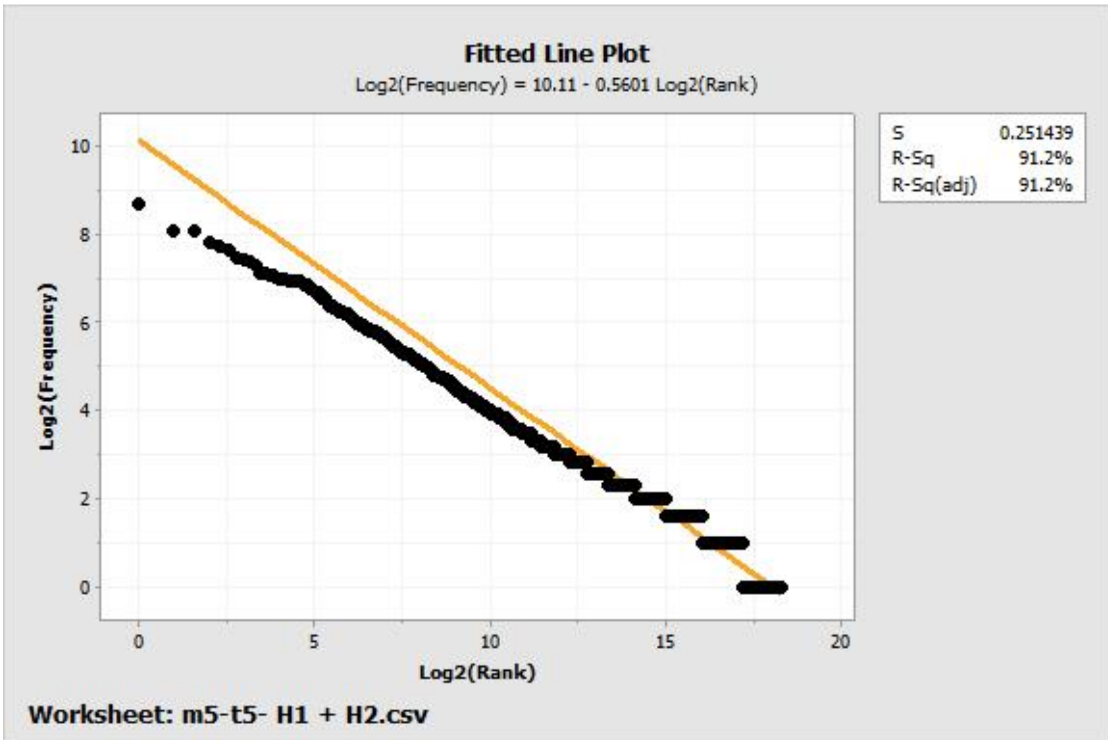


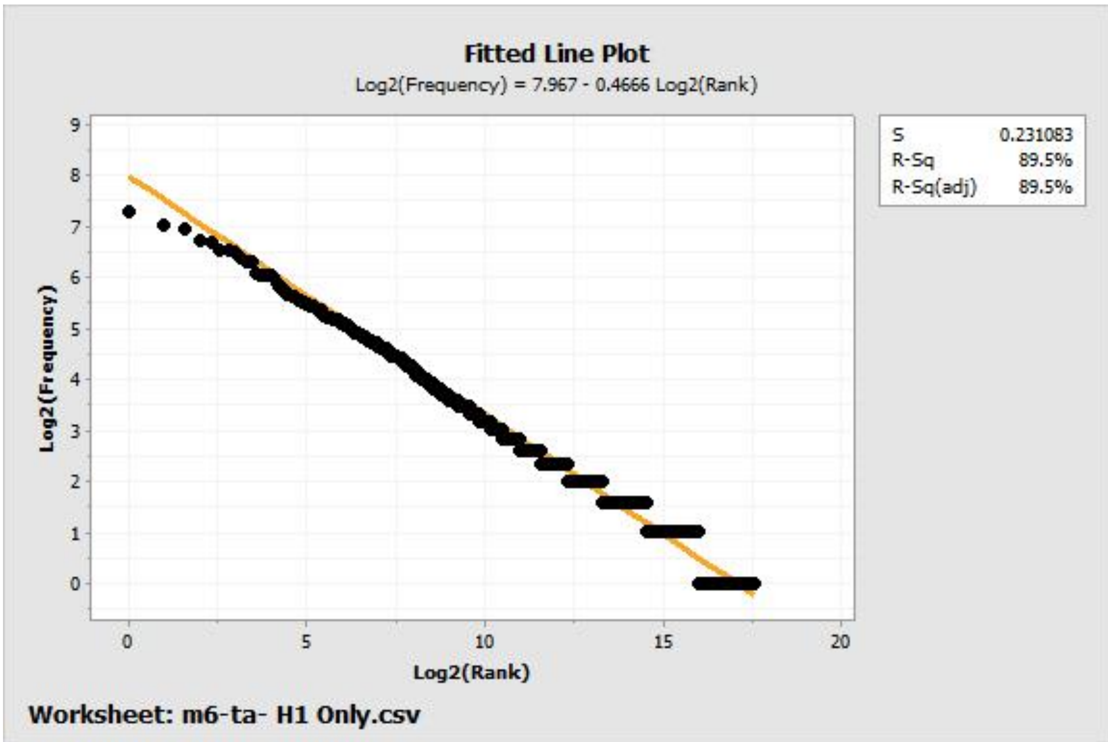
Fitted Line Plot
Log2(Frequency) = 8.188 - 0.4786 Log2(Rank)
S 0.231334
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-ta- H2 Only.csv

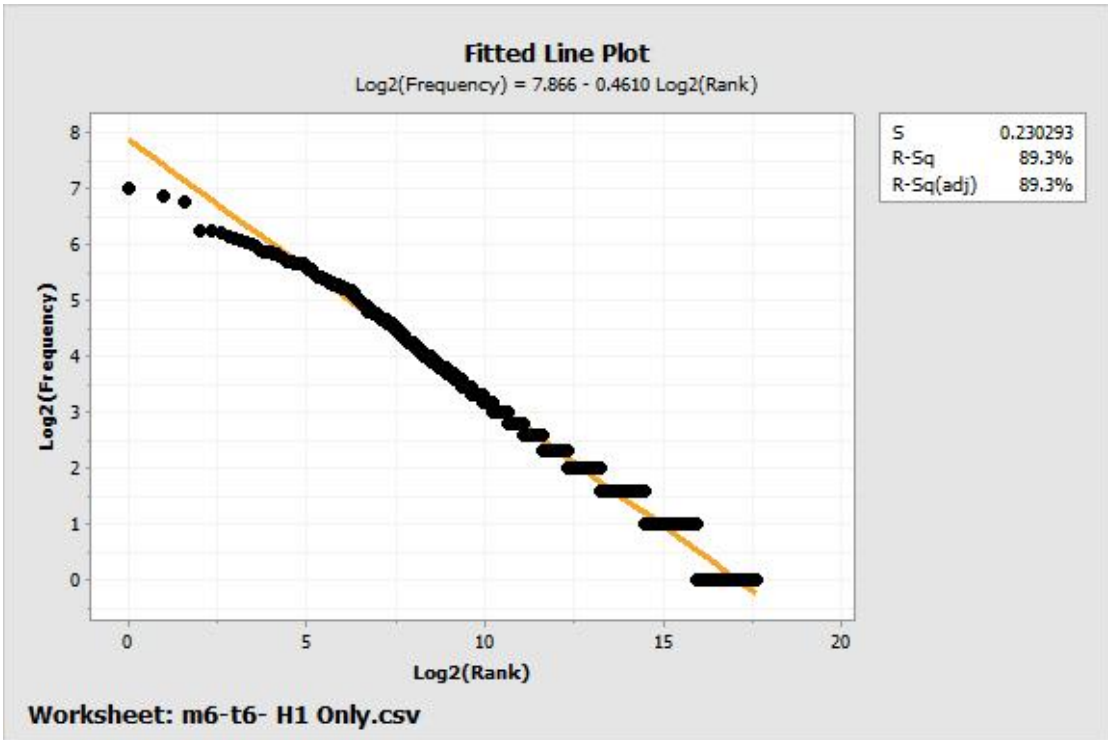


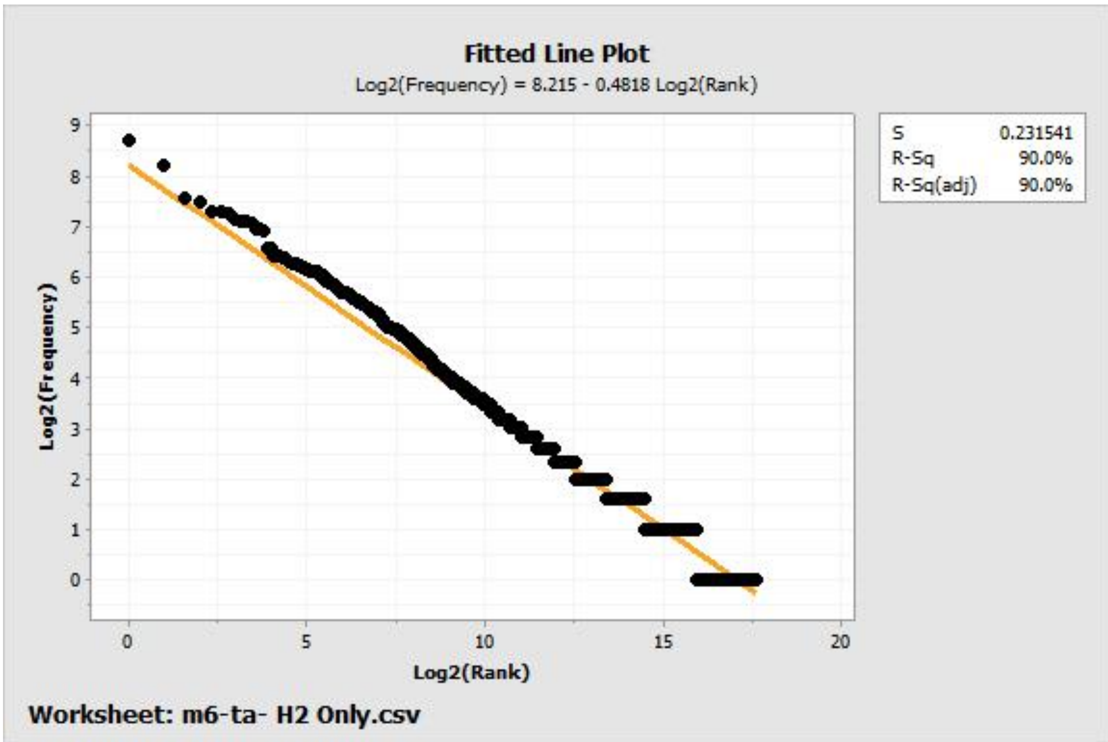
Fitted Line Plot
Log2(Frequency) = 8.582 - 0.5025 Log2(Rank)
S 0.231119
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-t5- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.04 - 0.5556 Log2(Rank)
S 0.255032
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m5-ta- H1 + H2.csv

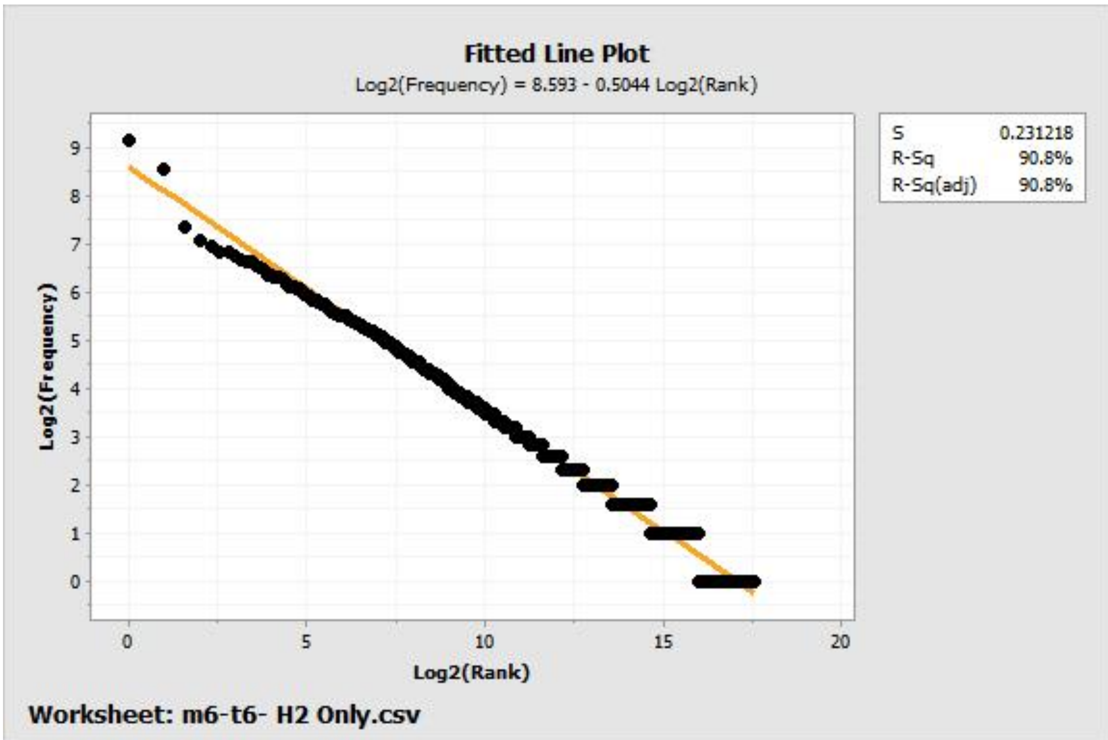

Fitted Line Plot
Log2(Frequency) = 10.11 - 0.5601 Log2(Rank)
S 0.251439
R-Sq 91.2%
R-Sq(adj) 91.2%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m5-t5- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 7.967 - 0.4666 Log2(Rank)
S 0.231083
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m6-ta- H1 Only.csv

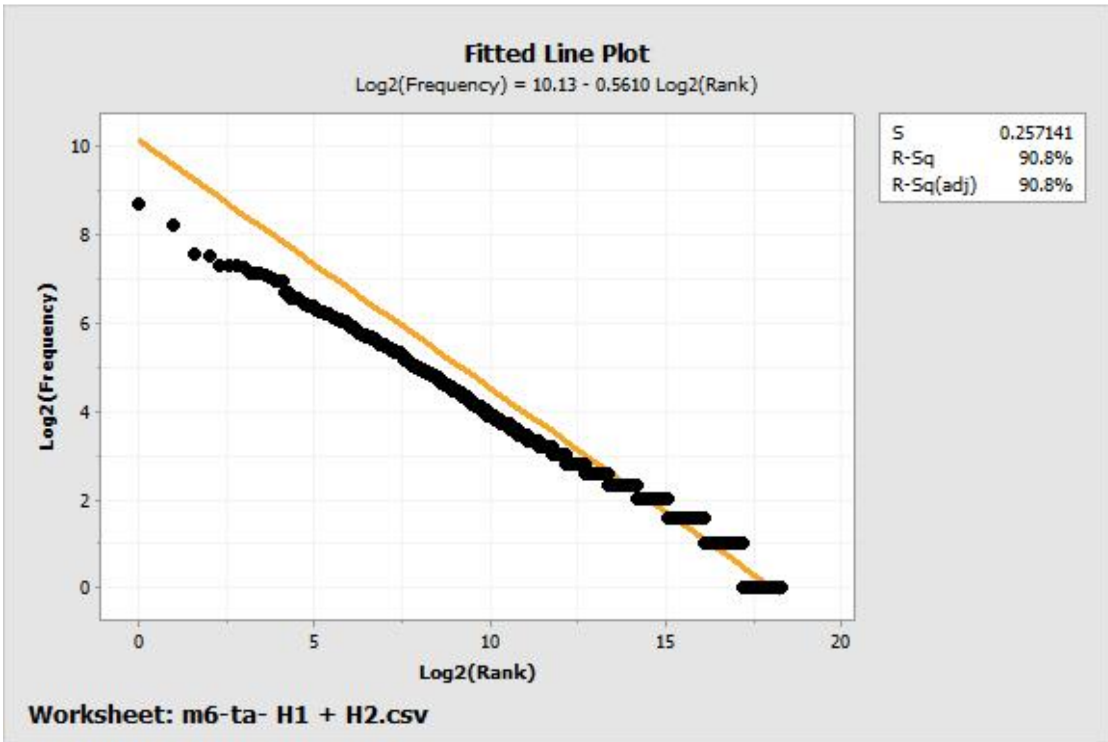

Fitted Line Plot
Log2(Frequency) = 7.866 - 0.4610 Log2(Rank)
S 0.230293
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
Worksheet: m6-t6- H1 Only.csv

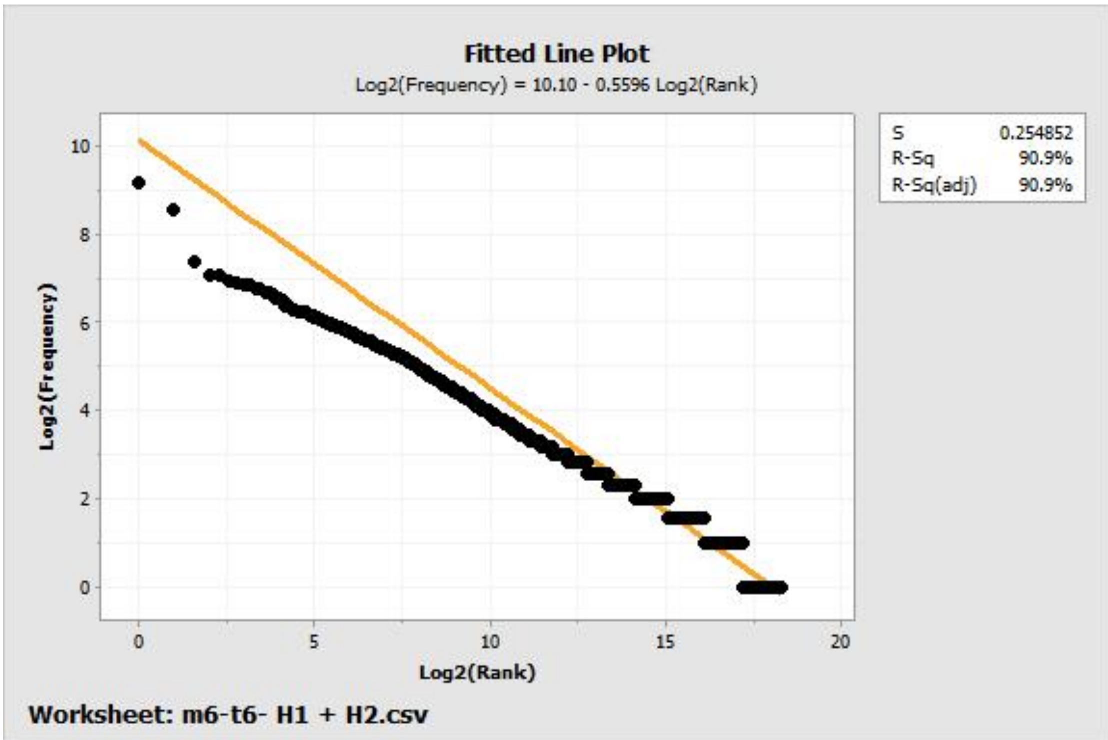


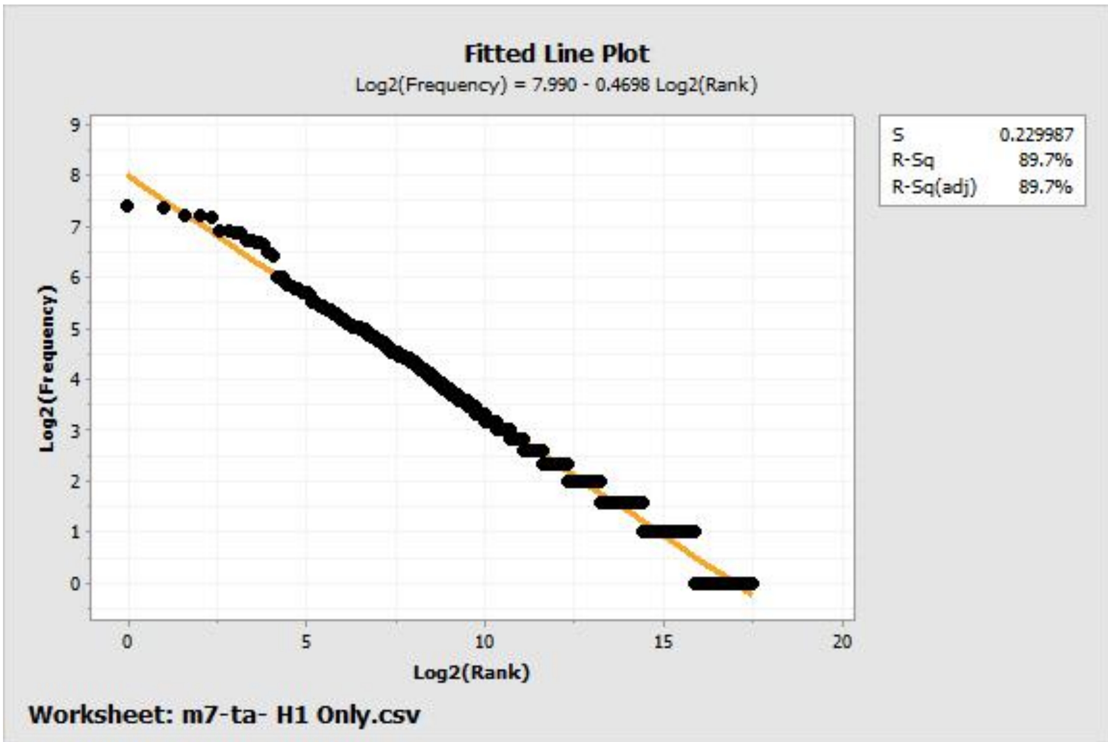
Fitted Line Plot
Log2(Frequency) = 8.215 - 0.4818 Log2(Rank)
S 0.231541
R-Sq 90.0%
R-Sq(adj) 90.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-ta- H2 Only.csv

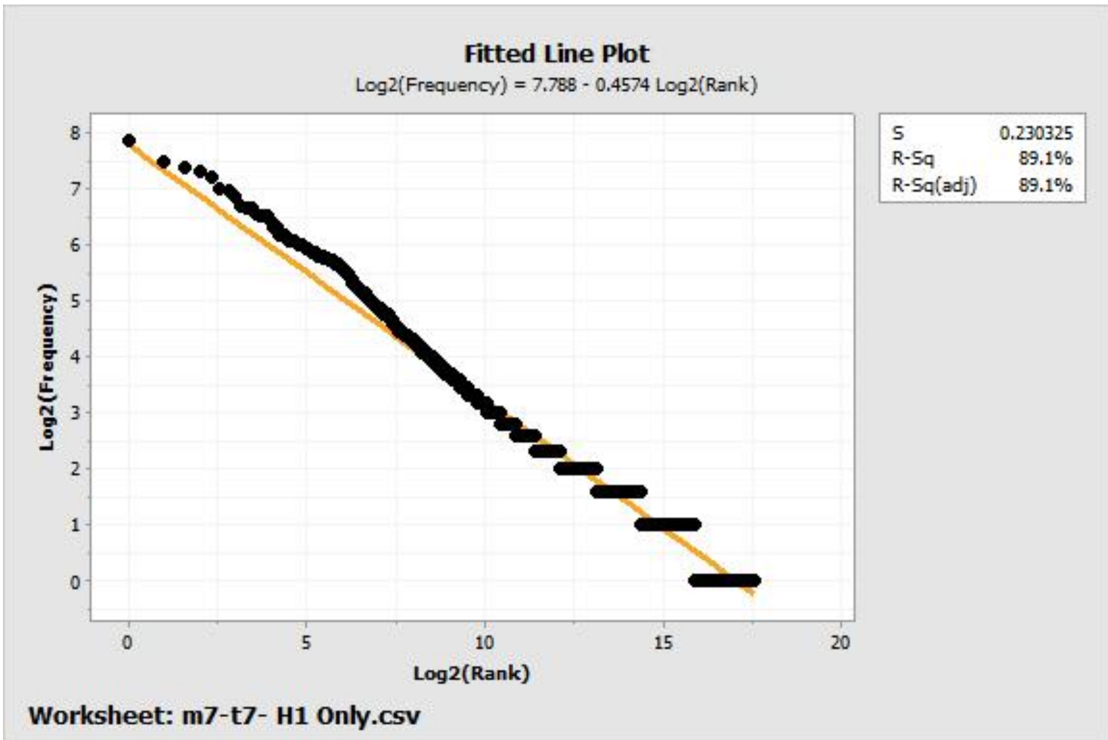


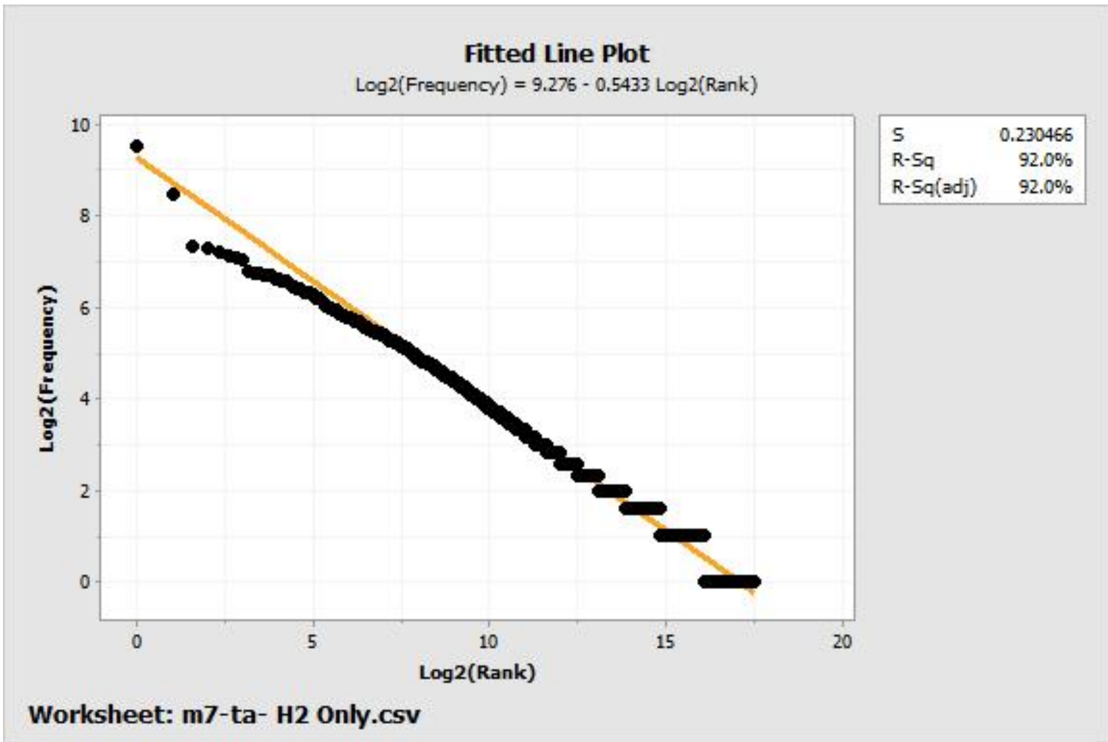
Fitted Line Plot
Log2(Frequency) = 8.593 - 0.5044 Log2(Rank)
S 0.231218
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-t6- H2 Only.csv

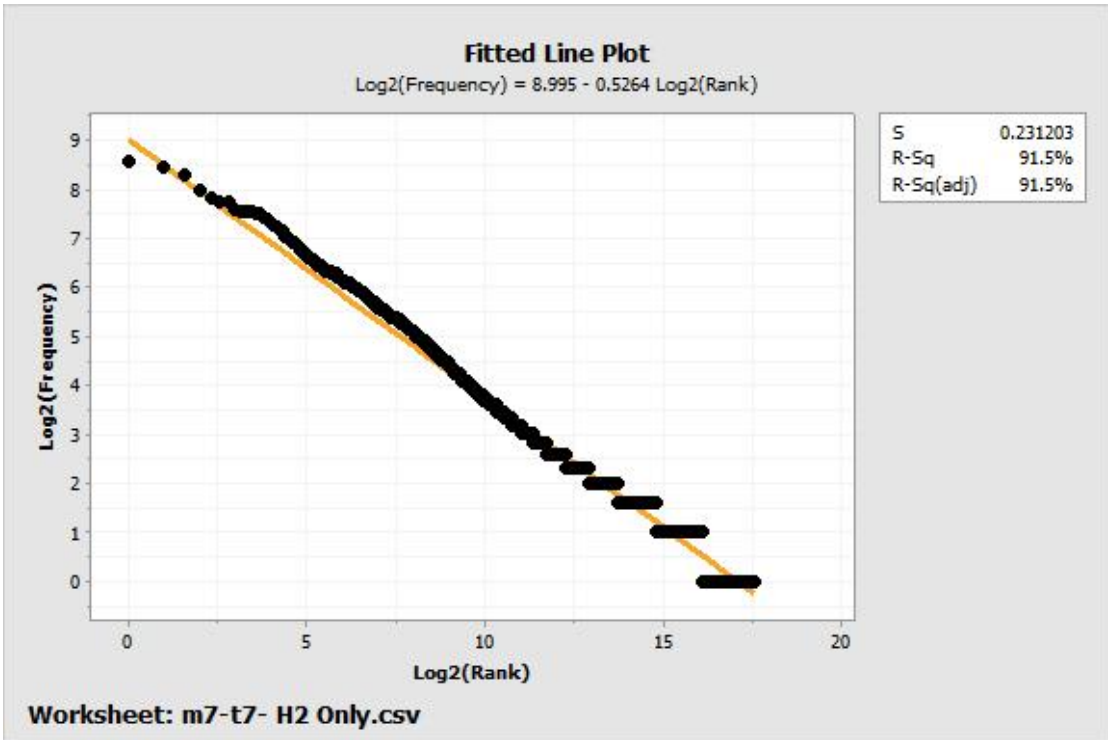

Fitted Line Plot
Log2(Frequency) = 10.13 - 0.5610 Log2(Rank)
S 0.257141
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-ta- H1 + H2.csv

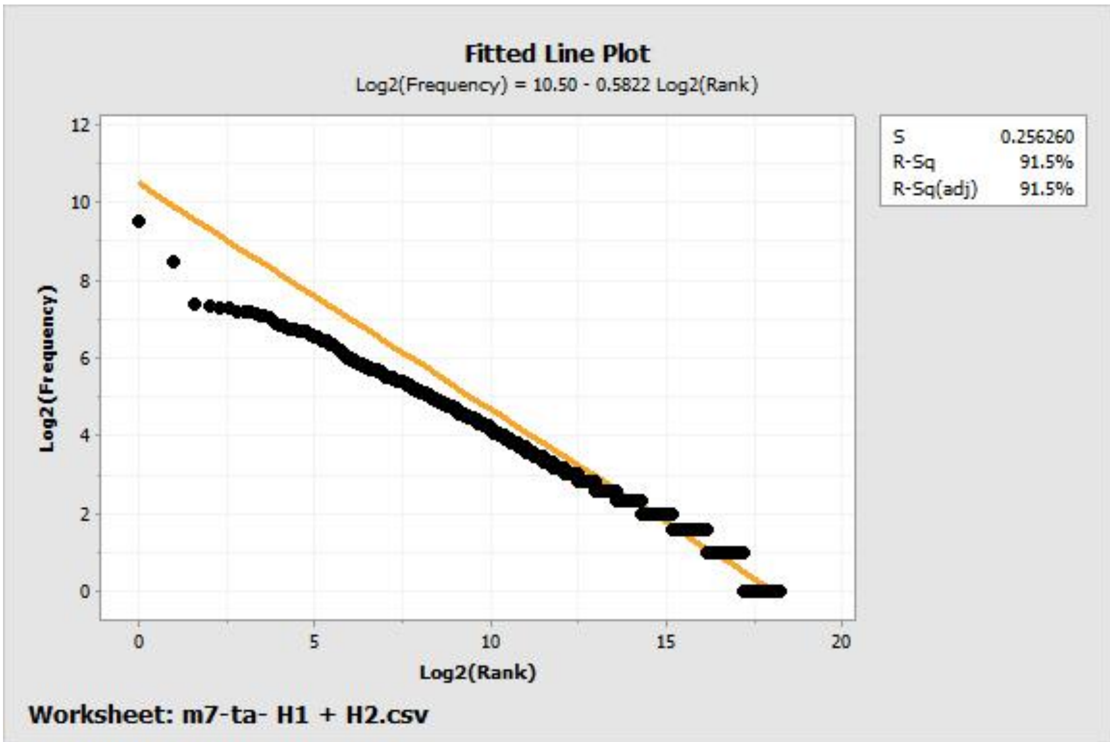

Fitted Line Plot
Log2(Frequency) = 10.10 - 0.5596 Log2(Rank)
S 0.254852
R-Sq 90.9%
R-Sq(adj) 90.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-t6- H1 + H2.csv

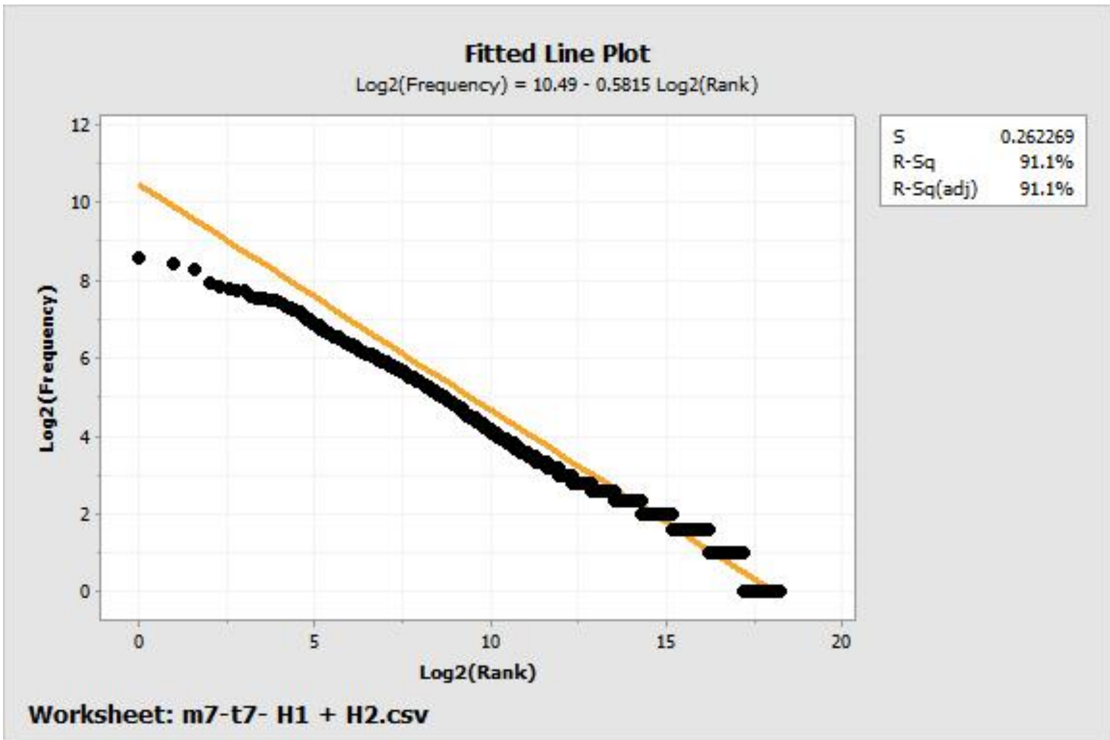

Fitted Line Plot
Log2(Frequency) = 7.990 - 0.4698 Log2(Rank)
S 0.229987
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta- H1 Only.csv

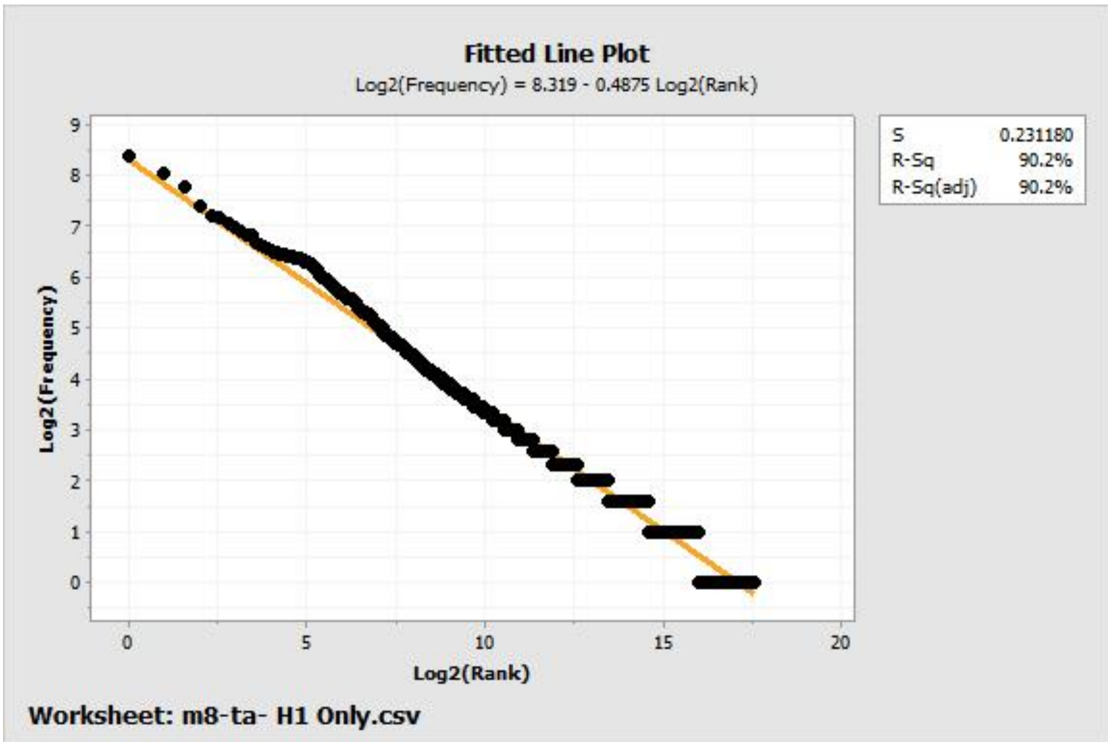

Fitted Line Plot
Log2(Frequency) = 7.788 - 0.4574 Log2(Rank)
S 0.230325
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-t7- H1 Only.csv

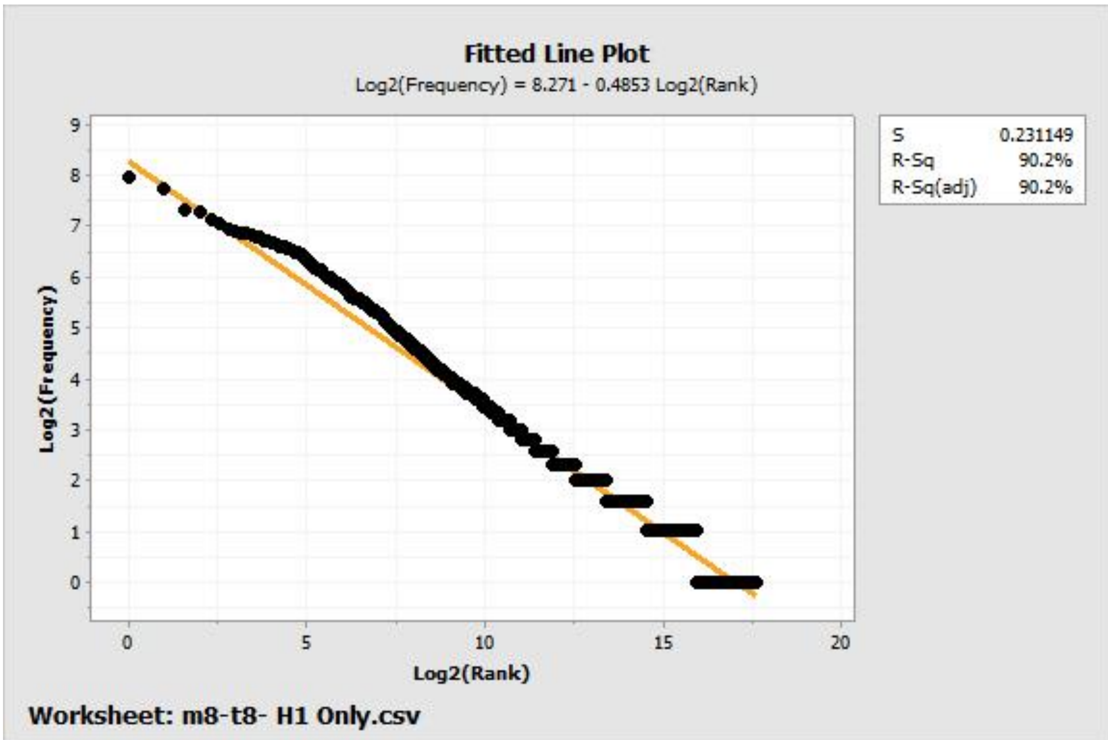

Fitted Line Plot
Log2(Frequency) = 9.276 - 0.5433 Log2(Rank)
S 0.230466
R-Sq 92.0%
R-Sq(adj) 92.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta- H2 Only.csv

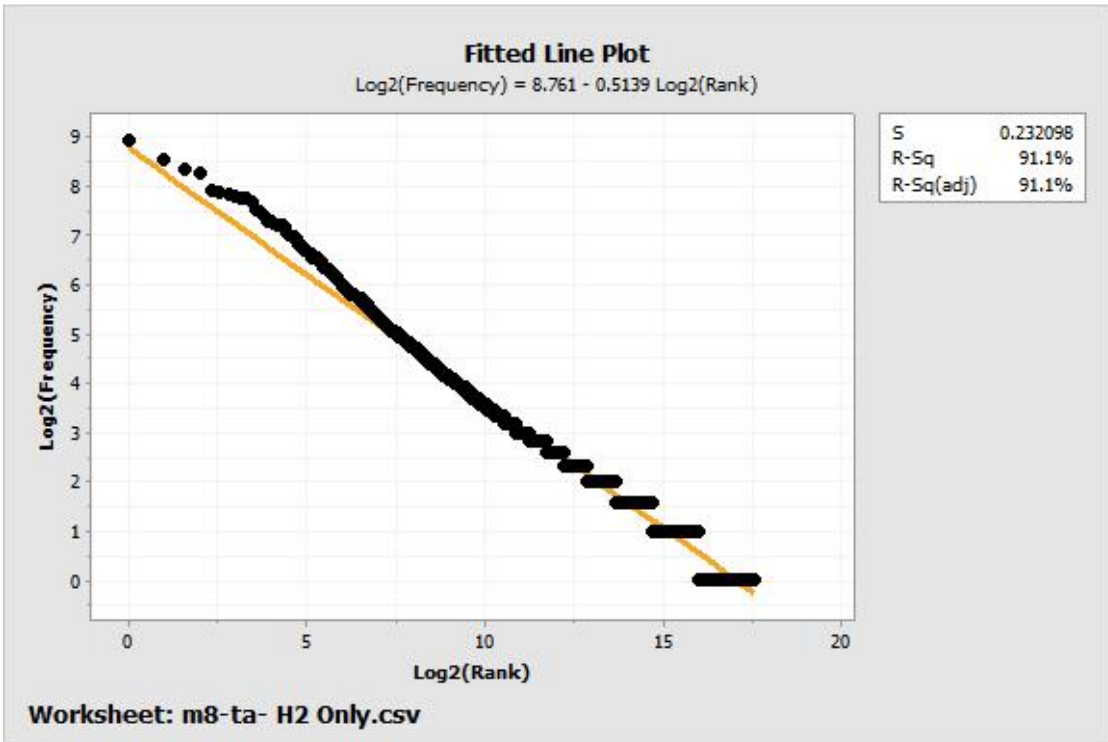

Fitted Line Plot
Log2(Frequency) = 8.995 - 0.5264 Log2(Rank)
S 0.231203
R-Sq 91.5%
R-Sq(adj) 91.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-t7- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.50 - 0.5822 Log2(Rank)
S 0.256260
R-Sq 91.5%
R-Sq(adj) 91.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta- H1 + H2.csv

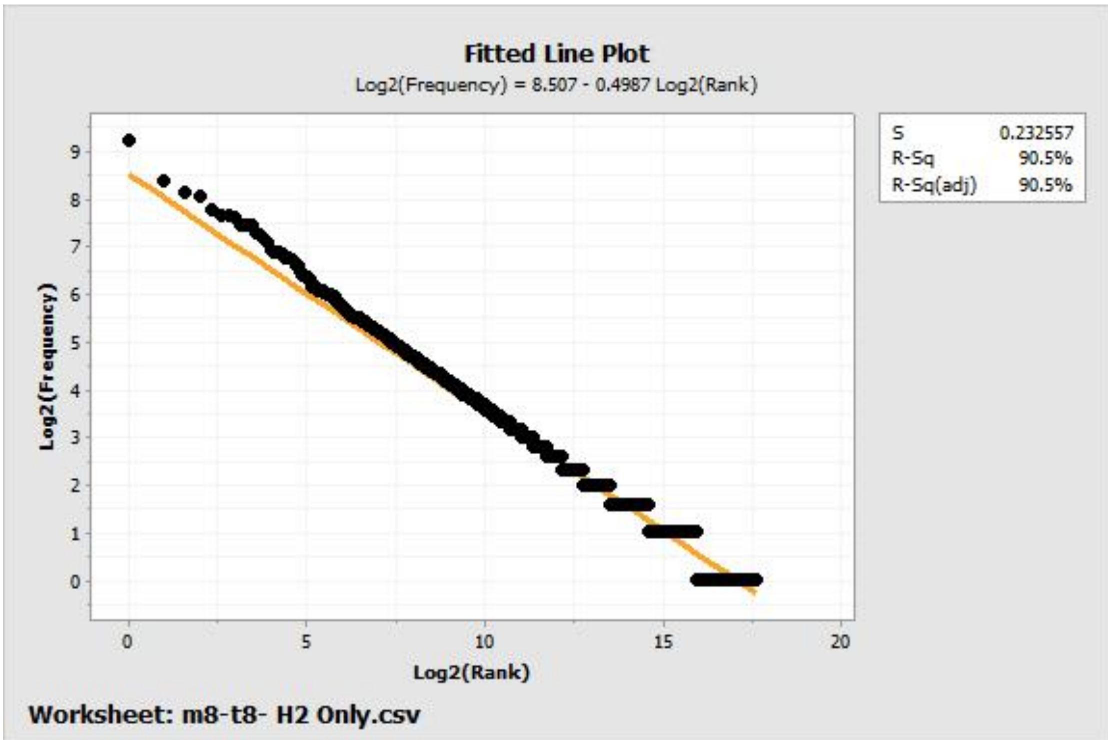

Fitted Line Plot
Log2(Frequency) = 10.49 - 0.5815 Log2(Rank)
S 0.262269
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-t7- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 8.319 - 0.4875 Log2(Rank)
S 0.231180
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta- H1 Only.csv

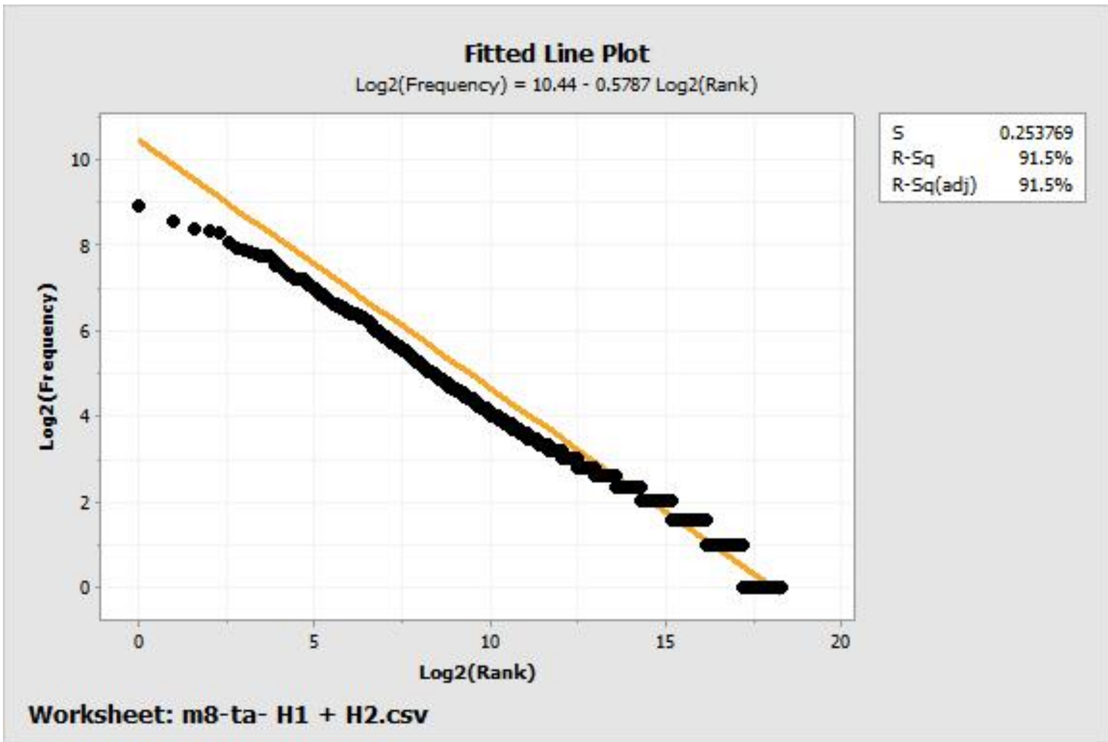

Fitted Line Plot
Log2(Frequency) = 8.271 - 0.4853 Log2(Rank)
S 0.231149
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-t8- H1 Only.csv



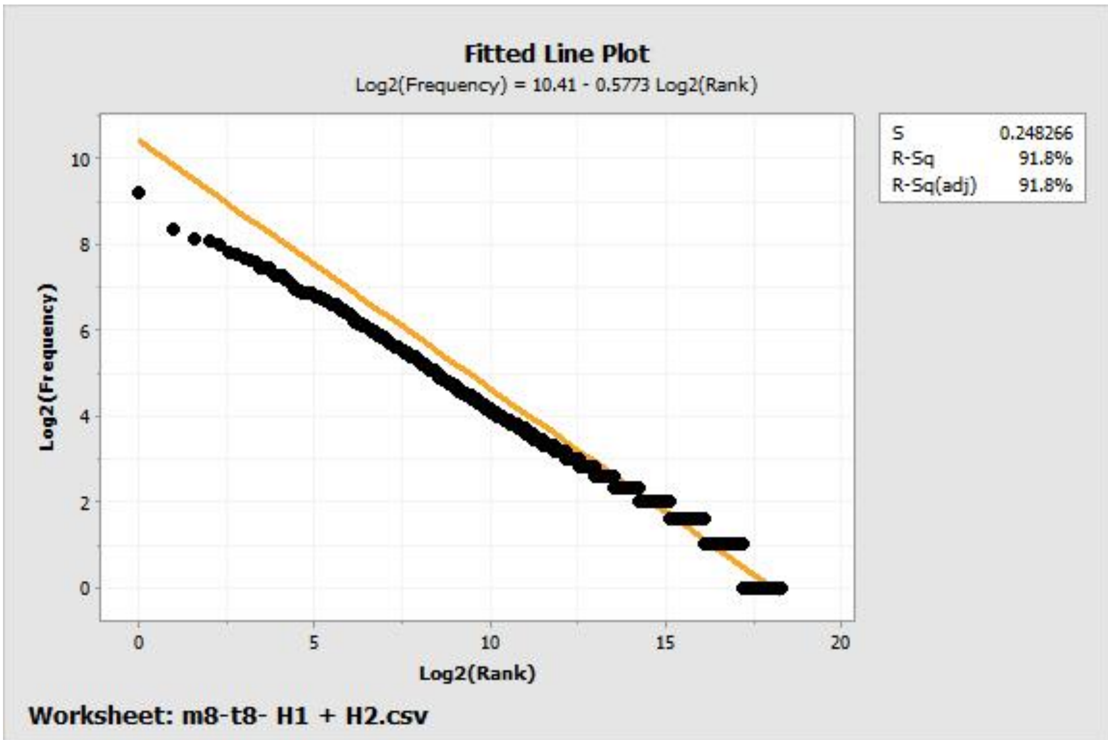
Fitted Line Plot
Log2(Frequency) = 8.761 - 0.5139 Log2(Rank)
S 0.232098
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta- H2 Only.csv



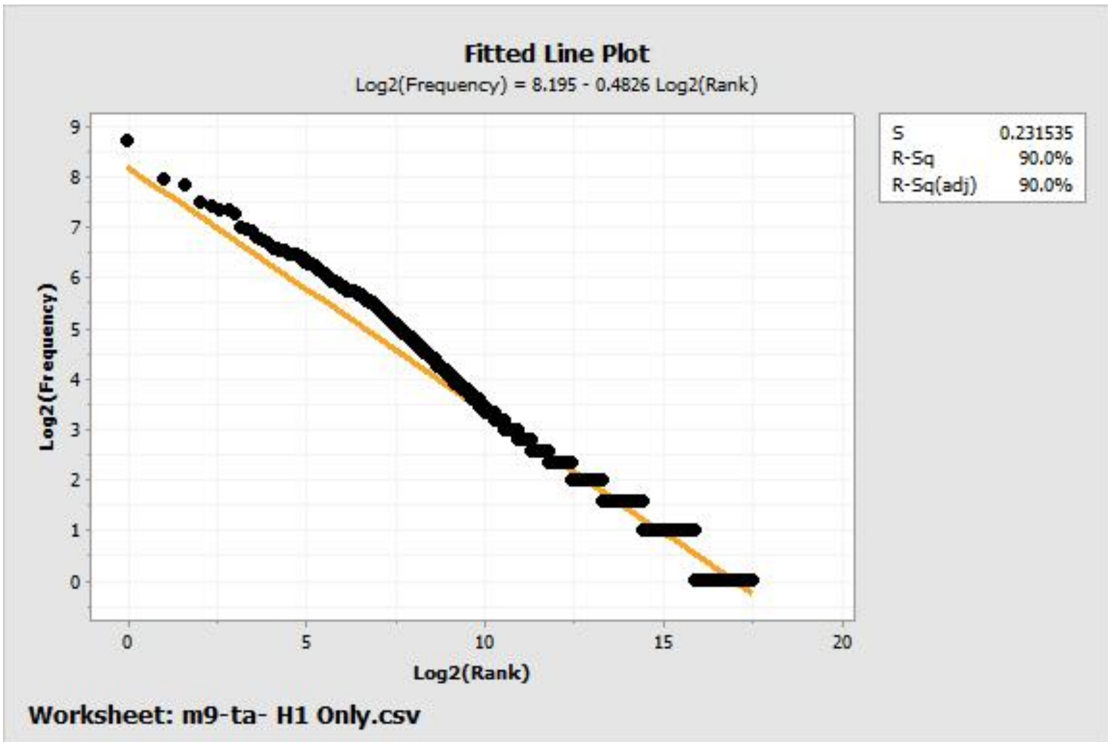
Fitted Line Plot
Log2(Frequency) = 8.507 - 0.4987 Log2(Rank)
S 0.232557
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-t8- H2 Only.csv

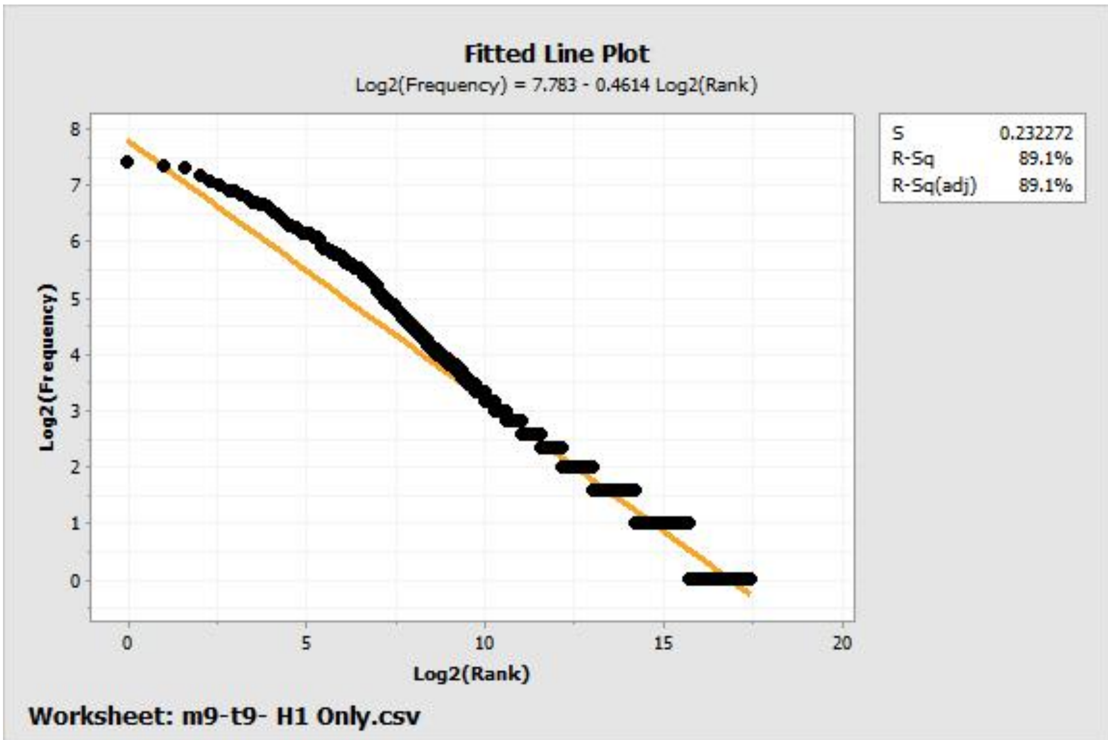


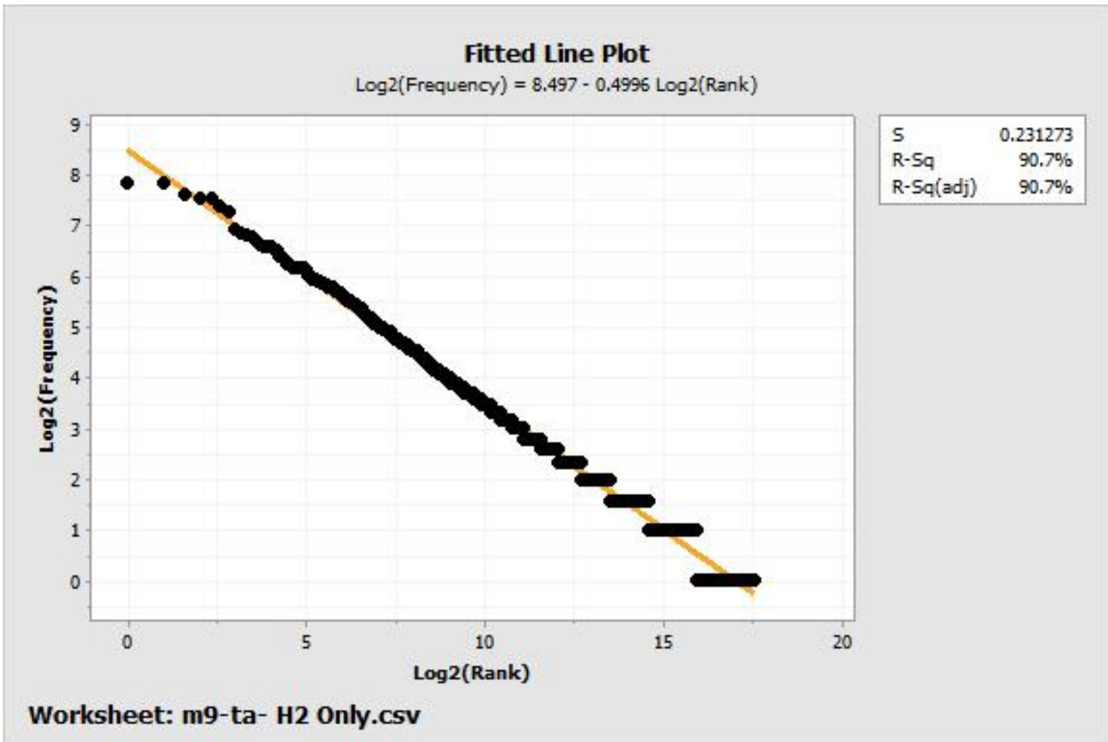
Fitted Line Plot
Log2(Frequency) = 10.44 - 0.5787 Log2(Rank)
S 0.253769
R-Sq 91.5%
R-Sq(adj) 91.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta- H1 + H2.csv



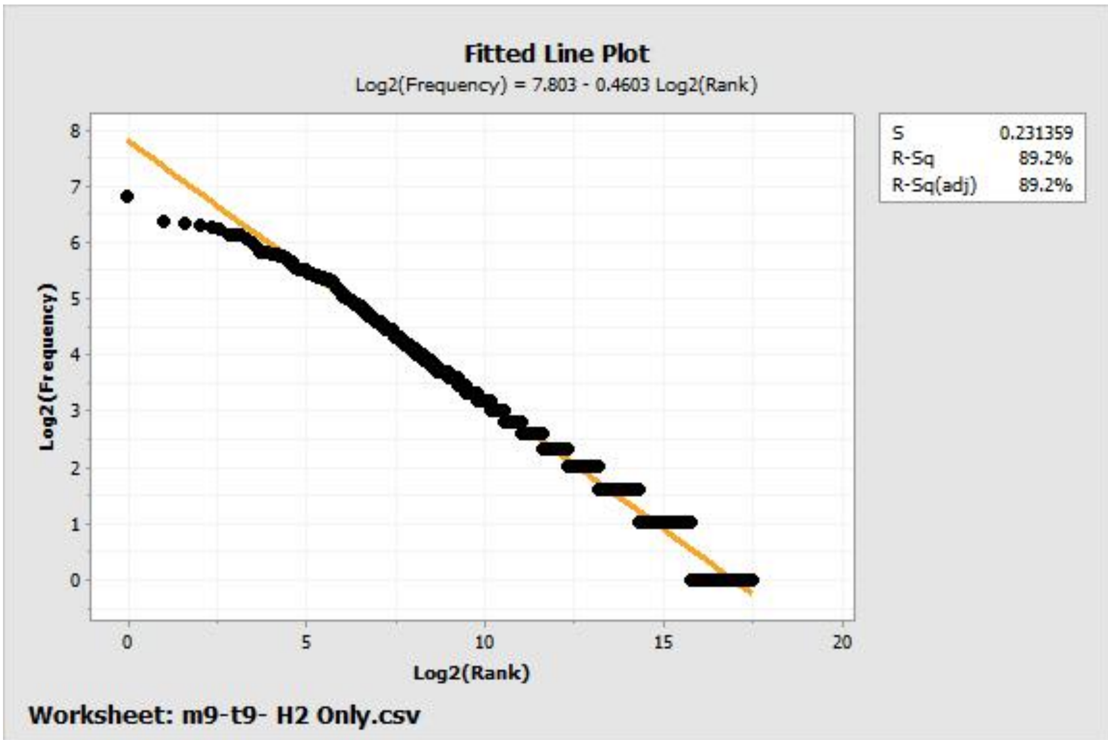
Fitted Line Plot
Log2(Frequency) = 10.41 - 0.5773 Log2(Rank)
S 0.248266
R-Sq 91.8%
R-Sq(adj) 91.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-t8- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 8.195 - 0.4826 Log2(Rank)
S 0.231535
R-Sq 90.0%
R-Sq(adj) 90.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m9-ta- H1 Only.csv

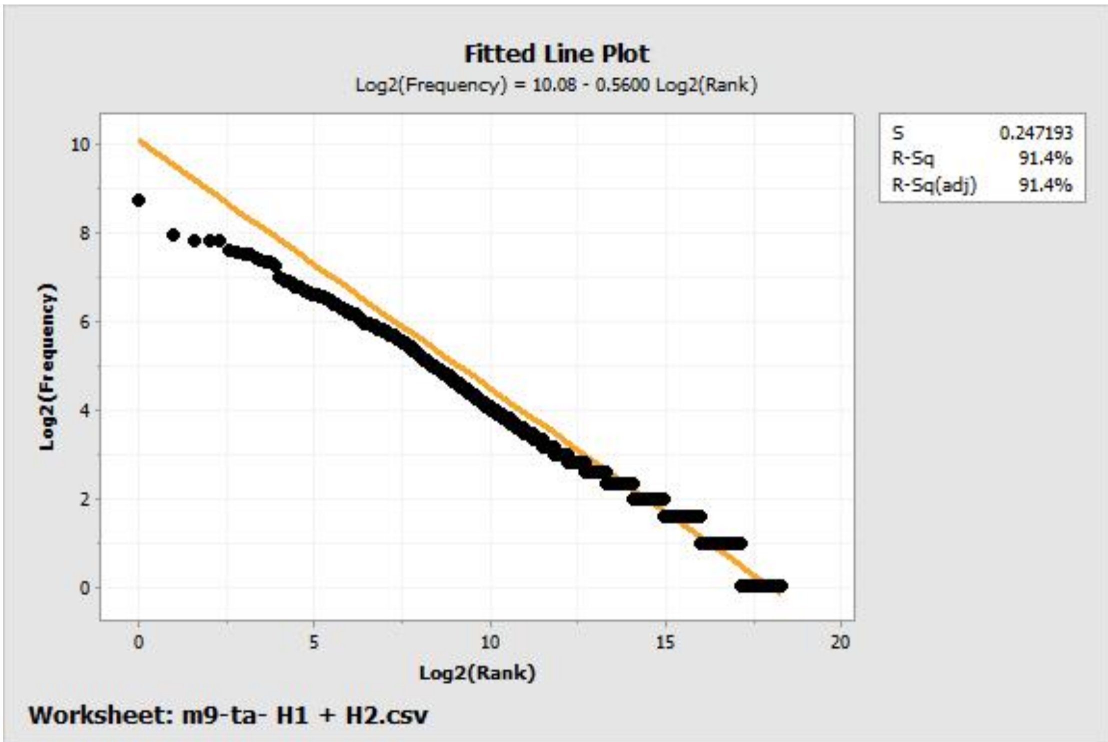

Fitted Line Plot
Log2(Frequency) = 7.783 - 0.4614 Log2(Rank)
S 0.232272
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m9-t9- H1 Only.csv

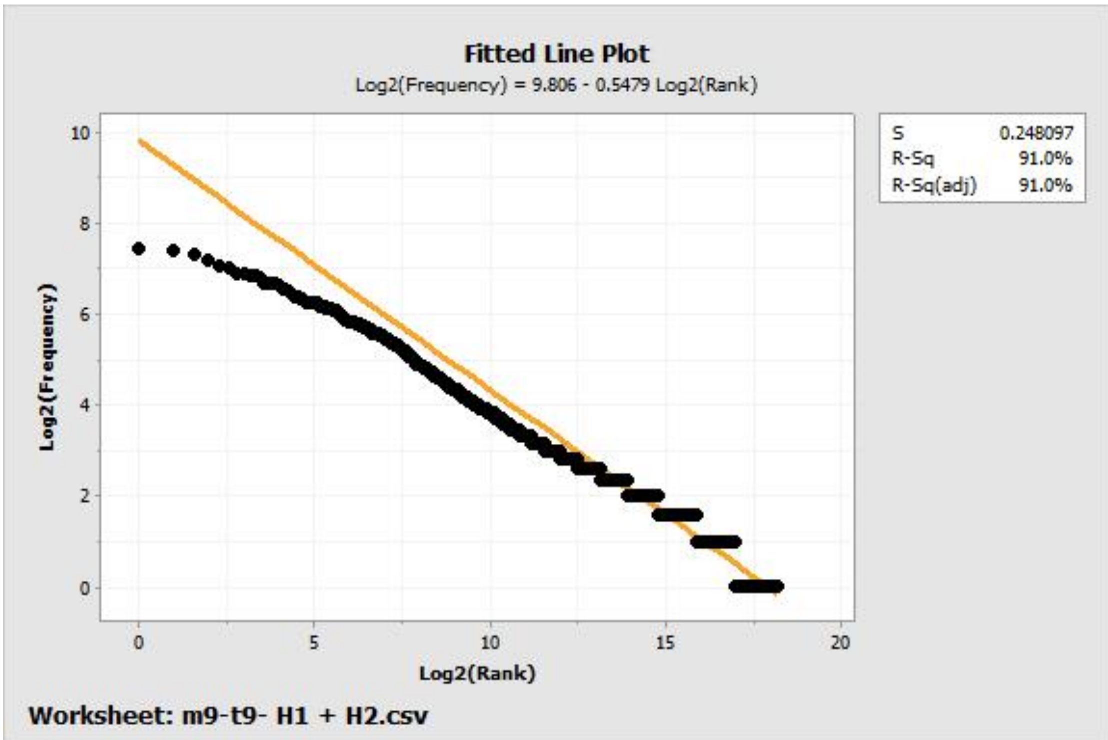


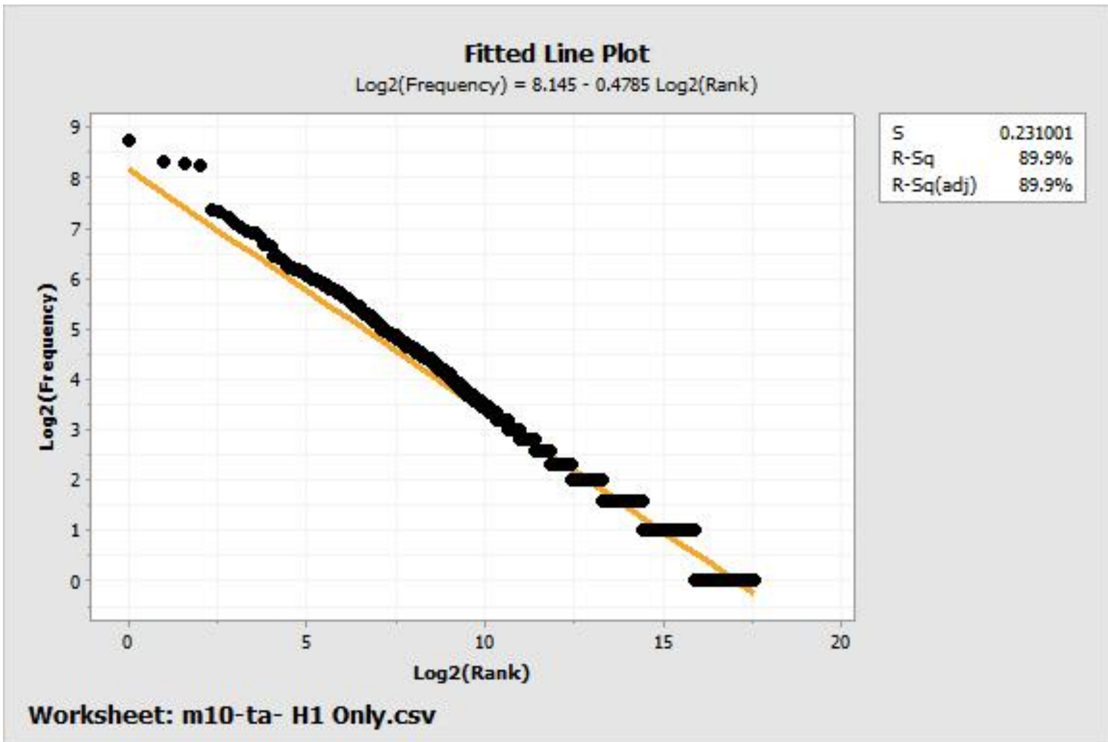
Fitted Line Plot
Log2(Frequency) = 8.497 - 0.4996 Log2(Rank)
S 0.231273
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m9-ta- H2 Only.csv

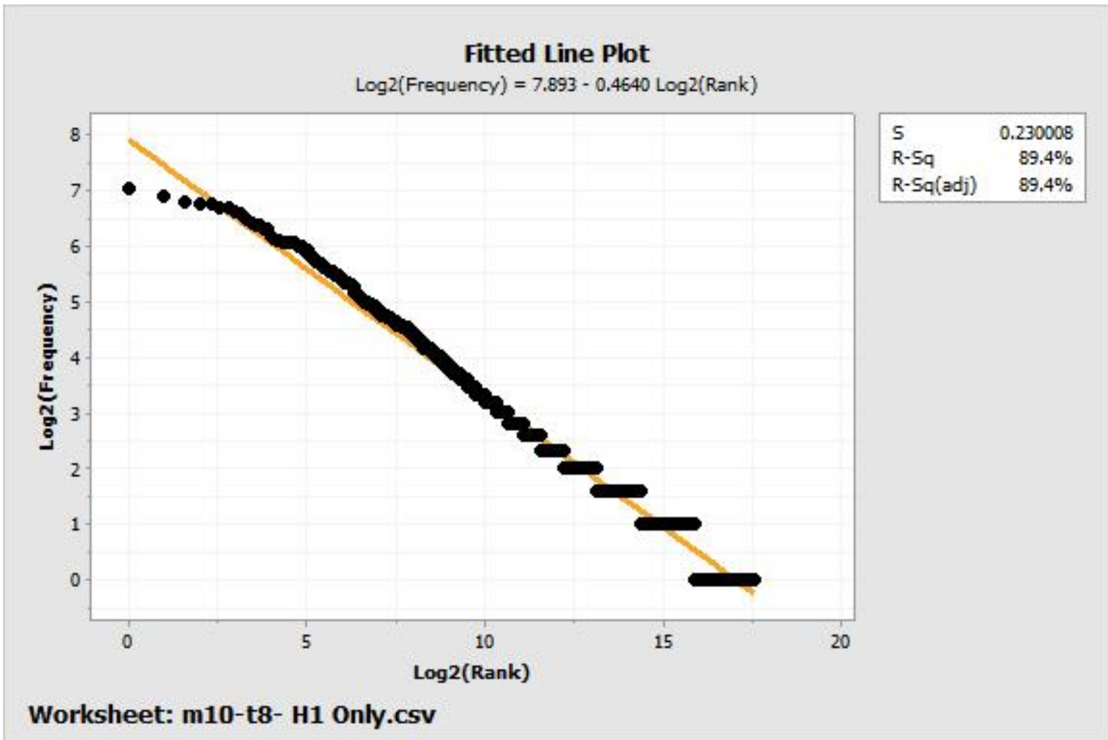


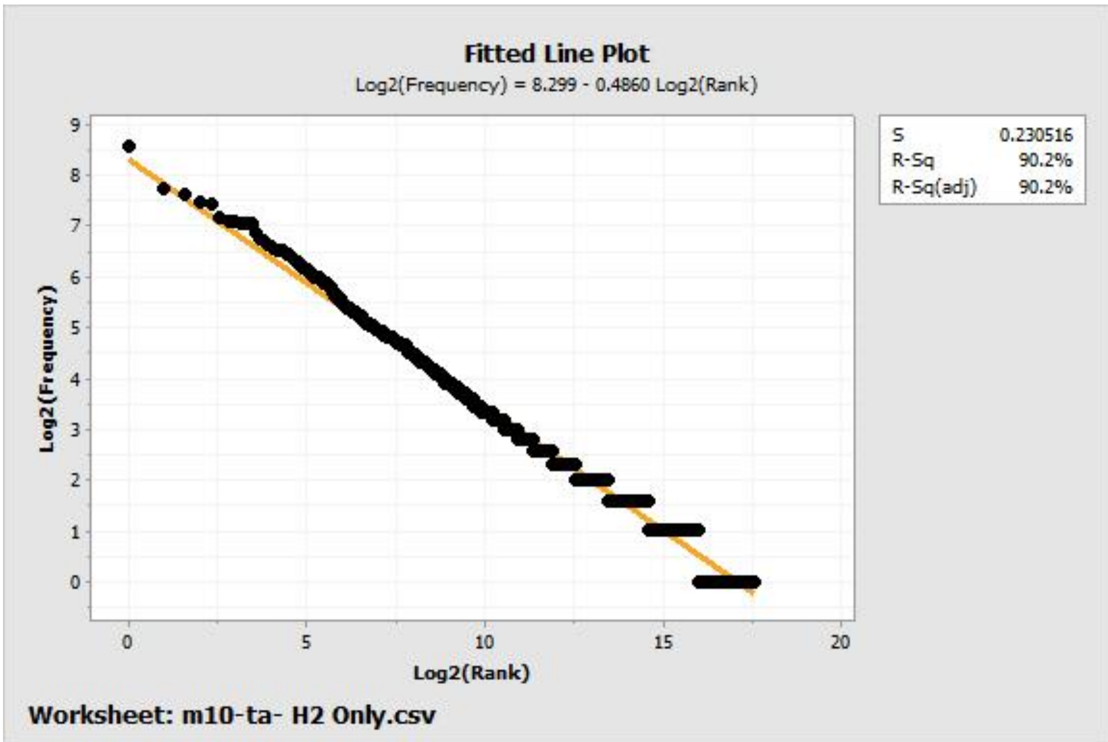
Fitted Line Plot
Log2(Frequency) = 7.803 - 0.4603 Log2(Rank)
S 0.231359
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m9-t9- H2 Only.csv

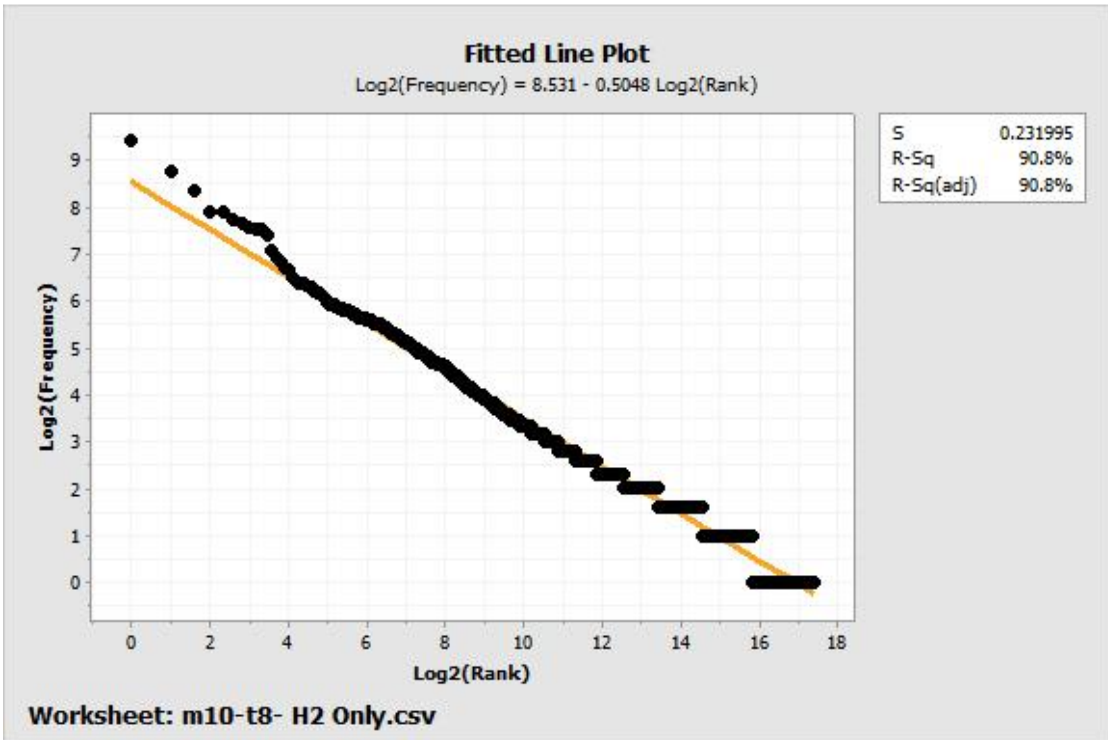

Fitted Line Plot
Log2(Frequency) = 10.08 - 0.5600 Log2(Rank)
S 0.247193
R-Sq 91.4%
R-Sq(adj) 91.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m9-ta- H1 + H2.csv

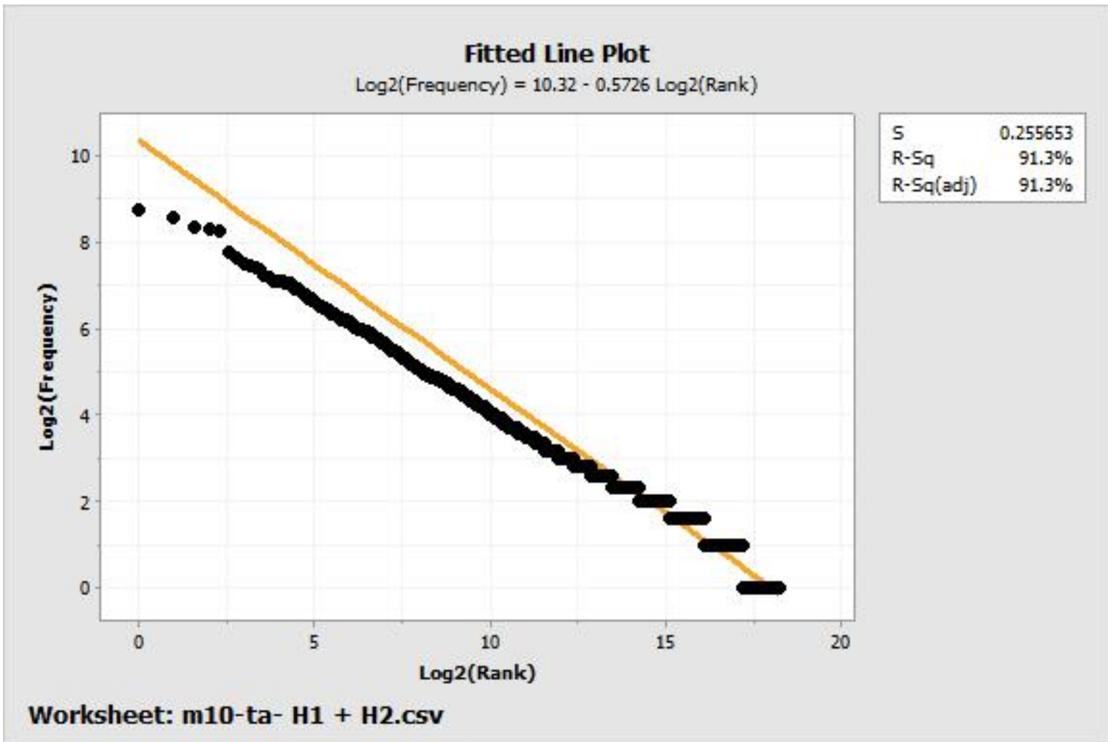

Fitted Line Plot
Log2(Frequency) = 9.806 - 0.5479 Log2(Rank)
S 0.248097
R-Sq 91.0%
R-Sq(adj) 91.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m9-t9- H1 + H2.csv

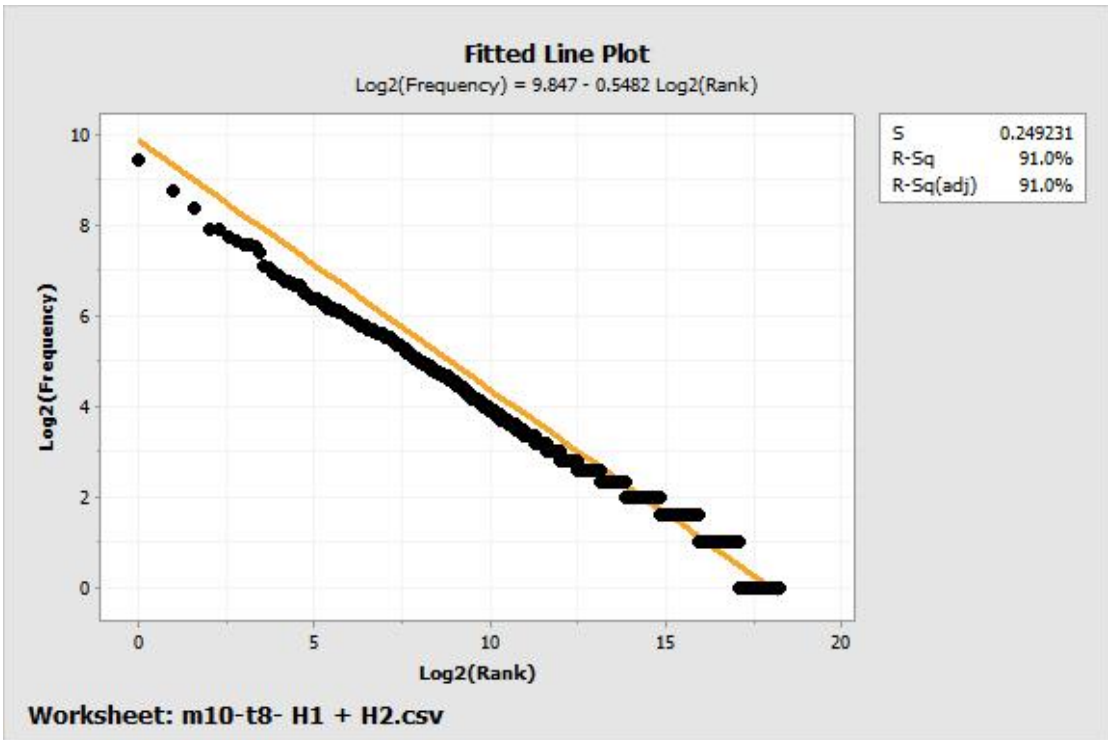

Fitted Line Plot
Log2(Frequency) = 8.145 - 0.4785 Log2(Rank)
S 0.231001
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta- H1 Only.csv

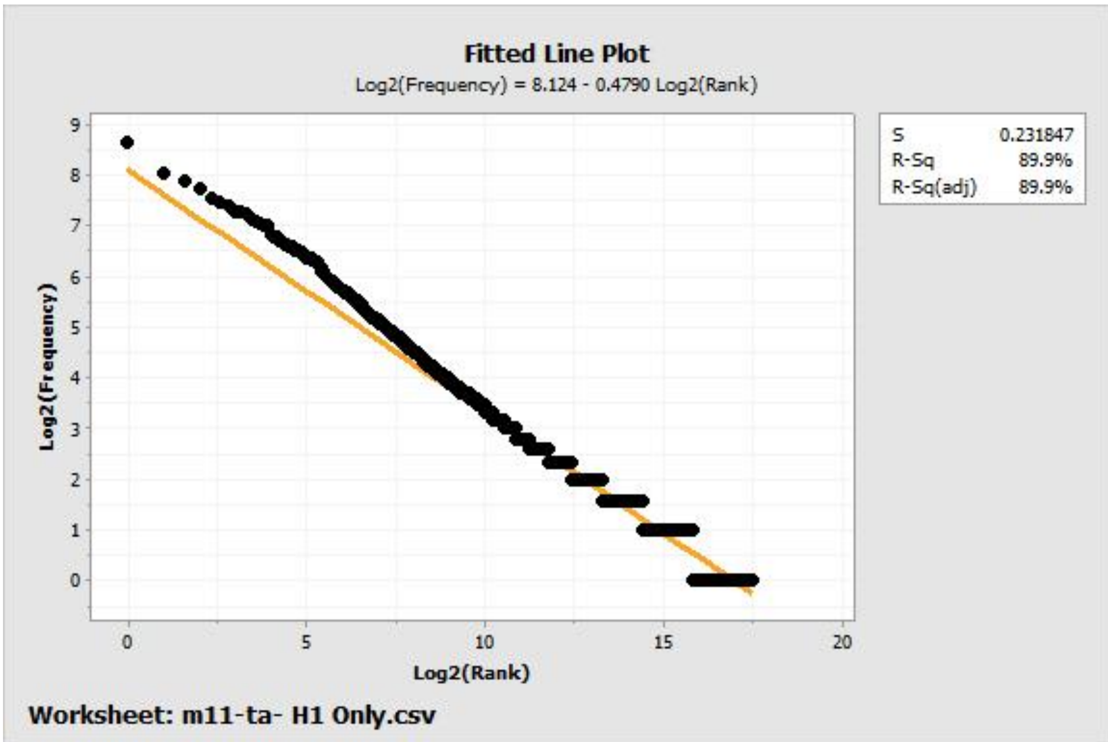

Fitted Line Plot
Log2(Frequency) = 7.893 - 0.4640 Log2(Rank)
S 0.230008
R-Sq 89.4%
R-Sq(adj) 89.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8- H1 Only.csv

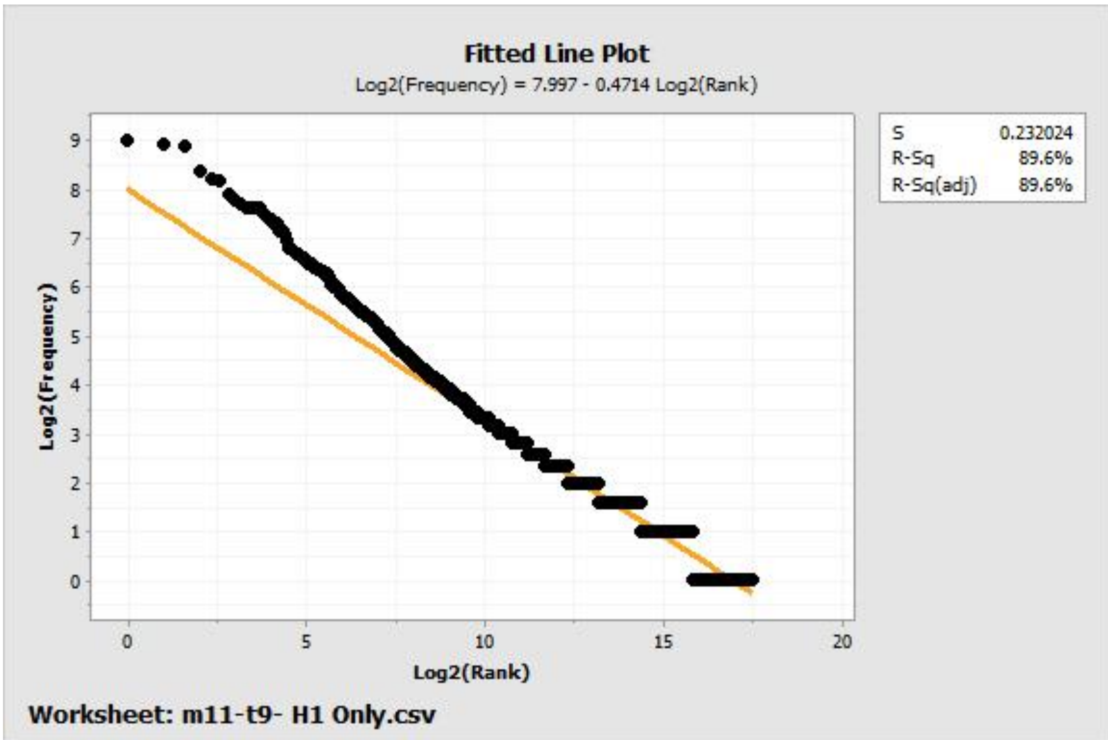

Fitted Line Plot
Log2(Frequency) = 8.299 - 0.4860 Log2(Rank)
S 0.230516
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta- H2 Only.csv

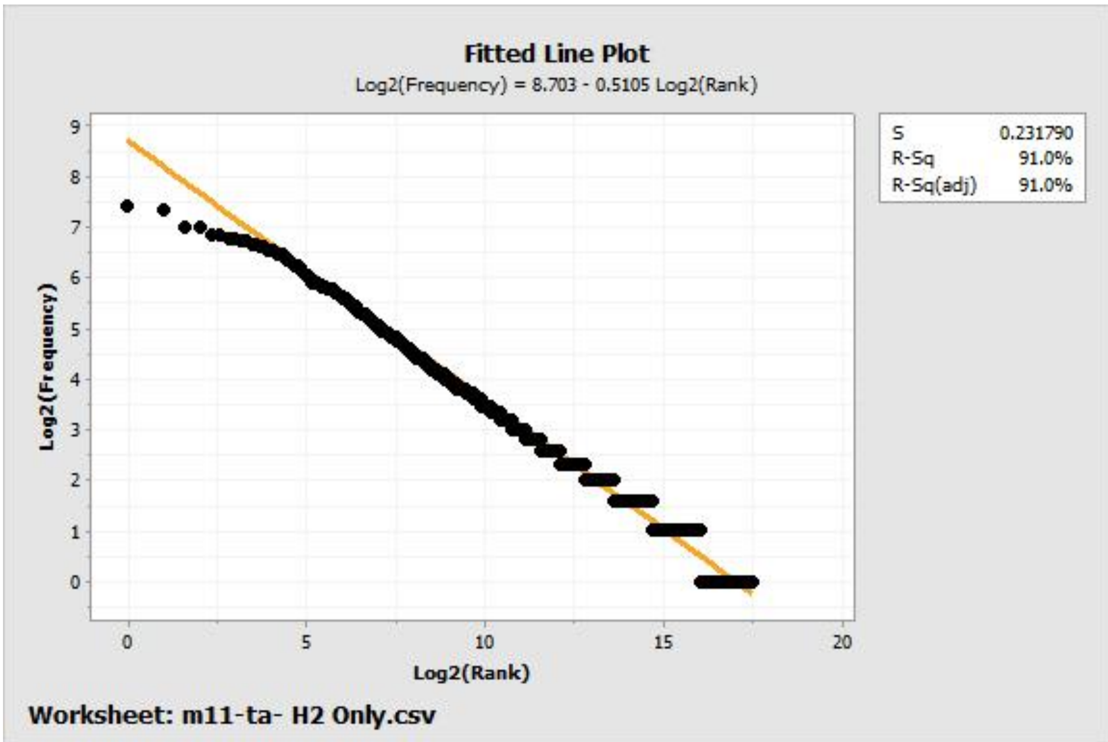

Fitted Line Plot
Log2(Frequency) = 8.531 - 0.5048 Log2(Rank)
S 0.231995
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8- H2 Only.csv

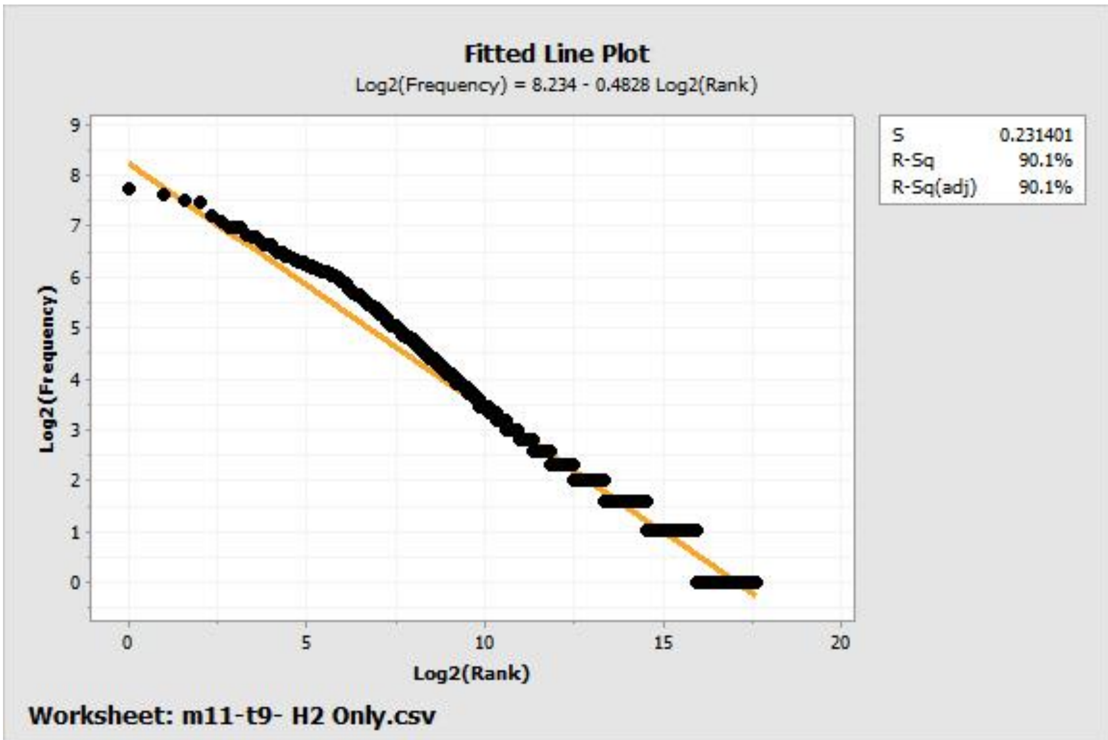

Fitted Line Plot
Log2(Frequency) = 10.32 - 0.5726 Log2(Rank)
S 0.255653
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta- H1 + H2.csv

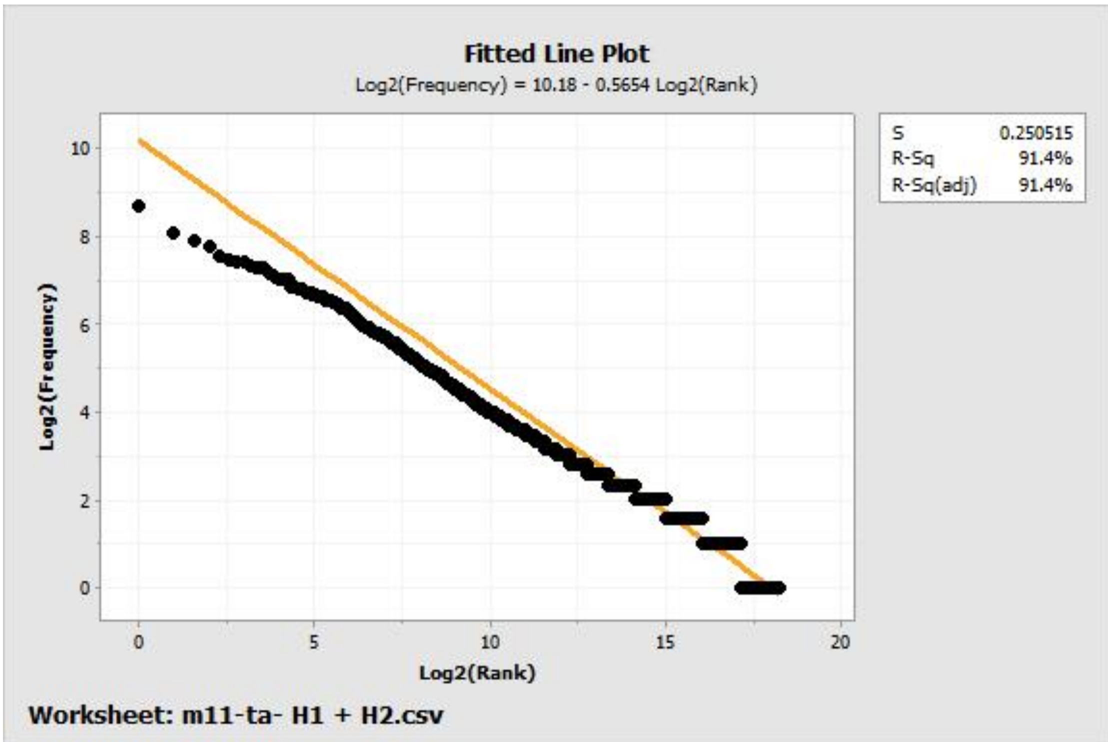

Fitted Line Plot
Log2(Frequency) = 9.847 - 0.5482 Log2(Rank)
S 0.249231
R-Sq 91.0%
R-Sq(adj) 91.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8- H1 + H2.csv

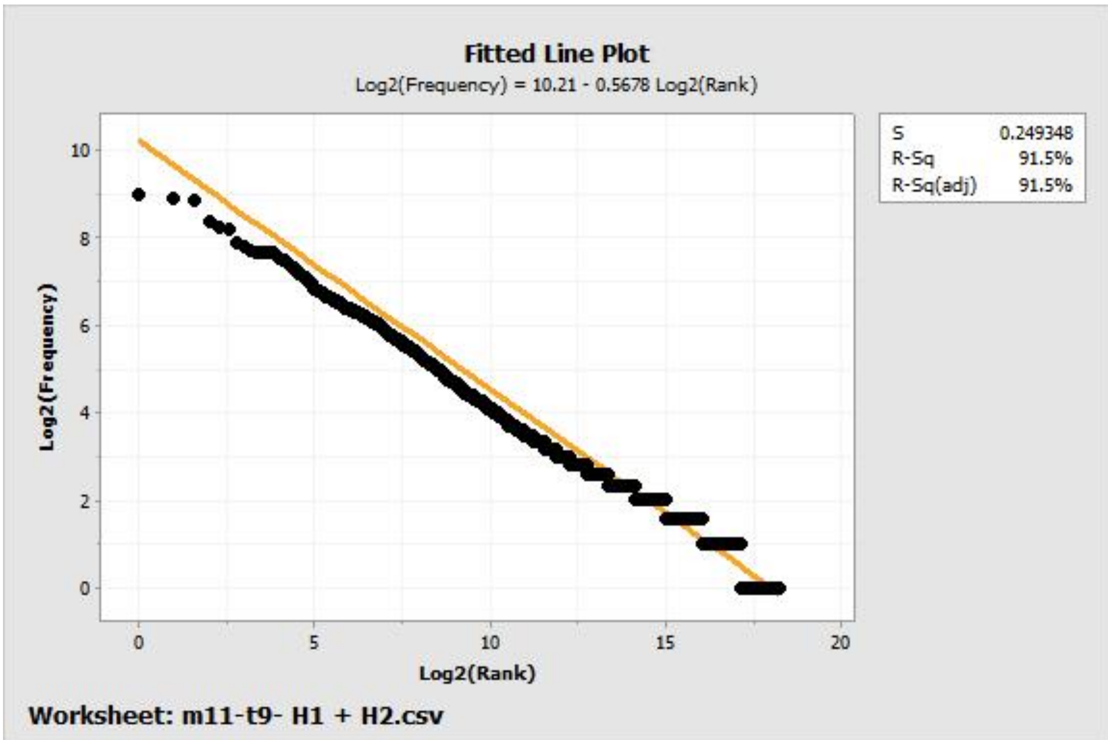

Fitted Line Plot
Log2(Frequency) = 8.124 - 0.4790 Log2(Rank)
S 0.231847
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta- H1 Only.csv

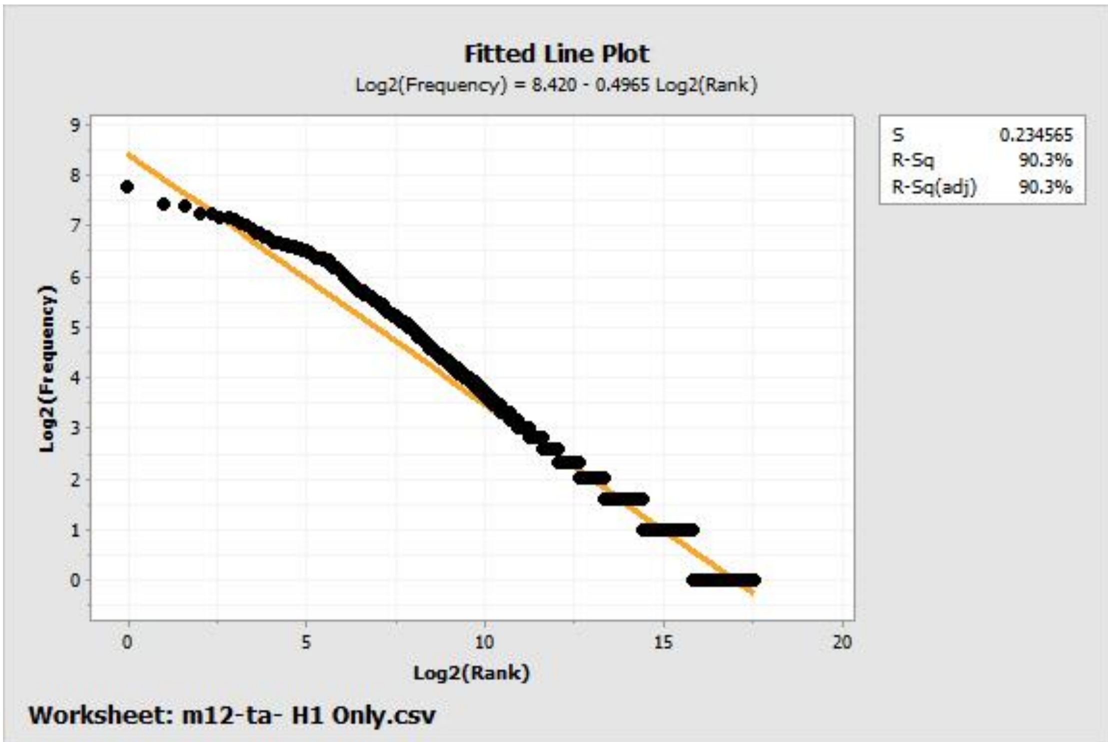

Fitted Line Plot
Log2(Frequency) = 7.997 - 0.4714 Log2(Rank)
S 0.232024
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9- H1 Only.csv

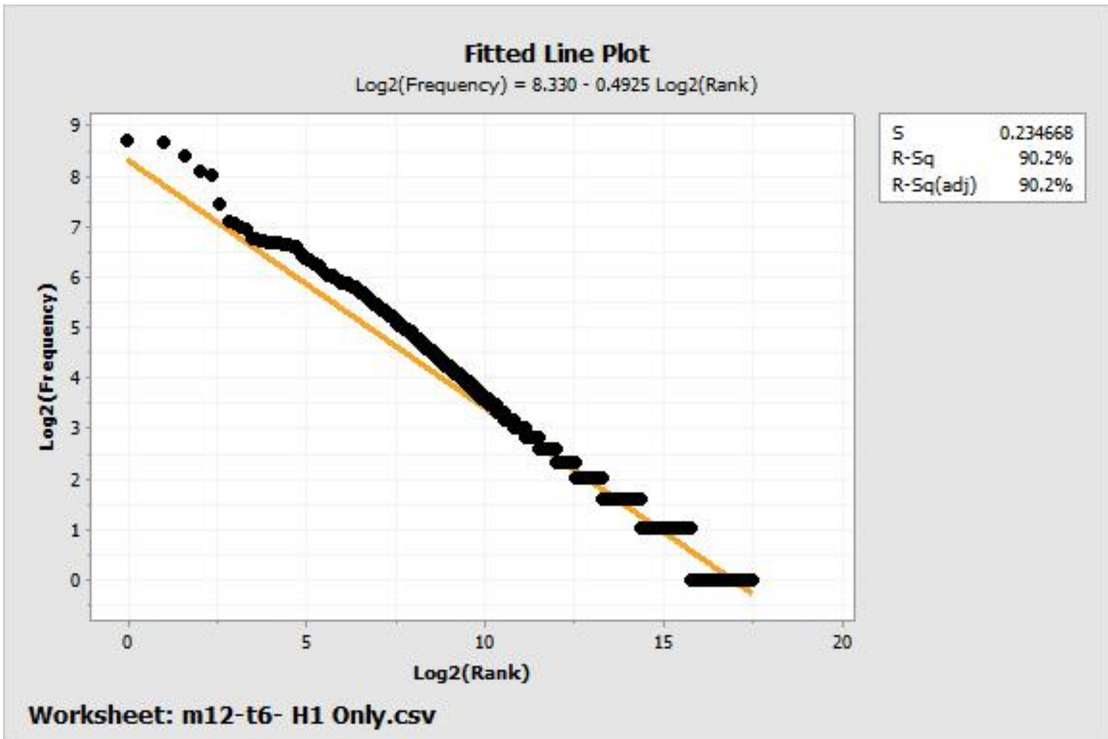

Fitted Line Plot
Log2(Frequency) = 8.703 - 0.5105 Log2(Rank)
S 0.231790
R-Sq 91.0%
R-Sq(adj) 91.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta- H2 Only.csv

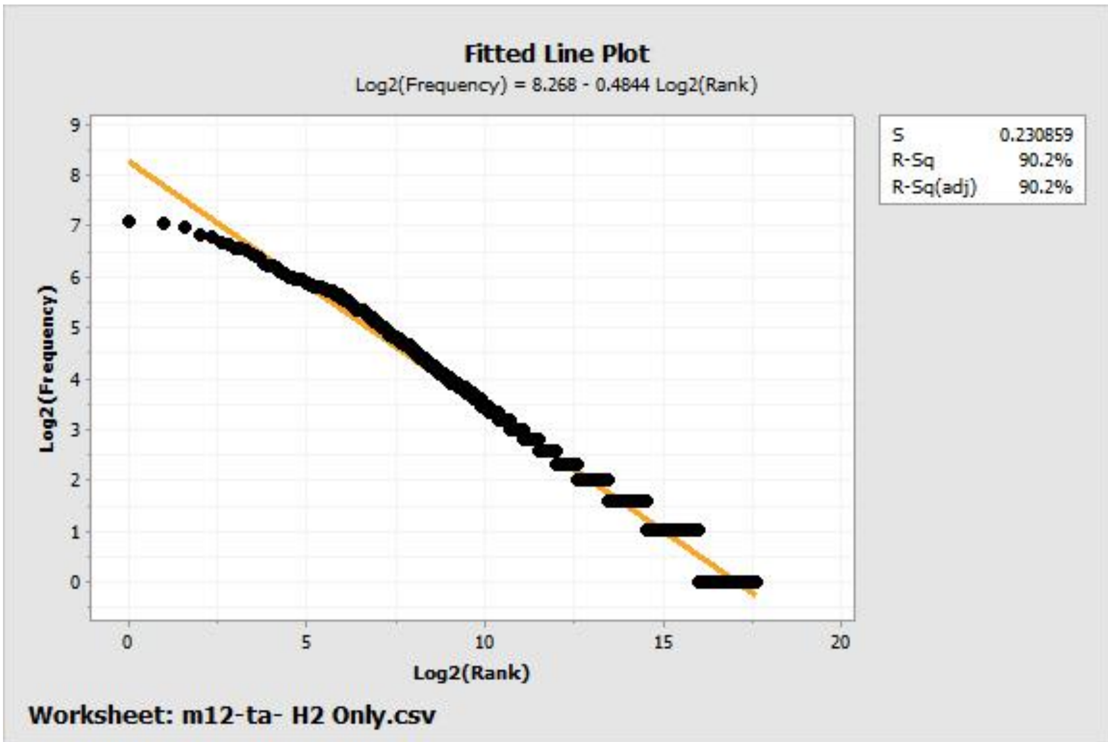

Fitted Line Plot
Log2(Frequency) = 8.234 - 0.4828 Log2(Rank)
S 0.231401
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9- H2 Only.csv

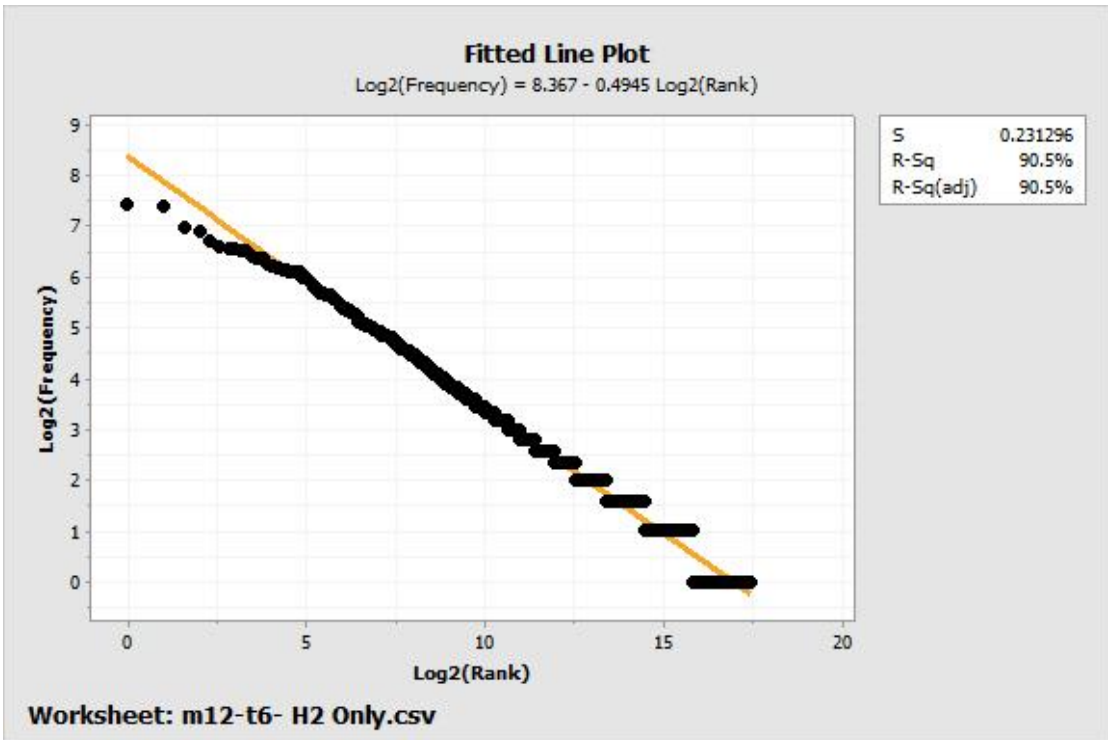

Fitted Line Plot
Log2(Frequency) = 10.18 - 0.5654 Log2(Rank)
S 0.250515
R-Sq 91.4%
R-Sq(adj) 91.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta- H1 + H2.csv

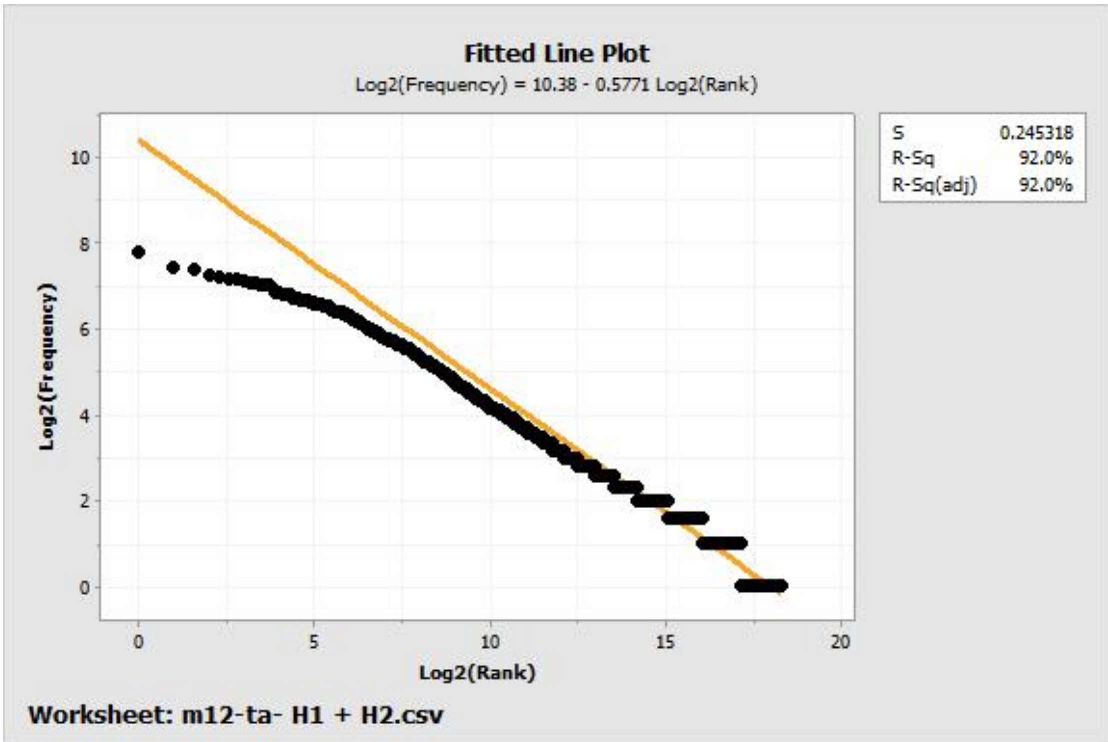

Fitted Line Plot
Log2(Frequency) = 10.21 - 0.5678 Log2(Rank)
S 0.249348
R-Sq 91.5%
R-Sq(adj) 91.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9- H1 + H2.csv

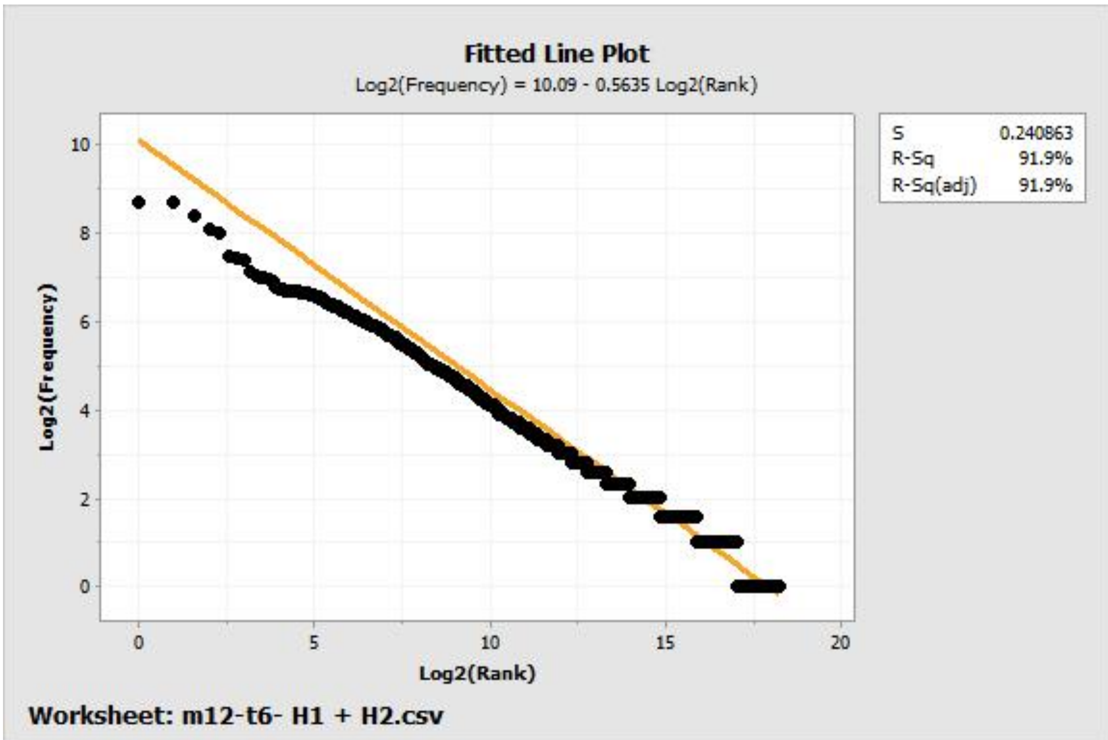

Fitted Line Plot
Log2(Frequency) = 8.420 - 0.4965 Log2(Rank)
S 0.234565
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta- H1 Only.csv

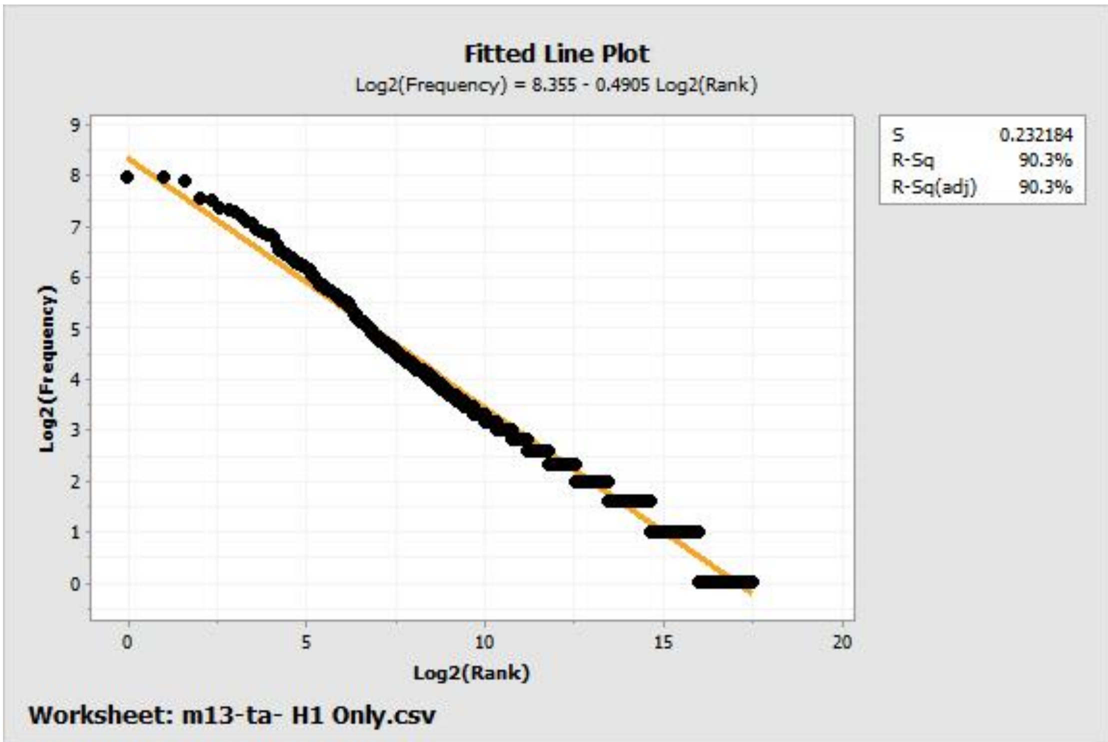

Fitted Line Plot
Log2(Frequency) = 8.330 - 0.4925 Log2(Rank)
S 0.234668
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6- H1 Only.csv

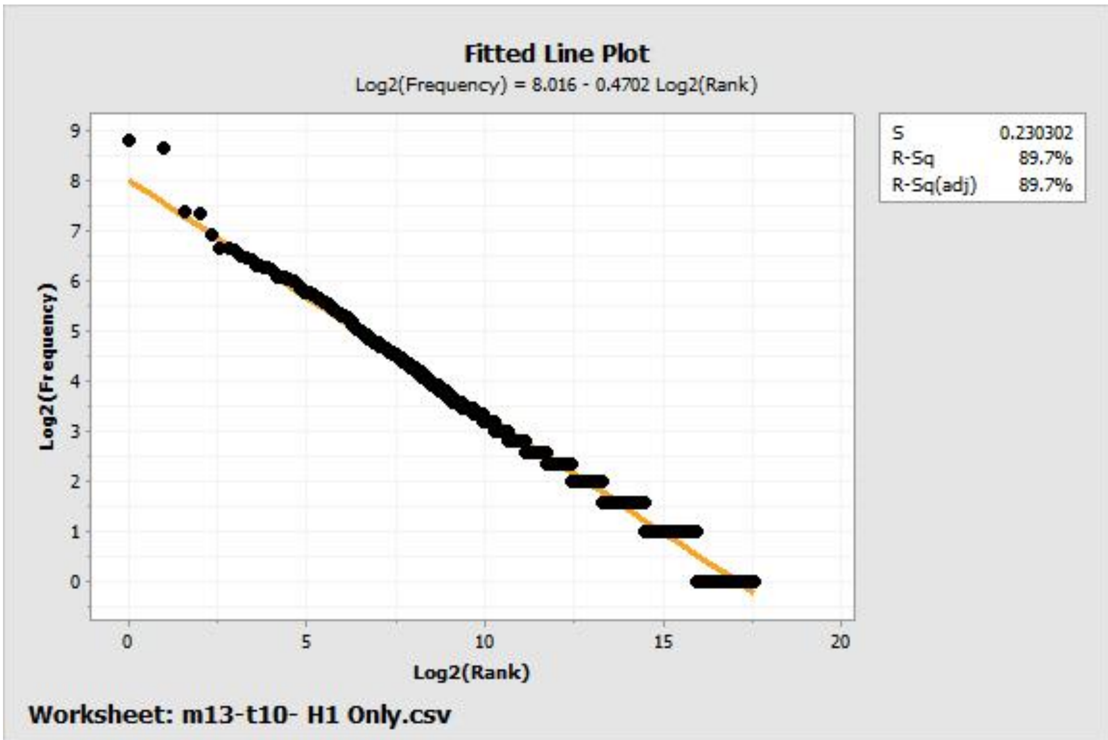

Fitted Line Plot
Log2(Frequency) = 8.268 - 0.4844 Log2(Rank)
S 0.230859
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta- H2 Only.csv

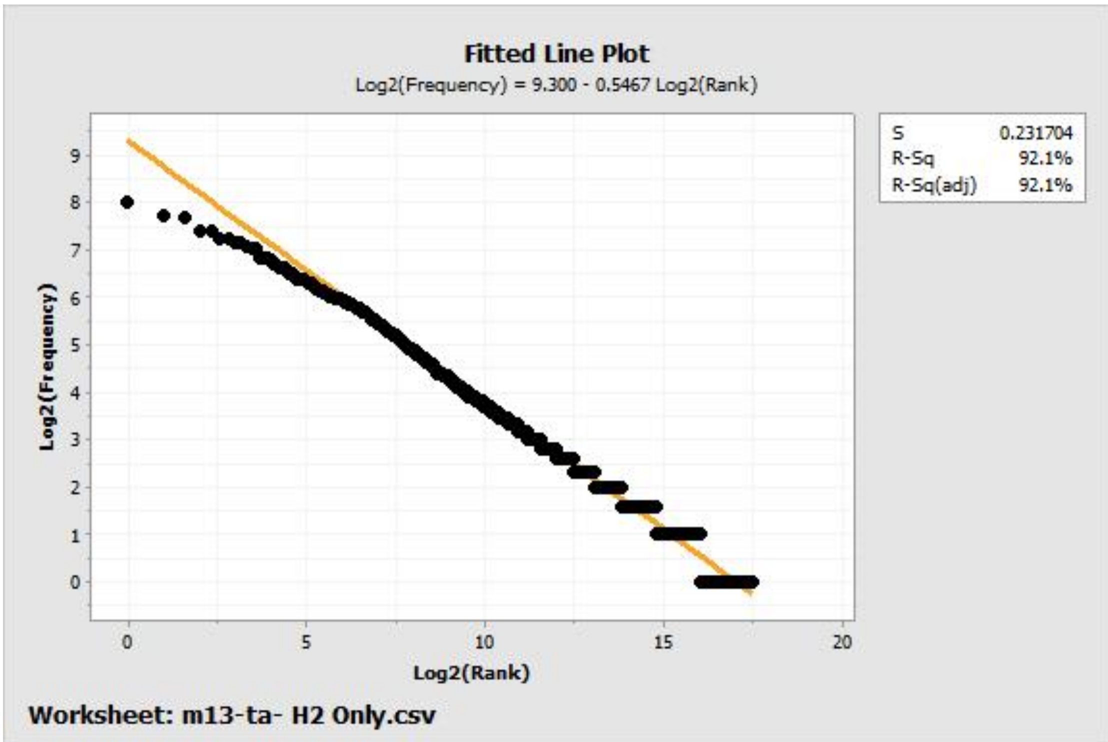

Fitted Line Plot
Log2(Frequency) = 8.367 - 0.4945 Log2(Rank)
S 0.231296
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6- H2 Only.csv

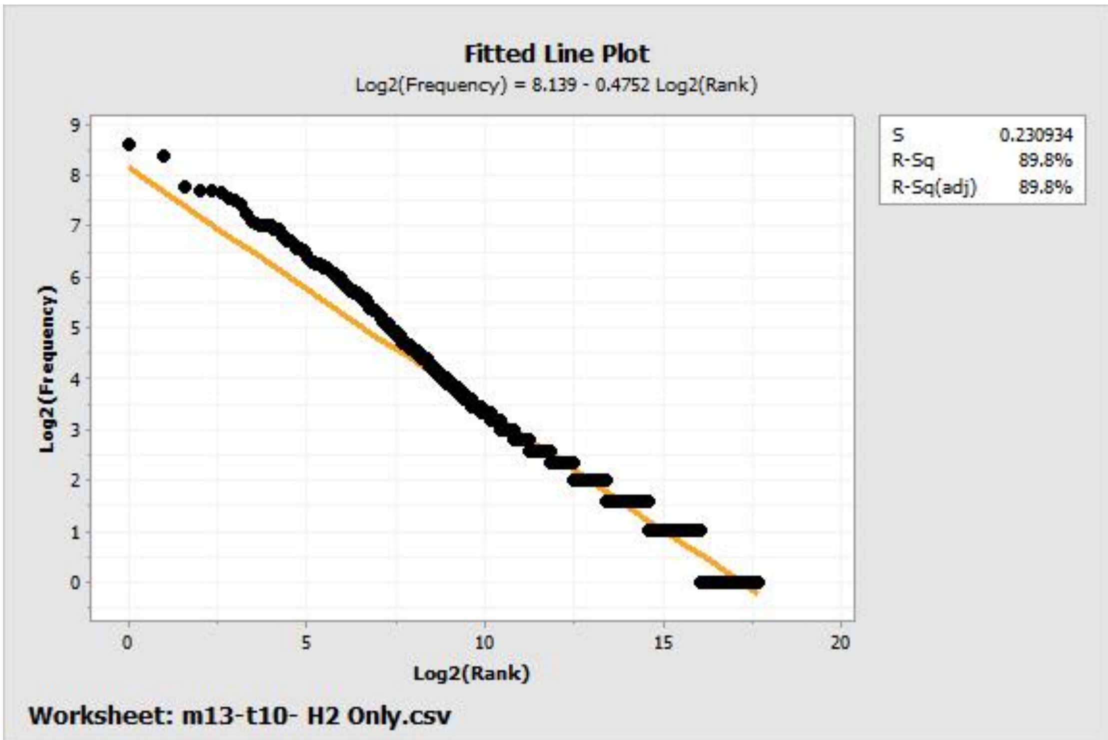

Fitted Line Plot
Log2(Frequency) = 10.38 - 0.5771 Log2(Rank)
S 0.245318
R-Sq 92.0%
R-Sq(adj) 92.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta- H1 + H2.csv

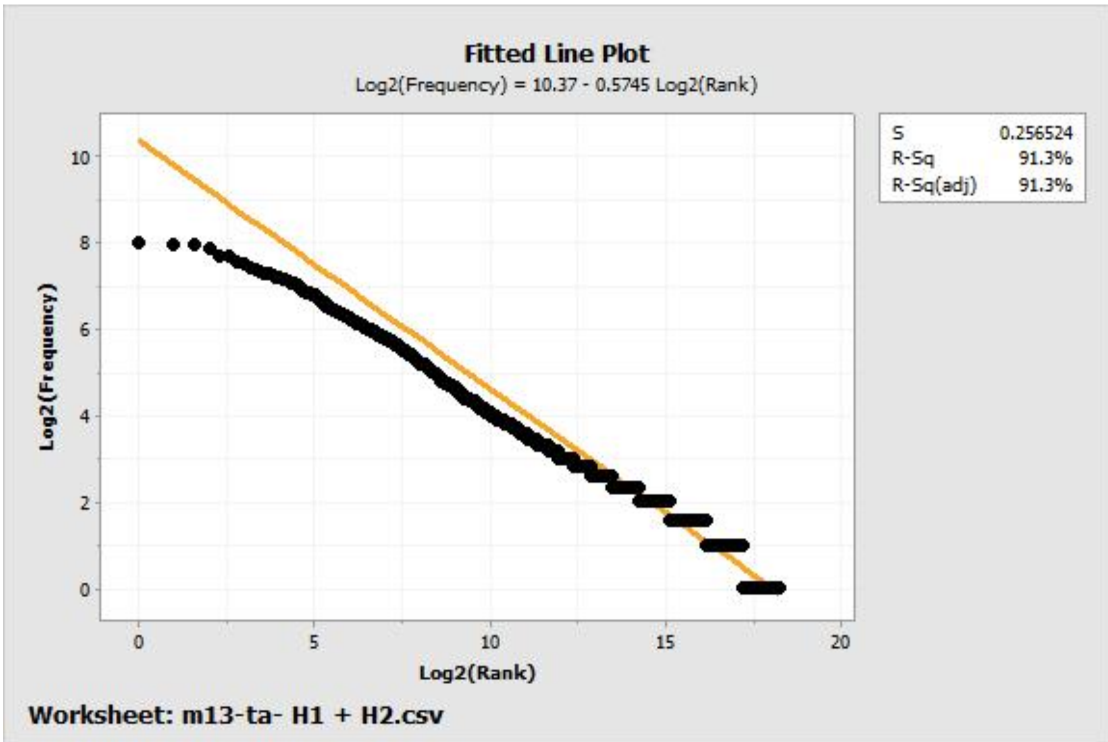

Fitted Line Plot
Log2(Frequency) = 10.09 - 0.5635 Log2(Rank)
S 0.240863
R-Sq 91.9%
R-Sq(adj) 91.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6- H1 + H2.csv

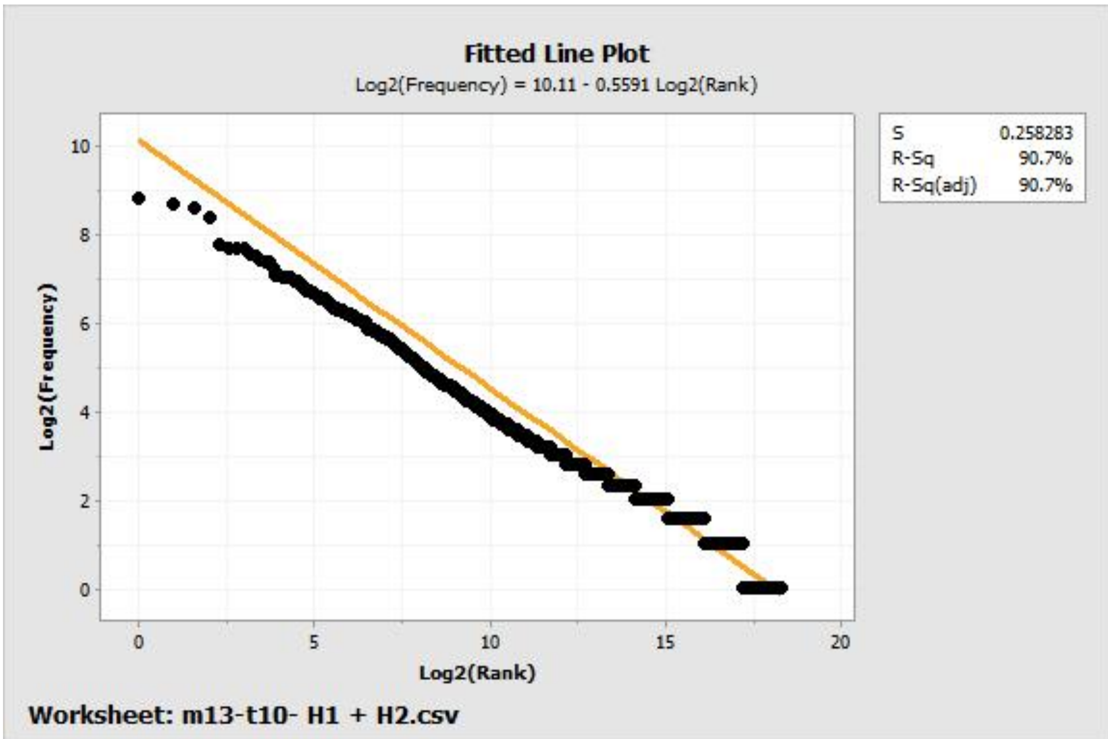

Fitted Line Plot
Log2(Frequency) = 8.355 - 0.4905 Log2(Rank)
S 0.232184
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta- H1 Only.csv

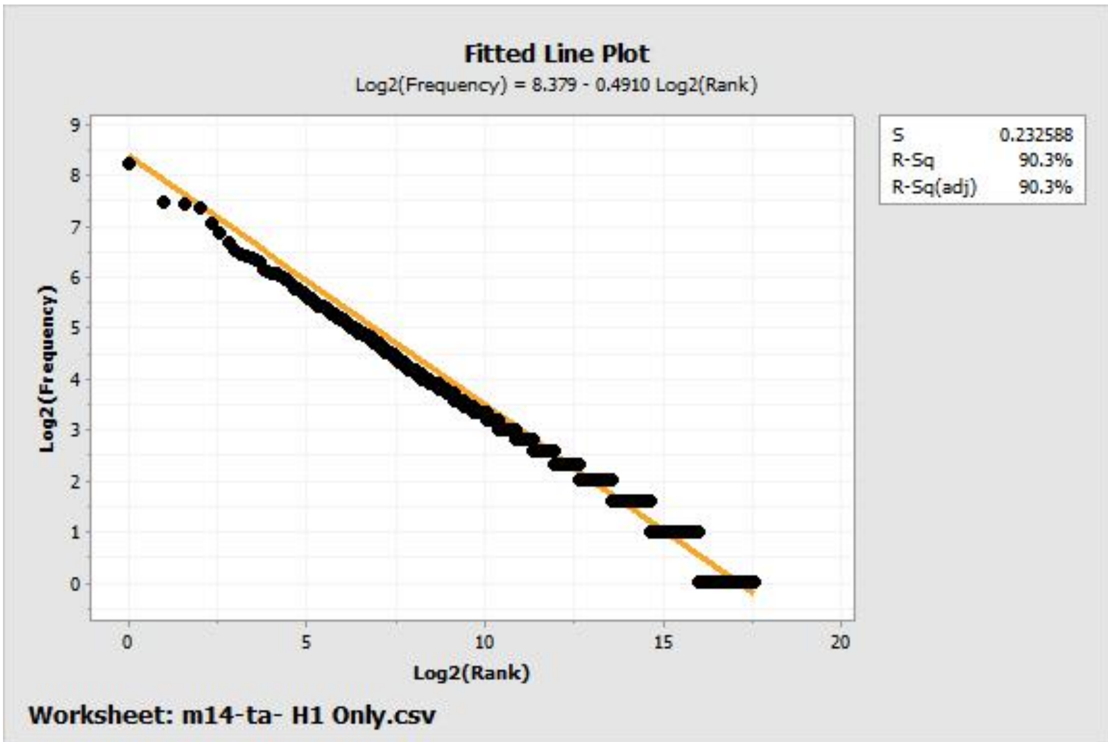

Fitted Line Plot
Log2(Frequency) = 8.016 - 0.4702 Log2(Rank)
S 0.230302
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-t10- H1 Only.csv

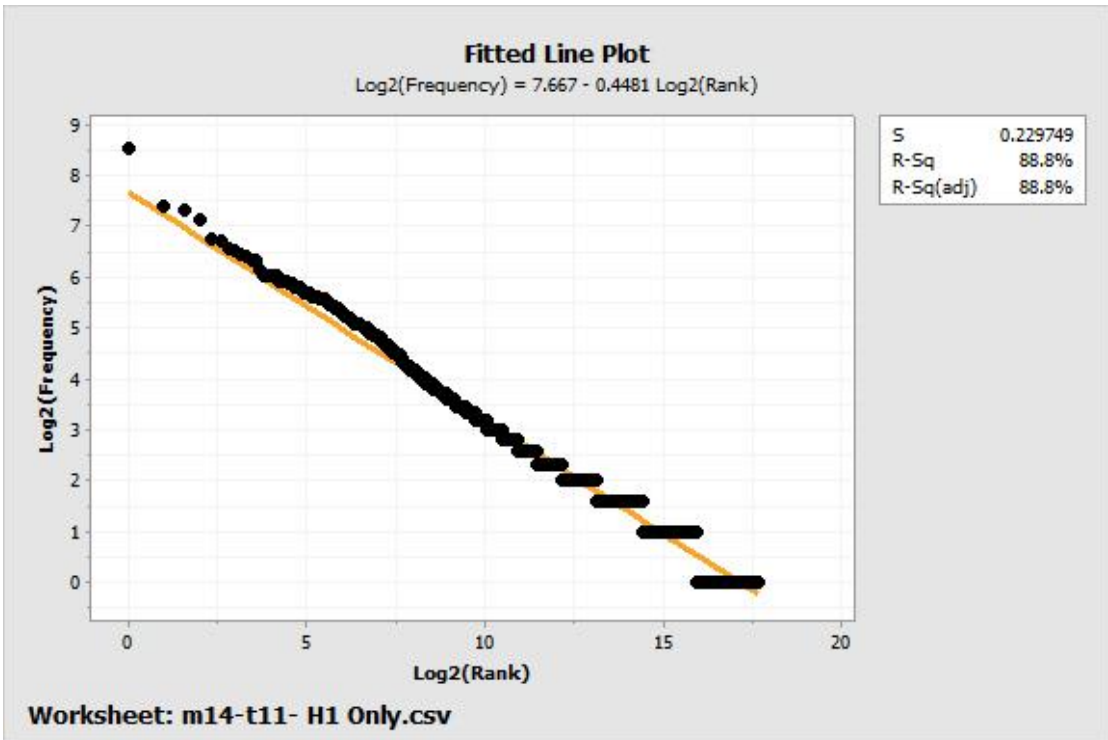

Fitted Line Plot
Log2(Frequency) = 9.300 - 0.5467 Log2(Rank)
S 0.231704
R-Sq 92.1%
R-Sq(adj) 92.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta- H2 Only.csv

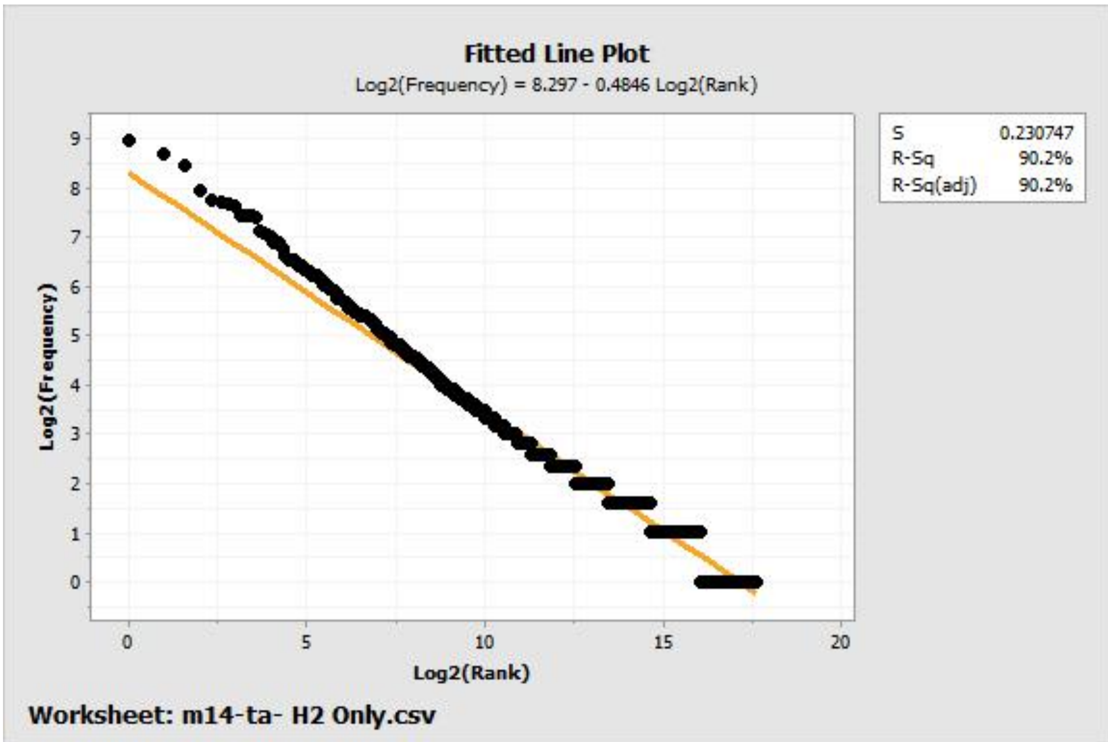

Fitted Line Plot
Log2(Frequency) = 8.139 - 0.4752 Log2(Rank)
S 0.230934
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-t10- H2 Only.csv

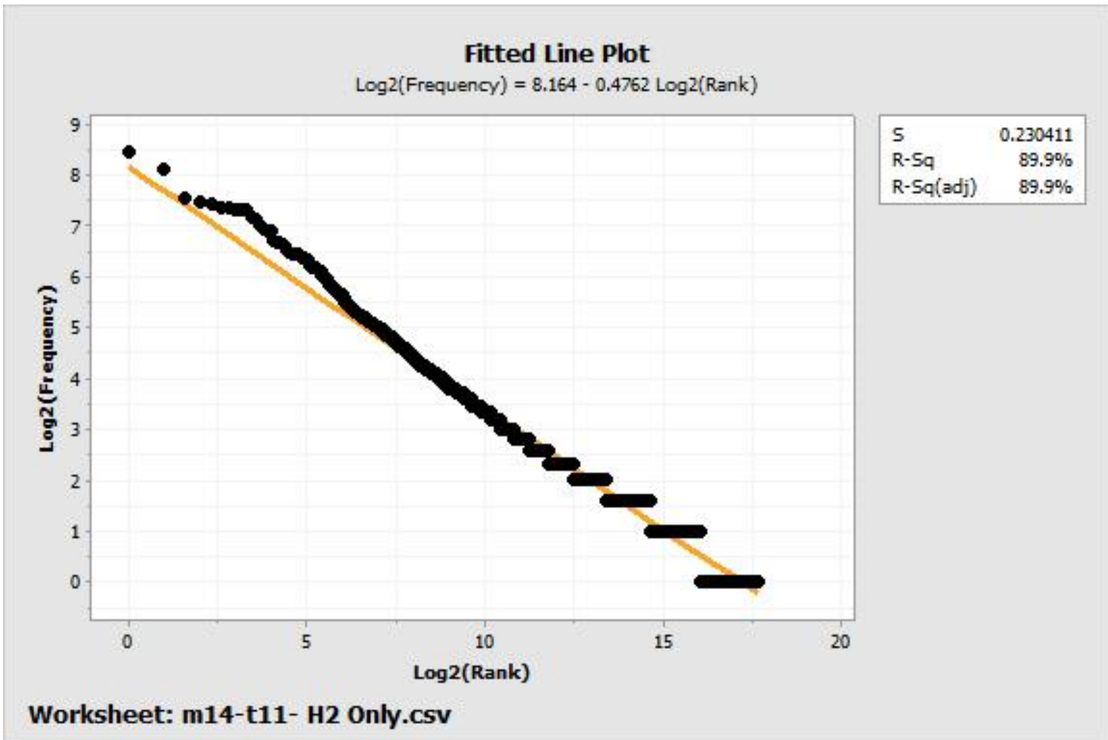

Fitted Line Plot
Log2(Frequency) = 10.37 - 0.5745 Log2(Rank)
S 0.256524
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta- H1 + H2.csv

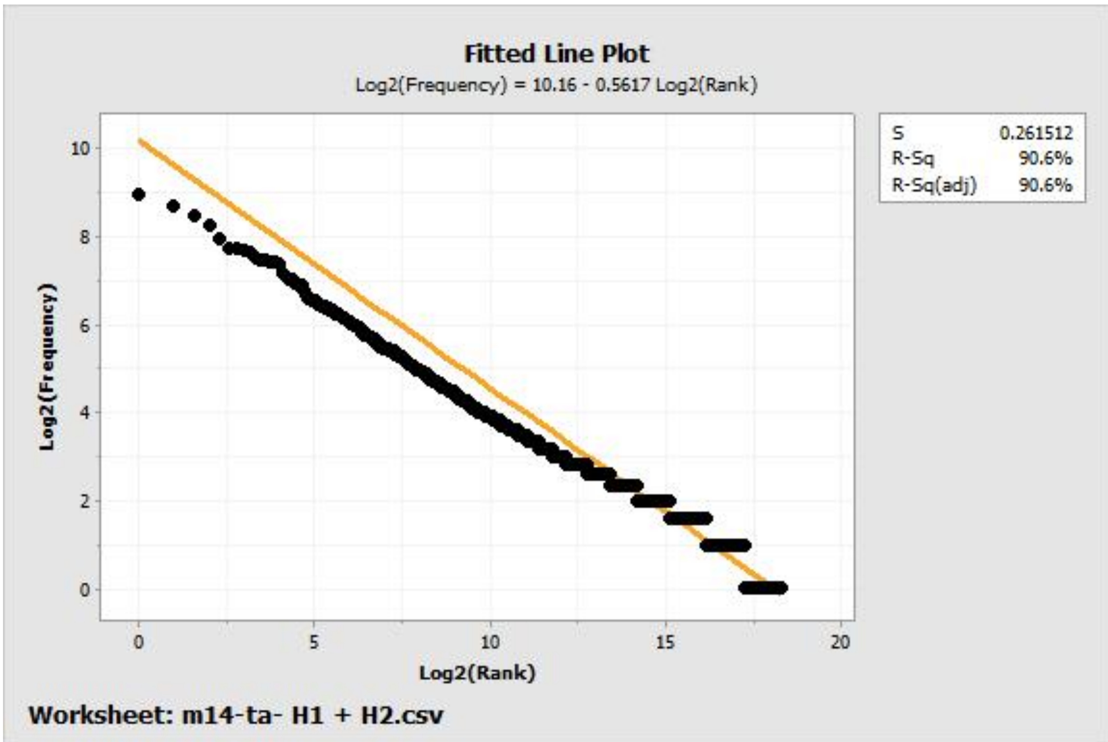

Fitted Line Plot
Log2(Frequency) = 10.11 - 0.5591 Log2(Rank)
S 0.258283
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-t10- H1 + H2.csv

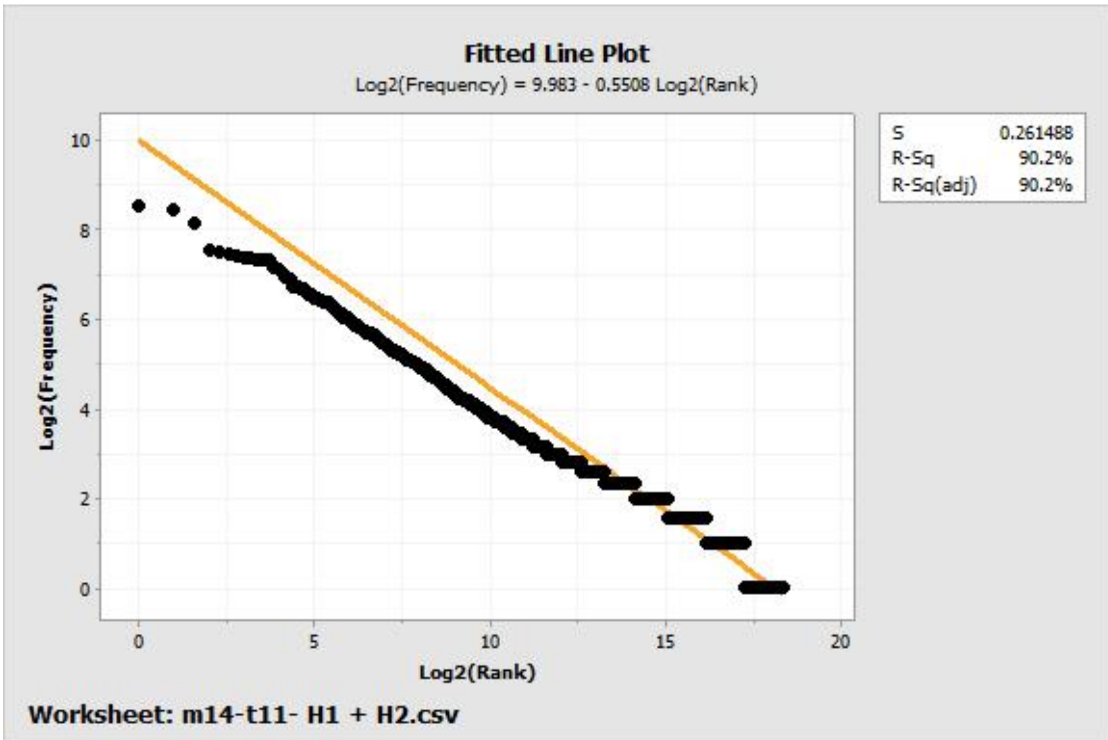

Fitted Line Plot
Log2(Frequency) = 8.379 - 0.4910 Log2(Rank)
S 0.232588
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-ta- H1 Only.csv

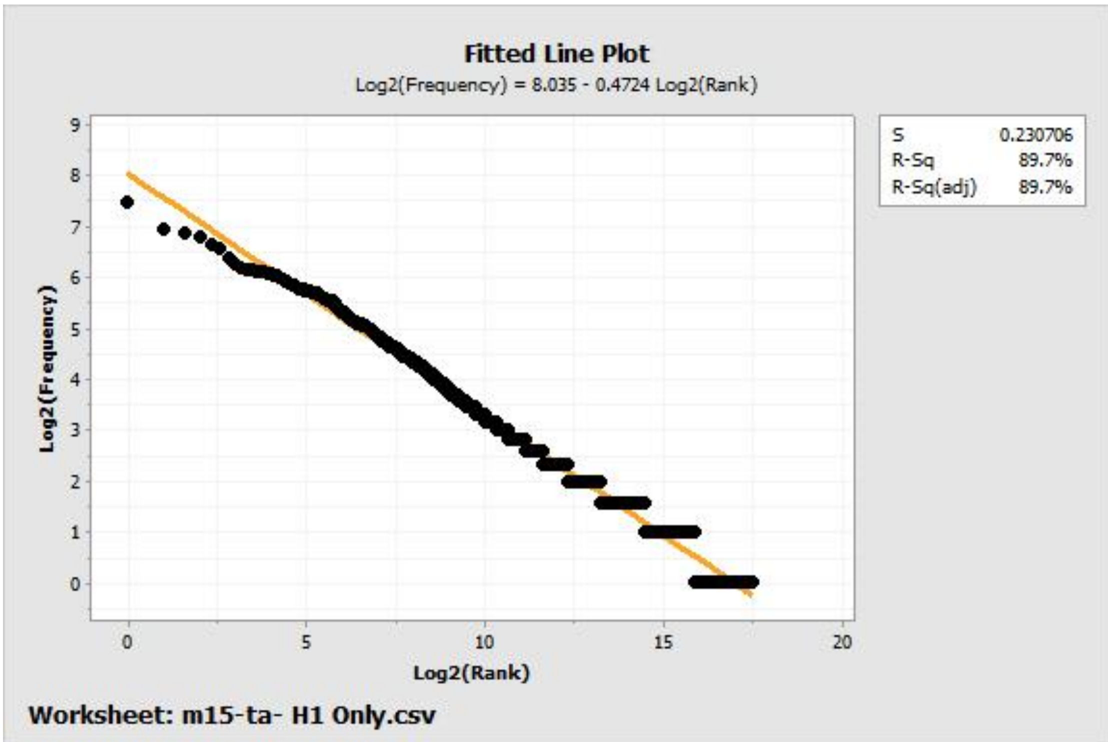

Fitted Line Plot
Log2(Frequency) = 7.667 - 0.4481 Log2(Rank)
S 0.229749
R-Sq 88.8%
R-Sq(adj) 88.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-t11- H1 Only.csv

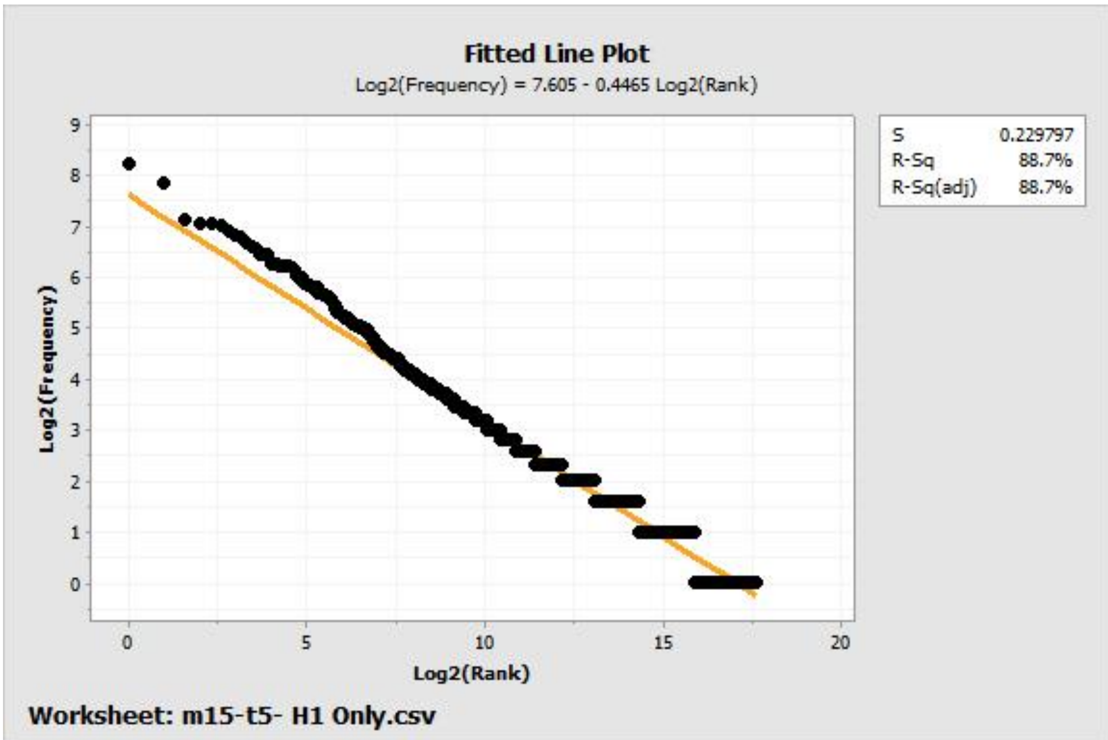

Fitted Line Plot
Log2(Frequency) = 8.297 - 0.4846 Log2(Rank)
S 0.230747
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-ta- H2 Only.csv

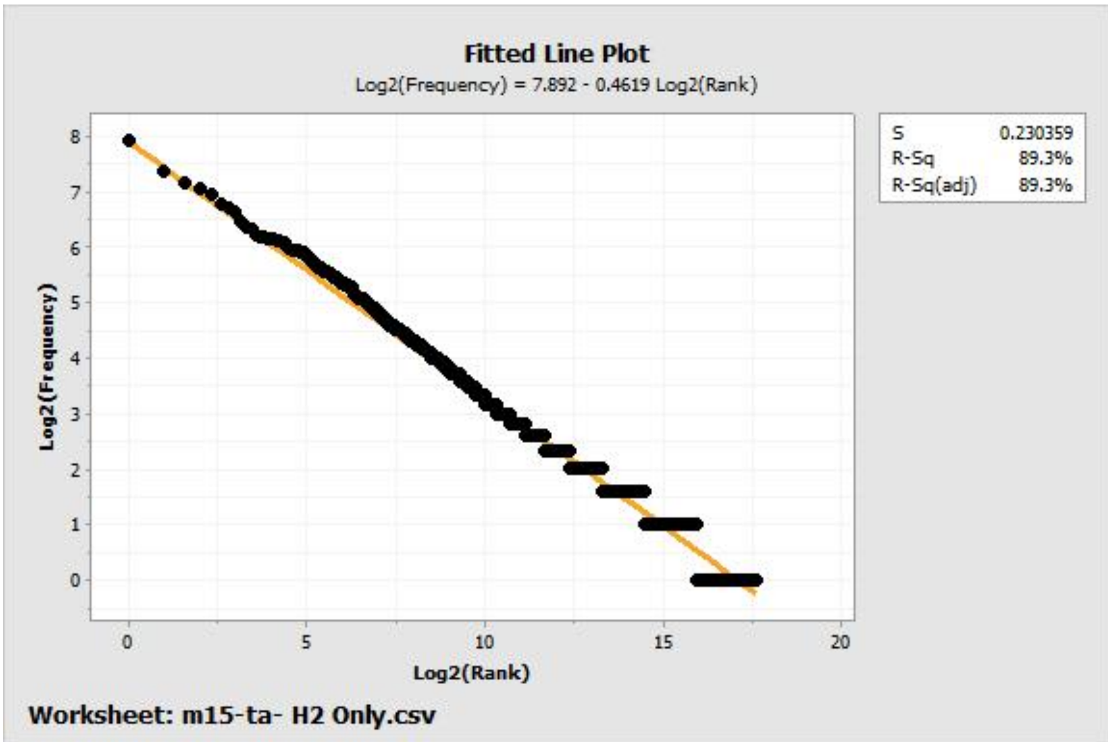

Fitted Line Plot
Log2(Frequency) = 8.164 - 0.4762 Log2(Rank)
S 0.230411
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-t11- H2 Only.csv

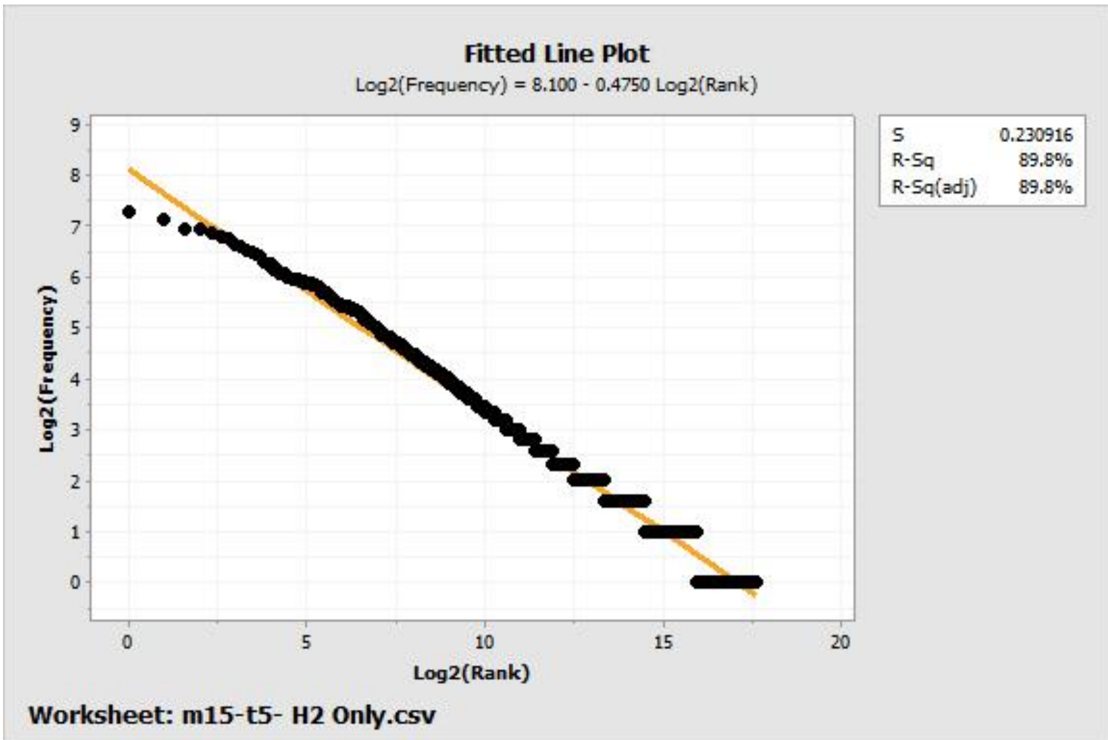

Fitted Line Plot
Log2(Frequency) = 10.16 - 0.5617 Log2(Rank)
S 0.261512
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m14-ta- H1 + H2.csv

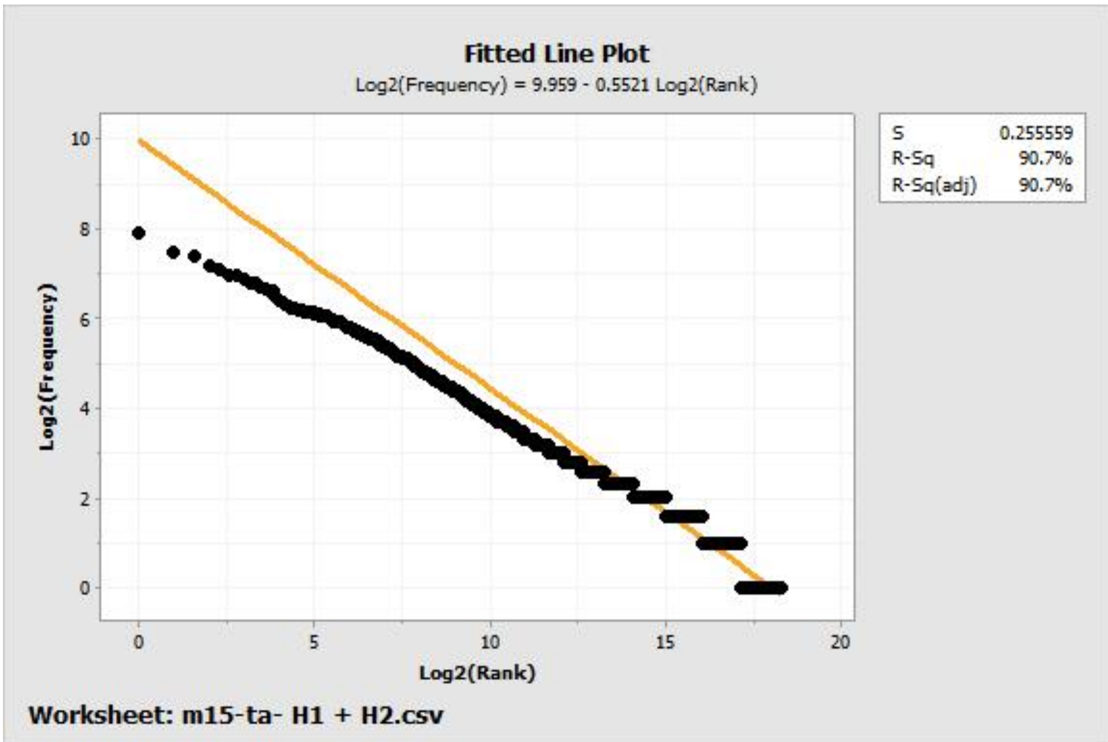

Fitted Line Plot
Log2(Frequency) = 9.983 - 0.5508 Log2(Rank)
S 0.261488
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m14-t11- H1 + H2.csv

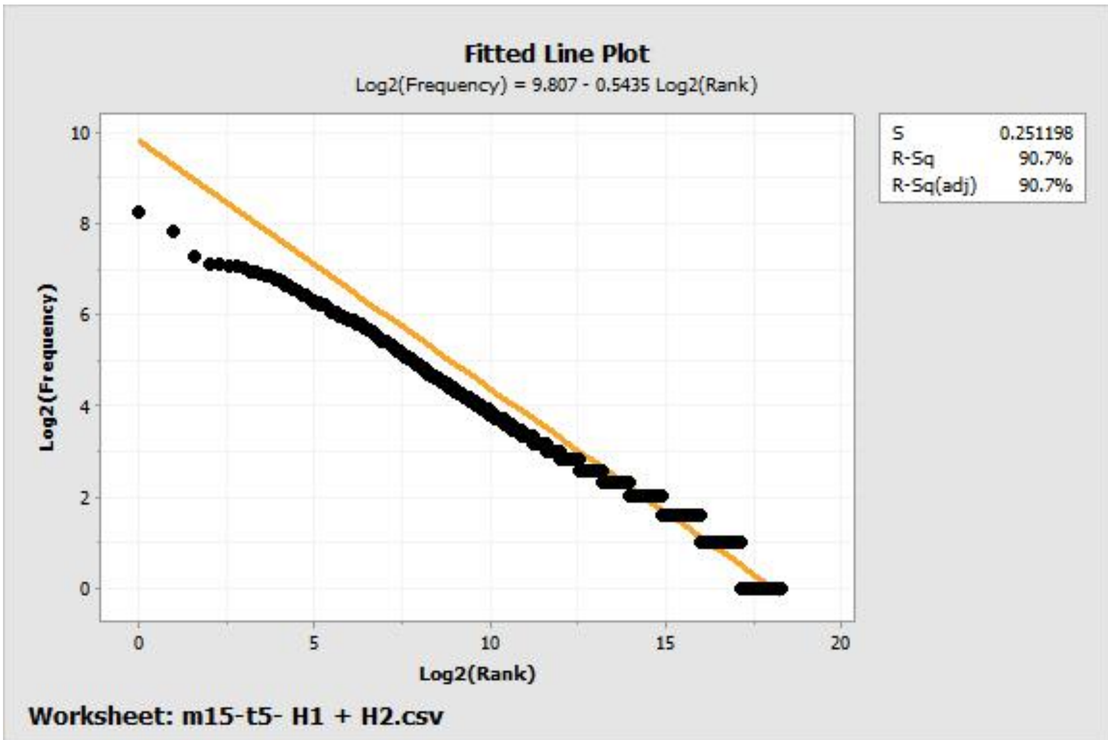

Fitted Line Plot
Log2(Frequency) = 8.035 - 0.4724 Log2(Rank)
S 0.230706
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-ta- H1 Only.csv

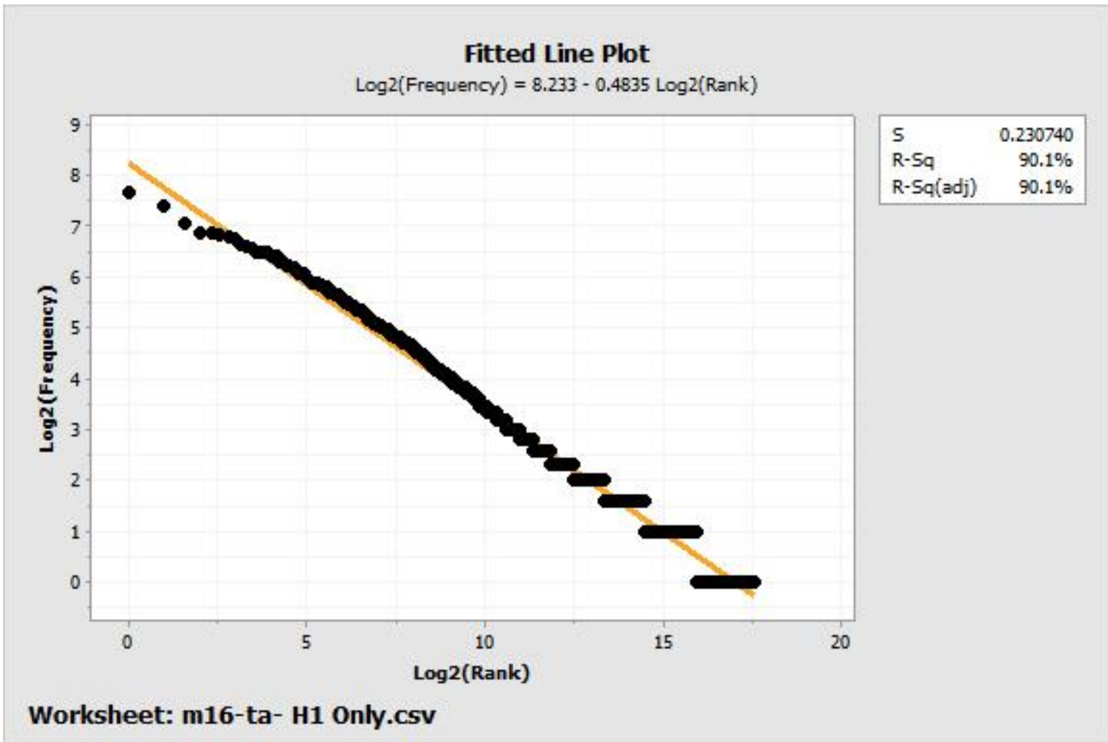

Fitted Line Plot
Log2(Frequency) = 7.605 - 0.4465 Log2(Rank)
S 0.229797
R-Sq 88.7%
R-Sq(adj) 88.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-t5- H1 Only.csv

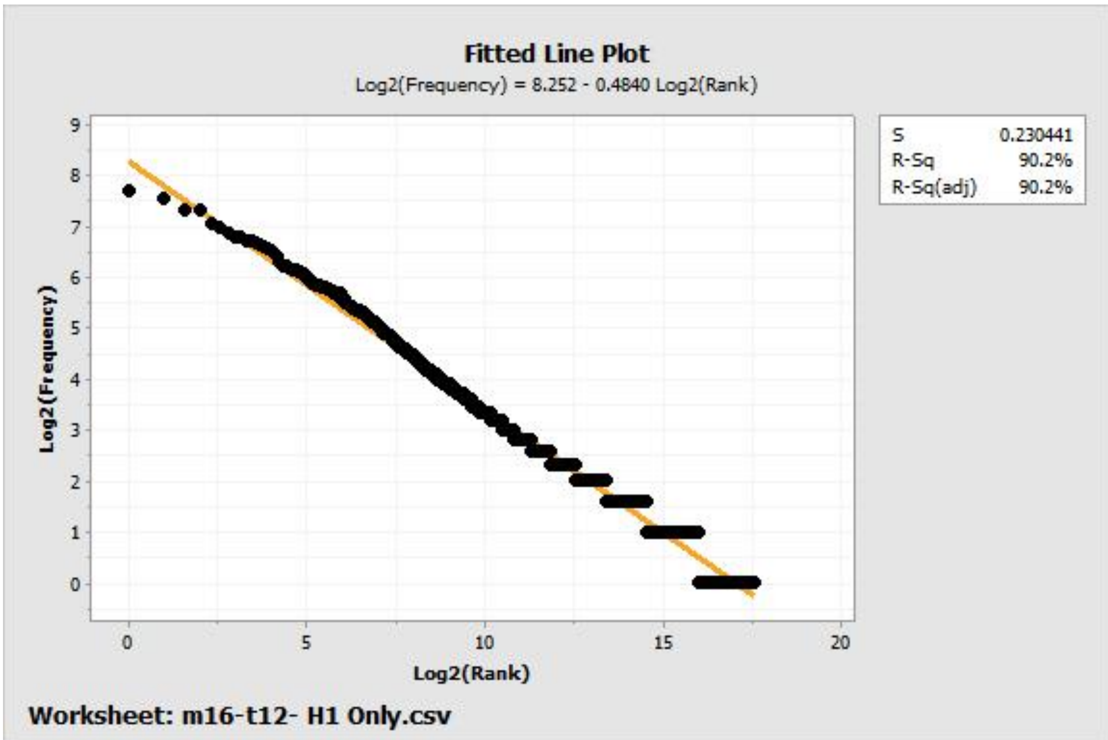

Fitted Line Plot
Log2(Frequency) = 7.892 - 0.4619 Log2(Rank)
S 0.230359
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-ta- H2 Only.csv

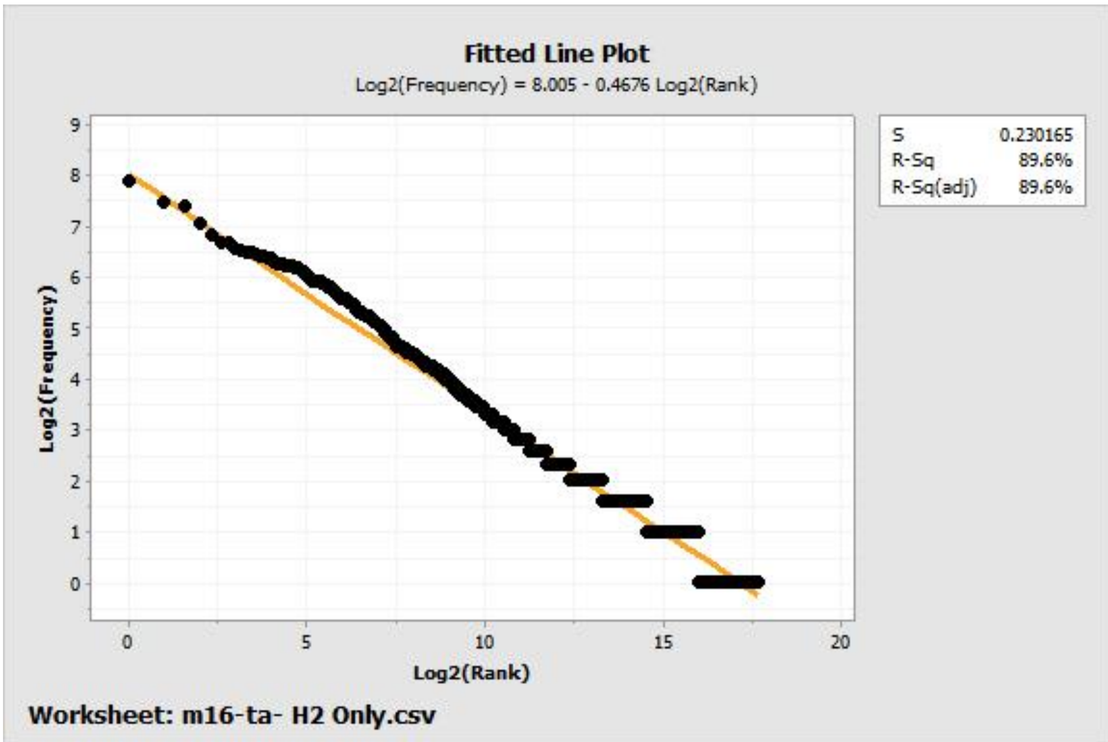

Fitted Line Plot
Log2(Frequency) = 8.100 - 0.4750 Log2(Rank)
S 0.230916
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-t5- H2 Only.csv

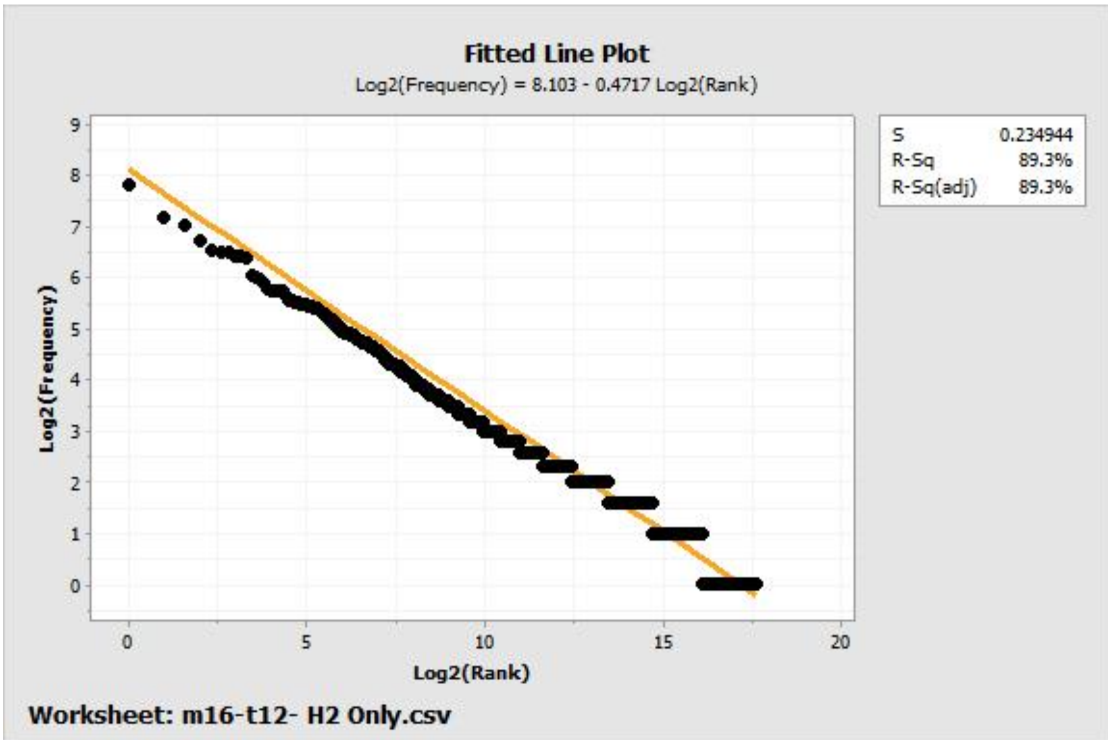

Fitted Line Plot
Log2(Frequency) = 9.959 - 0.5521 Log2(Rank)
S 0.255559
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m15-ta- H1 + H2.csv

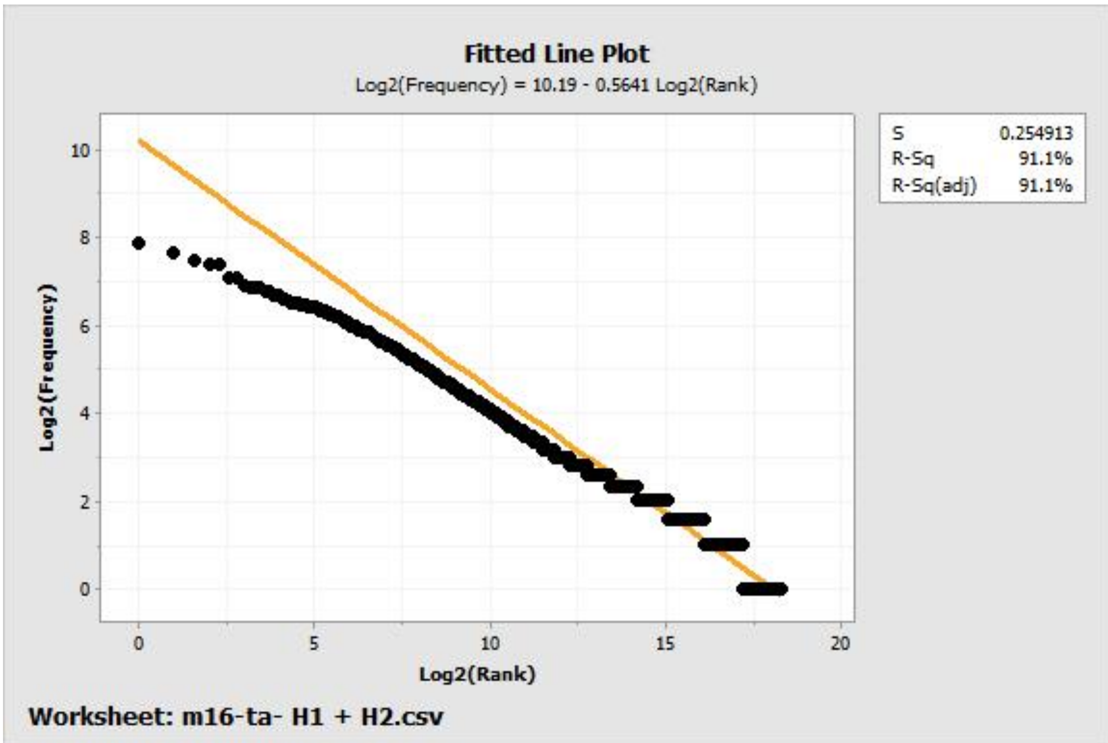

Fitted Line Plot
Log2(Frequency) = 9.807 - 0.5435 Log2(Rank)
S 0.251198
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m15-t5- H1 + H2.csv

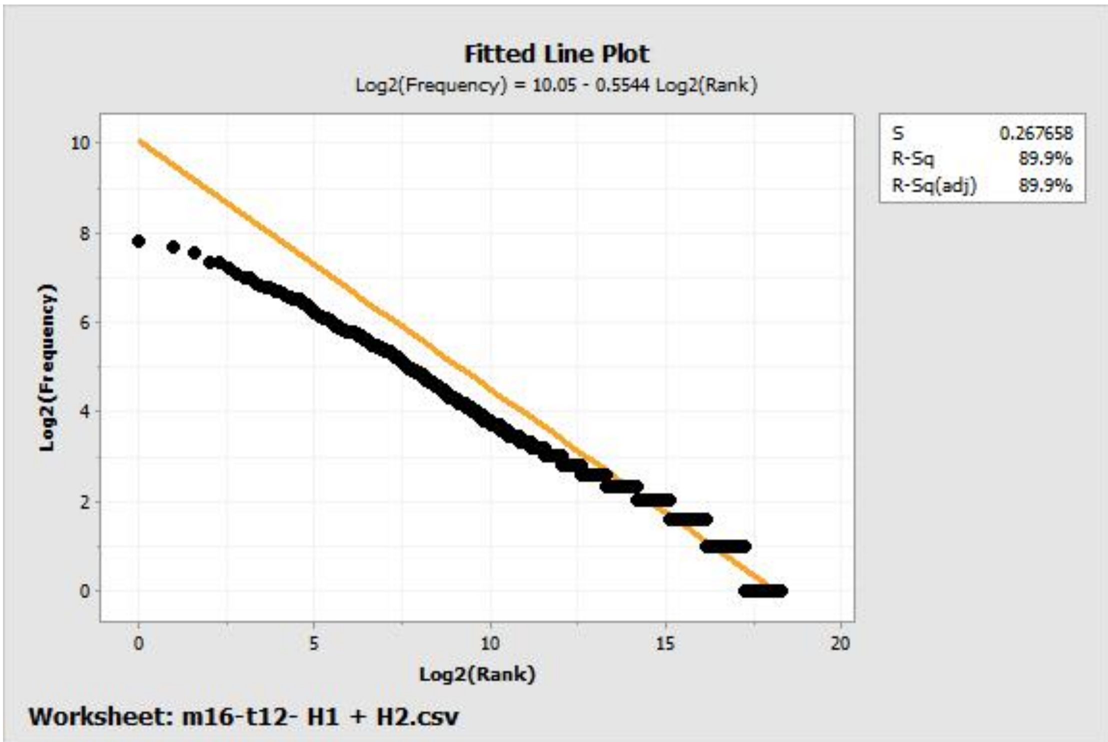

Fitted Line Plot
Log2(Frequency) = 8.233 - 0.4835 Log2(Rank)
S 0.230740
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-ta- H1 Only.csv

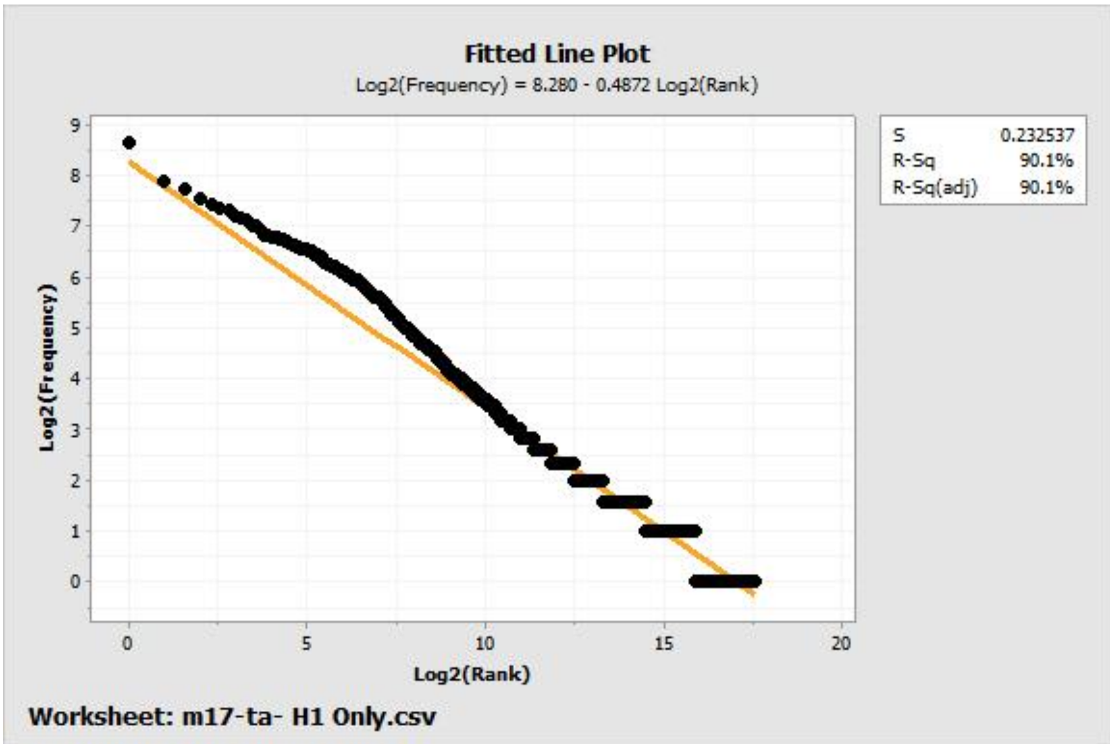

Fitted Line Plot
Log2(Frequency) = 8.252 - 0.4840 Log2(Rank)
S 0.230441
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-t12- H1 Only.csv

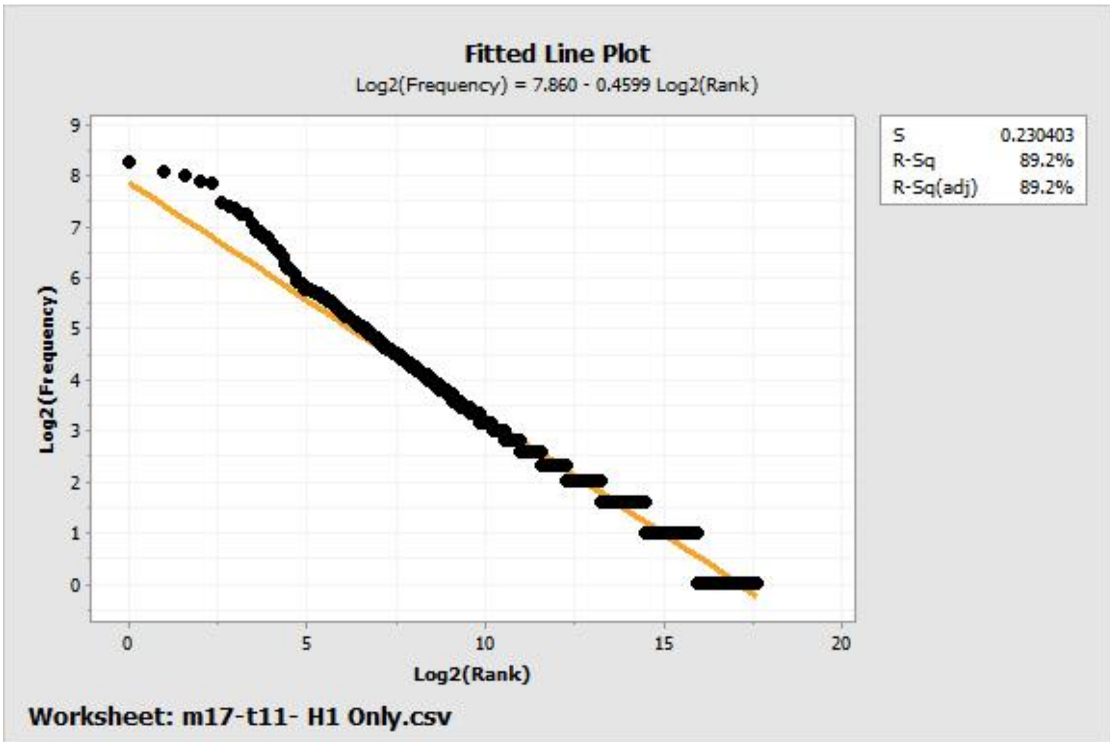

Fitted Line Plot
Log2(Frequency) = 8.005 - 0.4676 Log2(Rank)
S 0.230165
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-ta- H2 Only.csv

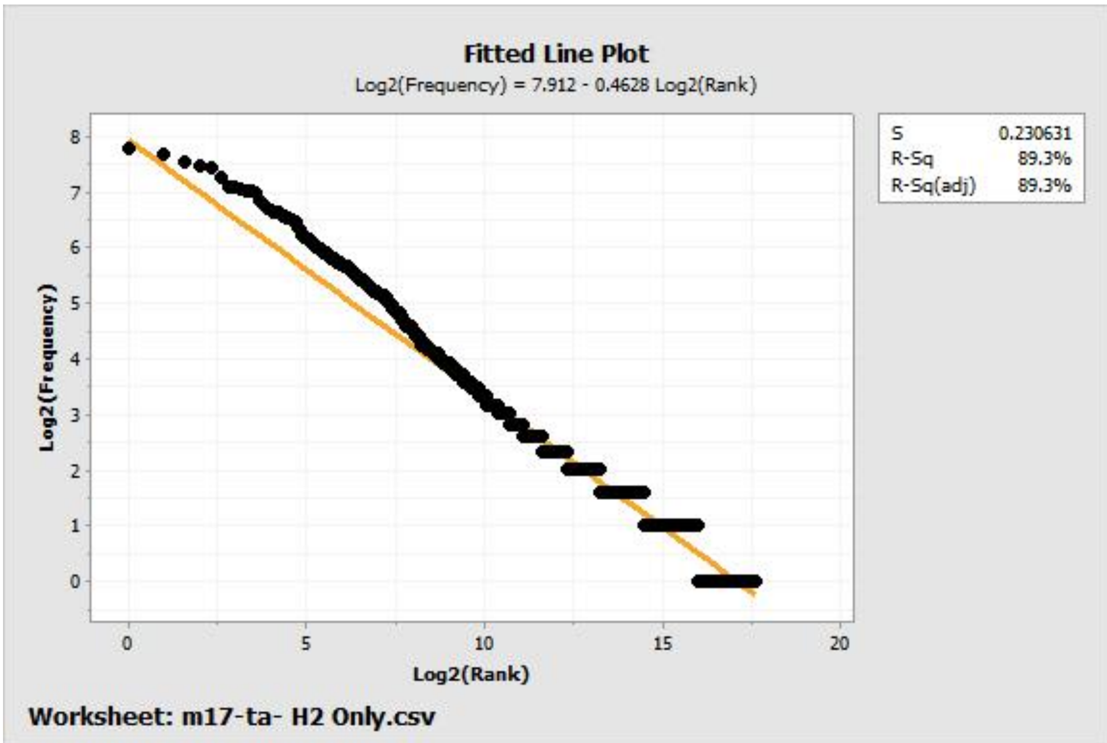

Fitted Line Plot
Log2(Frequency) = 8.103 - 0.4717 Log2(Rank)
S 0.234944
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-t12- H2 Only.csv

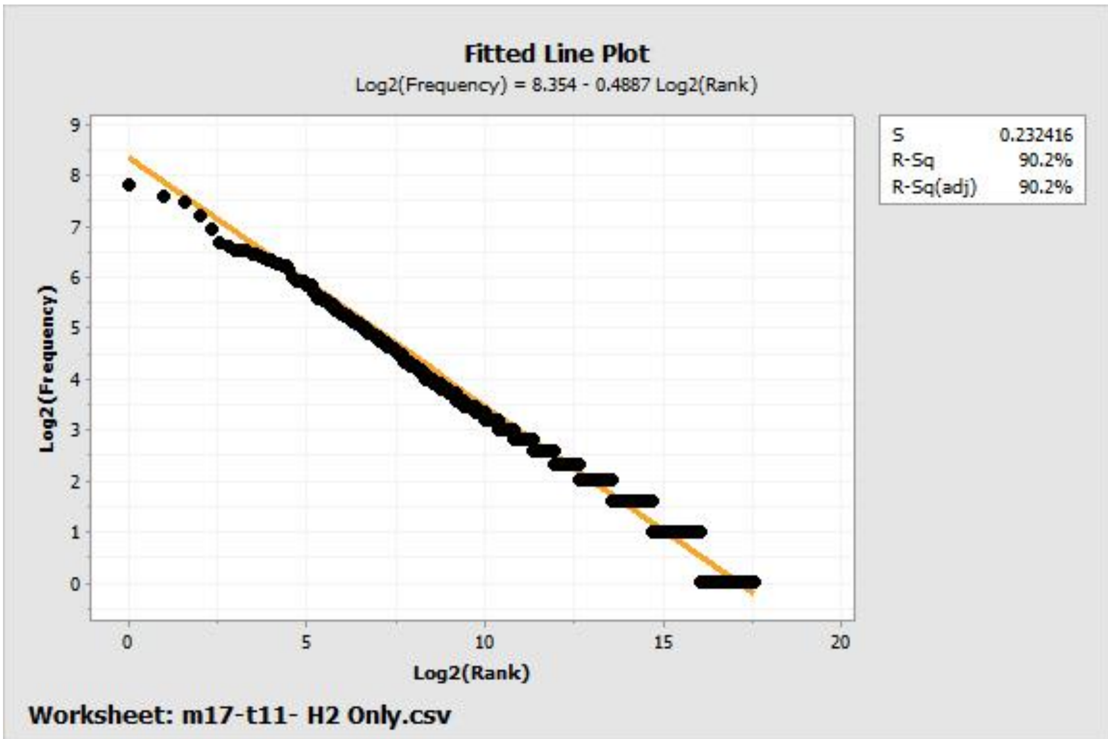

Fitted Line Plot
Log2(Frequency) = 10.19 - 0.5641 Log2(Rank)
S 0.254913
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m16-ta- H1 + H2.csv

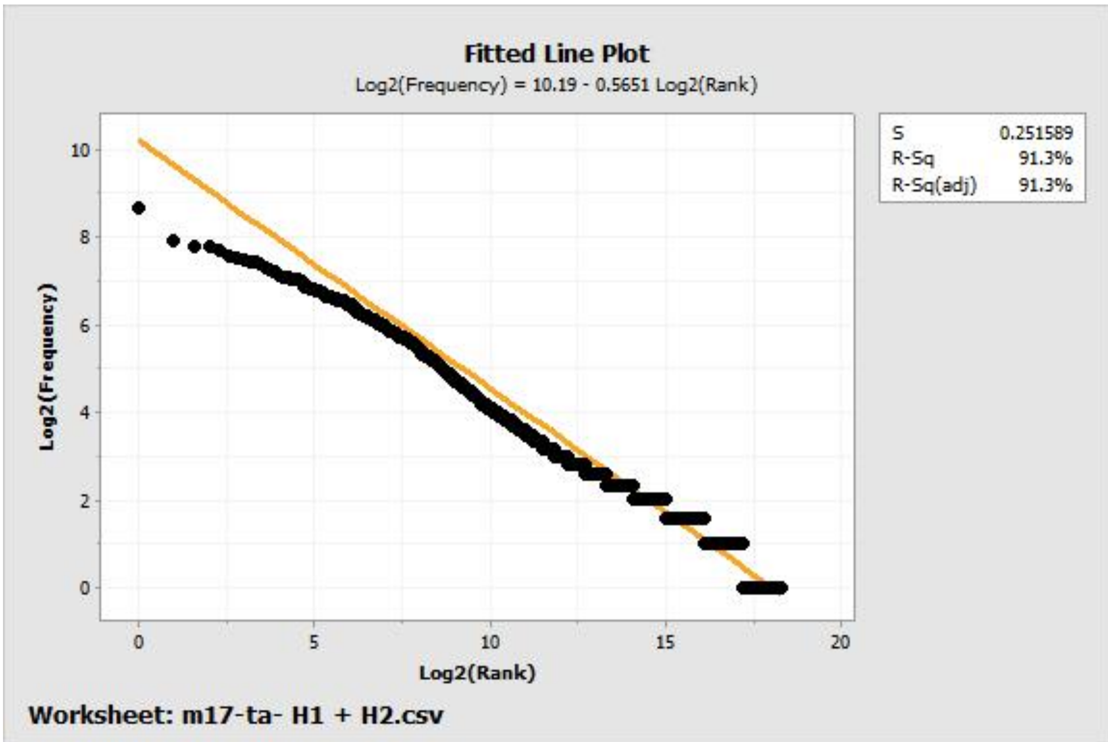

Fitted Line Plot
Log2(Frequency) = 10.05 - 0.5544 Log2(Rank)
S 0.267658
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m16-t12- H1 + H2.csv

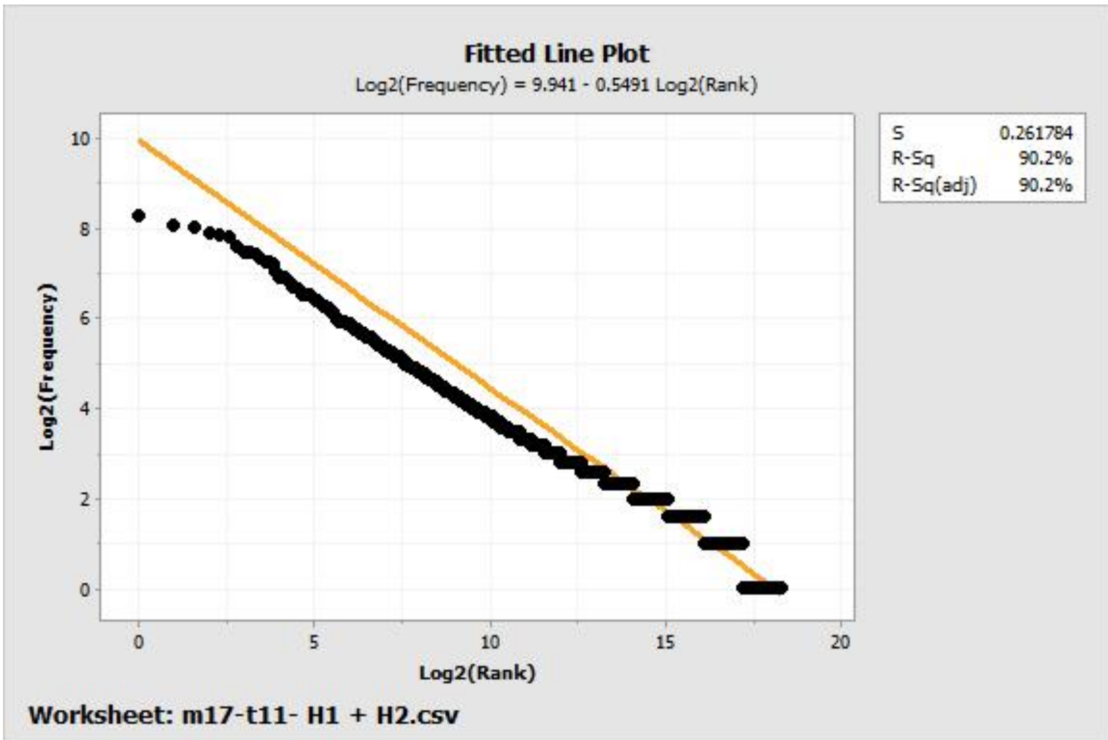

Fitted Line Plot
Log2(Frequency) = 8.280 - 0.4872 Log2(Rank)
S 0.232537
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m17-ta- H1 Only.csv

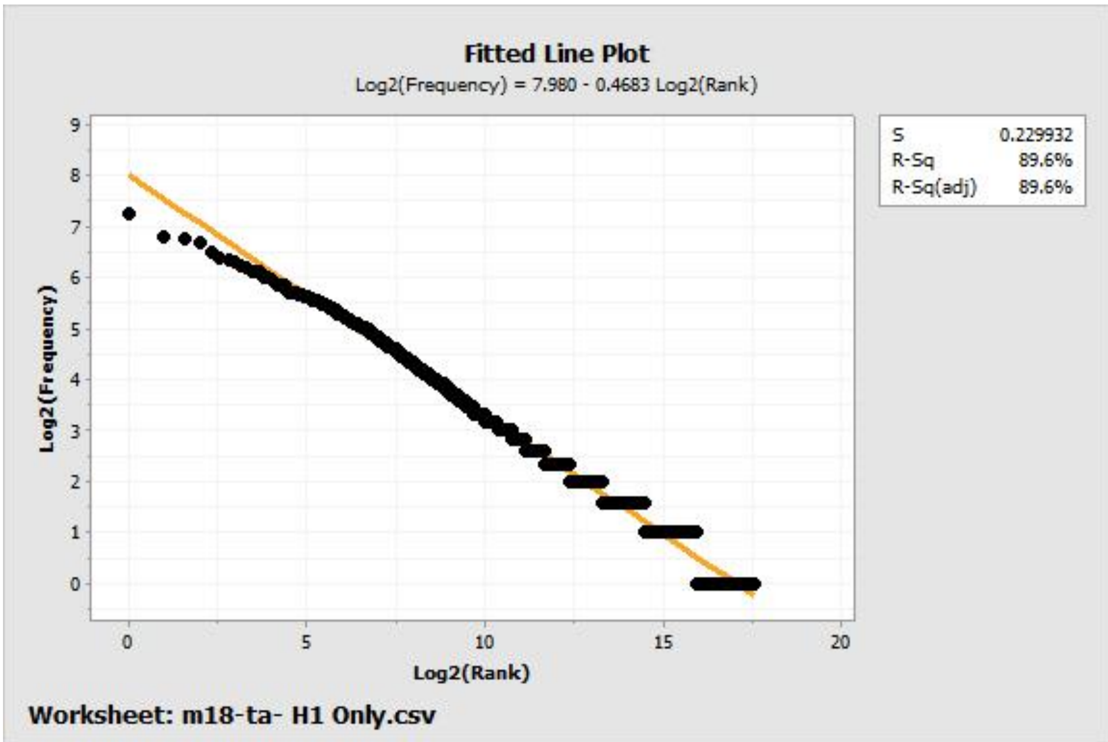

Fitted Line Plot
Log2(Frequency) = 7.860 - 0.4599 Log2(Rank)
S 0.230403
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m17-t11- H1 Only.csv


Fitted Line Plot
Log2(Frequency) = 7.912 - 0.4628 Log2(Rank)
S 0.230631
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-ta- H2 Only.csv

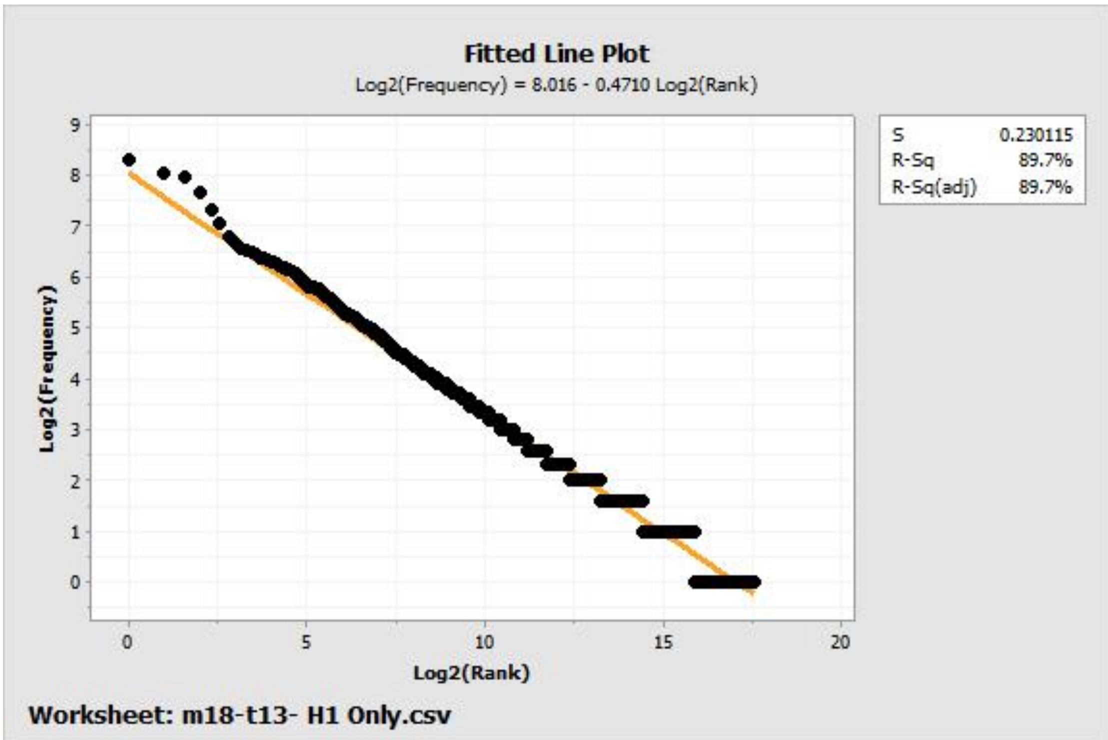

Fitted Line Plot
Log2(Frequency) = 8.354 - 0.4887 Log2(Rank)
S 0.232416
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-t11- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.19 - 0.5651 Log2(Rank)
S 0.251589
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-ta- H1 + H2.csv

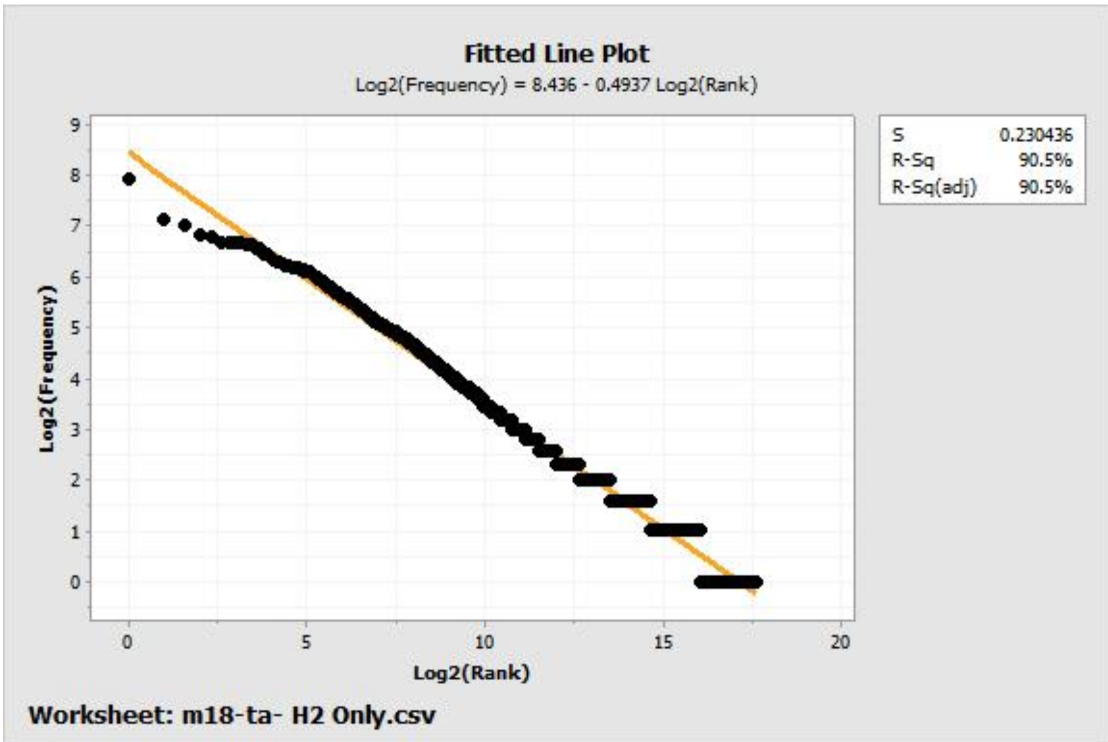

Fitted Line Plot
Log2(Frequency) = 9.941 - 0.5491 Log2(Rank)
S 0.261784
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-t11- H1 + H2.csv

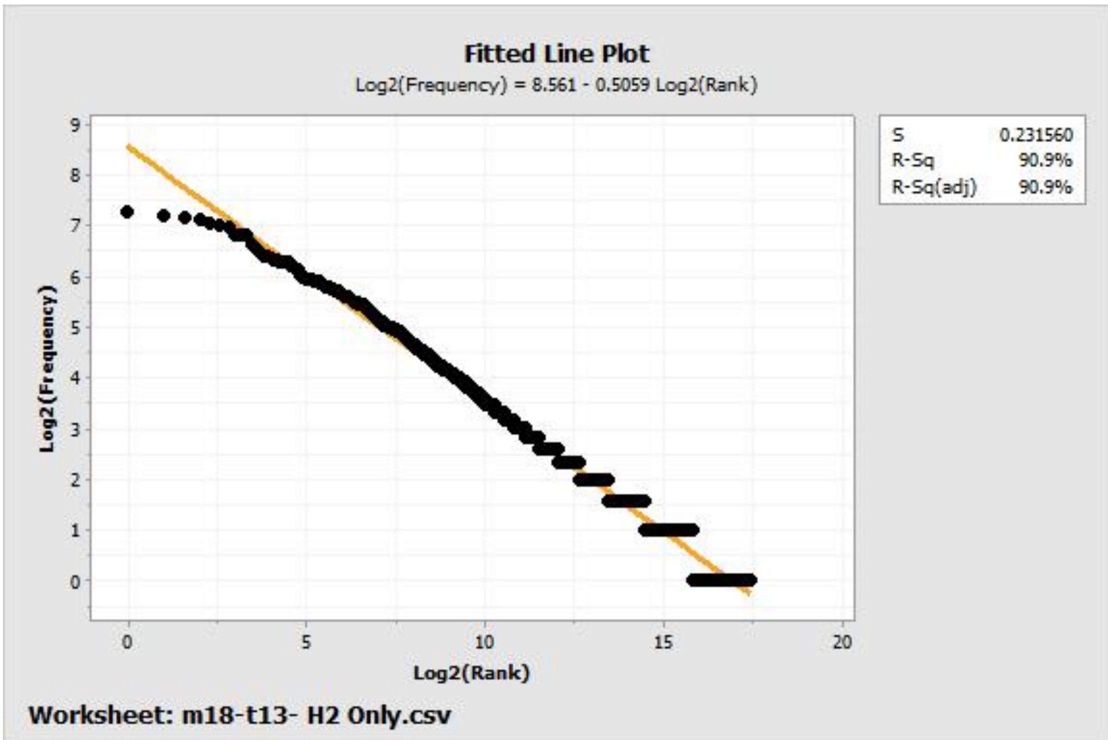


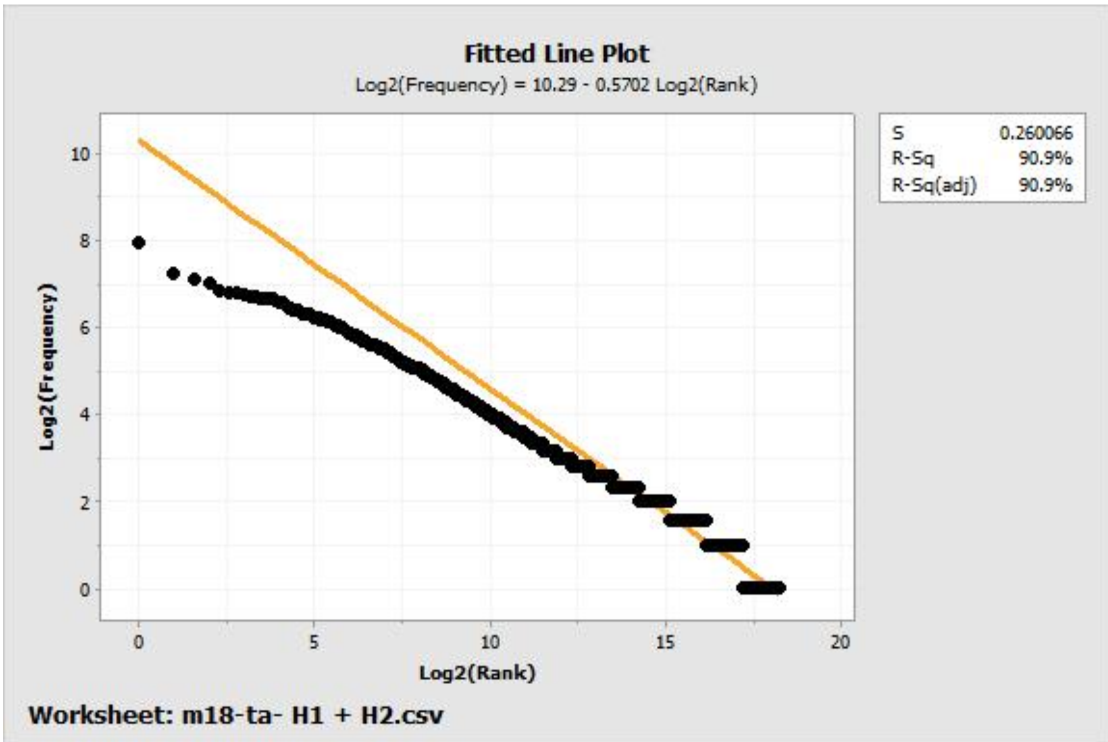
Fitted Line Plot
Log2(Frequency) = 7.980 - 0.4683 Log2(Rank)
S 0.229932
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta- H1 Only.csv

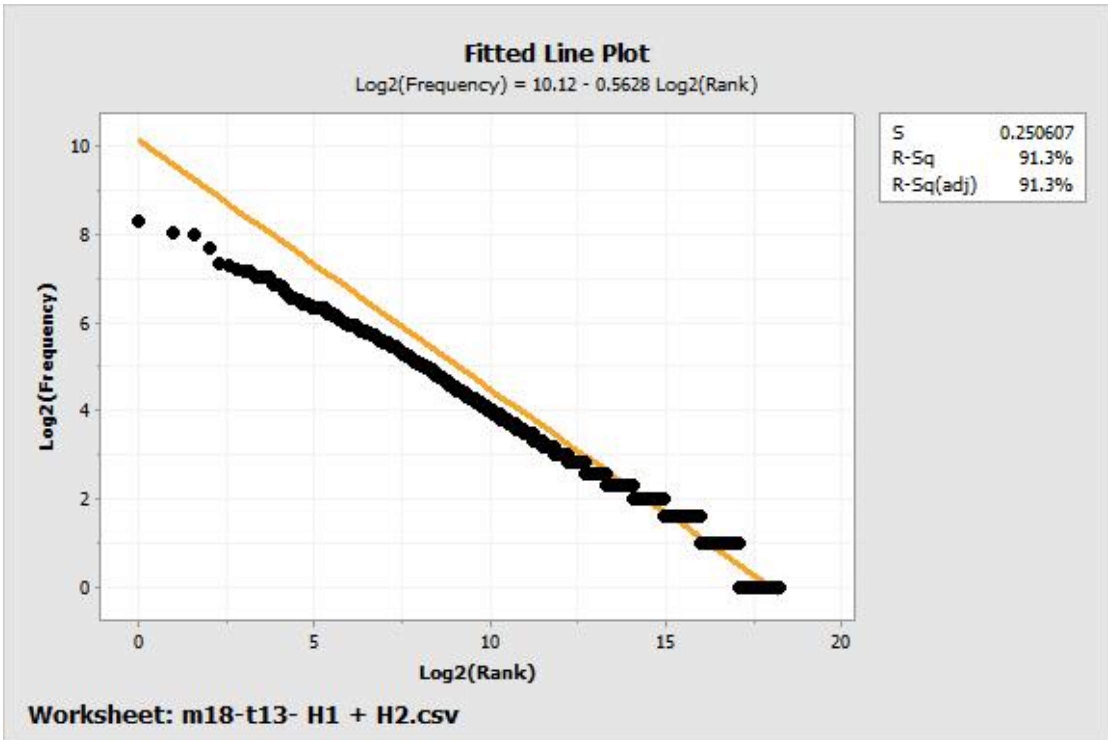


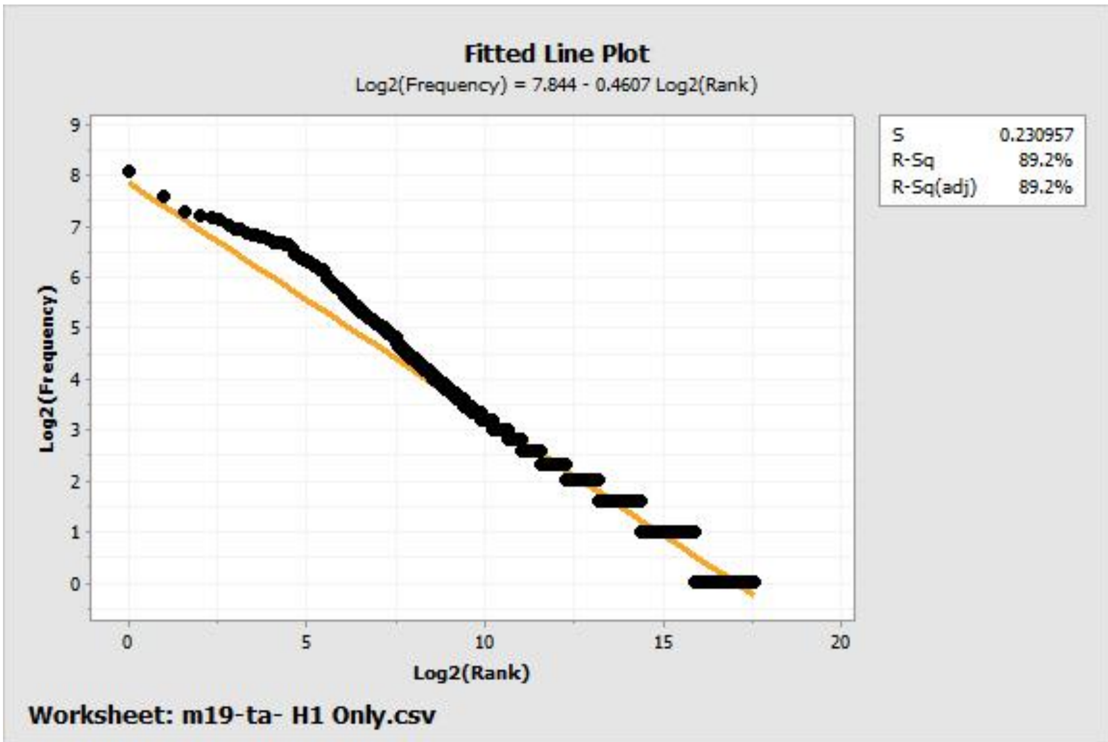
Fitted Line Plot
Log2(Frequency) = 8.016 - 0.4710 Log2(Rank)
S 0.230115
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13- H1 Only.csv

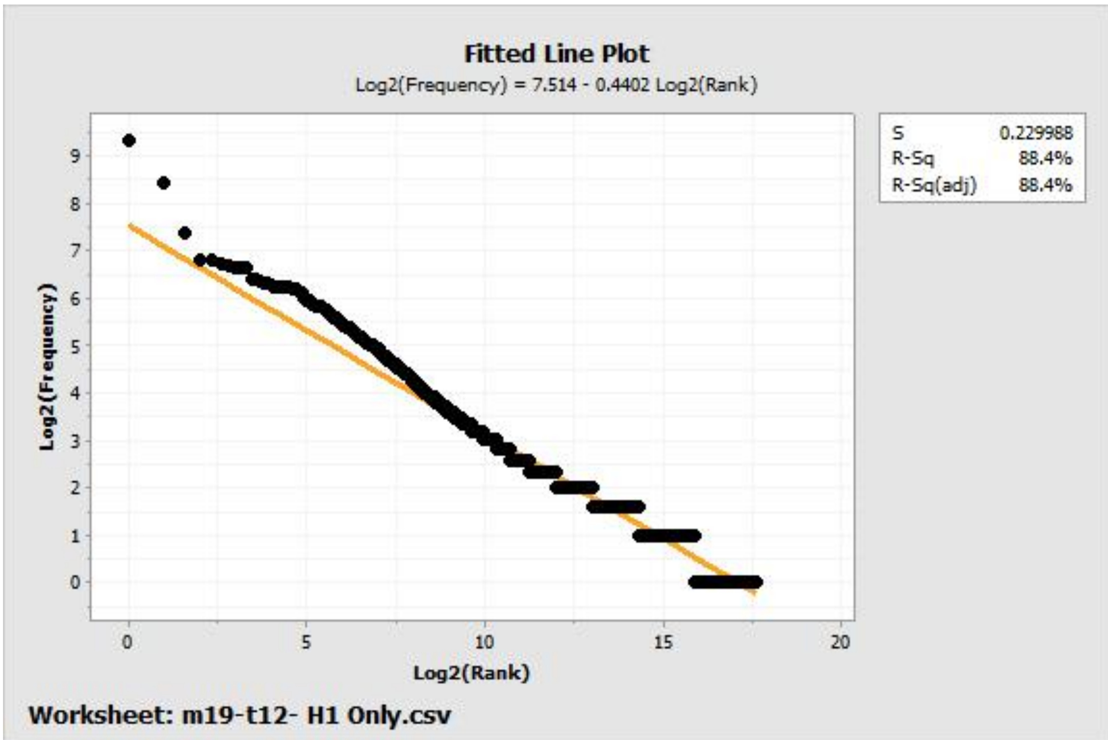

Fitted Line Plot
Log2(Frequency) = 8.436 - 0.4937 Log2(Rank)
S 0.230436
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta- H2 Only.csv

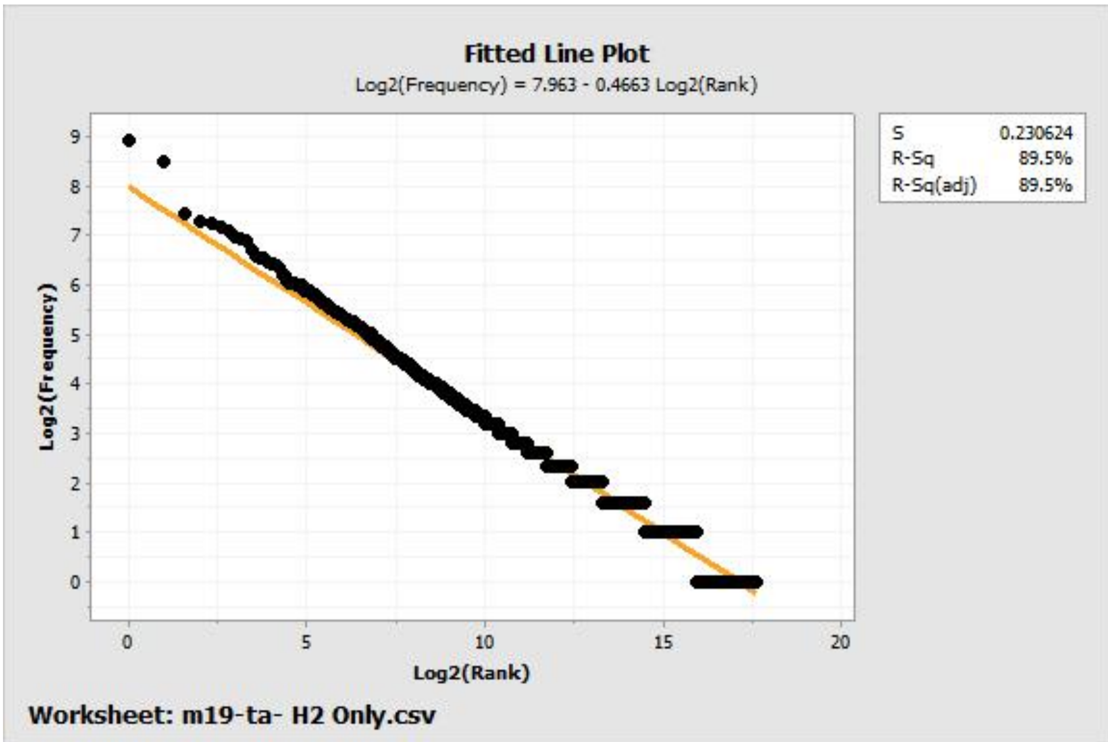

Fitted Line Plot
Log2(Frequency) = 8.561 - 0.5059 Log2(Rank)
S 0.231560
R-Sq 90.9%
R-Sq(adj) 90.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13- H2 Only.csv

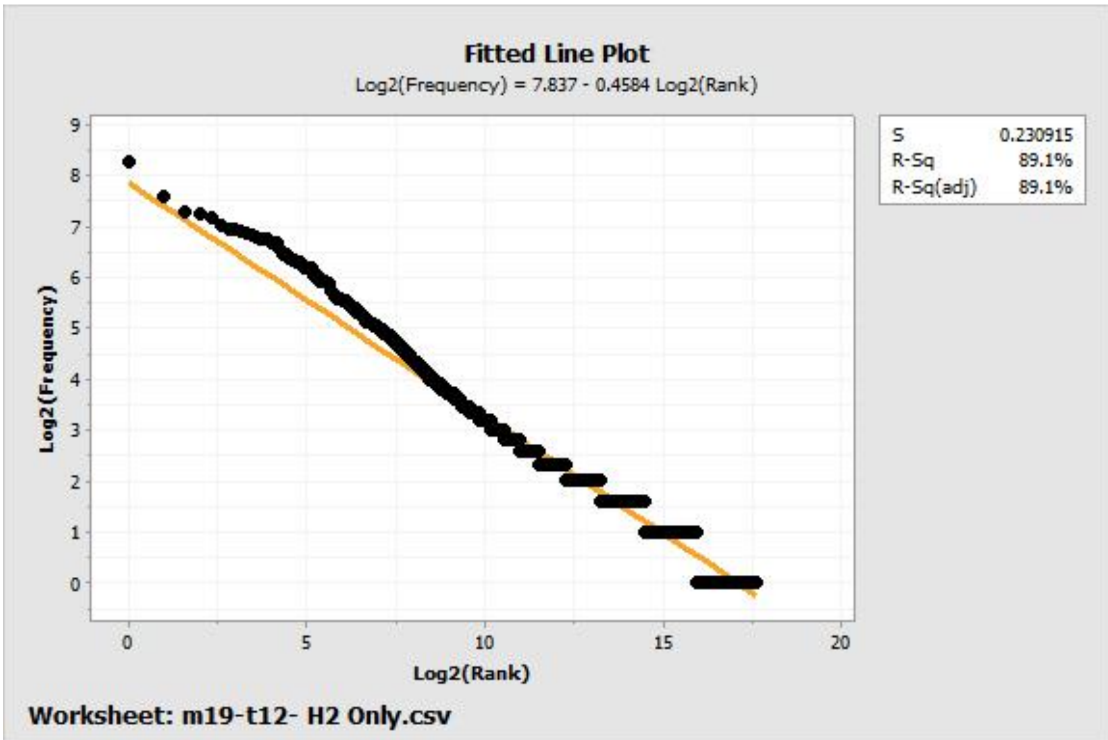

Fitted Line Plot
Log2(Frequency) = 10.29 - 0.5702 Log2(Rank)
S 0.260066
R-Sq 90.9%
R-Sq(adj) 90.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta- H1 + H2.csv

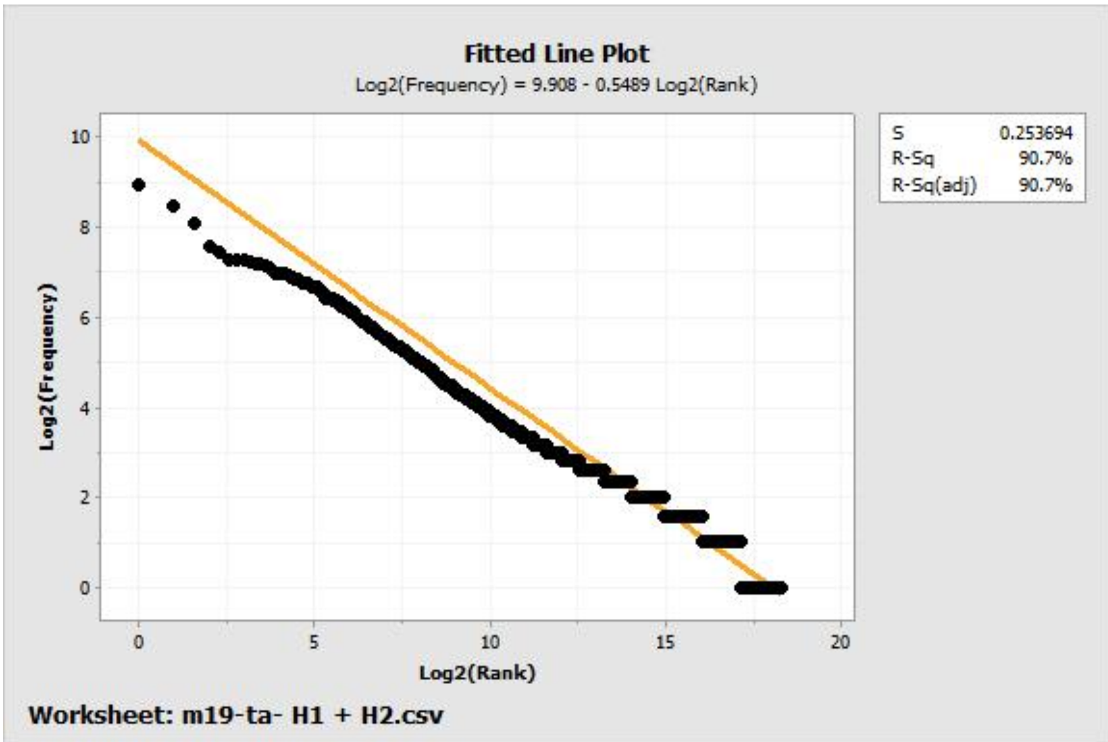

Fitted Line Plot
Log2(Frequency) = 10.12 - 0.5628 Log2(Rank)
S 0.250607
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13- H1 + H2.csv

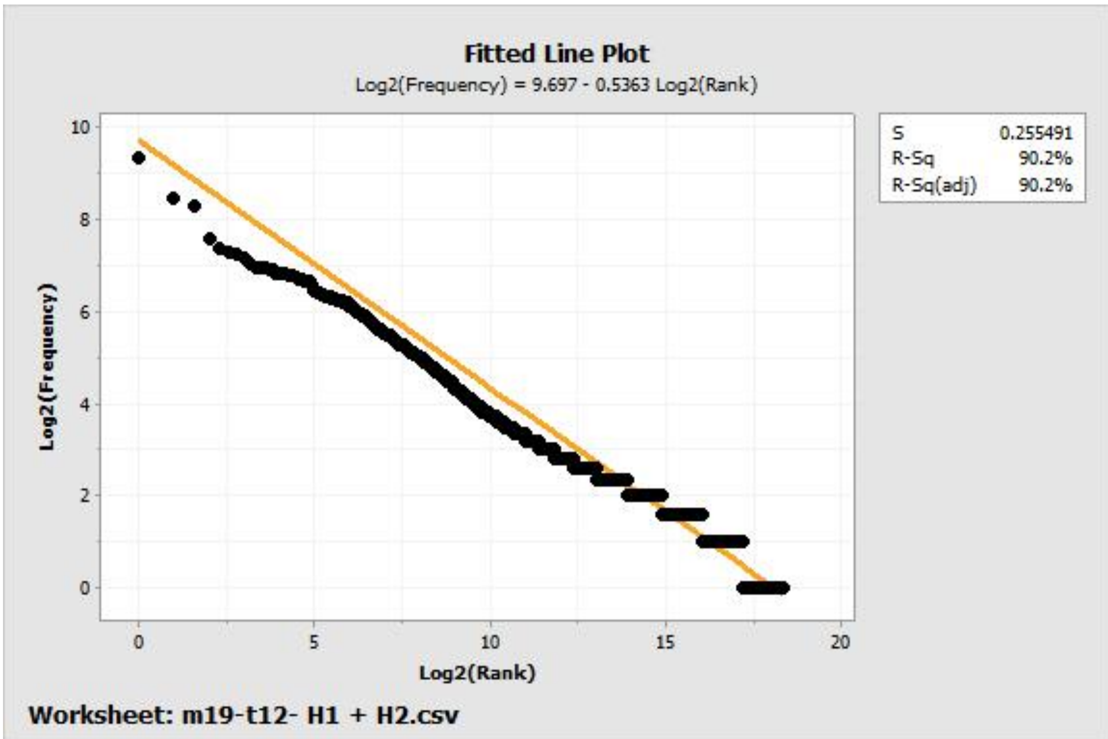

Fitted Line Plot
Log2(Frequency) = 7.844 - 0.4607 Log2(Rank)
S 0.230957
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta- H1 Only.csv

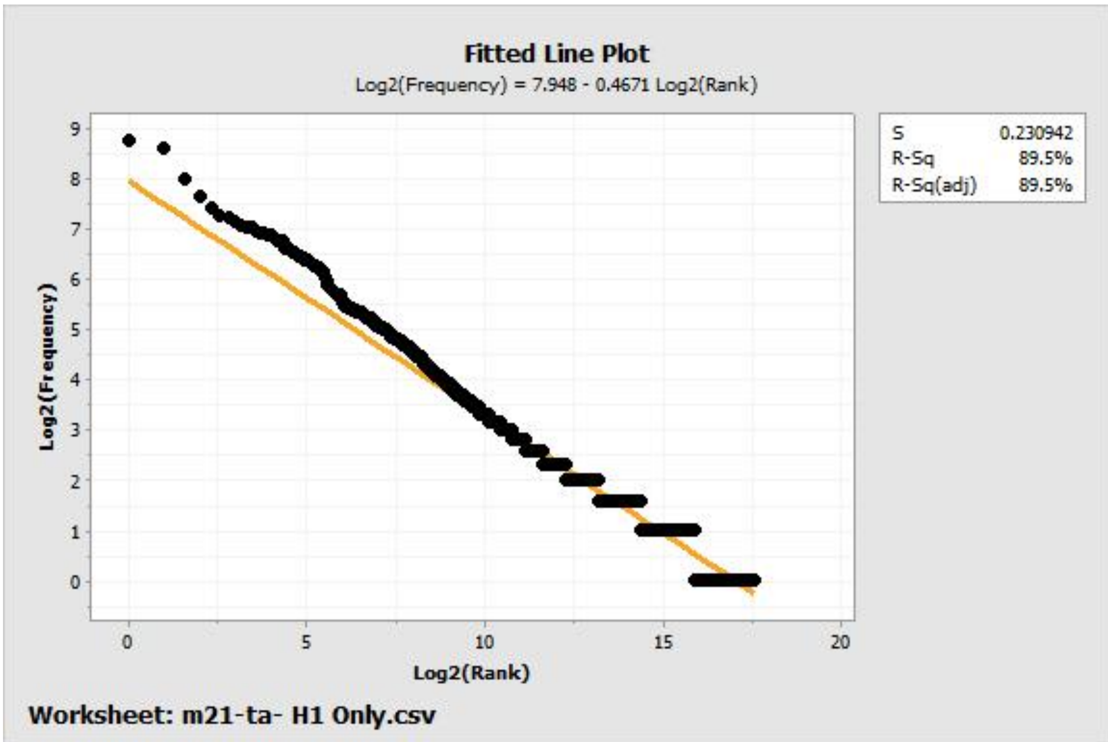

Fitted Line Plot
Log2(Frequency) = 7.514 - 0.4402 Log2(Rank)
S 0.229988
R-Sq 88.4%
R-Sq(adj) 88.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12- H1 Only.csv

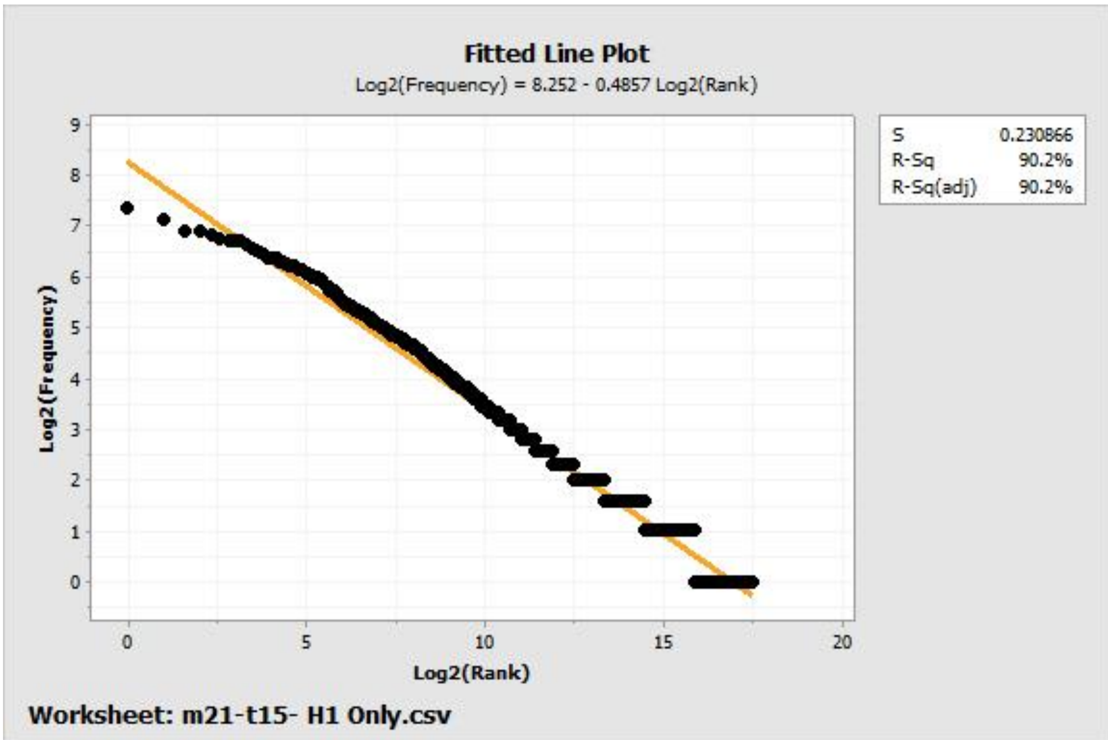

Fitted Line Plot
Log2(Frequency) = 7.963 - 0.4663 Log2(Rank)
S 0.230624
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta- H2 Only.csv

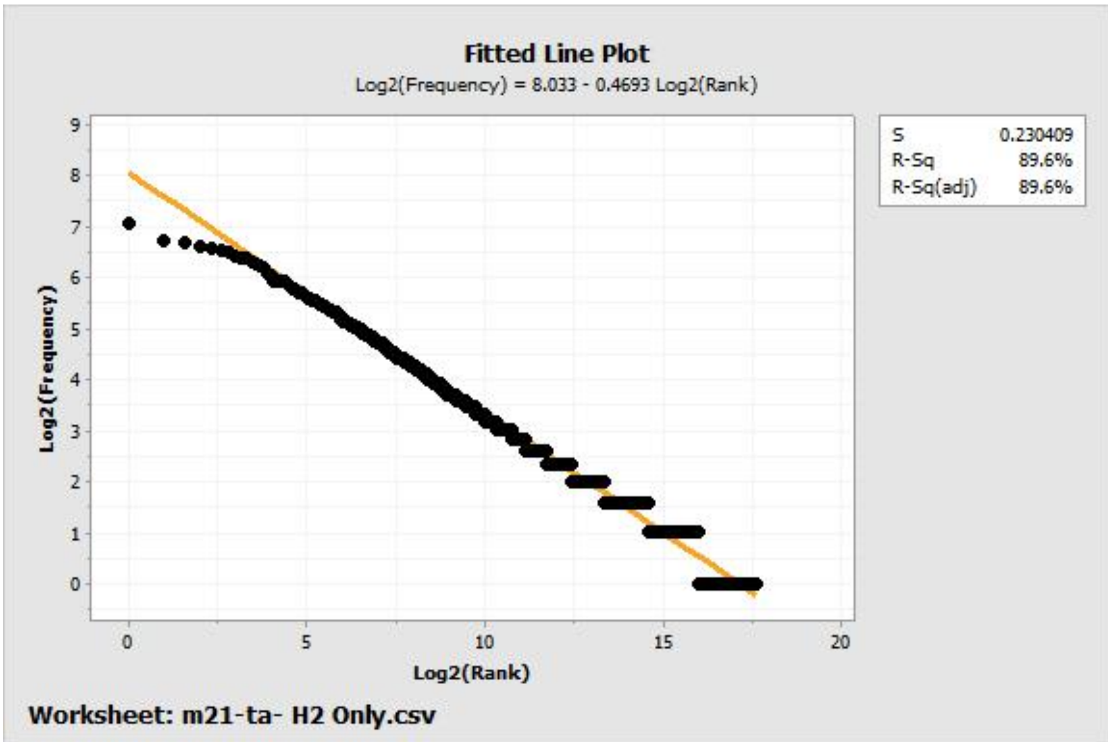

Fitted Line Plot
Log2(Frequency) = 7.837 - 0.4584 Log2(Rank)
S 0.230915
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12- H2 Only.csv

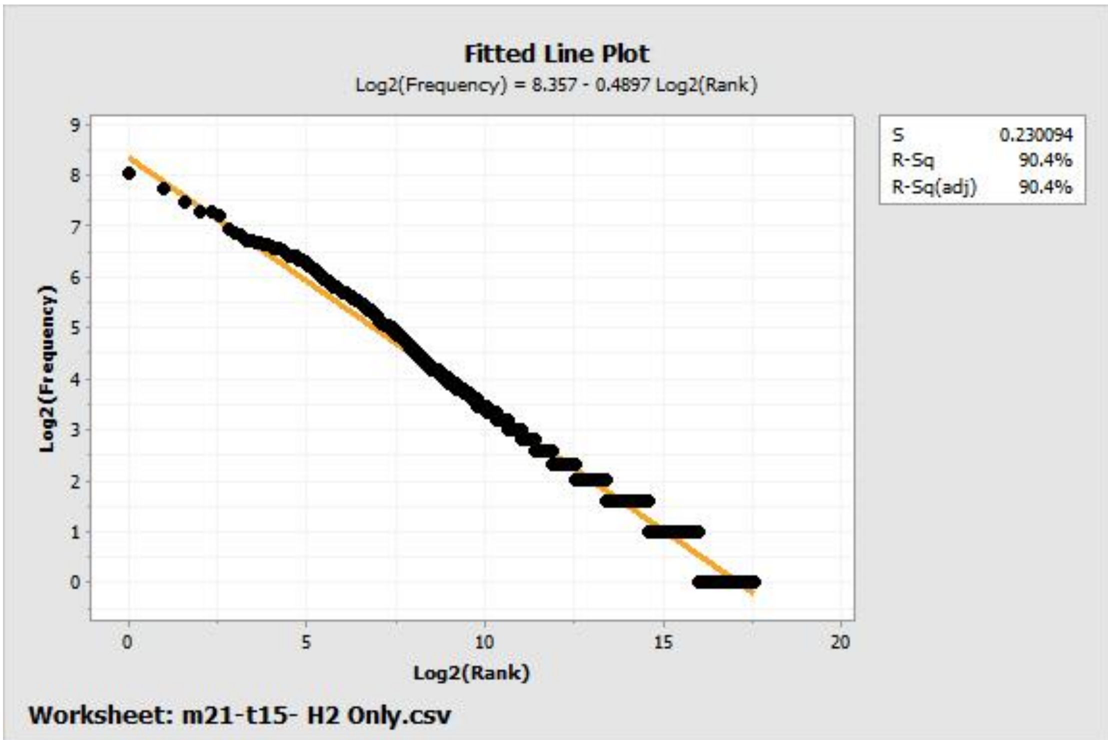

Fitted Line Plot
Log2(Frequency) = 9.908 - 0.5489 Log2(Rank)
S 0.253694
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta- H1 + H2.csv

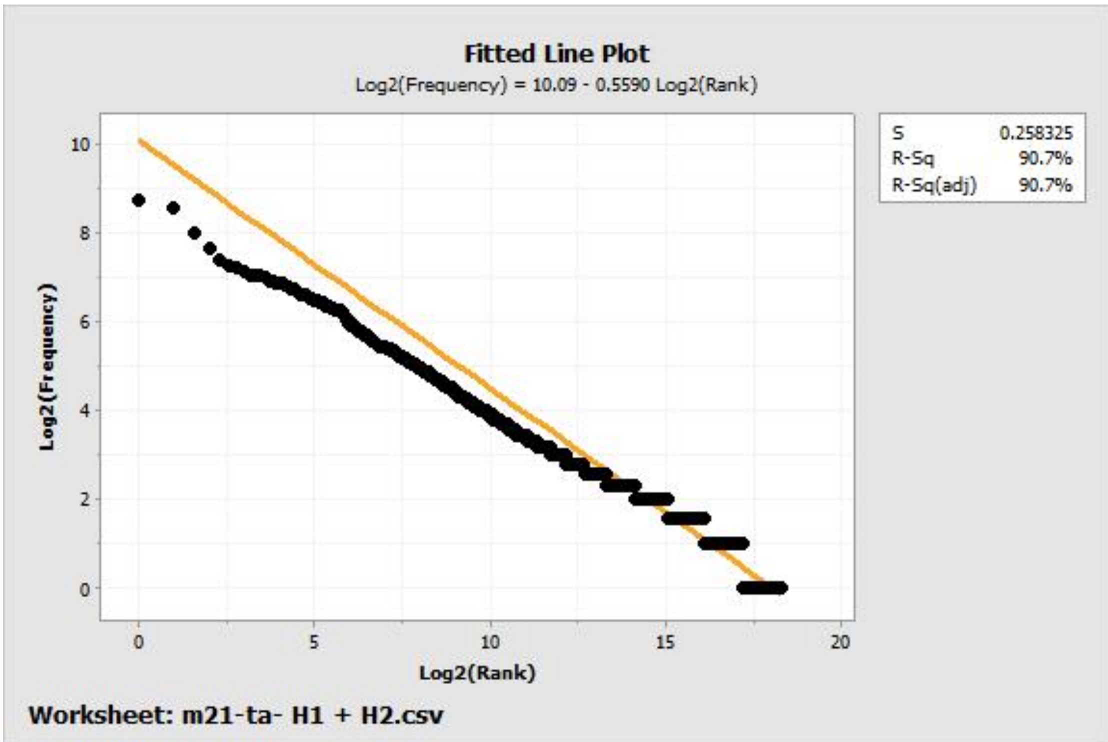

Fitted Line Plot
Log2(Frequency) = 9.697 - 0.5363 Log2(Rank)
S 0.255491
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12- H1 + H2.csv

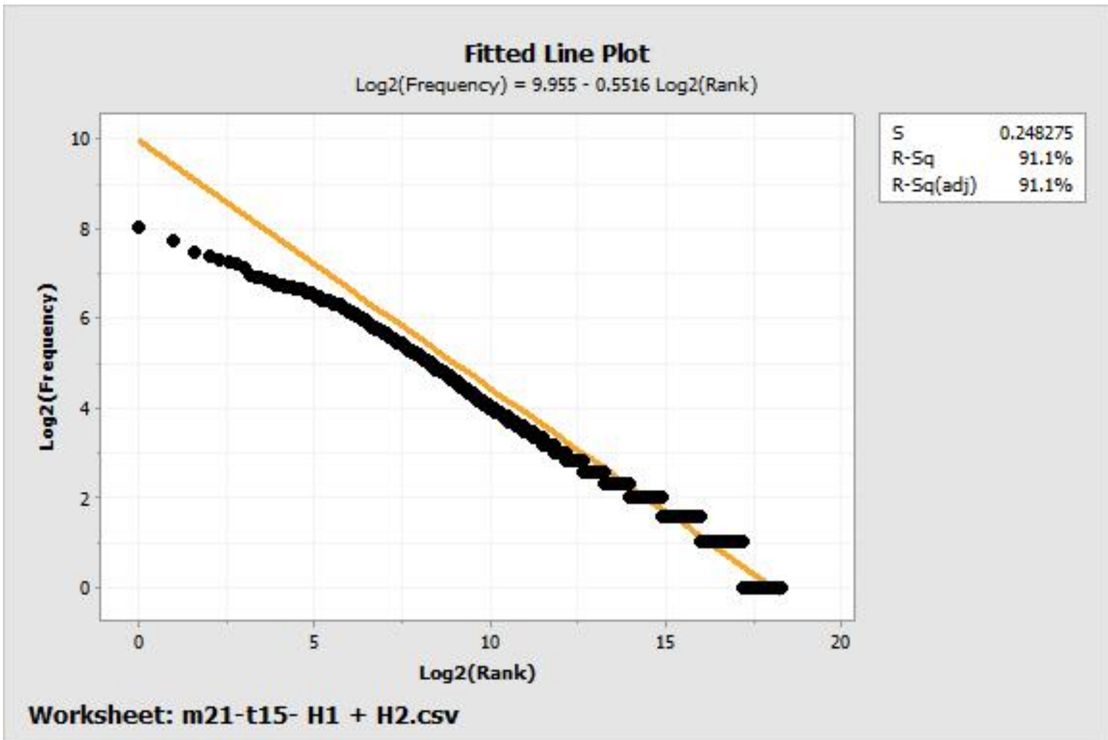

Fitted Line Plot
Log2(Frequency) = 7.948 - 0.4671 Log2(Rank)
S 0.230942
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m21-ta- H1 Only.csv

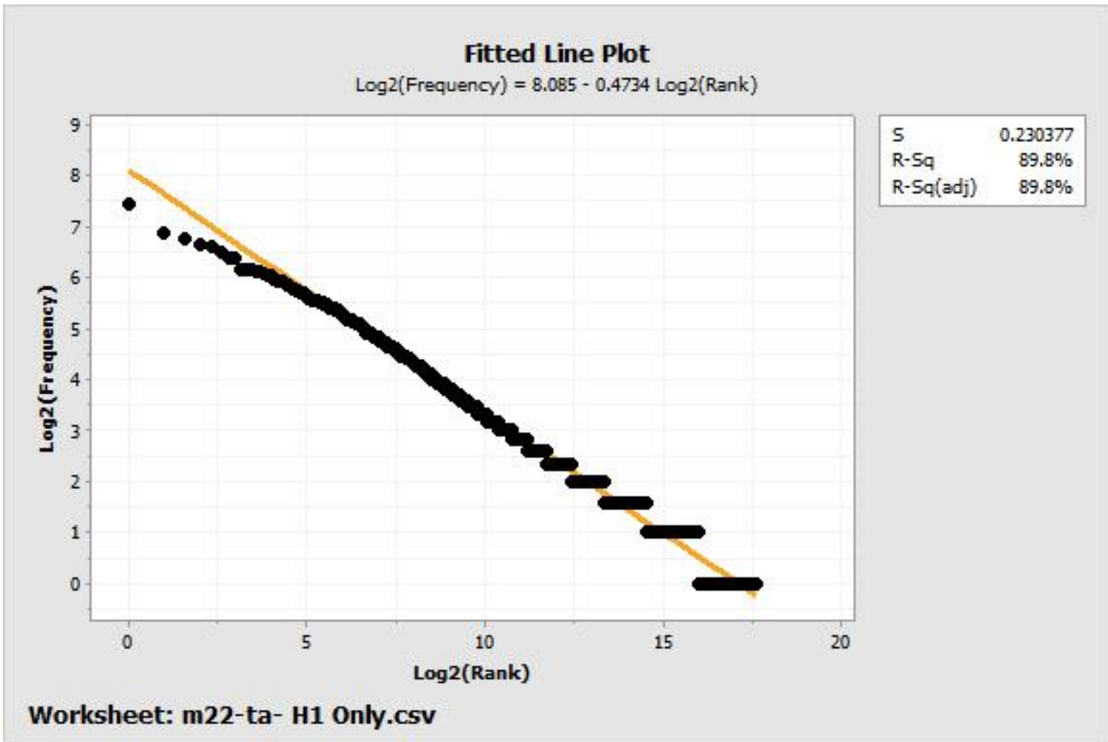

Fitted Line Plot
Log2(Frequency) = 8.252 - 0.4857 Log2(Rank)
S 0.230866
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
0
1
2
3
4
5
6
7
8
9
0
5
10
15
20
Worksheet: m21-t15- H1 Only.csv

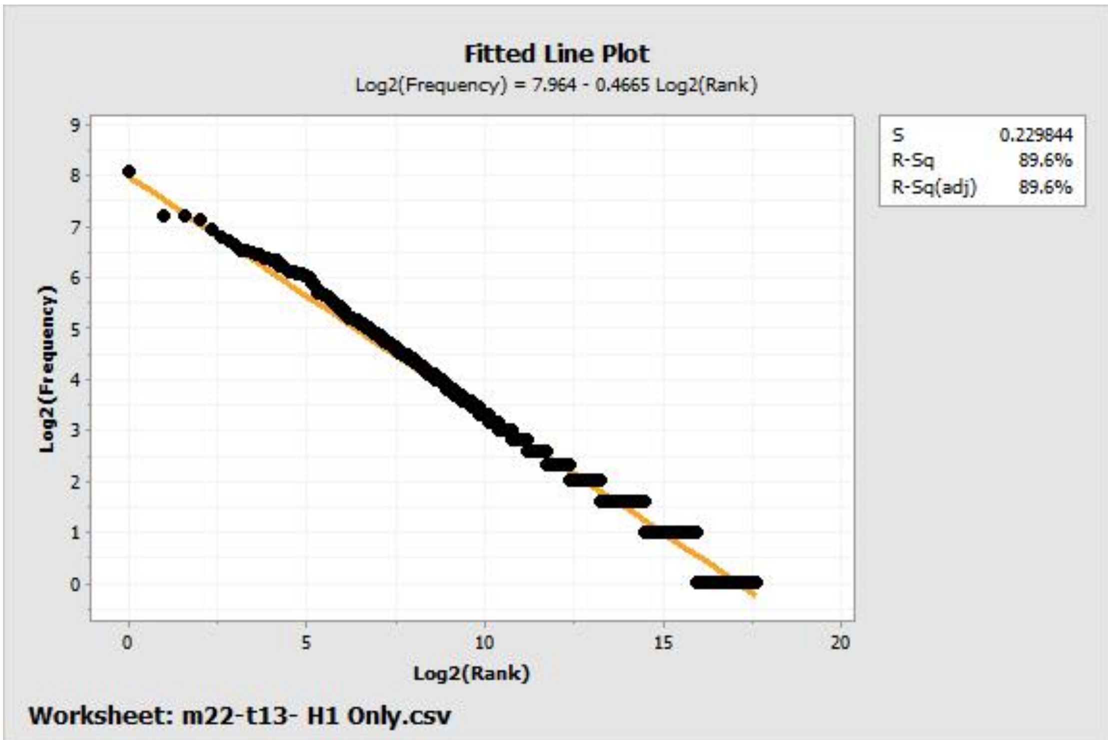

Fitted Line Plot
Log2(Frequency) = 8.033 - 0.4693 Log2(Rank)
S 0.230409
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-ta- H2 Only.csv

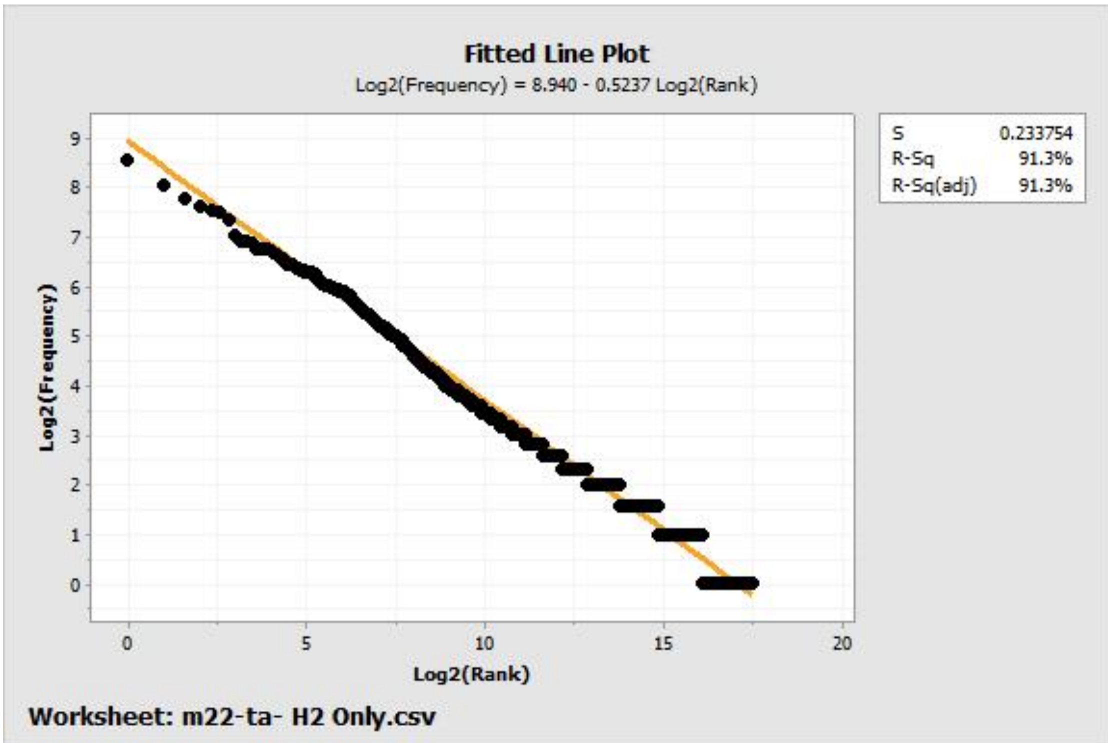

Fitted Line Plot
Log2(Frequency) = 8.357 - 0.4897 Log2(Rank)
S 0.230094
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-t15- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.09 - 0.5590 Log2(Rank)
S 0.258325
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m21-ta- H1 + H2.csv

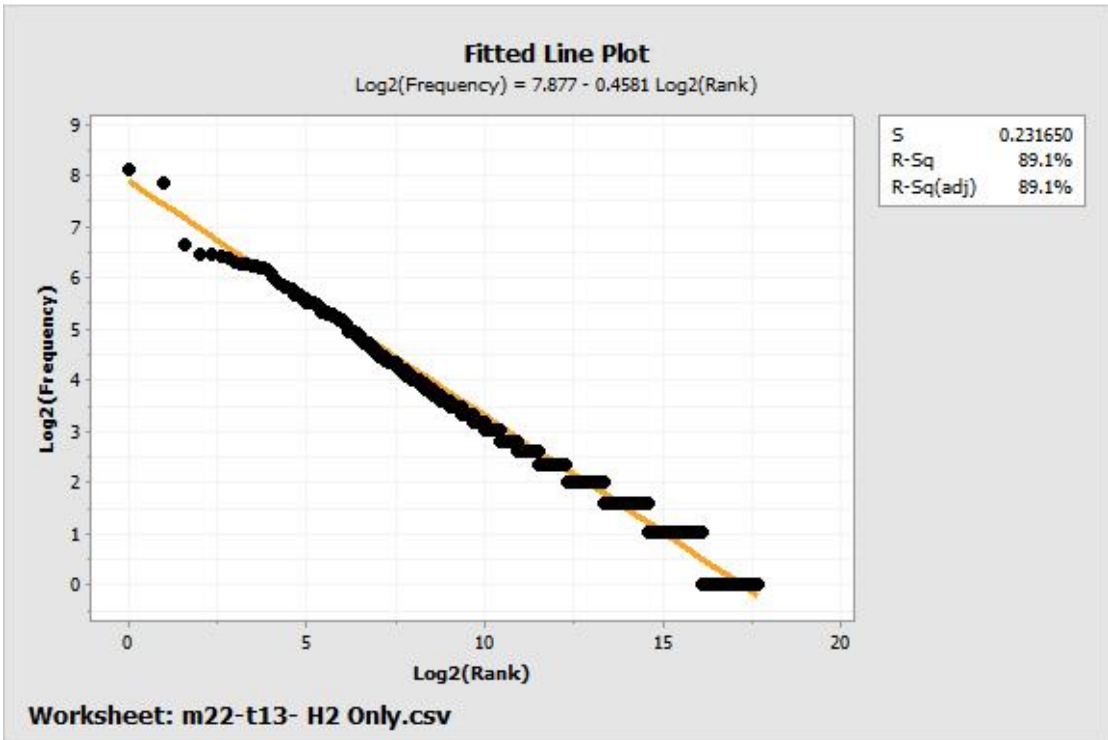

Fitted Line Plot
Log2(Frequency) = 9.955 - 0.5516 Log2(Rank)
S 0.248275
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m21-t15- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 8.085 - 0.4734 Log2(Rank)
S 0.230377
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-ta- H1 Only.csv

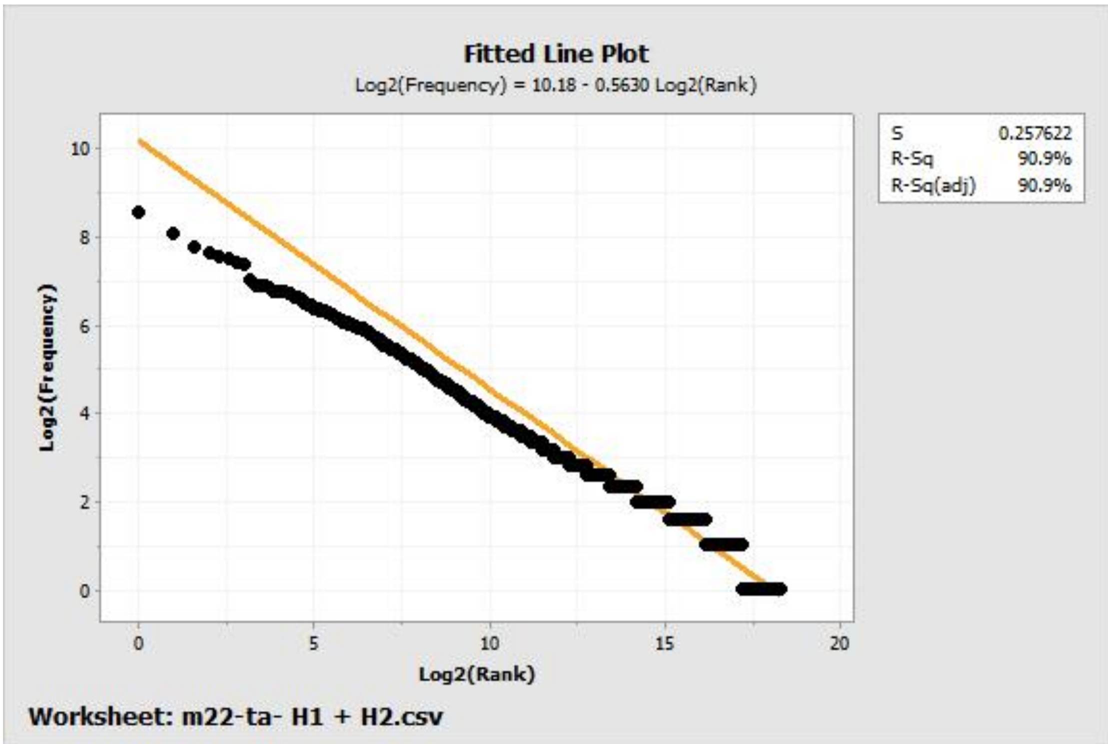

Fitted Line Plot
Log2(Frequency) = 7.964 - 0.4665 Log2(Rank)
S 0.229844
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13- H1 Only.csv

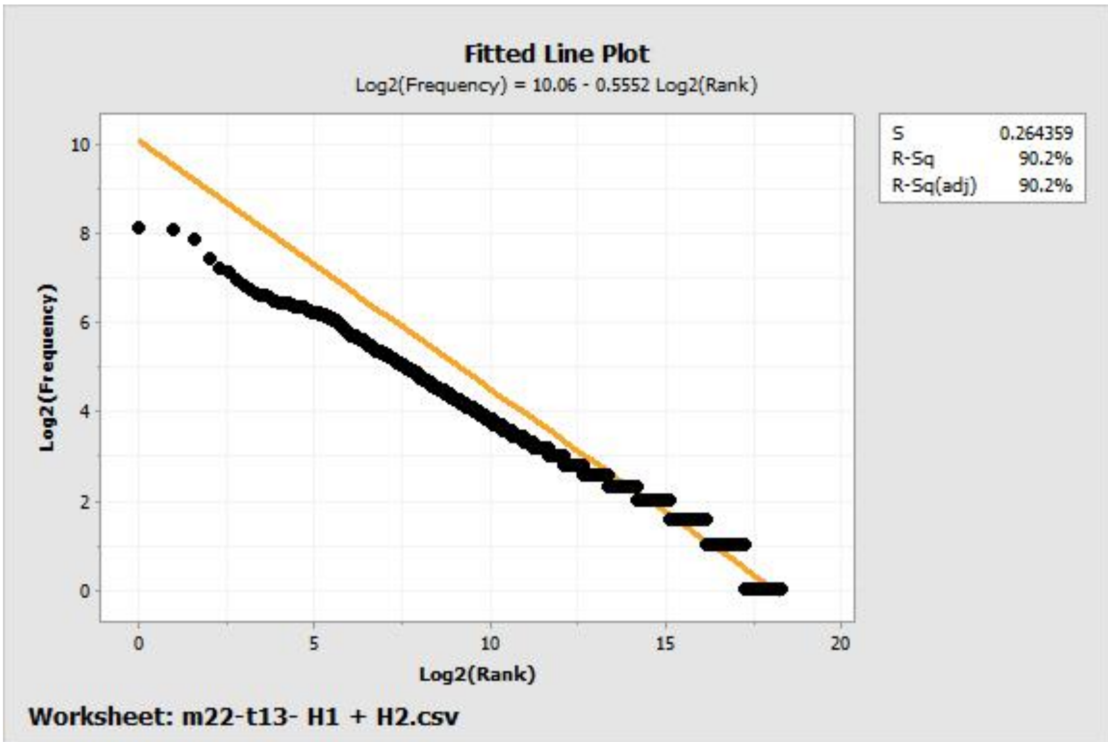


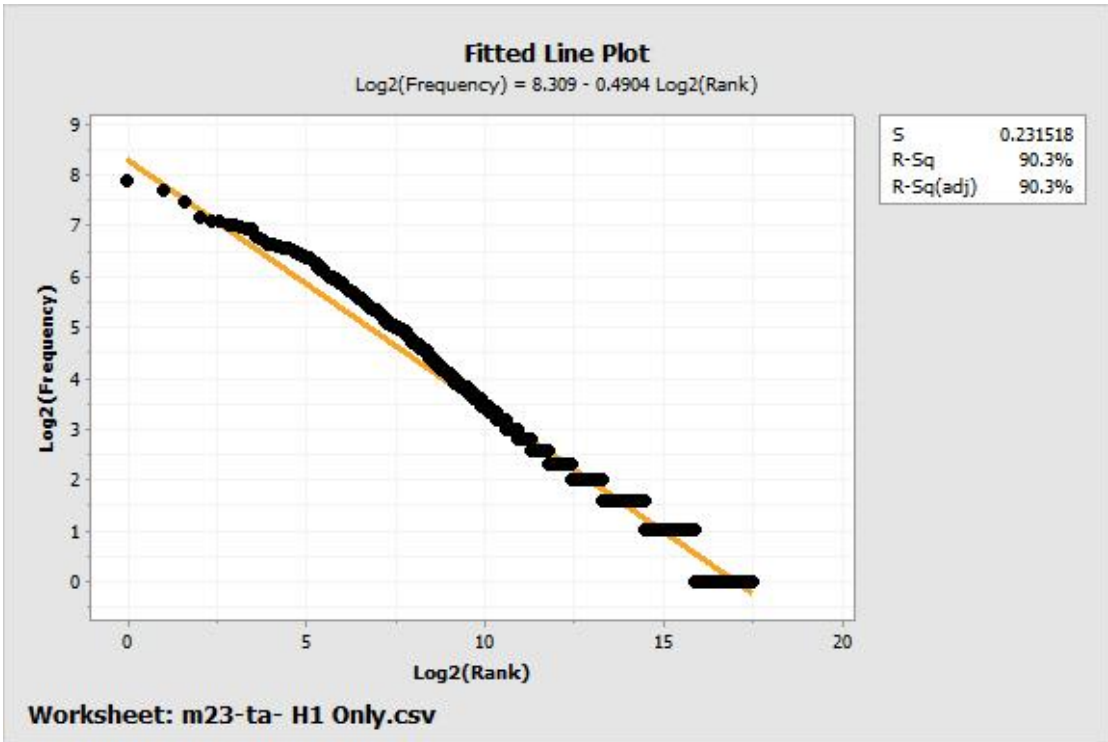
Fitted Line Plot
Log2(Frequency) = 8.940 - 0.5237 Log2(Rank)
S 0.233754
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-ta- H2 Only.csv

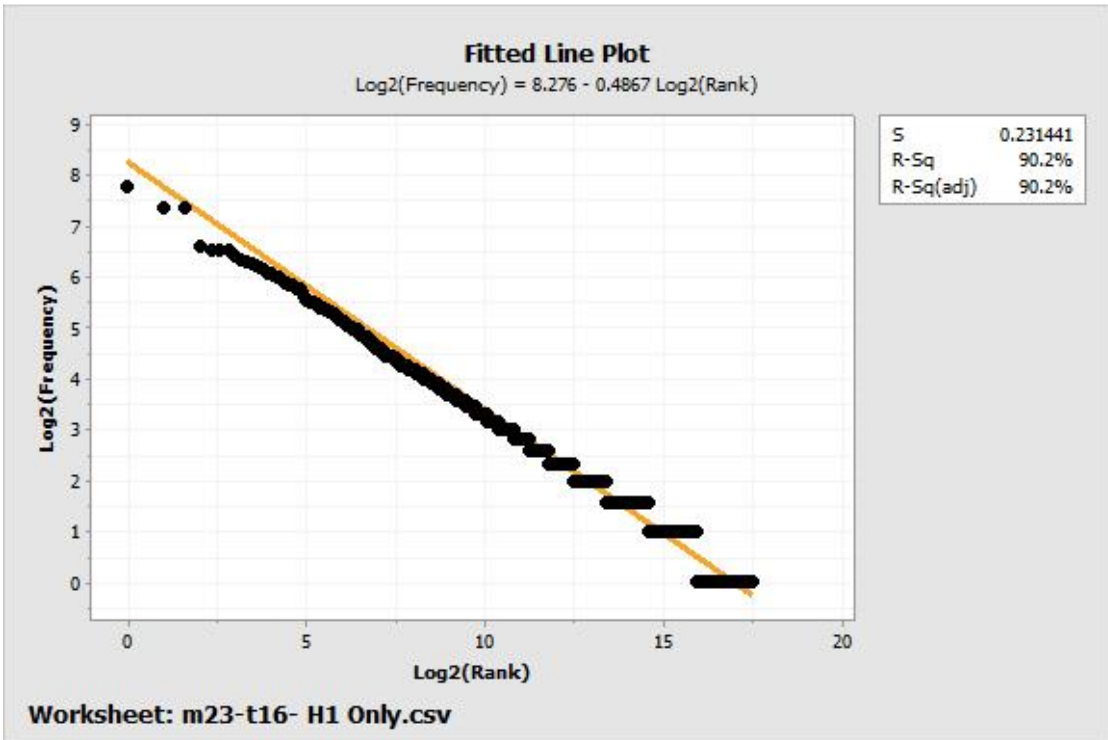


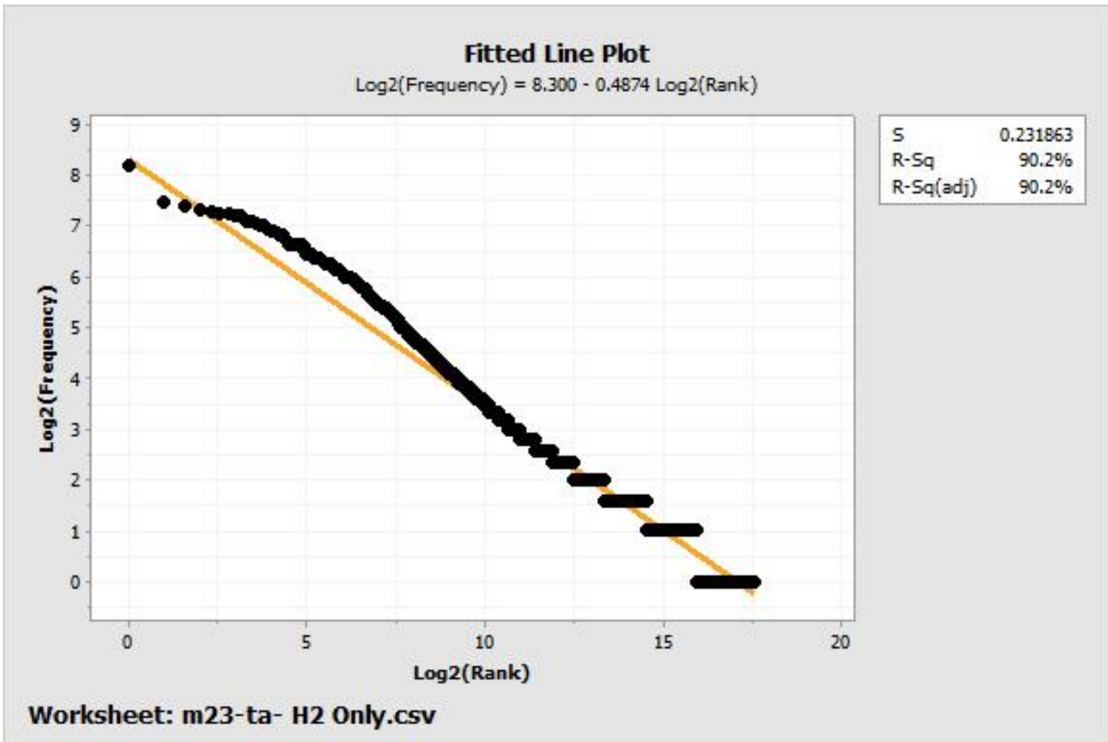
Fitted Line Plot
Log2(Frequency) = 7.877 - 0.4581 Log2(Rank)
S 0.231650
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13- H2 Only.csv

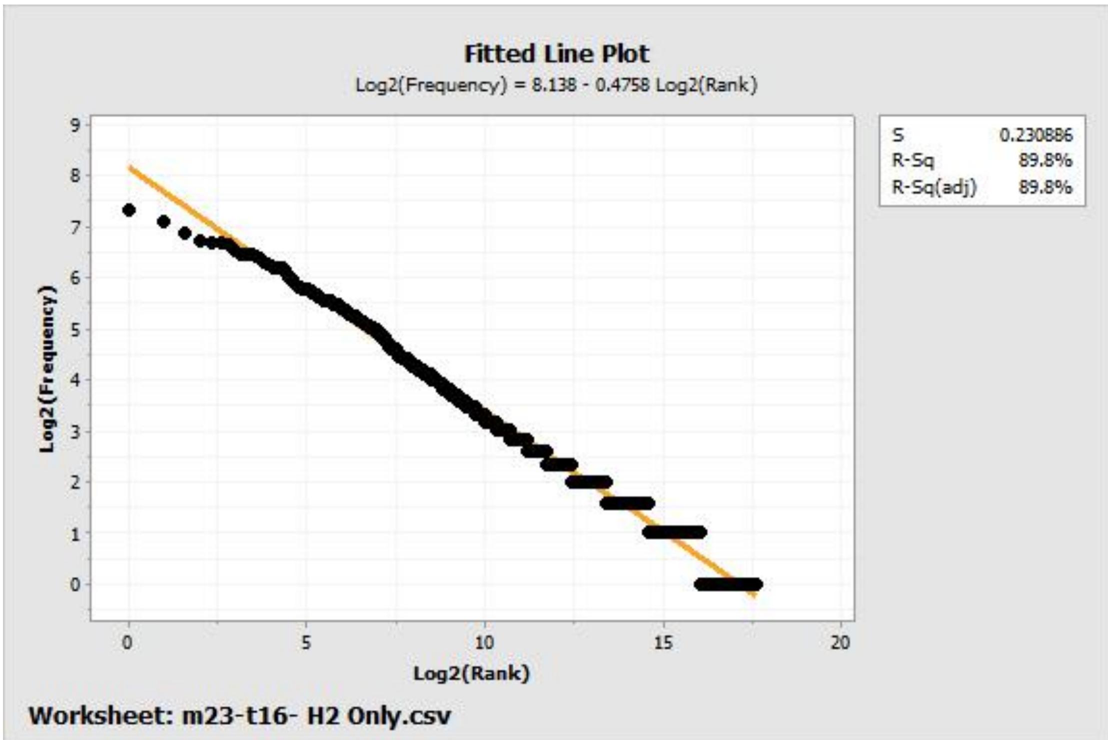

Fitted Line Plot
Log2(Frequency) = 10.18 - 0.5630 Log2(Rank)
S 0.257622
R-Sq 90.9%
R-Sq(adj) 90.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-ta- H1 + H2.csv

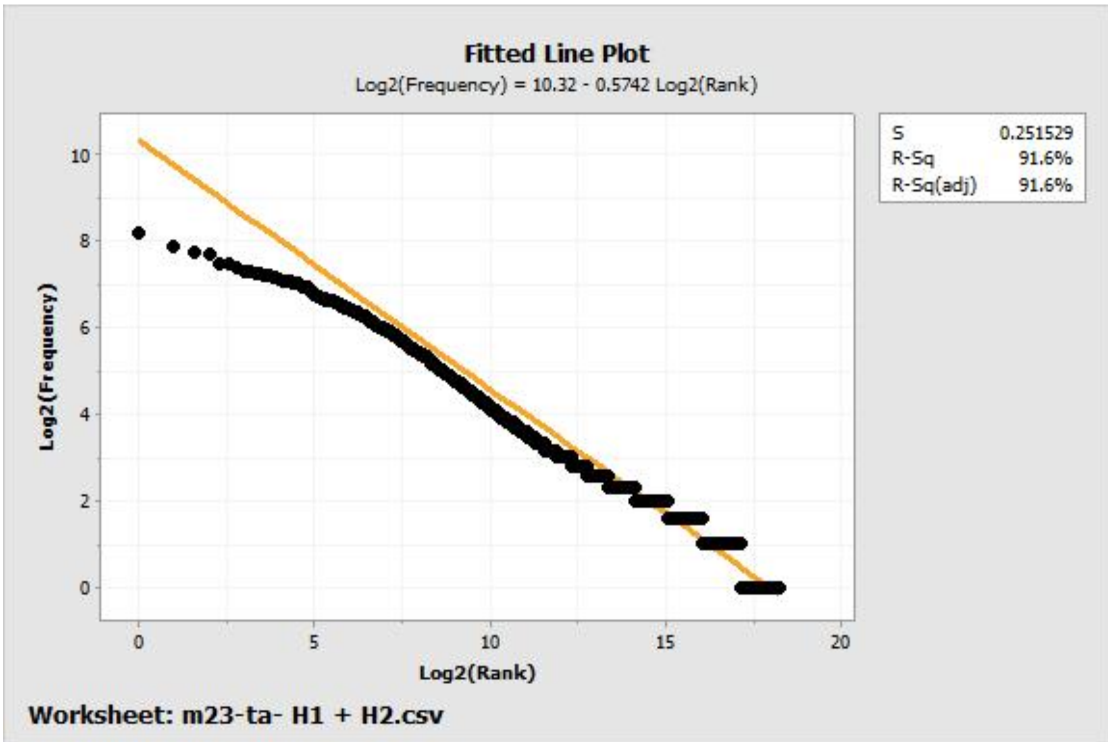

Fitted Line Plot
Log2(Frequency) = 10.06 - 0.5552 Log2(Rank)
S 0.264359
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 8.309 - 0.4904 Log2(Rank)
S 0.231518
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta- H1 Only.csv

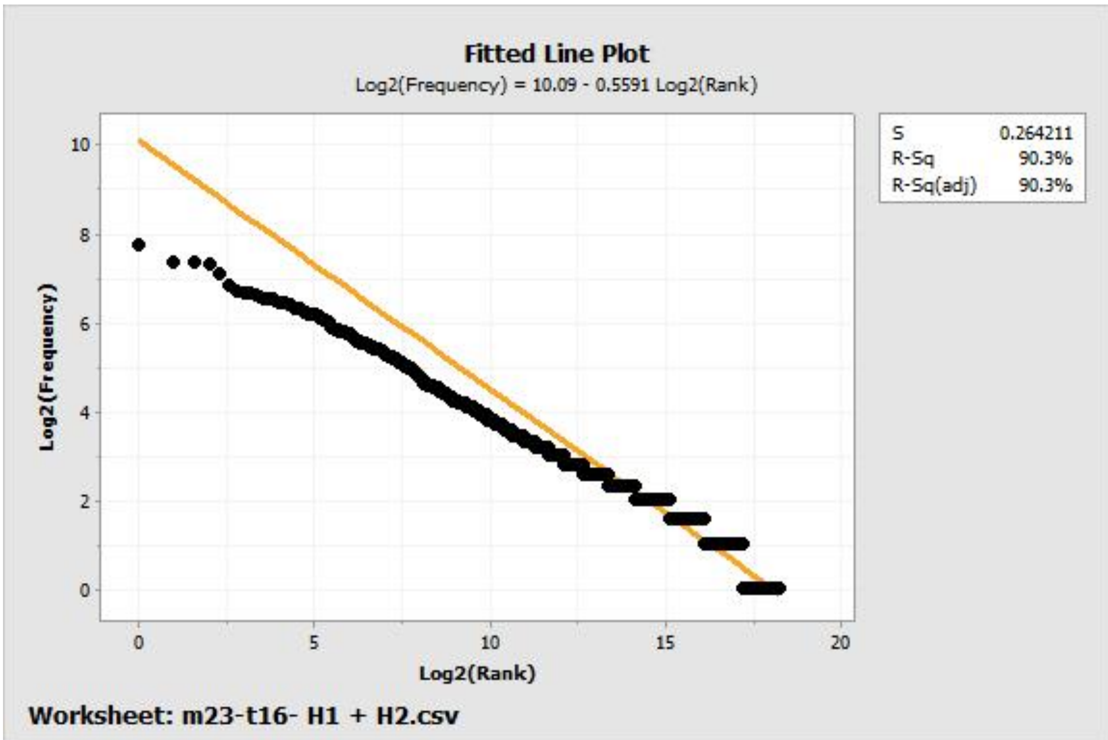

Fitted Line Plot
Log2(Frequency) = 8.276 - 0.4867 Log2(Rank)
S 0.231441
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16- H1 Only.csv


Fitted Line Plot
Log2(Frequency) = 8.300 - 0.4874 Log2(Rank)
S 0.231863
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta- H2 Only.csv

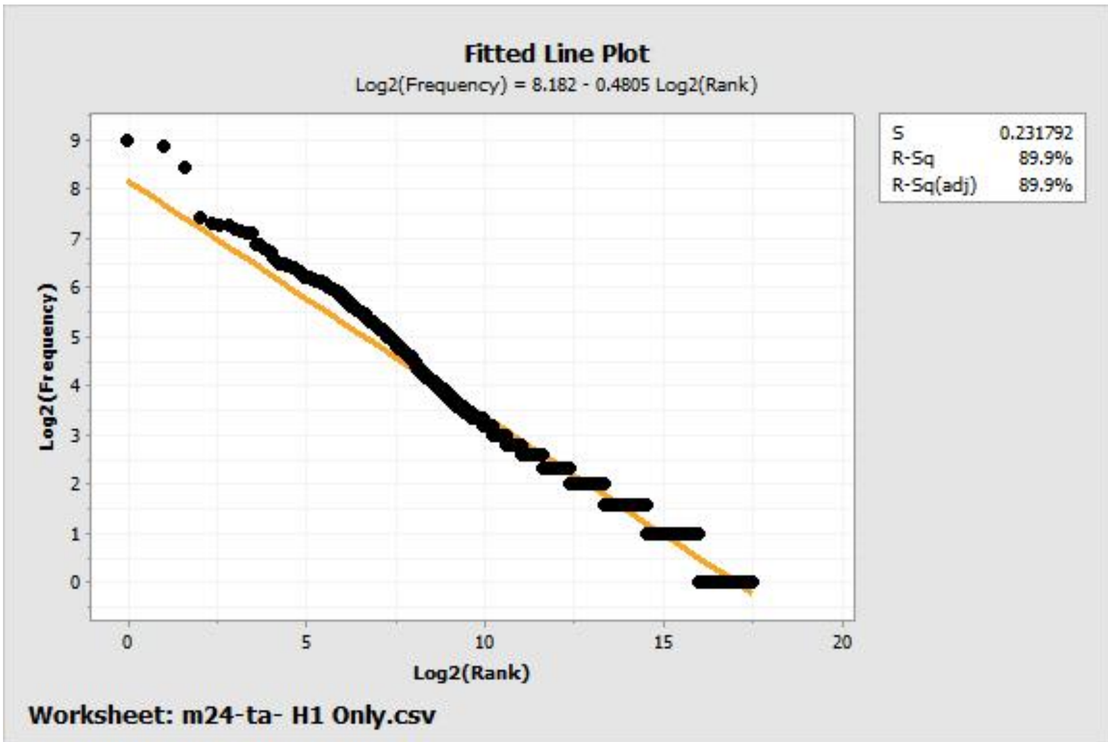

Fitted Line Plot
Log2(Frequency) = 8.138 - 0.4758 Log2(Rank)
S 0.230886
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16- H2 Only.csv

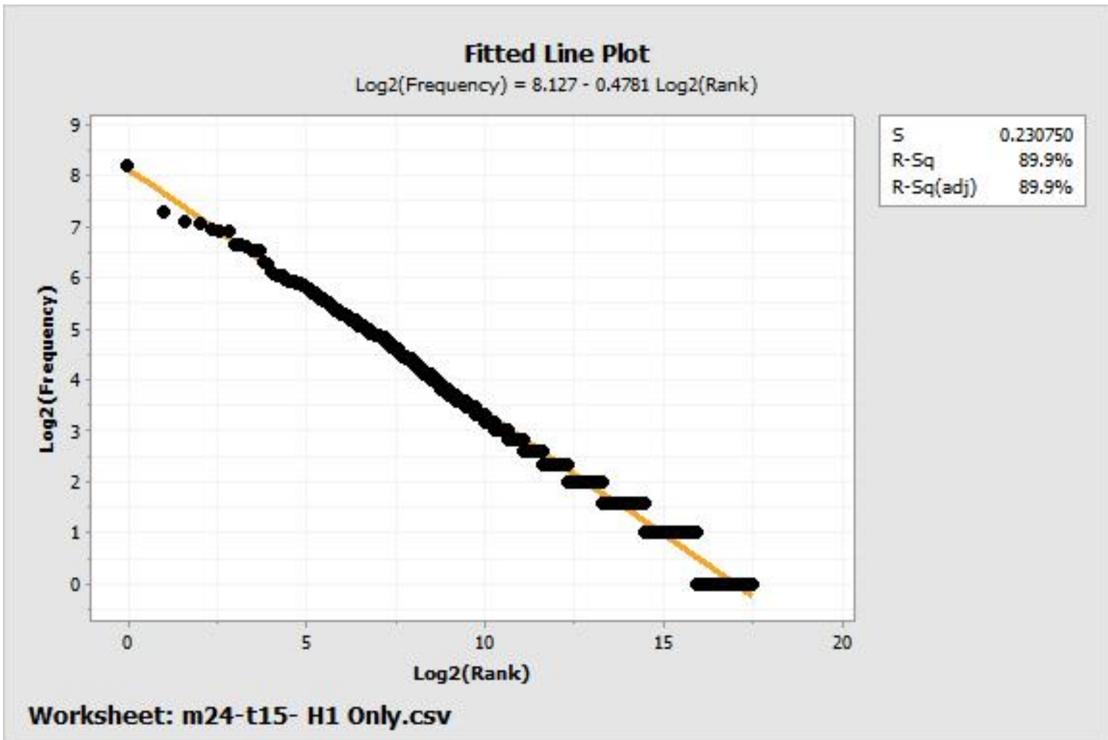


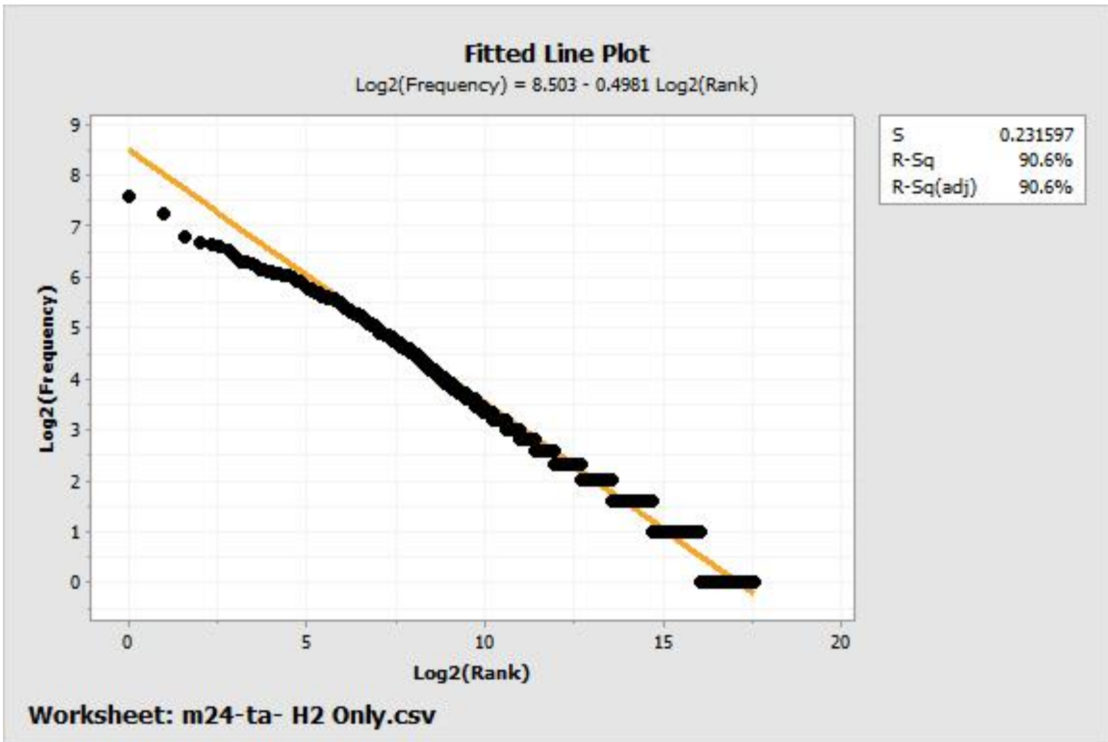
Fitted Line Plot
Log2(Frequency) = 10.32 - 0.5742 Log2(Rank)
S 0.251529
R-Sq 91.6%
R-Sq(adj) 91.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta- H1 + H2.csv

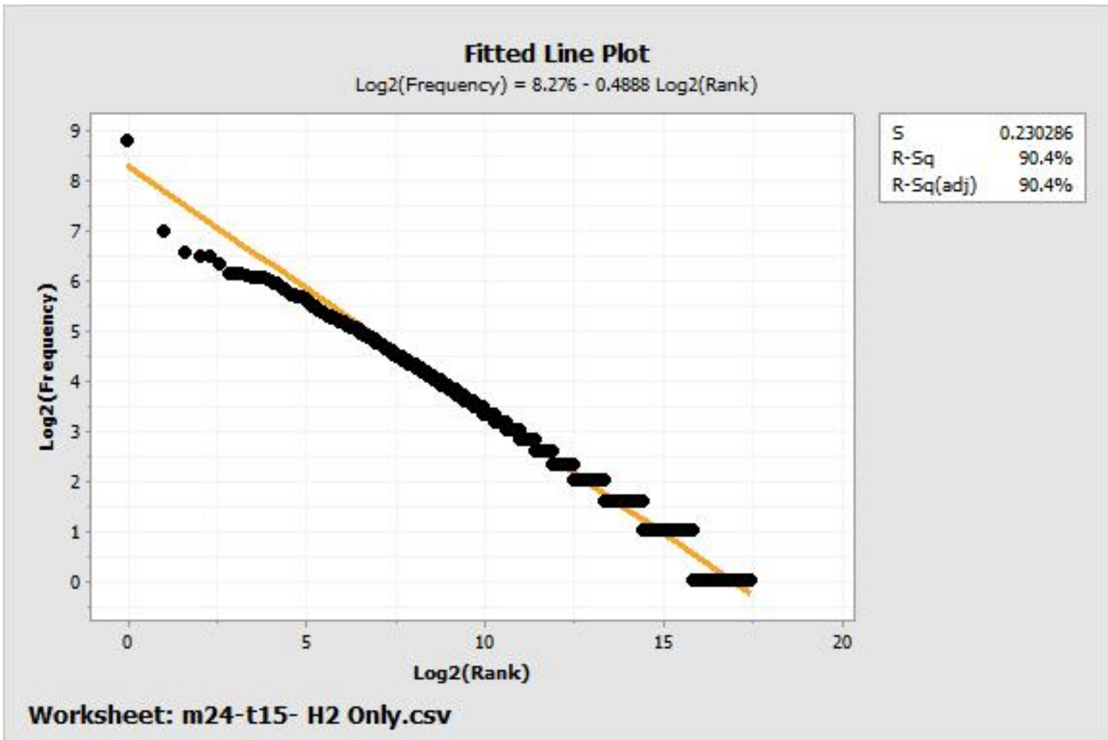


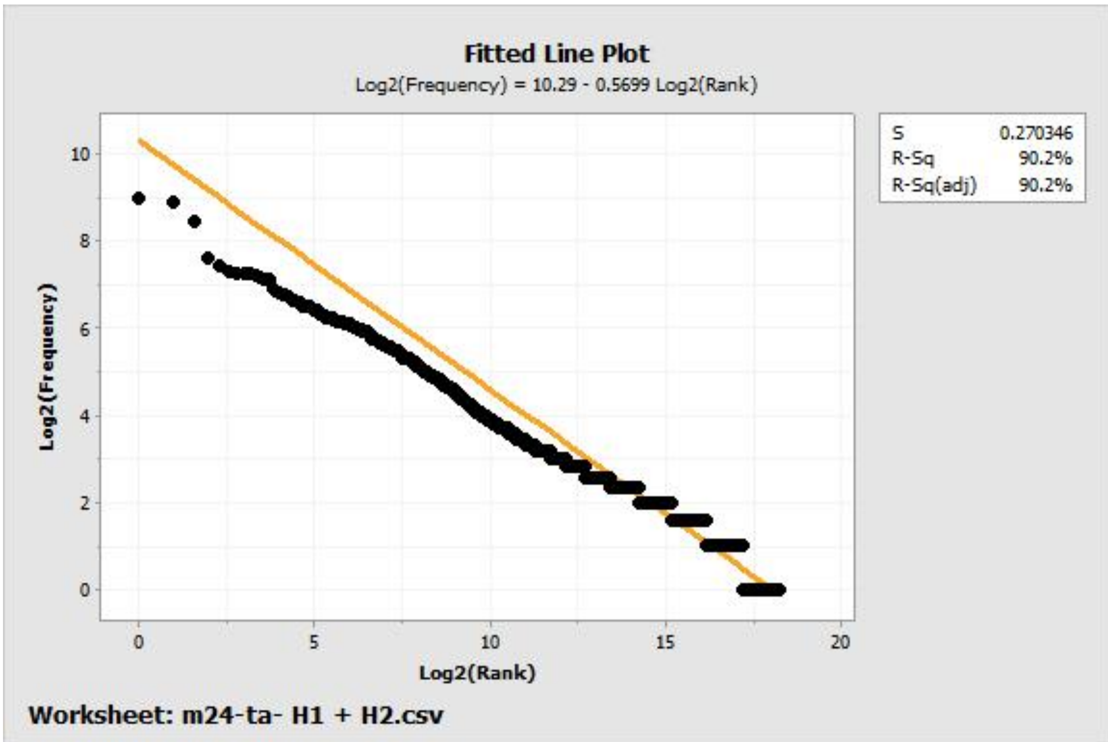
Fitted Line Plot
Log2(Frequency) = 10.09 - 0.5591 Log2(Rank)
S 0.264211
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16- H1 + H2.csv

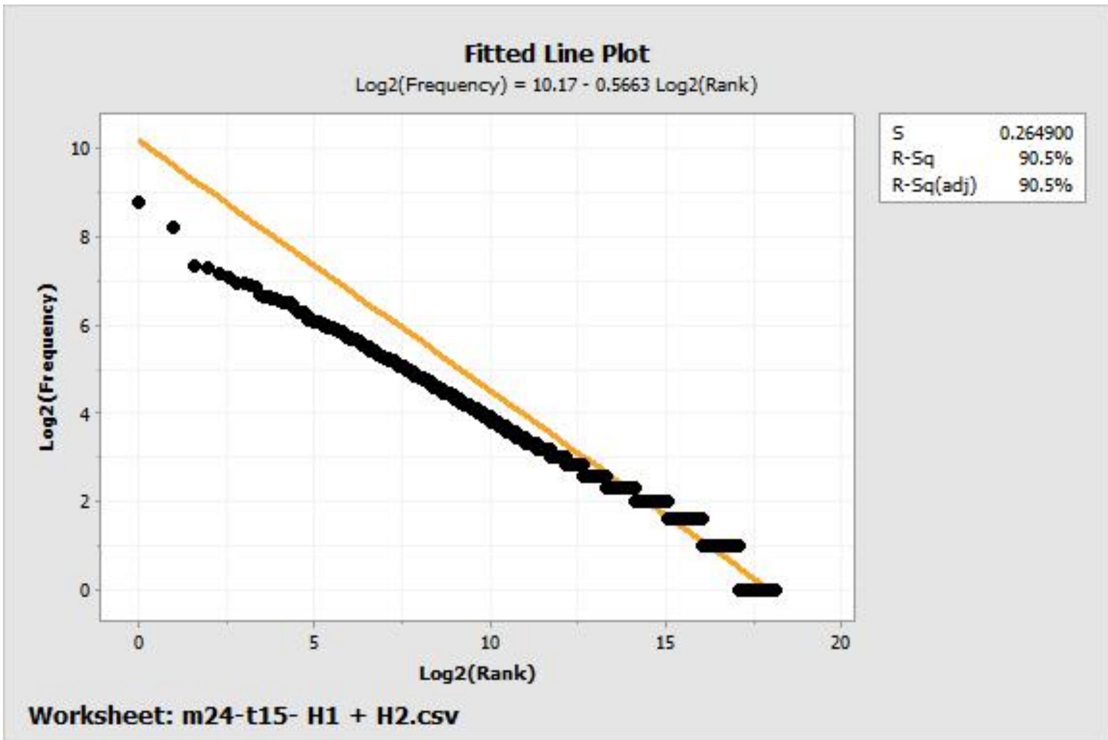

Fitted Line Plot
Log2(Frequency) = 8.182 - 0.4805 Log2(Rank)
S 0.231792
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
0
5
10
15
20
1
2
3
4
5
6
7
8
9
Worksheet: m24-ta- H1 Only.csv

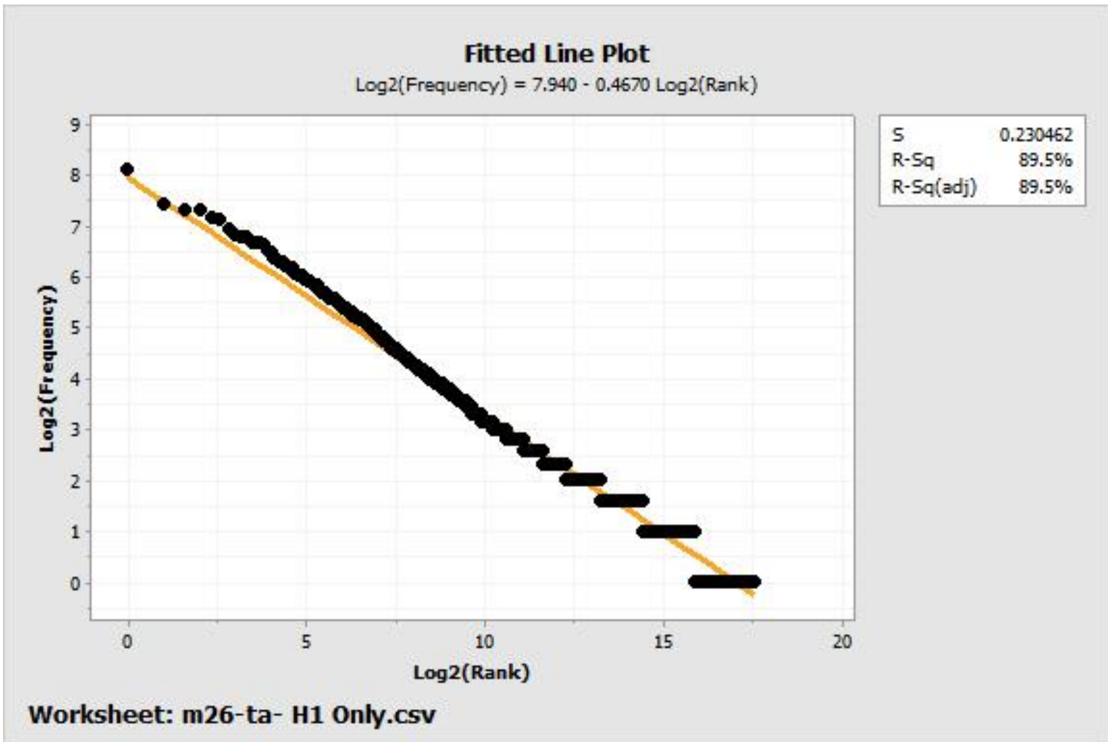

Fitted Line Plot
Log2(Frequency) = 8.127 - 0.4781 Log2(Rank)
S 0.230750
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
0
5
10
15
20
1
2
3
4
5
6
7
8
9
Worksheet: m24-t15- H1 Only.csv

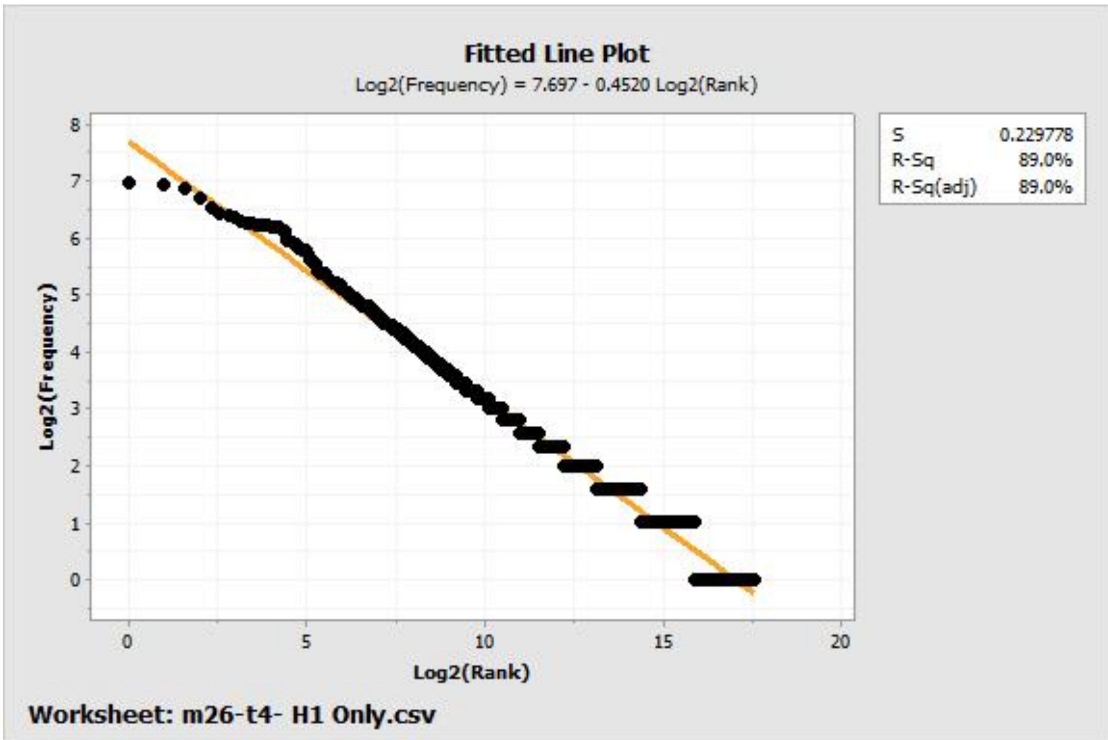

Fitted Line Plot
Log2(Frequency) = 8.503 - 0.4981 Log2(Rank)
S 0.231597
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-ta- H2 Only.csv

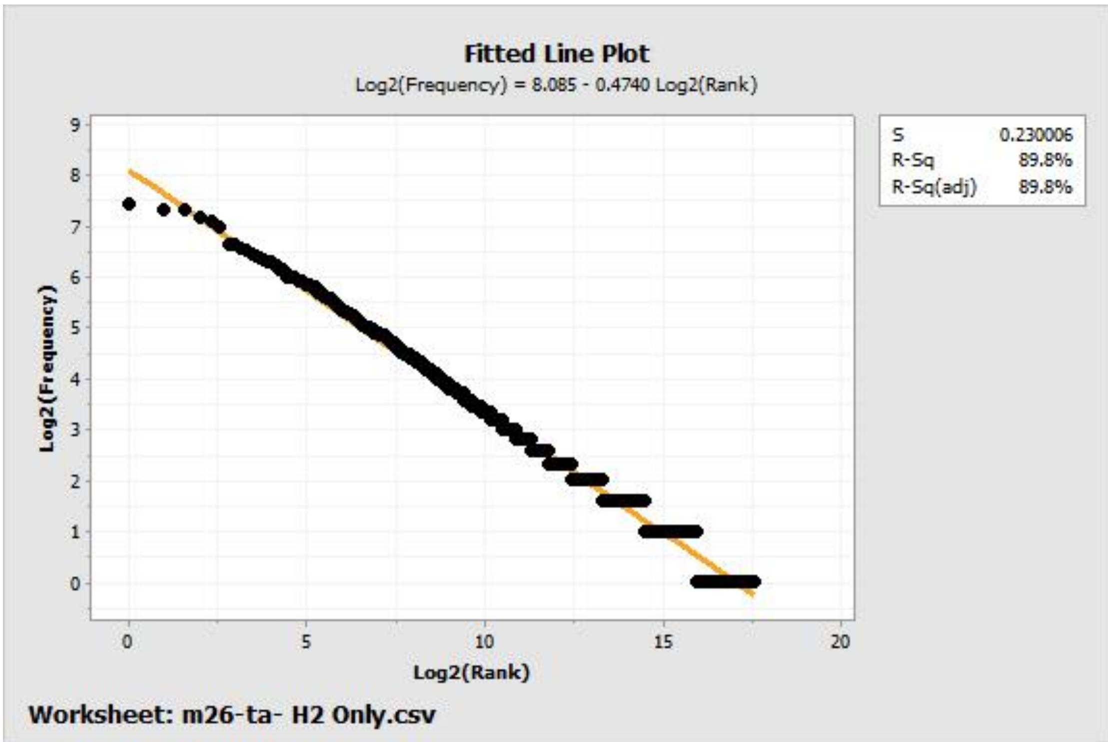

Fitted Line Plot
Log2(Frequency) = 8.276 - 0.4888 Log2(Rank)
S 0.230286
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-t15- H2 Only.csv

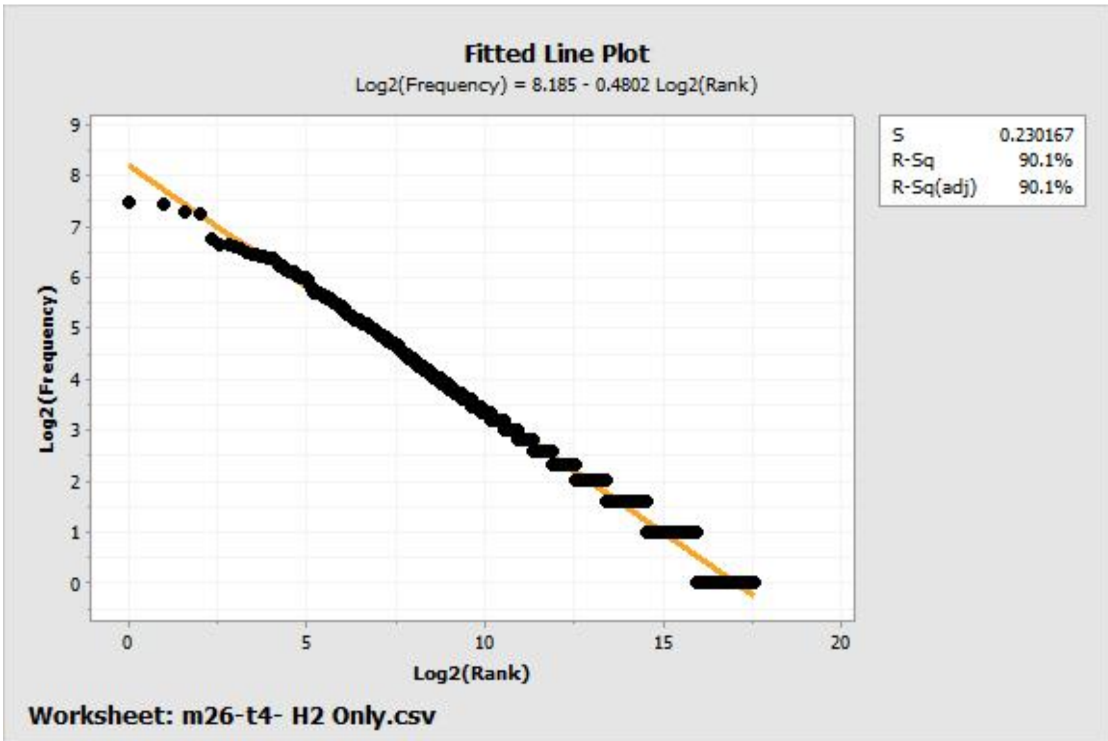

Fitted Line Plot
Log2(Frequency) = 10.29 - 0.5699 Log2(Rank)
S 0.270346
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-ta- H1 + H2.csv

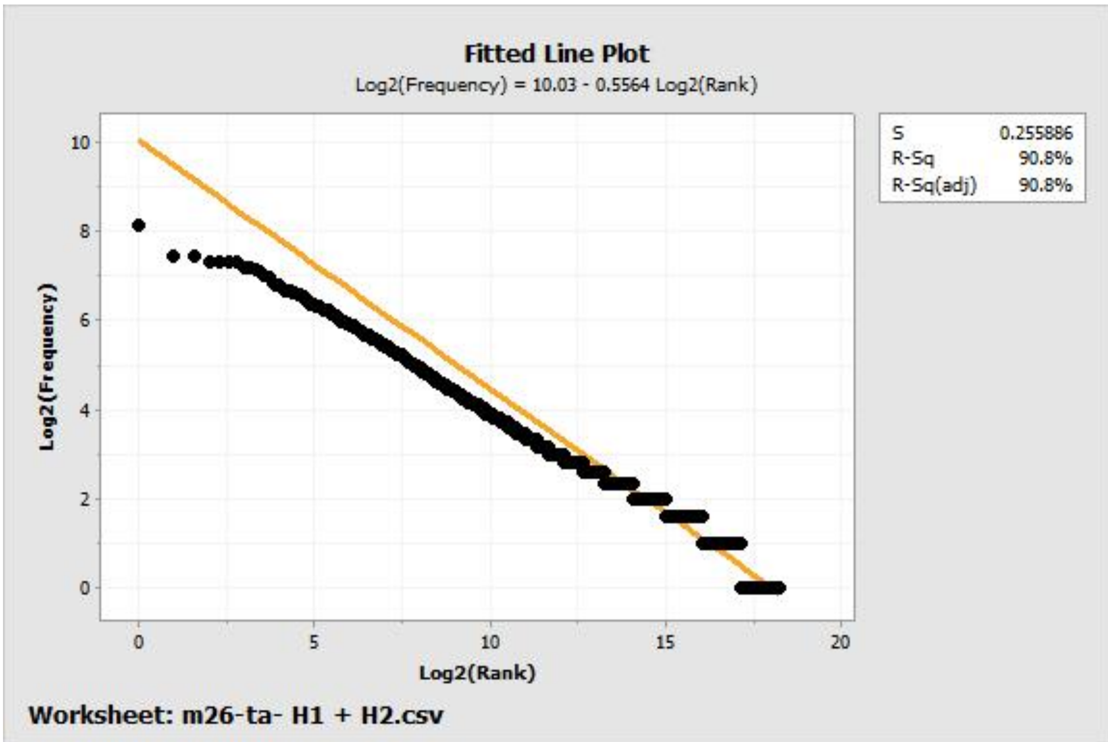

Fitted Line Plot
Log2(Frequency) = 10.17 - 0.5663 Log2(Rank)
S 0.264900
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-t15- H1 + H2.csv

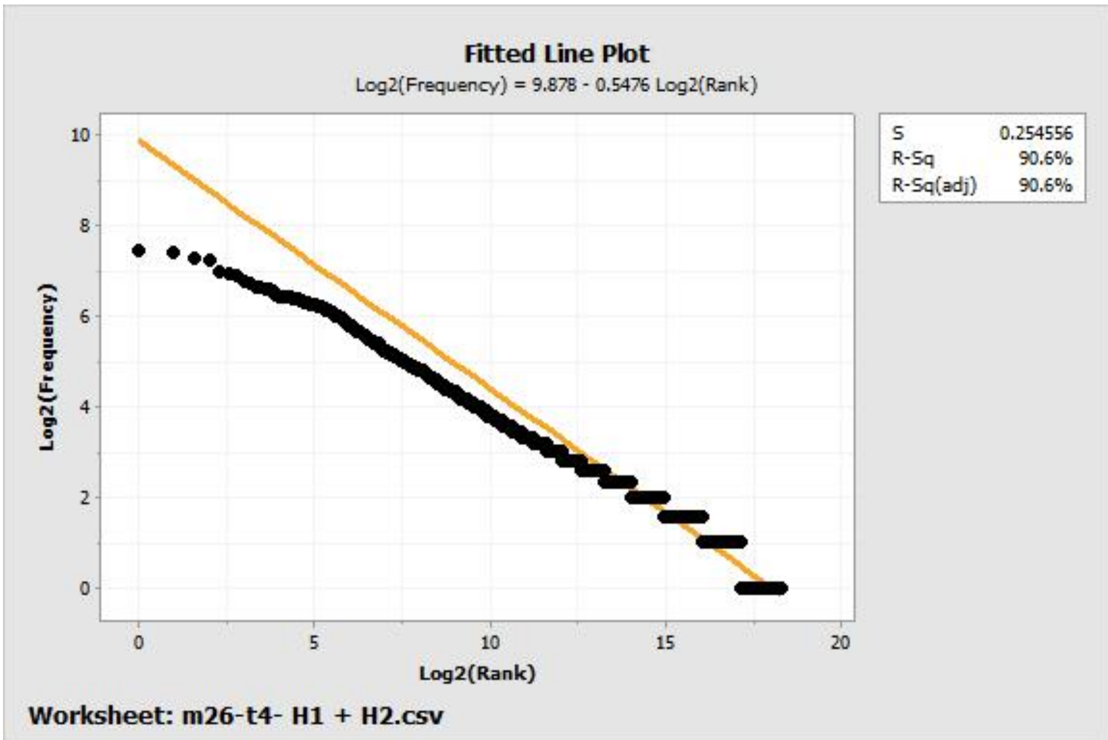

Fitted Line Plot
Log2(Frequency) = 7.940 - 0.4670 Log2(Rank)
S 0.230462
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta- H1 Only.csv

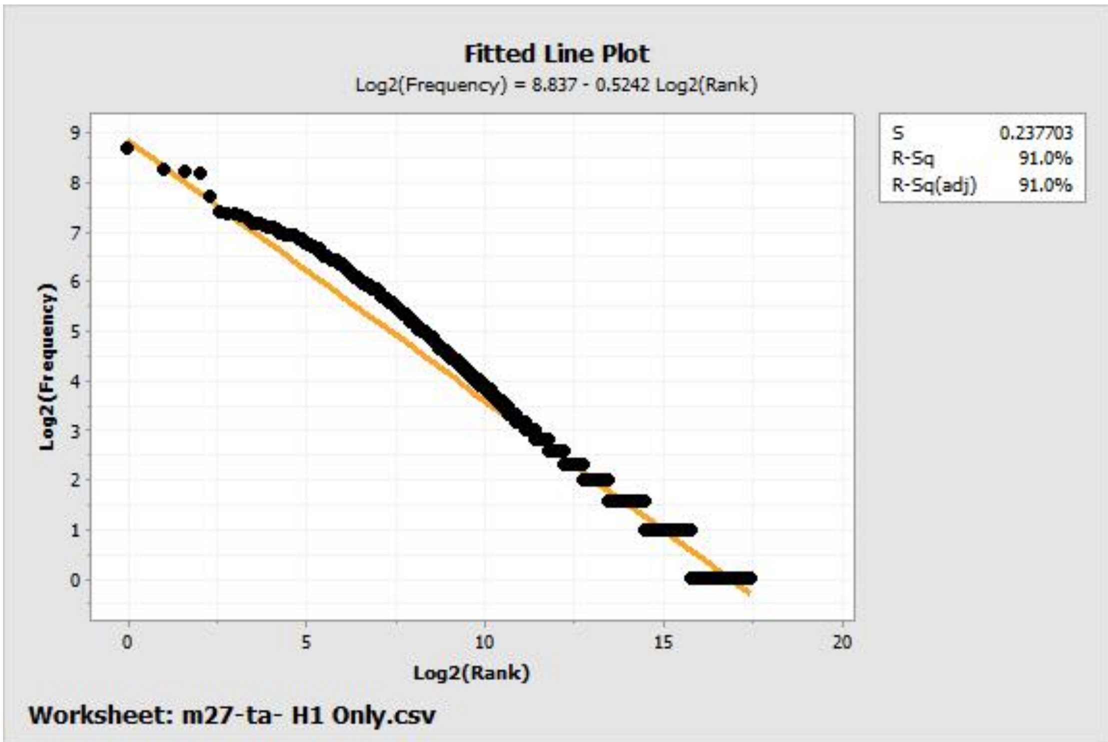

Fitted Line Plot
Log2(Frequency) = 7.697 - 0.4520 Log2(Rank)
S 0.229778
R-Sq 89.0%
R-Sq(adj) 89.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-t4- H1 Only.csv

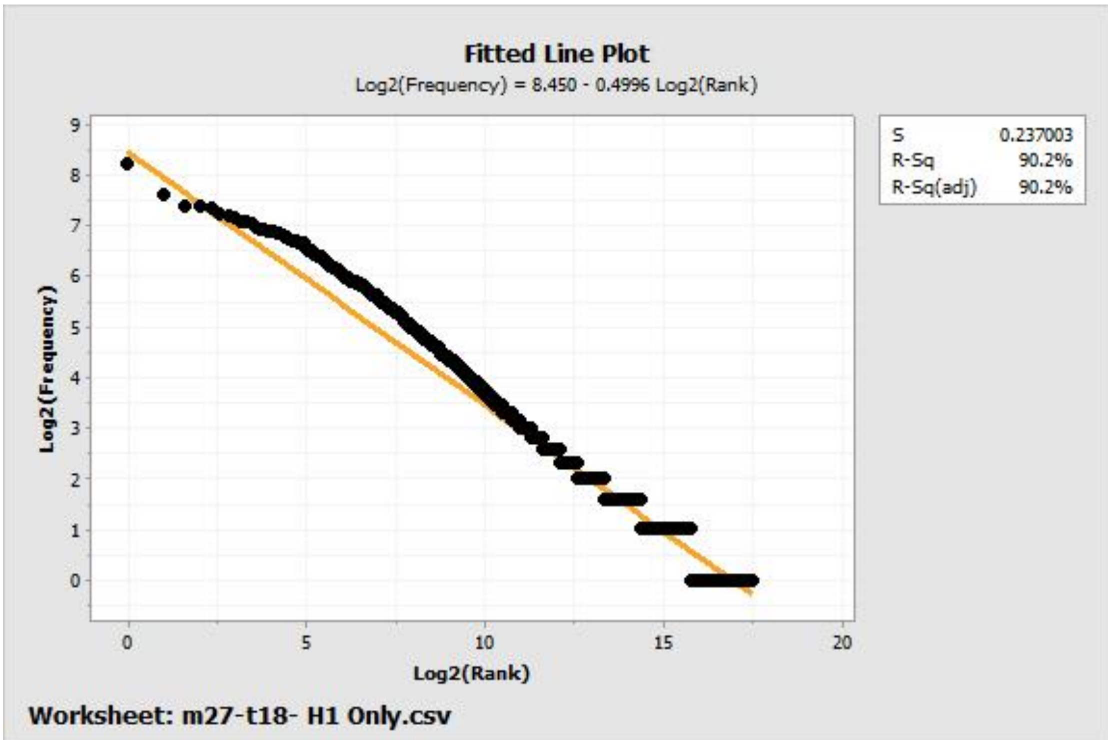

Fitted Line Plot
Log2(Frequency) = 8.085 - 0.4740 Log2(Rank)
S 0.230006
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta- H2 Only.csv

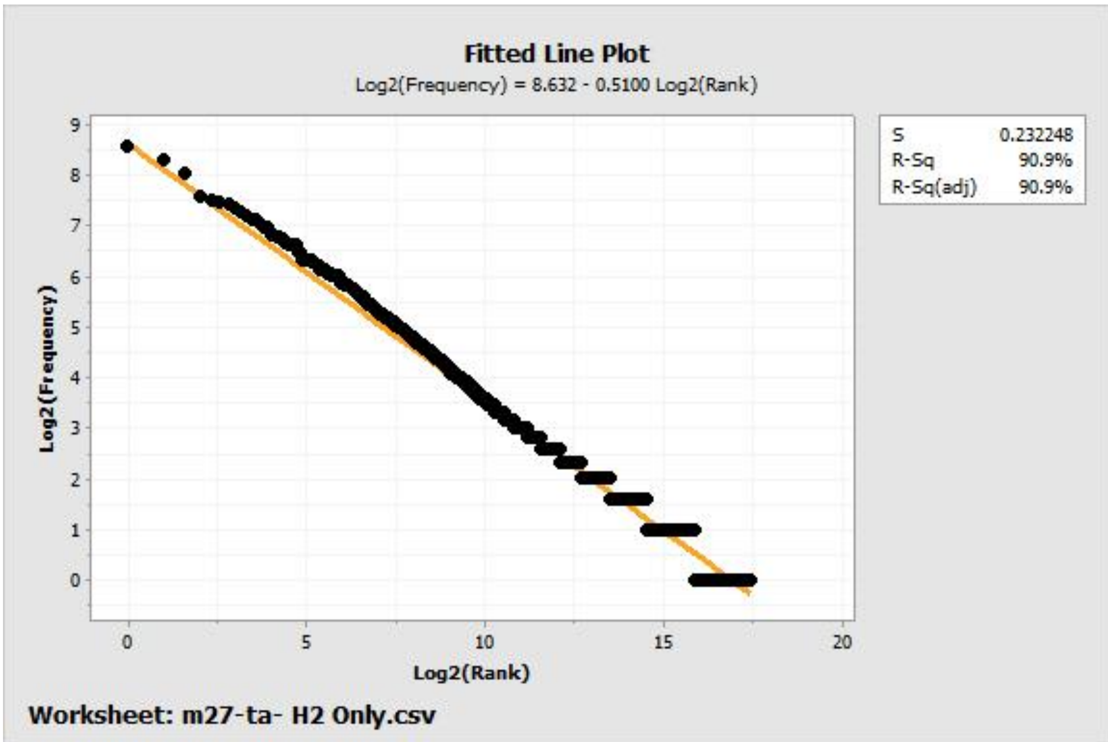

Fitted Line Plot
Log2(Frequency) = 8.185 - 0.4802 Log2(Rank)
S 0.230167
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-t4- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.03 - 0.5564 Log2(Rank)
S 0.255886
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta- H1 + H2.csv

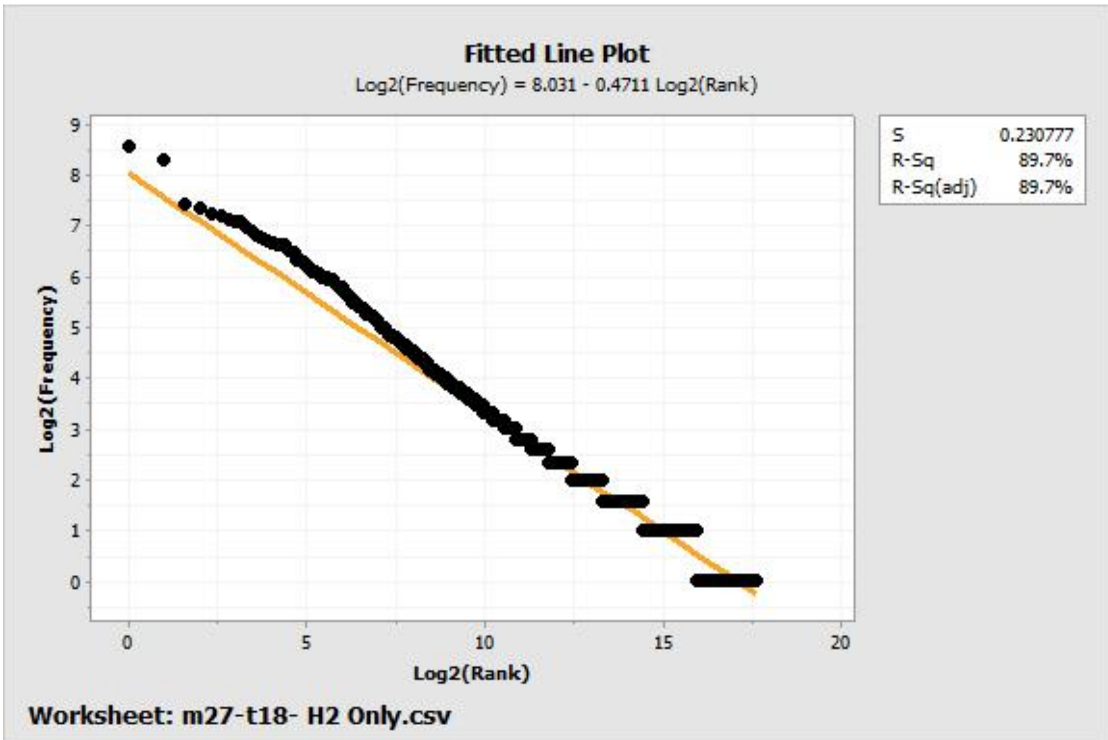

Fitted Line Plot
Log2(Frequency) = 9.878 - 0.5476 Log2(Rank)
S 0.254556
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-t4- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 8.837 - 0.5242 Log2(Rank)
S 0.237703
R-Sq 91.0%
R-Sq(adj) 91.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta- H1 Only.csv

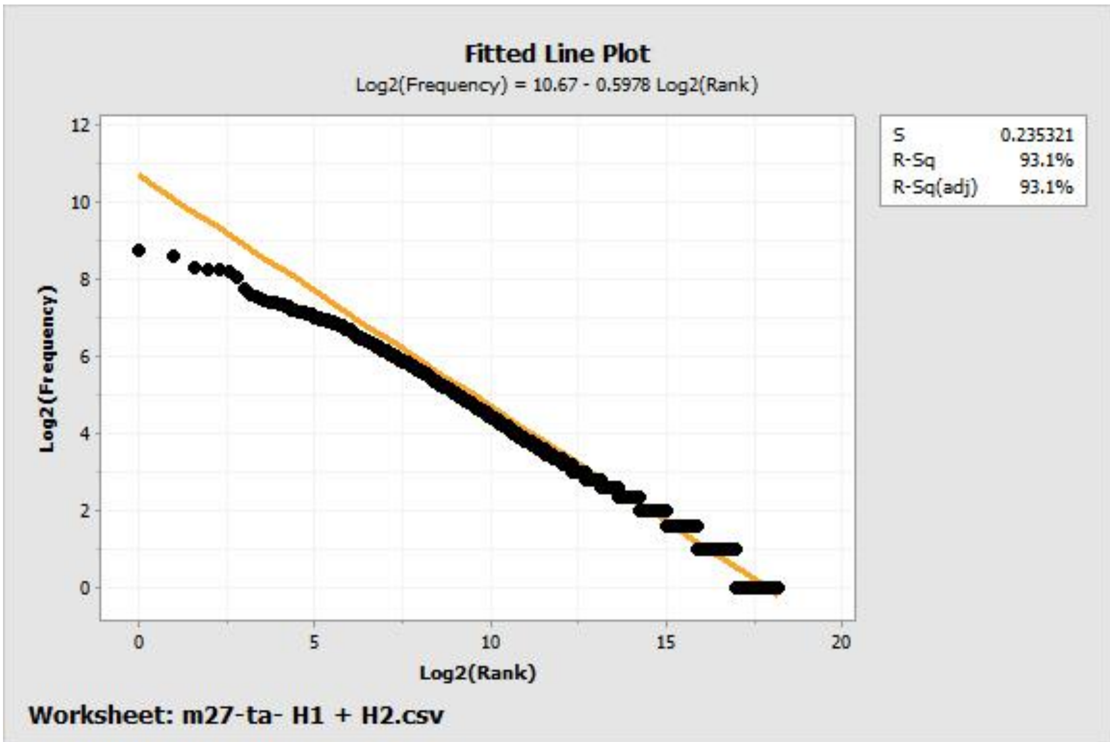

Fitted Line Plot
Log2(Frequency) = 8.450 - 0.4996 Log2(Rank)
S 0.237003
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18- H1 Only.csv

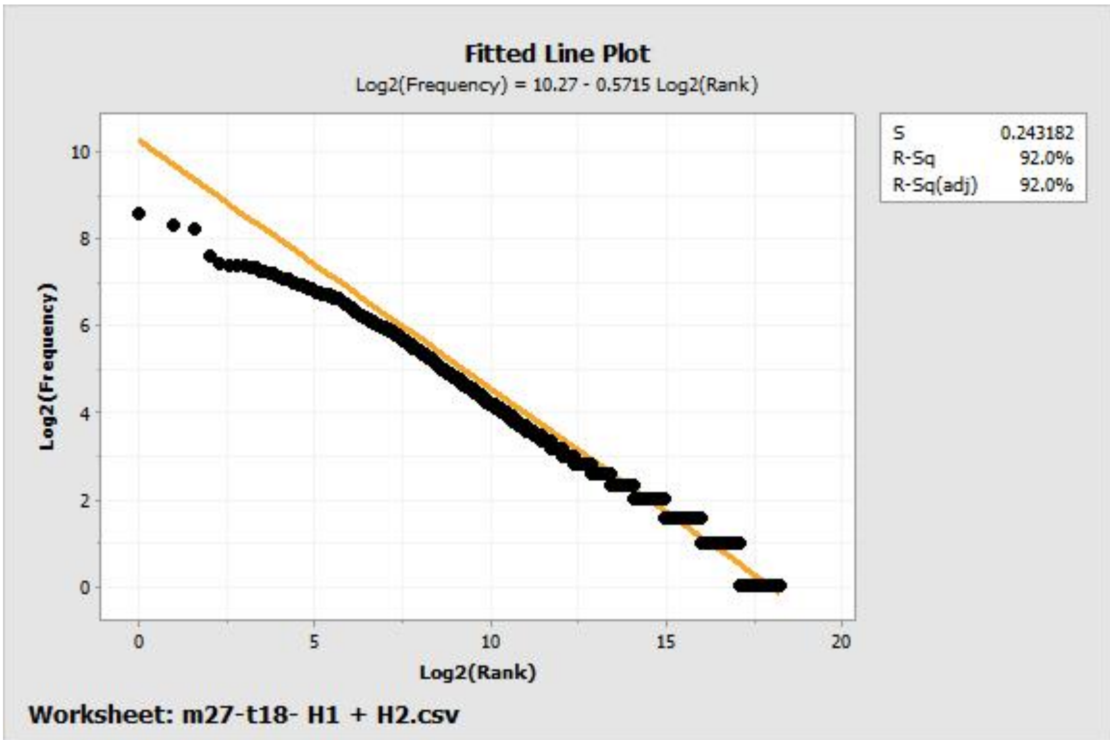


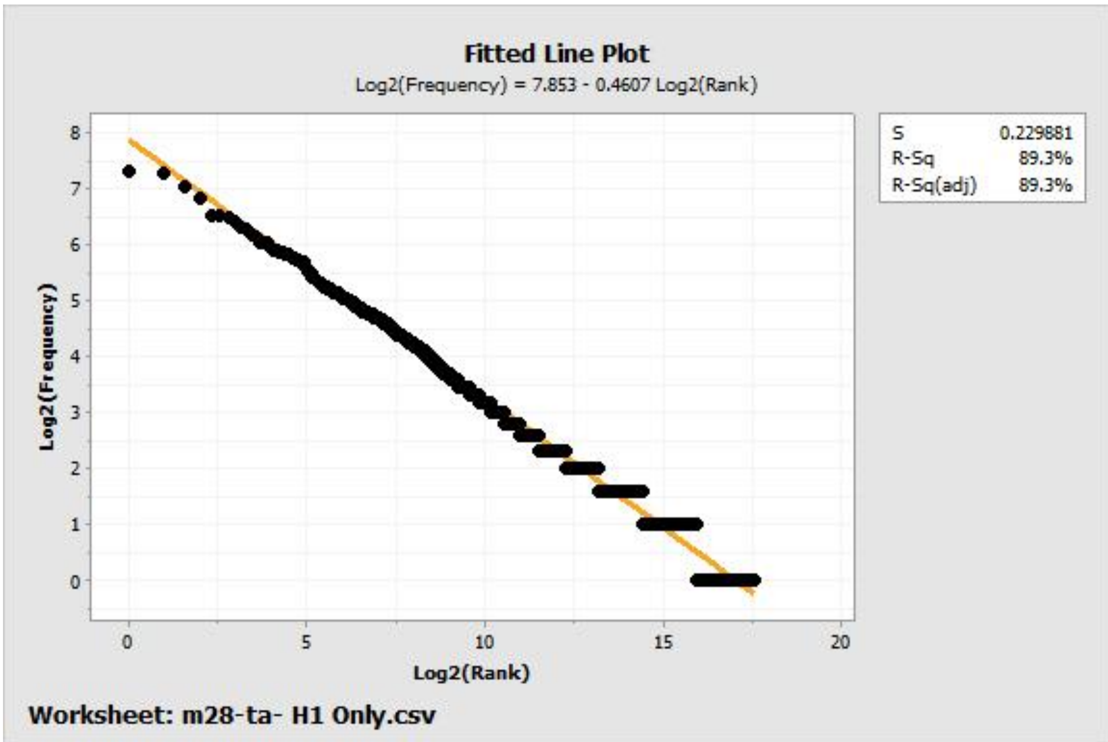
Fitted Line Plot
Log2(Frequency) = 8.632 - 0.5100 Log2(Rank)
S 0.232248
R-Sq 90.9%
R-Sq(adj) 90.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta- H2 Only.csv

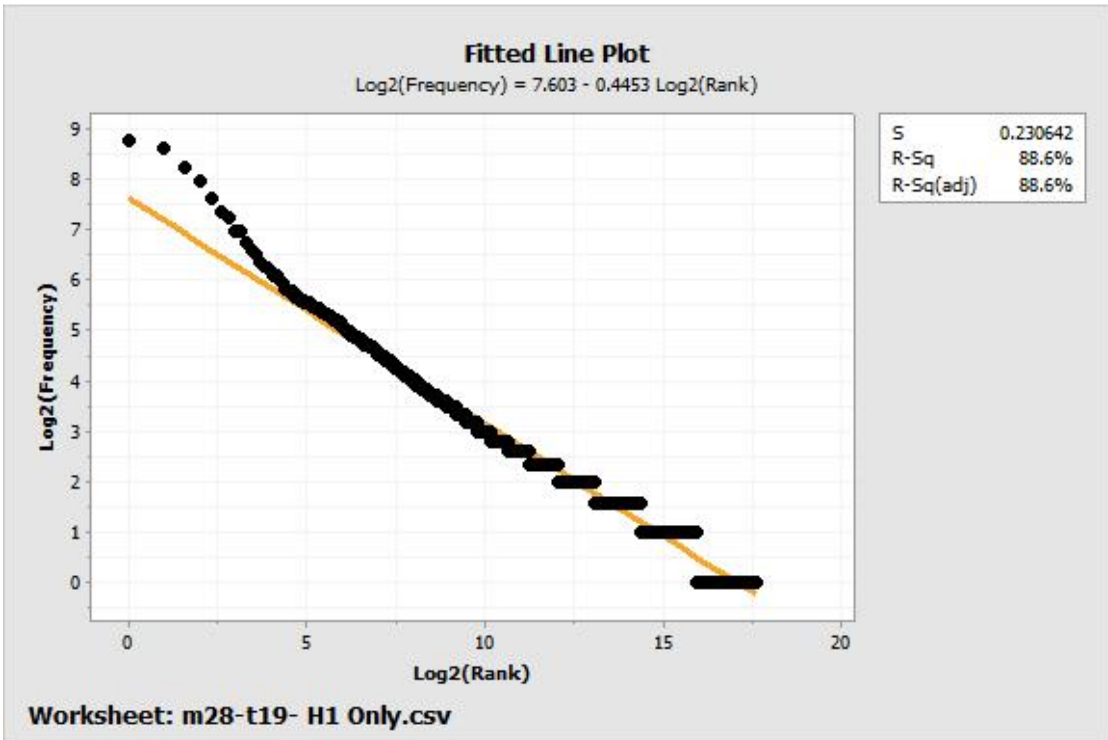


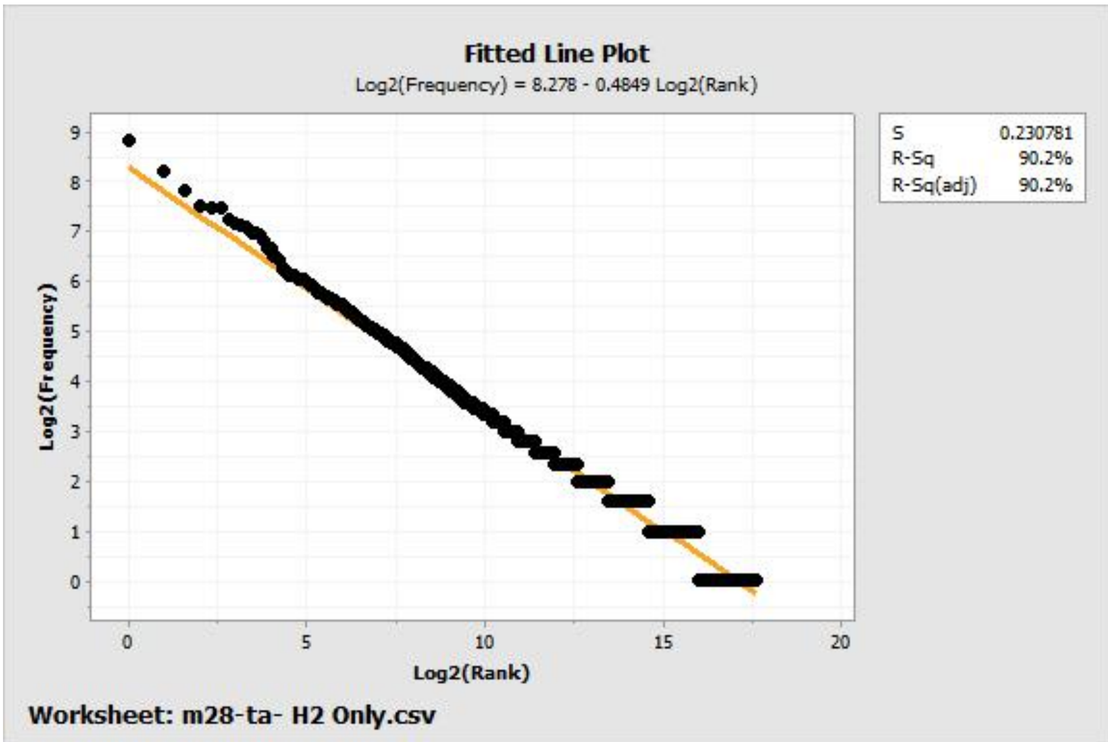
Fitted Line Plot
Log2(Frequency) = 8.031 - 0.4711 Log2(Rank)
S 0.230777
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 10.67 - 0.5978 Log2(Rank)
S 0.235321
R-Sq 93.1%
R-Sq(adj) 93.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta- H1 + H2.csv

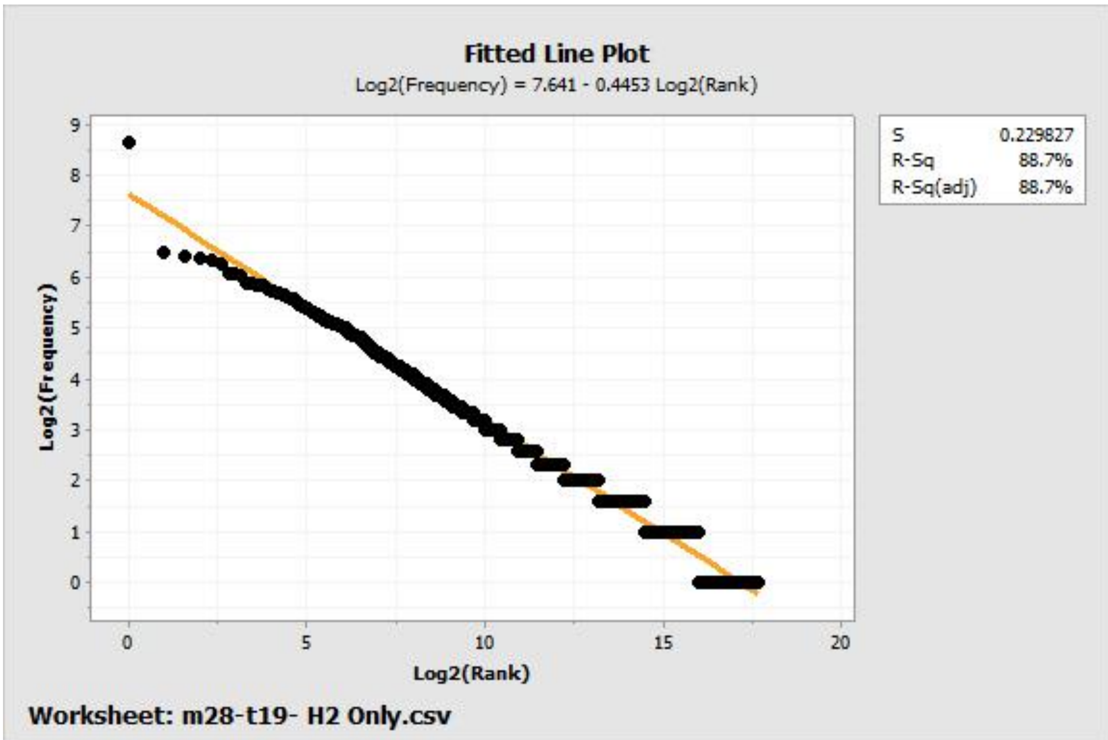

Fitted Line Plot
Log2(Frequency) = 10.27 - 0.5715 Log2(Rank)
S 0.243182
R-Sq 92.0%
R-Sq(adj) 92.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 7.853 - 0.4607 Log2(Rank)
S 0.229881
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-ta- H1 Only.csv

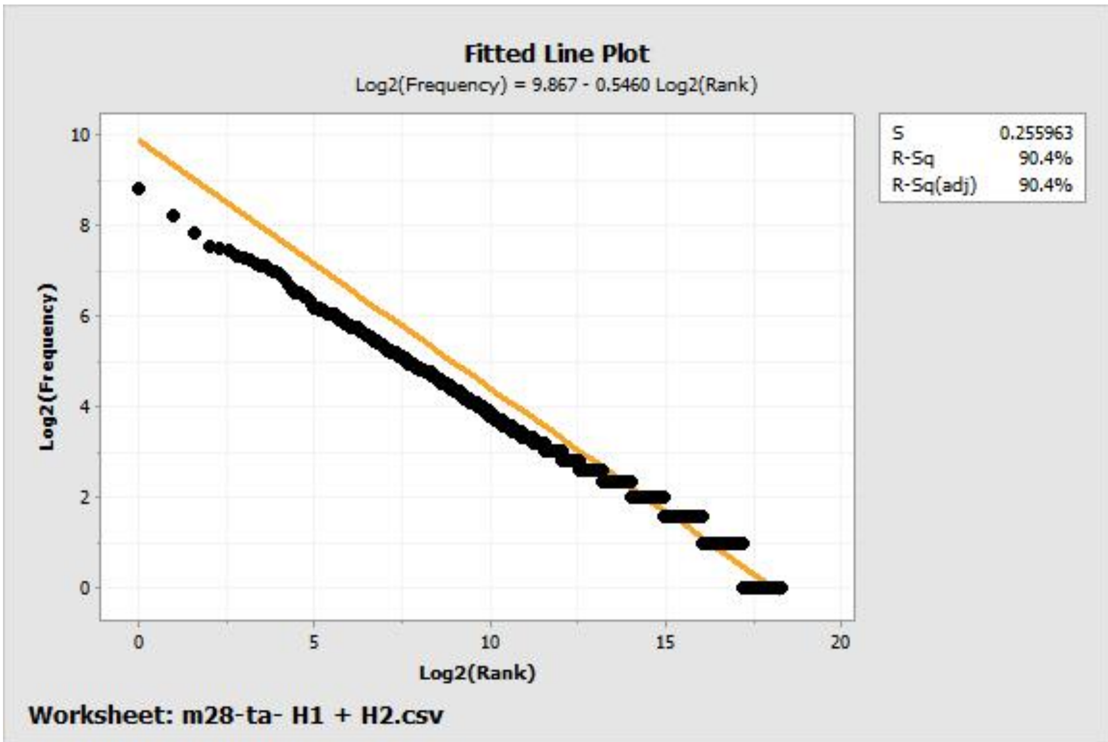

Fitted Line Plot
Log2(Frequency) = 7.603 - 0.4453 Log2(Rank)
S 0.230642
R-Sq 88.6%
R-Sq(adj) 88.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-t19- H1 Only.csv

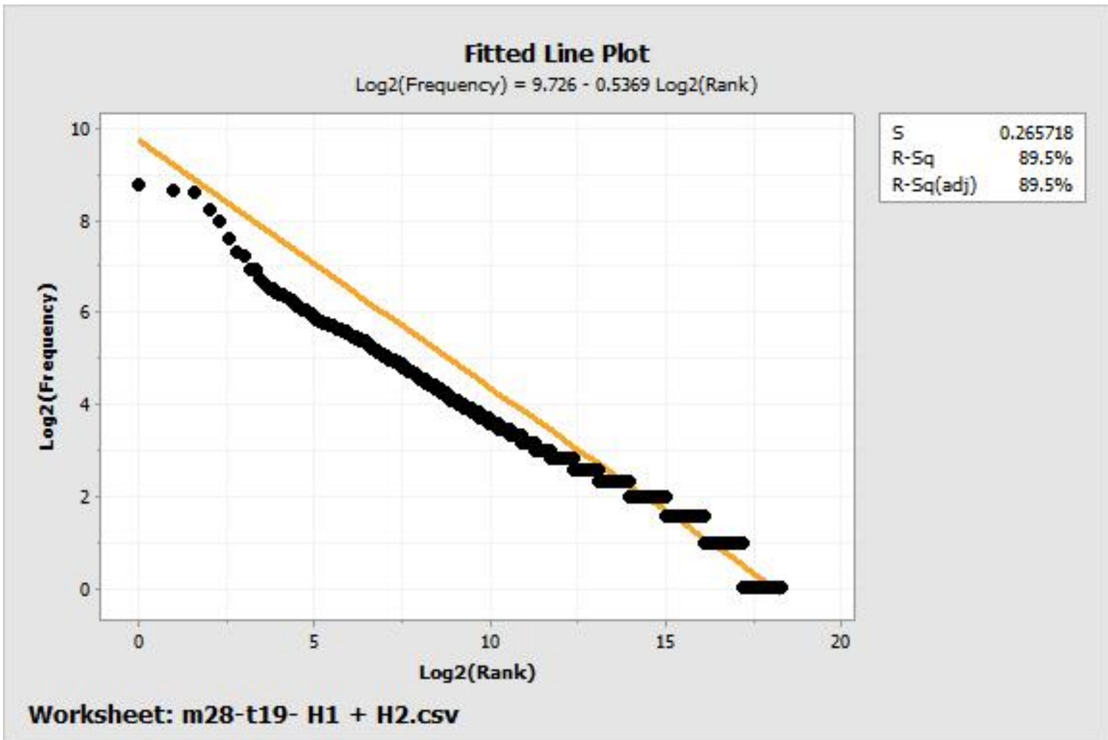


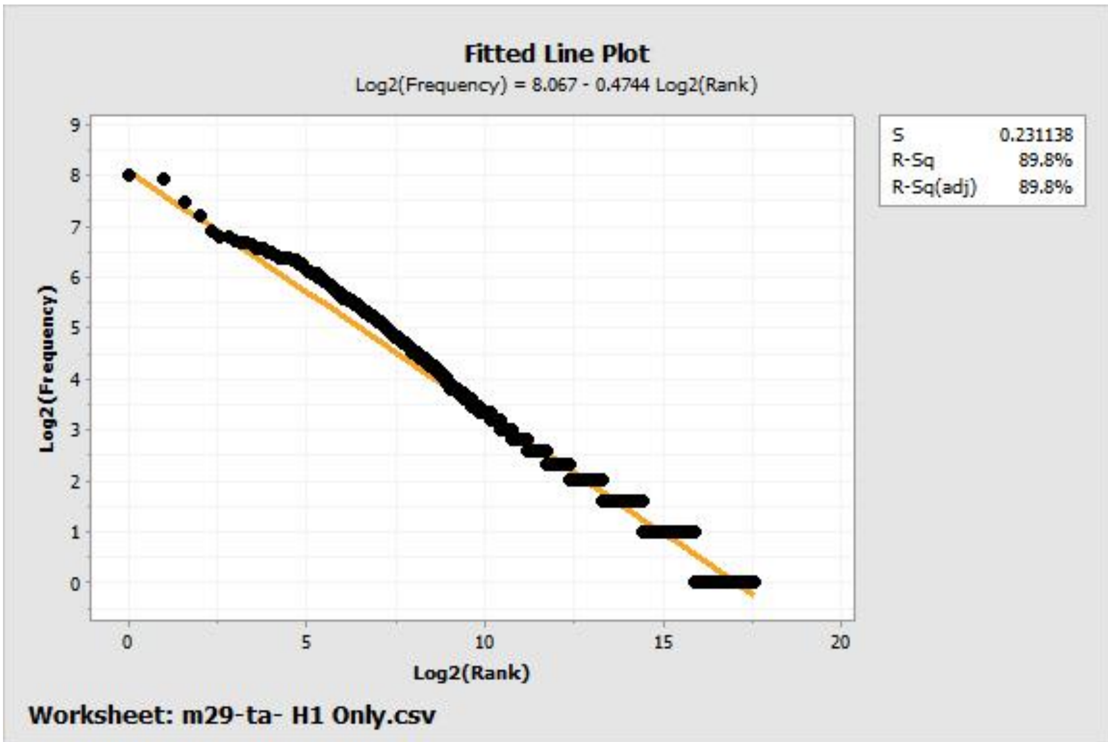
Fitted Line Plot
Log2(Frequency) = 8.278 - 0.4849 Log2(Rank)
S 0.230781
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-ta- H2 Only.csv

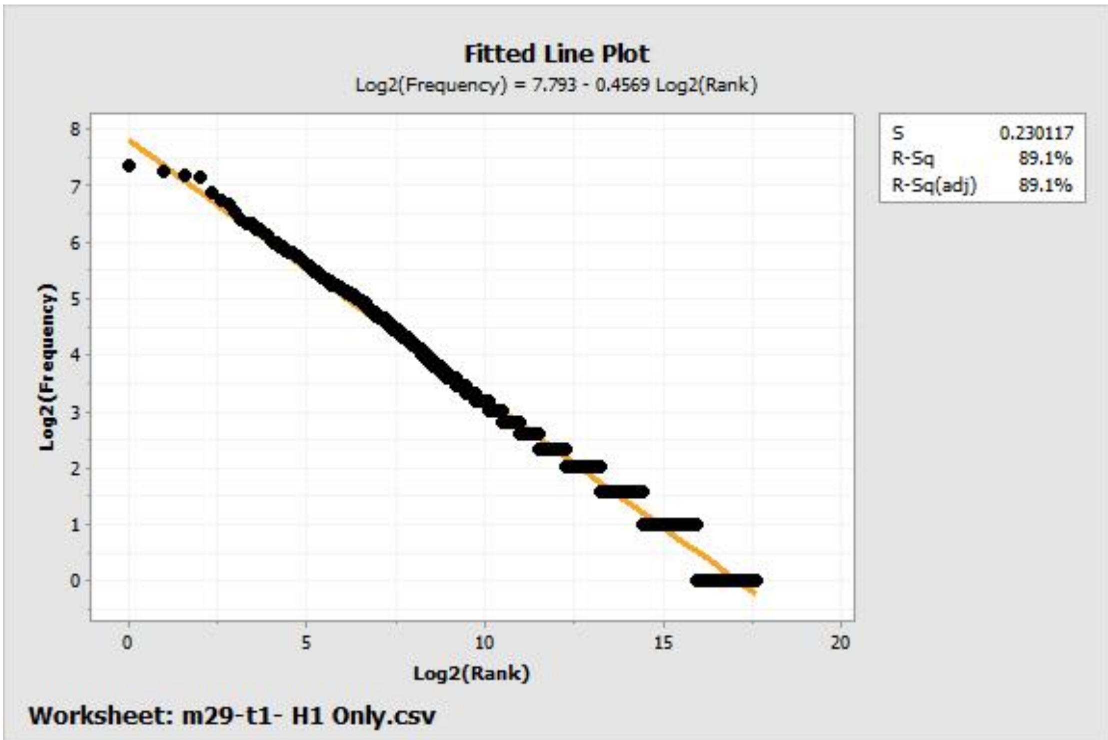


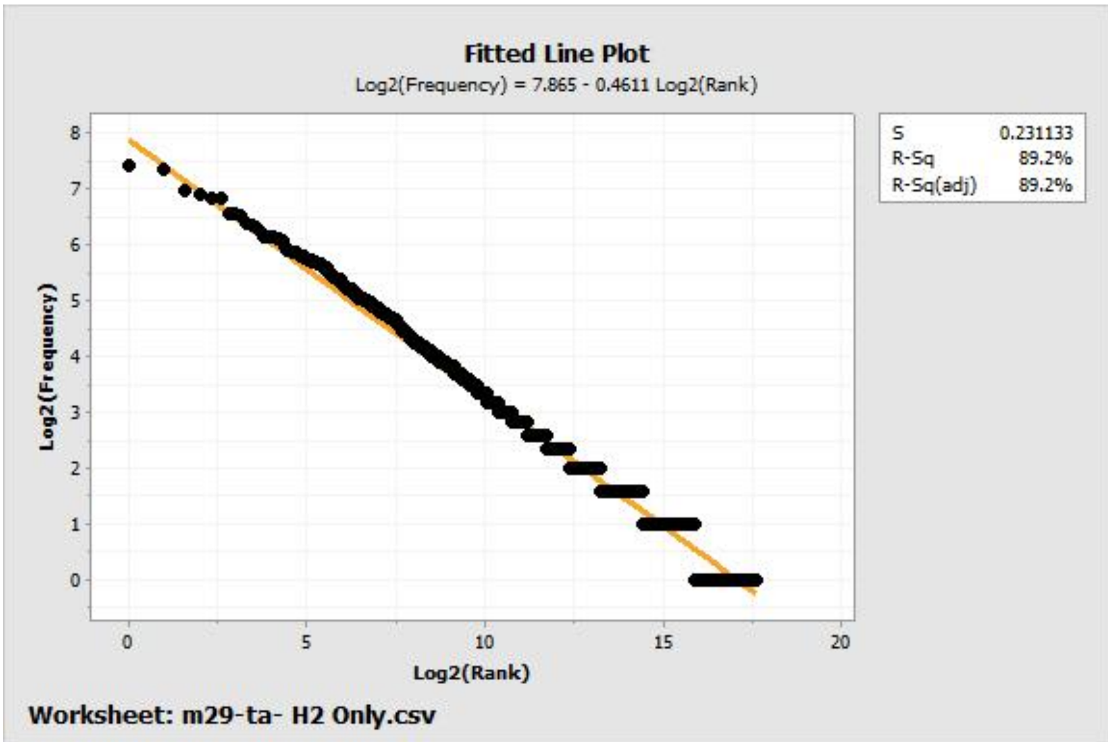
Fitted Line Plot
Log2(Frequency) = 7.641 - 0.4453 Log2(Rank)
S 0.229827
R-Sq 88.7%
R-Sq(adj) 88.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-t19- H2 Only.csv

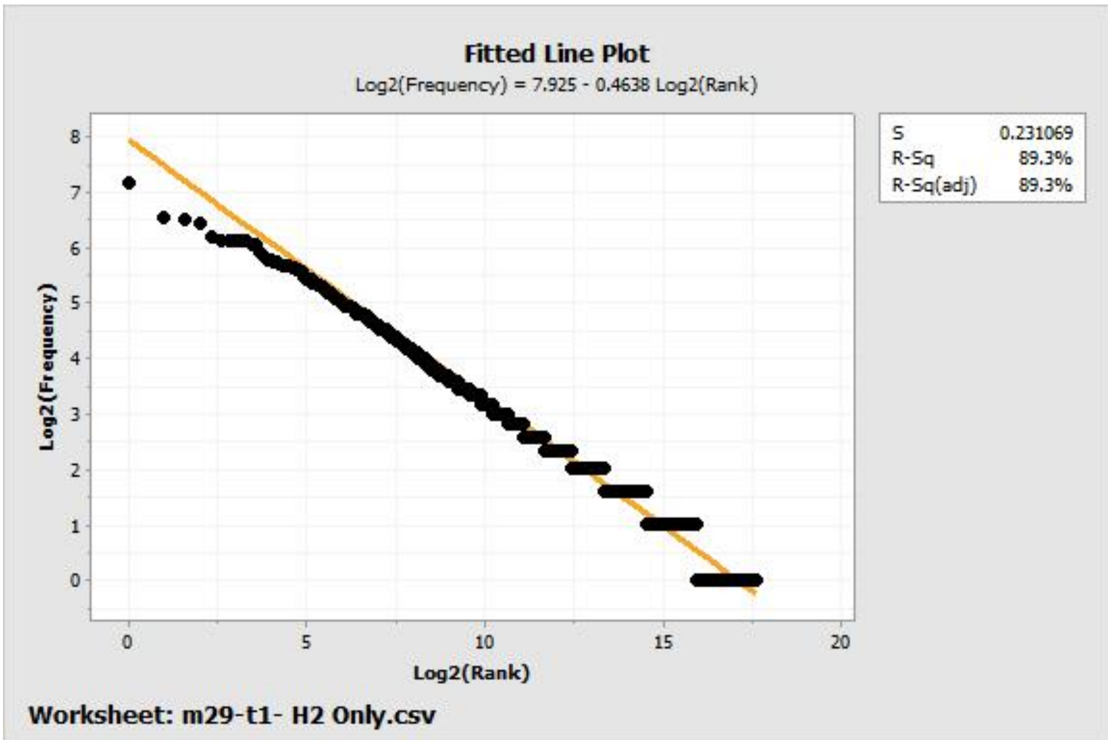

Fitted Line Plot
Log2(Frequency) = 9.867 - 0.5460 Log2(Rank)
S 0.255963
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
5
15
20
Worksheet: m28-ta- H1 + H2.csv

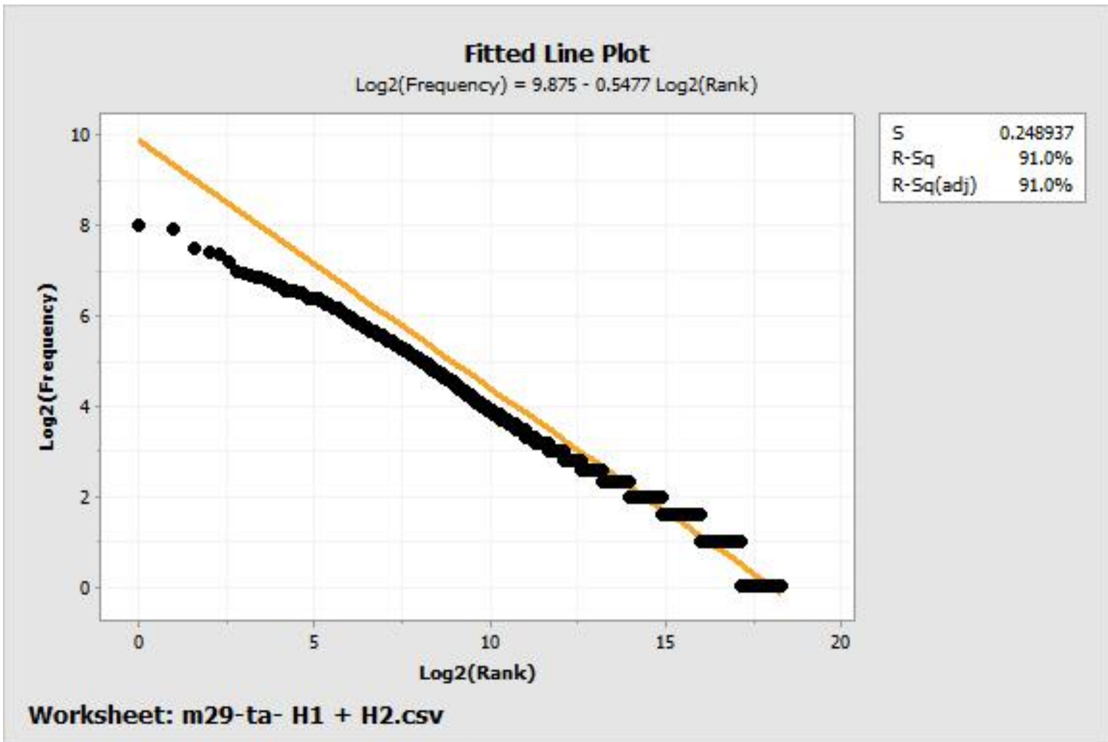

Fitted Line Plot
Log2(Frequency) = 9.726 - 0.5369 Log2(Rank)
S 0.265718
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
5
15
20
Worksheet: m28-t19- H1 + H2.csv

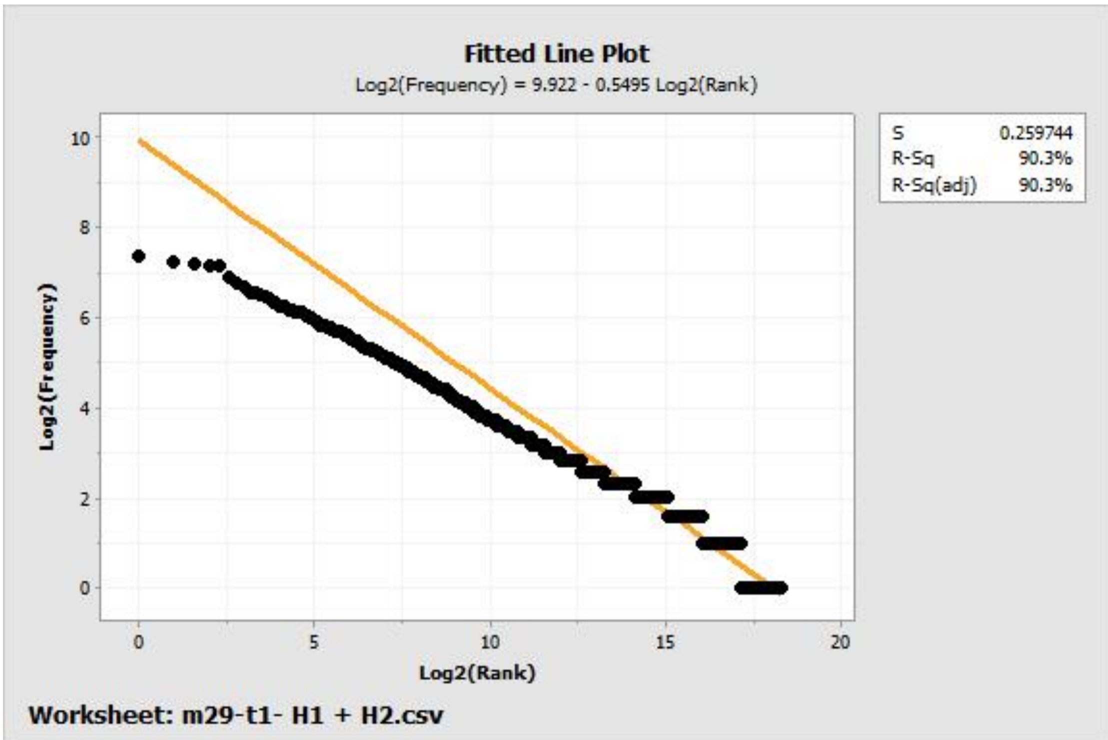

Fitted Line Plot
Log2(Frequency) = 8.067 - 0.4744 Log2(Rank)
S 0.231138
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta- H1 Only.csv

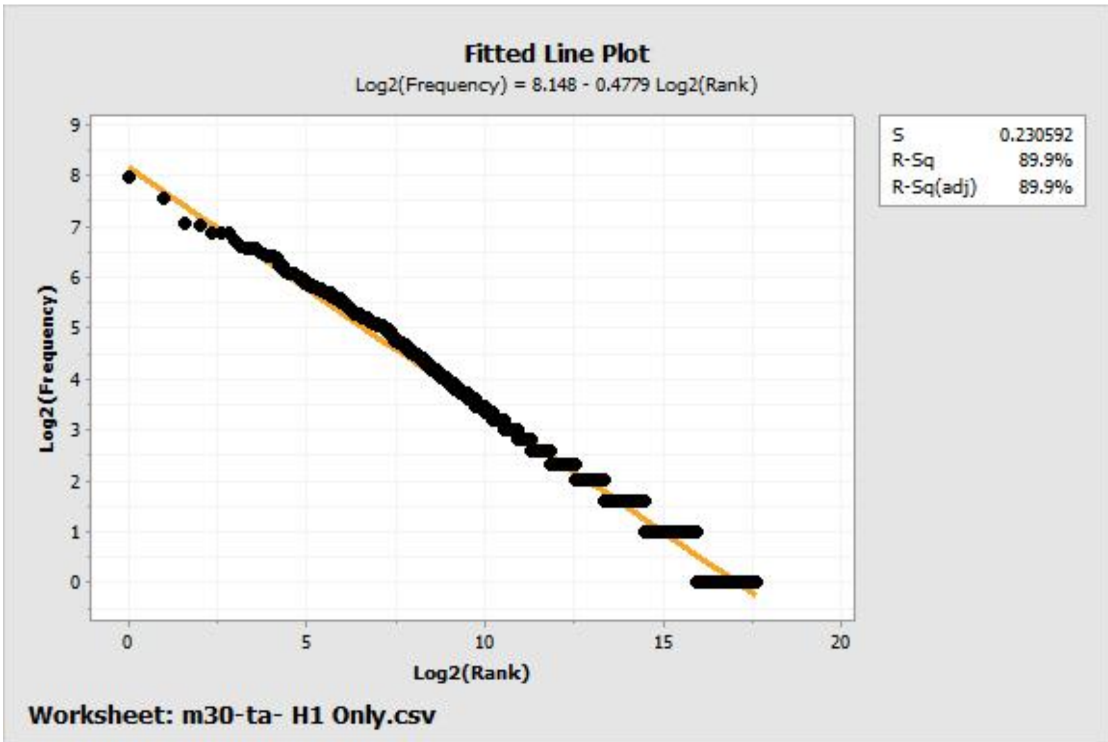

Fitted Line Plot
Log2(Frequency) = 7.793 - 0.4569 Log2(Rank)
S 0.230117
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1- H1 Only.csv

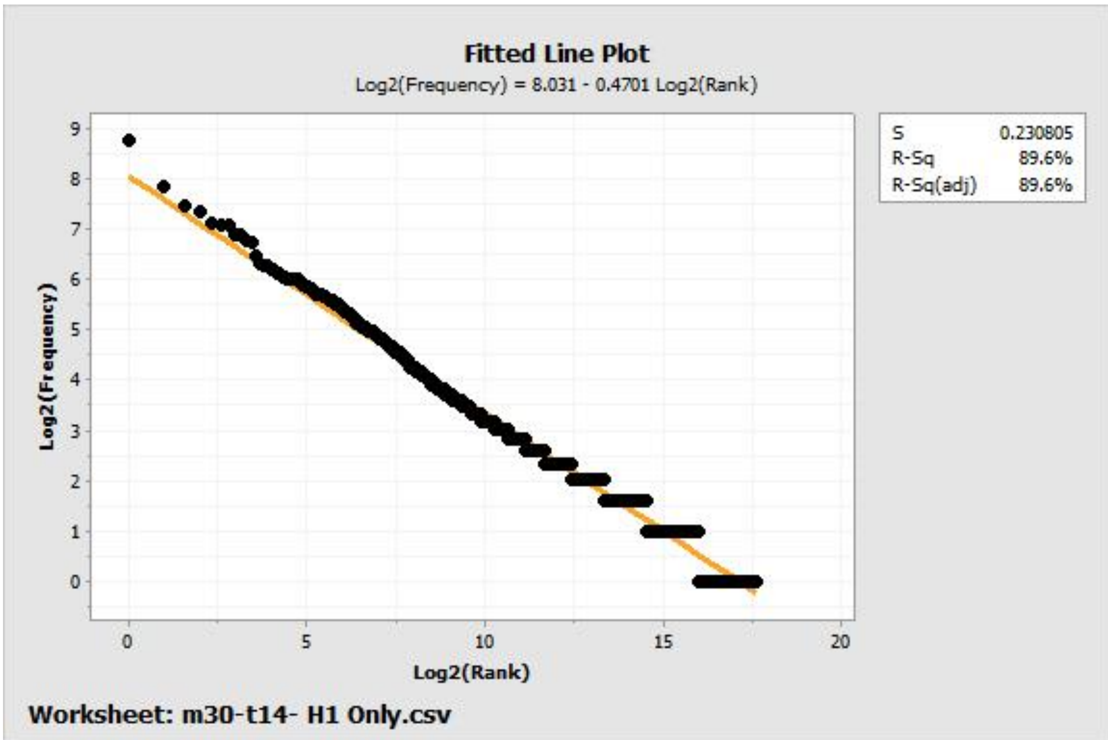

Fitted Line Plot
Log2(Frequency) = 7.865 - 0.4611 Log2(Rank)
S 0.231133
R-Sq 89.2%
R-Sq(adj) 89.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta- H2 Only.csv

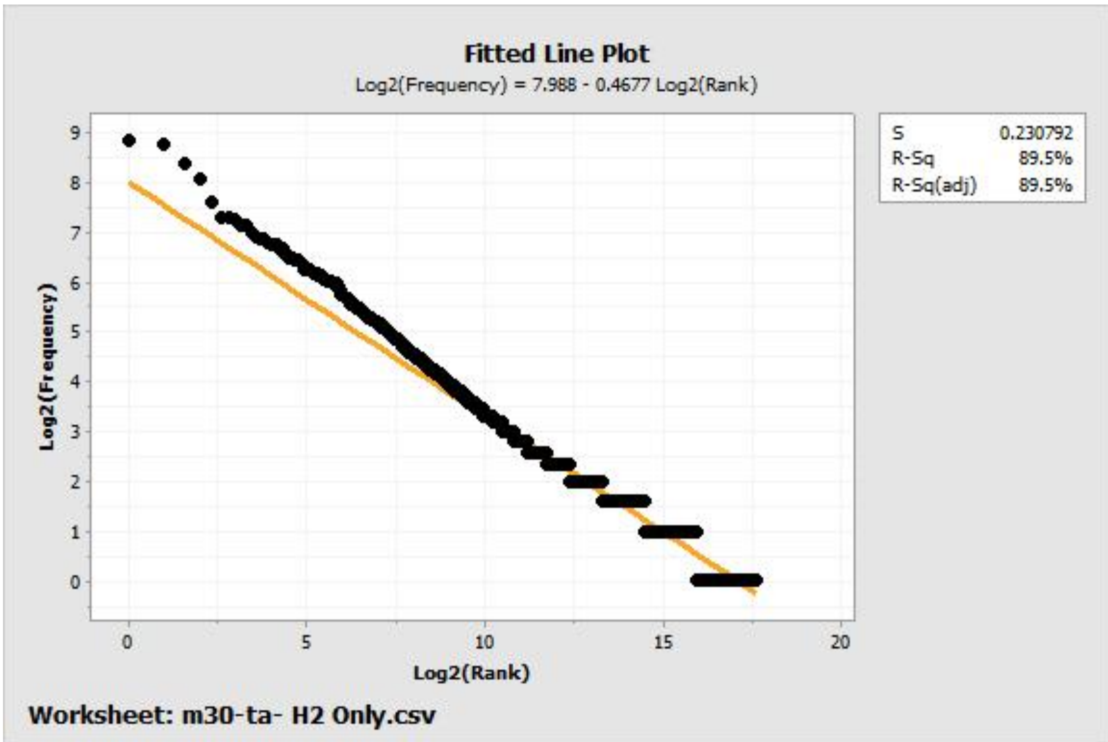

Fitted Line Plot
Log2(Frequency) = 7.925 - 0.4638 Log2(Rank)
S 0.231069
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1- H2 Only.csv

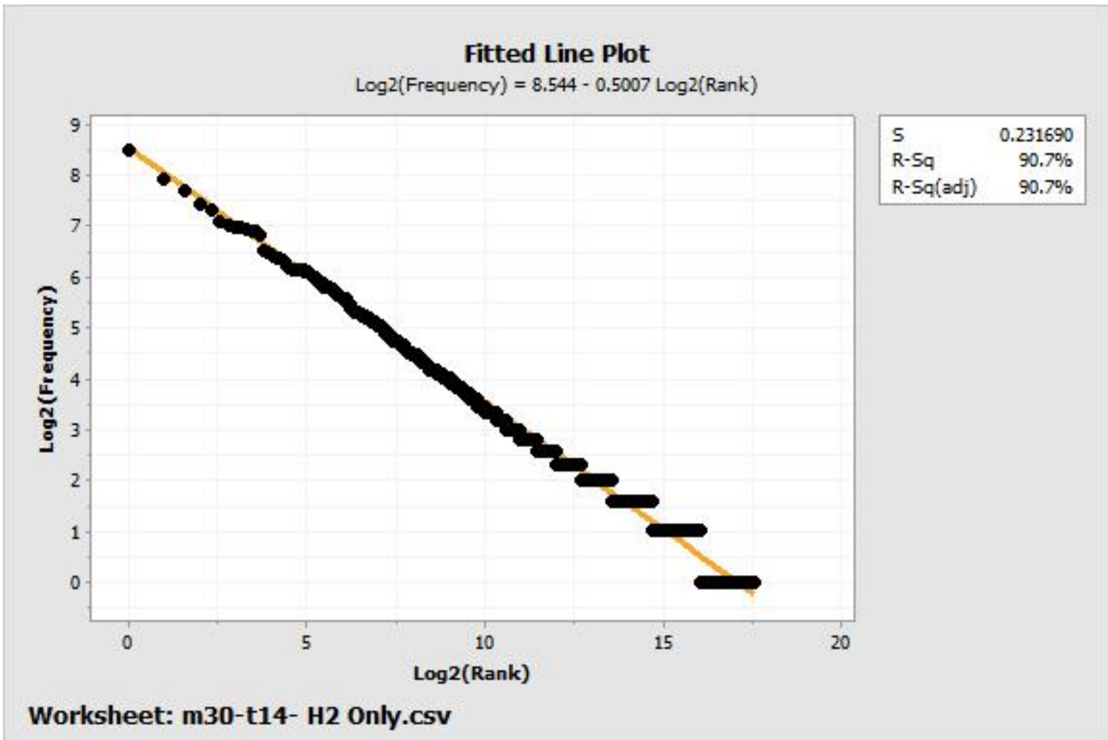

Fitted Line Plot
Log2(Frequency) = 9.875 - 0.5477 Log2(Rank)
S 0.248937
R-Sq 91.0%
R-Sq(adj) 91.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta- H1 + H2.csv

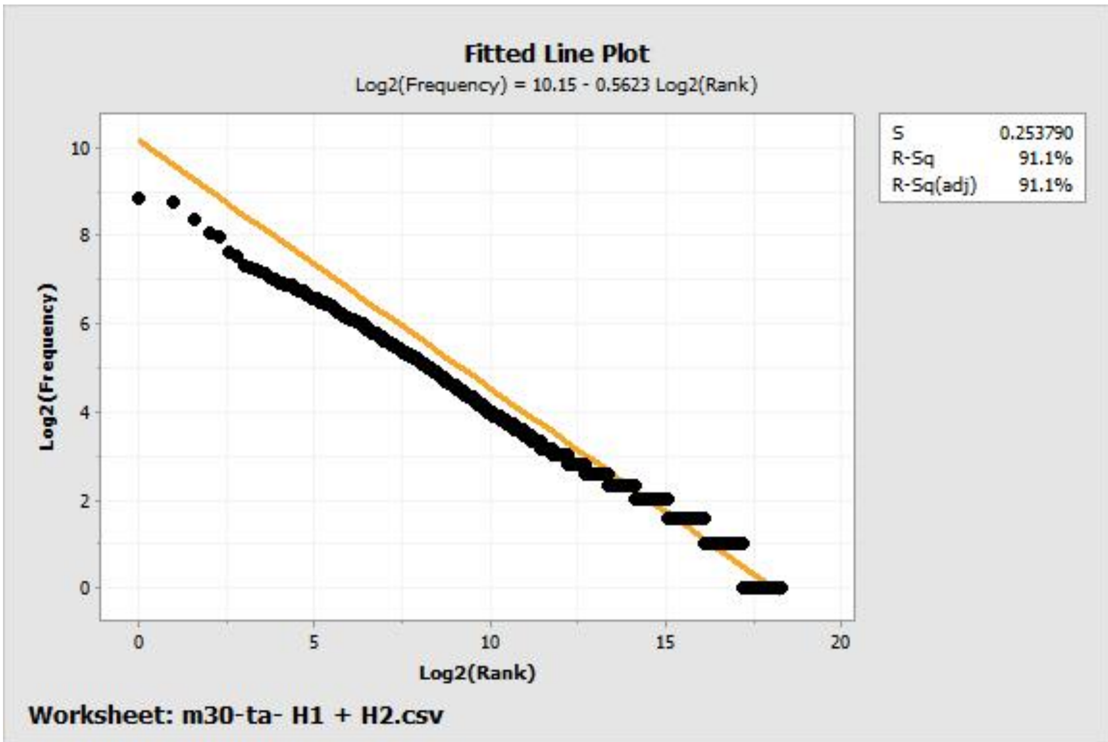

Fitted Line Plot
Log2(Frequency) = 9.922 - 0.5495 Log2(Rank)
S 0.259744
R-Sq 90.3%
R-Sq(adj) 90.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1- H1 + H2.csv

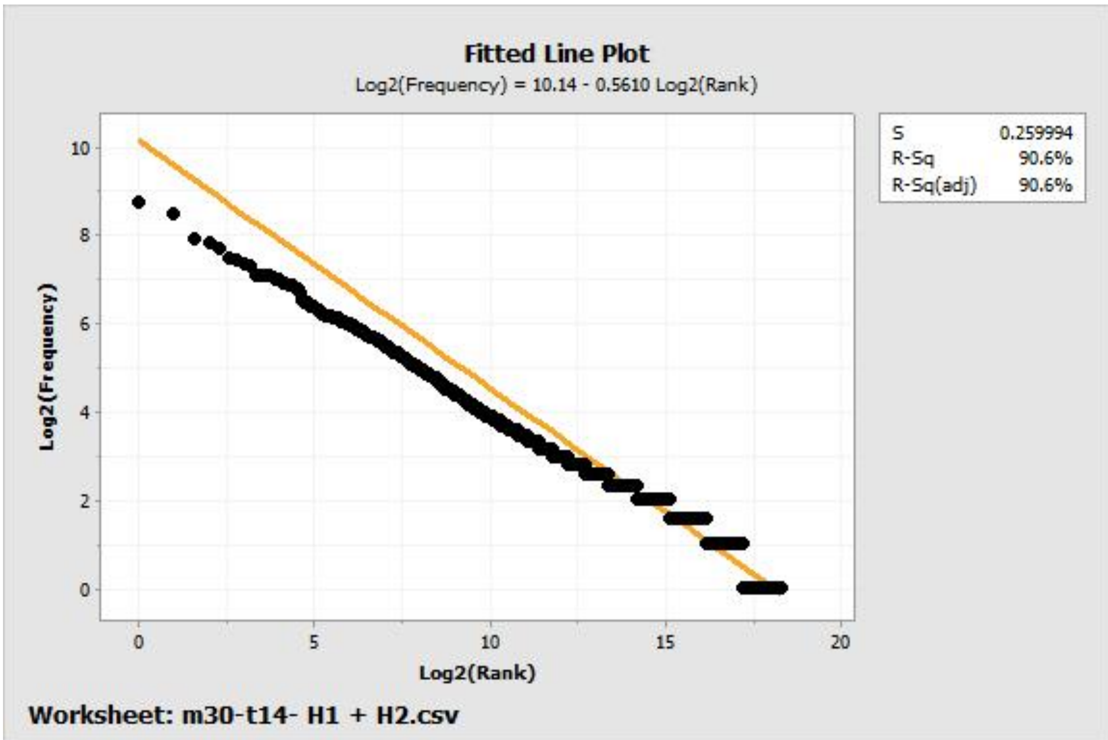

Fitted Line Plot
Log2(Frequency) = 8.148 - 0.4779 Log2(Rank)
S 0.230592
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-ta- H1 Only.csv

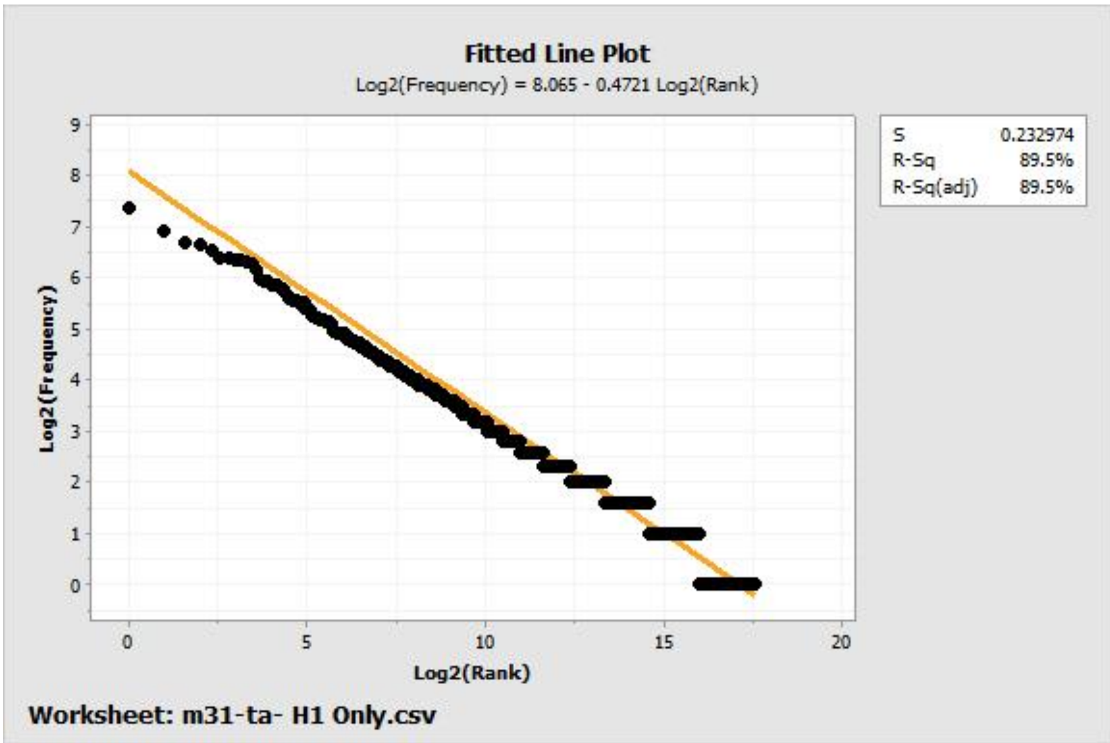

Fitted Line Plot
Log2(Frequency) = 8.031 - 0.4701 Log2(Rank)
S 0.230805
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-t14- H1 Only.csv

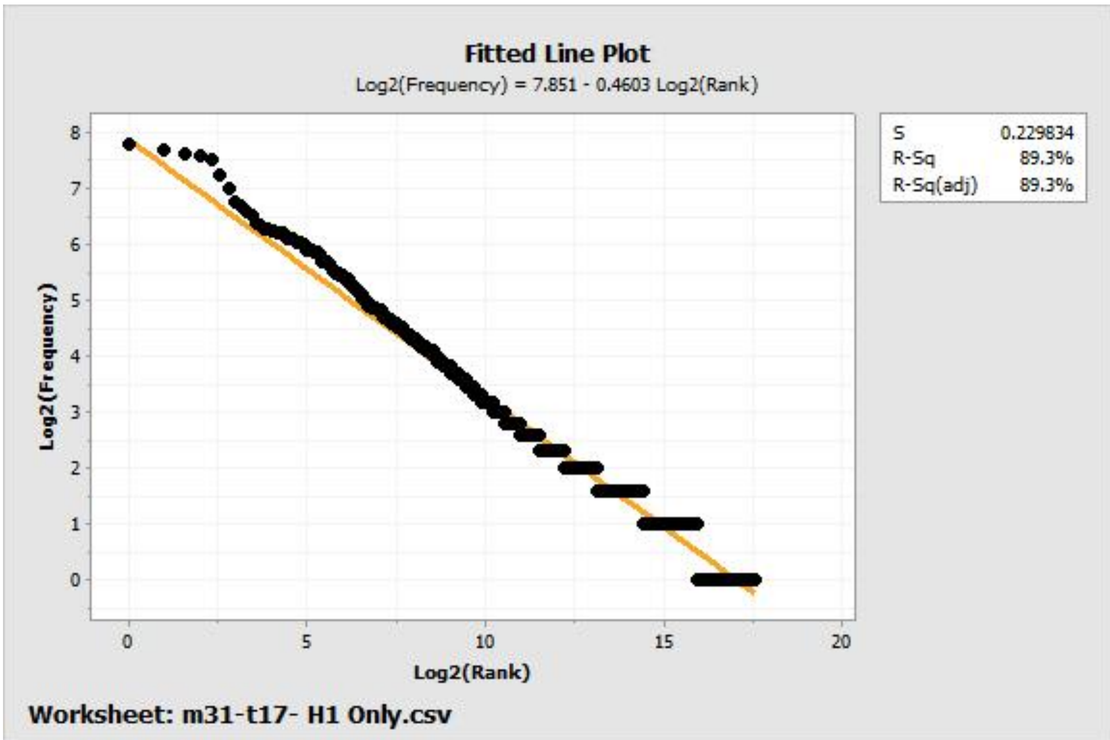

Fitted Line Plot
Log2(Frequency) = 7.988 - 0.4677 Log2(Rank)
S 0.230792
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-ta- H2 Only.csv

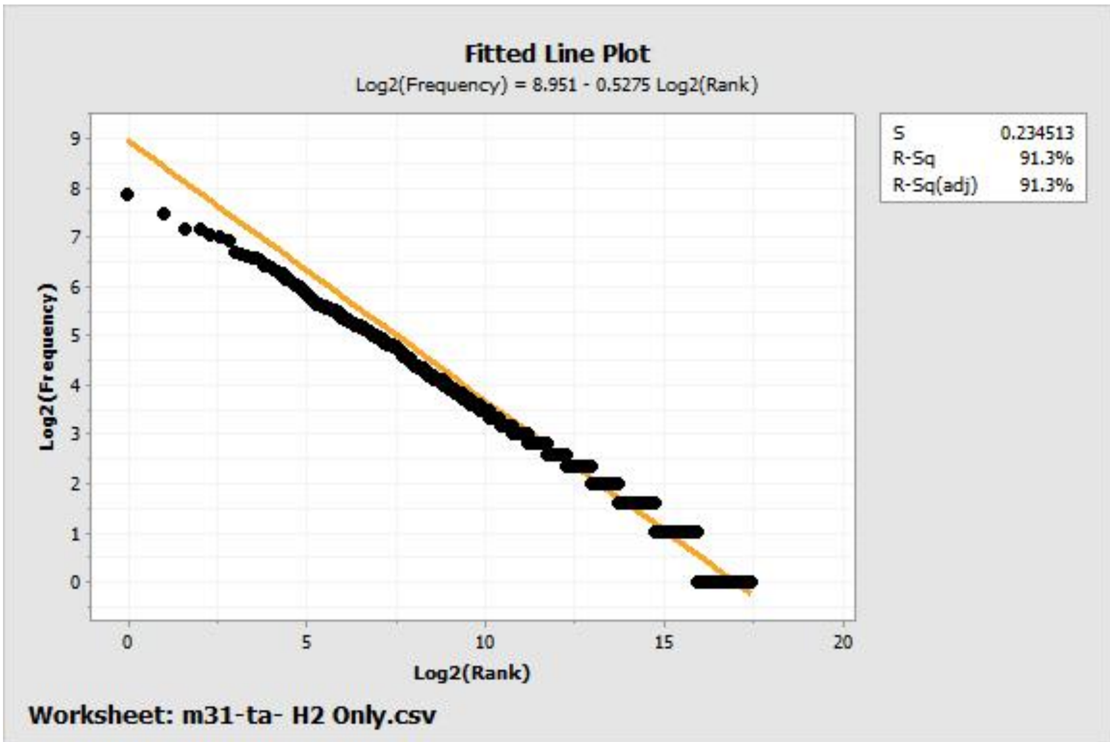

Fitted Line Plot
Log2(Frequency) = 8.544 - 0.5007 Log2(Rank)
S 0.231690
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-t14- H2 Only.csv

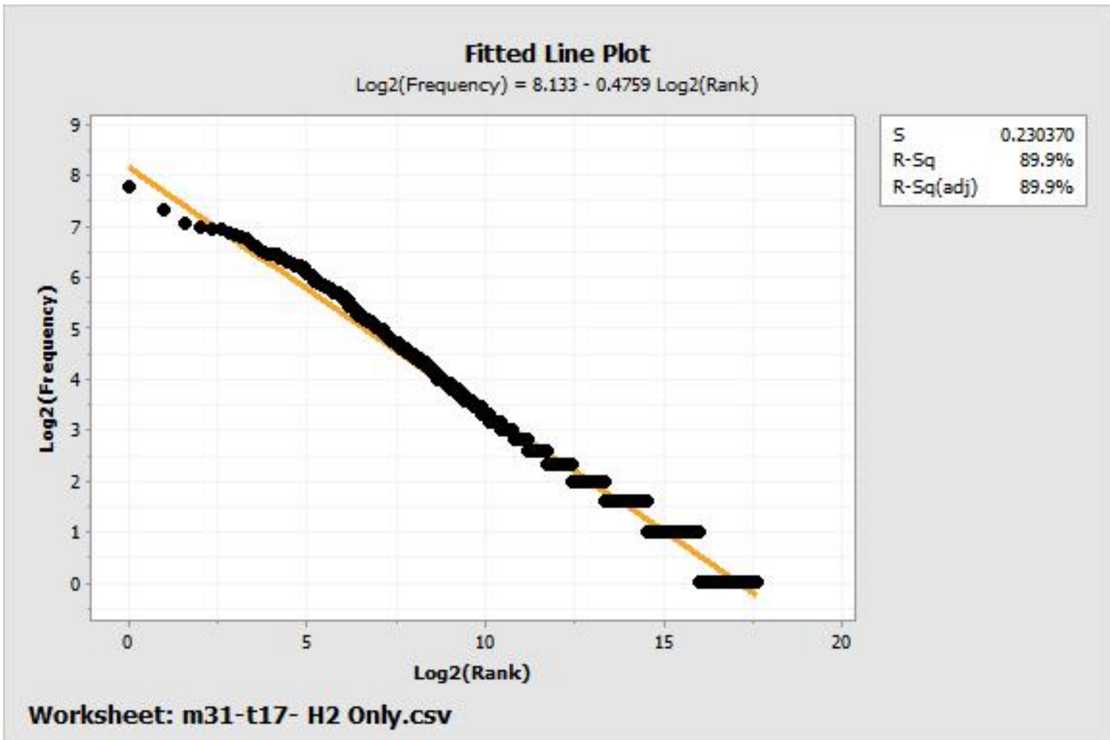

Fitted Line Plot
Log2(Frequency) = 10.15 - 0.5623 Log2(Rank)
S 0.253790
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m30-ta- H1 + H2.csv

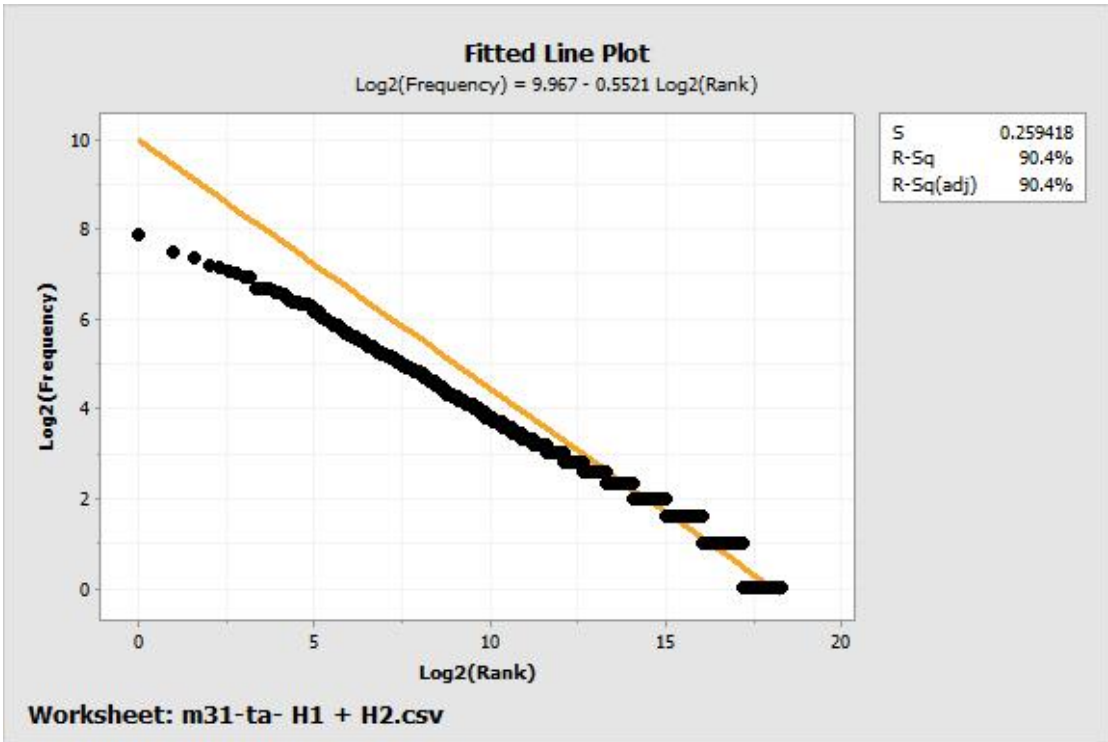

Fitted Line Plot
Log2(Frequency) = 10.14 - 0.5610 Log2(Rank)
S 0.259994
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
0
5
10
15
20
Worksheet: m30-t14- H1 + H2.csv

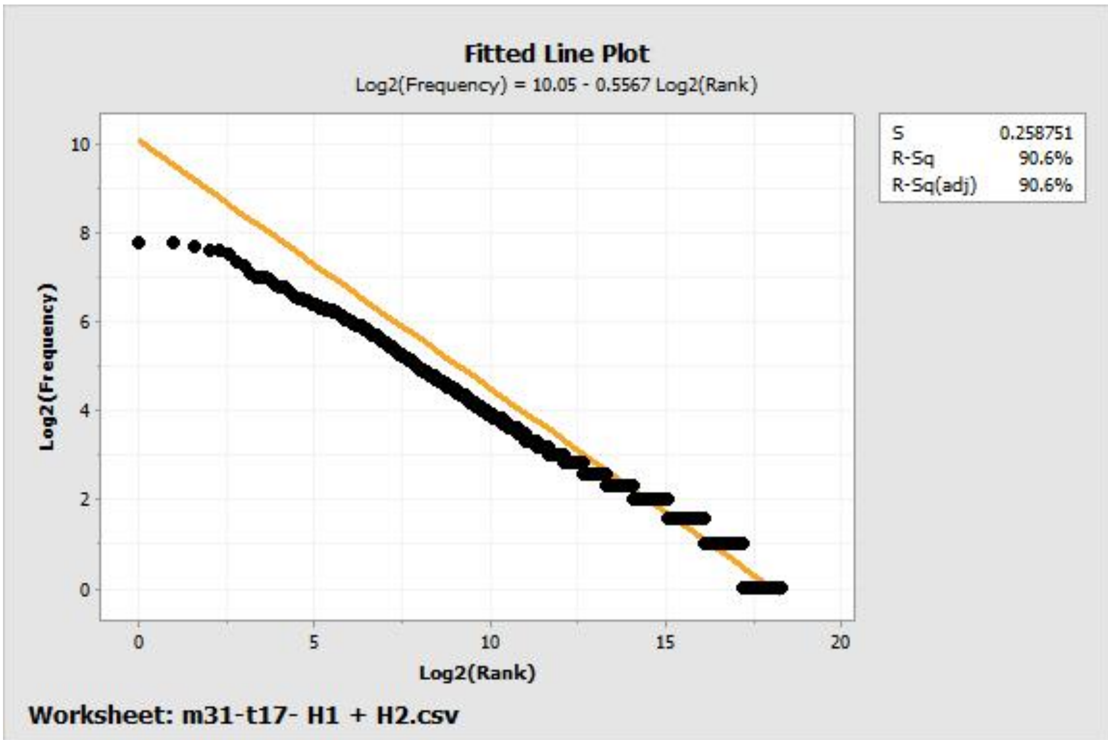

Fitted Line Plot
Log2(Frequency) = 8.065 - 0.4721 Log2(Rank)
S 0.232974
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta- H1 Only.csv

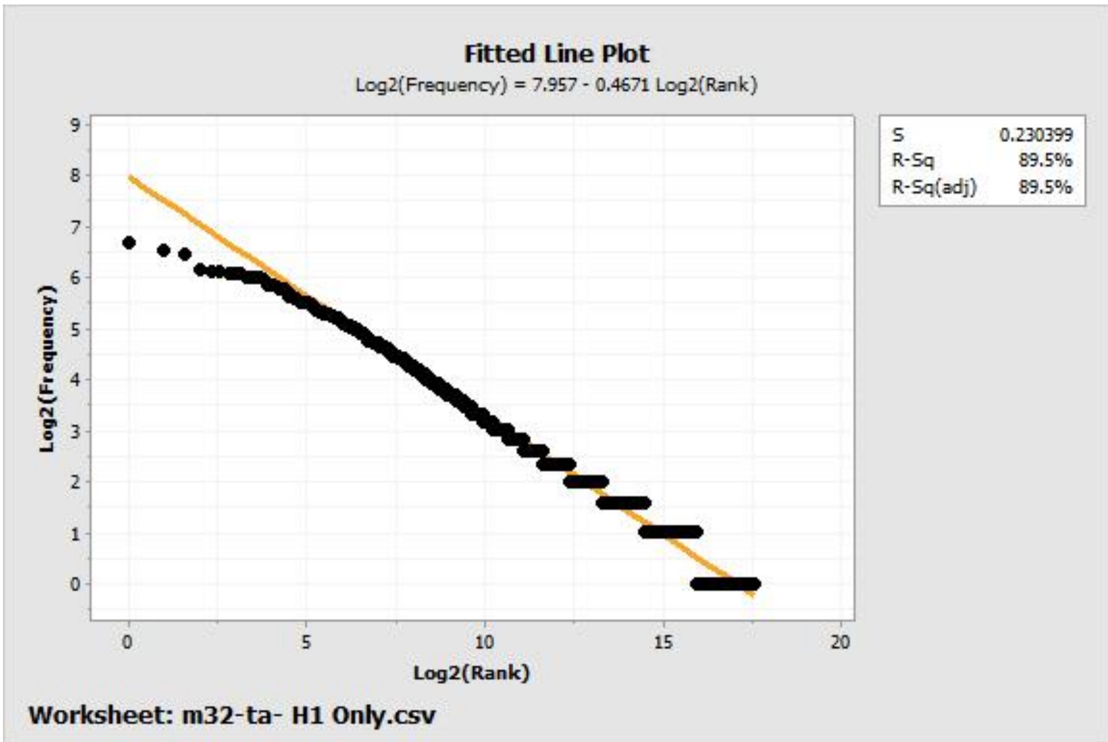

Fitted Line Plot
Log2(Frequency) = 7.851 - 0.4603 Log2(Rank)
S 0.229834
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17- H1 Only.csv

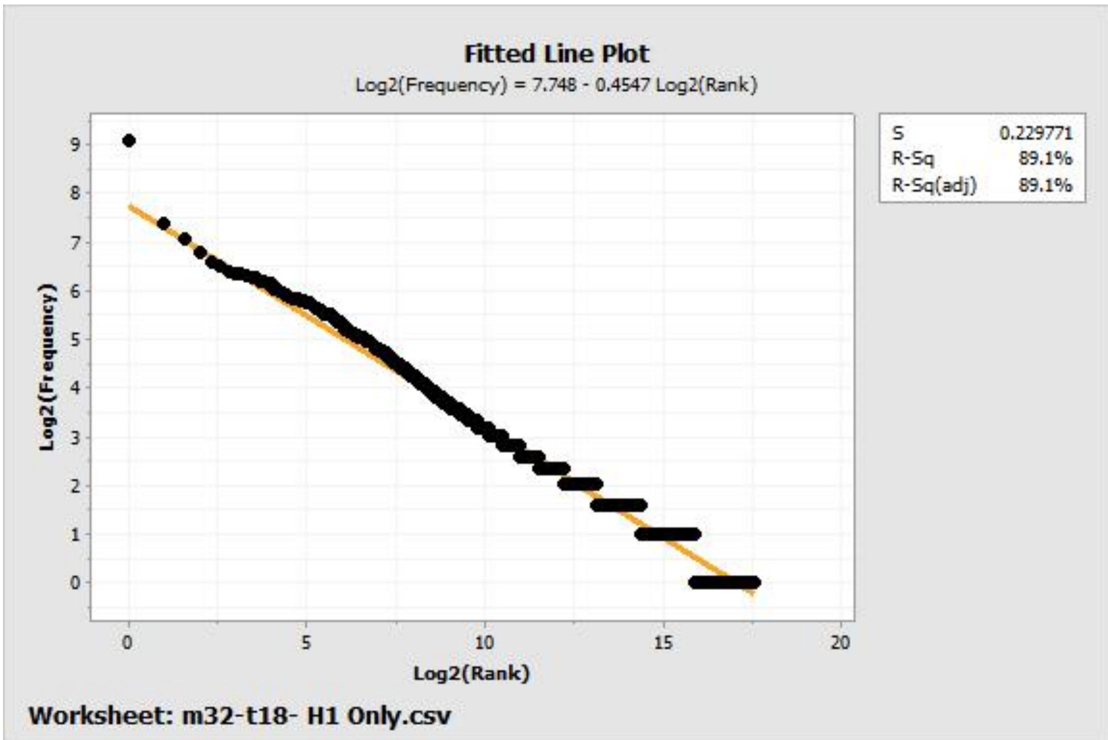

Fitted Line Plot
Log2(Frequency) = 8.951 - 0.5275 Log2(Rank)
S 0.234513
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta- H2 Only.csv

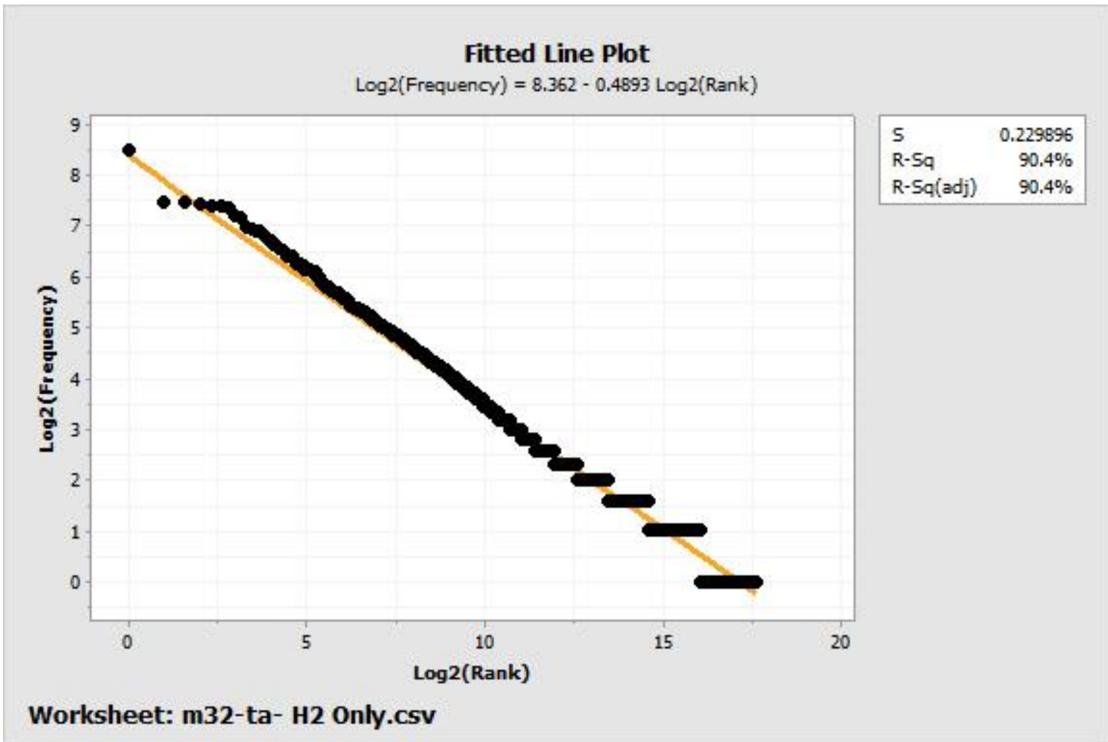

Fitted Line Plot
Log2(Frequency) = 8.133 - 0.4759 Log2(Rank)
S 0.230370
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17- H2 Only.csv

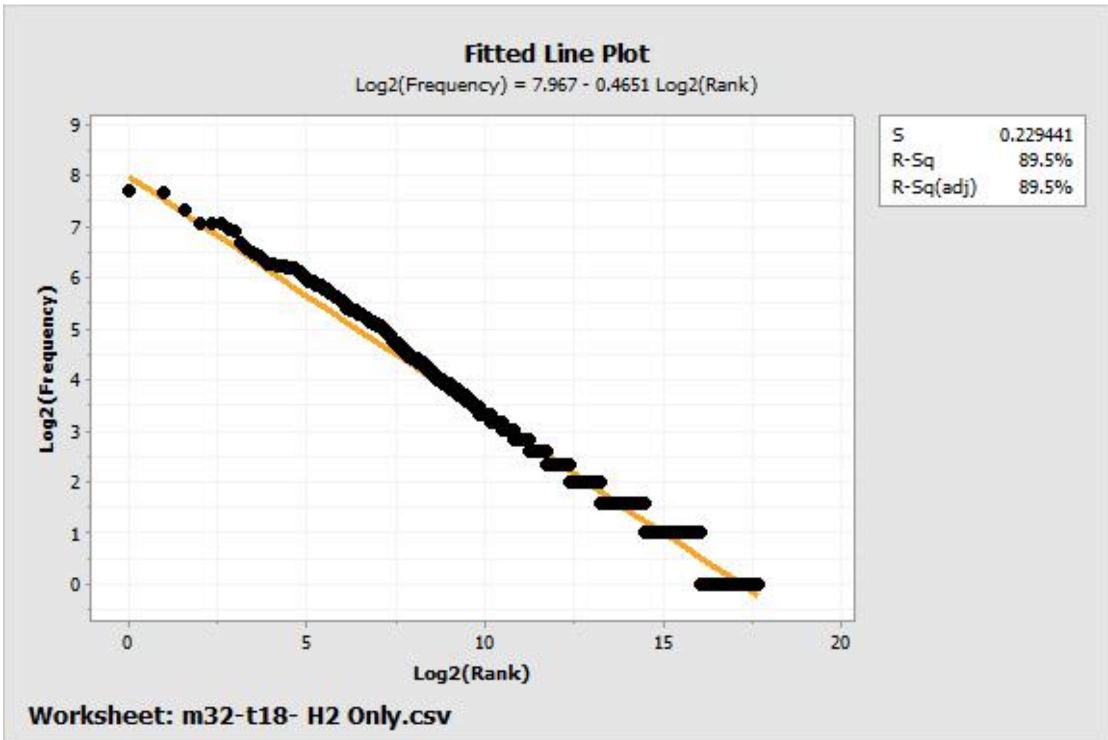

Fitted Line Plot
Log2(Frequency) = 9.967 - 0.5521 Log2(Rank)
S 0.259418
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta- H1 + H2.csv

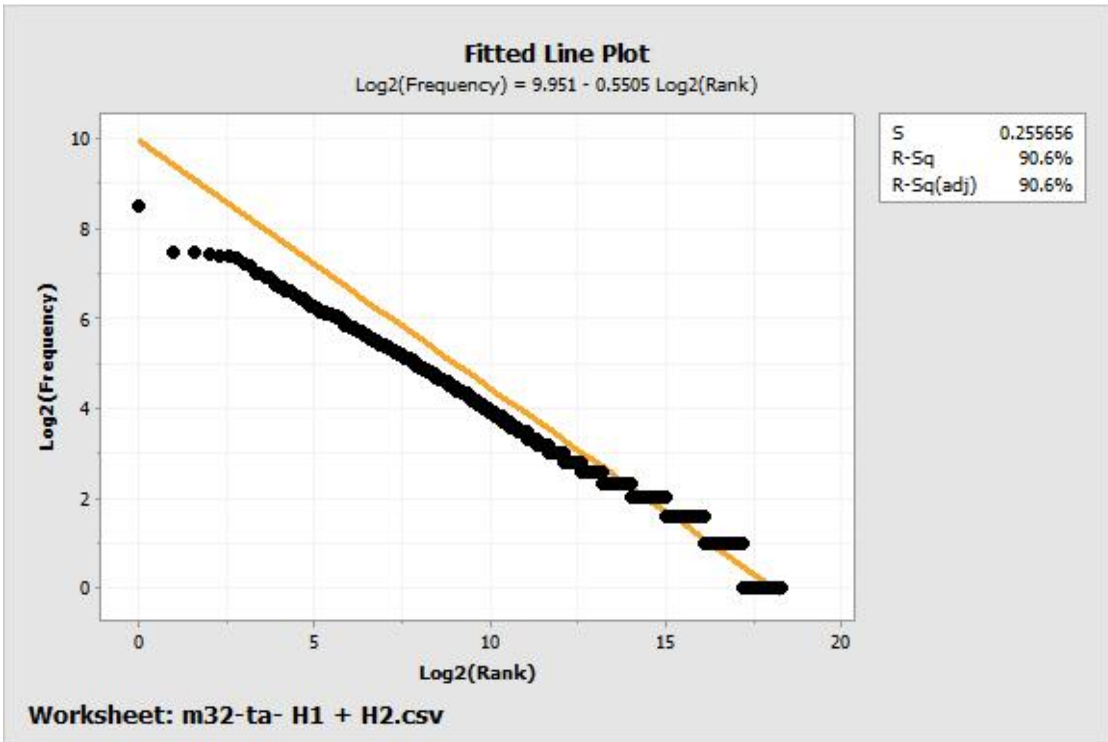

Fitted Line Plot
Log2(Frequency) = 10.05 - 0.5567 Log2(Rank)
S 0.258751
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17- H1 + H2.csv

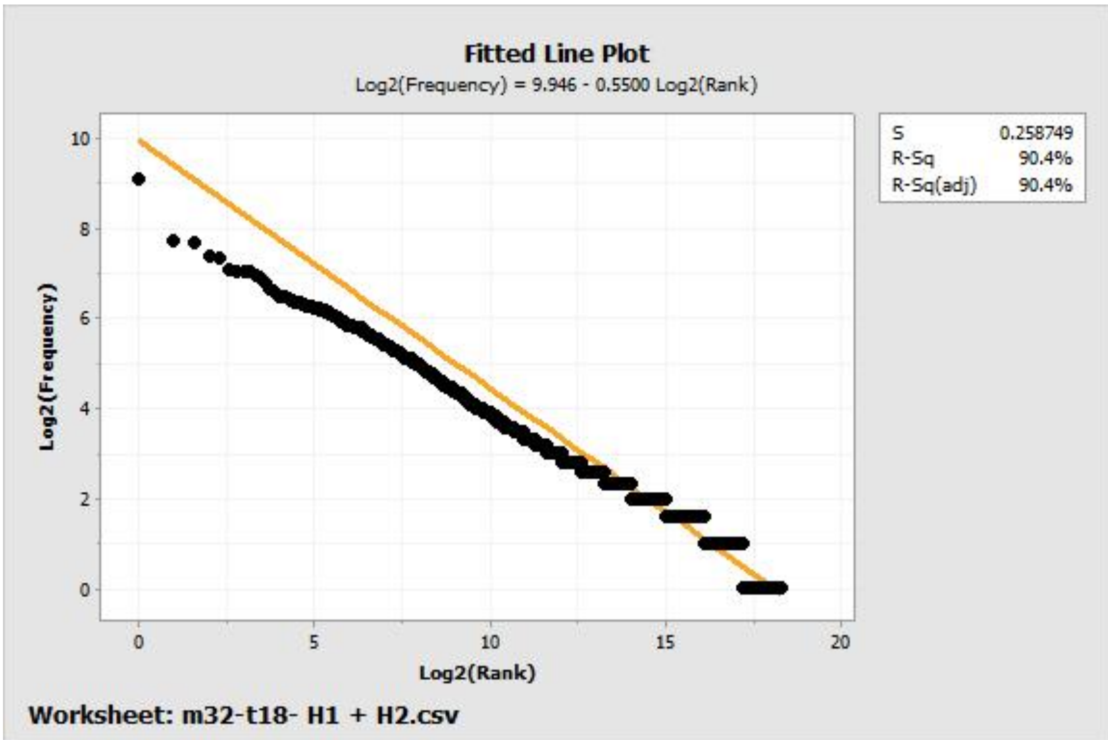

Fitted Line Plot
Log2(Frequency) = 7.957 - 0.4671 Log2(Rank)
S 0.230399
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta- H1 Only.csv

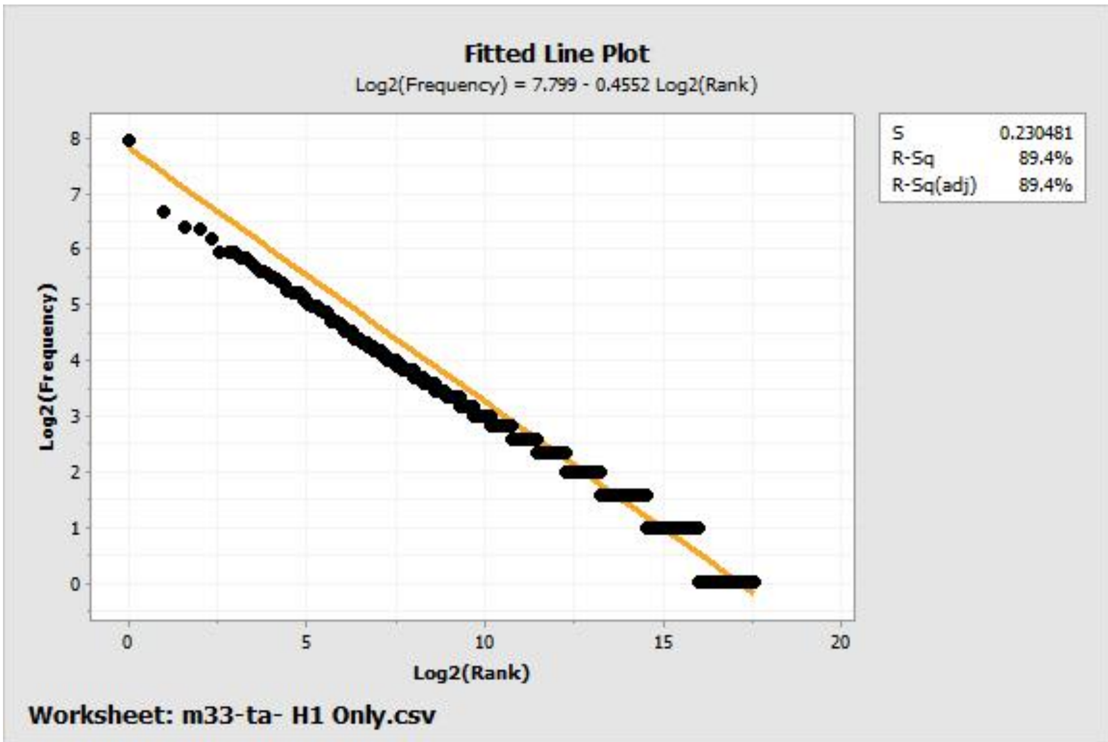

Fitted Line Plot
Log2(Frequency) = 7.748 - 0.4547 Log2(Rank)
S 0.229771
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-t18- H1 Only.csv

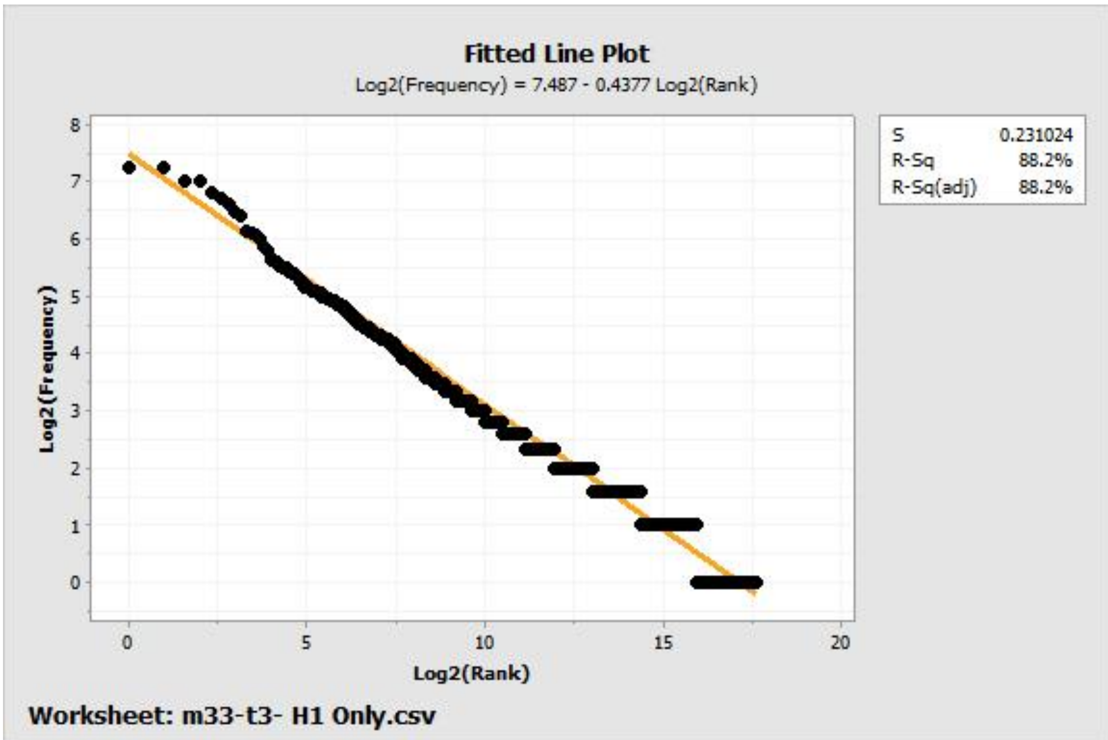

Fitted Line Plot
Log2(Frequency) = 8.362 - 0.4893 Log2(Rank)
S 0.229896
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta- H2 Only.csv

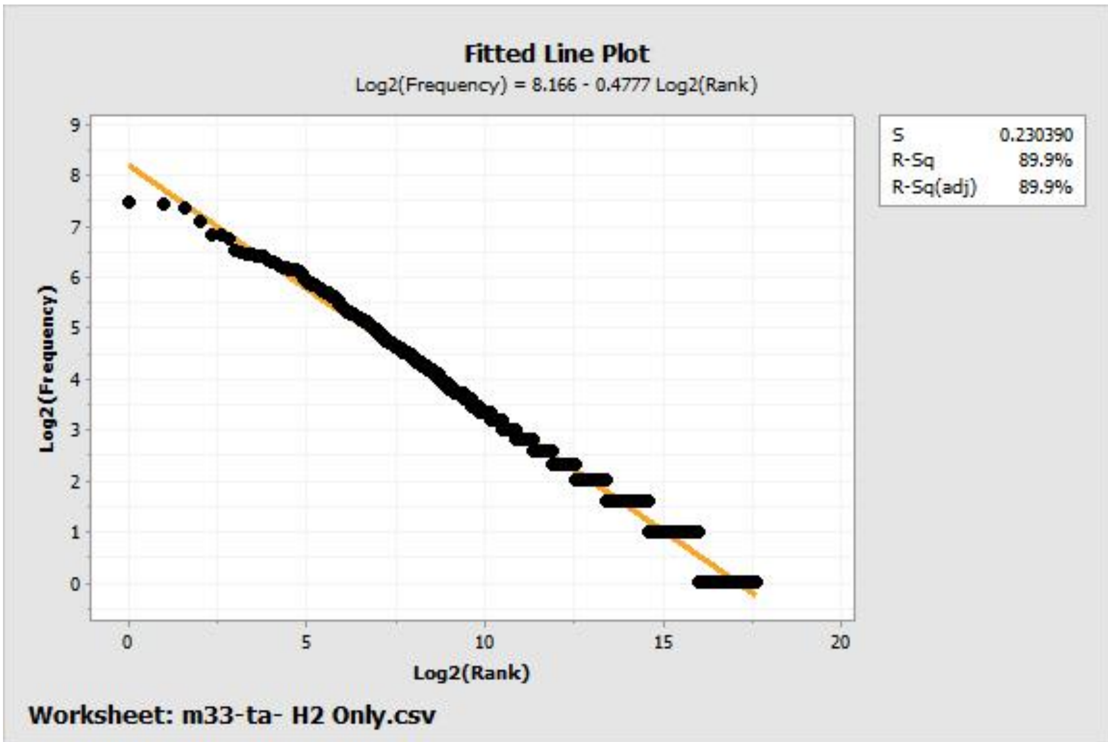

Fitted Line Plot
Log2(Frequency) = 7.967 - 0.4651 Log2(Rank)
S 0.229441
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-t18- H2 Only.csv

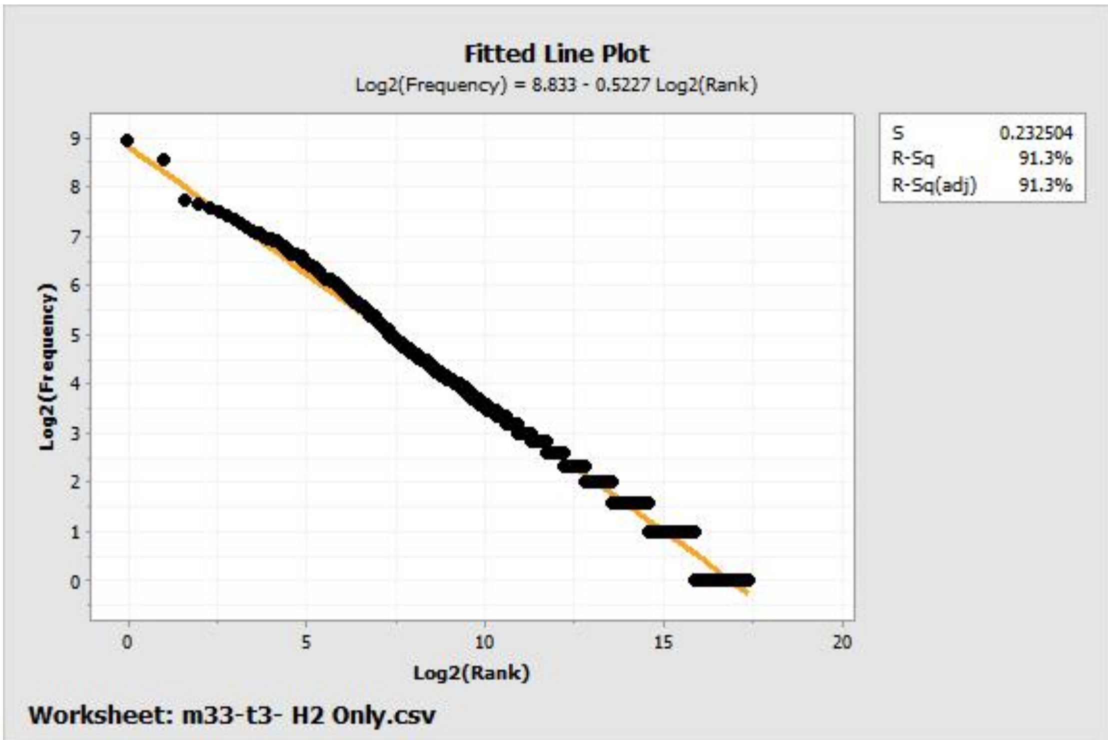

Fitted Line Plot
Log2(Frequency) = 9.951 - 0.5505 Log2(Rank)
S 0.255656
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta- H1 + H2.csv

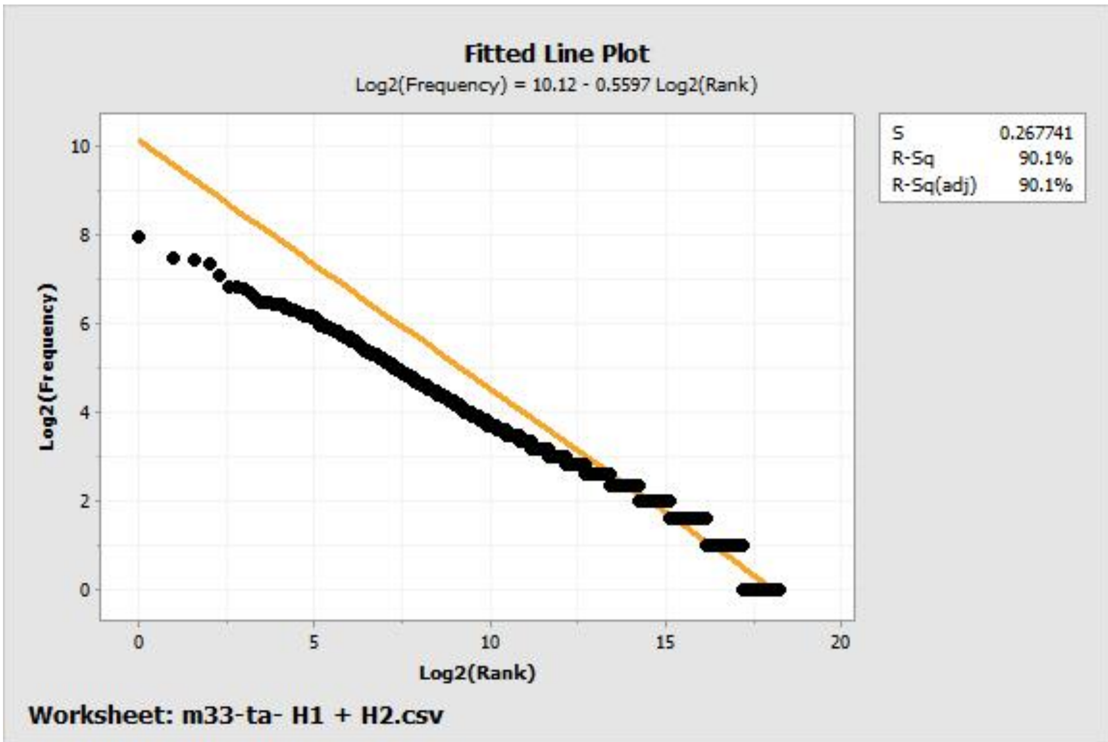

Fitted Line Plot
Log2(Frequency) = 9.946 - 0.5500 Log2(Rank)
S 0.258749
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-t18- H1 + H2.csv

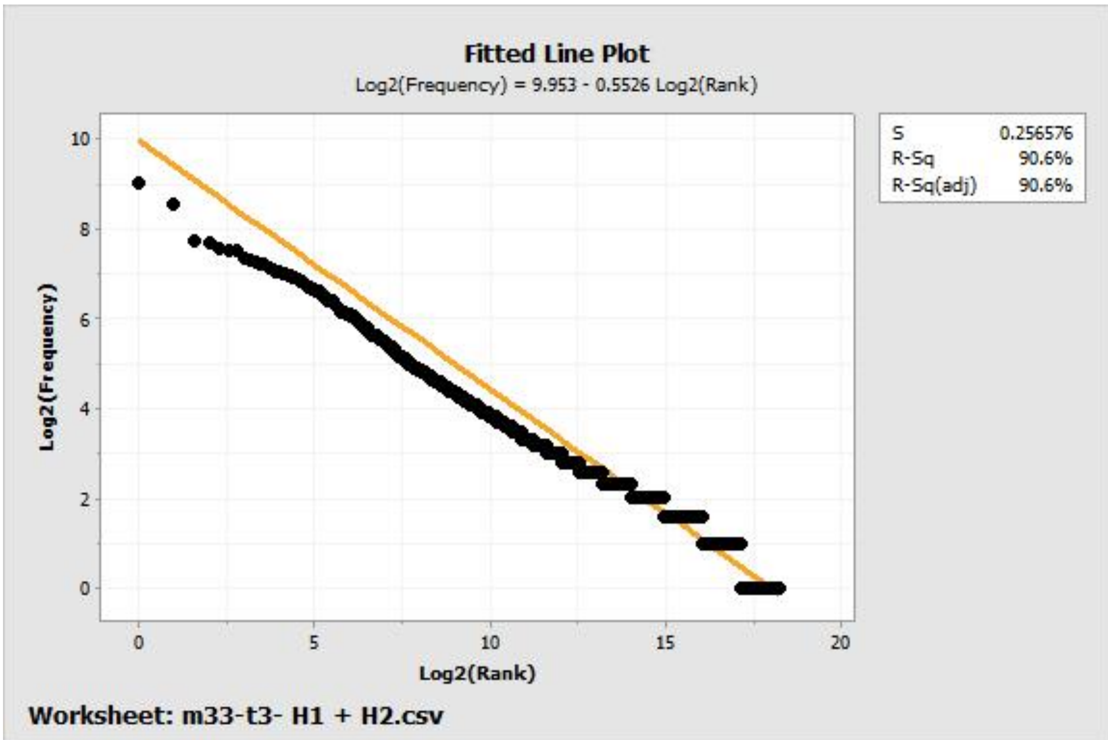

Fitted Line Plot
Log2(Frequency) = 7.799 - 0.4552 Log2(Rank)
S 0.230481
R-Sq 89.4%
R-Sq(adj) 89.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta- H1 Only.csv

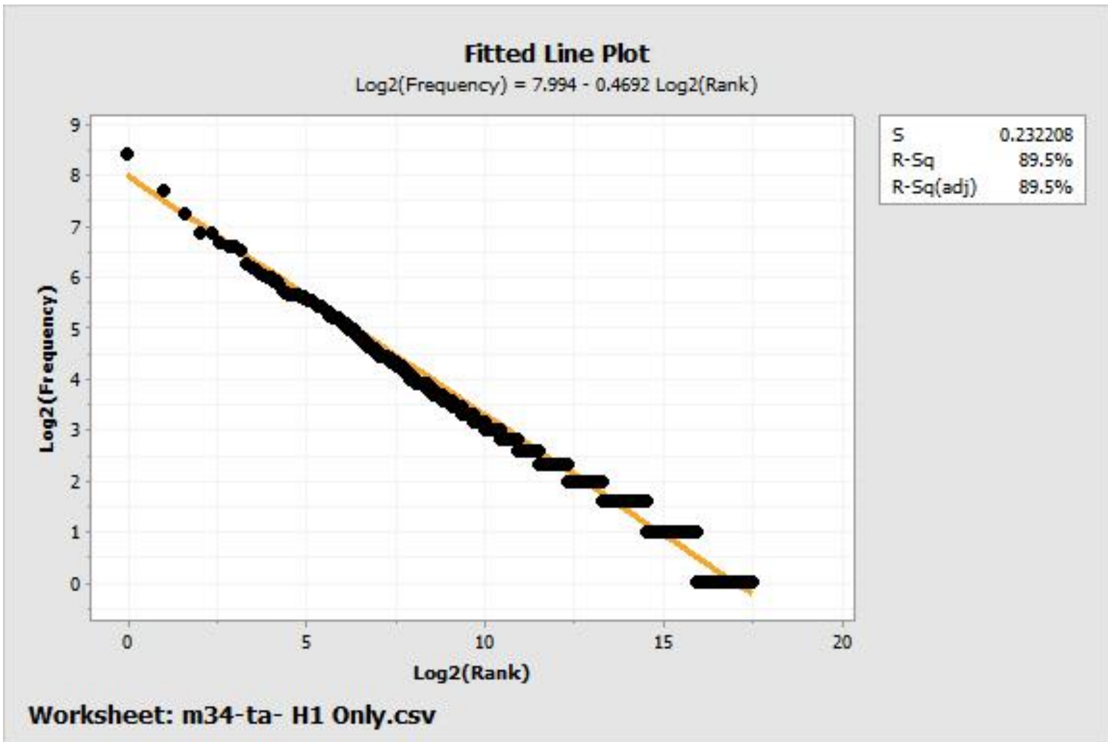

Fitted Line Plot
Log2(Frequency) = 7.487 - 0.4377 Log2(Rank)
S 0.231024
R-Sq 88.2%
R-Sq(adj) 88.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3- H1 Only.csv

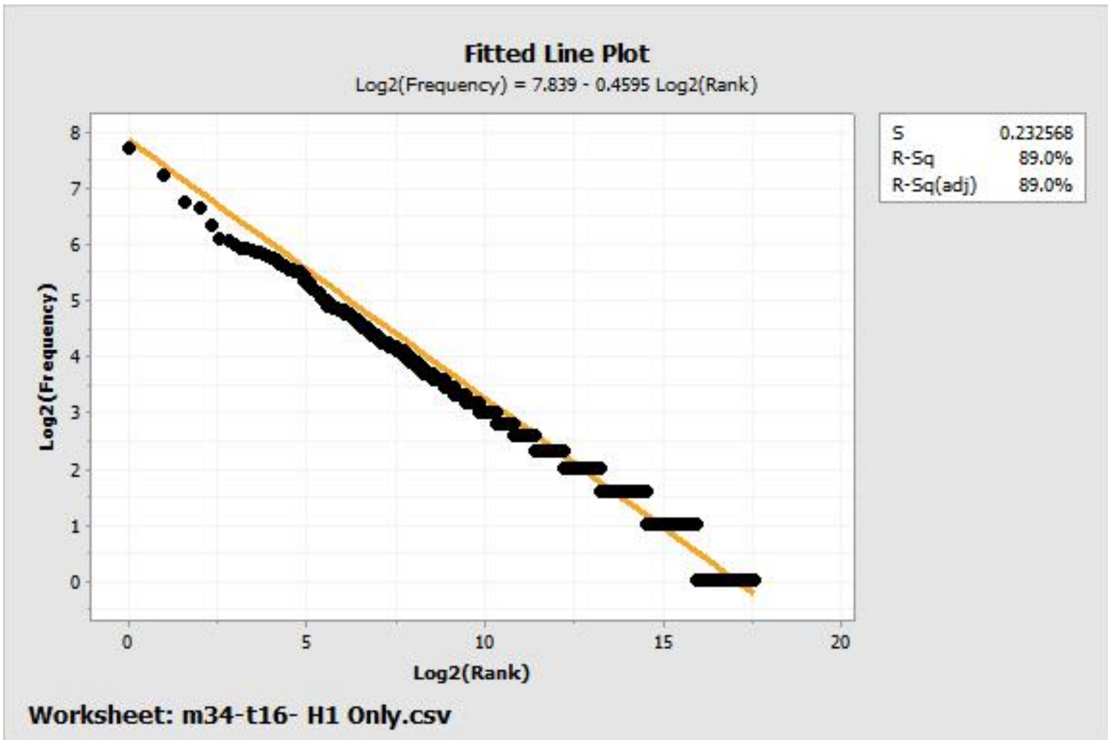

Fitted Line Plot
Log2(Frequency) = 8.166 - 0.4777 Log2(Rank)
S 0.230390
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta- H2 Only.csv

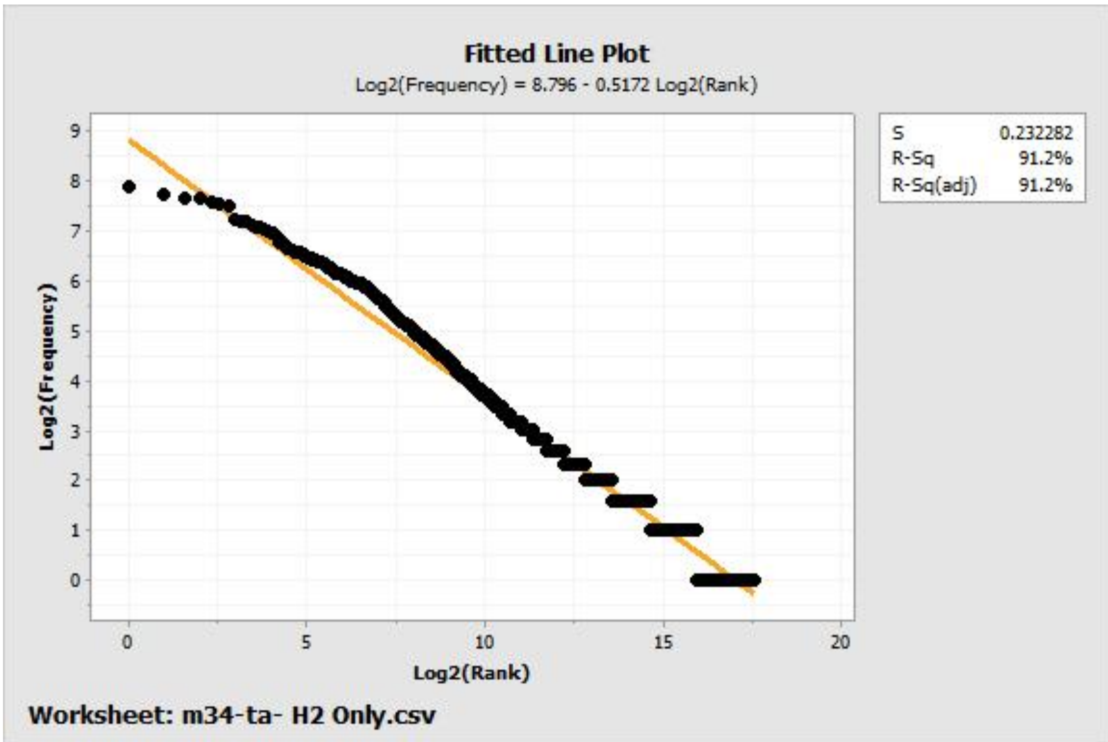

Fitted Line Plot
Log2(Frequency) = 8.833 - 0.5227 Log2(Rank)
S 0.232504
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3- H2 Only.csv

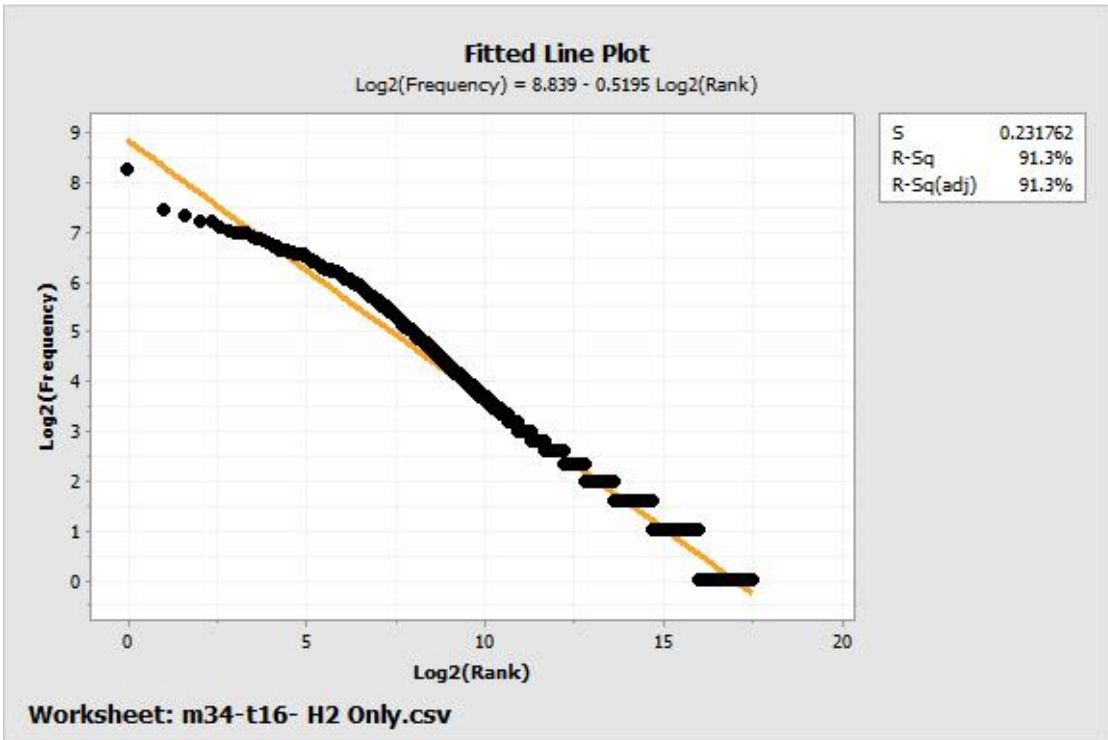

Fitted Line Plot
Log2(Frequency) = 10.12 - 0.5597 Log2(Rank)
S 0.267741
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta- H1 + H2.csv

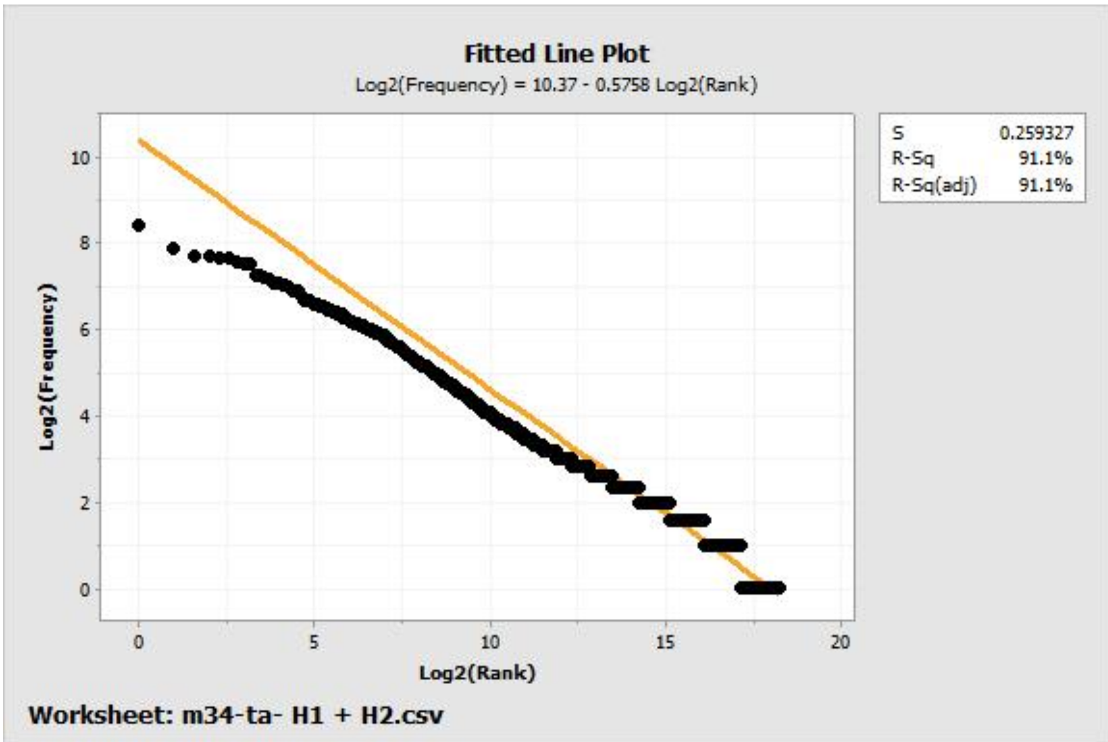

Fitted Line Plot
Log2(Frequency) = 9.953 - 0.5526 Log2(Rank)
S 0.256576
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3- H1 + H2.csv

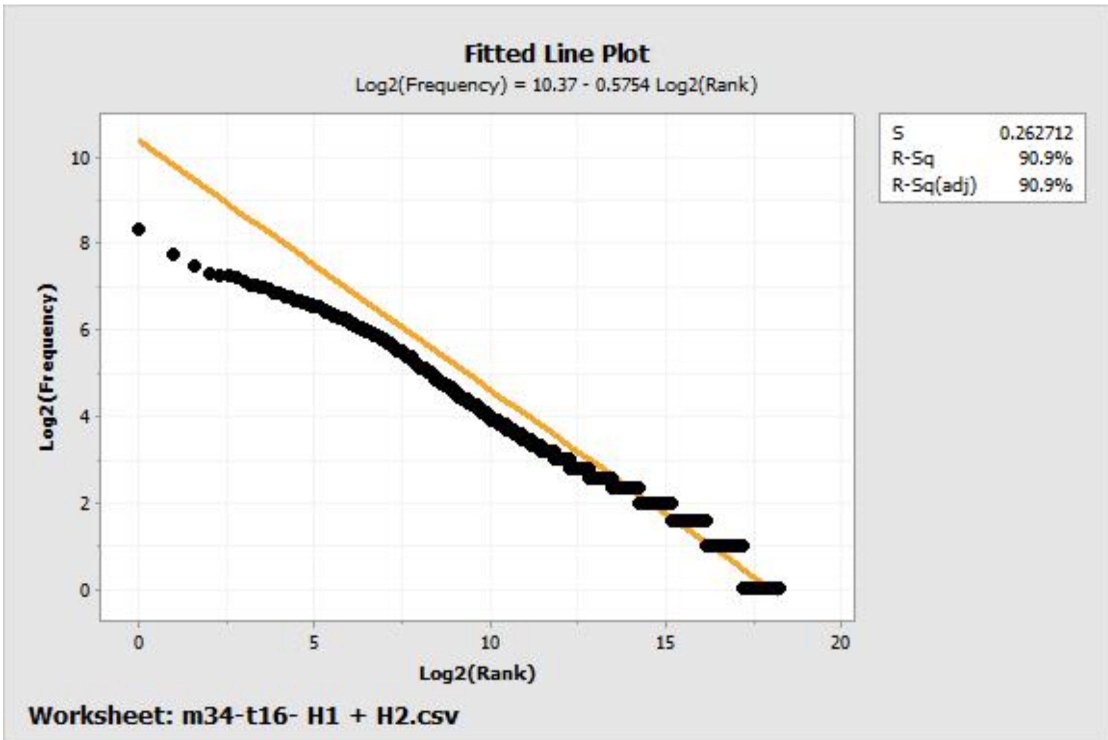

Fitted Line Plot
Log2(Frequency) = 7.994 - 0.4692 Log2(Rank)
S 0.232208
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-ta- H1 Only.csv

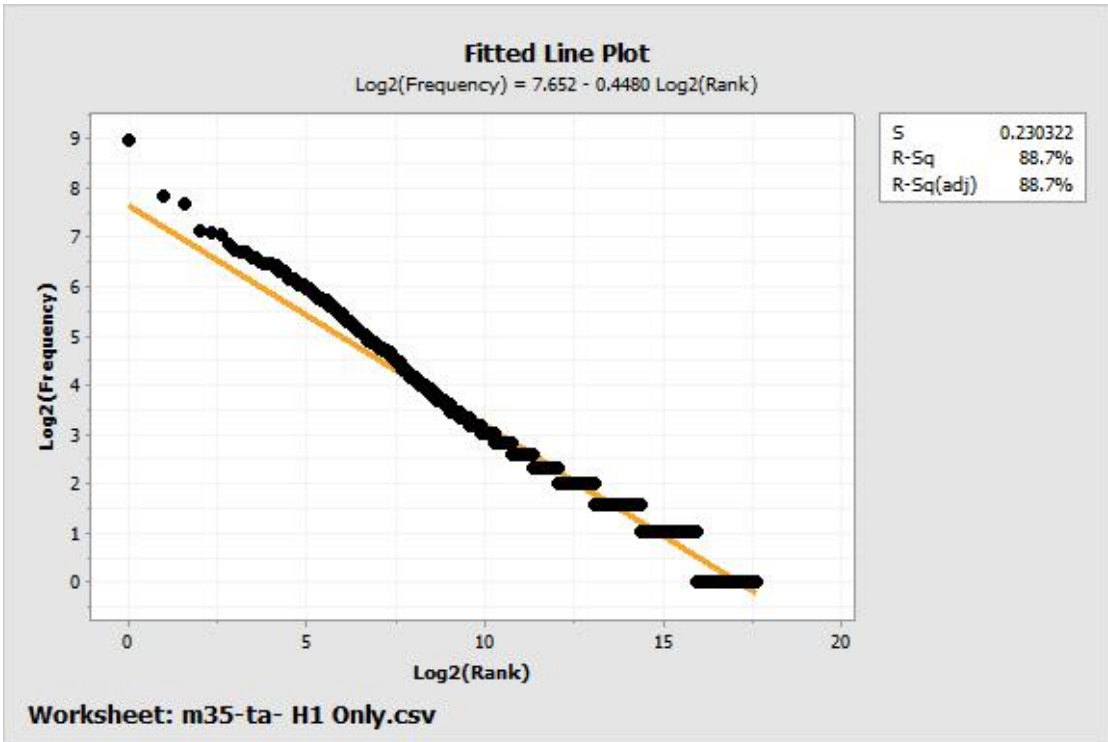

Fitted Line Plot
Log2(Frequency) = 7.839 - 0.4595 Log2(Rank)
S 0.232568
R-Sq 89.0%
R-Sq(adj) 89.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16- H1 Only.csv

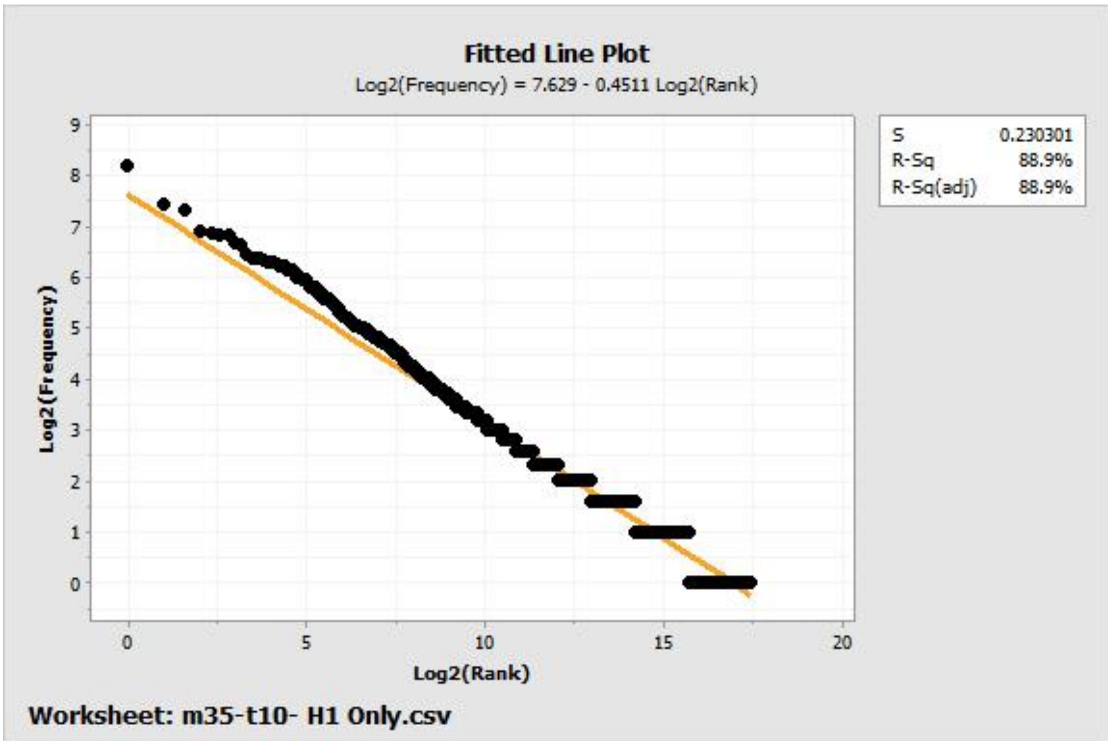

Fitted Line Plot
Log2(Frequency) = 8.796 - 0.5172 Log2(Rank)
S 0.232282
R-Sq 91.2%
R-Sq(adj) 91.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-ta- H2 Only.csv

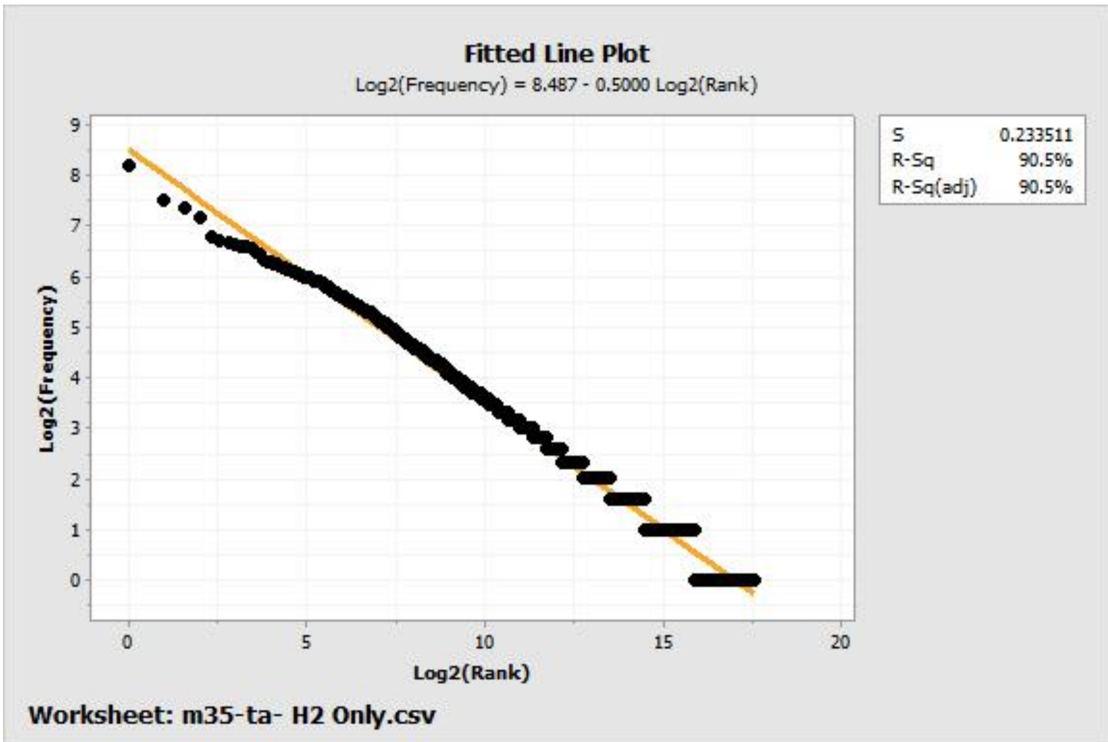

Fitted Line Plot
Log2(Frequency) = 8.839 - 0.5195 Log2(Rank)
S 0.231762
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16- H2 Only.csv

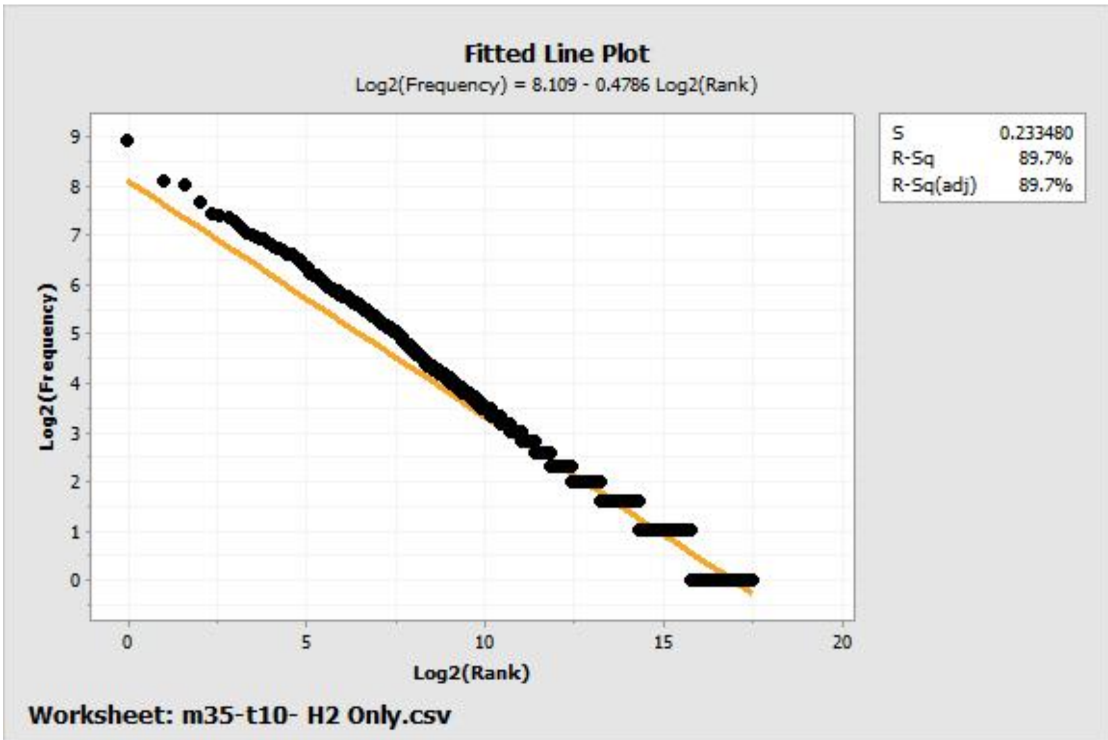

Fitted Line Plot
Log2(Frequency) = 10.37 - 0.5758 Log2(Rank)
S 0.259327
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-ta- H1 + H2.csv

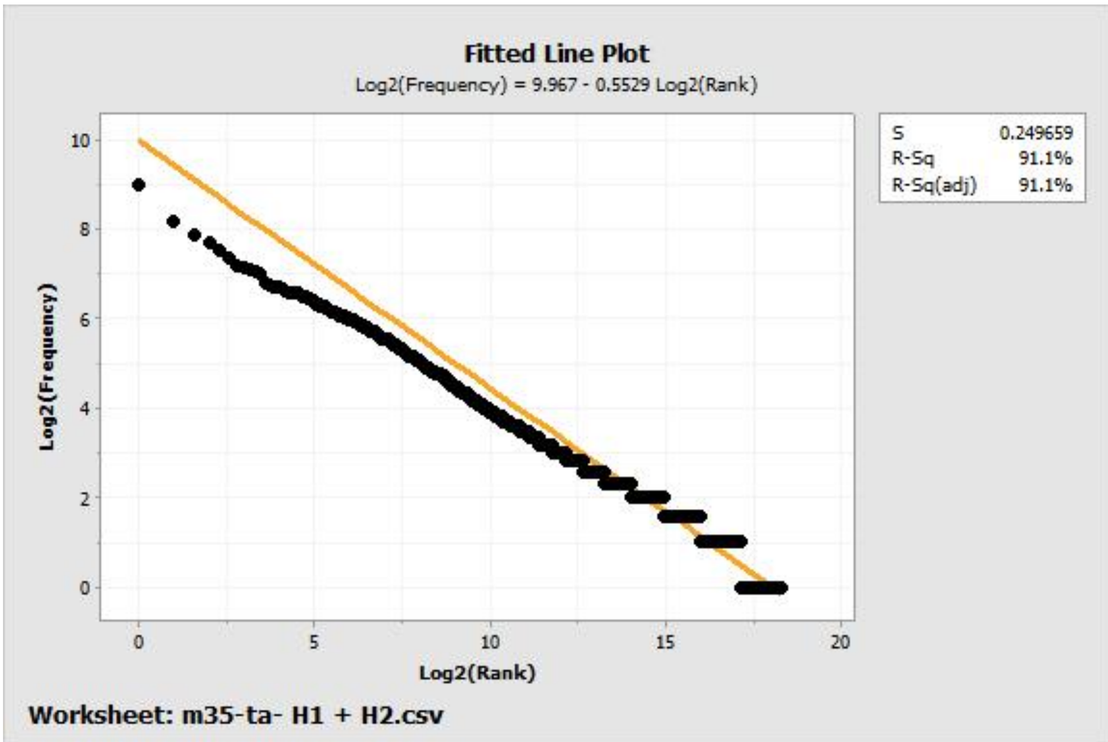

Fitted Line Plot
Log2(Frequency) = 10.37 - 0.5754 Log2(Rank)
S 0.262712
R-Sq 90.9%
R-Sq(adj) 90.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16- H1 + H2.csv

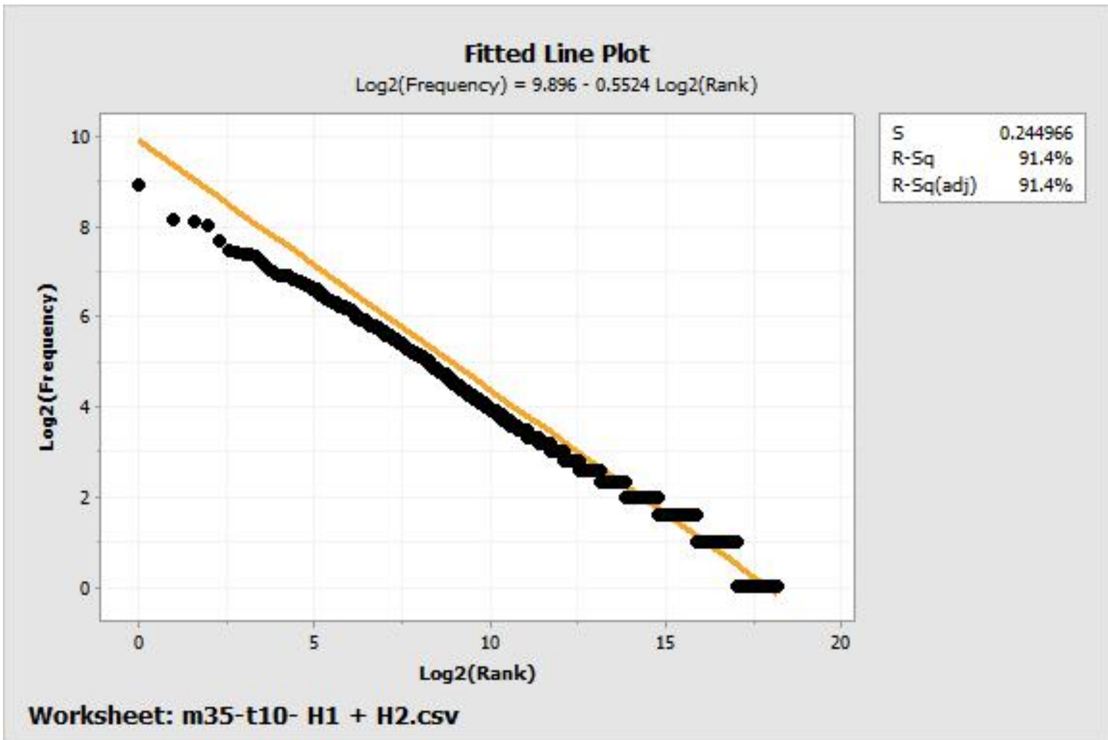

Fitted Line Plot
Log2(Frequency) = 7.652 - 0.4480 Log2(Rank)
S 0.230322
R-Sq 88.7%
R-Sq(adj) 88.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m35-ta- H1 Only.csv

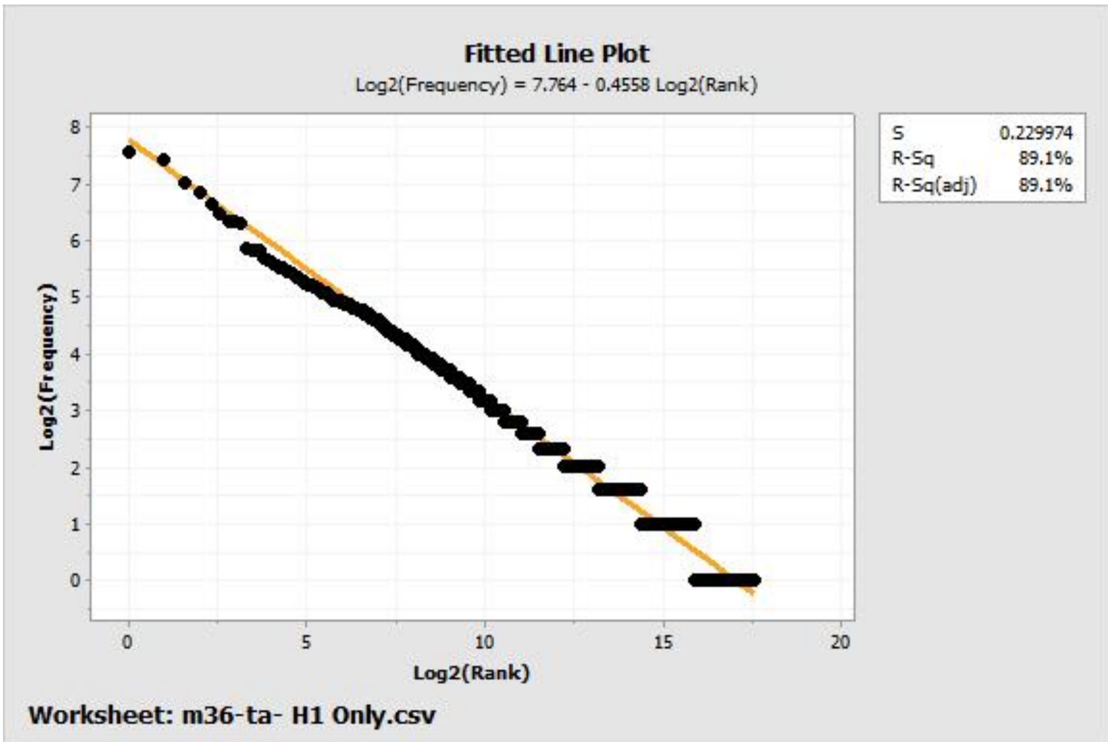

Fitted Line Plot
Log2(Frequency) = 7.629 - 0.4511 Log2(Rank)
S 0.230301
R-Sq 88.9%
R-Sq(adj) 88.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m35-t10- H1 Only.csv

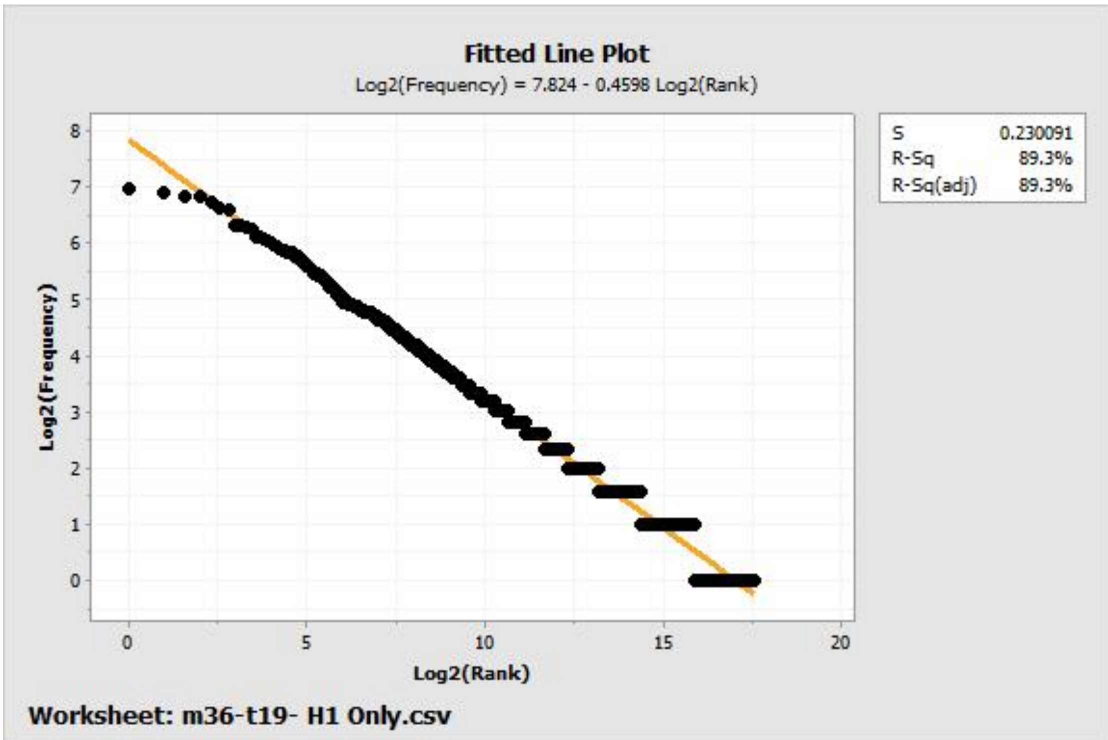

Fitted Line Plot
Log2(Frequency) = 8.487 - 0.5000 Log2(Rank)
S 0.233511
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m35-ta- H2 Only.csv

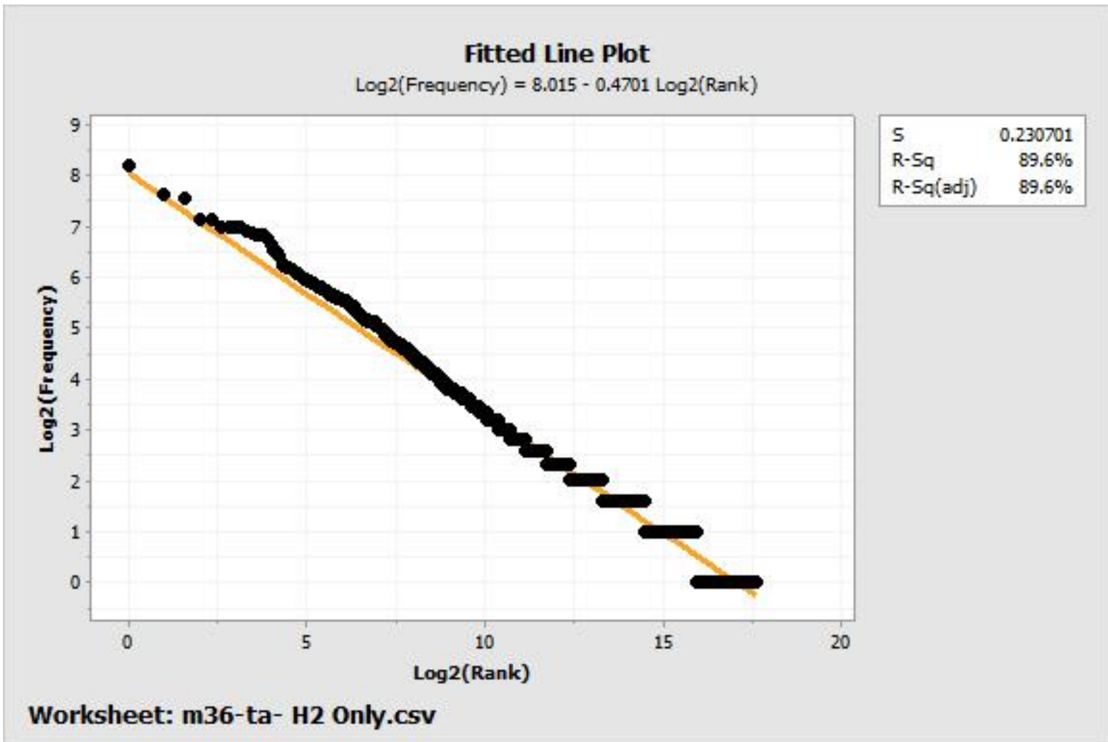

Fitted Line Plot
Log2(Frequency) = 8.109 - 0.4786 Log2(Rank)
S 0.233480
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m35-t10- H2 Only.csv

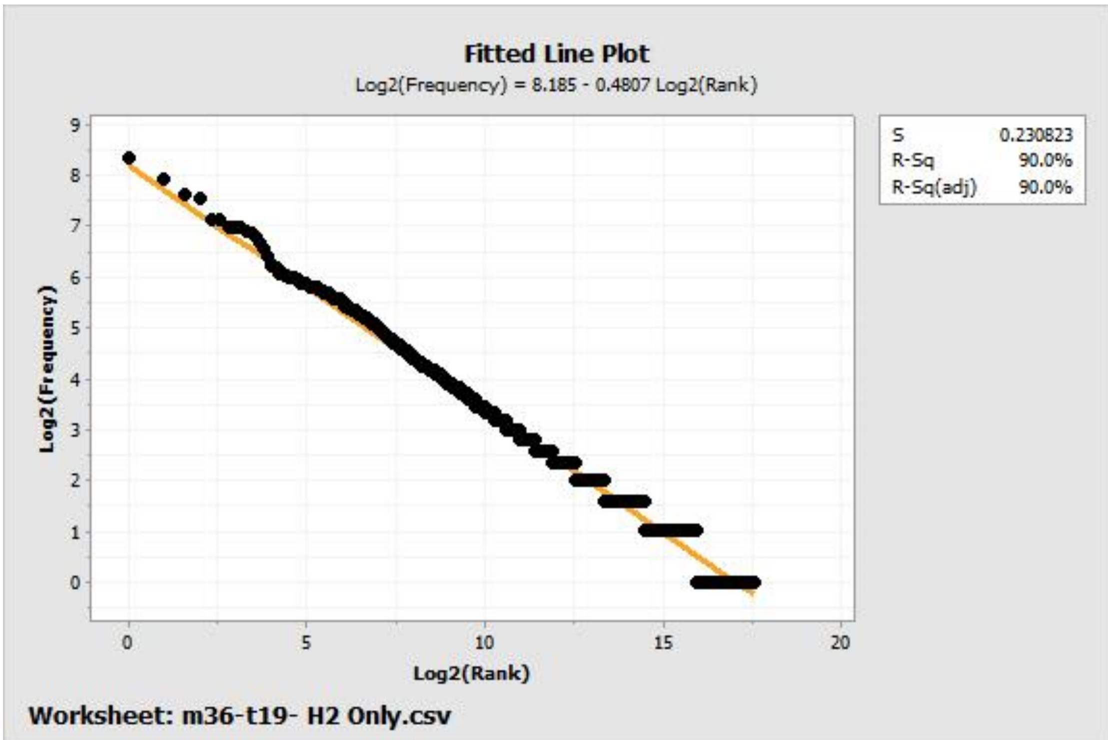

Fitted Line Plot
Log2(Frequency) = 9.967 - 0.5529 Log2(Rank)
S 0.249659
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m35-ta- H1 + H2.csv

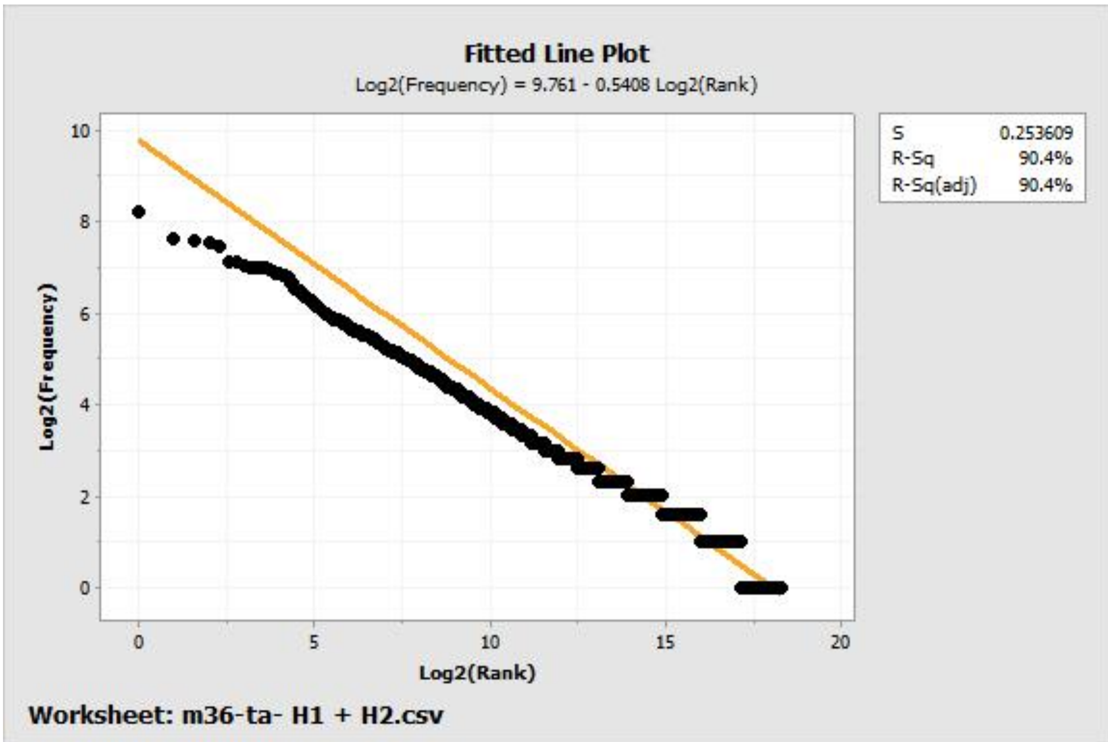

Fitted Line Plot
Log2(Frequency) = 9.896 - 0.5524 Log2(Rank)
S 0.244966
R-Sq 91.4%
R-Sq(adj) 91.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m35-t10- H1 + H2.csv

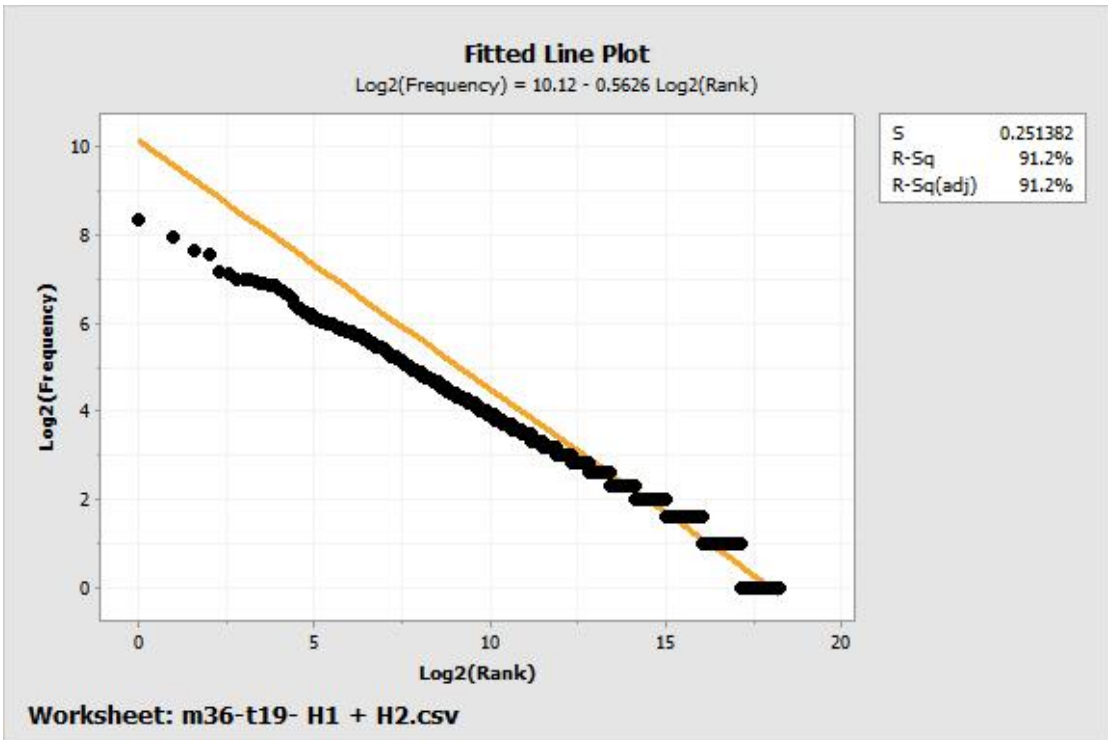

Fitted Line Plot
Log2(Frequency) = 7.764 - 0.4558 Log2(Rank)
S 0.229974
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-ta- H1 Only.csv

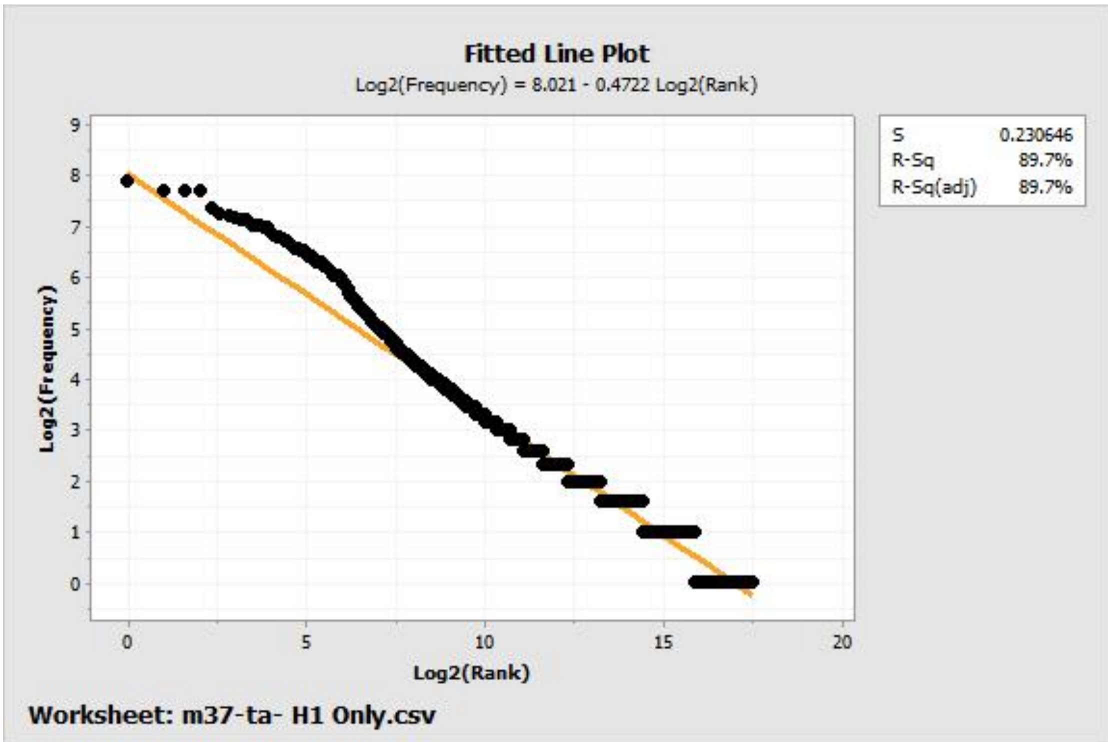

Fitted Line Plot
Log2(Frequency) = 7.824 - 0.4598 Log2(Rank)
S 0.230091
R-Sq 89.3%
R-Sq(adj) 89.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-t19- H1 Only.csv

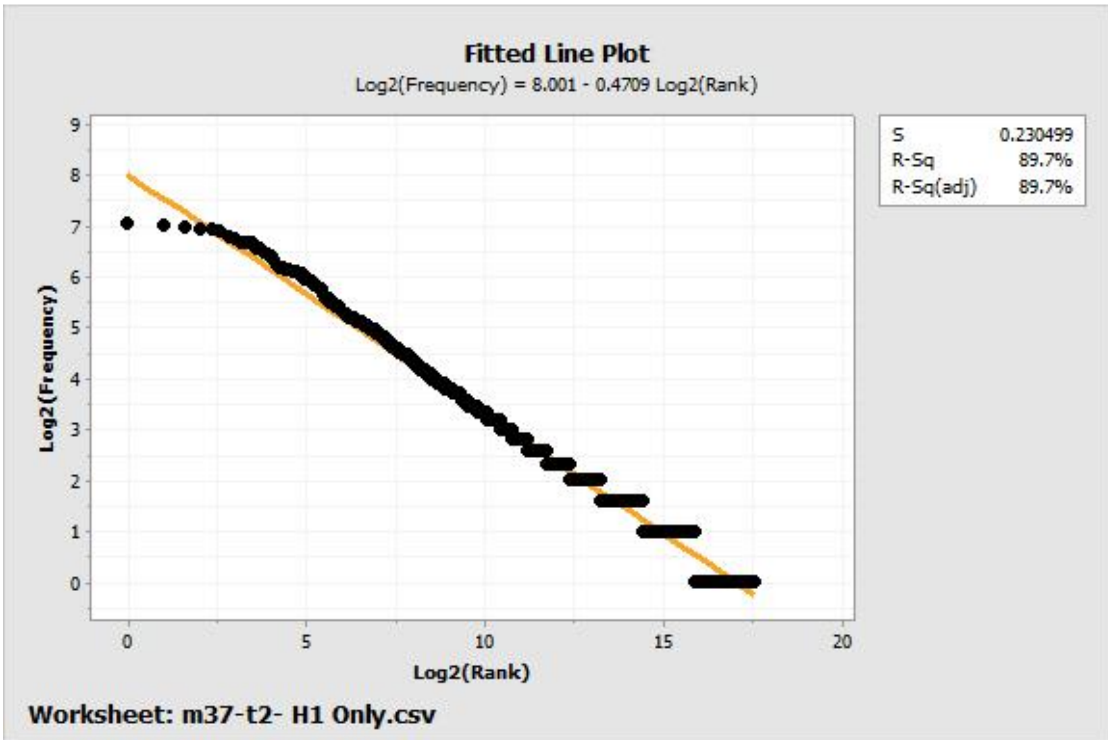

Fitted Line Plot
Log2(Frequency) = 8.015 - 0.4701 Log2(Rank)
S 0.230701
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
0
5
10
15
20
1
2
3
4
5
6
7
8
9
Worksheet: m36-ta- H2 Only.csv

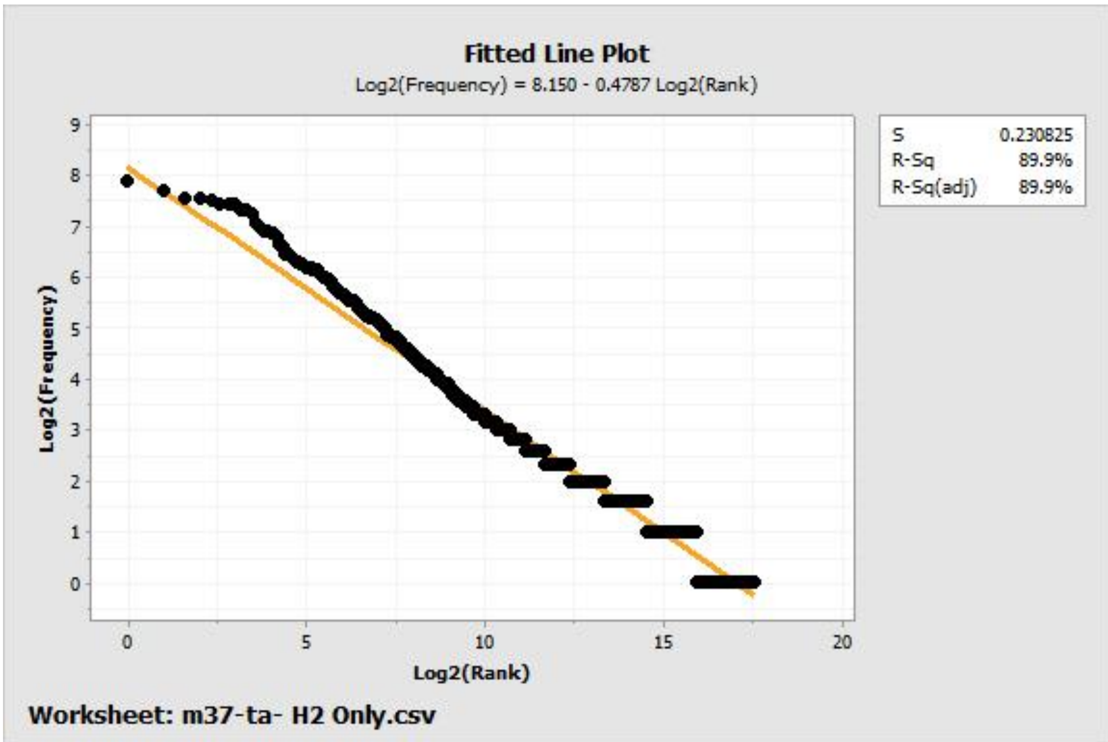

Fitted Line Plot
Log2(Frequency) = 8.185 - 0.4807 Log2(Rank)
S 0.230823
R-Sq 90.0%
R-Sq(adj) 90.0%
Log2(Frequency)
Log2(Rank)
0
5
10
15
20
1
2
3
4
5
6
7
8
9
Worksheet: m36-t19- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 9.761 - 0.5408 Log2(Rank)
S 0.253609
R-Sq 90.4%
R-Sq(adj) 90.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-ta- H1 + H2.csv

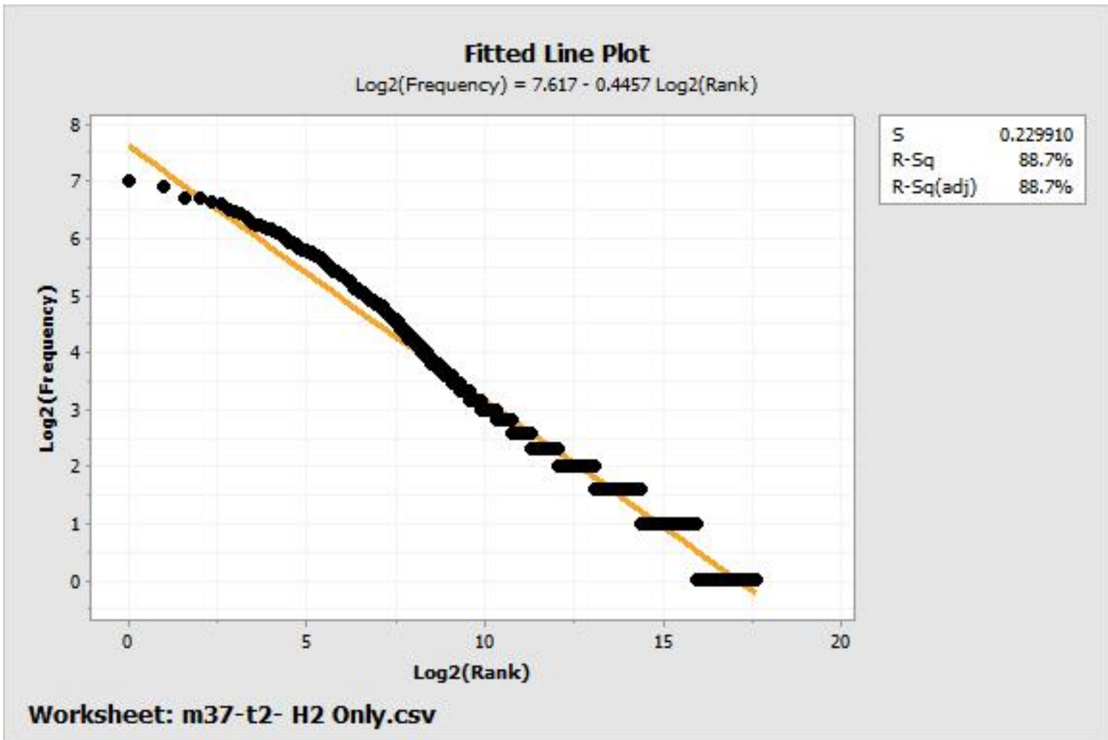

Fitted Line Plot
Log2(Frequency) = 10.12 - 0.5626 Log2(Rank)
S 0.251382
R-Sq 91.2%
R-Sq(adj) 91.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-t19- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 8.021 - 0.4722 Log2(Rank)
S 0.230646
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-ta- H1 Only.csv

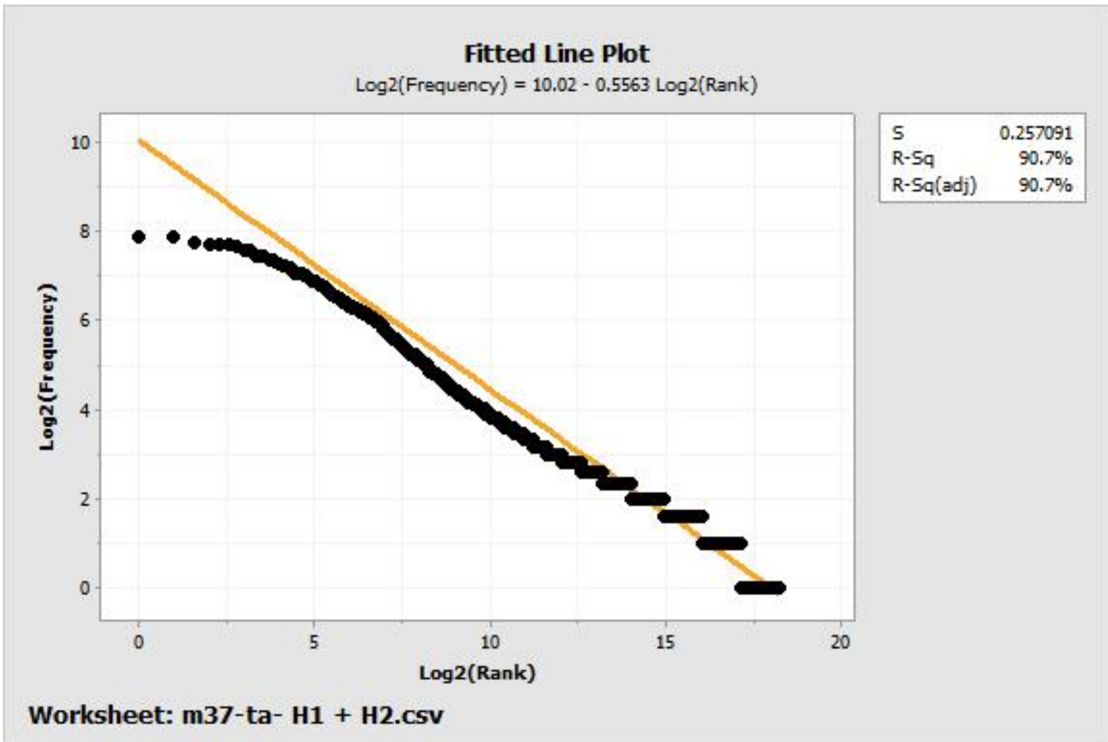

Fitted Line Plot
Log2(Frequency) = 8.001 - 0.4709 Log2(Rank)
S 0.230499
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2- H1 Only.csv

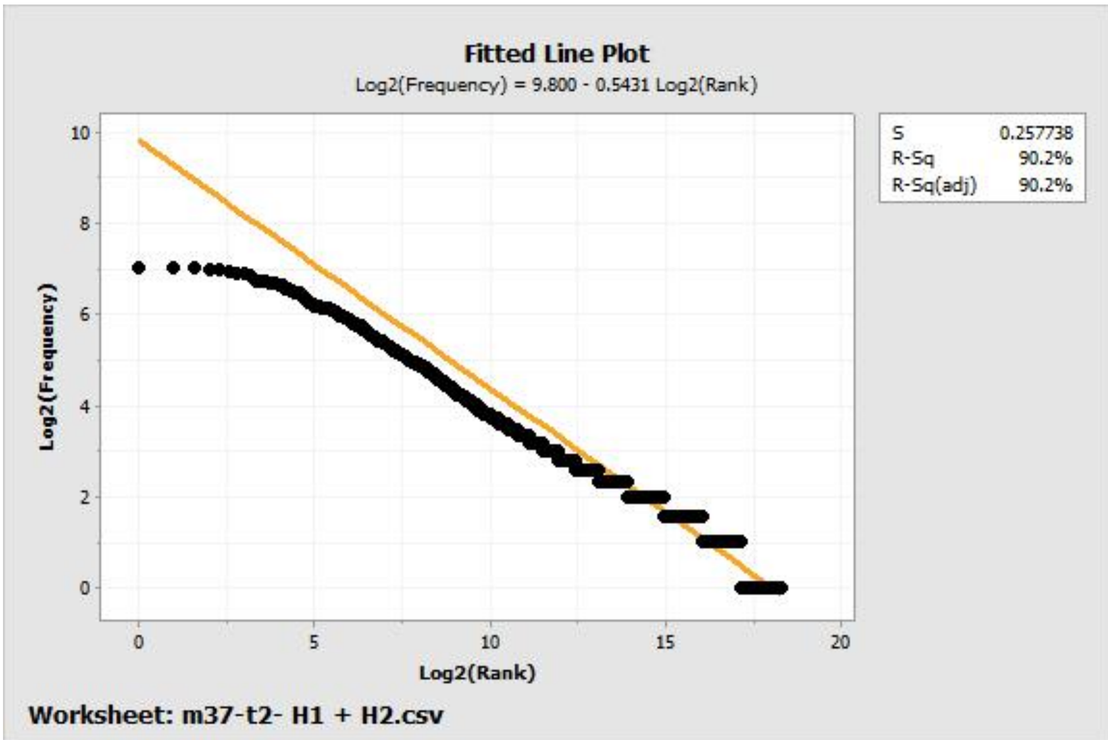


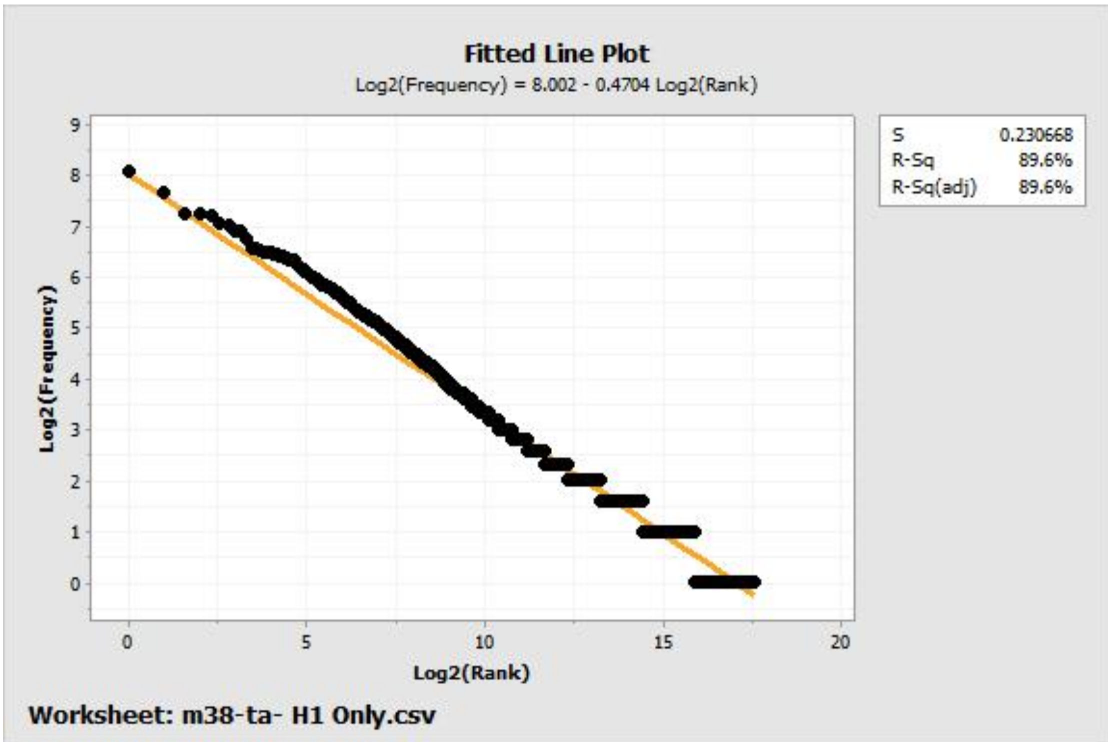
Fitted Line Plot
Log2(Frequency) = 8.150 - 0.4787 Log2(Rank)
S 0.230825
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-ta- H2 Only.csv

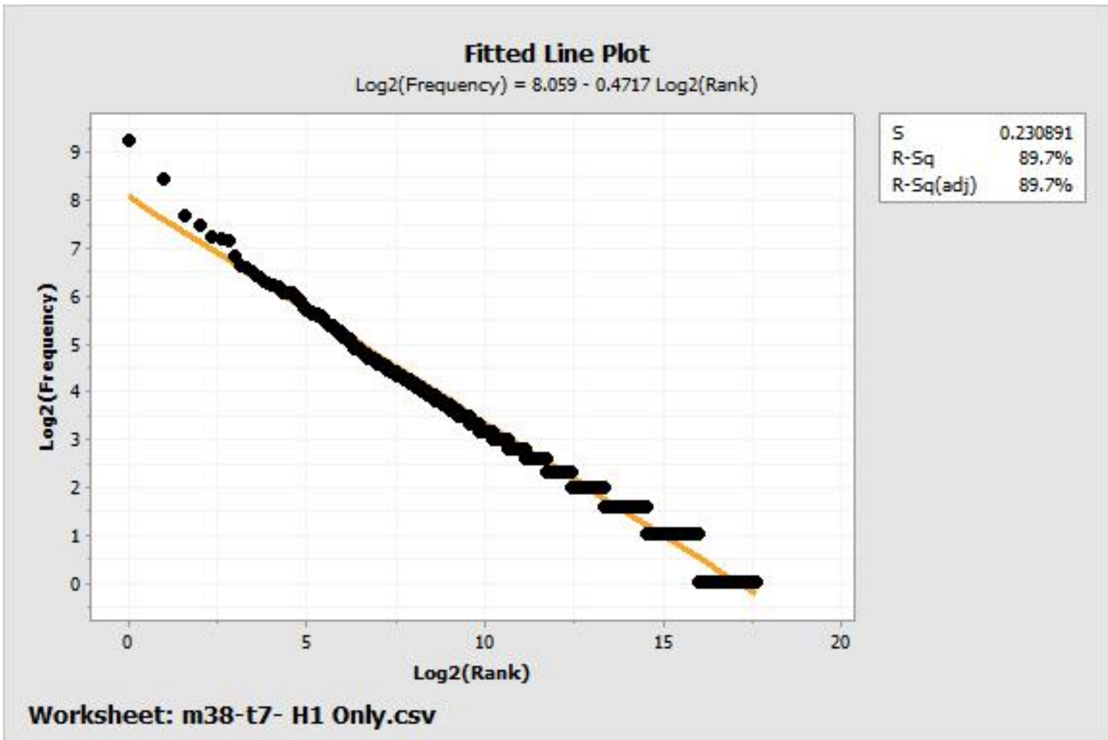


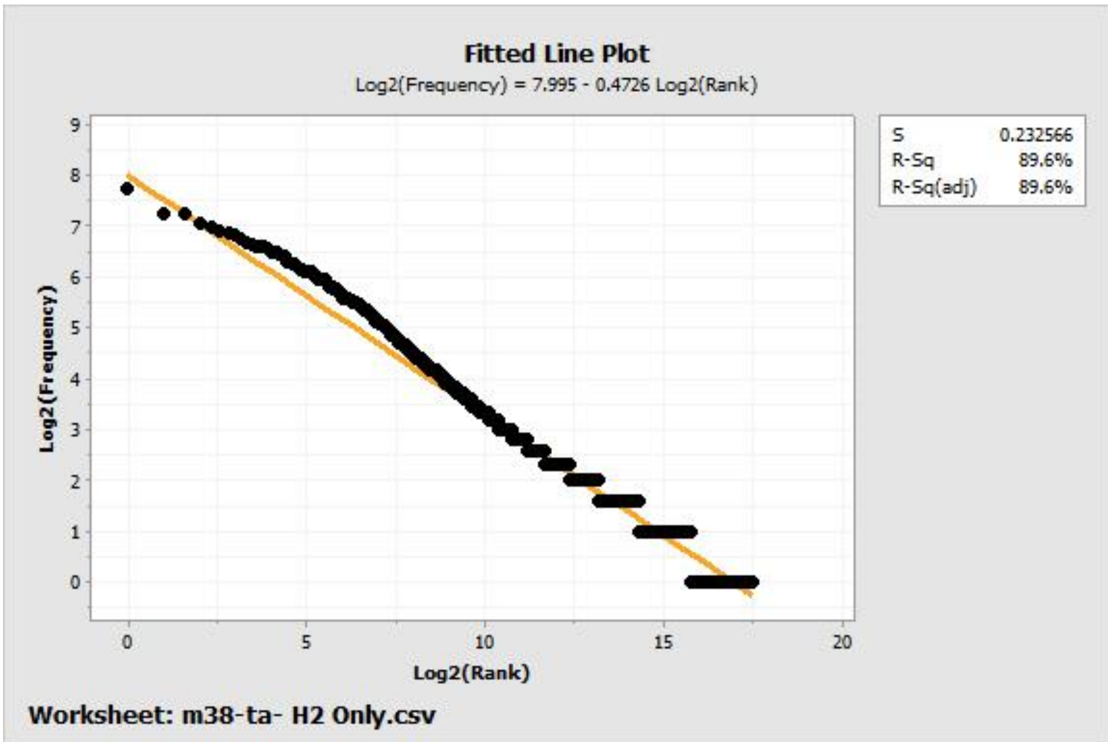
Fitted Line Plot
Log2(Frequency) = 7.617 - 0.4457 Log2(Rank)
S 0.229910
R-Sq 88.7%
R-Sq(adj) 88.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2- H2 Only.csv

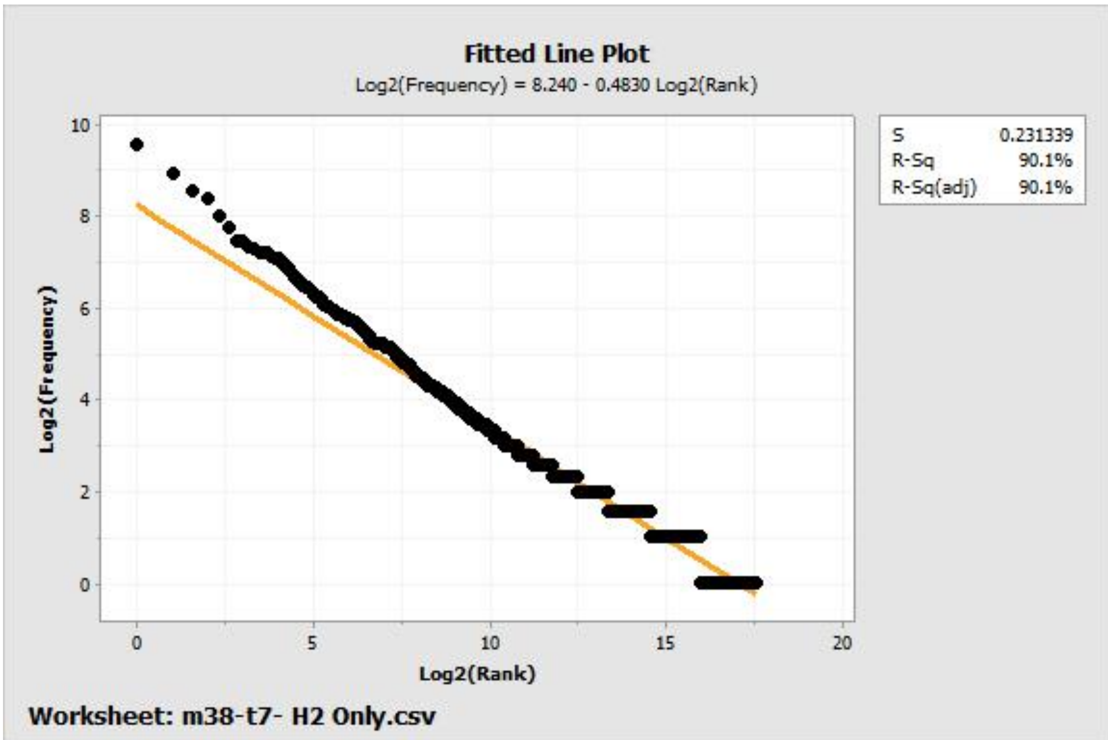

Fitted Line Plot
Log2(Frequency) = 10.02 - 0.5563 Log2(Rank)
S 0.257091
R-Sq 90.7%
R-Sq(adj) 90.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-ta- H1 + H2.csv

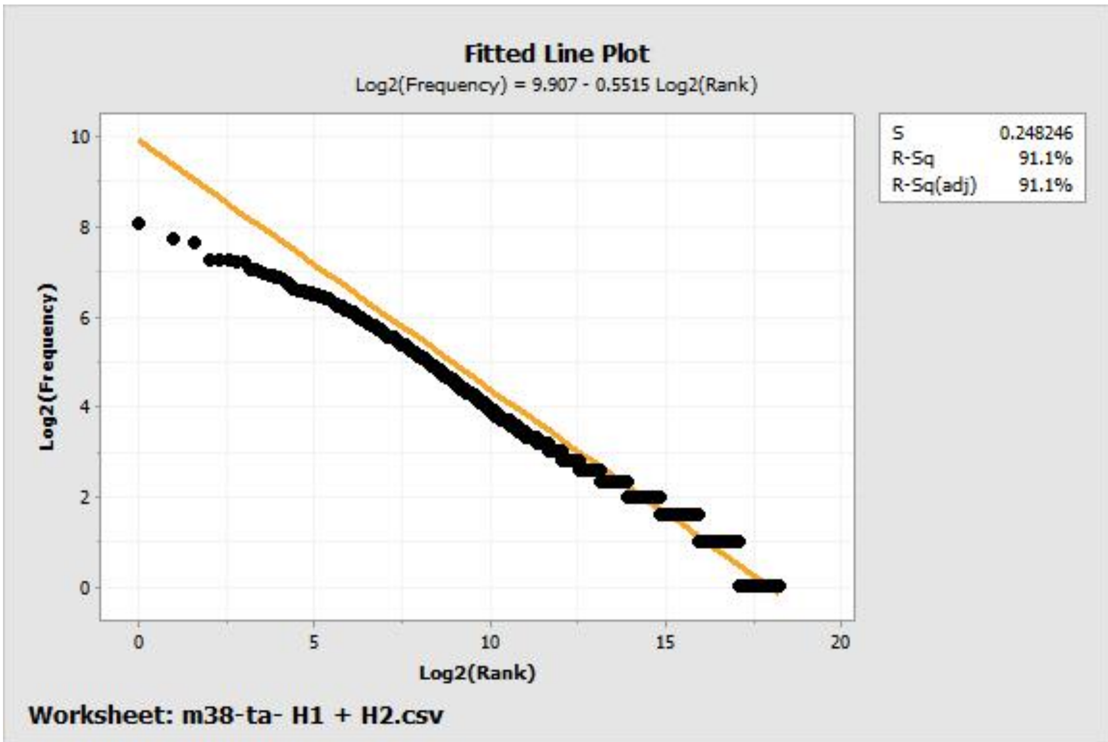

Fitted Line Plot
Log2(Frequency) = 9.800 - 0.5431 Log2(Rank)
S 0.257738
R-Sq 90.2%
R-Sq(adj) 90.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2- H1 + H2.csv

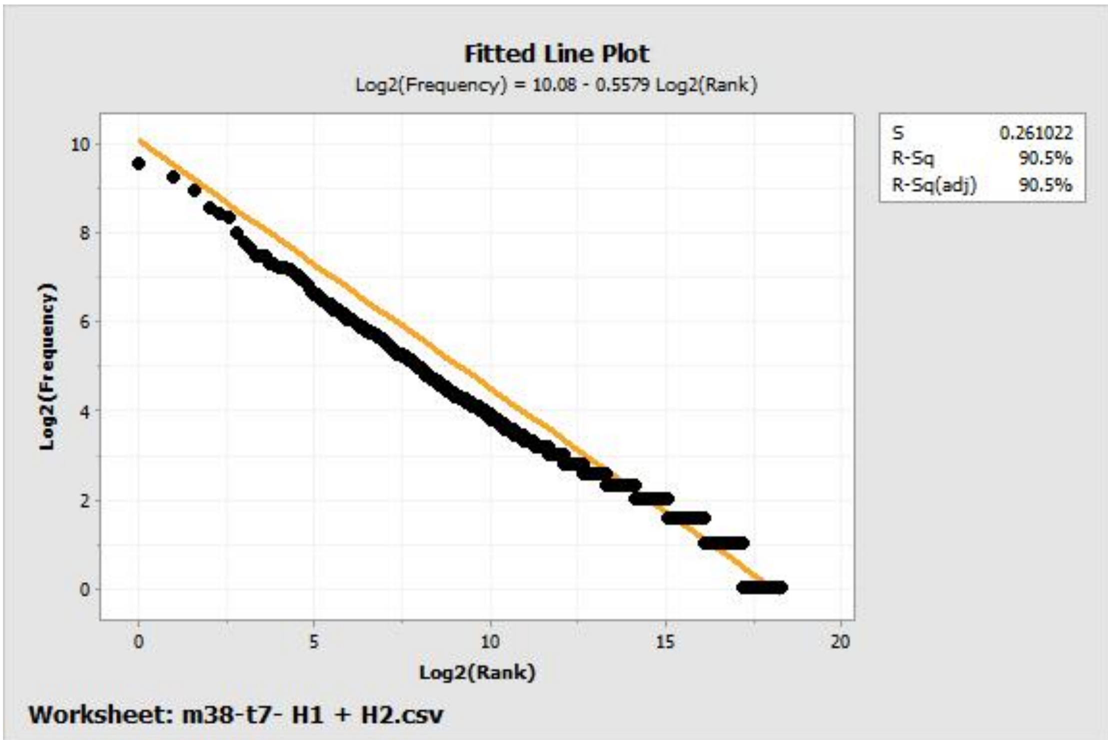

Fitted Line Plot
Log2(Frequency) = 8.002 - 0.4704 Log2(Rank)
S 0.230668
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta- H1 Only.csv


Fitted Line Plot
Log2(Frequency) = 8.059 - 0.4717 Log2(Rank)
S 0.230891
R-Sq 89.7%
R-Sq(adj) 89.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7- H1 Only.csv


Fitted Line Plot
Log2(Frequency) = 7.995 - 0.4726 Log2(Rank)
S 0.232566
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 8.240 - 0.4830 Log2(Rank)
S 0.231339
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7- H2 Only.csv


Fitted Line Plot
Log2(Frequency) = 9.907 - 0.5515 Log2(Rank)
S 0.248246
R-Sq 91.1%
R-Sq(adj) 91.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta- H1 + H2.csv


Fitted Line Plot
Log2(Frequency) = 10.08 - 0.5579 Log2(Rank)
S 0.261022
R-Sq 90.5%
R-Sq(adj) 90.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7- H1 + H2.csv

Appendix 2 – Emergent Policy Characteristics

In the same manner as Appendix 1, the graphs presented on each page of this appendix depict the log-log plots of the policy frequency with respect to the rank of that frequency for all policies (positions being equivalent to policies) exhibited by the team in action. The difference here is that the plots presented are those that not only relate to the dynamically recomputed centroid coordinates for Team A as determined by the policies (hence changes in position) enacted by each player, but also those for the opposing team that they confronted. Accordingly, the plots describe the dynamical characteristics of the emergent policies of Team A and their various opponents in terms of its Attack, Midfield, Defence and Whole Team emergent centroid dynamics.

Each match is described by the contents of every eight pages i.e. on a two graphs per page basis. The graphs in these eight page subsections of this appendix pertain to both halves of each match that the team participated in.

Each plot is suitably coded. The coding scheme used is: **mX-tY- h1 + h2 - ZPrfd**

Where:

X is the match number (1 to 37) (the m prefix is used to denote 'match' and does not take a value here);

Y is the Team identifier (Team A (a) or specified Team Number) (the prefix t denotes 'team');

h1 + **h2** refers to first and second half of each game

Z is the team colour (Red (r) or Blue (b))

P is the emergent policy centroid type which can take any of the following values:

a = attack function emergent centroid

m= midfield function emergent function

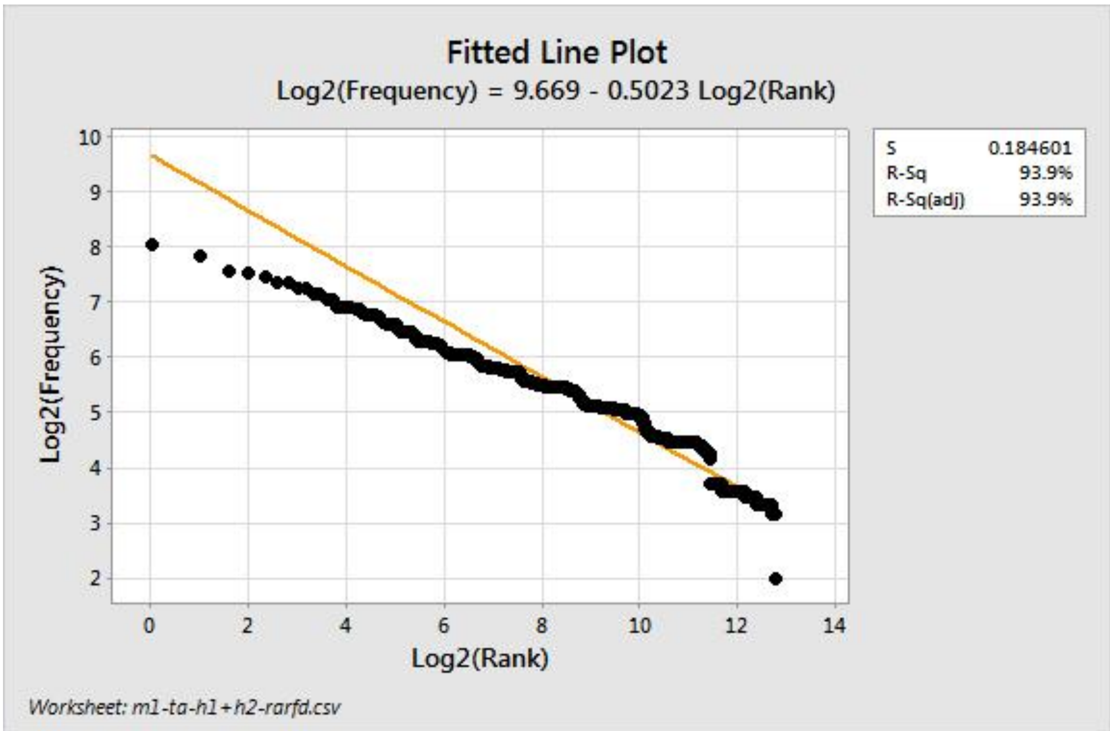
d=defence function emergent function

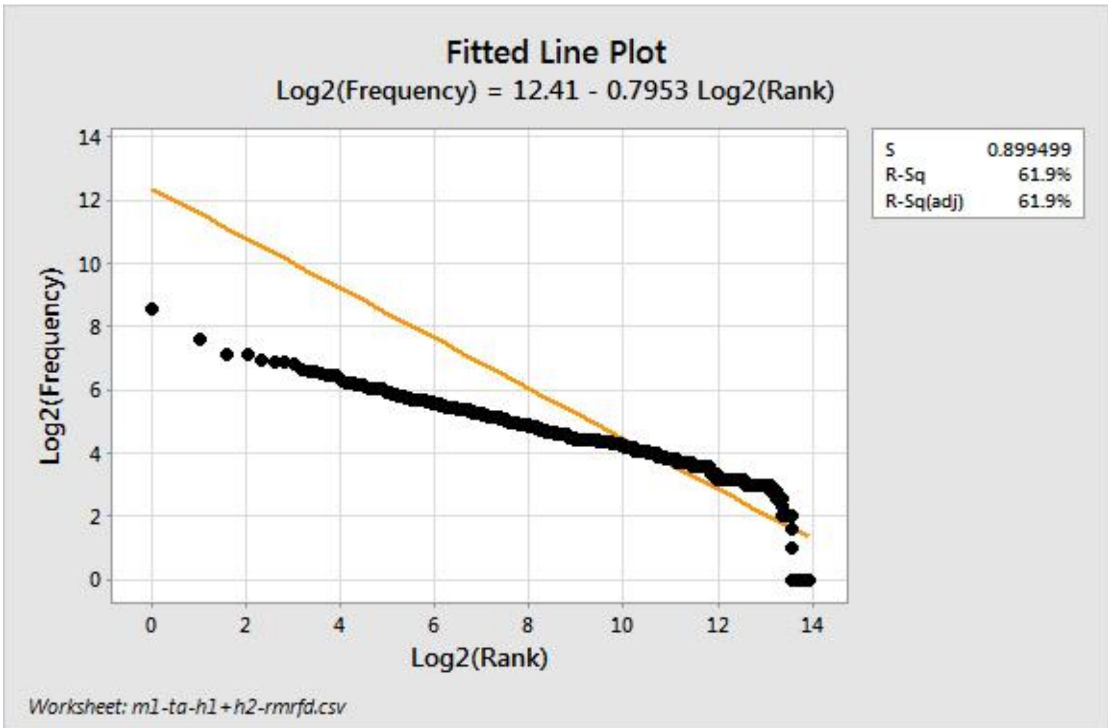
The term **rfd** is used to denote 'ranked frequency distribution' and does not take a value here

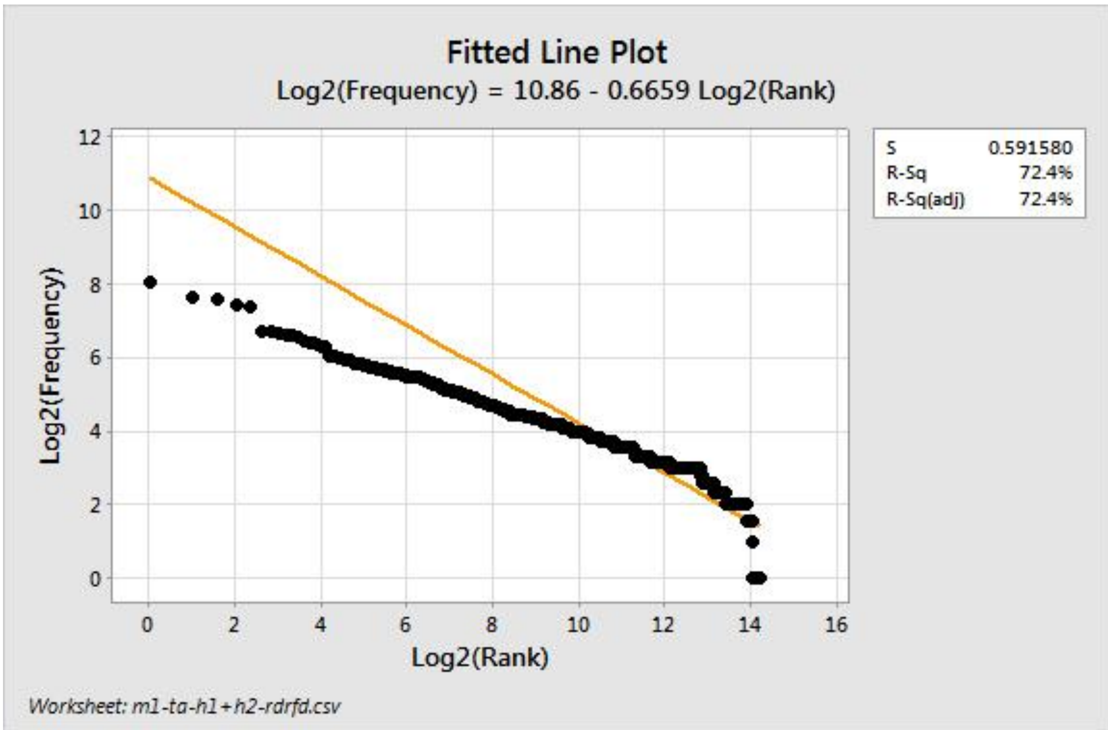
Example:

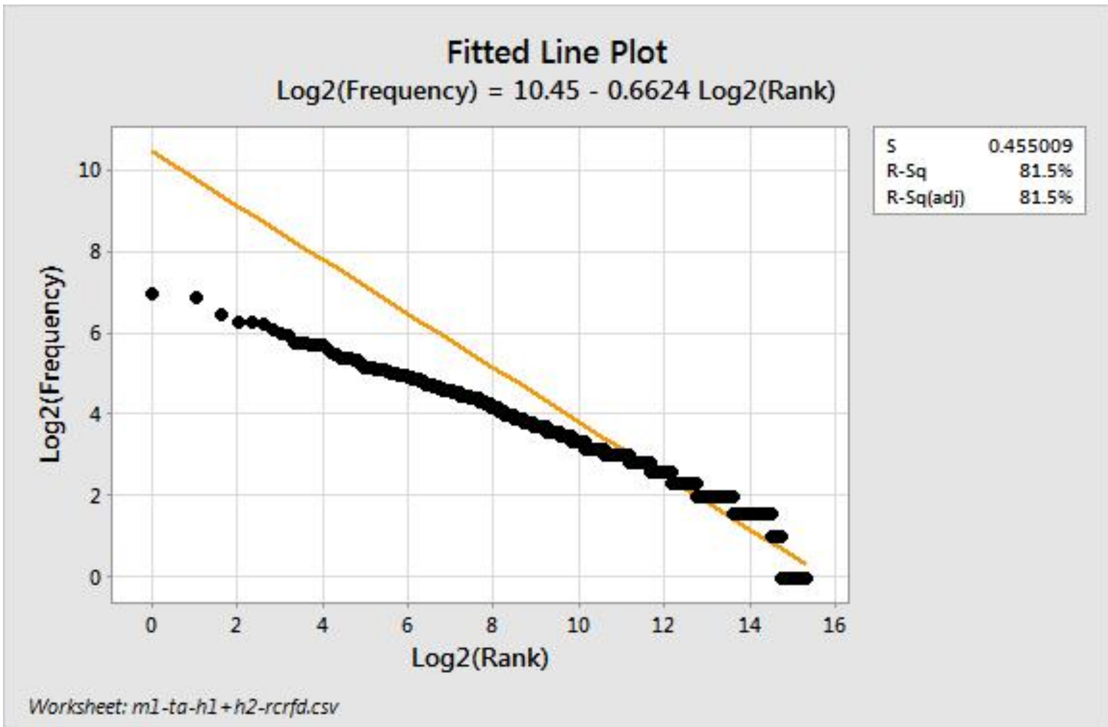
m1-ta-h1+h2-rarfd

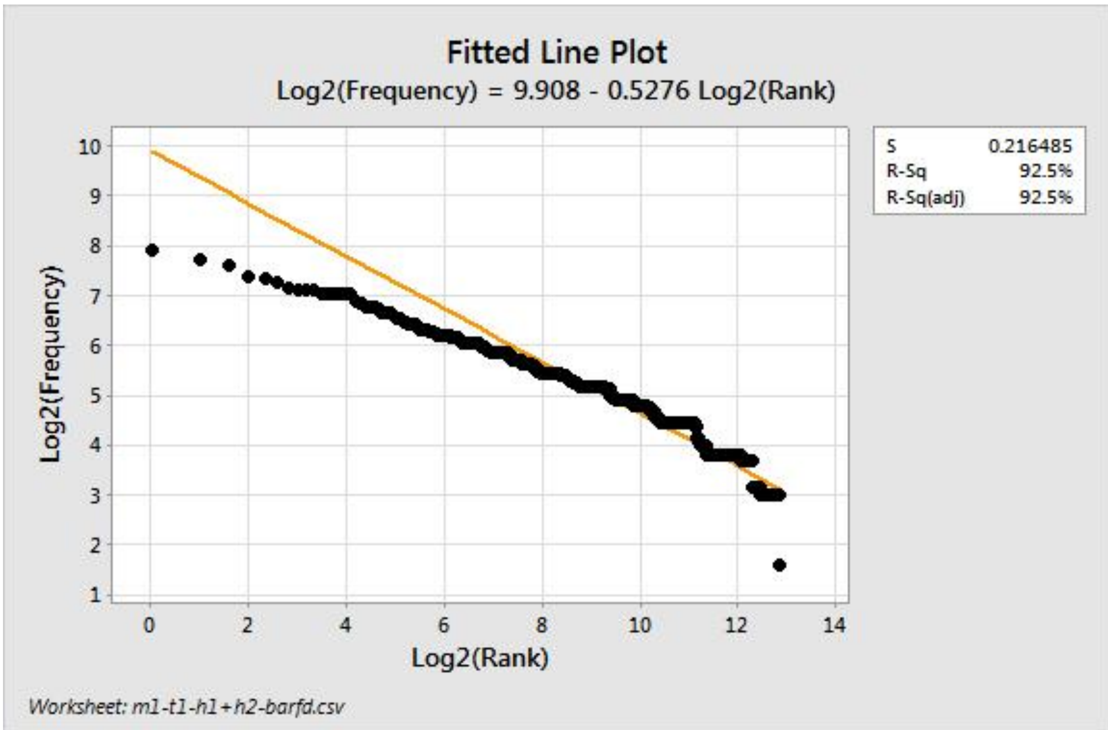
This means: Match 1; Team A (a); in the first and Second Half considered together (h1 + h2); Red (the colour of Team A = (r)); Attack Function (a) Ranked Frequency Distribution

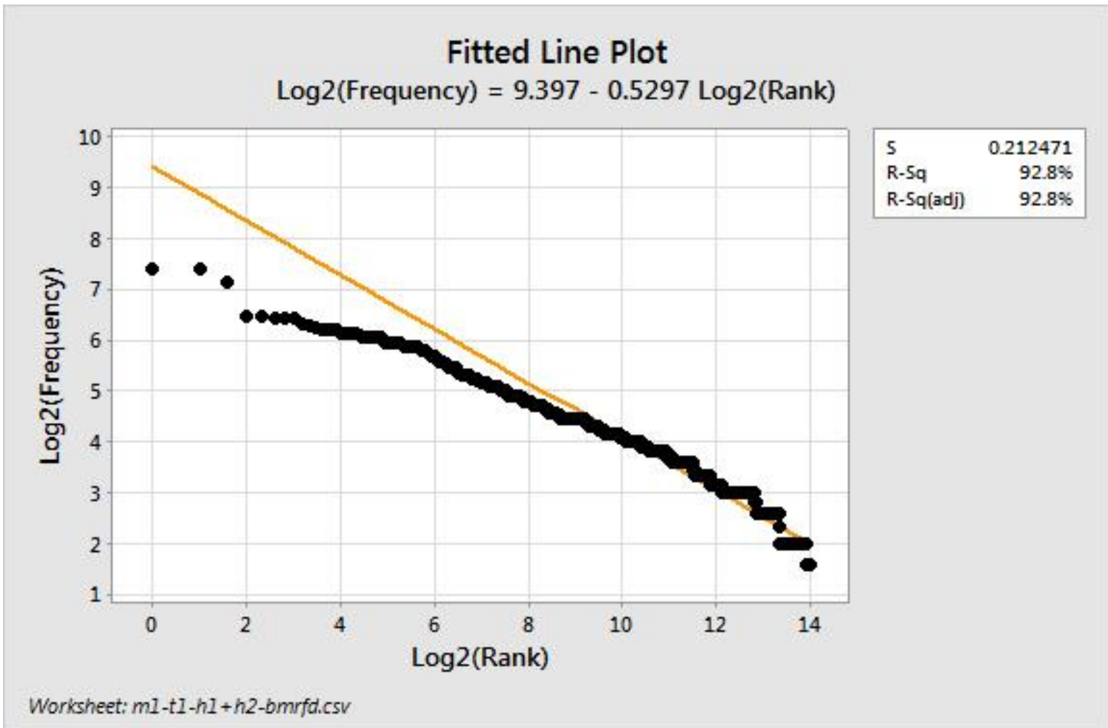


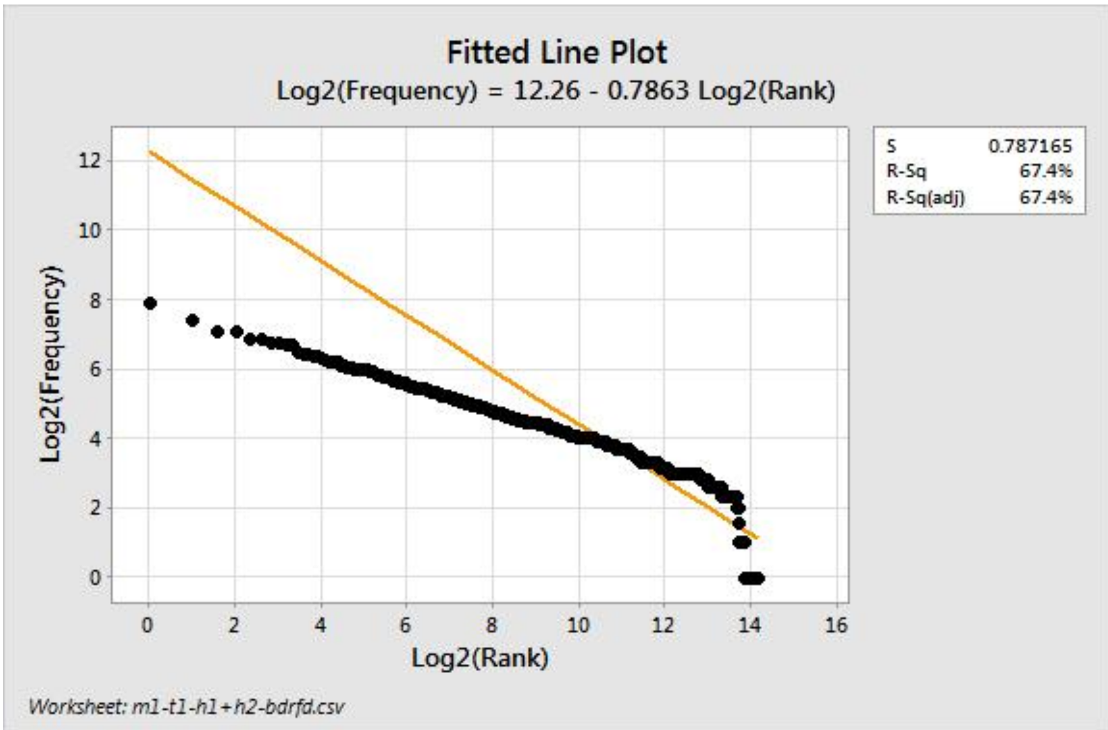



Fitted Line Plot
Log2(Frequency) = 10.86 - 0.6659 Log2(Rank)
S 0.591580
R-Sq 72.4%
R-Sq(adj) 72.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-ta-h1+h2-rdrfd.csv

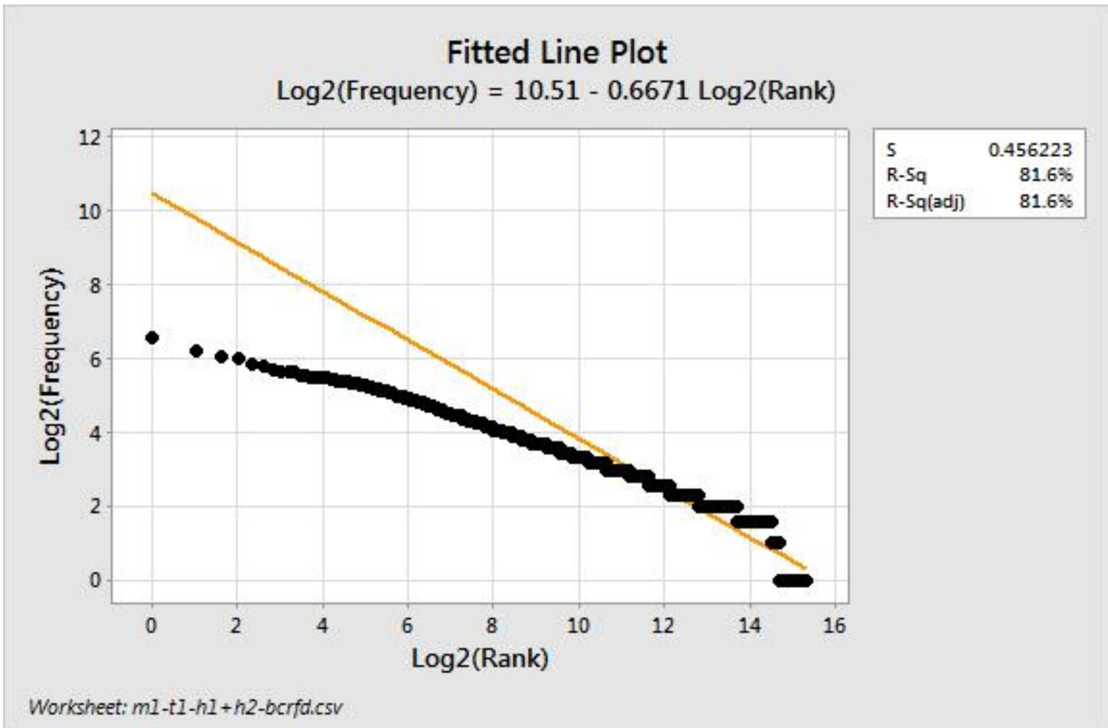

Fitted Line Plot
Log2(Frequency) = 10.45 - 0.6624 Log2(Rank)
S 0.455009
R-Sq 81.5%
R-Sq(adj) 81.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 9.908 - 0.5276 Log2(Rank)
S 0.216485
R-Sq 92.5%
R-Sq(adj) 92.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-t1-h1+h2-barfd.csv

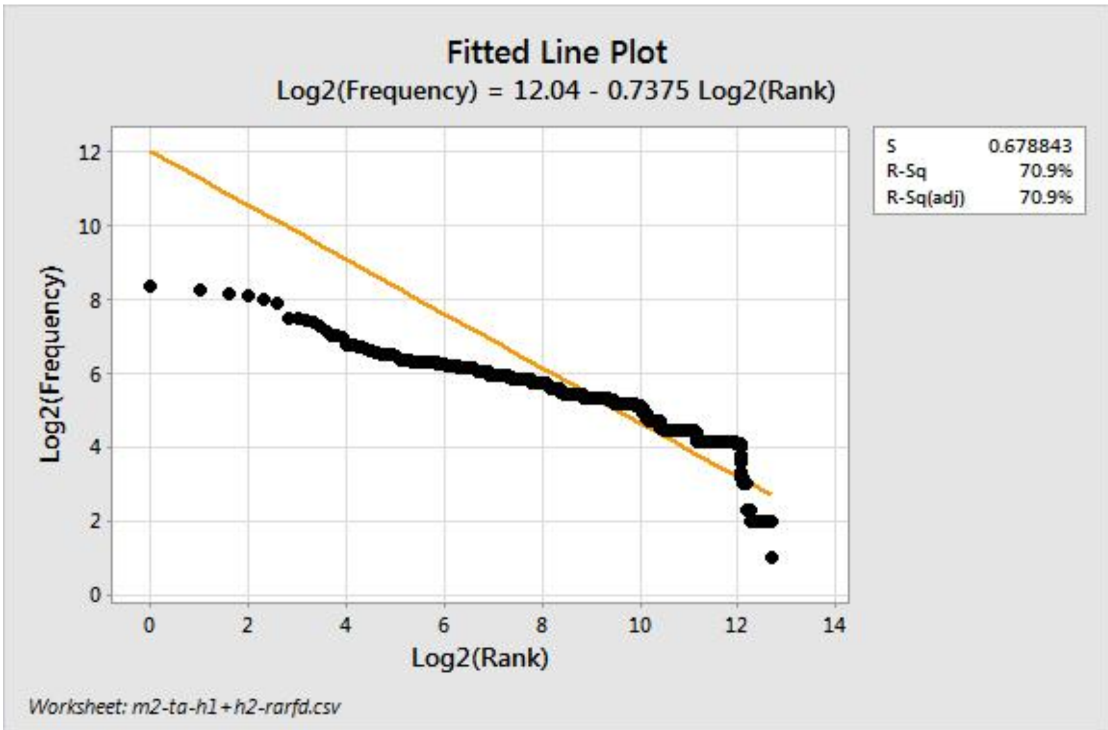

Fitted Line Plot
Log2(Frequency) = 9.397 - 0.5297 Log2(Rank)
S 0.212471
R-Sq 92.8%
R-Sq(adj) 92.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-t1-h1+h2-bmrfd.csv



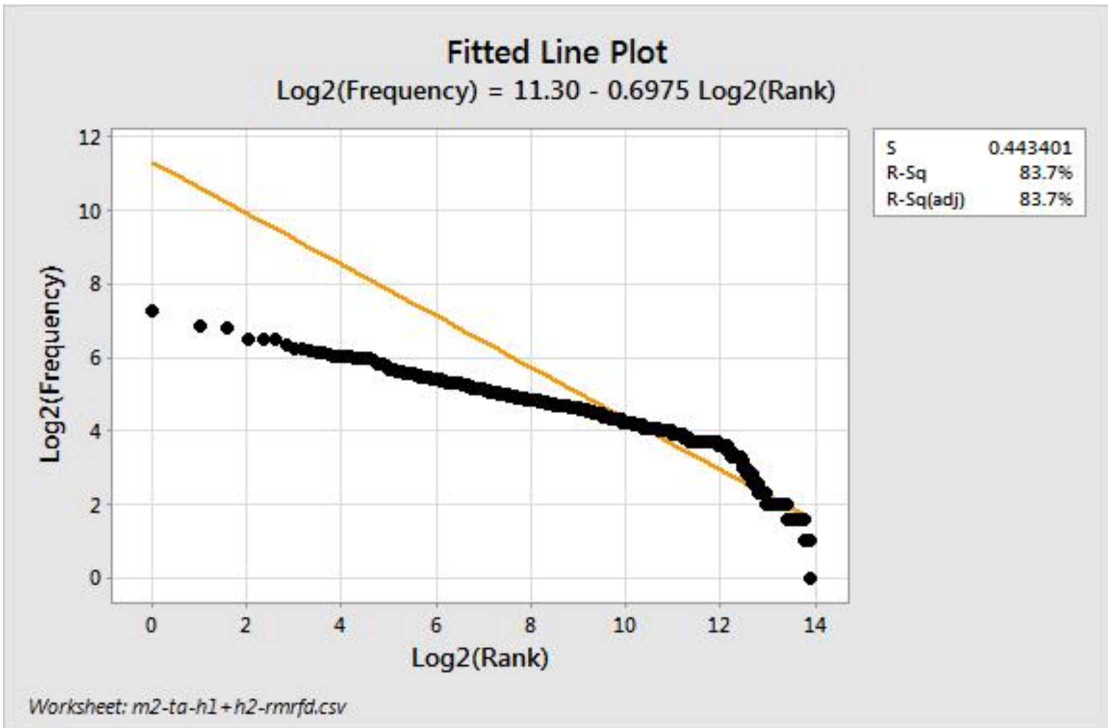
Fitted Line Plot
Log2(Frequency) = 12.26 - 0.7863 Log2(Rank)
S 0.787165
R-Sq 67.4%
R-Sq(adj) 67.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-t1-h1+h2-bdrfd.csv



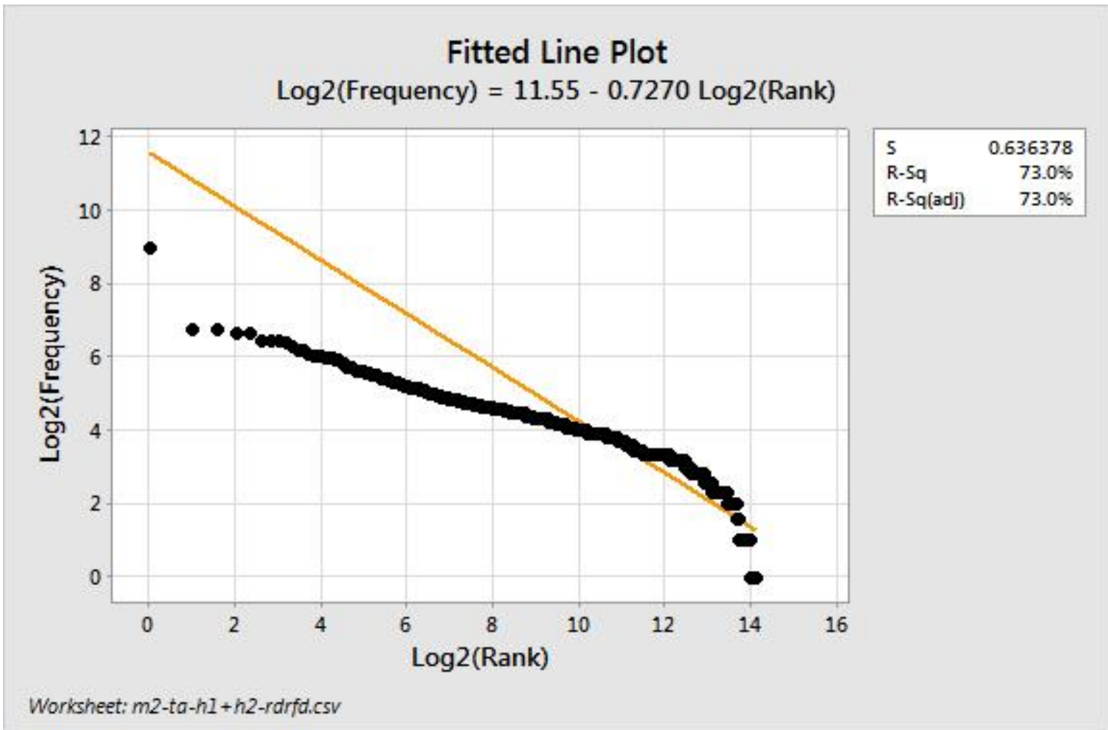
Fitted Line Plot
Log2(Frequency) = 10.51 - 0.6671 Log2(Rank)
S 0.456223
R-Sq 81.6%
R-Sq(adj) 81.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m1-t1-h1+h2-bcrfd.csv

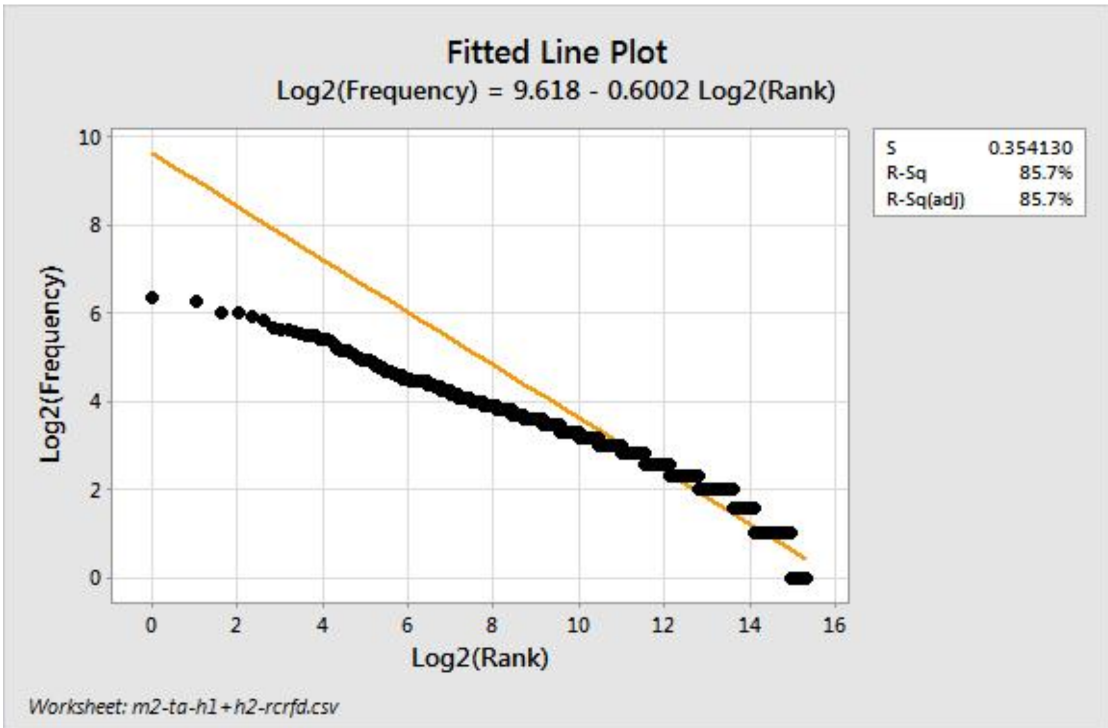


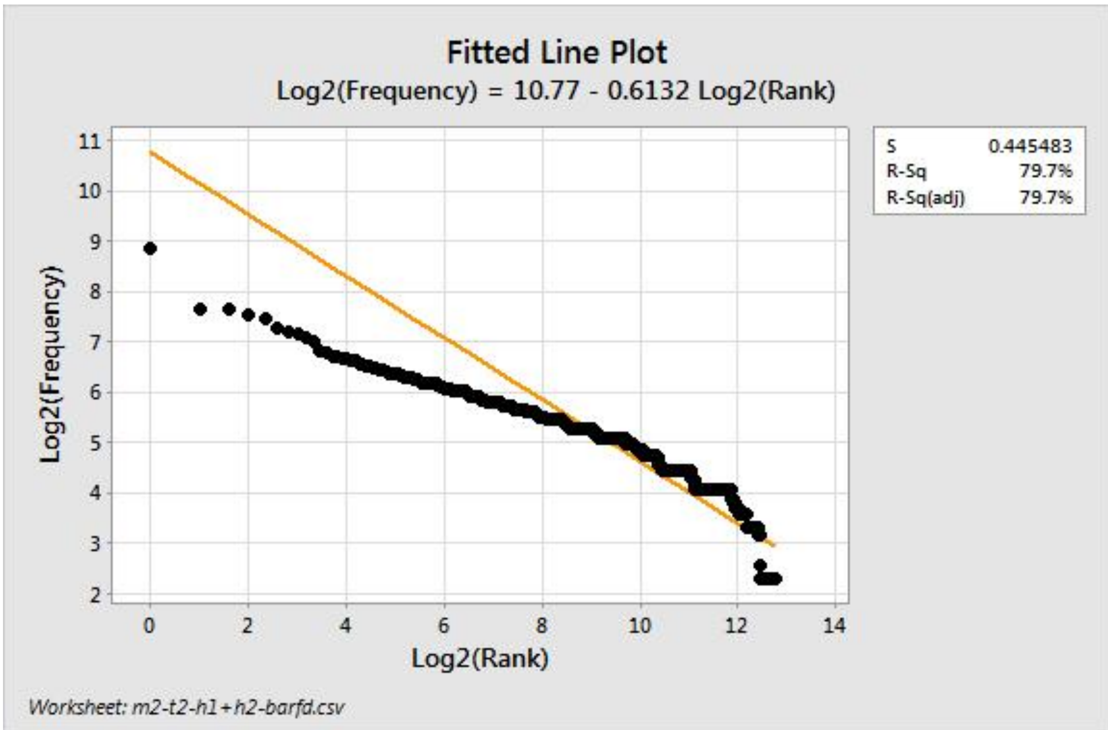
Fitted Line Plot
Log2(Frequency) = 12.04 - 0.7375 Log2(Rank)
S 0.678843
R-Sq 70.9%
R-Sq(adj) 70.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-ta-h1+h2-rarfd.csv

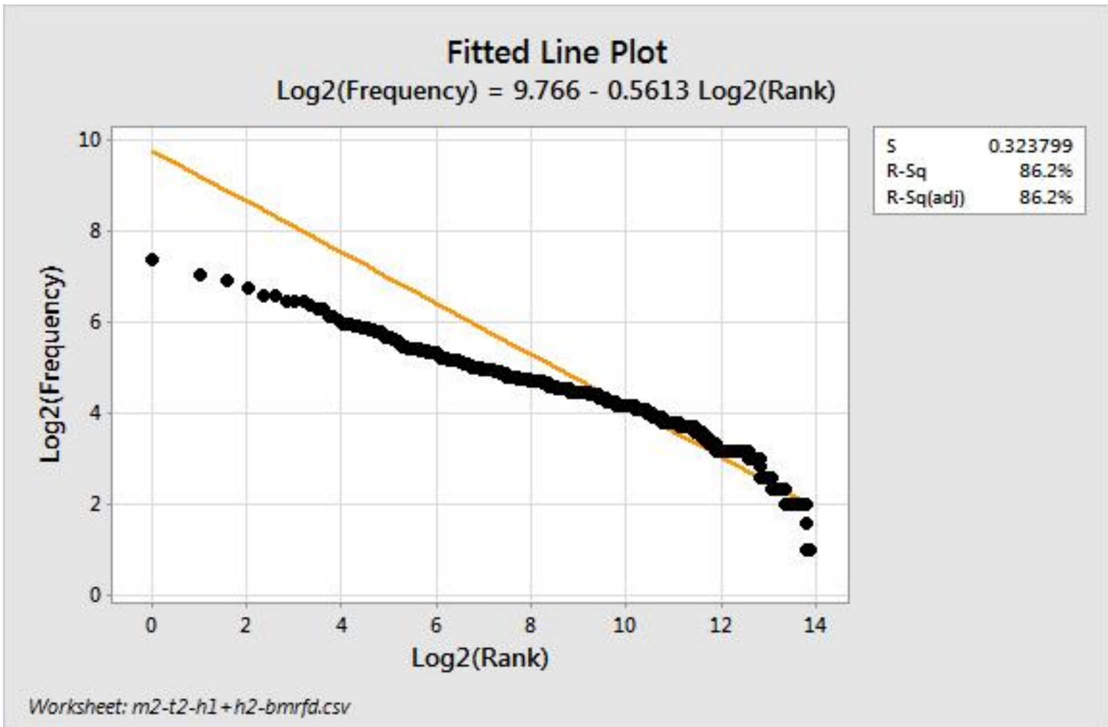


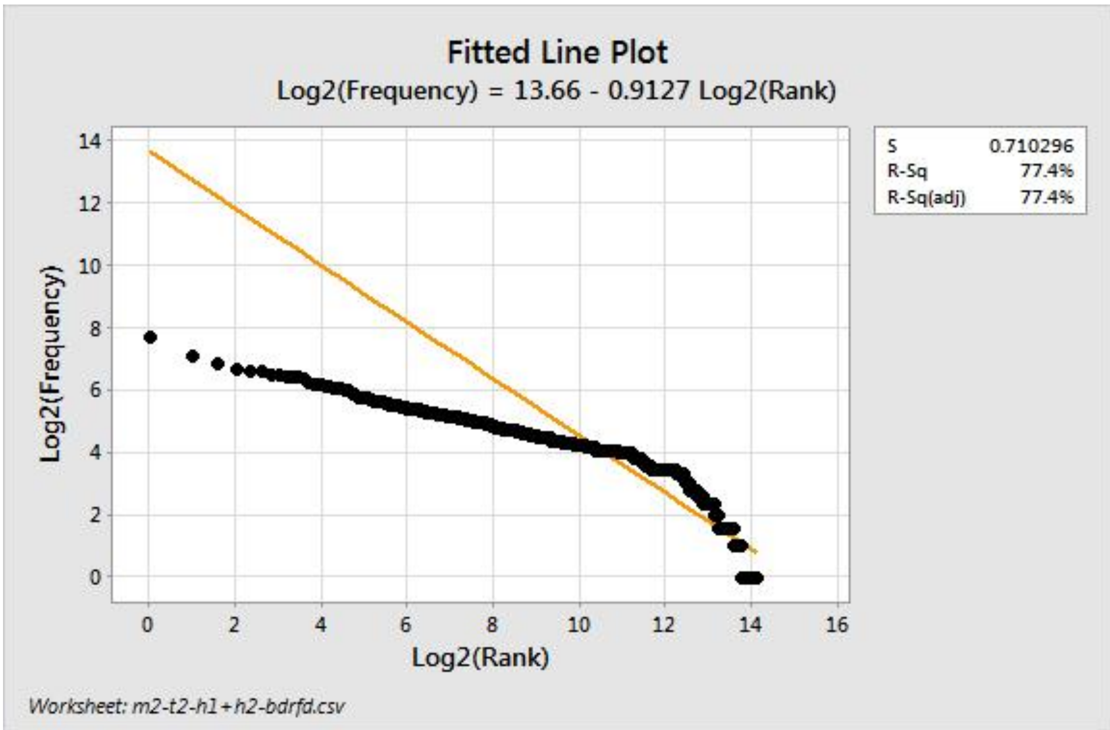
Fitted Line Plot
Log2(Frequency) = 11.30 - 0.6975 Log2(Rank)
S 0.443401
R-Sq 83.7%
R-Sq(adj) 83.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-ta-h1+h2-rmrfd.csv

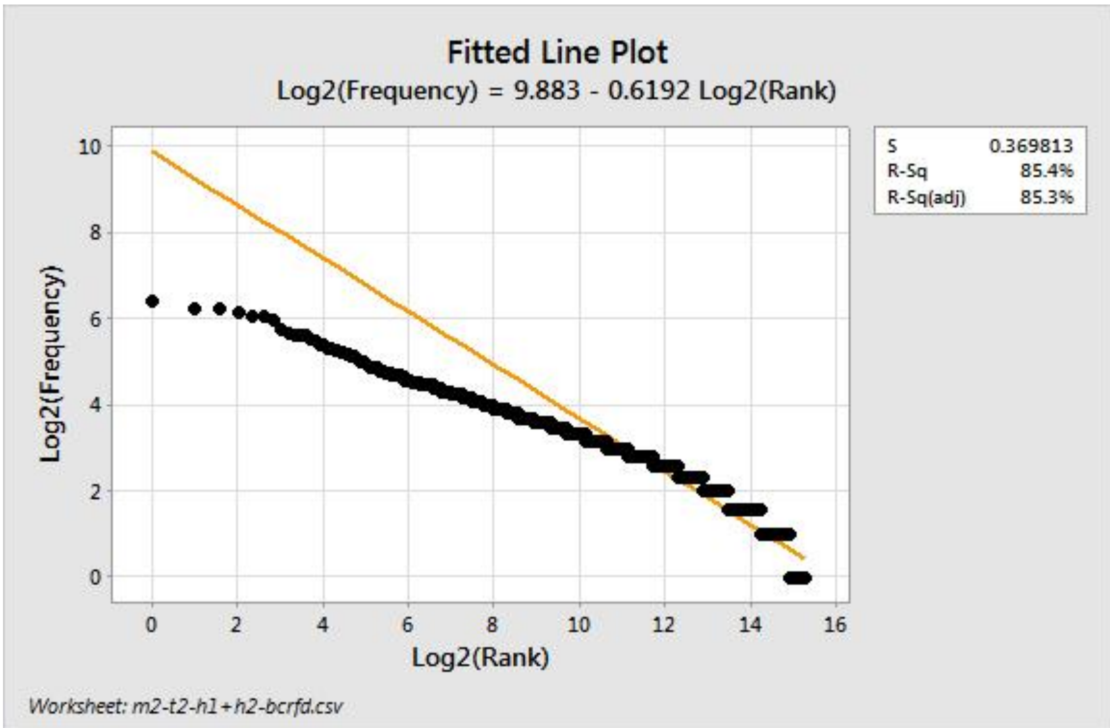

Fitted Line Plot
Log2(Frequency) = 11.55 - 0.7270 Log2(Rank)
S 0.636378
R-Sq 73.0%
R-Sq(adj) 73.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-ta-h1+h2-rdrfd.csv

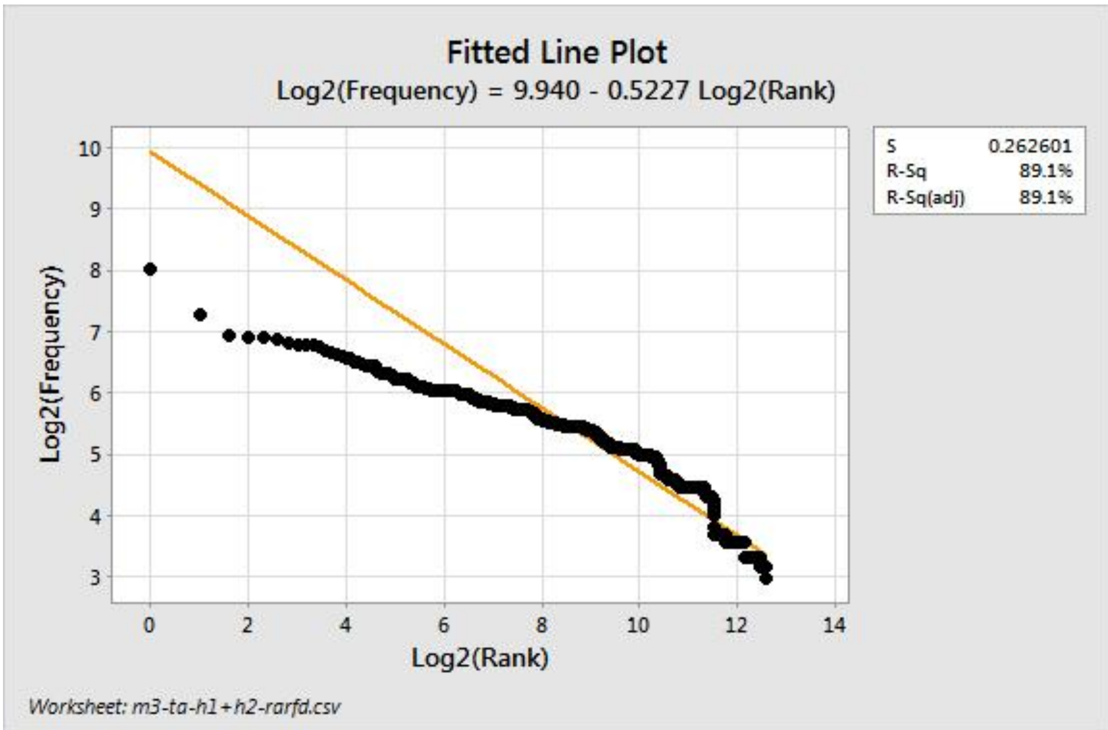

Fitted Line Plot
Log2(Frequency) = 9.618 - 0.6002 Log2(Rank)
S 0.354130
R-Sq 85.7%
R-Sq(adj) 85.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-ta-h1+h2-rcrfd.csv

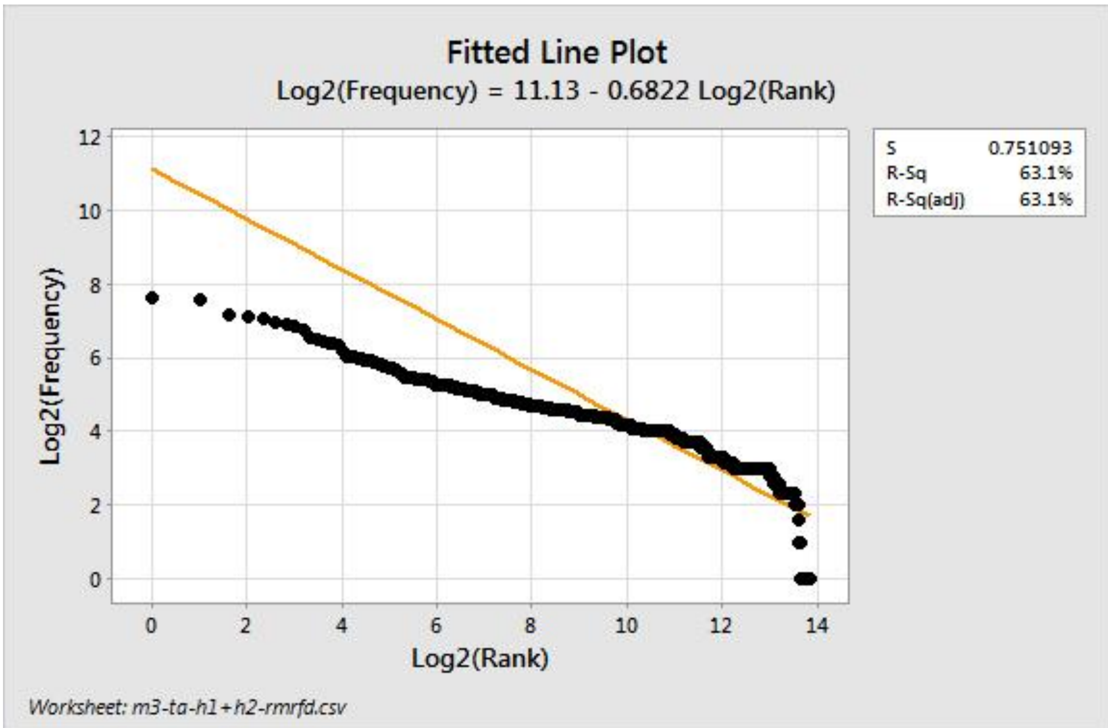

Fitted Line Plot
Log2(Frequency) = 10.77 - 0.6132 Log2(Rank)
S 0.445483
R-Sq 79.7%
R-Sq(adj) 79.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-t2-h1+h2-barfd.csv

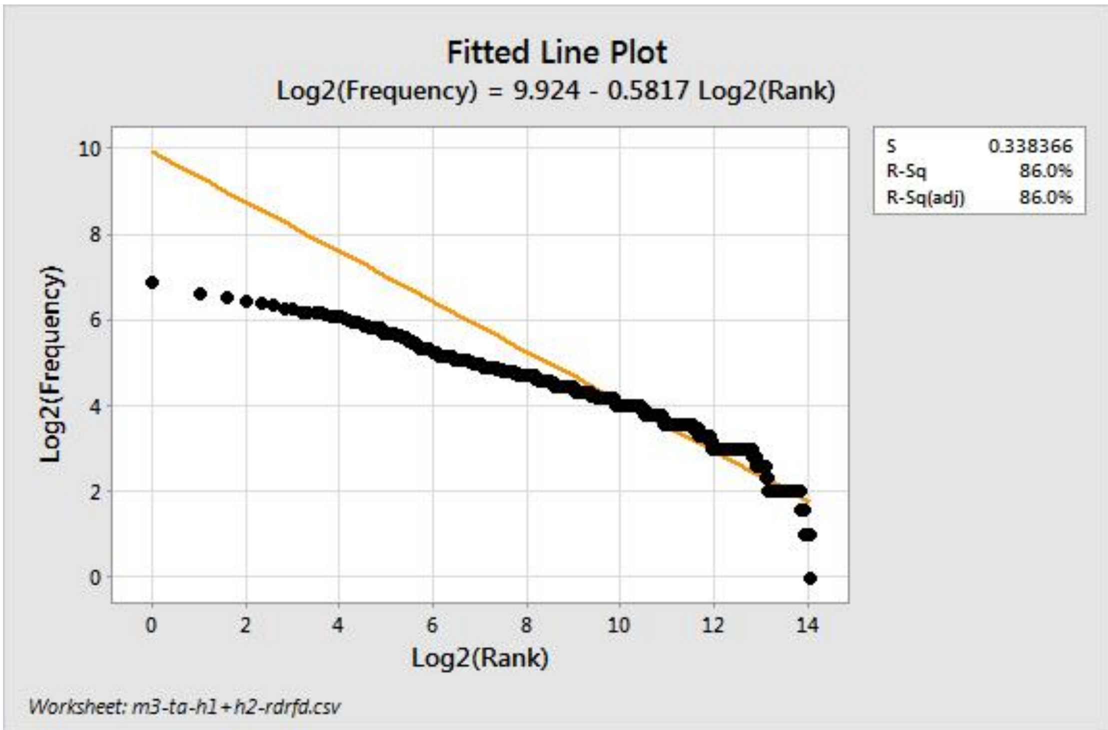

Fitted Line Plot
Log2(Frequency) = 9.766 - 0.5613 Log2(Rank)
S 0.323799
R-Sq 86.2%
R-Sq(adj) 86.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-t2-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.66 - 0.9127 Log2(Rank)
S 0.710296
R-Sq 77.4%
R-Sq(adj) 77.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-t2-h1+h2-bdrfd.csv

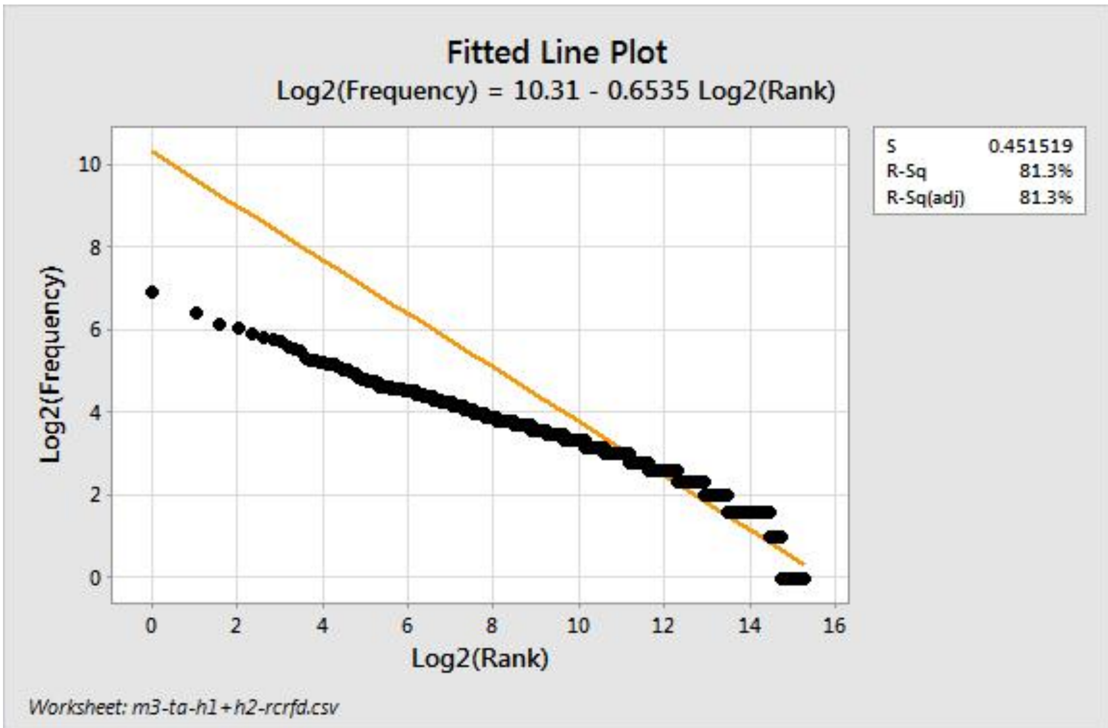

Fitted Line Plot
Log2(Frequency) = 9.883 - 0.6192 Log2(Rank)
S 0.369813
R-Sq 85.4%
R-Sq(adj) 85.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m2-t2-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 9.940 - 0.5227 Log2(Rank)
S 0.262601
R-Sq 89.1%
R-Sq(adj) 89.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-ta-h1+h2-rarfd.csv

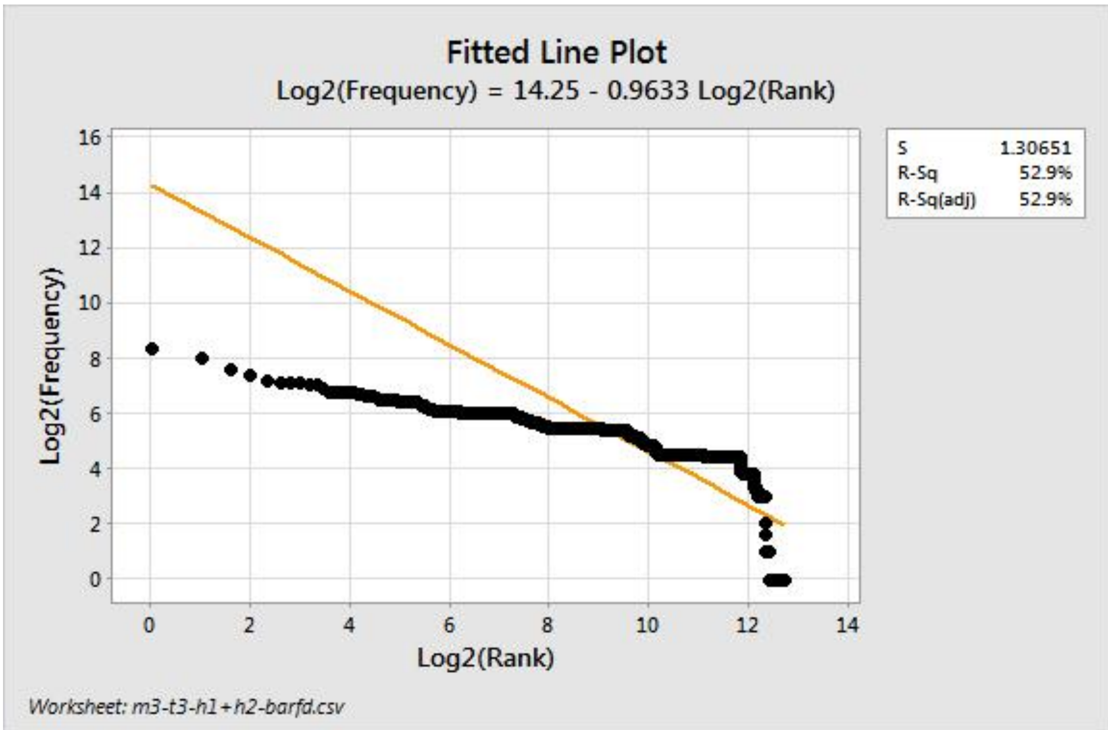

Fitted Line Plot
Log2(Frequency) = 11.13 - 0.6822 Log2(Rank)
S 0.751093
R-Sq 63.1%
R-Sq(adj) 63.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-ta-h1+h2-rmrfd.csv

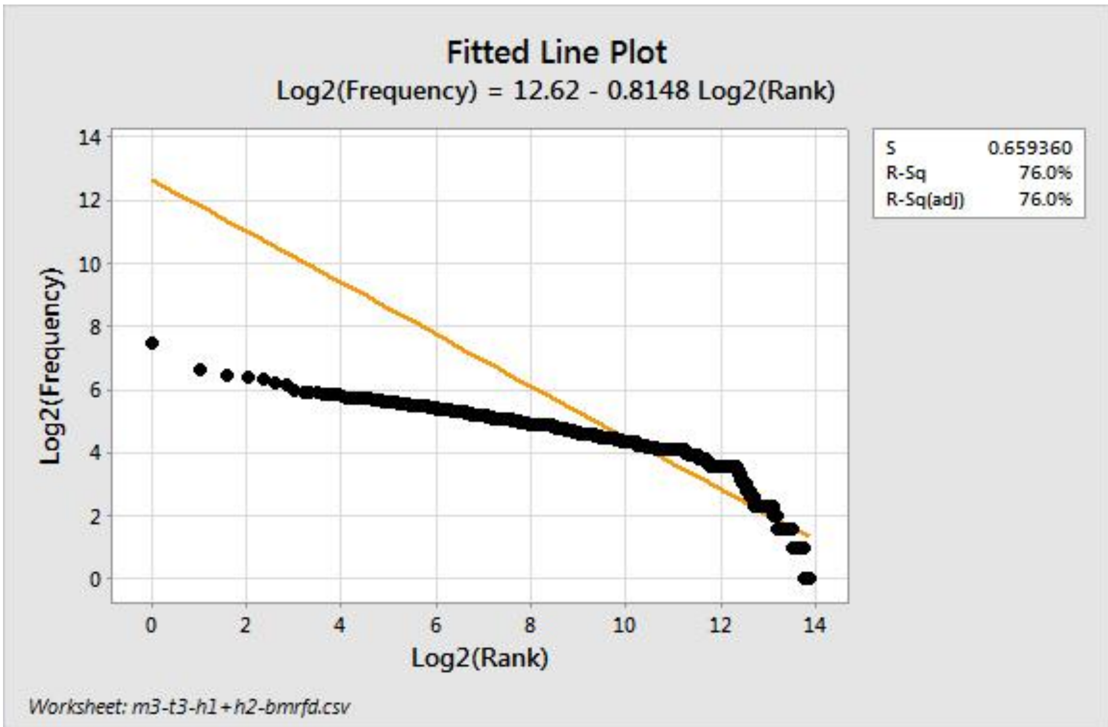


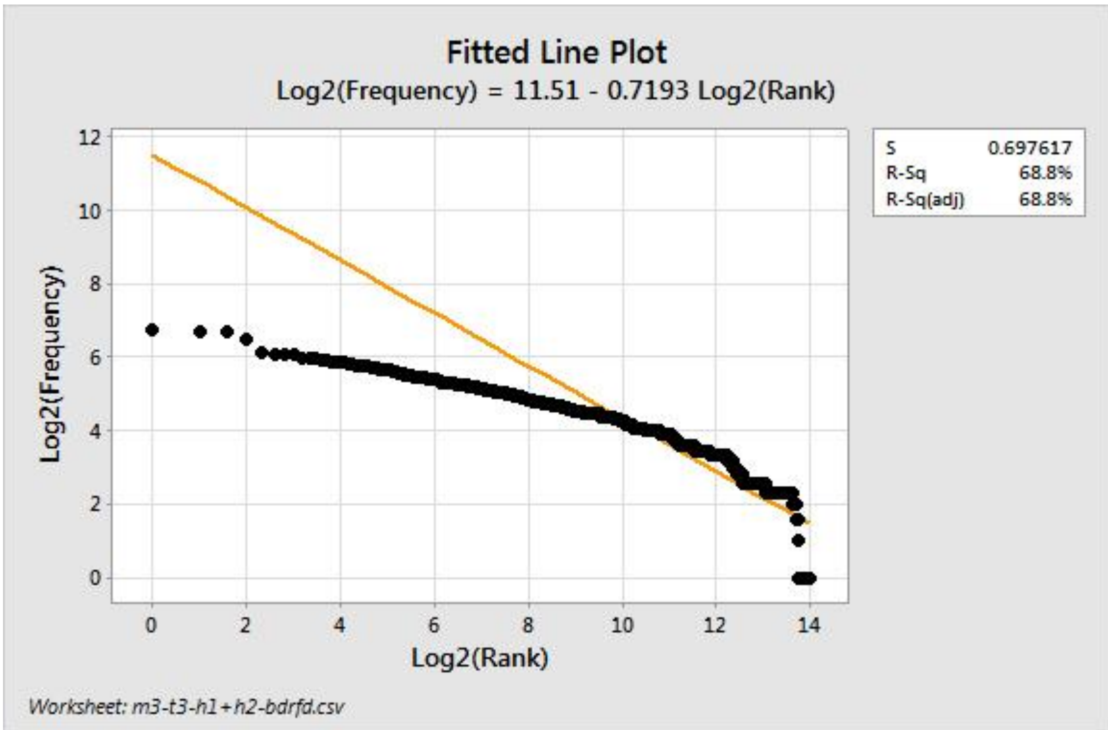
Fitted Line Plot
Log2(Frequency) = 9.924 - 0.5817 Log2(Rank)
S 0.338366
R-Sq 86.0%
R-Sq(adj) 86.0%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m3-ta-h1+h2-rdrfd.csv

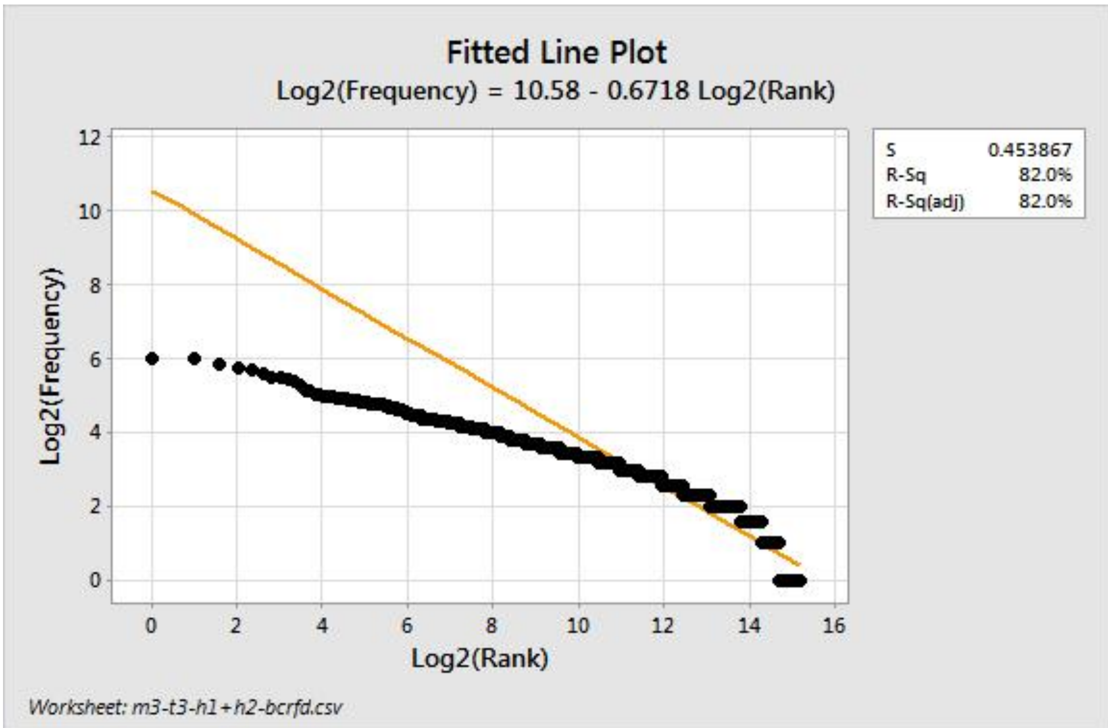


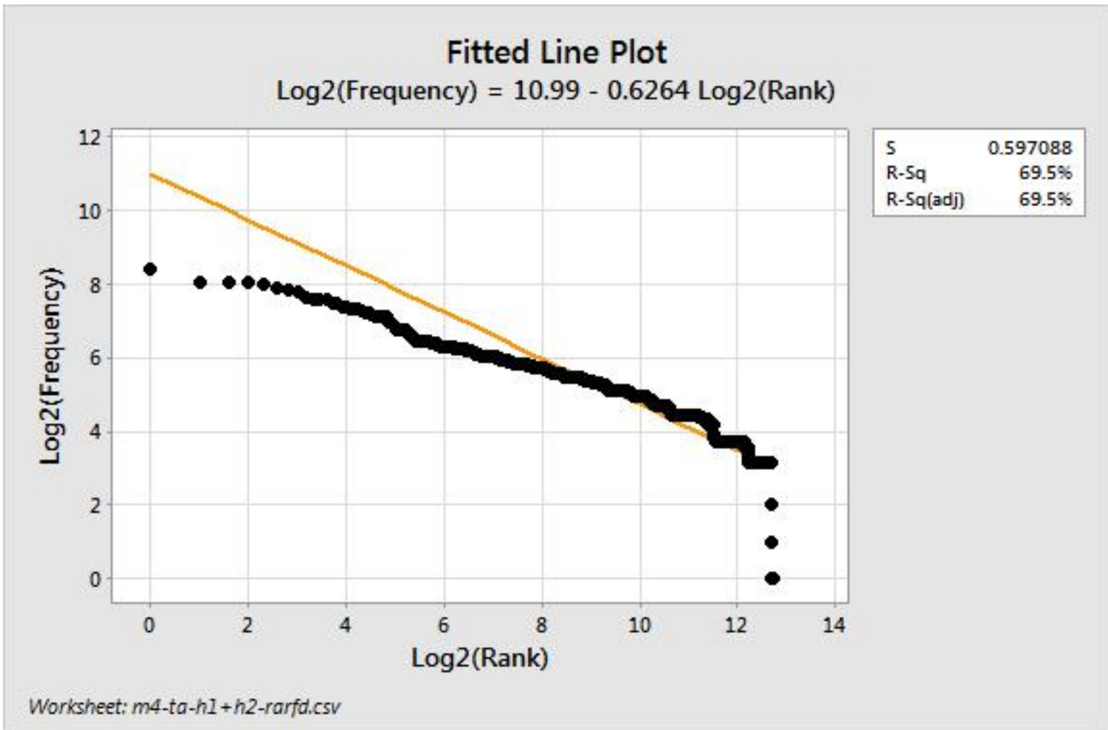
Fitted Line Plot
Log2(Frequency) = 10.31 - 0.6535 Log2(Rank)
S 0.451519
R-Sq 81.3%
R-Sq(adj) 81.3%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m3-ta-h1+h2-rcrfd.csv

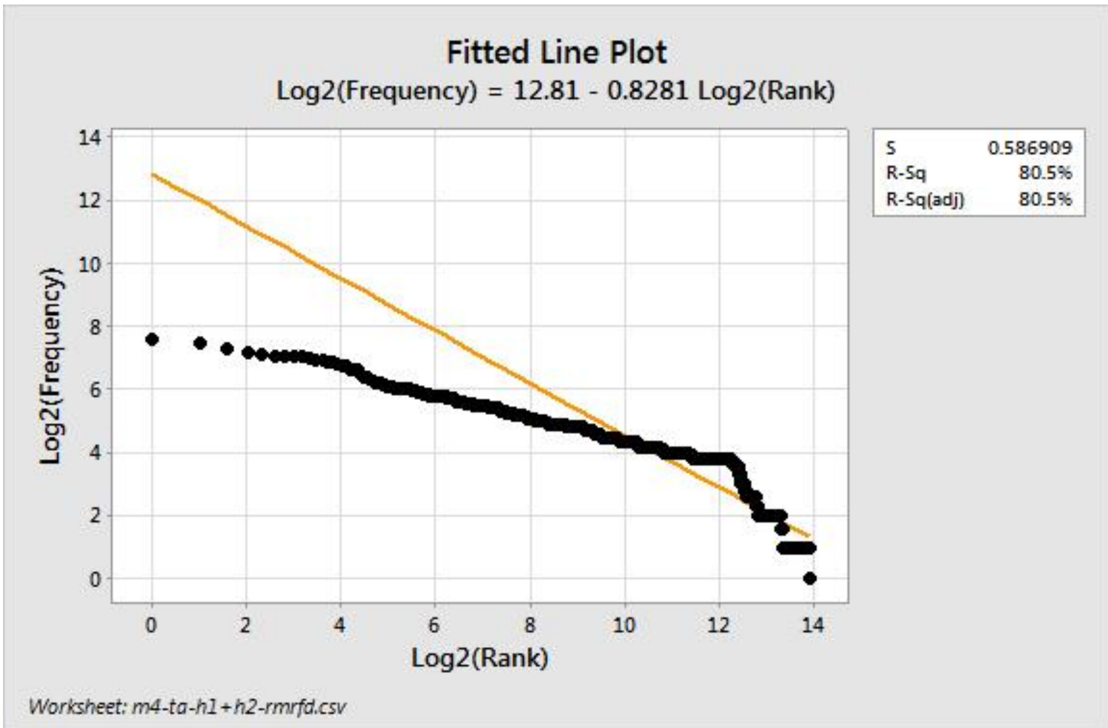

Fitted Line Plot
Log2(Frequency) = 14.25 - 0.9633 Log2(Rank)
S 1.30651
R-Sq 52.9%
R-Sq(adj) 52.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3-h1+h2-barfd.csv

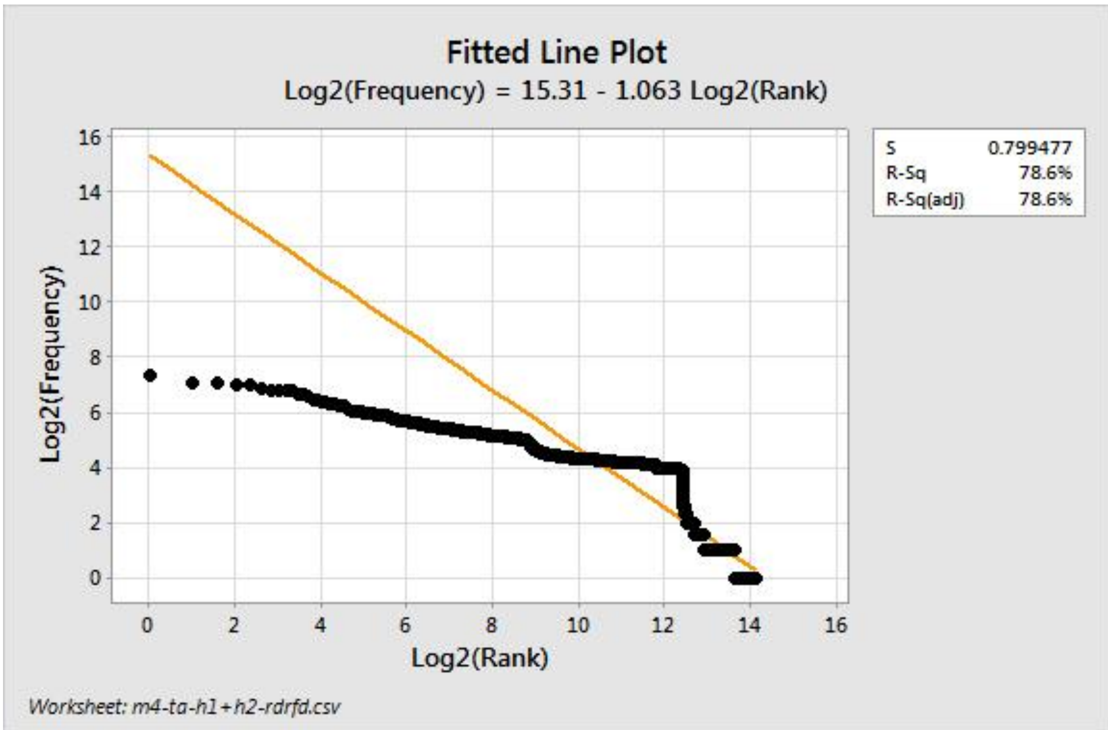

Fitted Line Plot
Log2(Frequency) = 12.62 - 0.8148 Log2(Rank)
S 0.659360
R-Sq 76.0%
R-Sq(adj) 76.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3-h1+h2-bmrfd.csv

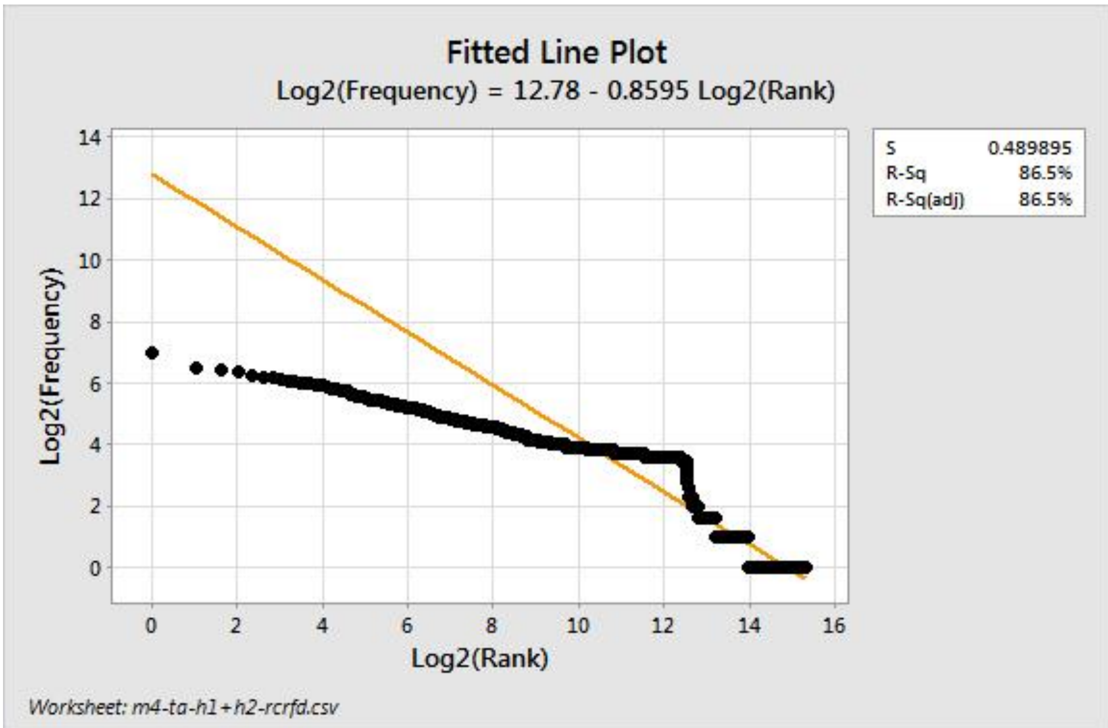

Fitted Line Plot
Log2(Frequency) = 11.51 - 0.7193 Log2(Rank)
S 0.697617
R-Sq 68.8%
R-Sq(adj) 68.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3-h1+h2-bdrfd.csv

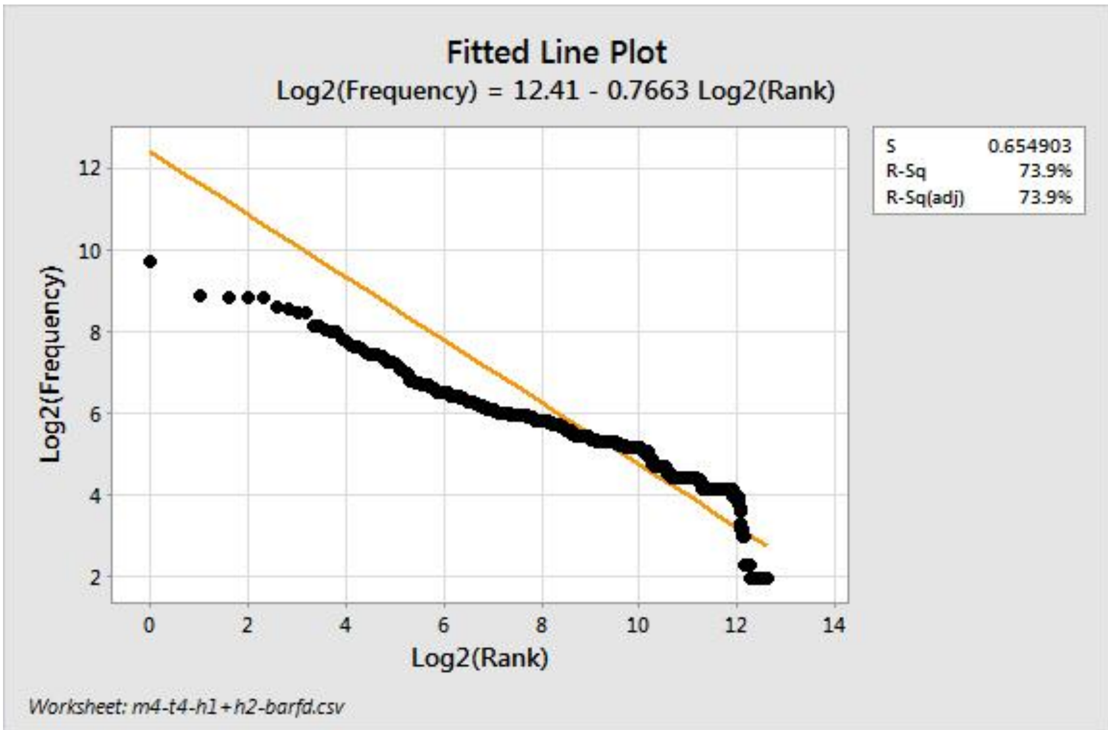

Fitted Line Plot
Log2(Frequency) = 10.58 - 0.6718 Log2(Rank)
S 0.453867
R-Sq 82.0%
R-Sq(adj) 82.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m3-t3-h1+h2-bcrfd.csv

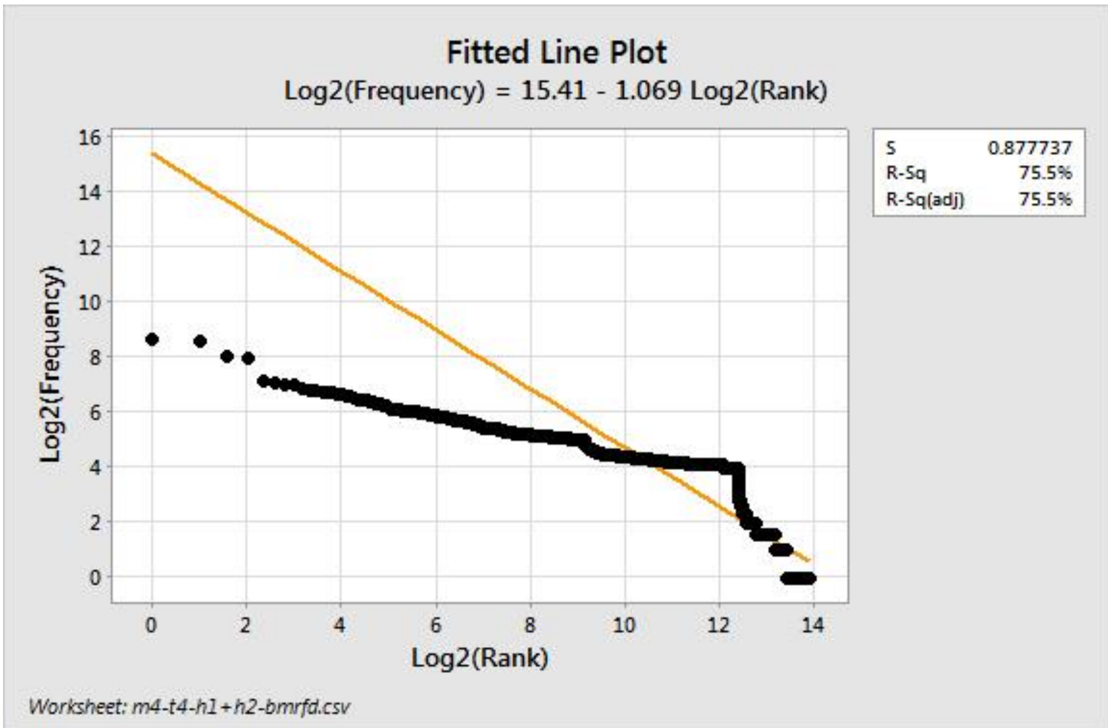

Fitted Line Plot
Log2(Frequency) = 10.99 - 0.6264 Log2(Rank)
S 0.597088
R-Sq 69.5%
R-Sq(adj) 69.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-ta-h1+h2-rarfd.csv

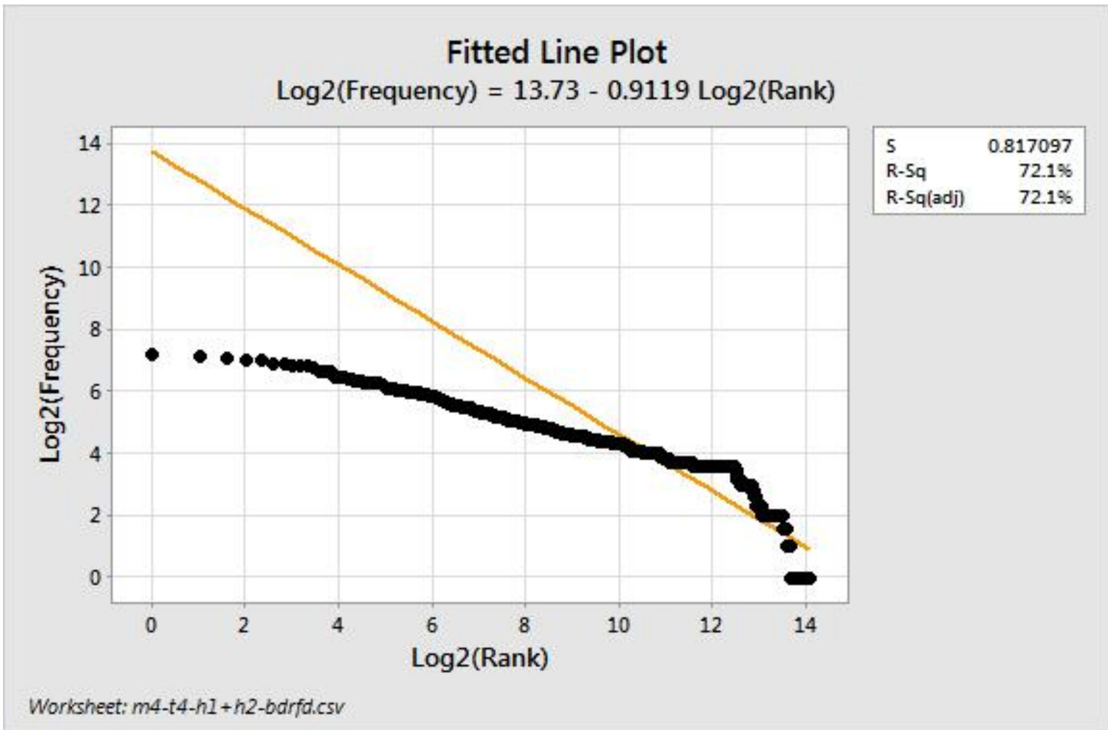

Fitted Line Plot
Log2(Frequency) = 12.81 - 0.8281 Log2(Rank)
S 0.586909
R-Sq 80.5%
R-Sq(adj) 80.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 15.31 - 1.063 Log2(Rank)
S 0.799477
R-Sq 78.6%
R-Sq(adj) 78.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-ta-h1+h2-rdrfd.csv

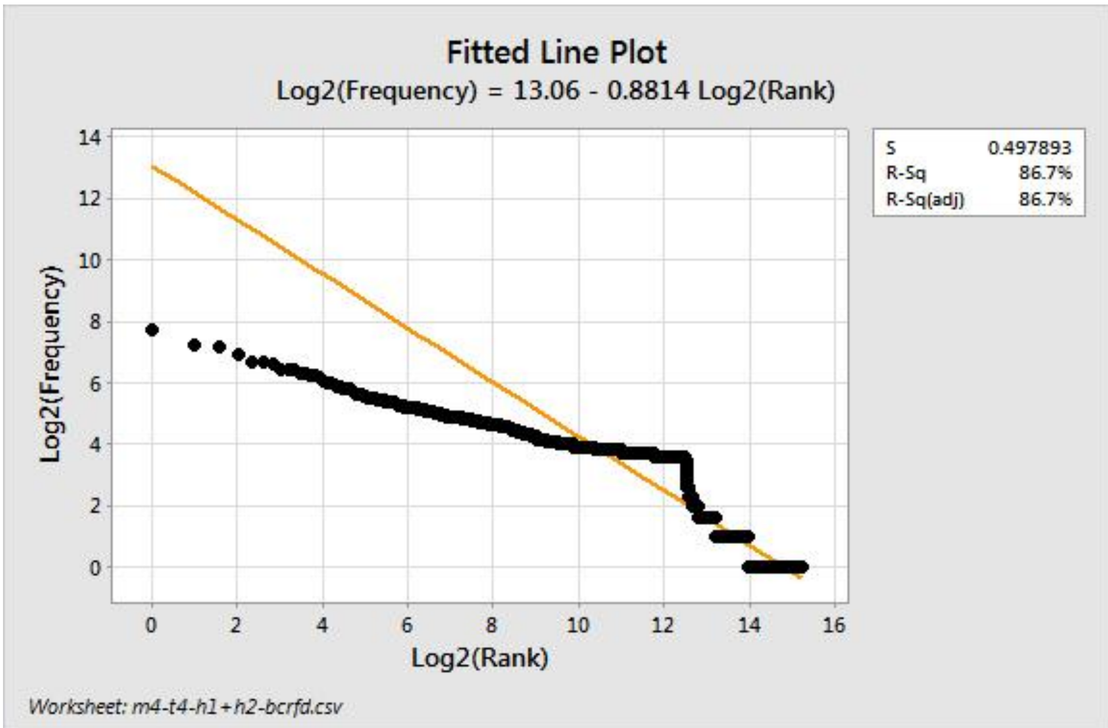

Fitted Line Plot
Log2(Frequency) = 12.78 - 0.8595 Log2(Rank)
S 0.489895
R-Sq 86.5%
R-Sq(adj) 86.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 12.41 - 0.7663 Log2(Rank)
S 0.654903
R-Sq 73.9%
R-Sq(adj) 73.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-t4-h1+h2-barfd.csv

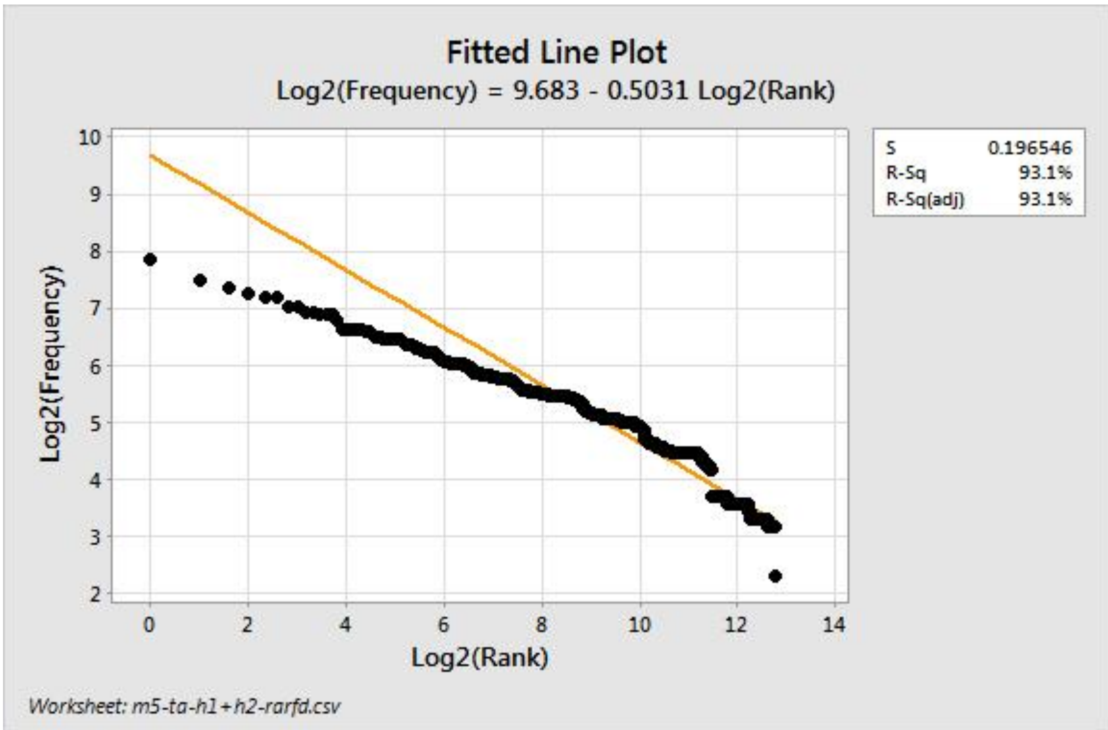

Fitted Line Plot
Log2(Frequency) = 15.41 - 1.069 Log2(Rank)
S 0.877737
R-Sq 75.5%
R-Sq(adj) 75.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-t4-h1+h2-bmrfd.csv

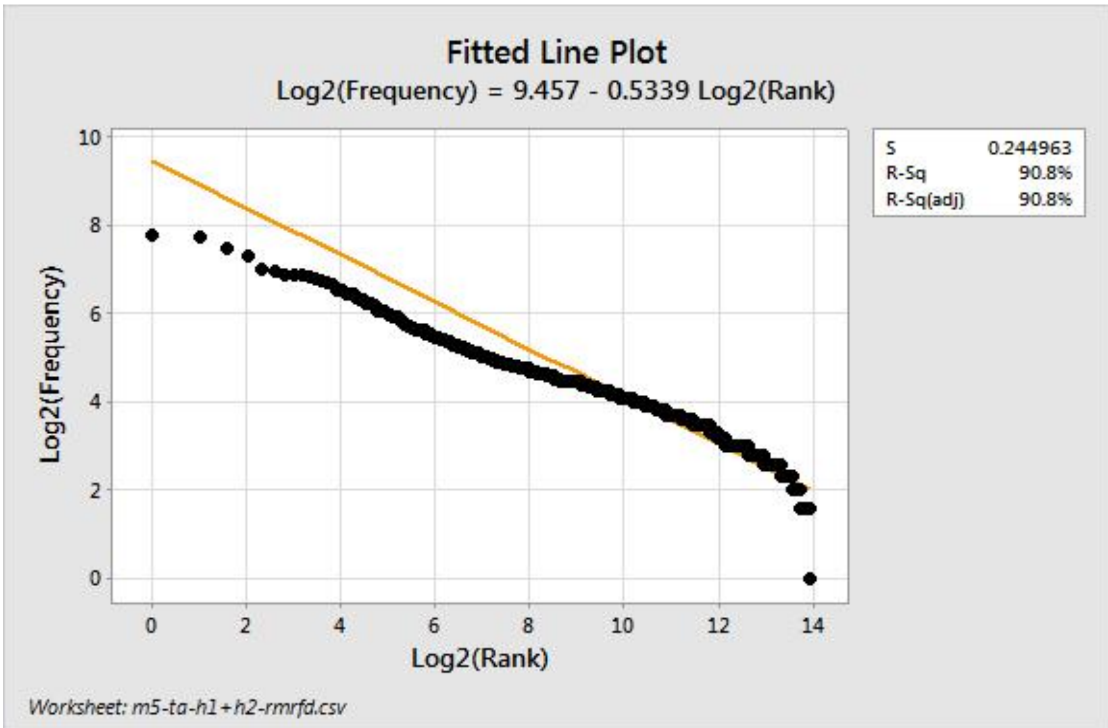


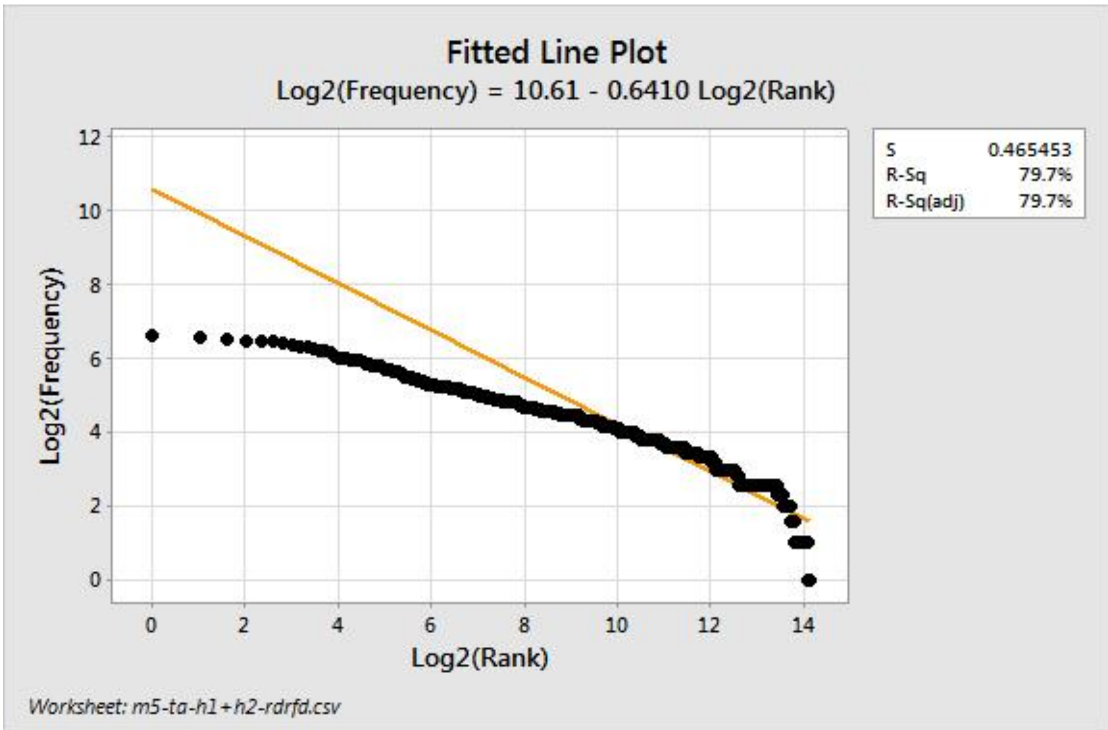
Fitted Line Plot
Log2(Frequency) = 13.73 - 0.9119 Log2(Rank)
S 0.817097
R-Sq 72.1%
R-Sq(adj) 72.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-t4-h1+h2-bdrfd.csv



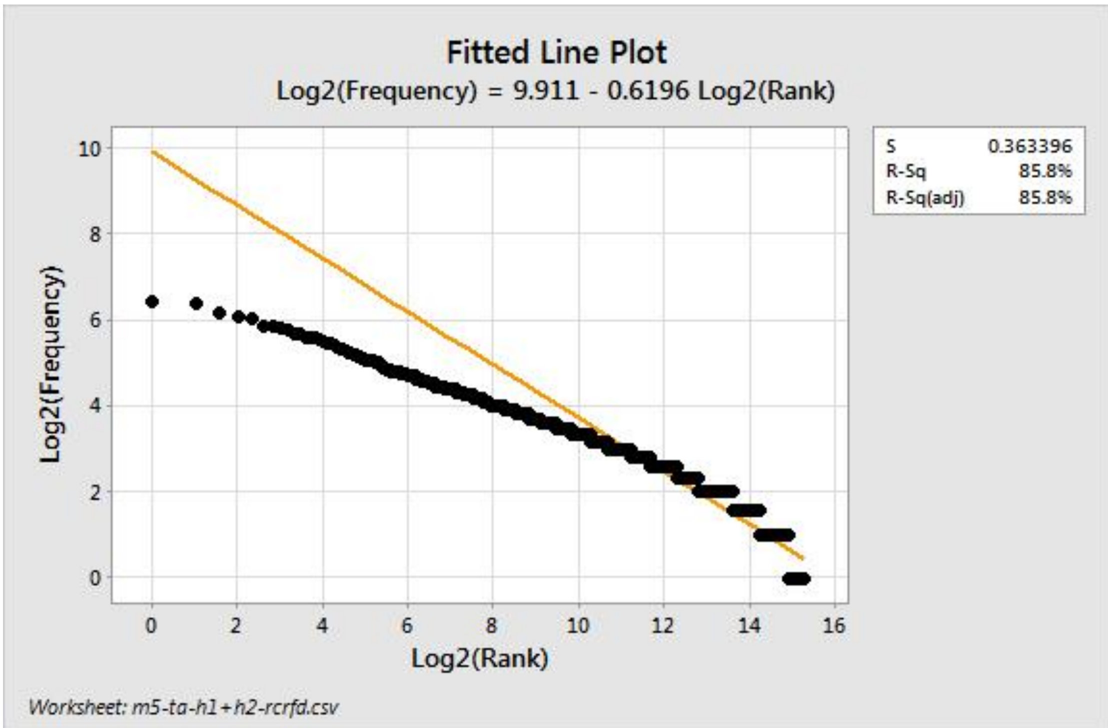
Fitted Line Plot
Log2(Frequency) = 13.06 - 0.8814 Log2(Rank)
S 0.497893
R-Sq 86.7%
R-Sq(adj) 86.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m4-t4-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 9.683 - 0.5031 Log2(Rank)
S 0.196546
R-Sq 93.1%
R-Sq(adj) 93.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-ta-h1+h2-rarfd.csv

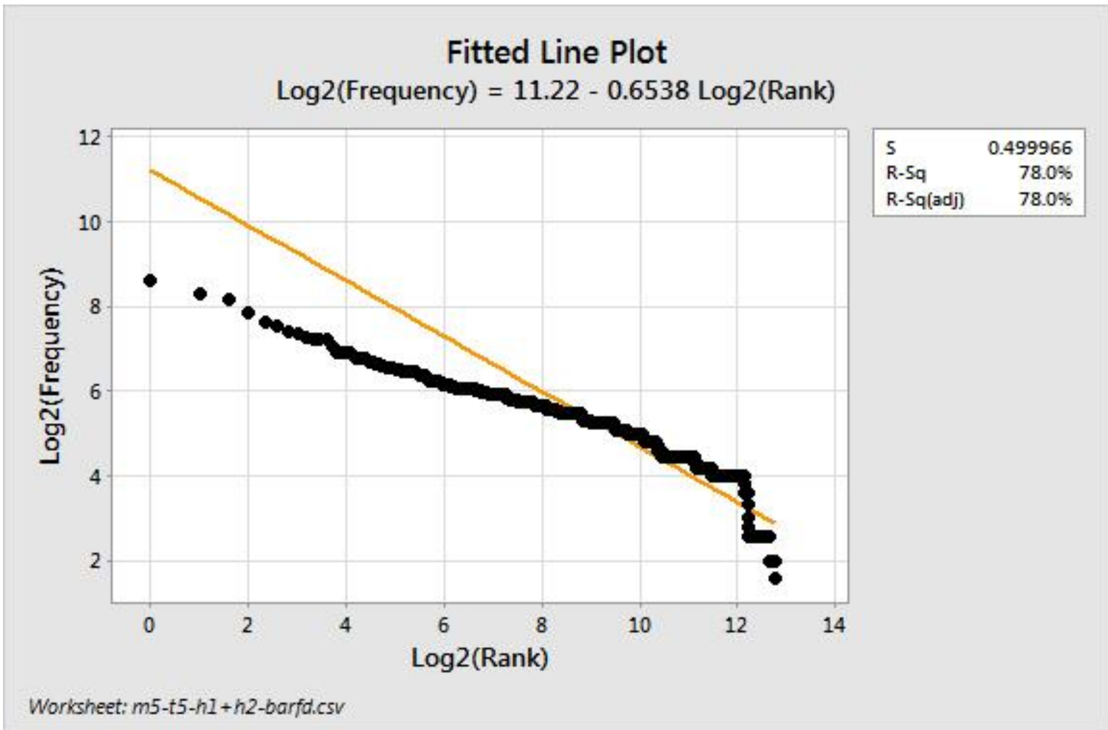

Fitted Line Plot
Log2(Frequency) = 9.457 - 0.5339 Log2(Rank)
S 0.244963
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-ta-h1+h2-rmrfd.csv

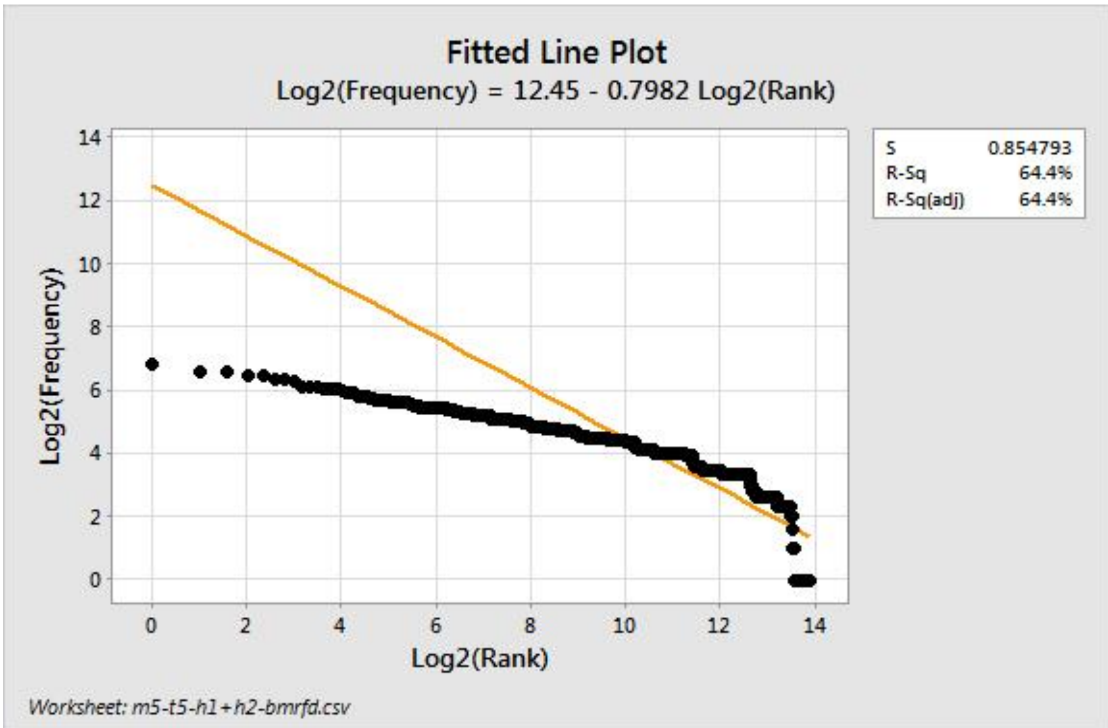


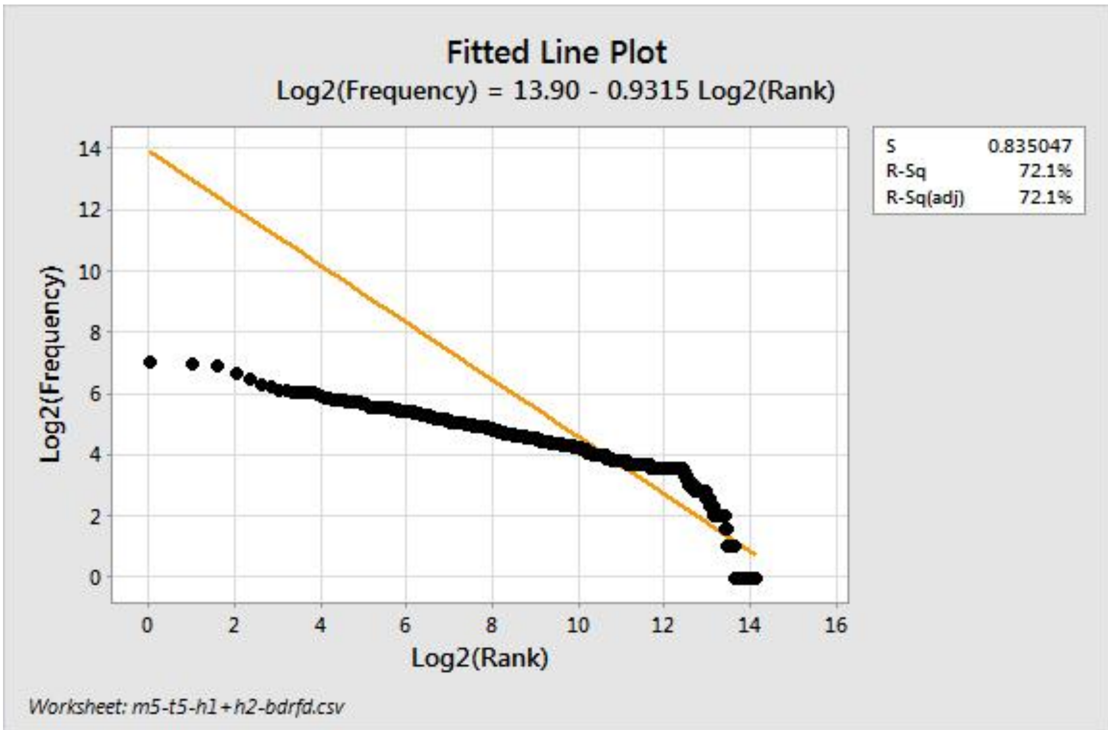
Fitted Line Plot
Log2(Frequency) = 10.61 - 0.6410 Log2(Rank)
S 0.465453
R-Sq 79.7%
R-Sq(adj) 79.7%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m5-ta-h1+h2-rdrfd.csv

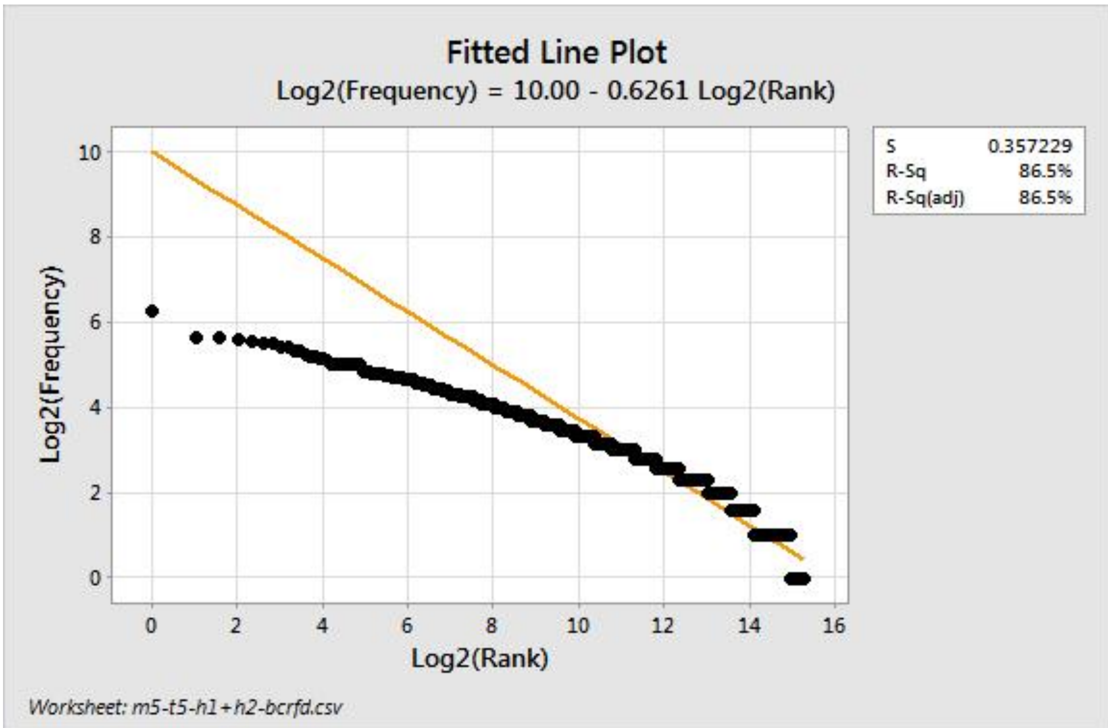


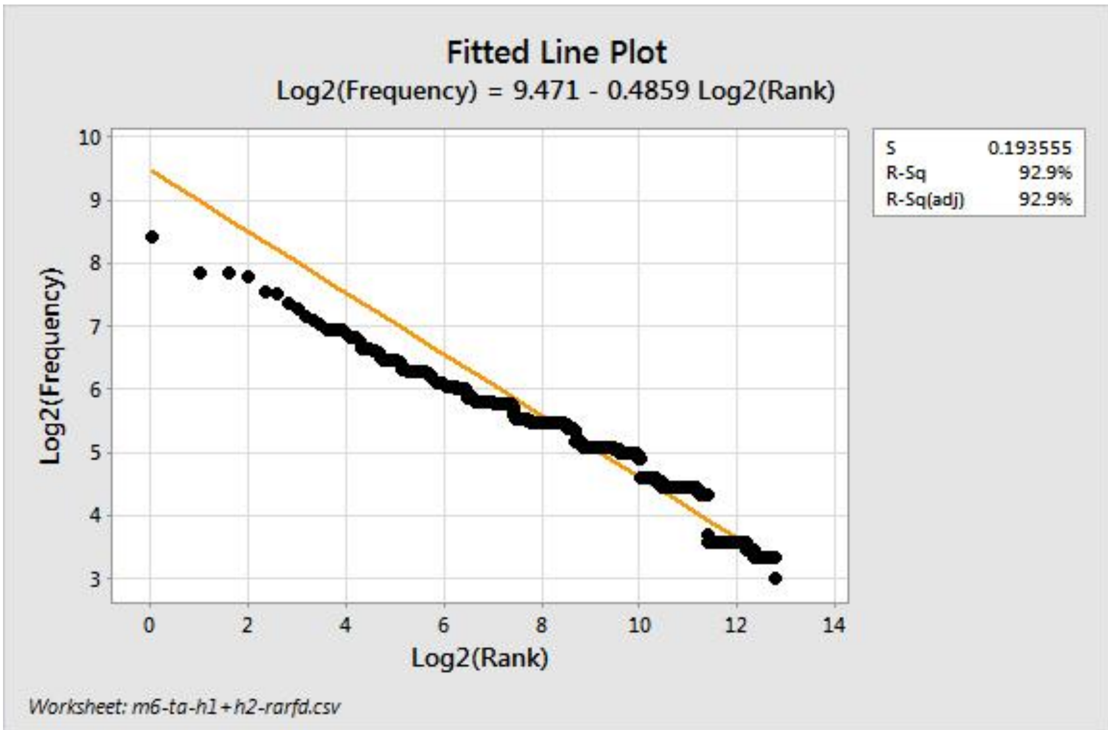
Fitted Line Plot
Log2(Frequency) = 9.911 - 0.6196 Log2(Rank)
S 0.363396
R-Sq 85.8%
R-Sq(adj) 85.8%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m5-ta-h1+h2-rcrfd.csv

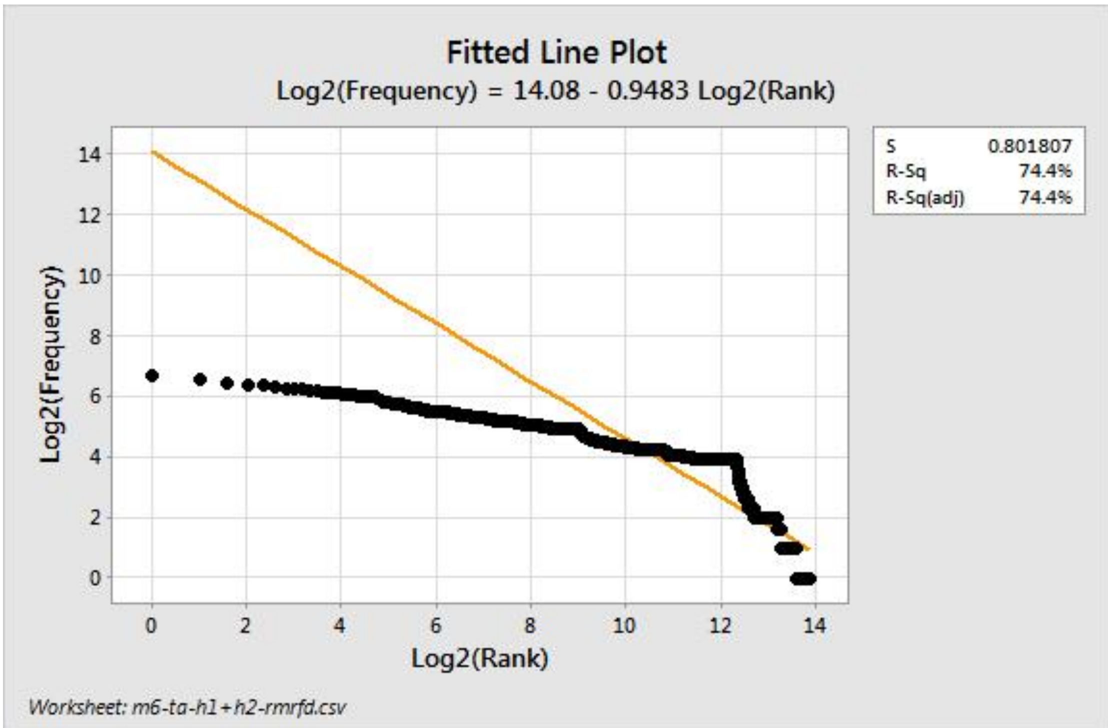

Fitted Line Plot
Log2(Frequency) = 11.22 - 0.6538 Log2(Rank)
S 0.499966
R-Sq 78.0%
R-Sq(adj) 78.0%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m5-t5-h1+h2-barfd.csv

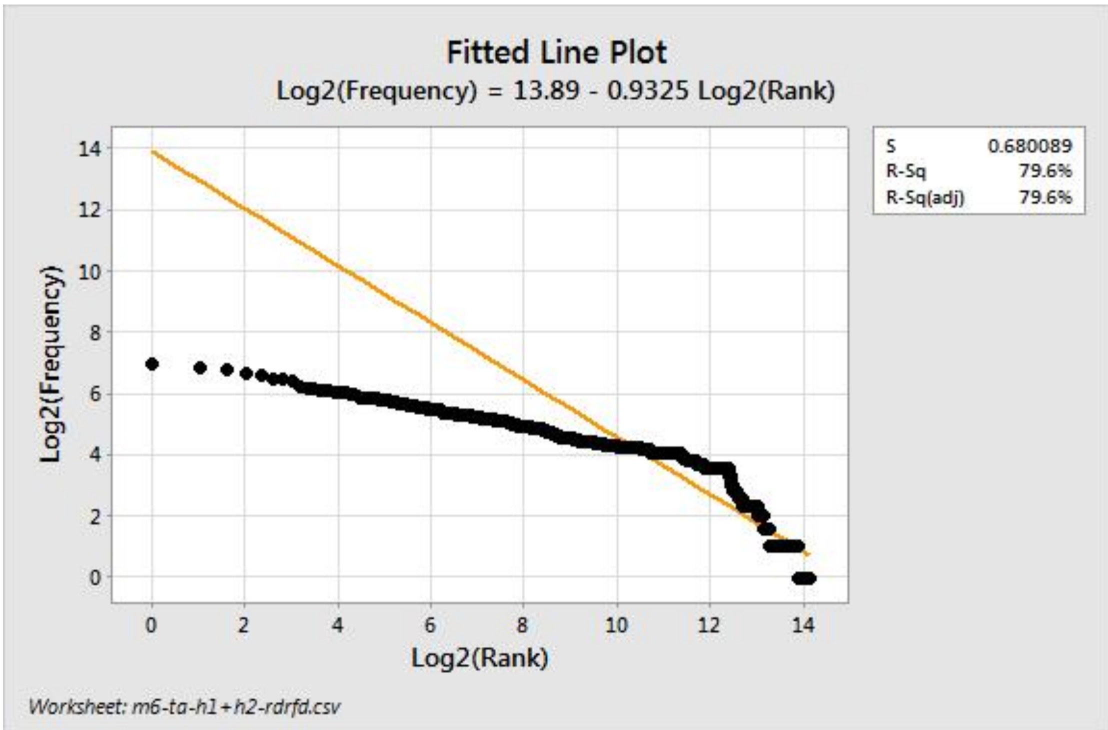

Fitted Line Plot
Log2(Frequency) = 12.45 - 0.7982 Log2(Rank)
S 0.854793
R-Sq 64.4%
R-Sq(adj) 64.4%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m5-t5-h1+h2-bmrfd.csv

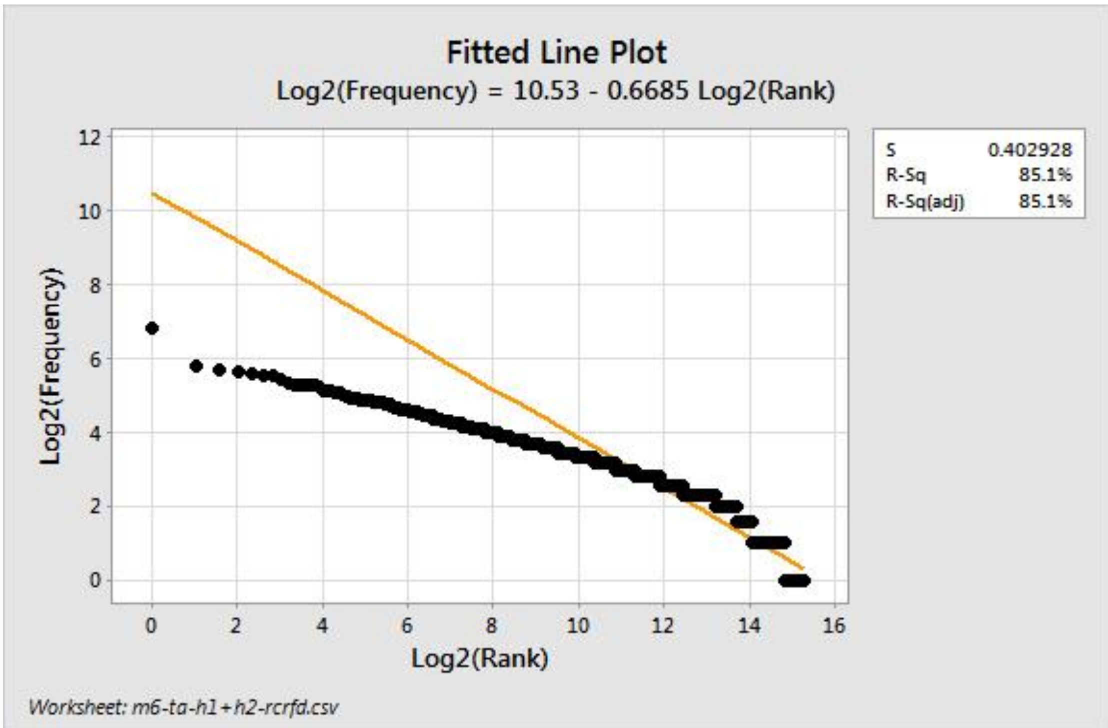

Fitted Line Plot
Log2(Frequency) = 13.90 - 0.9315 Log2(Rank)
S 0.835047
R-Sq 72.1%
R-Sq(adj) 72.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-t5-h1+h2-bdrfd.csv

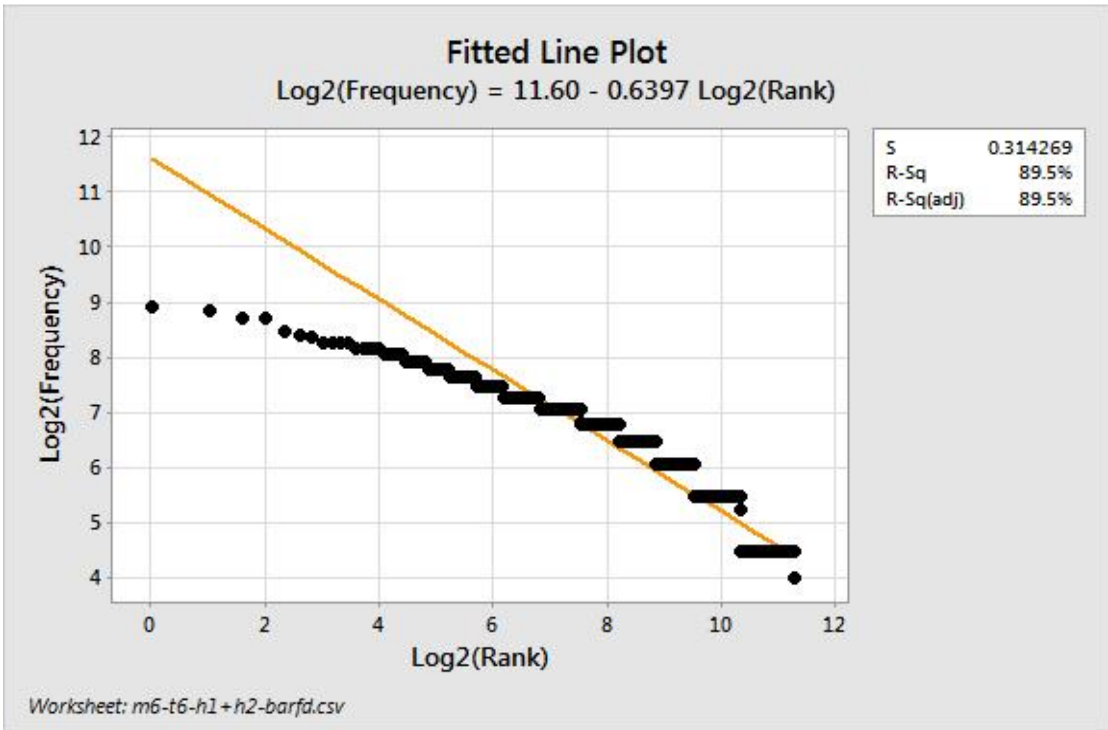

Fitted Line Plot
Log2(Frequency) = 10.00 - 0.6261 Log2(Rank)
S 0.357229
R-Sq 86.5%
R-Sq(adj) 86.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m5-t5-h1+h2-bcrfd.csv

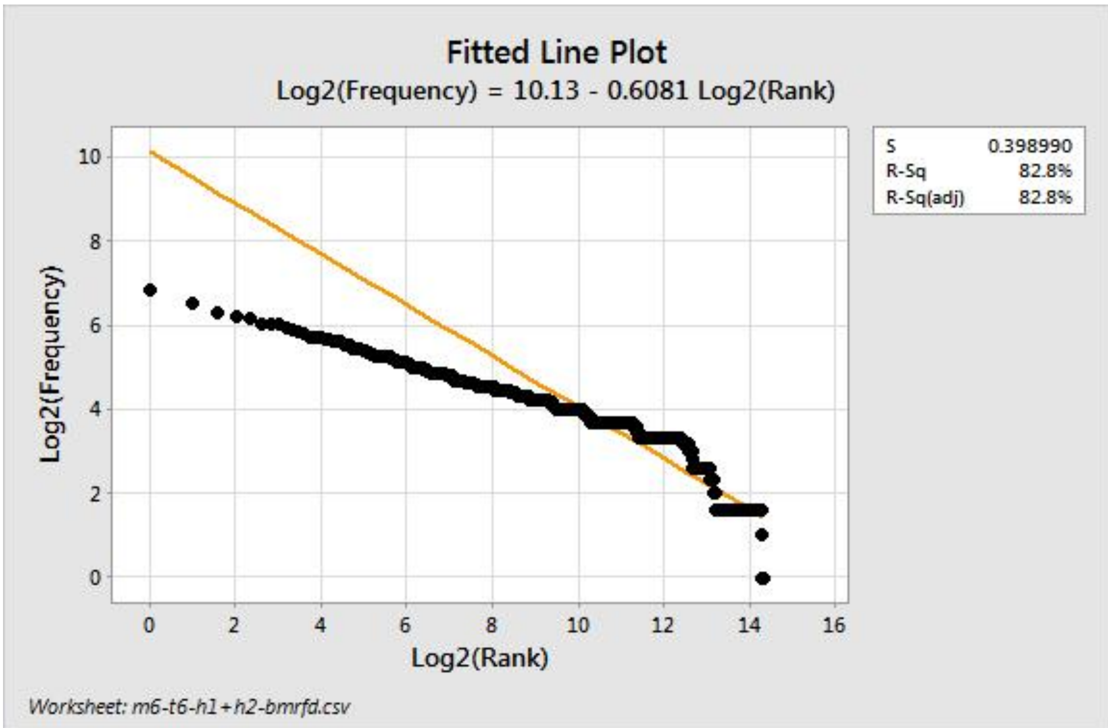

Fitted Line Plot
Log2(Frequency) = 9.471 - 0.4859 Log2(Rank)
S 0.193555
R-Sq 92.9%
R-Sq(adj) 92.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-ta-h1+h2-rarfd.csv

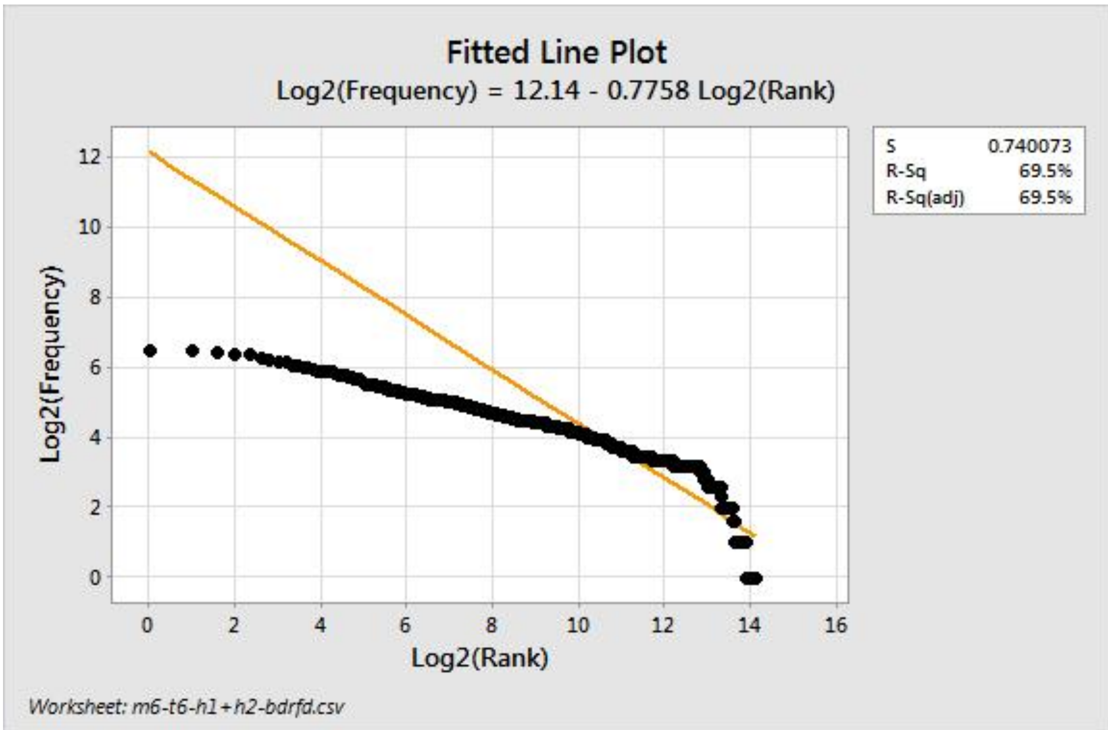

Fitted Line Plot
Log2(Frequency) = 14.08 - 0.9483 Log2(Rank)
S 0.801807
R-Sq 74.4%
R-Sq(adj) 74.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-ta-h1+h2-rmrfd.csv

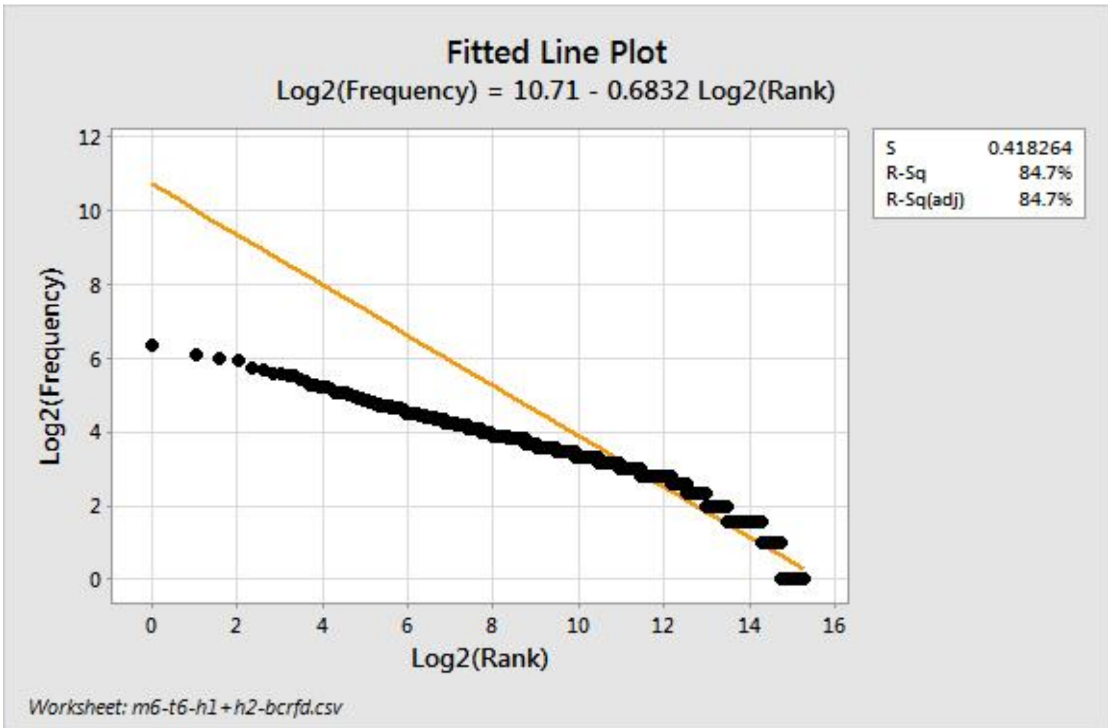

Fitted Line Plot
Log2(Frequency) = 13.89 - 0.9325 Log2(Rank)
S 0.680089
R-Sq 79.6%
R-Sq(adj) 79.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-ta-h1+h2-rdrfd.csv

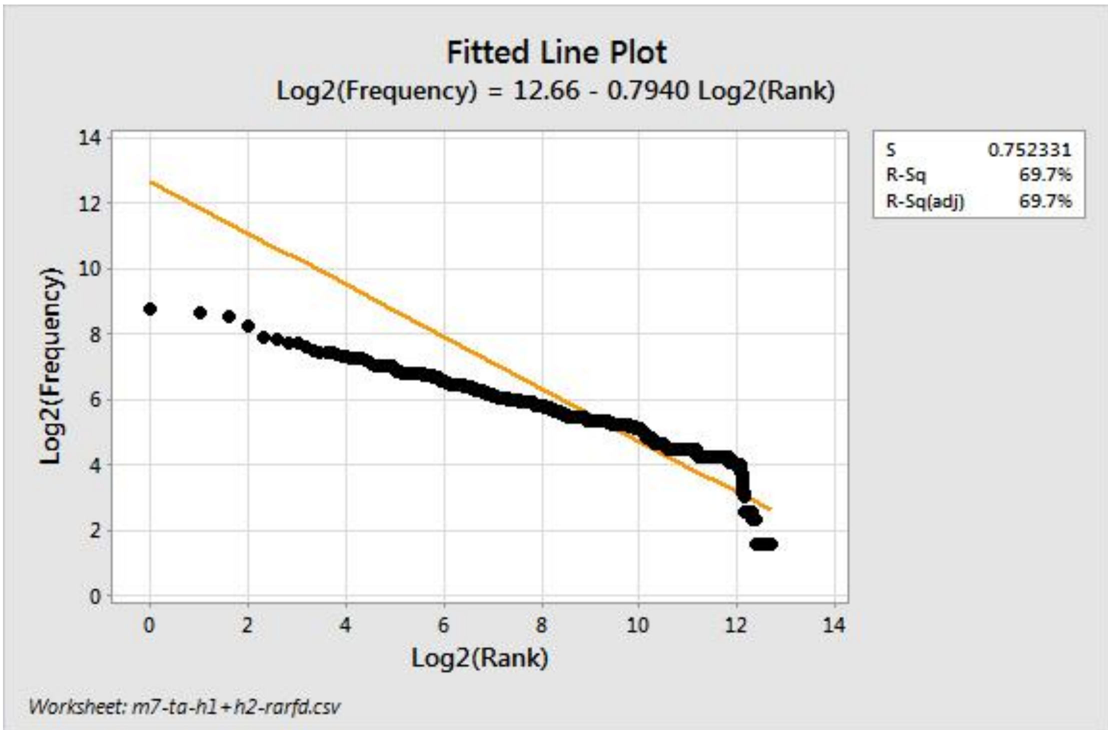

Fitted Line Plot
Log2(Frequency) = 10.53 - 0.6685 Log2(Rank)
S 0.402928
R-Sq 85.1%
R-Sq(adj) 85.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-ta-h1+h2-rcrfd.csv

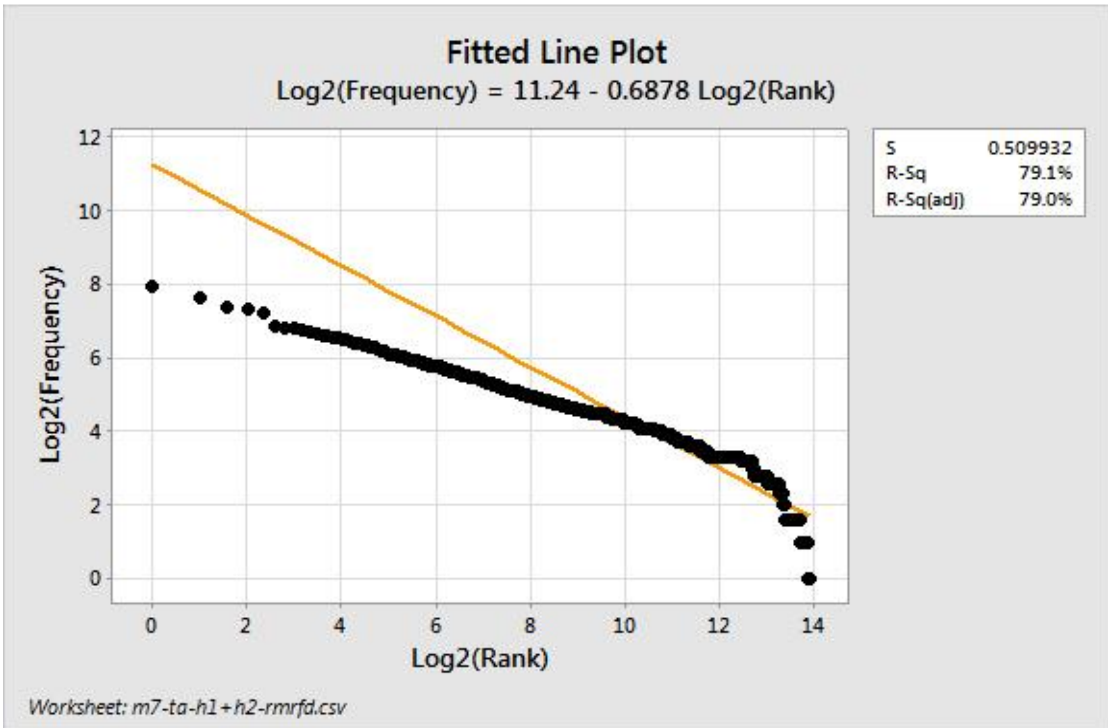

Fitted Line Plot
Log2(Frequency) = 11.60 - 0.6397 Log2(Rank)
S 0.314269
R-Sq 89.5%
R-Sq(adj) 89.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-t6-h1+h2-barfd.csv

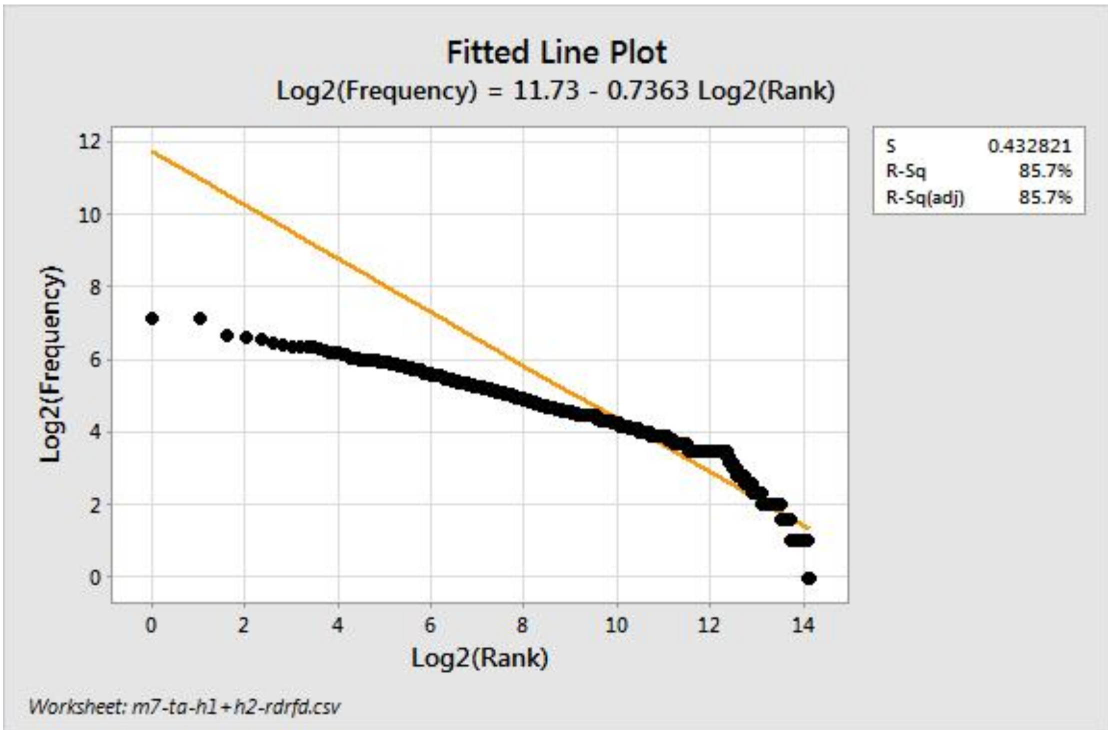

Fitted Line Plot
Log2(Frequency) = 10.13 - 0.6081 Log2(Rank)
S 0.398990
R-Sq 82.8%
R-Sq(adj) 82.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m6-t6-h1+h2-bmrfd.csv

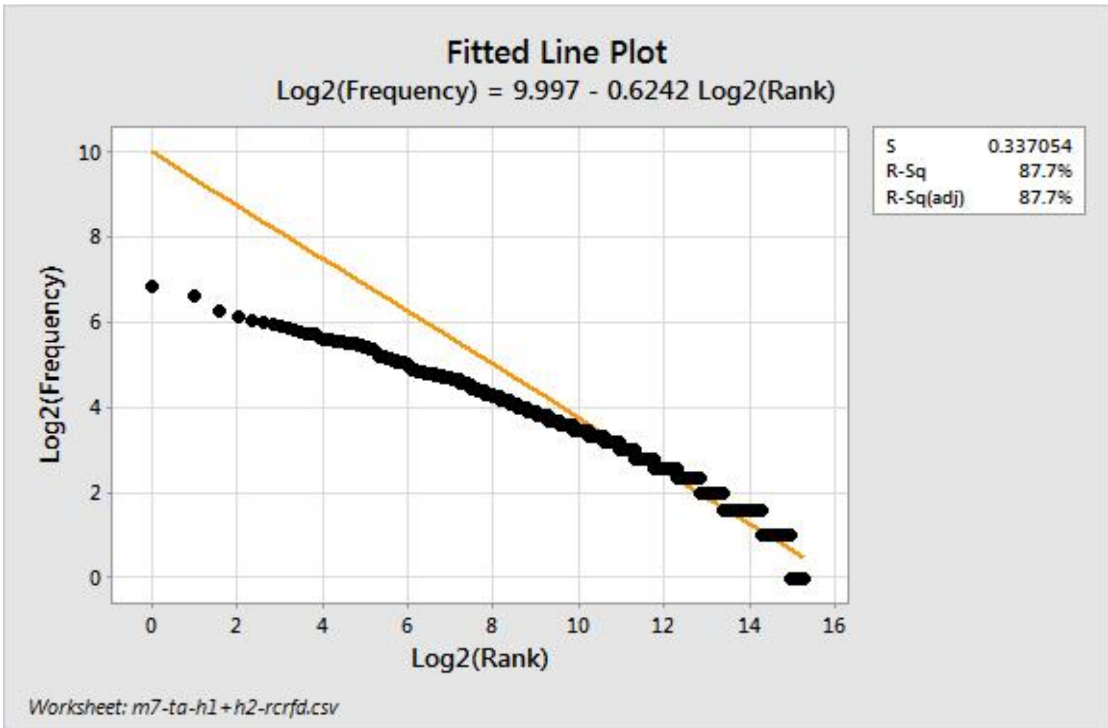

Fitted Line Plot
Log2(Frequency) = 12.14 - 0.7758 Log2(Rank)
S 0.740073
R-Sq 69.5%
R-Sq(adj) 69.5%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m6-t6-h1+h2-bdrfd.csv

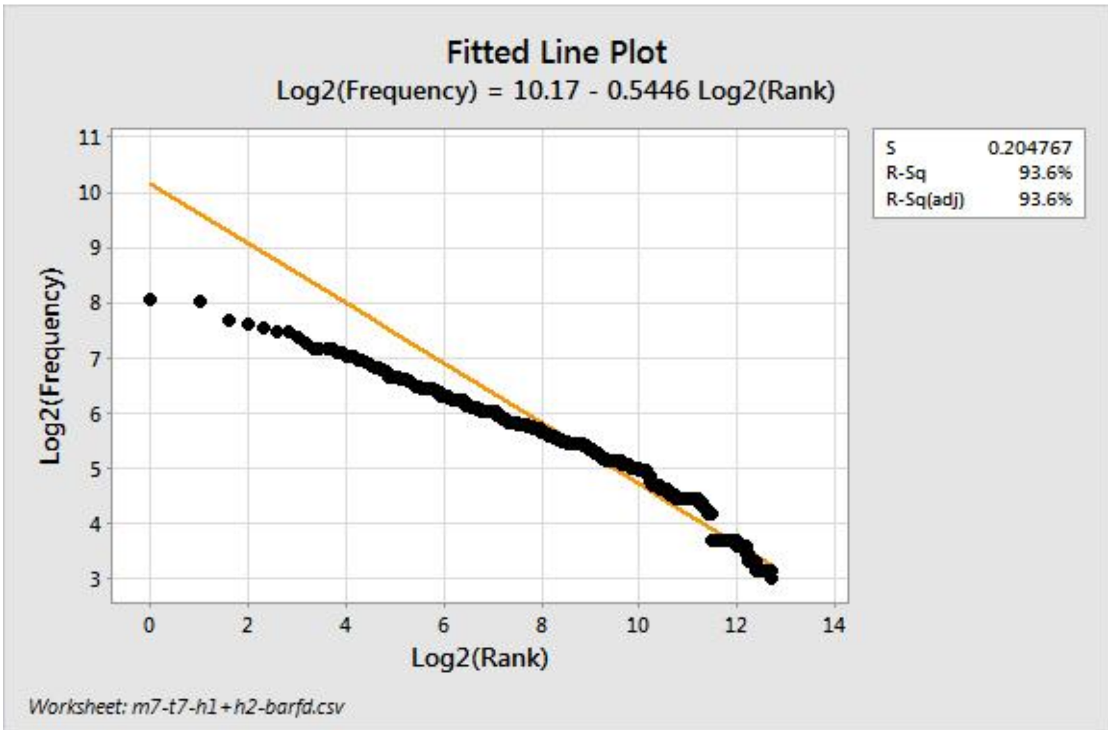

Fitted Line Plot
Log2(Frequency) = 10.71 - 0.6832 Log2(Rank)
S 0.418264
R-Sq 84.7%
R-Sq(adj) 84.7%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m6-t6-h1+h2-bcrfd.csv

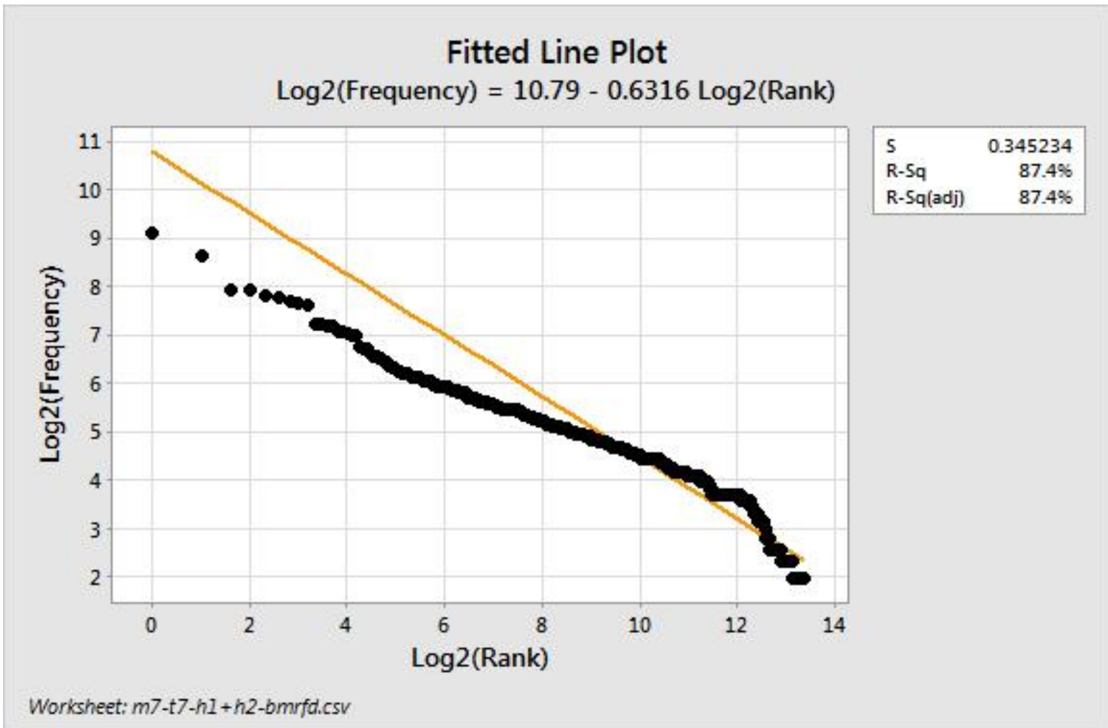

Fitted Line Plot
Log2(Frequency) = 12.66 - 0.7940 Log2(Rank)
S 0.752331
R-Sq 69.7%
R-Sq(adj) 69.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta-h1+h2-rarfd.csv

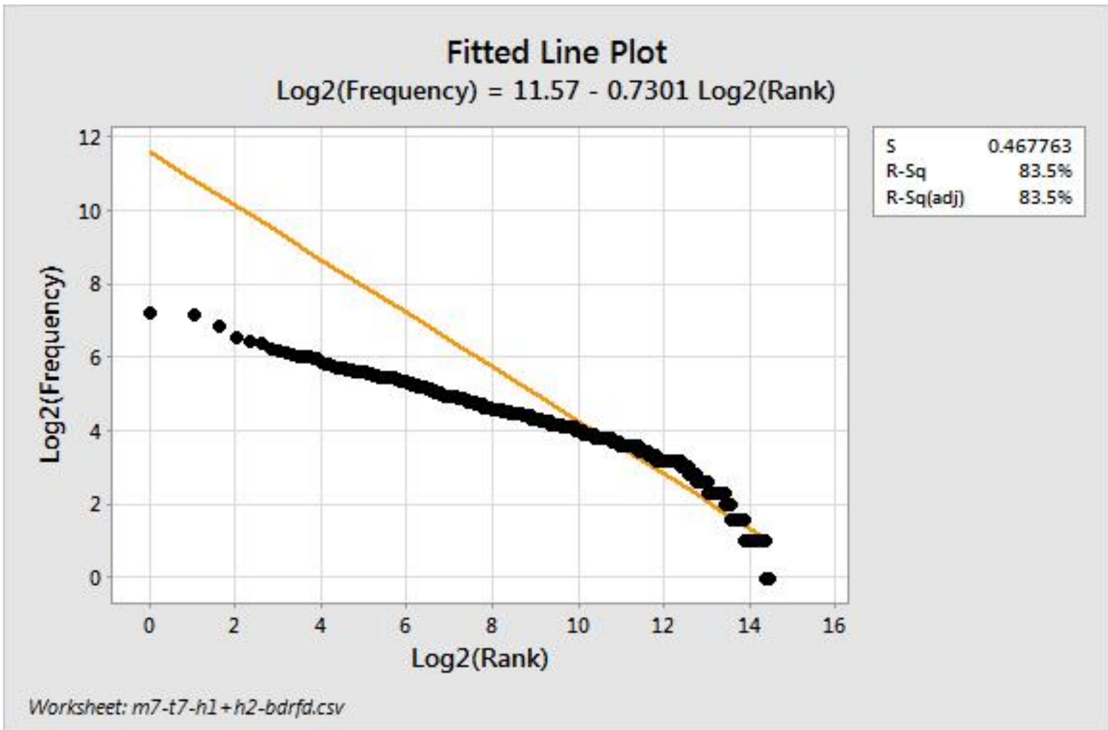

Fitted Line Plot
Log2(Frequency) = 11.24 - 0.6878 Log2(Rank)
S 0.509932
R-Sq 79.1%
R-Sq(adj) 79.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta-h1+h2-rmrfd.csv

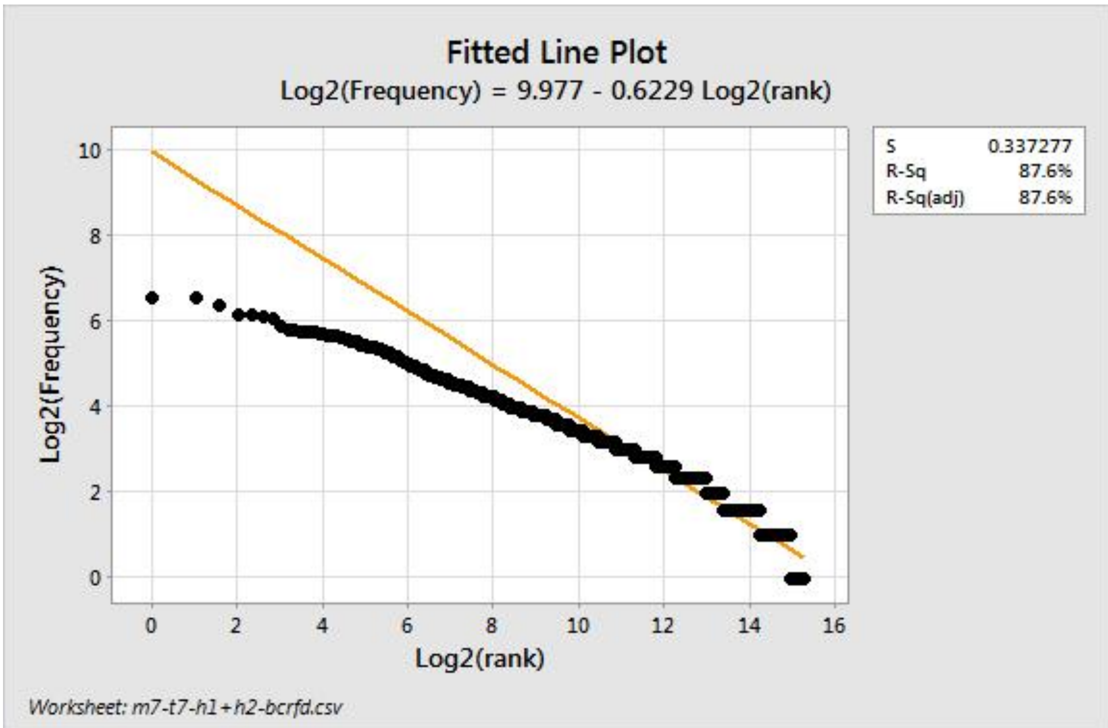

Fitted Line Plot
Log2(Frequency) = 11.73 - 0.7363 Log2(Rank)
S 0.432821
R-Sq 85.7%
R-Sq(adj) 85.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta-h1+h2-rdrfd.csv

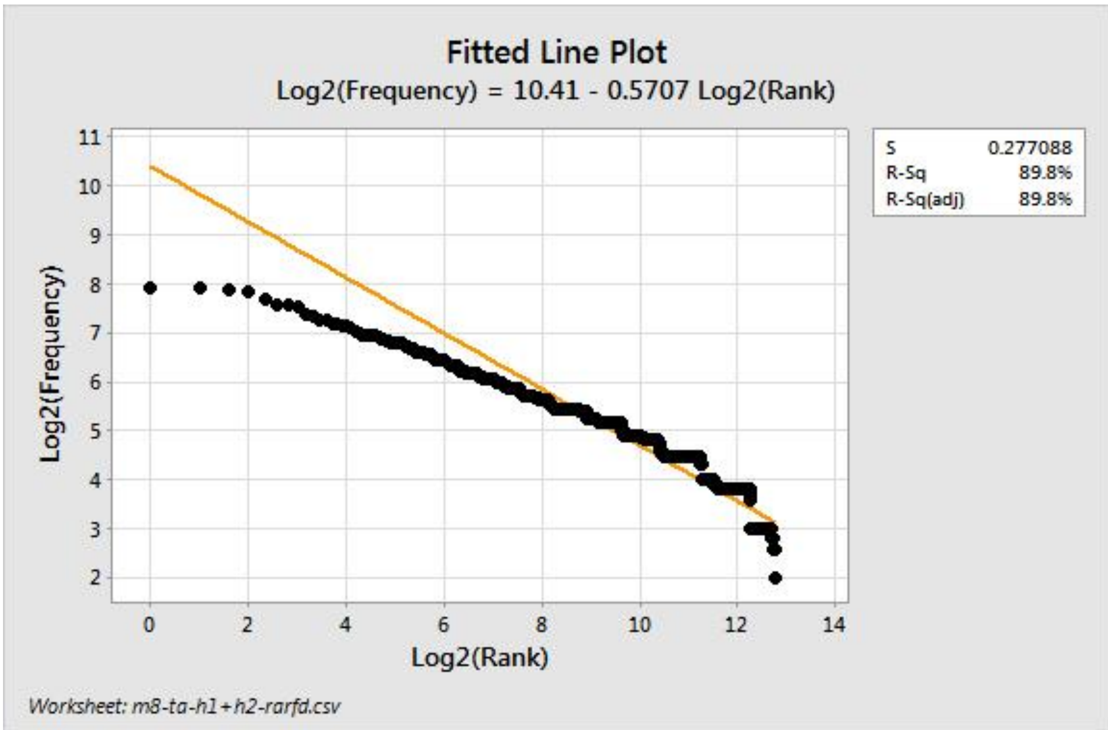

Fitted Line Plot
Log2(Frequency) = 9.997 - 0.6242 Log2(Rank)
S 0.337054
R-Sq 87.7%
R-Sq(adj) 87.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-ta-h1+h2-rcrfd.csv

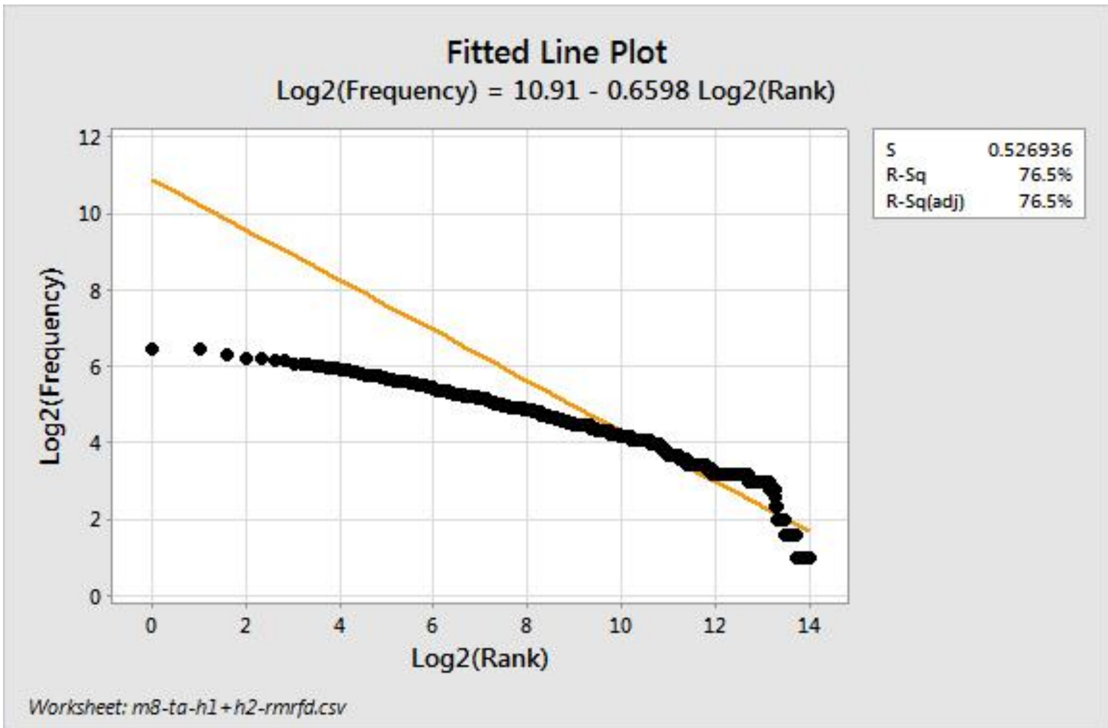

Fitted Line Plot
Log2(Frequency) = 10.17 - 0.5446 Log2(Rank)
S 0.204767
R-Sq 93.6%
R-Sq(adj) 93.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-t7-h1+h2-barfd.csv

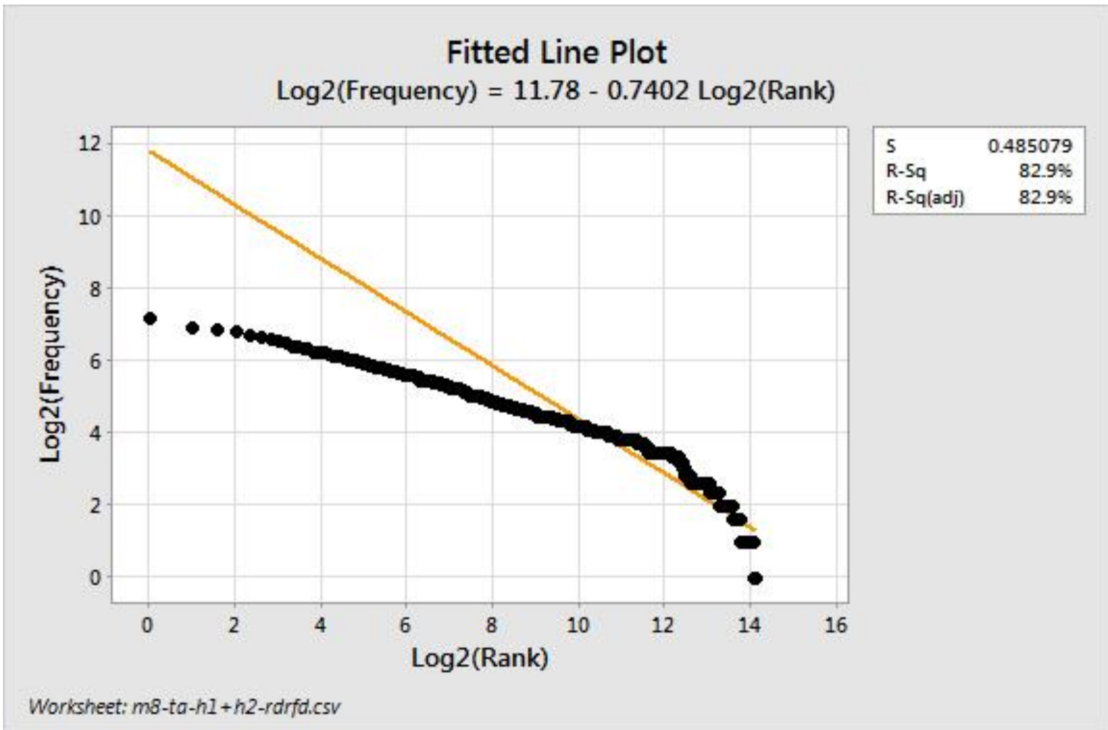

Fitted Line Plot
Log2(Frequency) = 10.79 - 0.6316 Log2(Rank)
S 0.345234
R-Sq 87.4%
R-Sq(adj) 87.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m7-t7-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 11.57 - 0.7301 Log2(Rank)
S 0.467763
R-Sq 83.5%
R-Sq(adj) 83.5%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m7-t7-h1+h2-bdrfd.csv

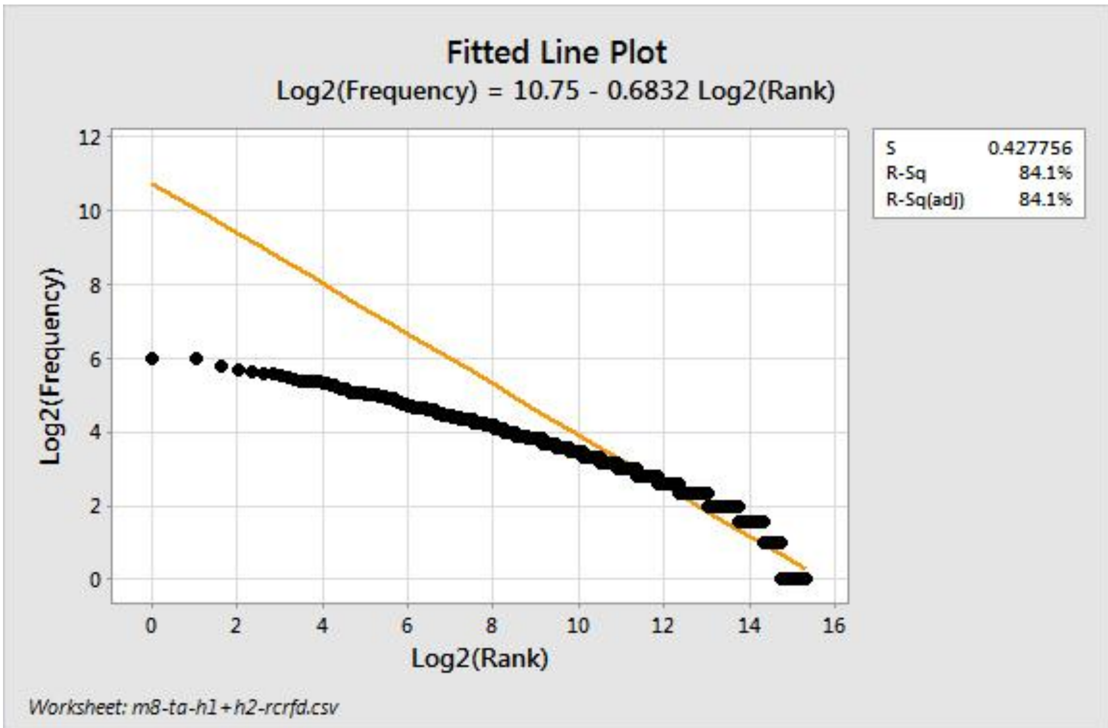

Fitted Line Plot
Log2(Frequency) = 9.977 - 0.6229 Log2(rank)
S 0.337277
R-Sq 87.6%
R-Sq(adj) 87.6%
Log2(Frequency)
Log2(rank)
0
2
4
6
8
10
12
14
16
Worksheet: m7-t7-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.41 - 0.5707 Log2(Rank)
S 0.277088
R-Sq 89.8%
R-Sq(adj) 89.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta-h1+h2-rarfd.csv

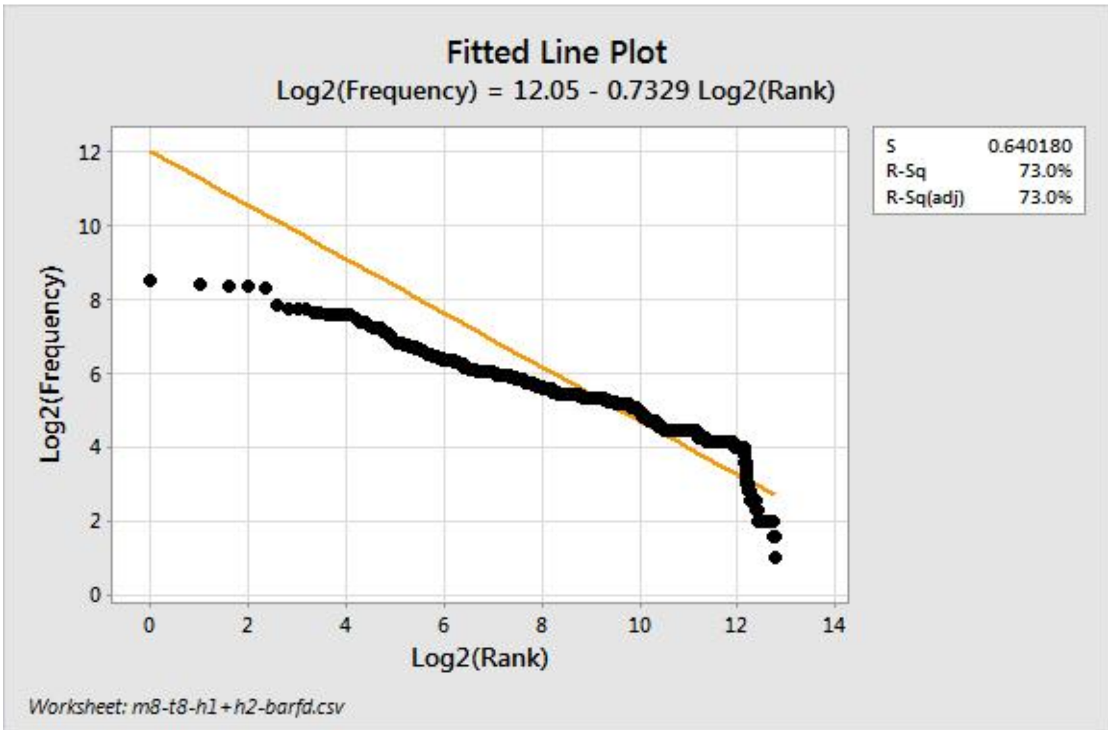

Fitted Line Plot
Log2(Frequency) = 10.91 - 0.6598 Log2(Rank)
S 0.526936
R-Sq 76.5%
R-Sq(adj) 76.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta-h1+h2-rmrfd.csv

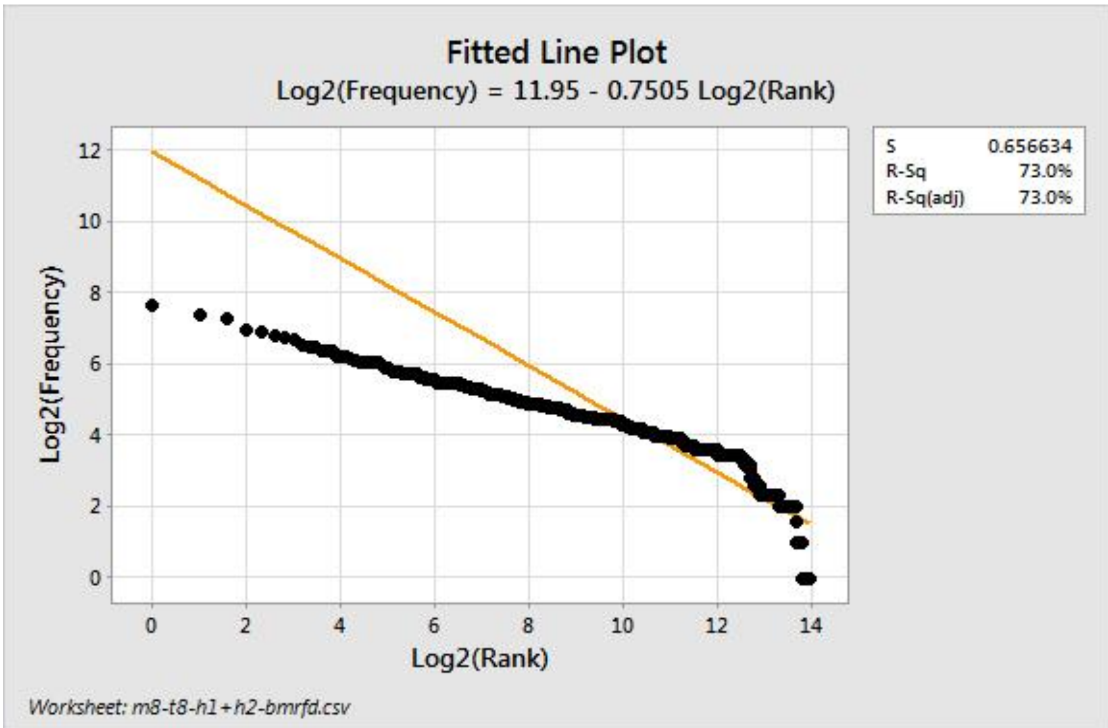


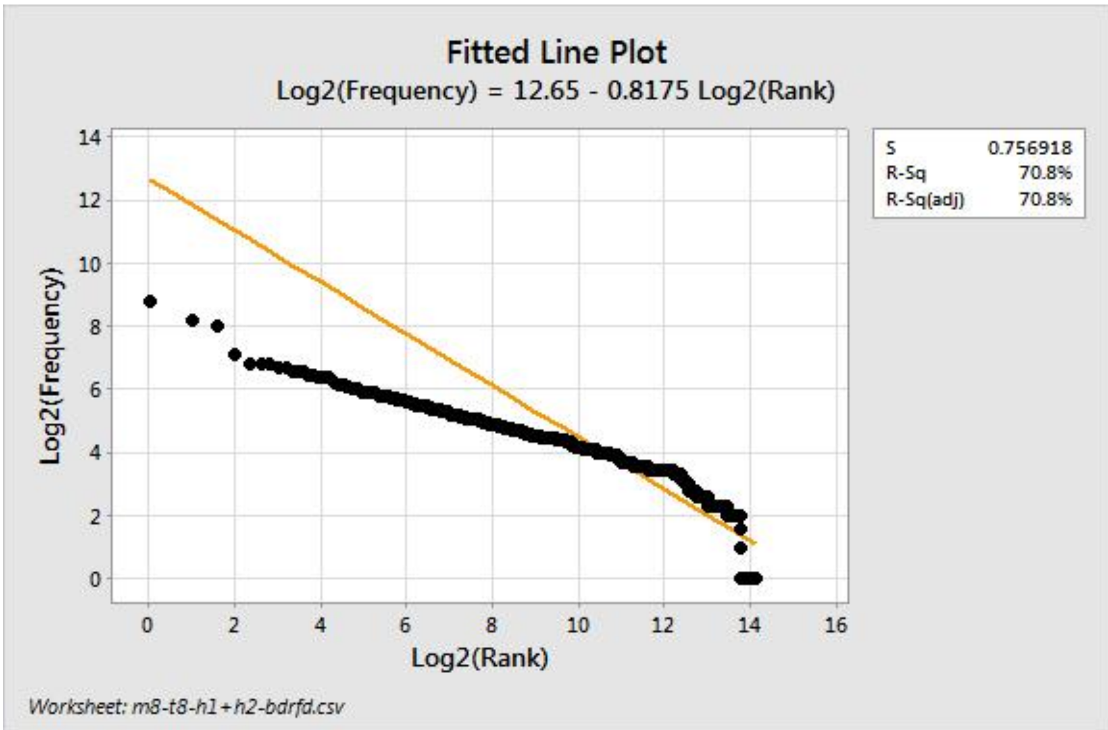
Fitted Line Plot
Log2(Frequency) = 11.78 - 0.7402 Log2(Rank)
S 0.485079
R-Sq 82.9%
R-Sq(adj) 82.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta-h1+h2-rdrfd.csv

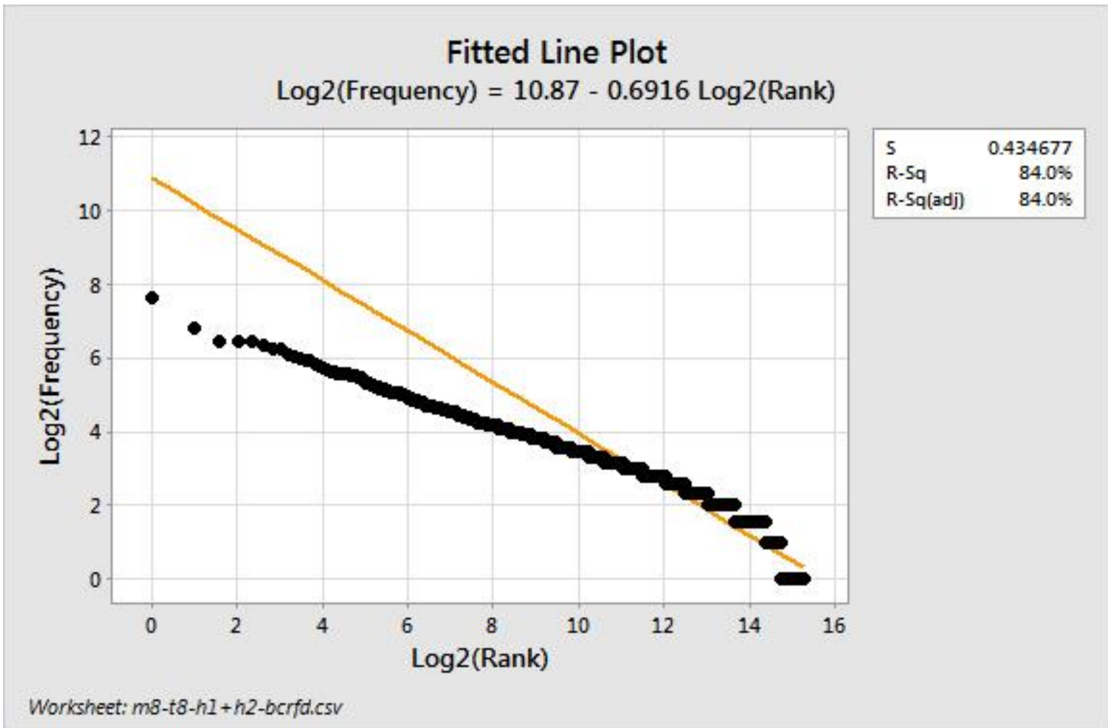


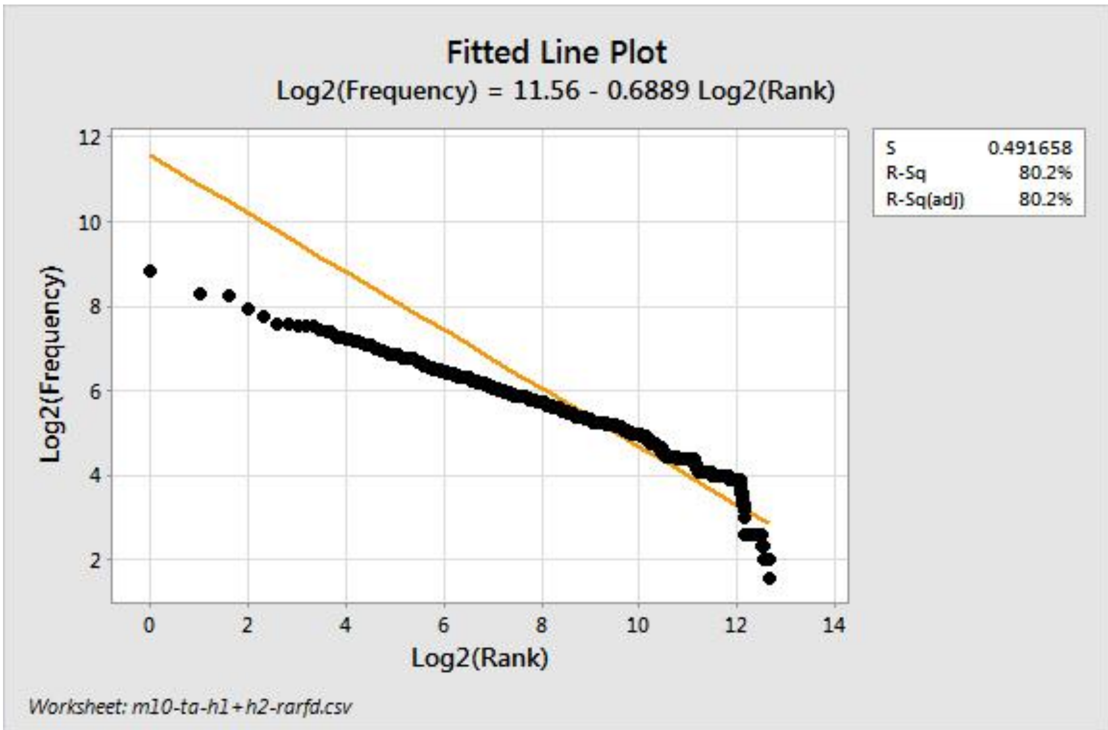
Fitted Line Plot
Log2(Frequency) = 10.75 - 0.6832 Log2(Rank)
S 0.427756
R-Sq 84.1%
R-Sq(adj) 84.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-ta-h1+h2-rcrfd.csv

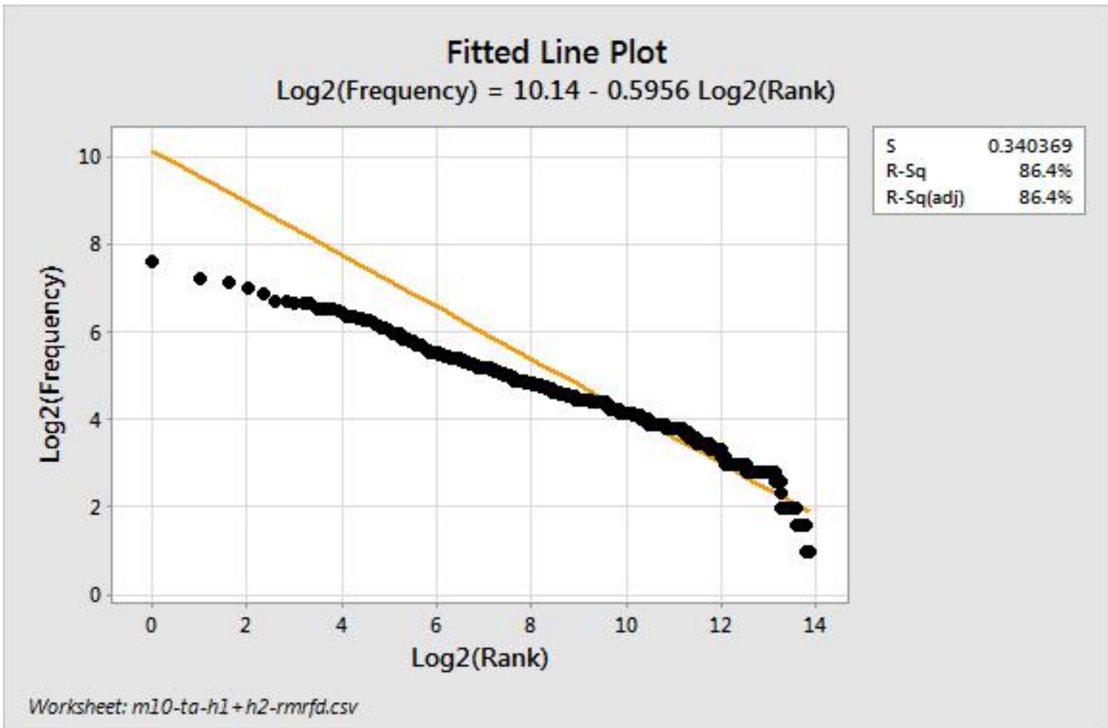

Fitted Line Plot
Log2(Frequency) = 12.05 - 0.7329 Log2(Rank)
S 0.640180
R-Sq 73.0%
R-Sq(adj) 73.0%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m8-t8-h1+h2-barfd.csv

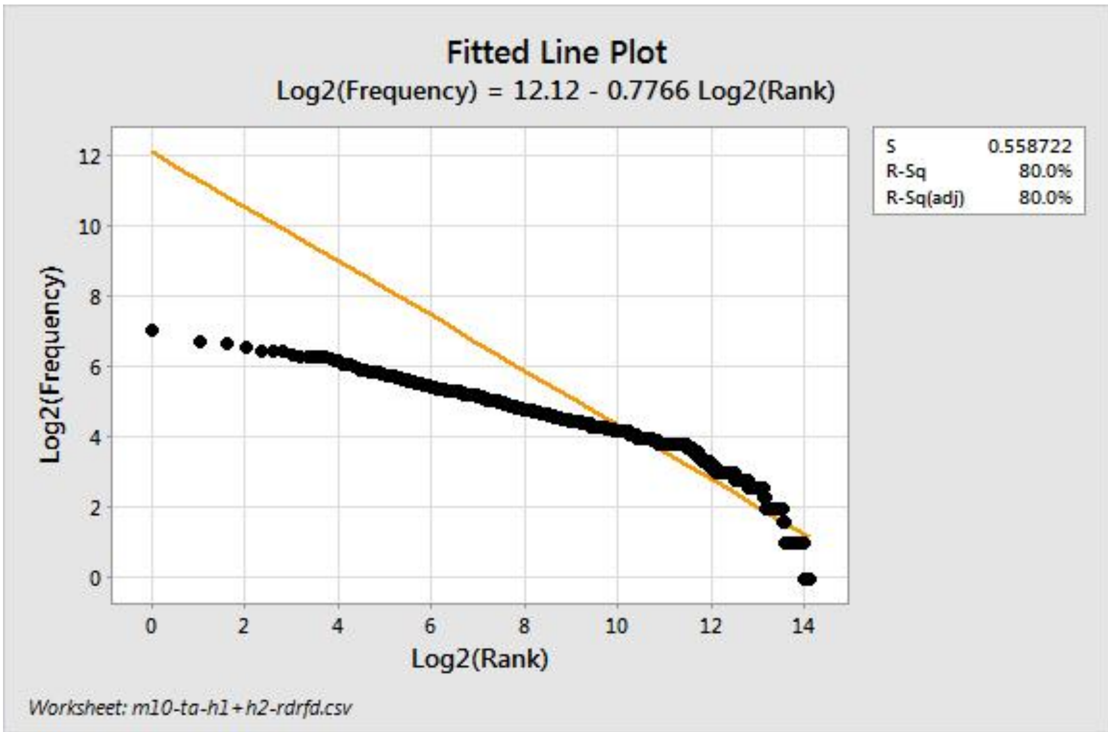

Fitted Line Plot
Log2(Frequency) = 11.95 - 0.7505 Log2(Rank)
S 0.656634
R-Sq 73.0%
R-Sq(adj) 73.0%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m8-t8-h1+h2-bmrfd.csv

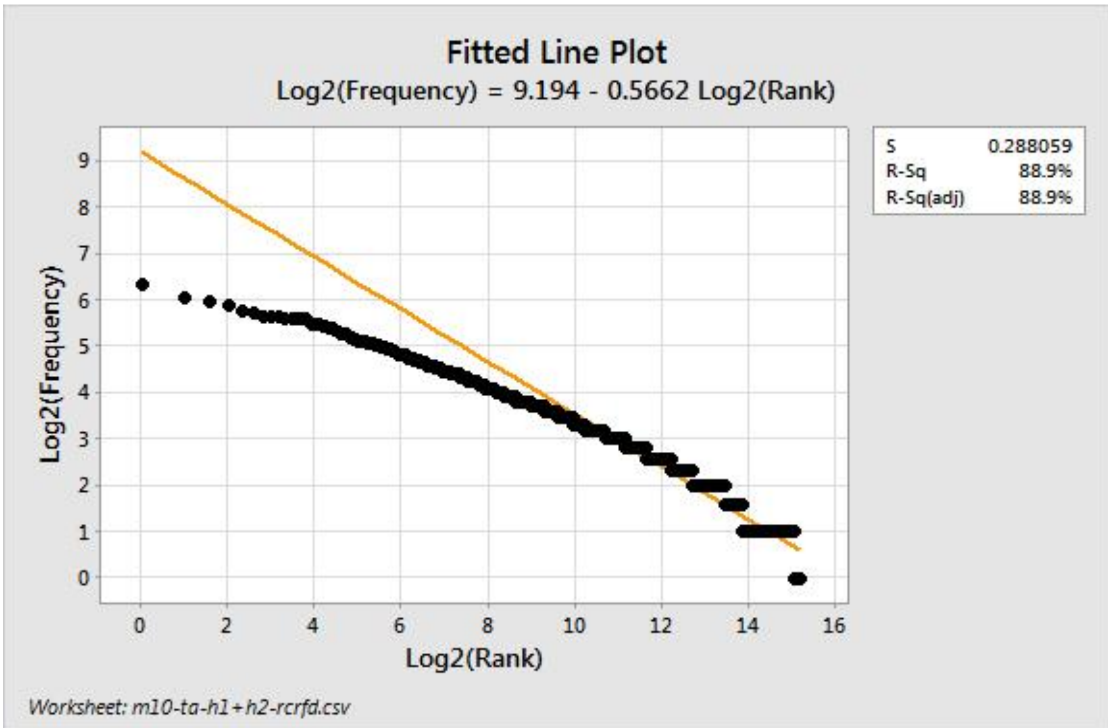

Fitted Line Plot
Log2(Frequency) = 12.65 - 0.8175 Log2(Rank)
S 0.756918
R-Sq 70.8%
R-Sq(adj) 70.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-t8-h1+h2-bdrfd.csv

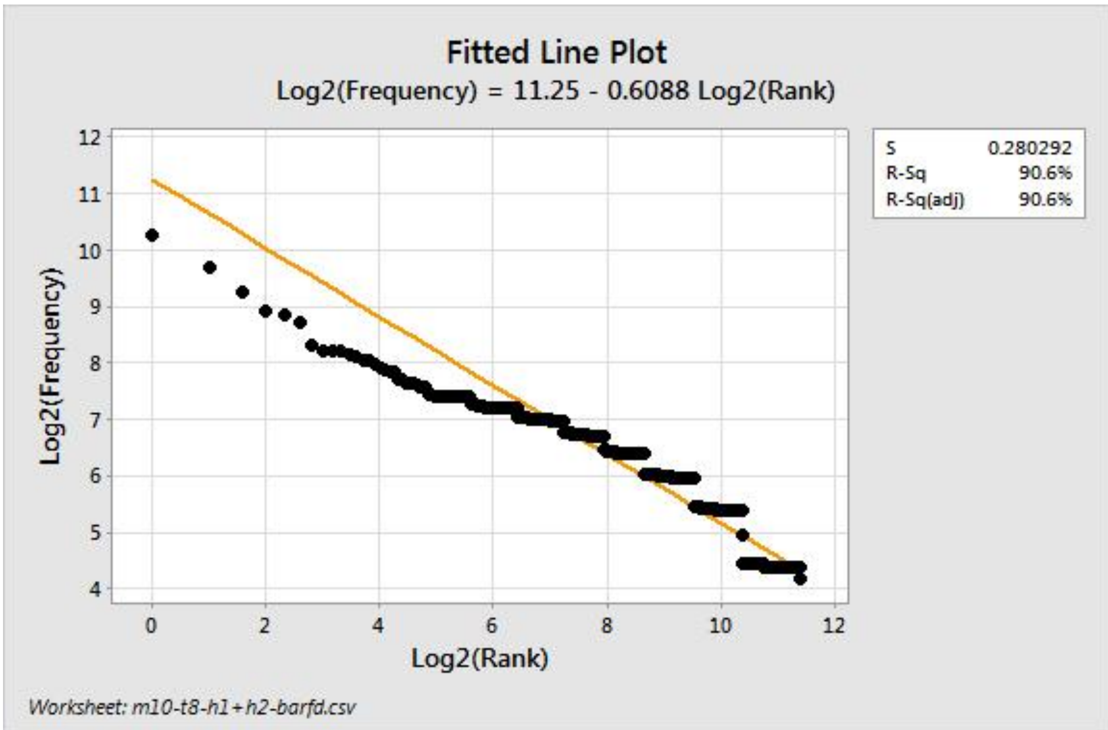

Fitted Line Plot
Log2(Frequency) = 10.87 - 0.6916 Log2(Rank)
S 0.434677
R-Sq 84.0%
R-Sq(adj) 84.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m8-t8-h1+h2-bcrfd.csv

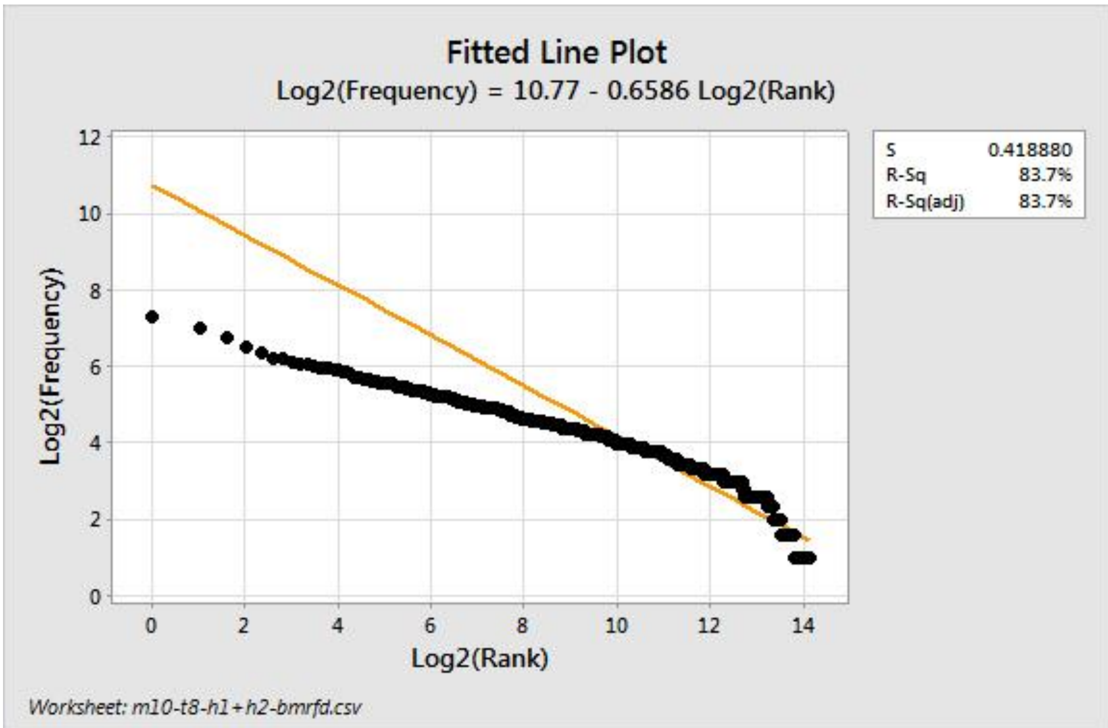

Fitted Line Plot
Log2(Frequency) = 11.56 - 0.6889 Log2(Rank)
S 0.491658
R-Sq 80.2%
R-Sq(adj) 80.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta-h1+h2-rarfd.csv

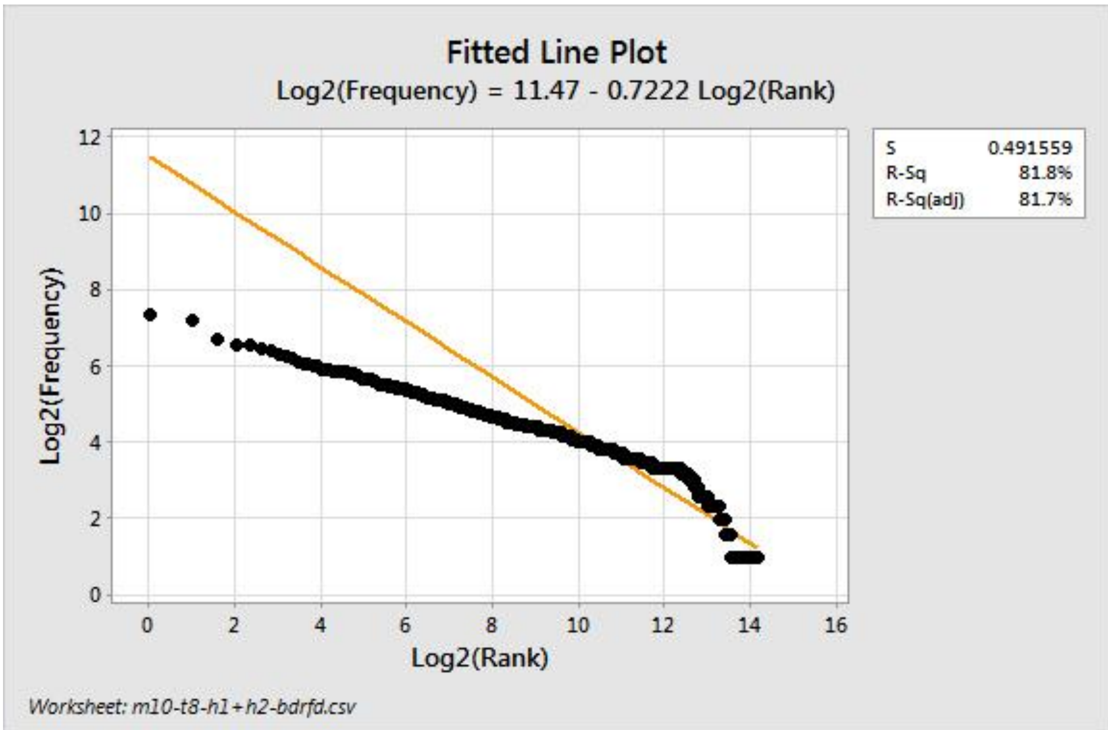

Fitted Line Plot
Log2(Frequency) = 10.14 - 0.5956 Log2(Rank)
S 0.340369
R-Sq 86.4%
R-Sq(adj) 86.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta-h1+h2-rmrfd.csv

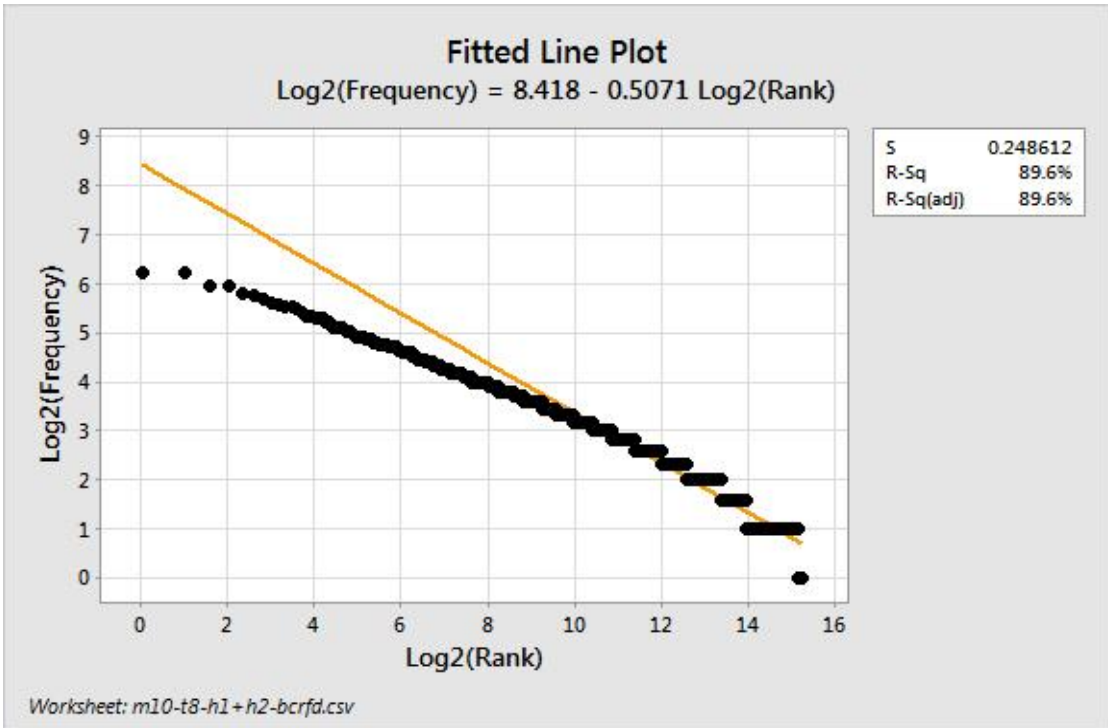

Fitted Line Plot
Log2(Frequency) = 12.12 - 0.7766 Log2(Rank)
S 0.558722
R-Sq 80.0%
R-Sq(adj) 80.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta-h1+h2-rdrfd.csv

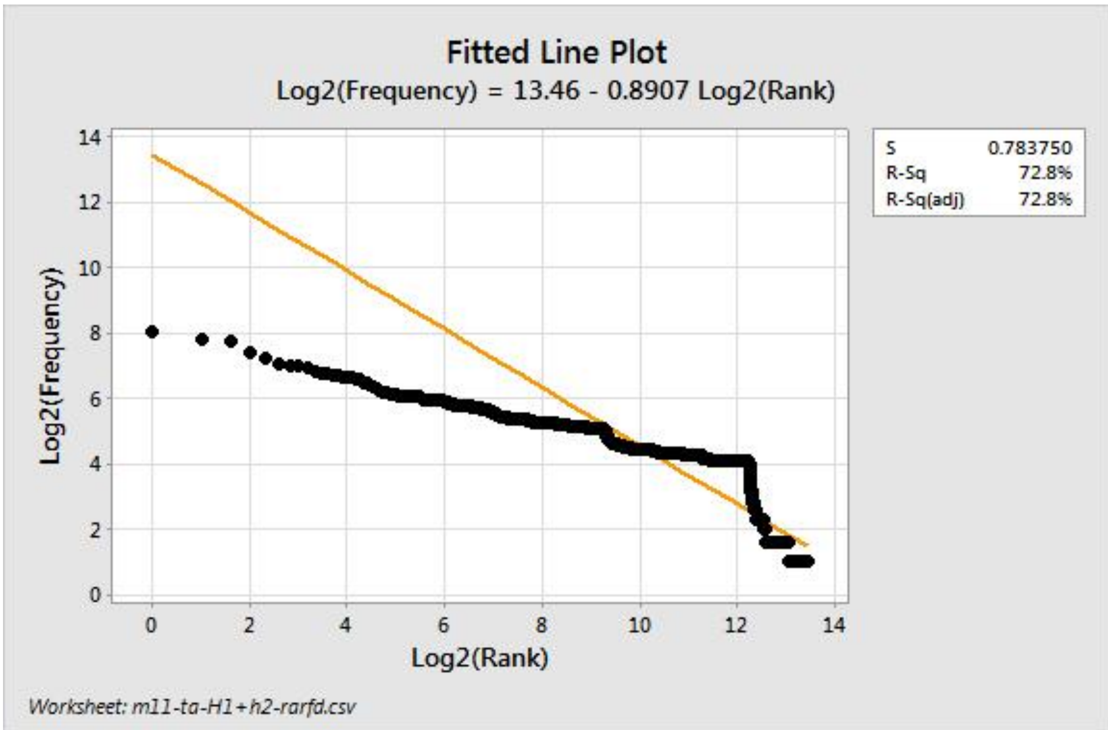

Fitted Line Plot
Log2(Frequency) = 9.194 - 0.5662 Log2(Rank)
S 0.288059
R-Sq 88.9%
R-Sq(adj) 88.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-ta-h1+h2-rcrfd.csv

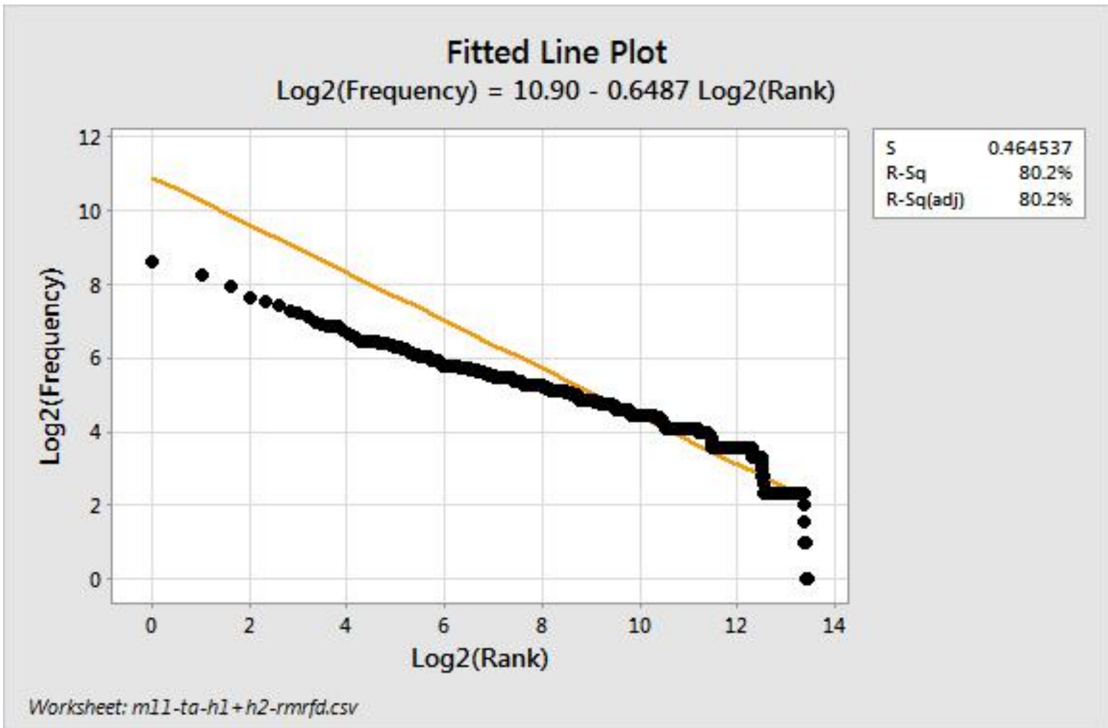

Fitted Line Plot
Log2(Frequency) = 11.25 - 0.6088 Log2(Rank)
S 0.280292
R-Sq 90.6%
R-Sq(adj) 90.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8-h1+h2-barfd.csv

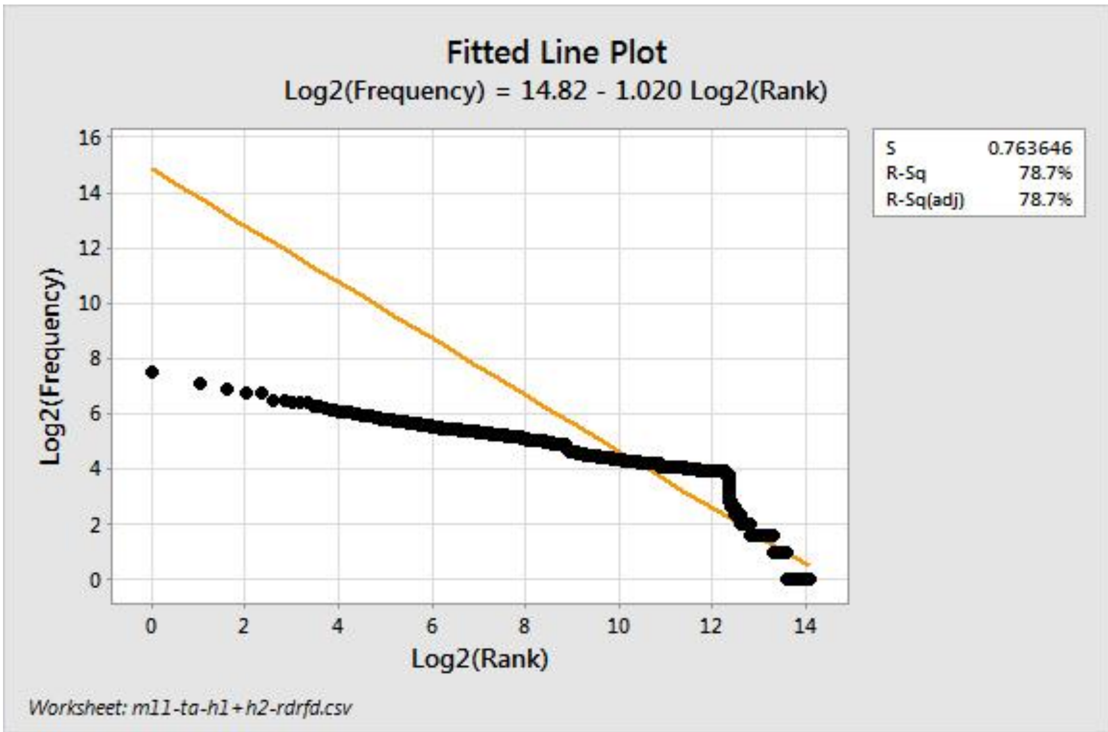

Fitted Line Plot
Log2(Frequency) = 10.77 - 0.6586 Log2(Rank)
S 0.418880
R-Sq 83.7%
R-Sq(adj) 83.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8-h1+h2-bmrfd.csv

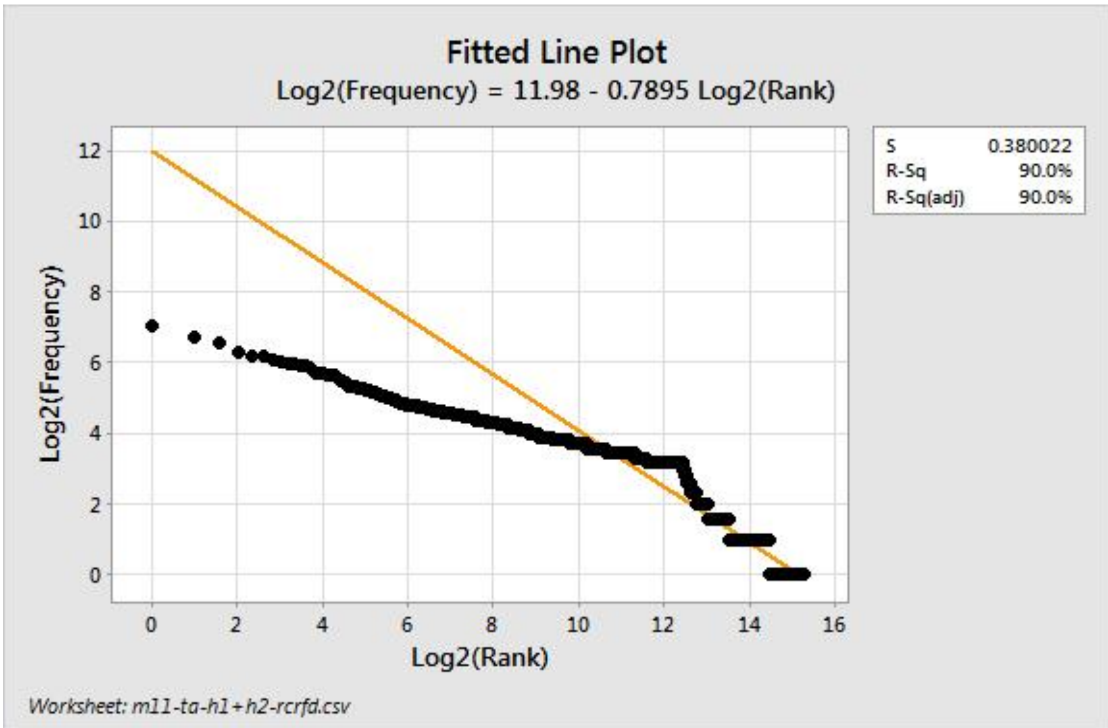

Fitted Line Plot
Log2(Frequency) = 11.47 - 0.7222 Log2(Rank)
S 0.491559
R-Sq 81.8%
R-Sq(adj) 81.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8-h1+h2-bdrfd.csv

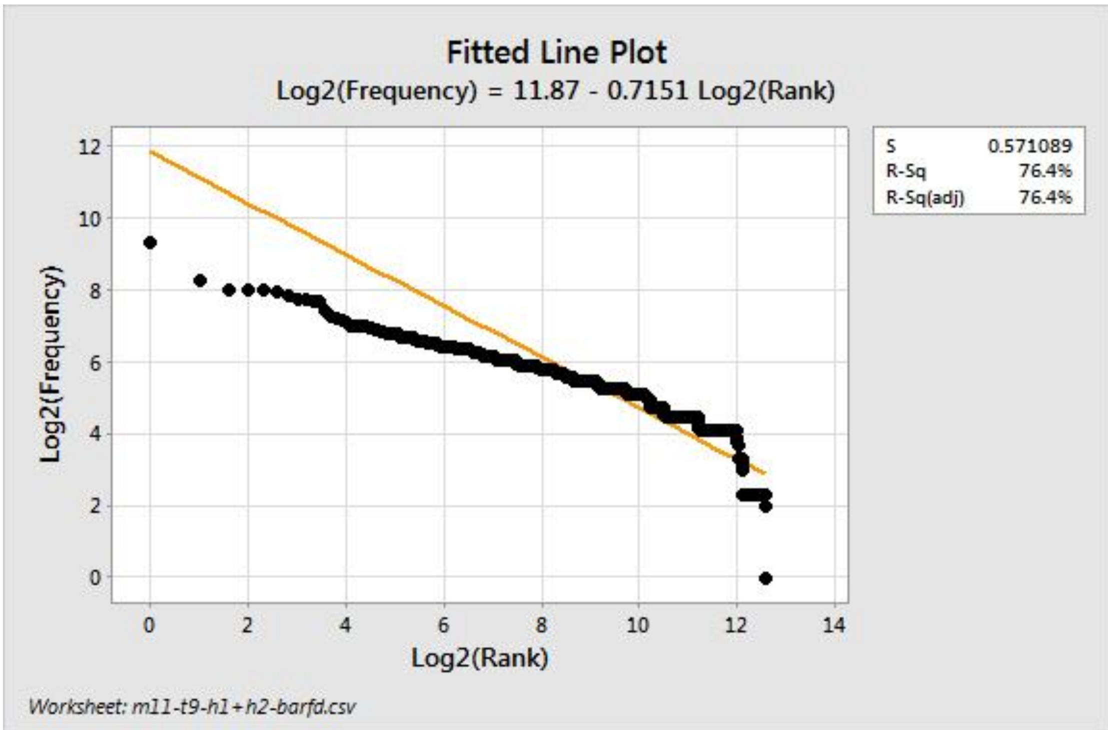

Fitted Line Plot
Log2(Frequency) = 8.418 - 0.5071 Log2(Rank)
S 0.248612
R-Sq 89.6%
R-Sq(adj) 89.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m10-t8-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.46 - 0.8907 Log2(Rank)
S 0.783750
R-Sq 72.8%
R-Sq(adj) 72.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta-H1+h2-rarfd.csv

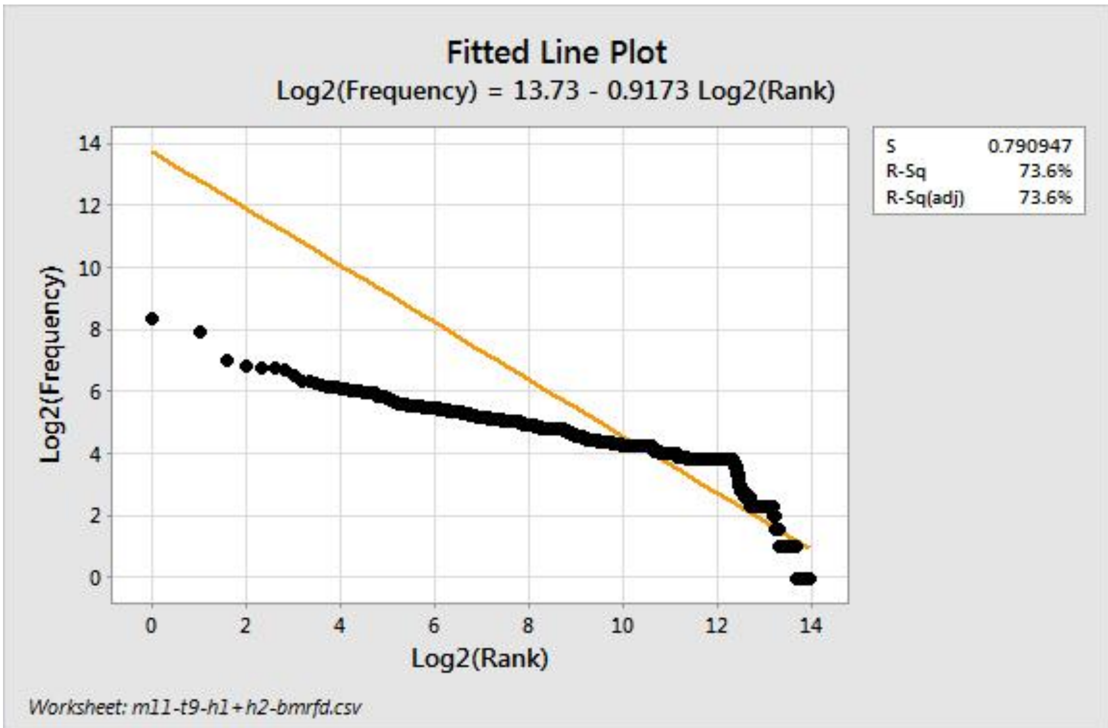

Fitted Line Plot
Log2(Frequency) = 10.90 - 0.6487 Log2(Rank)
S 0.464537
R-Sq 80.2%
R-Sq(adj) 80.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 14.82 - 1.020 Log2(Rank)
S 0.763646
R-Sq 78.7%
R-Sq(adj) 78.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta-h1+h2-rdrfd.csv

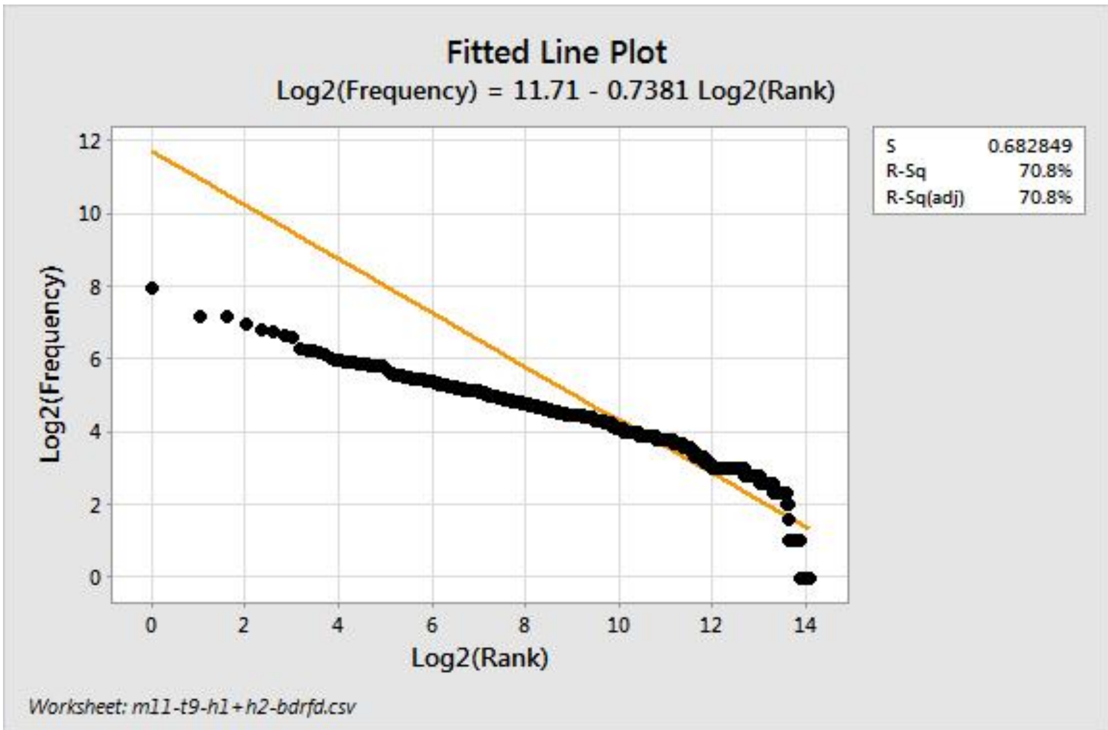

Fitted Line Plot
Log2(Frequency) = 11.98 - 0.7895 Log2(Rank)
S 0.380022
R-Sq 90.0%
R-Sq(adj) 90.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-ta-h1+h2-rcrfd.csv



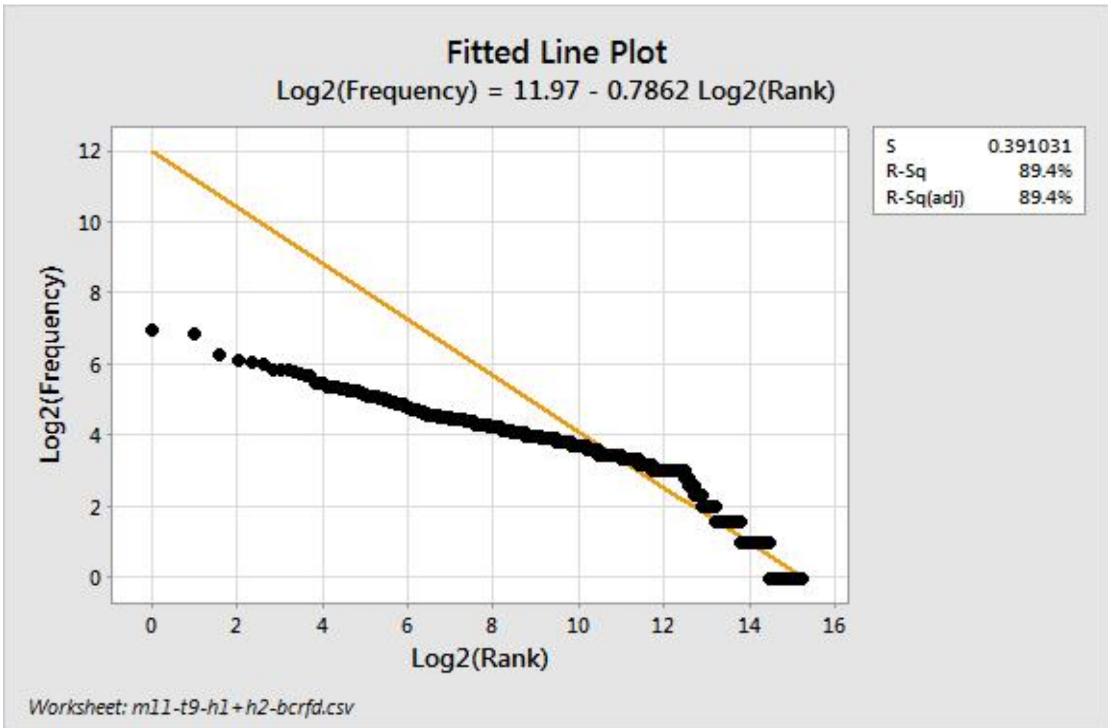
Fitted Line Plot
Log2(Frequency) = 11.87 - 0.7151 Log2(Rank)
S 0.571089
R-Sq 76.4%
R-Sq(adj) 76.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9-h1+h2-barfd.csv



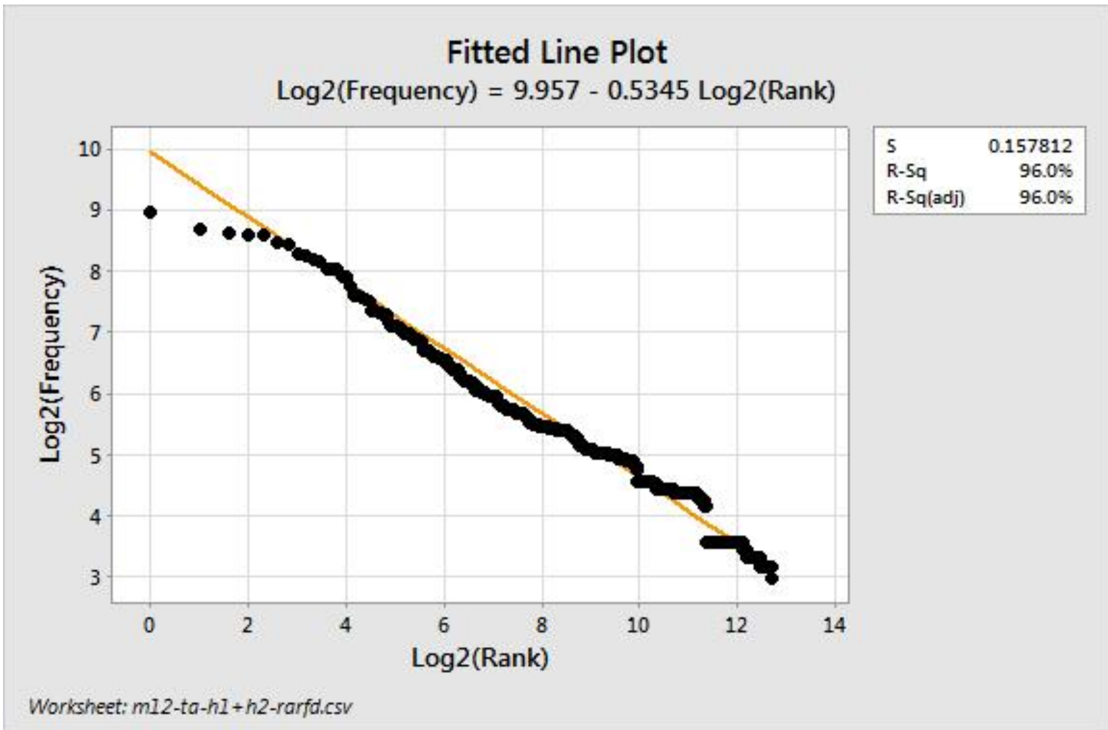
Fitted Line Plot
Log2(Frequency) = 13.73 - 0.9173 Log2(Rank)
S 0.790947
R-Sq 73.6%
R-Sq(adj) 73.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9-h1+h2-bmrfd.csv

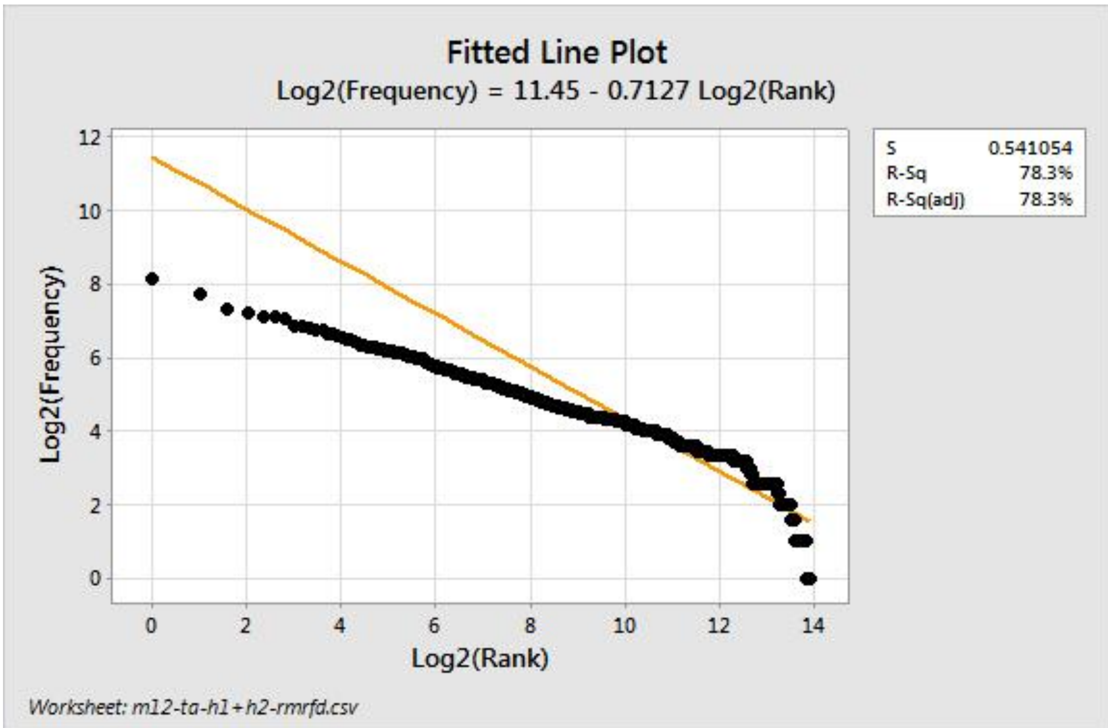


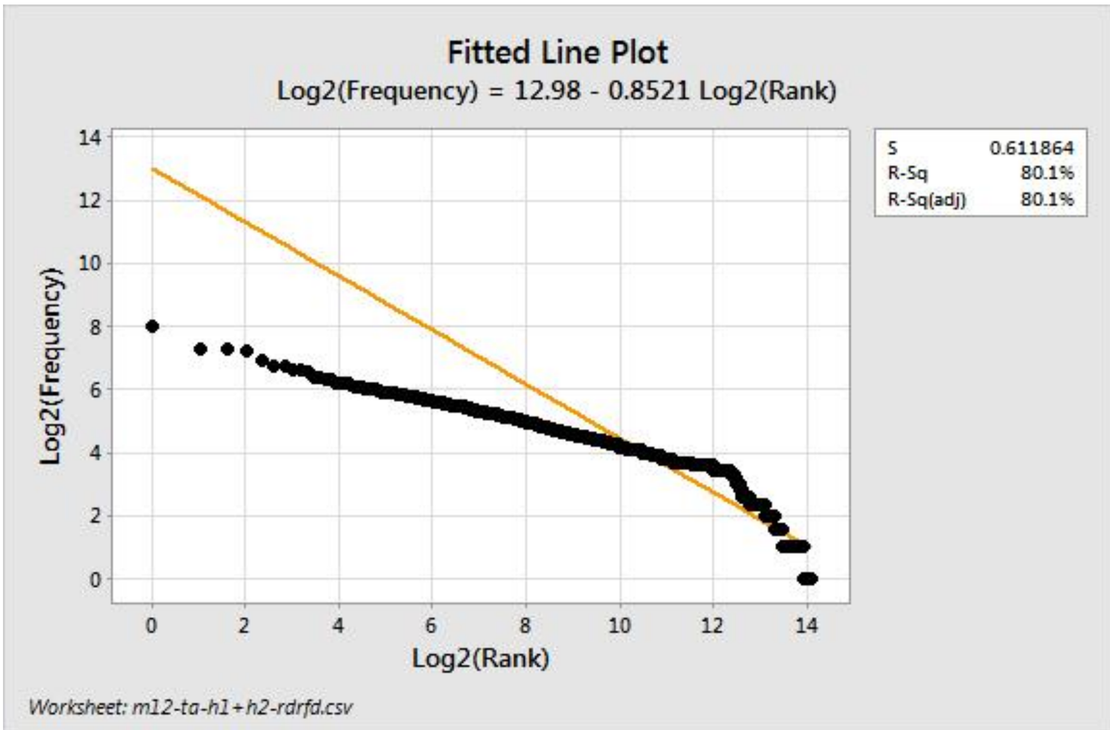
Fitted Line Plot
Log2(Frequency) = 11.71 - 0.7381 Log2(Rank)
S 0.682849
R-Sq 70.8%
R-Sq(adj) 70.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9-h1+h2-bdrfd.csv

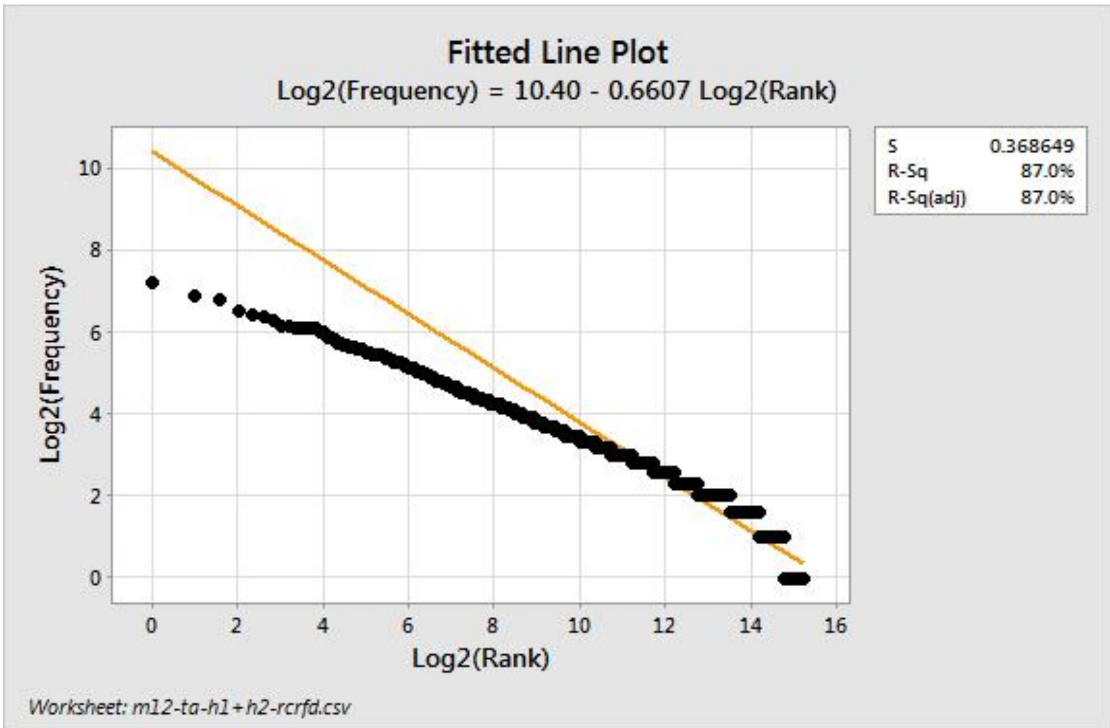


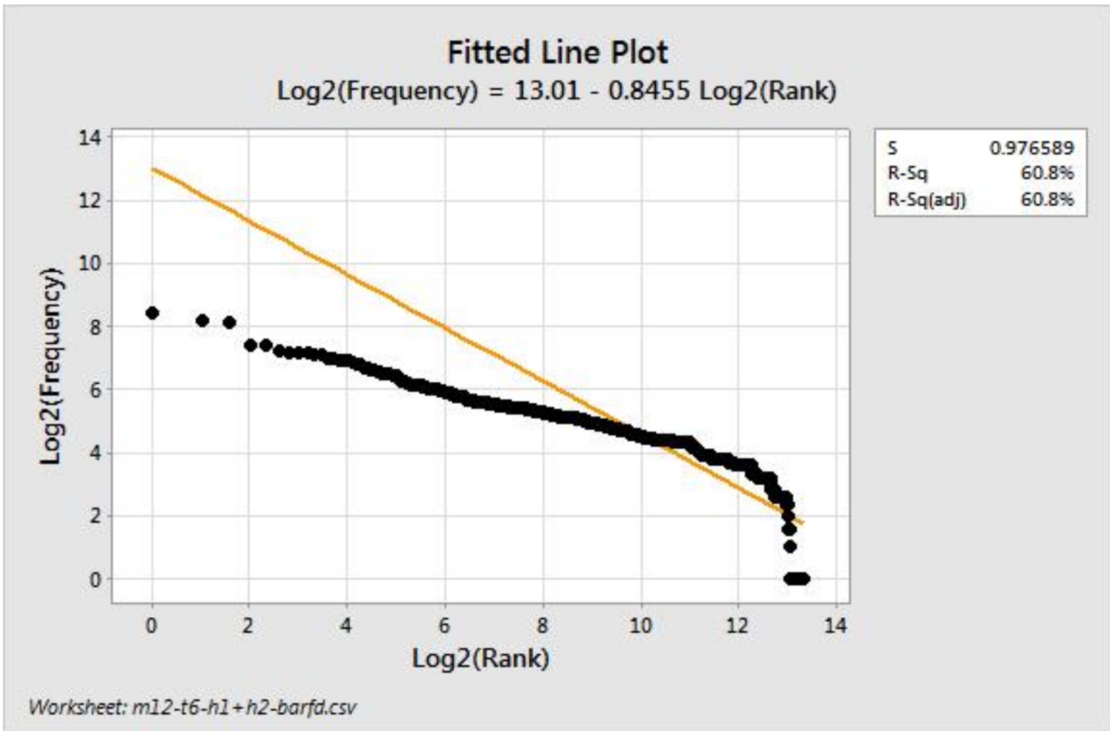
Fitted Line Plot
Log2(Frequency) = 11.97 - 0.7862 Log2(Rank)
S 0.391031
R-Sq 89.4%
R-Sq(adj) 89.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m11-t9-h1+h2-bcrfd.csv

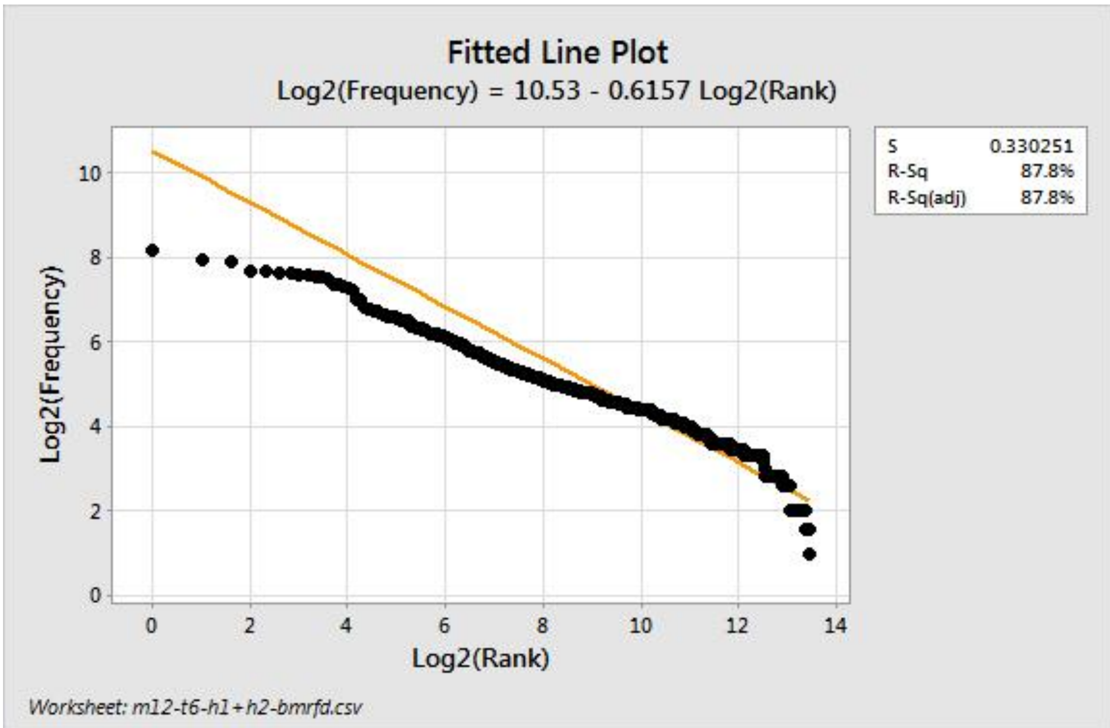

Fitted Line Plot
Log2(Frequency) = 9.957 - 0.5345 Log2(Rank)
S 0.157812
R-Sq 96.0%
R-Sq(adj) 96.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta-h1+h2-rarfd.csv

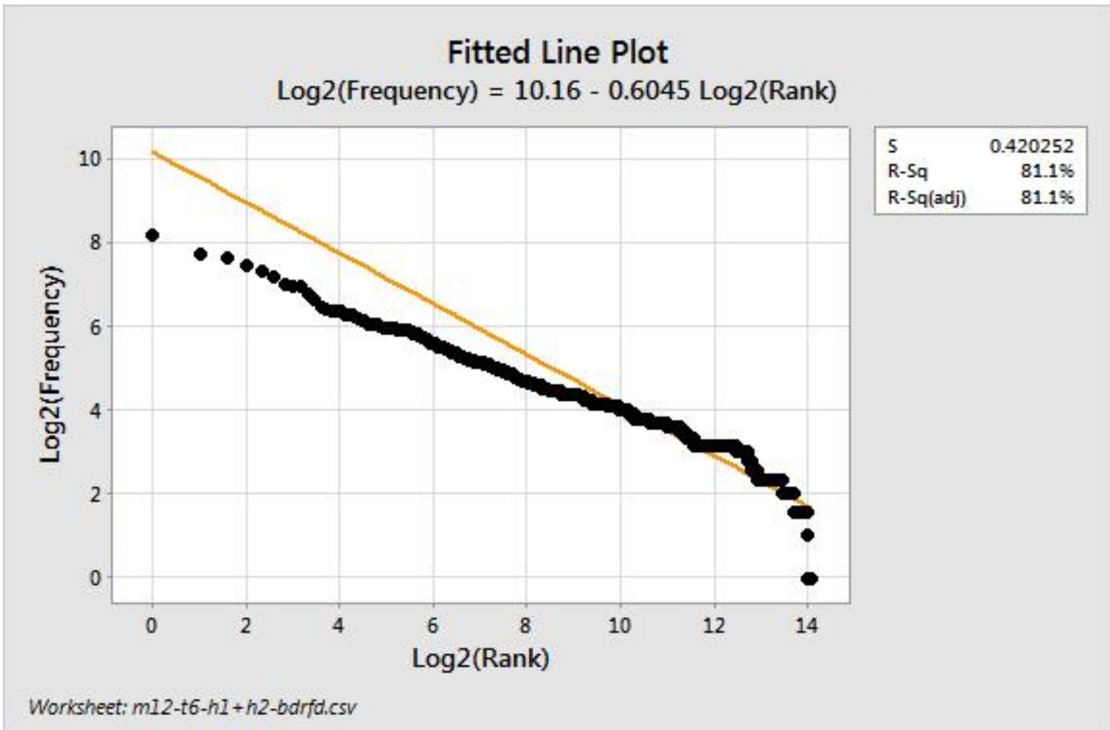

Fitted Line Plot
Log2(Frequency) = 11.45 - 0.7127 Log2(Rank)
S 0.541054
R-Sq 78.3%
R-Sq(adj) 78.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 12.98 - 0.8521 Log2(Rank)
S 0.611864
R-Sq 80.1%
R-Sq(adj) 80.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta-h1+h2-rdrfd.csv

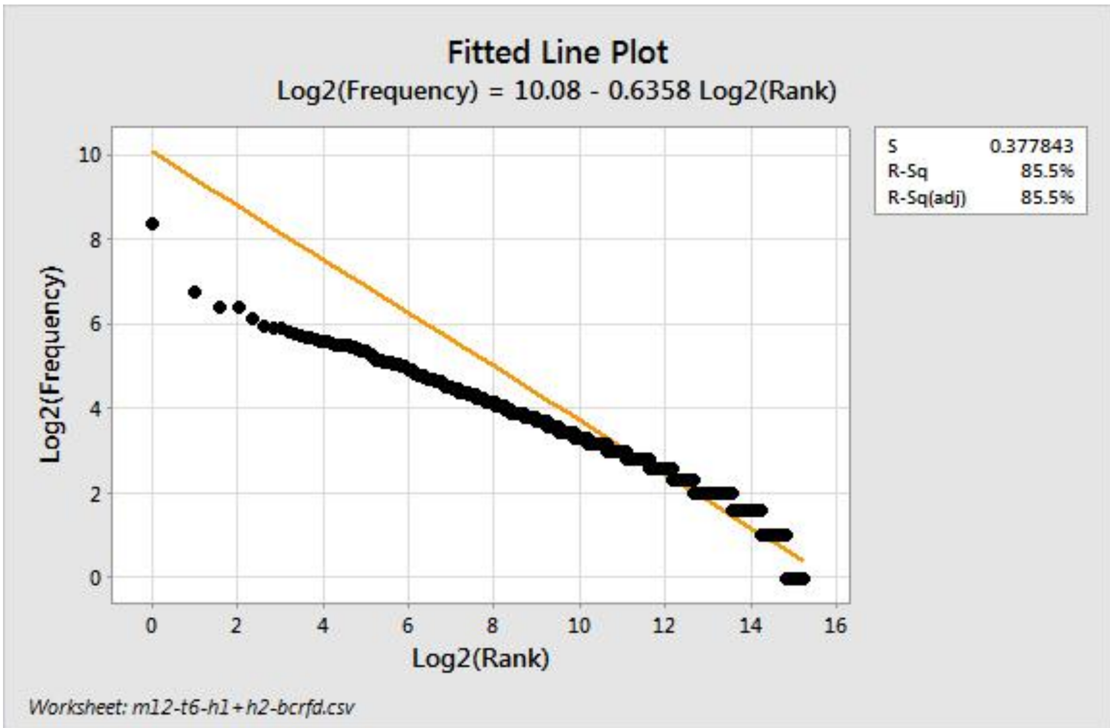

Fitted Line Plot
Log2(Frequency) = 10.40 - 0.6607 Log2(Rank)
S 0.368649
R-Sq 87.0%
R-Sq(adj) 87.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.01 - 0.8455 Log2(Rank)
S 0.976589
R-Sq 60.8%
R-Sq(adj) 60.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6-h1+h2-barfd.csv

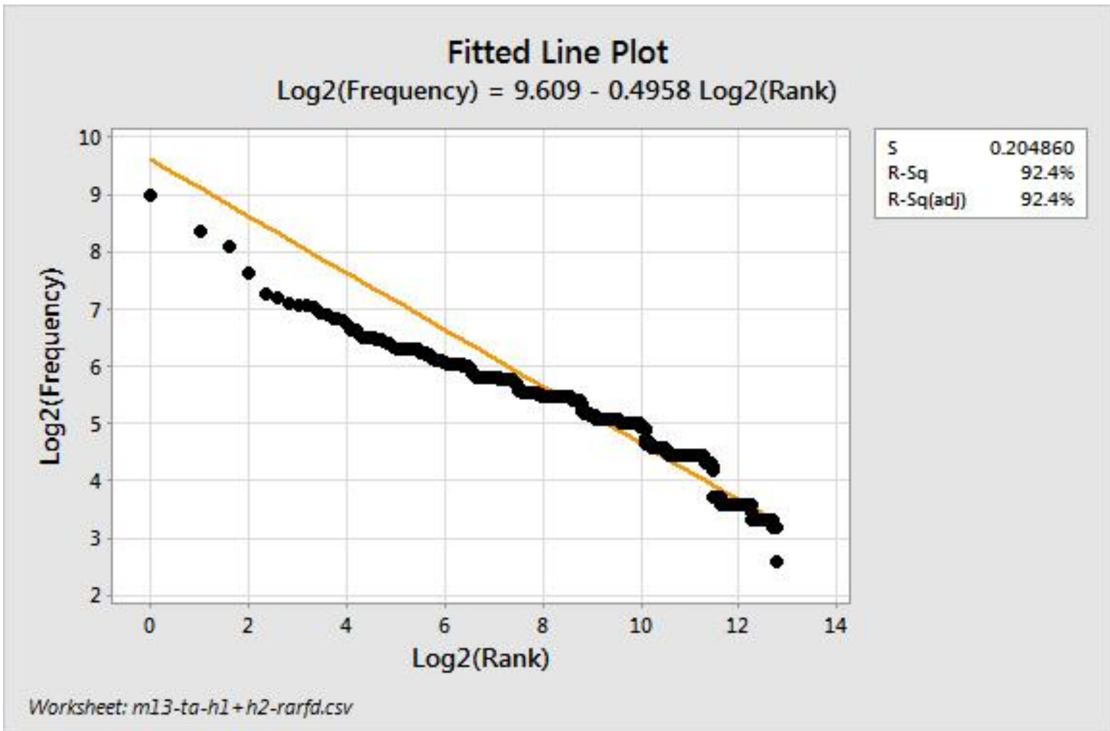

Fitted Line Plot
Log2(Frequency) = 10.53 - 0.6157 Log2(Rank)
S 0.330251
R-Sq 87.8%
R-Sq(adj) 87.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6-h1+h2-bmrfd.csv

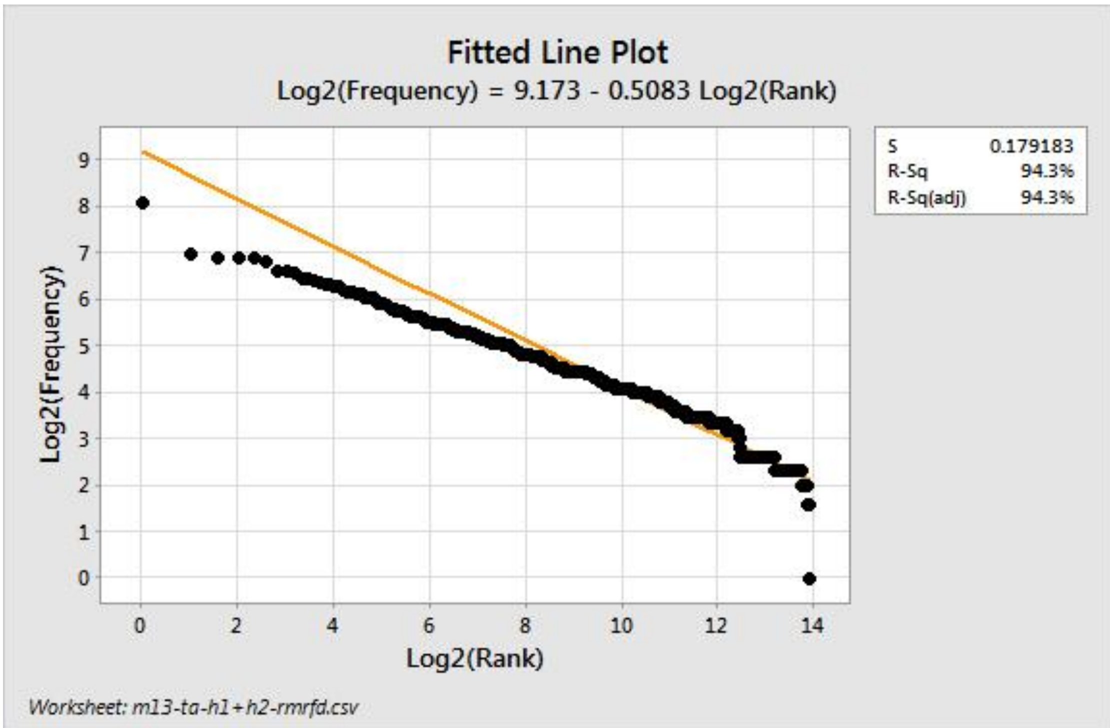


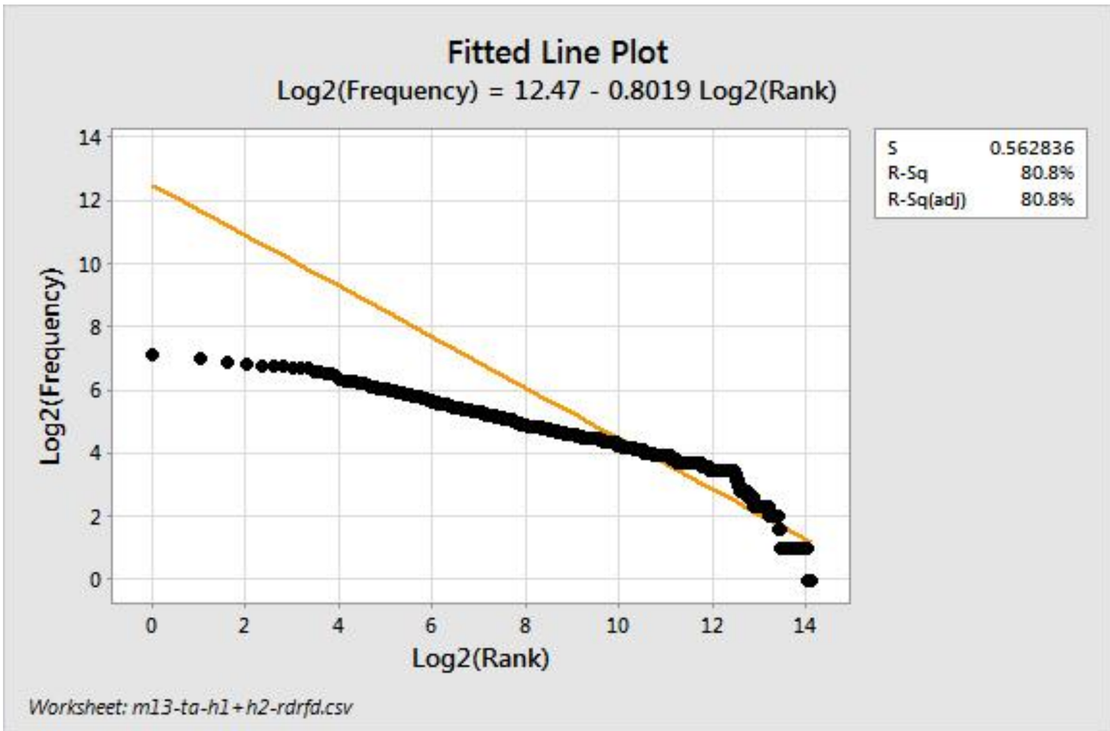
Fitted Line Plot
Log2(Frequency) = 10.16 - 0.6045 Log2(Rank)
S 0.420252
R-Sq 81.1%
R-Sq(adj) 81.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6-h1+h2-bdrfd.csv

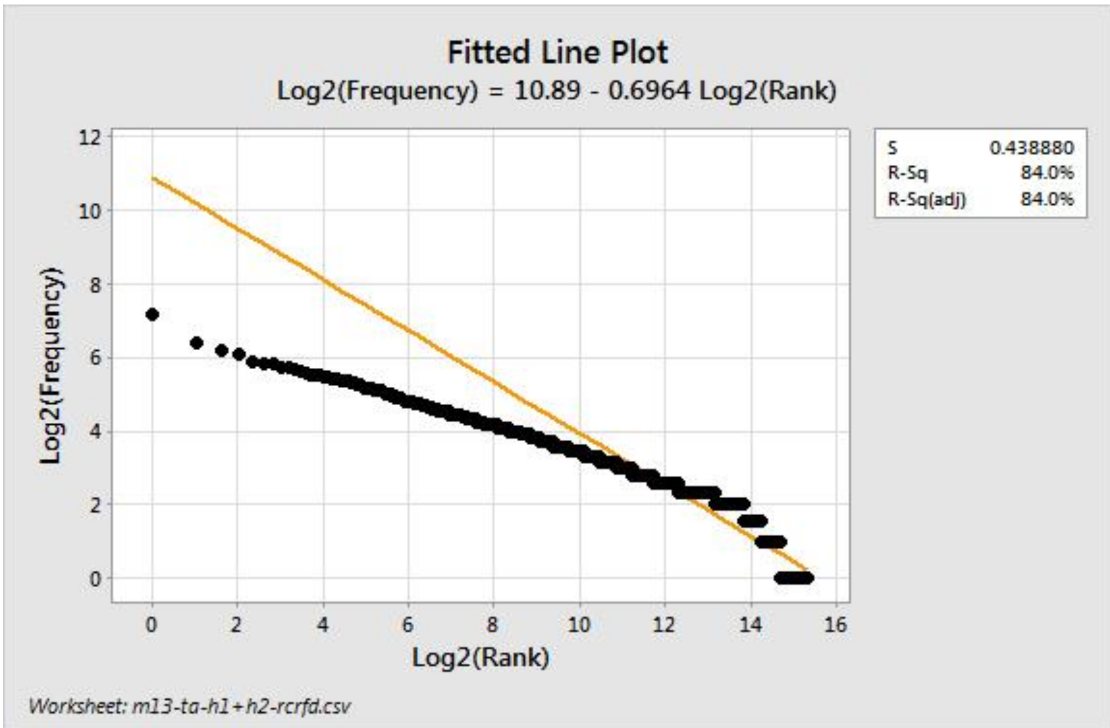


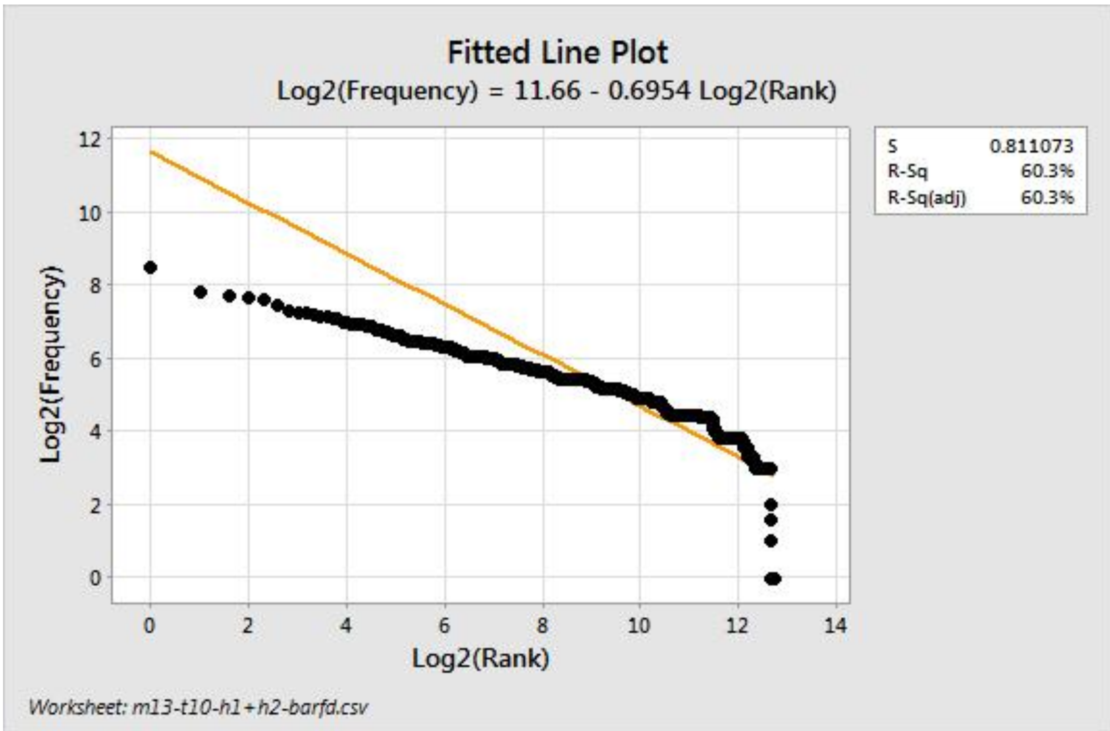
Fitted Line Plot
Log2(Frequency) = 10.08 - 0.6358 Log2(Rank)
S 0.377843
R-Sq 85.5%
R-Sq(adj) 85.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m12-t6-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 9.609 - 0.4958 Log2(Rank)
S 0.204860
R-Sq 92.4%
R-Sq(adj) 92.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta-h1+h2-rarfd.csv

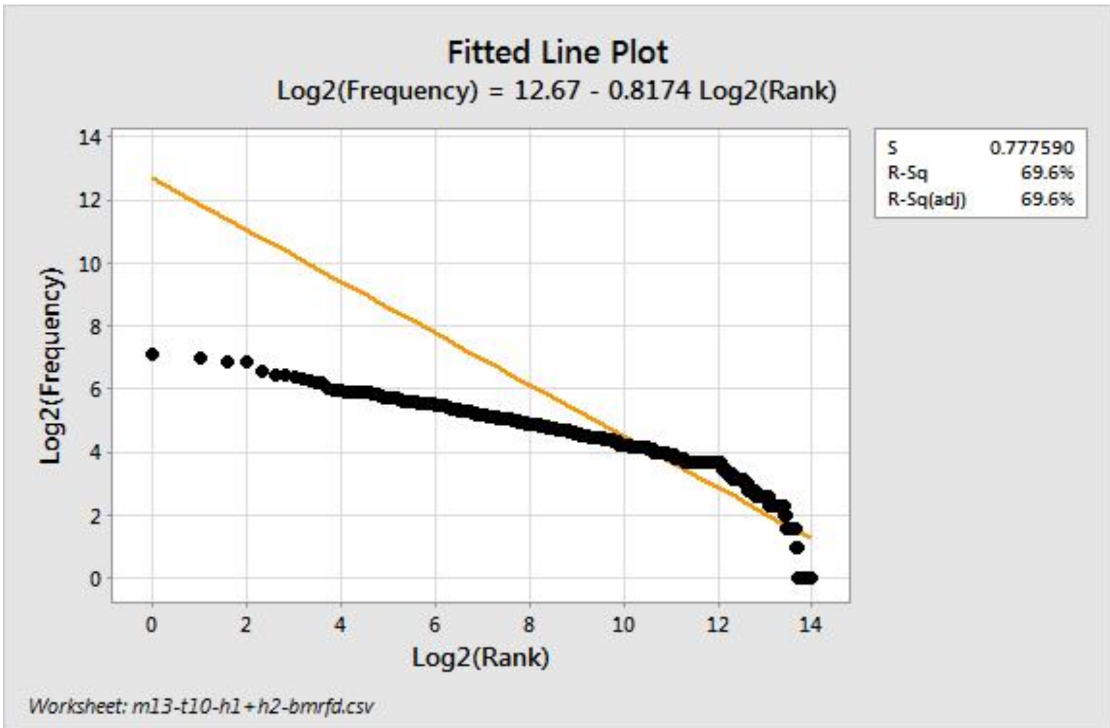

Fitted Line Plot
Log2(Frequency) = 9.173 - 0.5083 Log2(Rank)
S 0.179183
R-Sq 94.3%
R-Sq(adj) 94.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 12.47 - 0.8019 Log2(Rank)
S 0.562836
R-Sq 80.8%
R-Sq(adj) 80.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta-h1+h2-rdrfd.csv

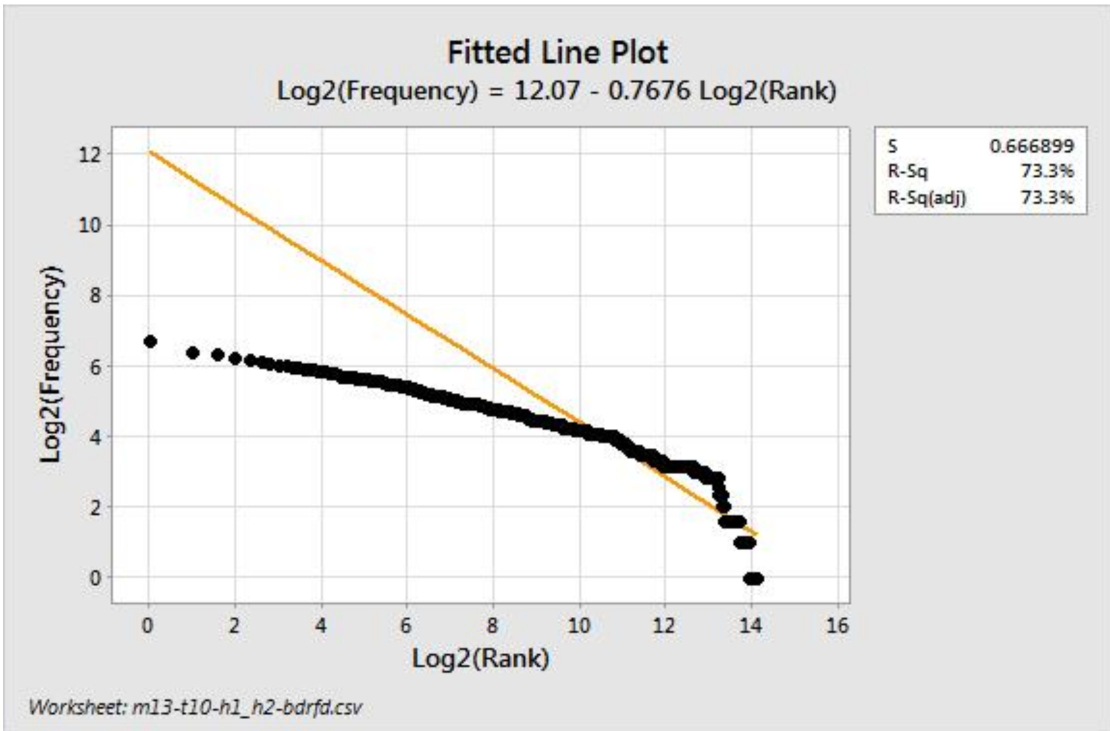

Fitted Line Plot
Log2(Frequency) = 10.89 - 0.6964 Log2(Rank)
S 0.438880
R-Sq 84.0%
R-Sq(adj) 84.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-ta-h1+h2-rcrfd.csv

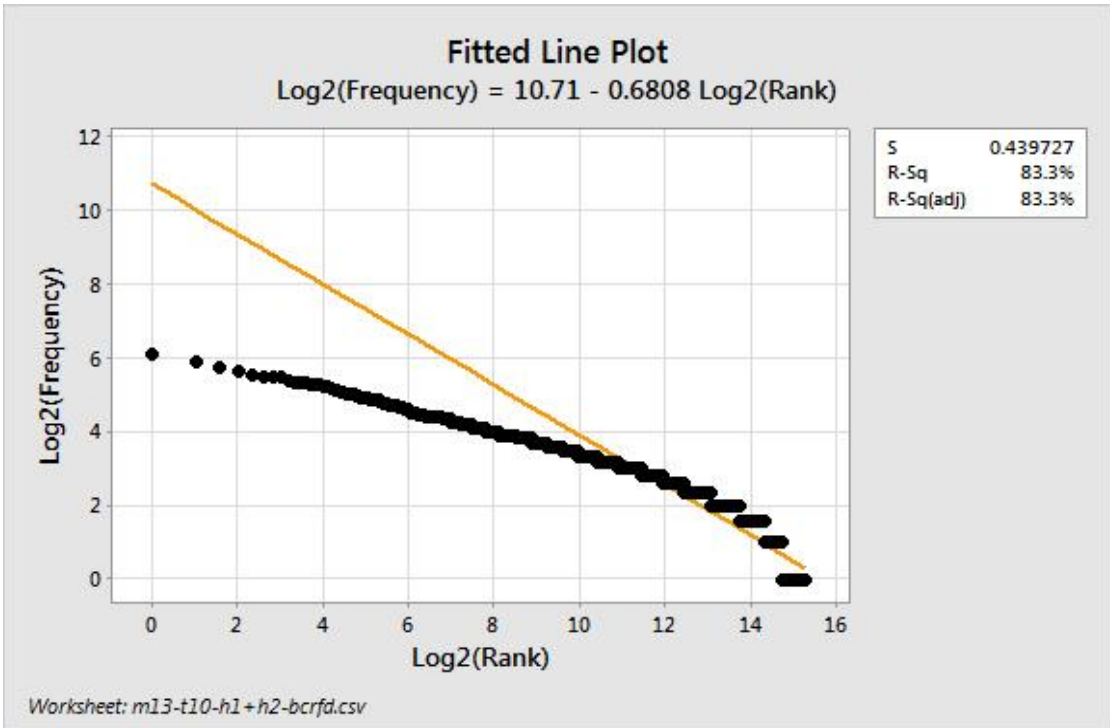


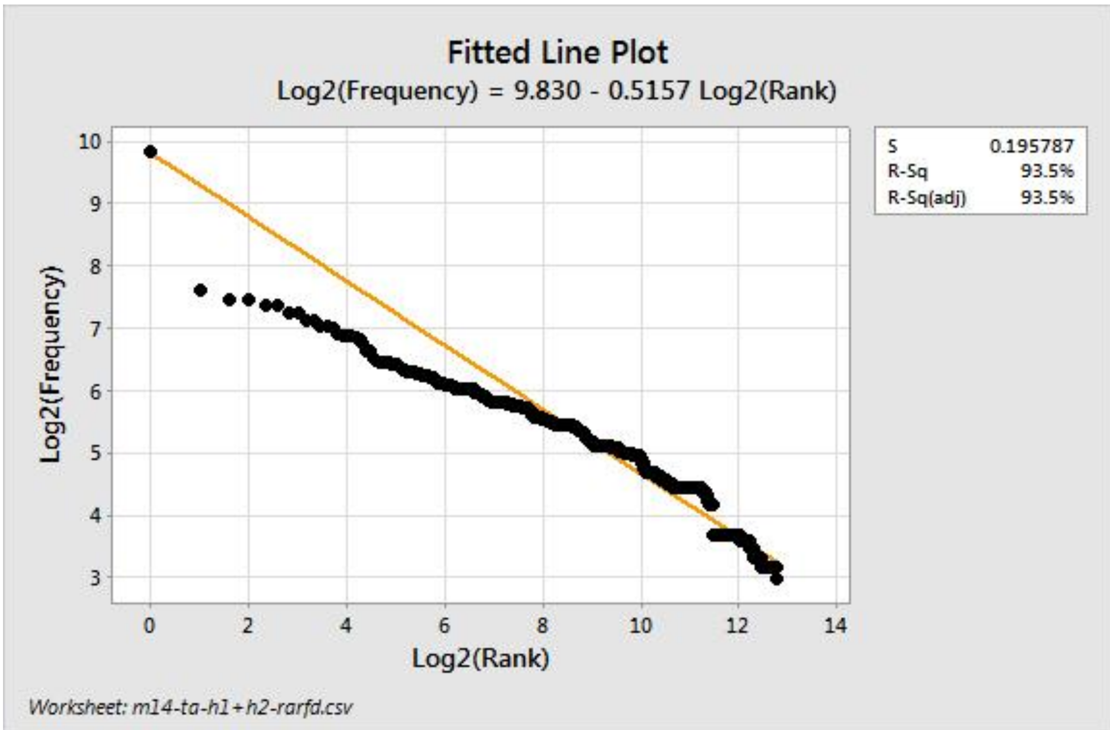
Fitted Line Plot
Log2(Frequency) = 11.66 - 0.6954 Log2(Rank)
S 0.811073
R-Sq 60.3%
R-Sq(adj) 60.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-t10-h1+h2-barfd.csv

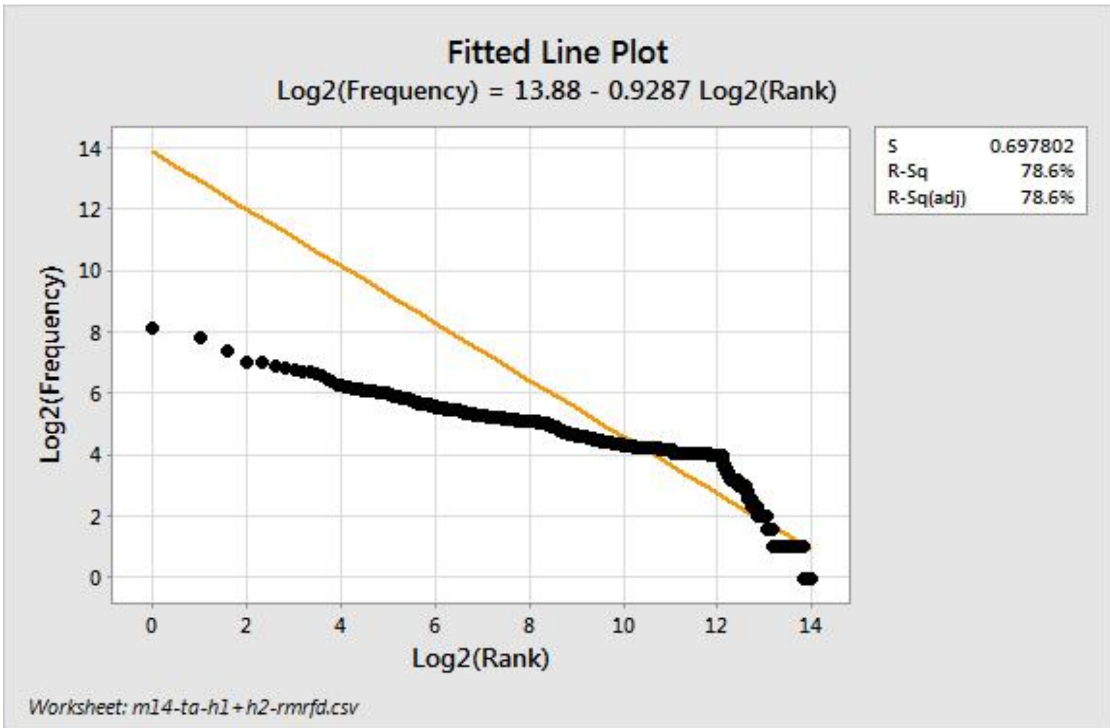


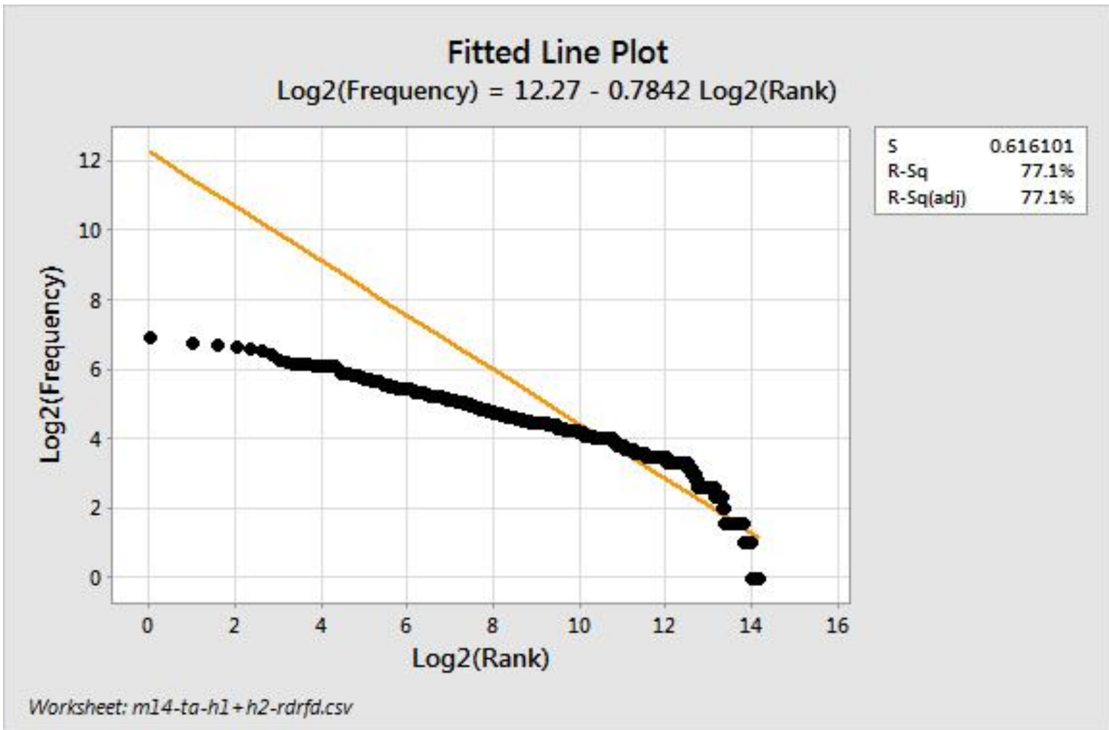
Fitted Line Plot
Log2(Frequency) = 12.67 - 0.8174 Log2(Rank)
S 0.777590
R-Sq 69.6%
R-Sq(adj) 69.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m13-t10-h1+h2-bmrfd.csv

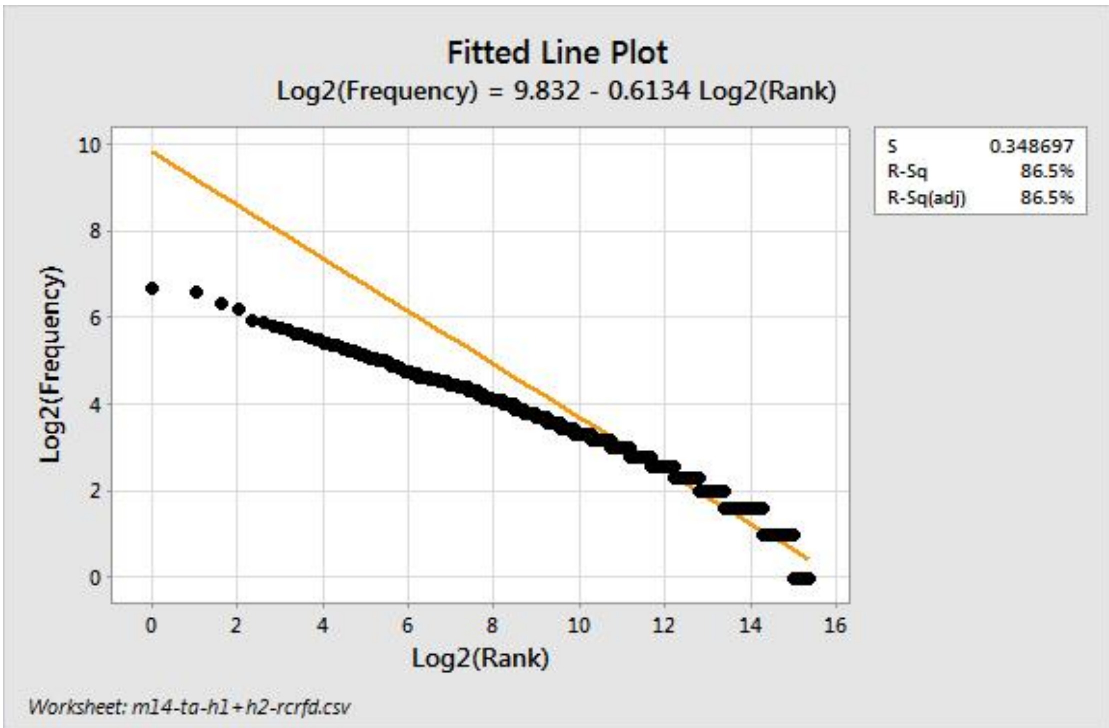

Fitted Line Plot
Log2(Frequency) = 12.07 - 0.7676 Log2(Rank)
S 0.666899
R-Sq 73.3%
R-Sq(adj) 73.3%
Log2(Frequency)
Log2(Rank)
0 2 4 6 8 10 12 14 16
Worksheet: m13-t10-h1_h2-bdrfd.csv

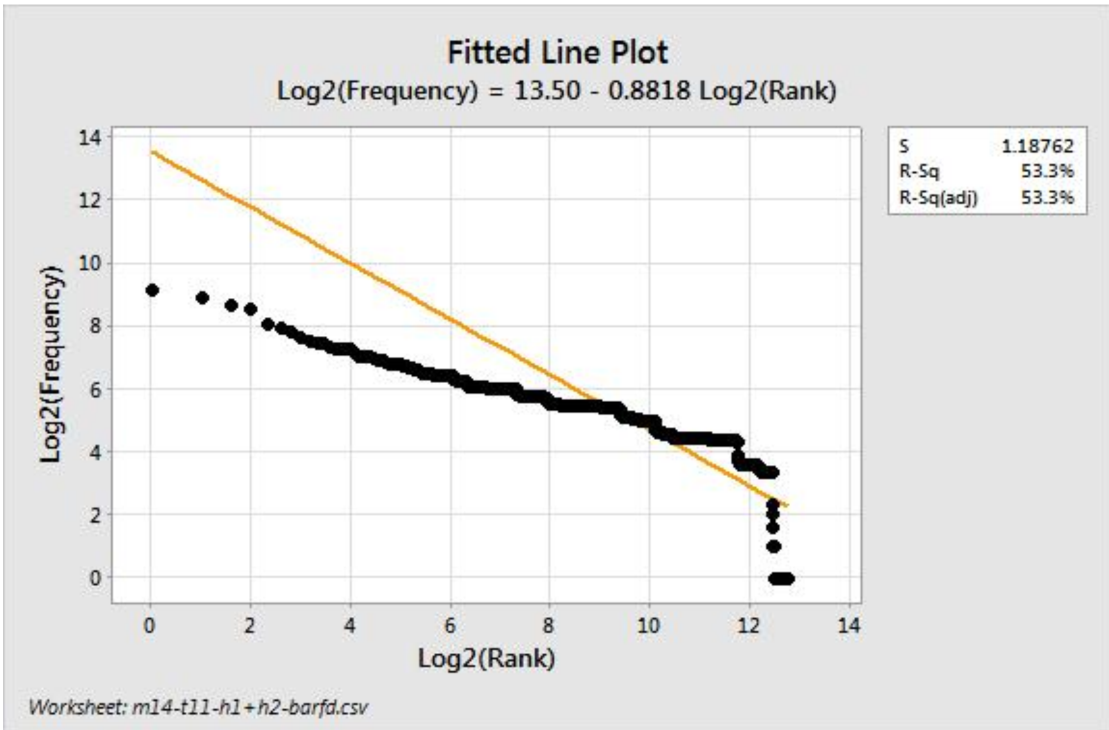

Fitted Line Plot
Log2(Frequency) = 10.71 - 0.6808 Log2(Rank)
S 0.439727
R-Sq 83.3%
R-Sq(adj) 83.3%
Log2(Frequency)
Log2(Rank)
0 2 4 6 8 10 12 14 16
Worksheet: m13-t10-h1+h2-bcrfd.csv

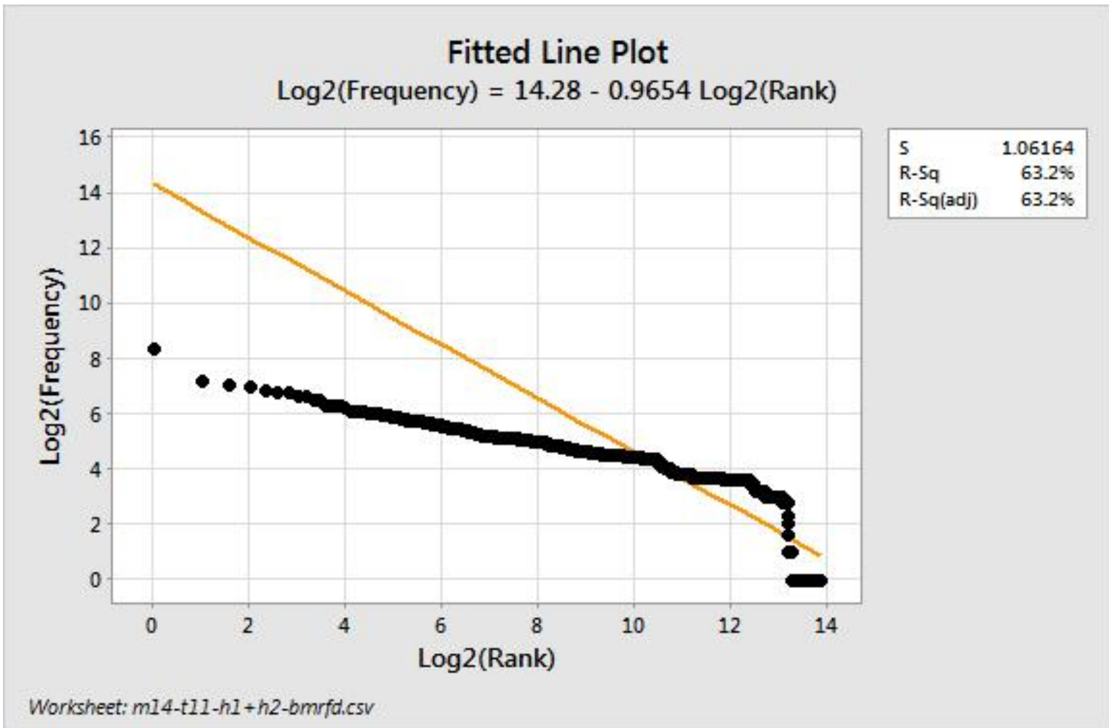

Fitted Line Plot
Log2(Frequency) = 9.830 - 0.5157 Log2(Rank)
S 0.195787
R-Sq 93.5%
R-Sq(adj) 93.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-ta-h1+h2-rarfd.csv

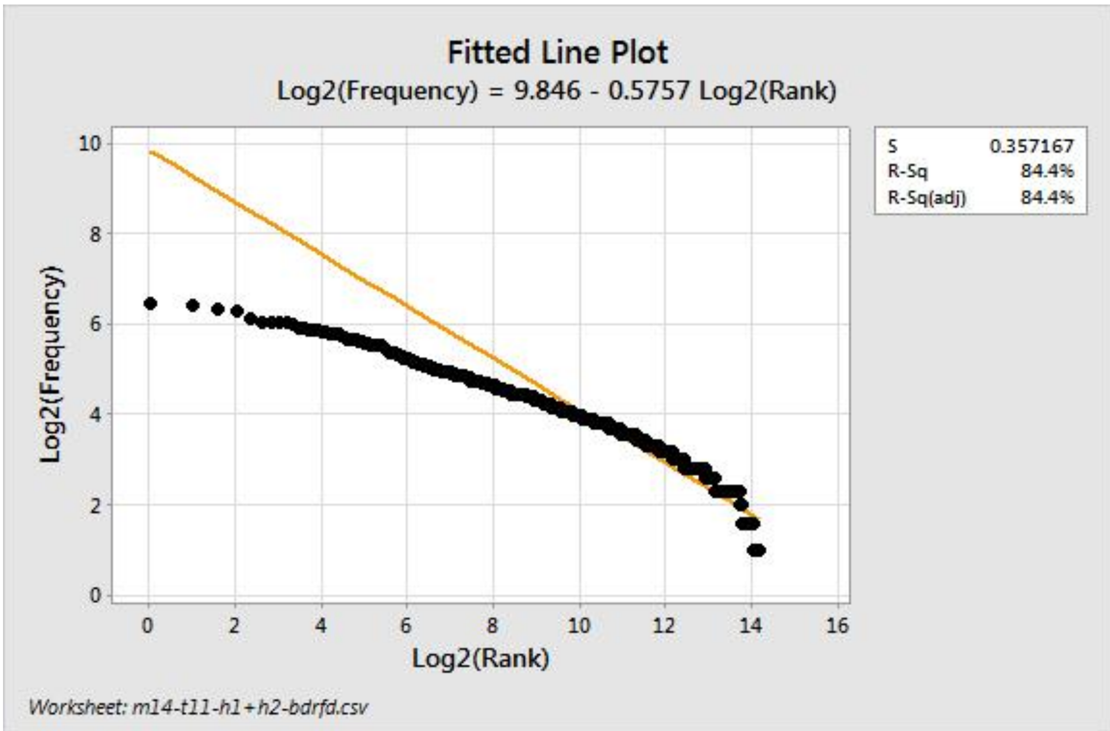

Fitted Line Plot
Log2(Frequency) = 13.88 - 0.9287 Log2(Rank)
S 0.697802
R-Sq 78.6%
R-Sq(adj) 78.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-ta-h1+h2-rmrfd.csv

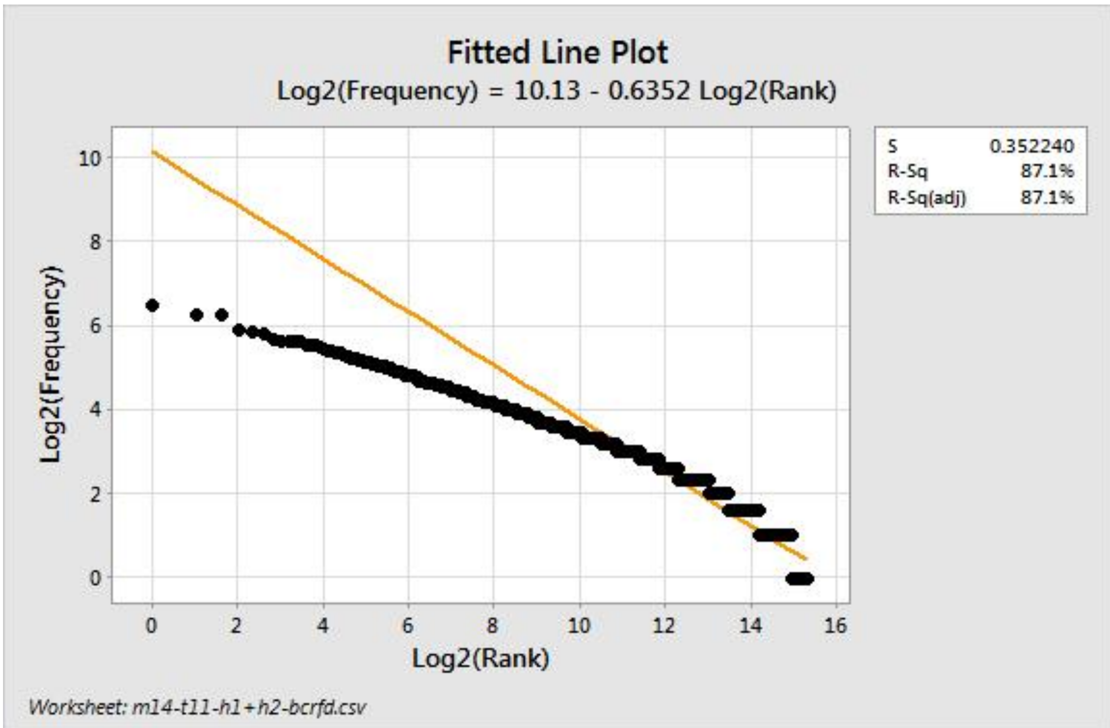

Fitted Line Plot
Log2(Frequency) = 12.27 - 0.7842 Log2(Rank)
S 0.616101
R-Sq 77.1%
R-Sq(adj) 77.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-ta-h1+h2-rdrfd.csv

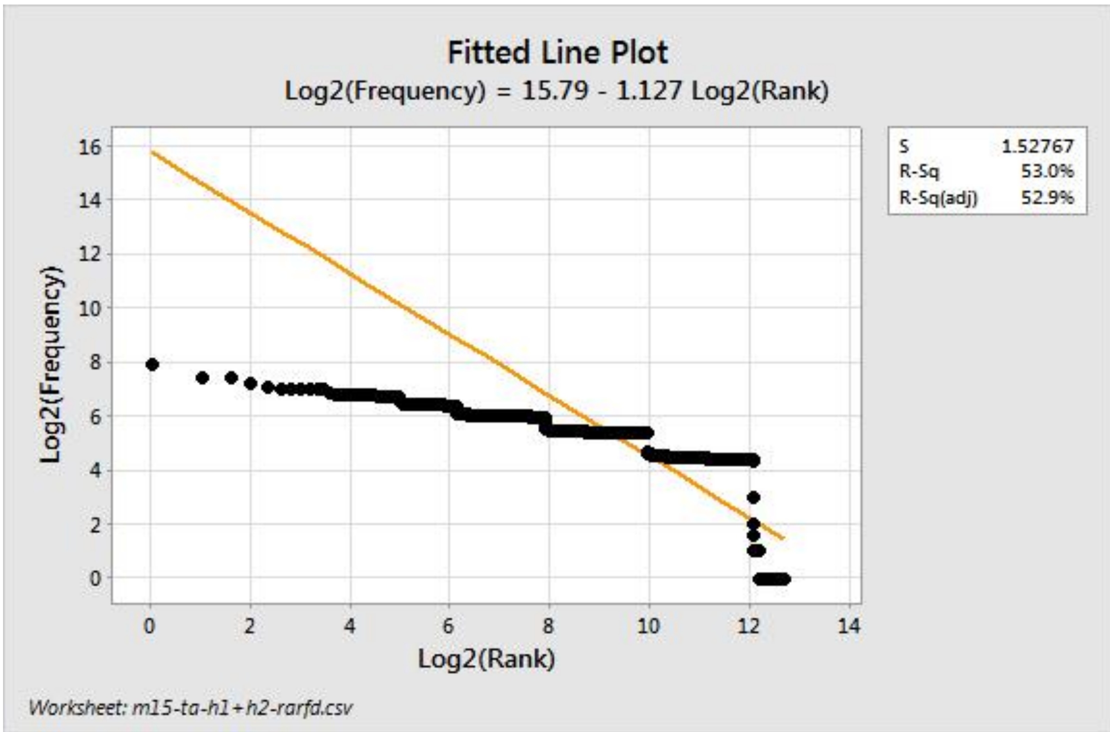

Fitted Line Plot
Log2(Frequency) = 9.832 - 0.6134 Log2(Rank)
S 0.348697
R-Sq 86.5%
R-Sq(adj) 86.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-ta-h1+h2-rcrfd.csv

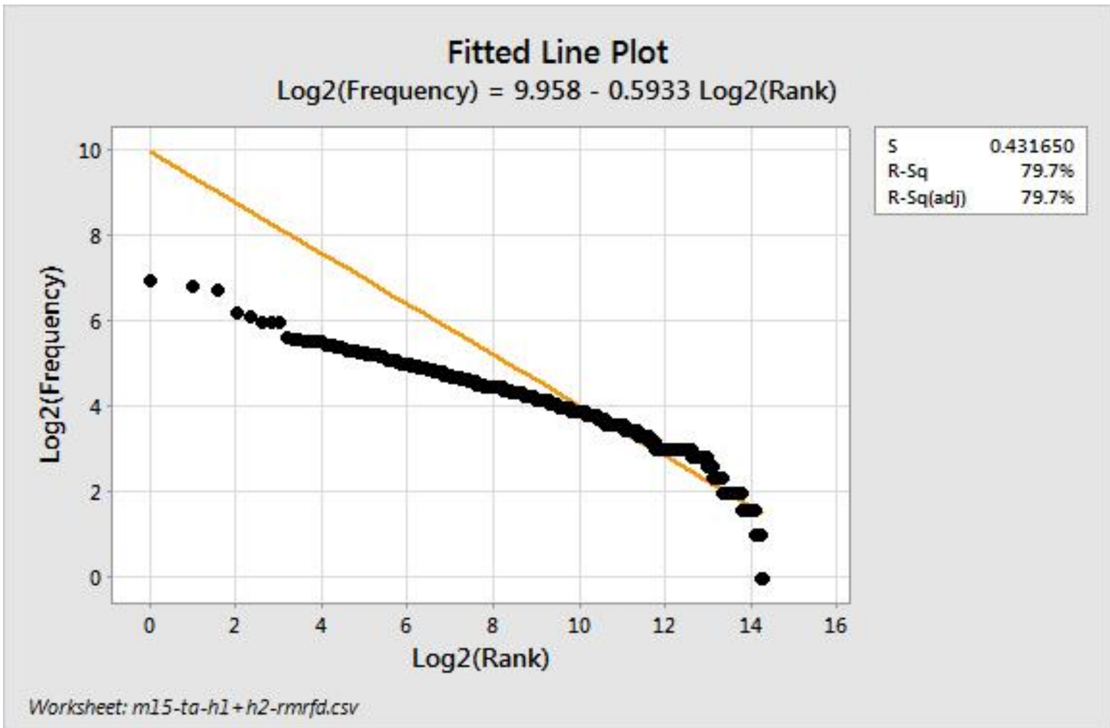

Fitted Line Plot
Log2(Frequency) = 13.50 - 0.8818 Log2(Rank)
S 1.18762
R-Sq 53.3%
R-Sq(adj) 53.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-t11-h1+h2-barfd.csv

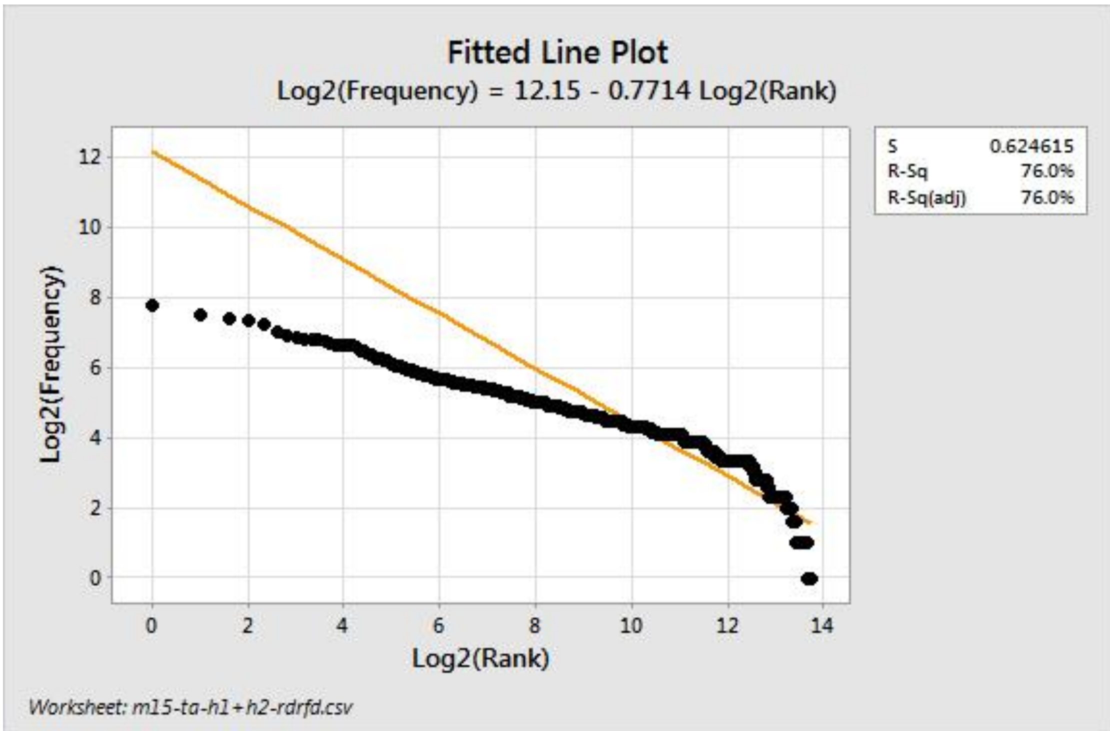

Fitted Line Plot
Log2(Frequency) = 14.28 - 0.9654 Log2(Rank)
S 1.06164
R-Sq 63.2%
R-Sq(adj) 63.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-t11-h1+h2-bmrfd.csv

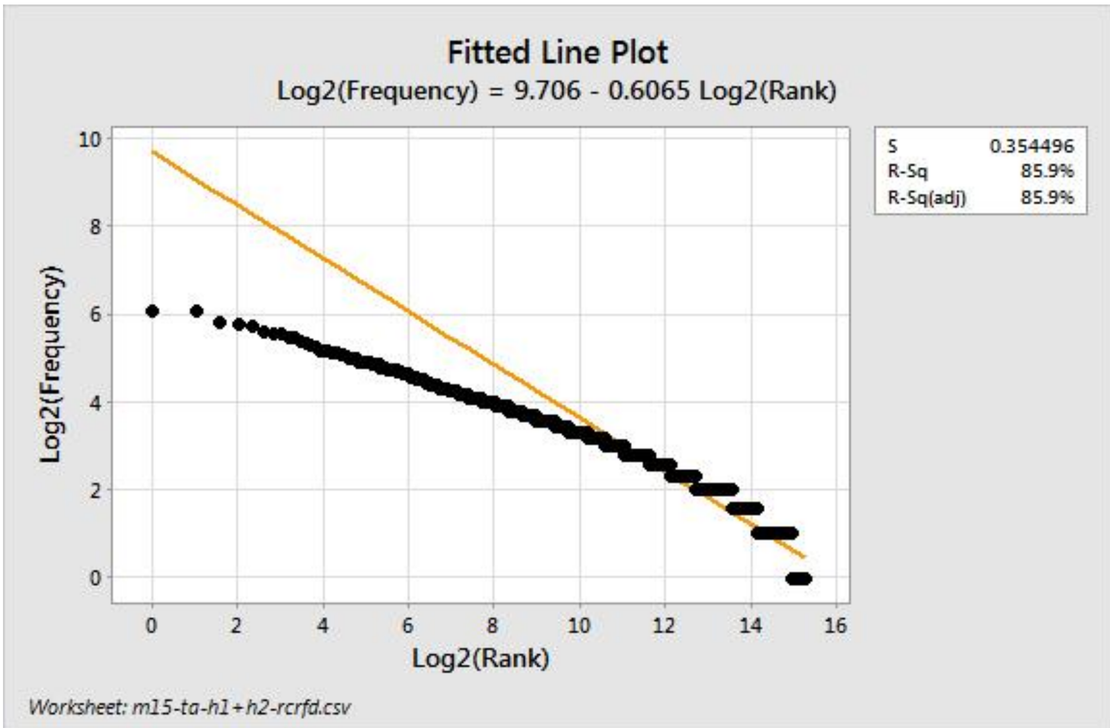

Fitted Line Plot
Log2(Frequency) = 9.846 - 0.5757 Log2(Rank)
S 0.357167
R-Sq 84.4%
R-Sq(adj) 84.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-t11-h1+h2-bdrfd.csv

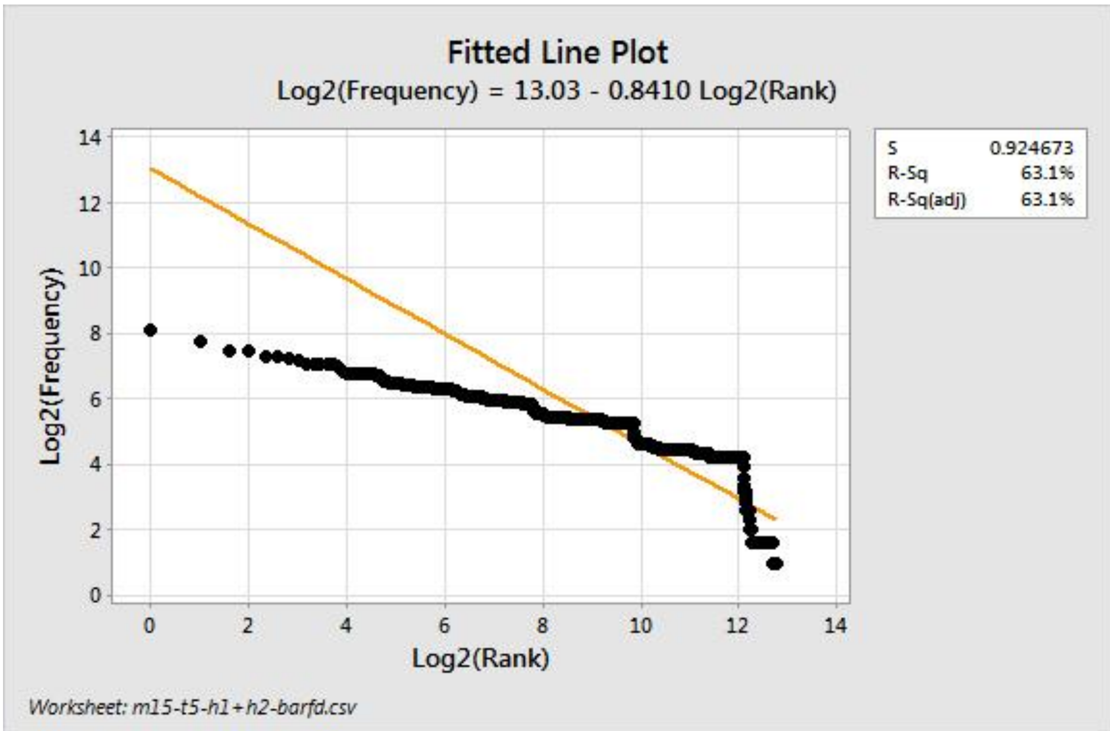

Fitted Line Plot
Log2(Frequency) = 10.13 - 0.6352 Log2(Rank)
S 0.352240
R-Sq 87.1%
R-Sq(adj) 87.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m14-t11-h1+h2-bcrfd.csv

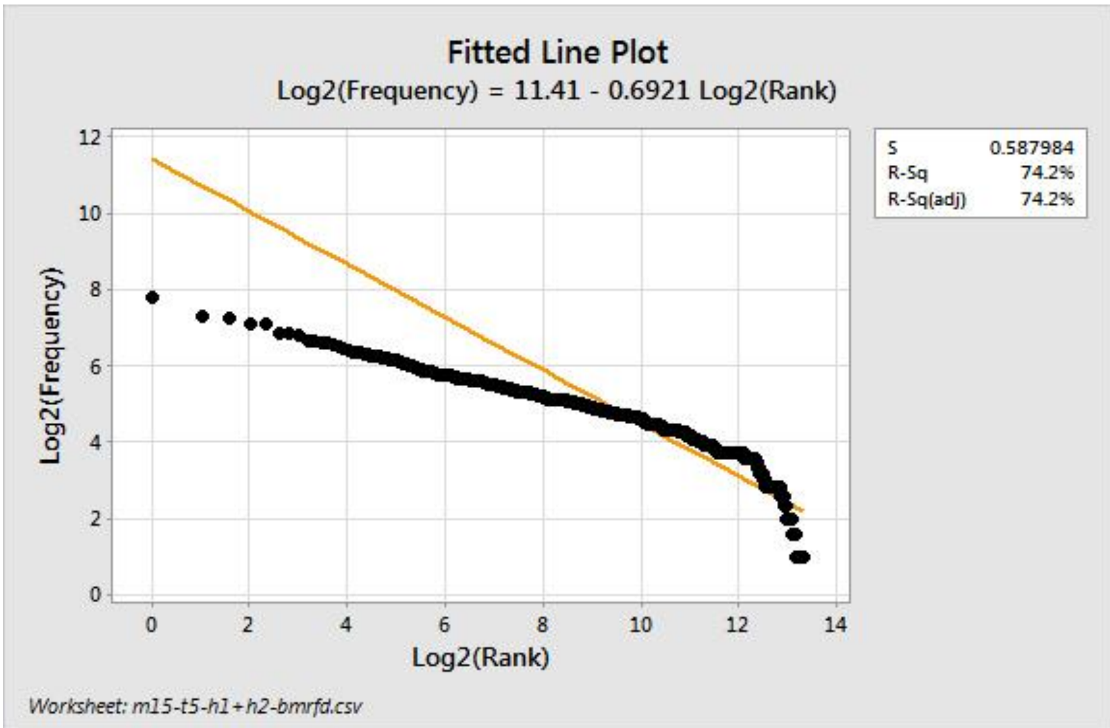

Fitted Line Plot
Log2(Frequency) = 15.79 - 1.127 Log2(Rank)
S 1.52767
R-Sq 53.0%
R-Sq(adj) 52.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-ta-h1+h2-rarfd.csv

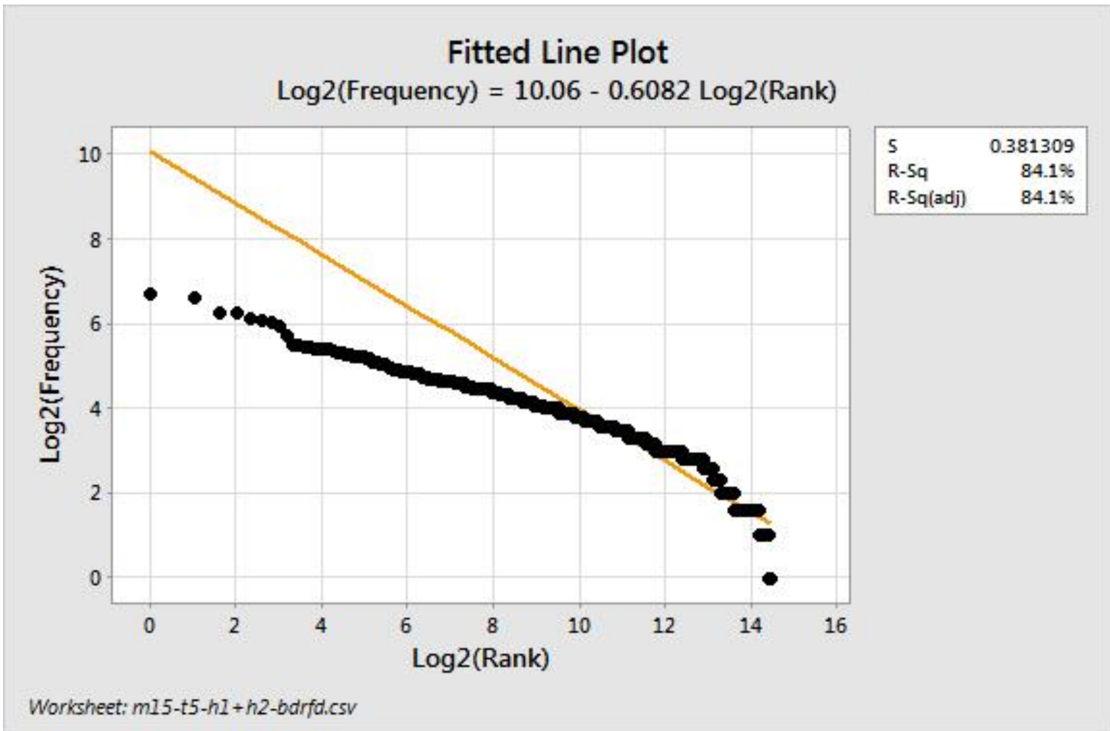

Fitted Line Plot
Log2(Frequency) = 9.958 - 0.5933 Log2(Rank)
S 0.431650
R-Sq 79.7%
R-Sq(adj) 79.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-ta-h1+h2-rmrfd.csv

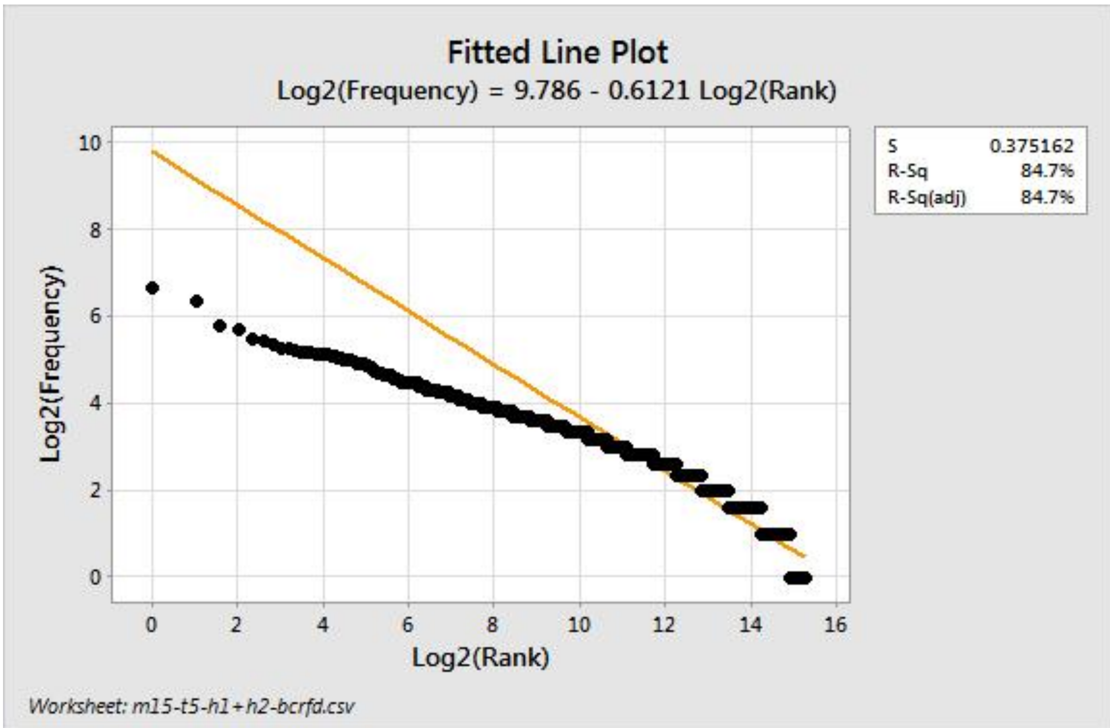

Fitted Line Plot
Log2(Frequency) = 12.15 - 0.7714 Log2(Rank)
S 0.624615
R-Sq 76.0%
R-Sq(adj) 76.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-ta-h1+h2-rdrfd.csv

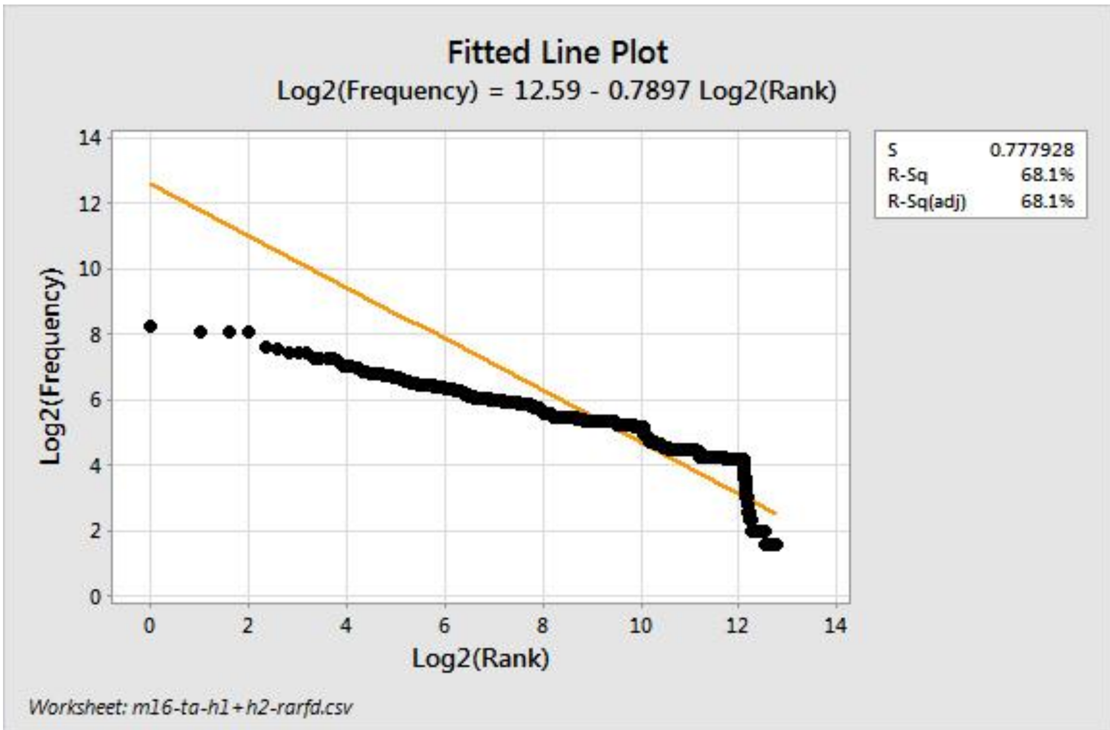

Fitted Line Plot
Log2(Frequency) = 9.706 - 0.6065 Log2(Rank)
S 0.354496
R-Sq 85.9%
R-Sq(adj) 85.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.03 - 0.8410 Log2(Rank)
S 0.924673
R-Sq 63.1%
R-Sq(adj) 63.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-t5-h1+h2-barfd.csv

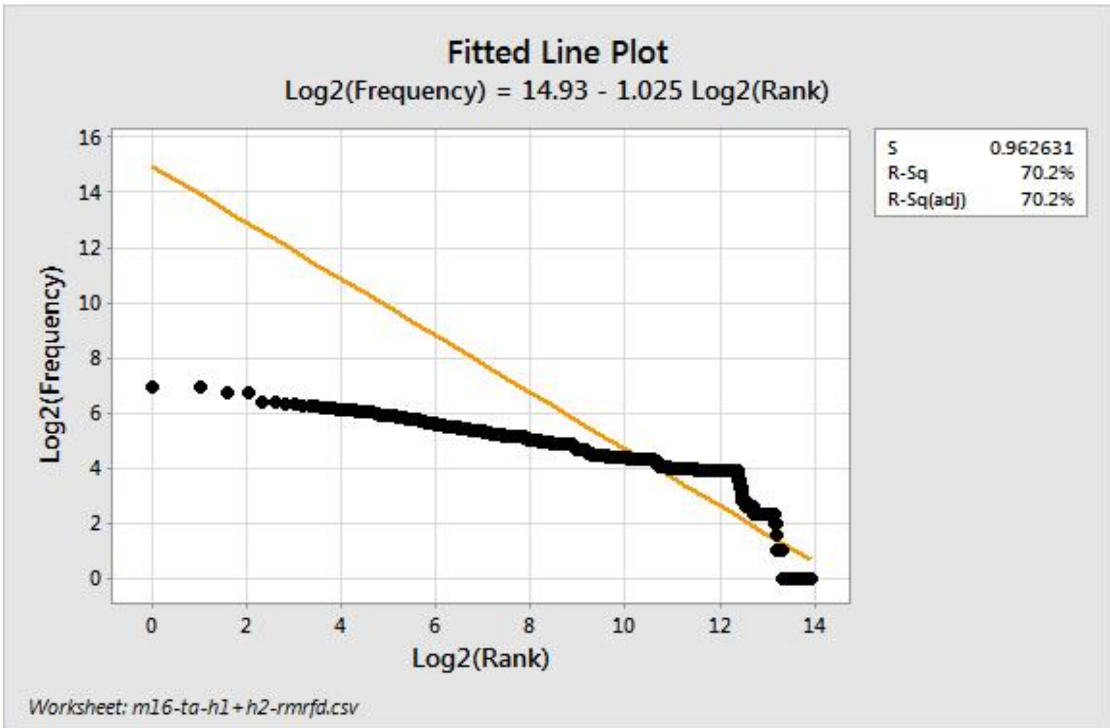

Fitted Line Plot
Log2(Frequency) = 11.41 - 0.6921 Log2(Rank)
S 0.587984
R-Sq 74.2%
R-Sq(adj) 74.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-t5-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.06 - 0.6082 Log2(Rank)
S 0.381309
R-Sq 84.1%
R-Sq(adj) 84.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-t5-h1+h2-bdrfd.csv

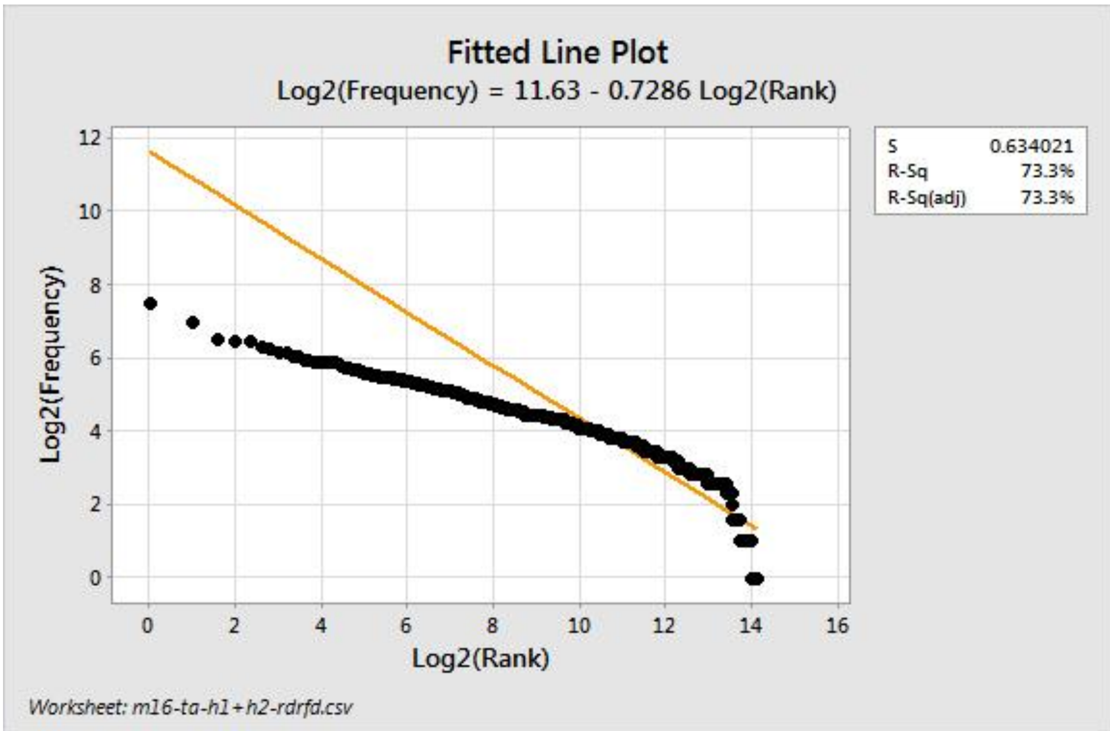

Fitted Line Plot
Log2(Frequency) = 9.786 - 0.6121 Log2(Rank)
S 0.375162
R-Sq 84.7%
R-Sq(adj) 84.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m15-t5-h1+h2-bcrfd.csv

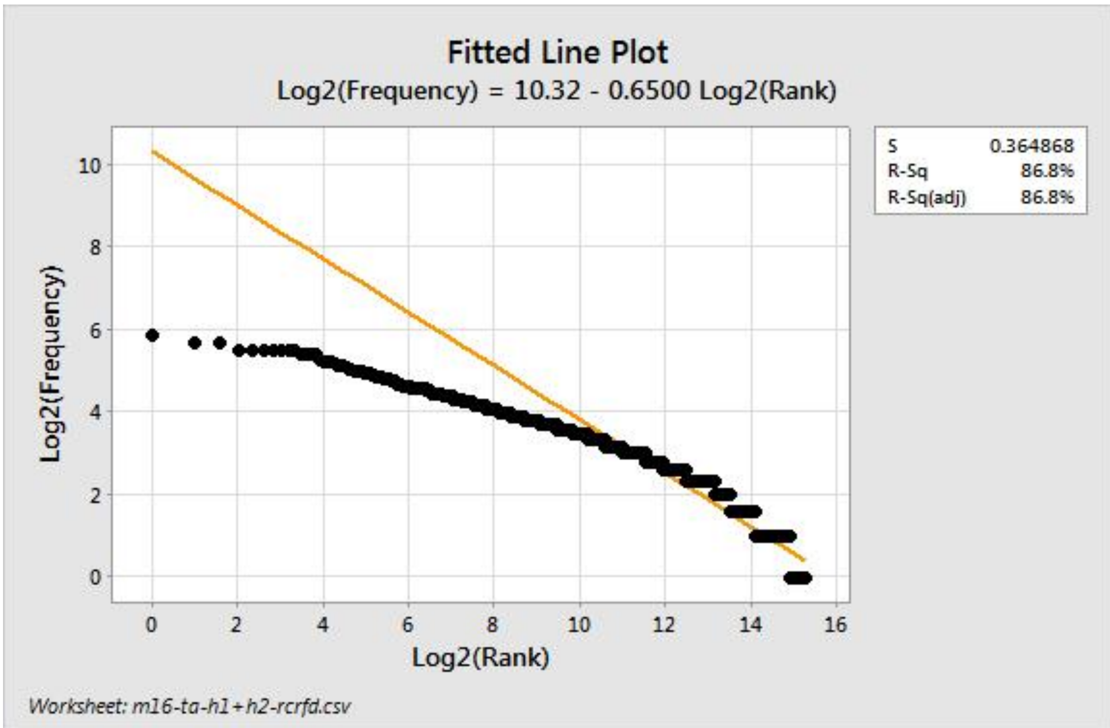


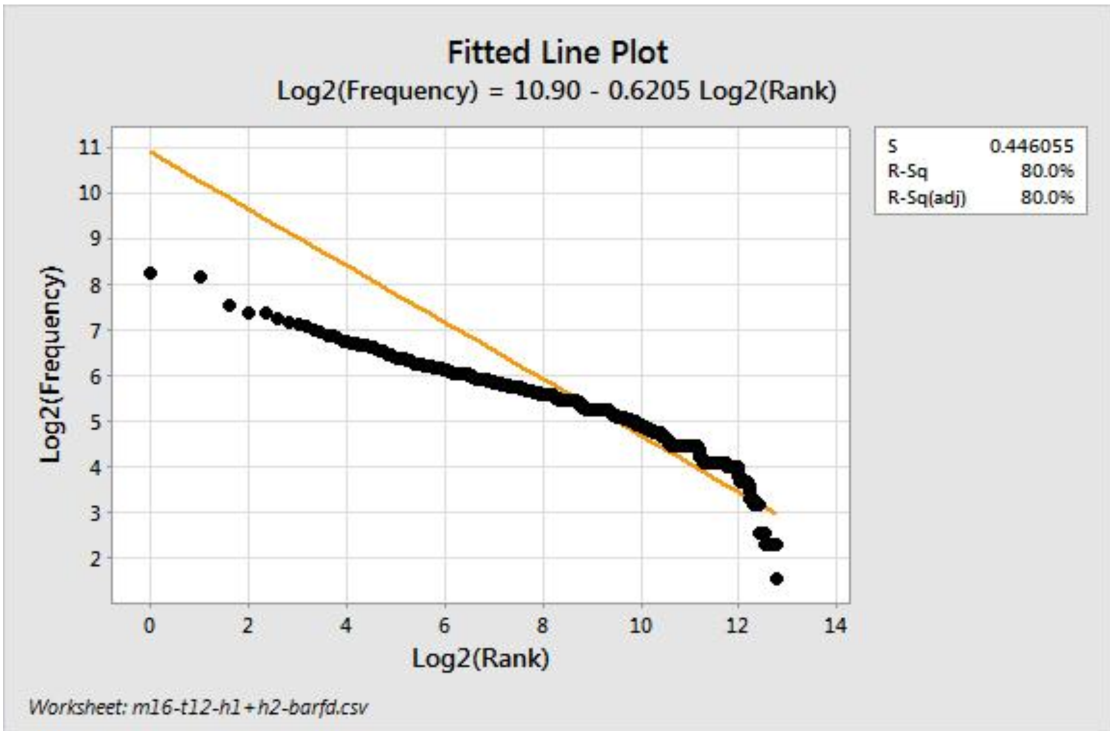
Fitted Line Plot
Log2(Frequency) = 12.59 - 0.7897 Log2(Rank)
S 0.777928
R-Sq 68.1%
R-Sq(adj) 68.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-ta-h1+h2-rarfd.csv



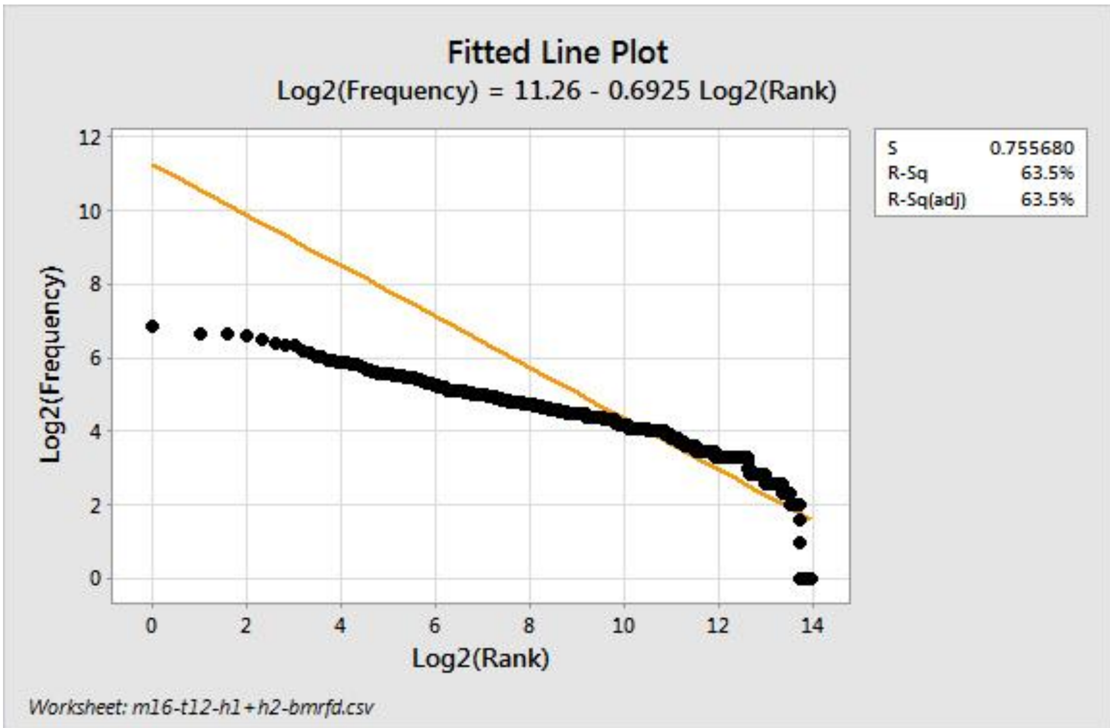
Fitted Line Plot
Log2(Frequency) = 14.93 - 1.025 Log2(Rank)
S 0.962631
R-Sq 70.2%
R-Sq(adj) 70.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 11.63 - 0.7286 Log2(Rank)
S 0.634021
R-Sq 73.3%
R-Sq(adj) 73.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-ta-h1+h2-rdrfd.csv

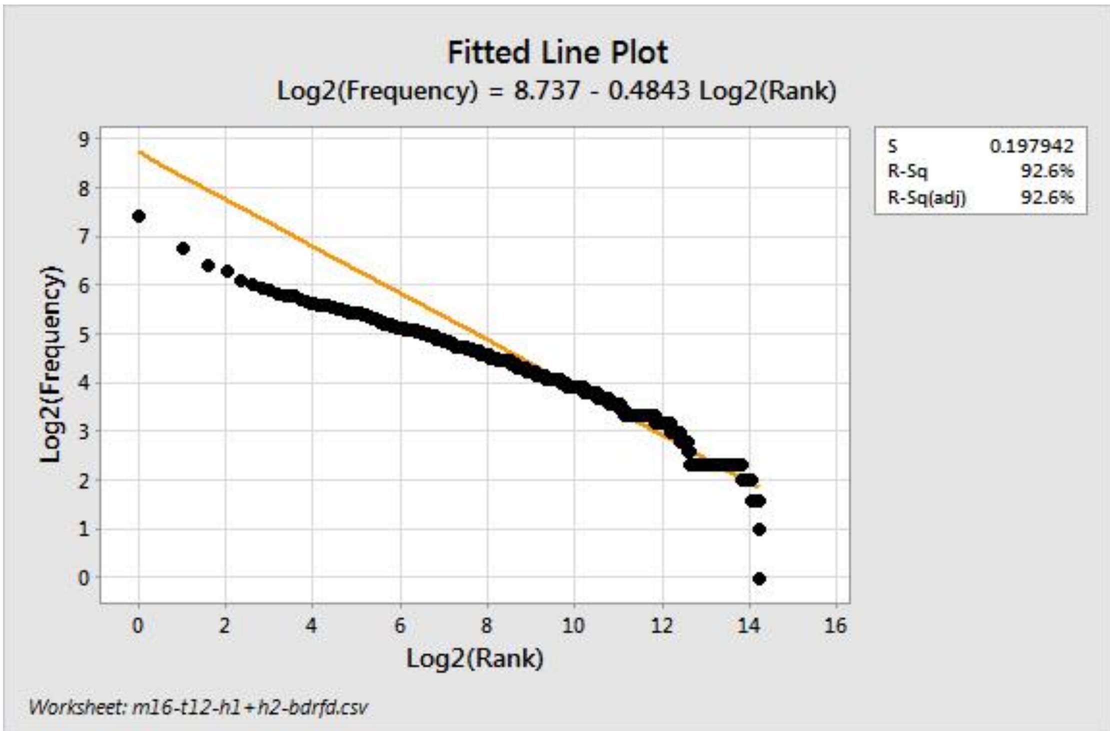

Fitted Line Plot
Log2(Frequency) = 10.32 - 0.6500 Log2(Rank)
S 0.364868
R-Sq 86.8%
R-Sq(adj) 86.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-ta-h1+h2-rcrfd.csv

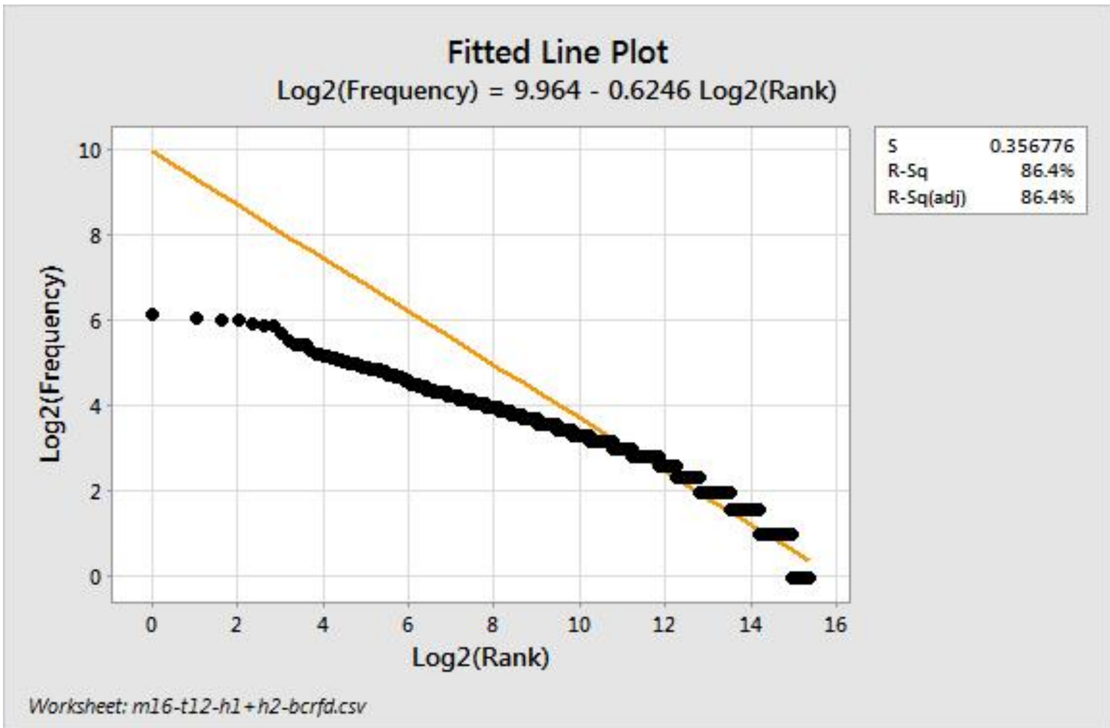


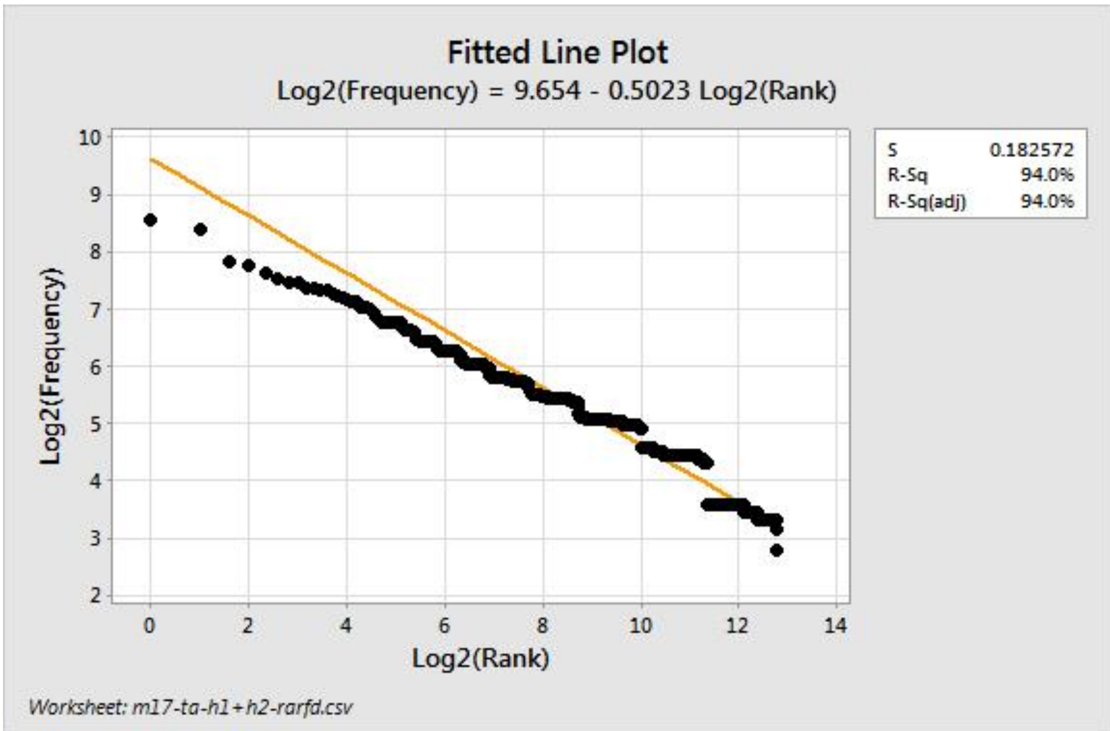
Fitted Line Plot
Log2(Frequency) = 10.90 - 0.6205 Log2(Rank)
S 0.446055
R-Sq 80.0%
R-Sq(adj) 80.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-t12-h1+h2-barfd.csv

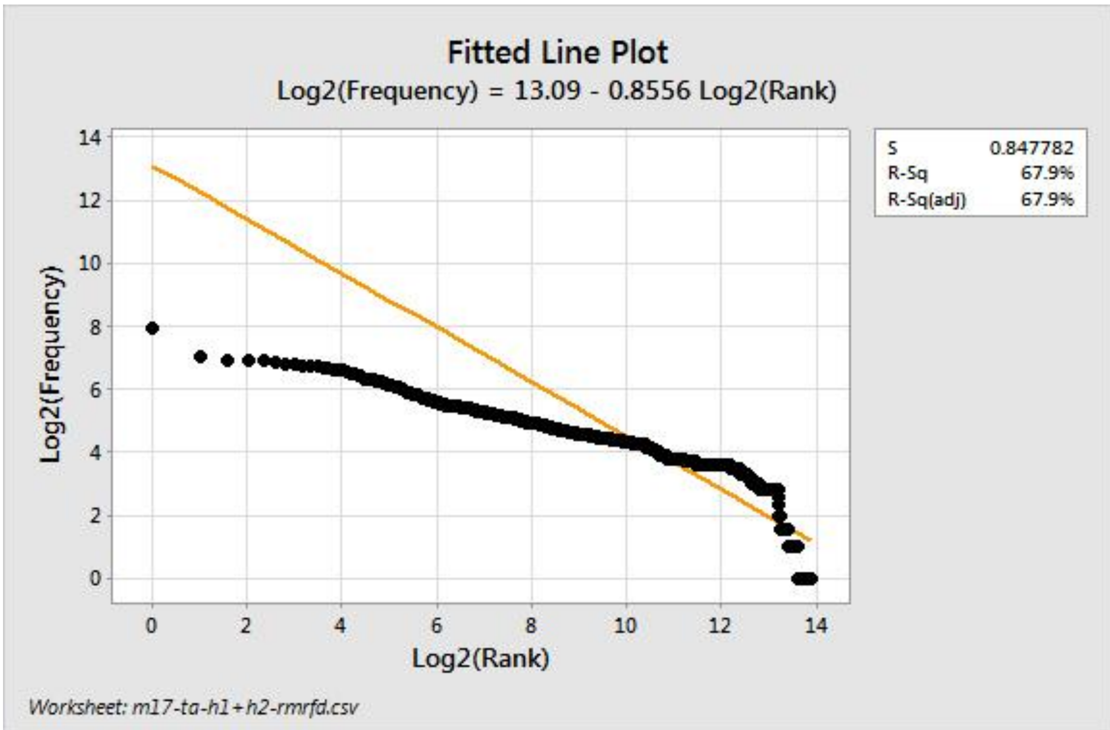


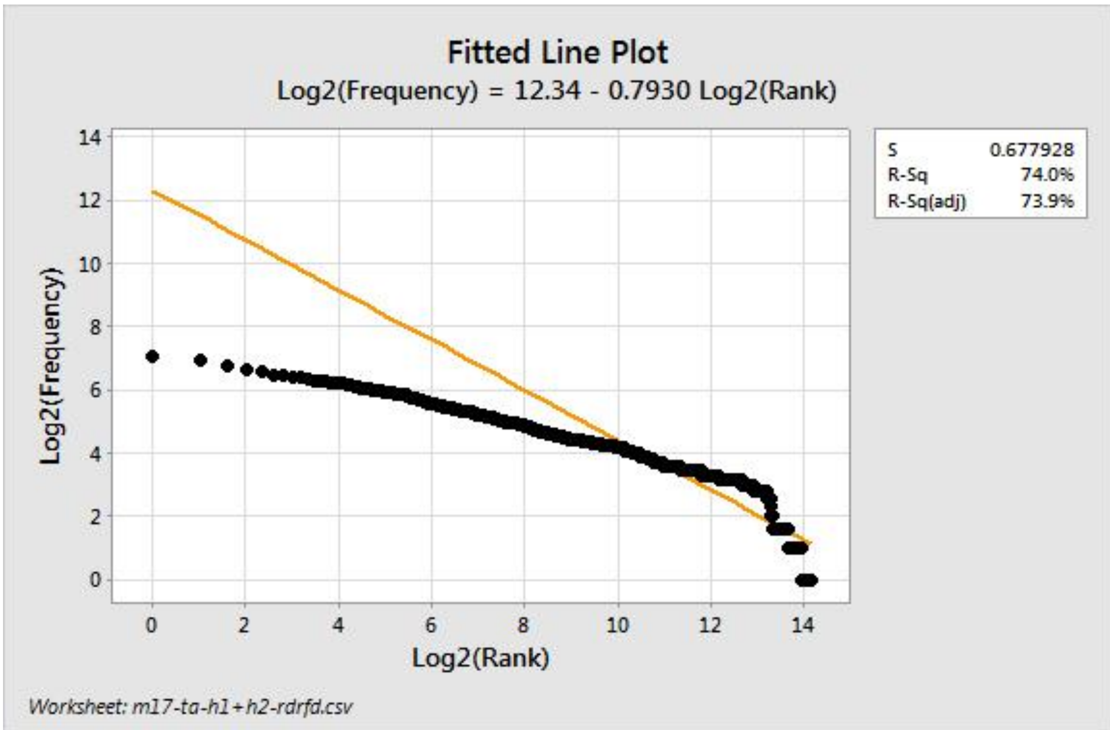
Fitted Line Plot
Log2(Frequency) = 11.26 - 0.6925 Log2(Rank)
S 0.755680
R-Sq 63.5%
R-Sq(adj) 63.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-t12-h1+h2-bmrfd.csv

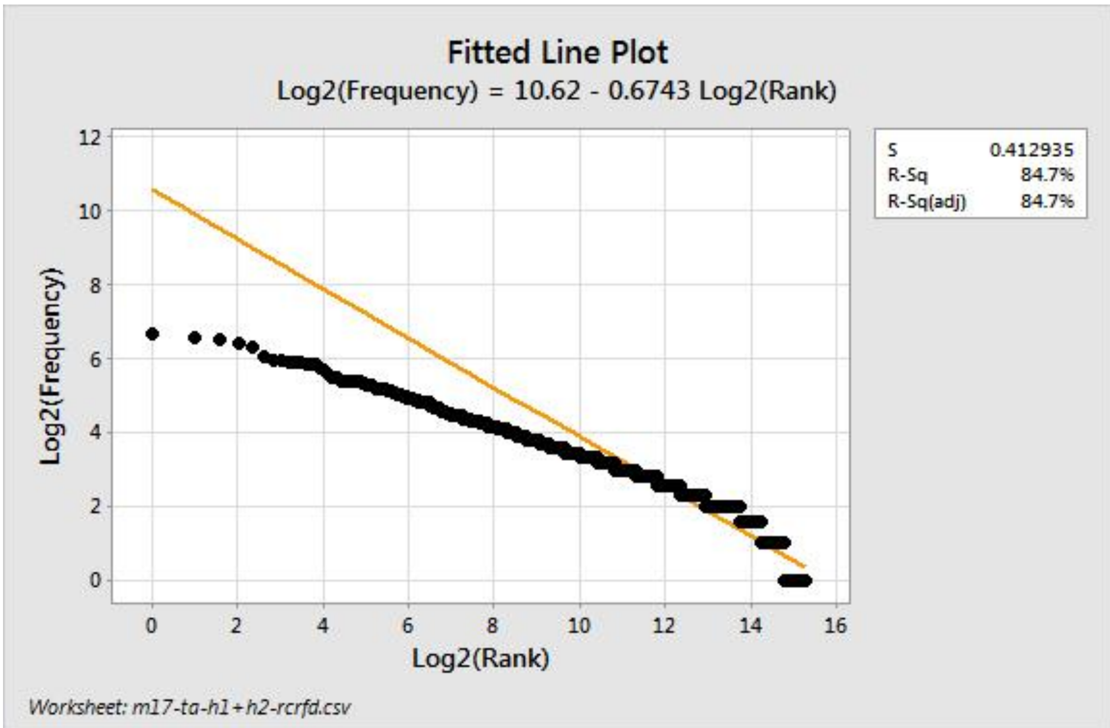

Fitted Line Plot
Log2(Frequency) = 8.737 - 0.4843 Log2(Rank)
S 0.197942
R-Sq 92.6%
R-Sq(adj) 92.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-t12-h1+h2-bdrfd.csv

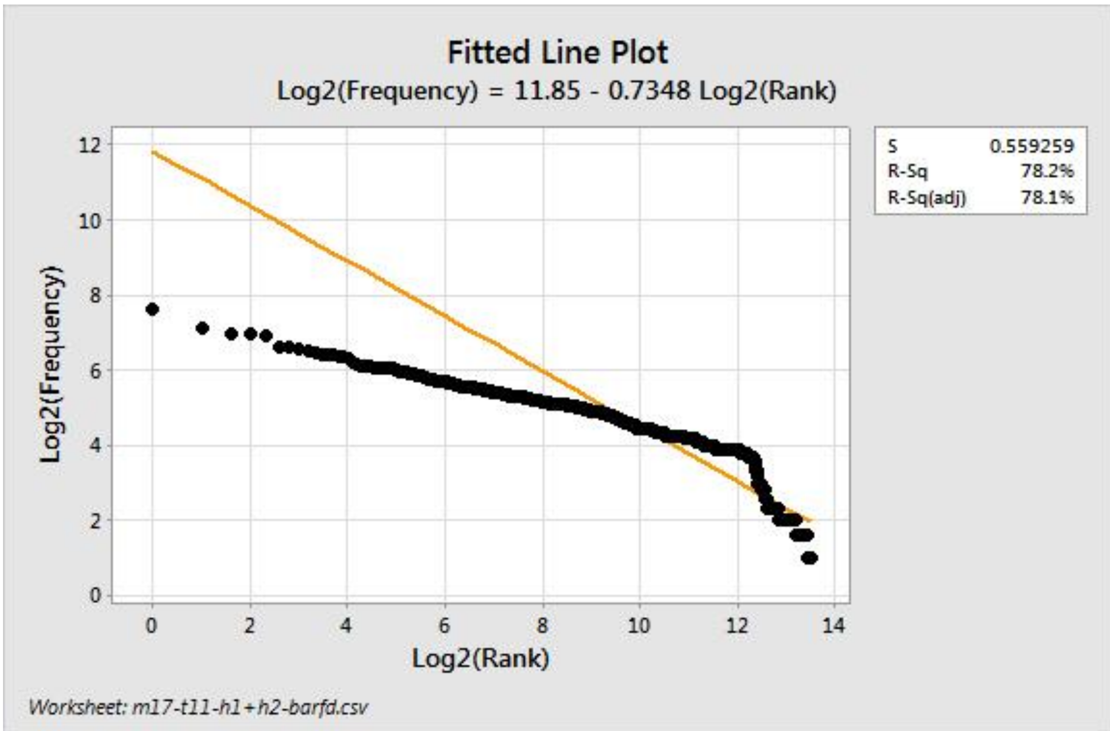

Fitted Line Plot
Log2(Frequency) = 9.964 - 0.6246 Log2(Rank)
S 0.356776
R-Sq 86.4%
R-Sq(adj) 86.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m16-t12-h1+h2-bcrfd.csv

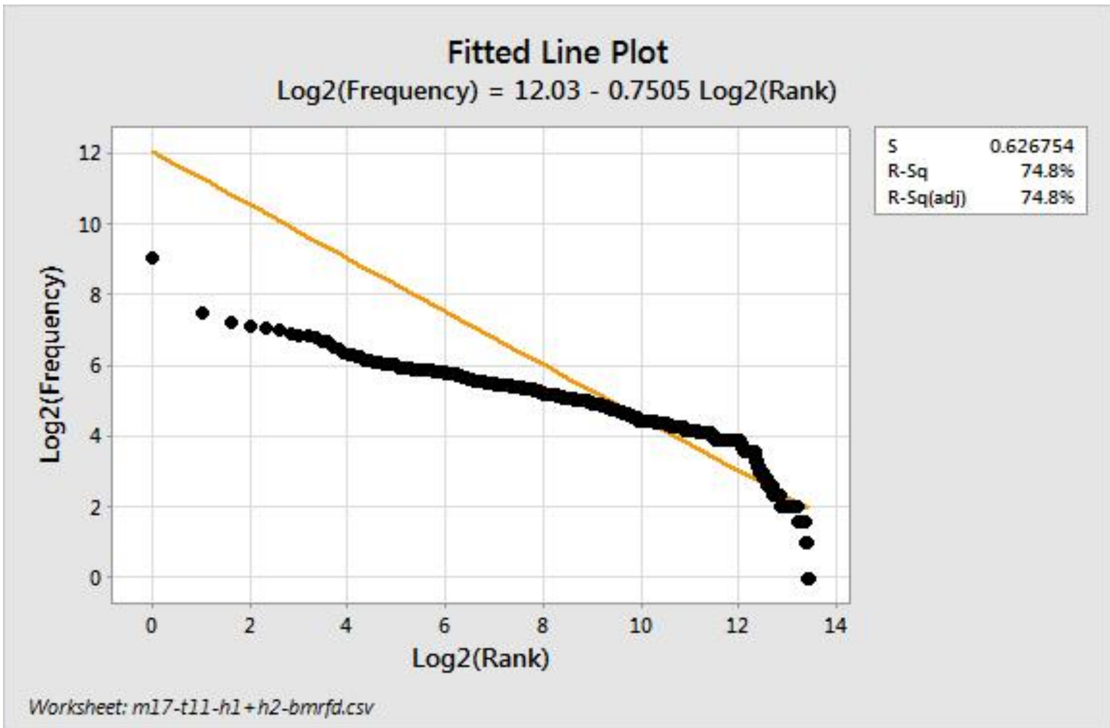

Fitted Line Plot
Log2(Frequency) = 9.654 - 0.5023 Log2(Rank)
S 0.182572
R-Sq 94.0%
R-Sq(adj) 94.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-ta-h1+h2-rarfd.csv

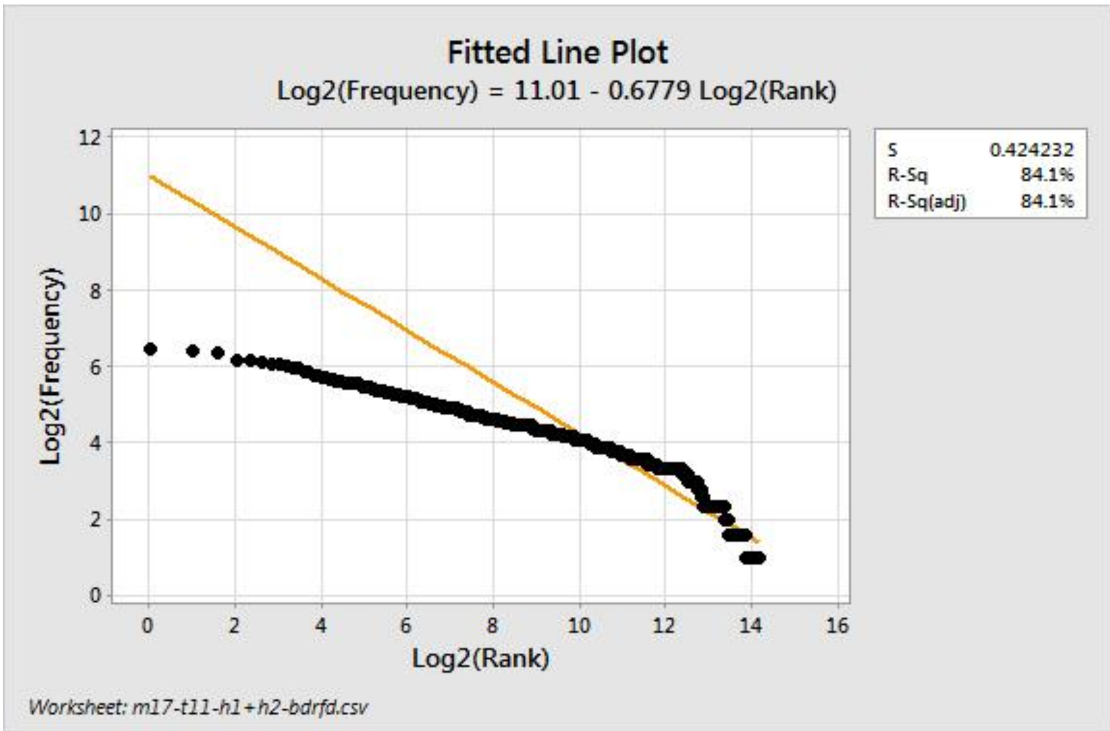

Fitted Line Plot
Log2(Frequency) = 13.09 - 0.8556 Log2(Rank)
S 0.847782
R-Sq 67.9%
R-Sq(adj) 67.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-ta-h1+h2-rmrfd.csv

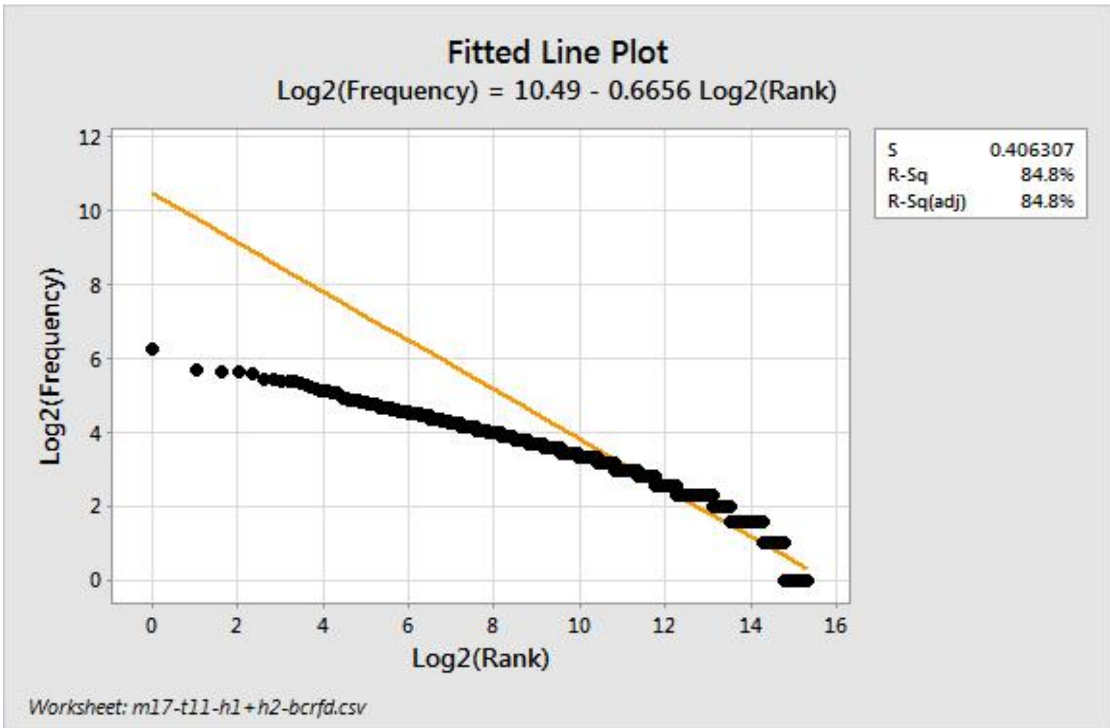

Fitted Line Plot
Log2(Frequency) = 12.34 - 0.7930 Log2(Rank)
S 0.677928
R-Sq 74.0%
R-Sq(adj) 73.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-ta-h1+h2-rdrfd.csv

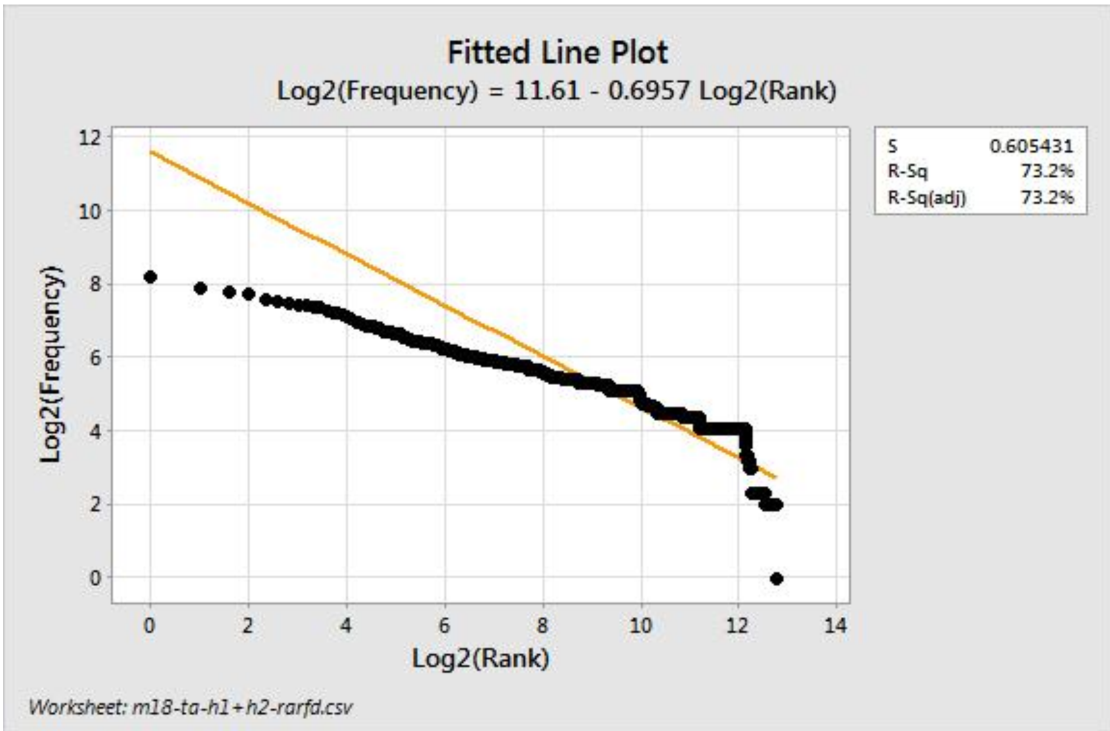

Fitted Line Plot
Log2(Frequency) = 10.62 - 0.6743 Log2(Rank)
S 0.412935
R-Sq 84.7%
R-Sq(adj) 84.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-ta-h1+h2-rcrfd.csv

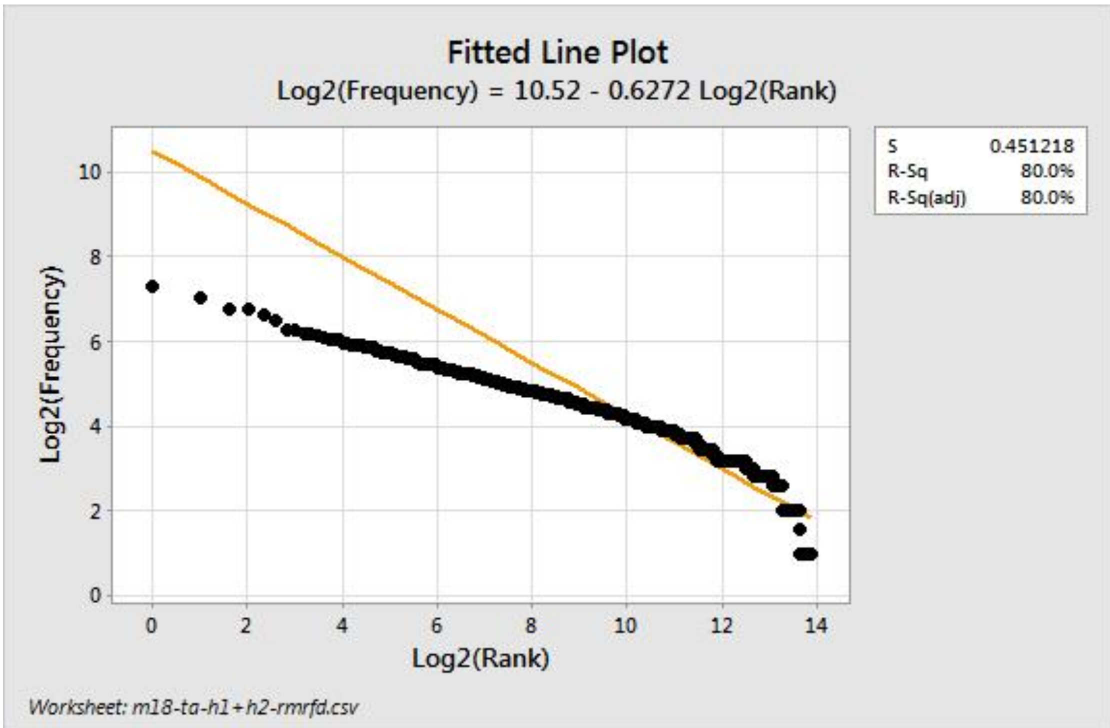

Fitted Line Plot
Log2(Frequency) = 11.85 - 0.7348 Log2(Rank)
S 0.559259
R-Sq 78.2%
R-Sq(adj) 78.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-t11-h1+h2-barfd.csv

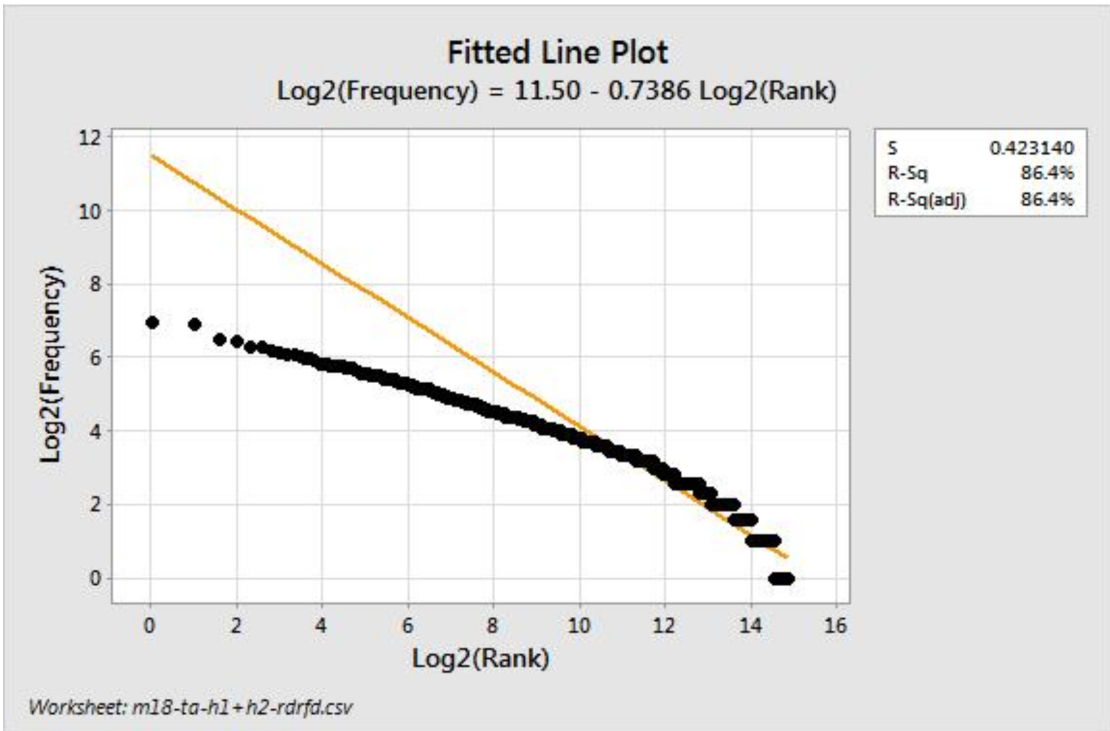

Fitted Line Plot
Log2(Frequency) = 12.03 - 0.7505 Log2(Rank)
S 0.626754
R-Sq 74.8%
R-Sq(adj) 74.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m17-t11-h1+h2-bmrfd.csv

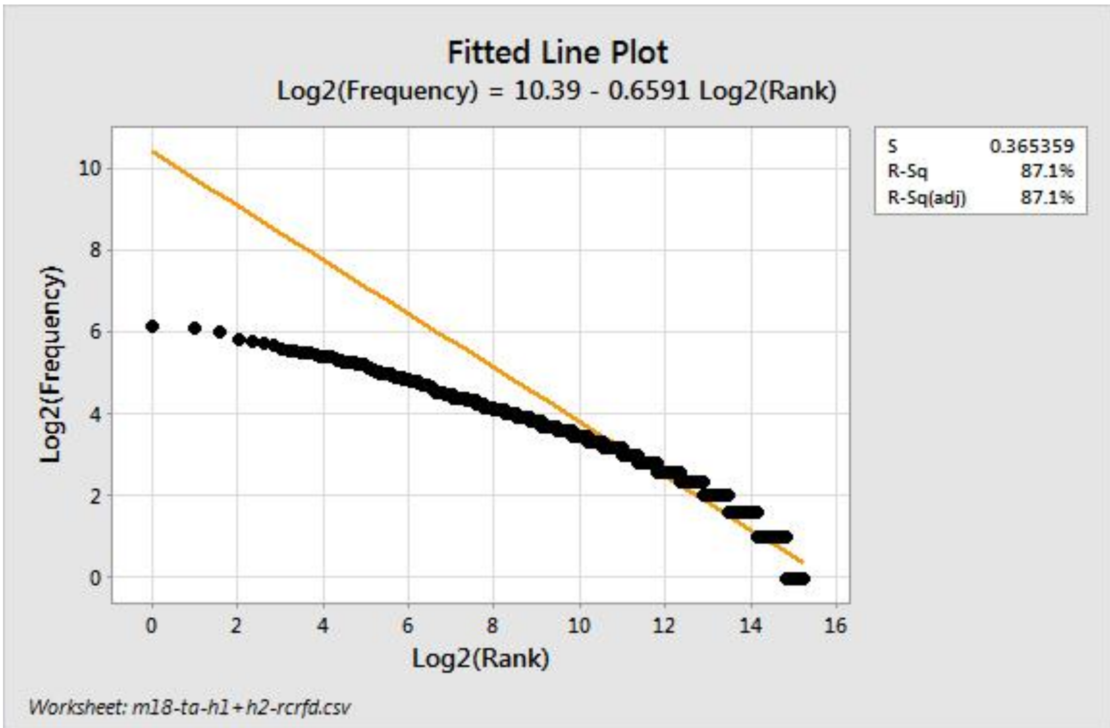

Fitted Line Plot
Log2(Frequency) = 11.01 - 0.6779 Log2(Rank)
S 0.424232
R-Sq 84.1%
R-Sq(adj) 84.1%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m17-t11-h1+h2-bdrfd.csv

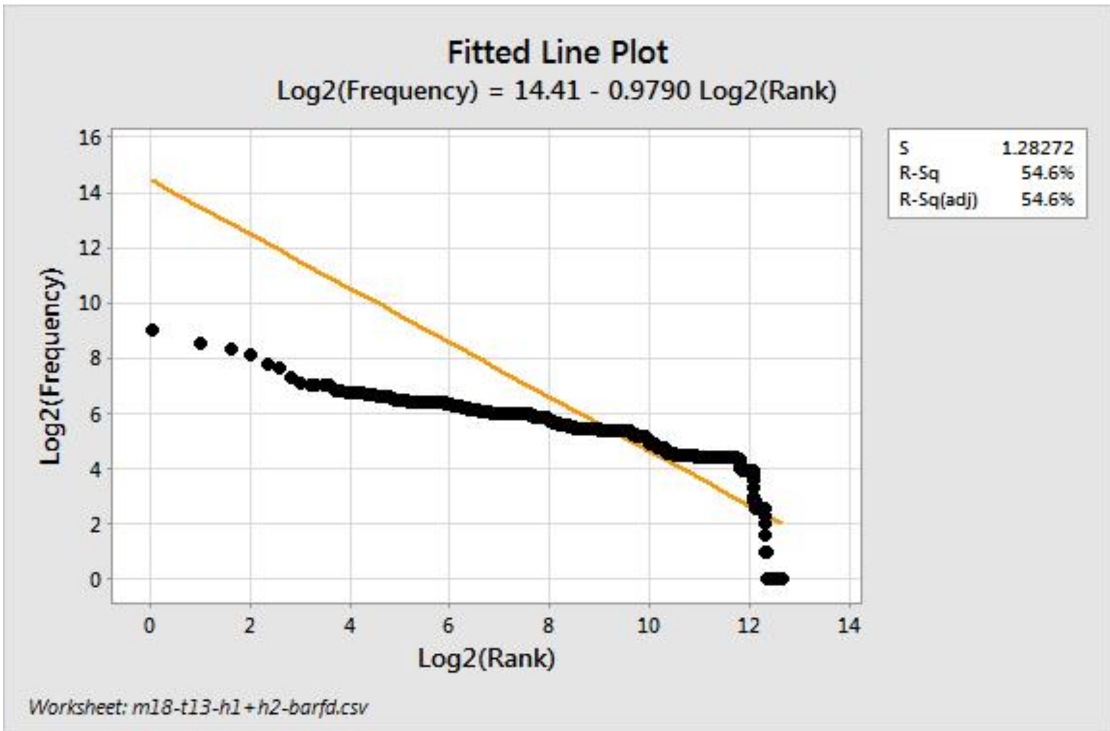

Fitted Line Plot
Log2(Frequency) = 10.49 - 0.6656 Log2(Rank)
S 0.406307
R-Sq 84.8%
R-Sq(adj) 84.8%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m17-t11-h1+h2-bcrfd.csv

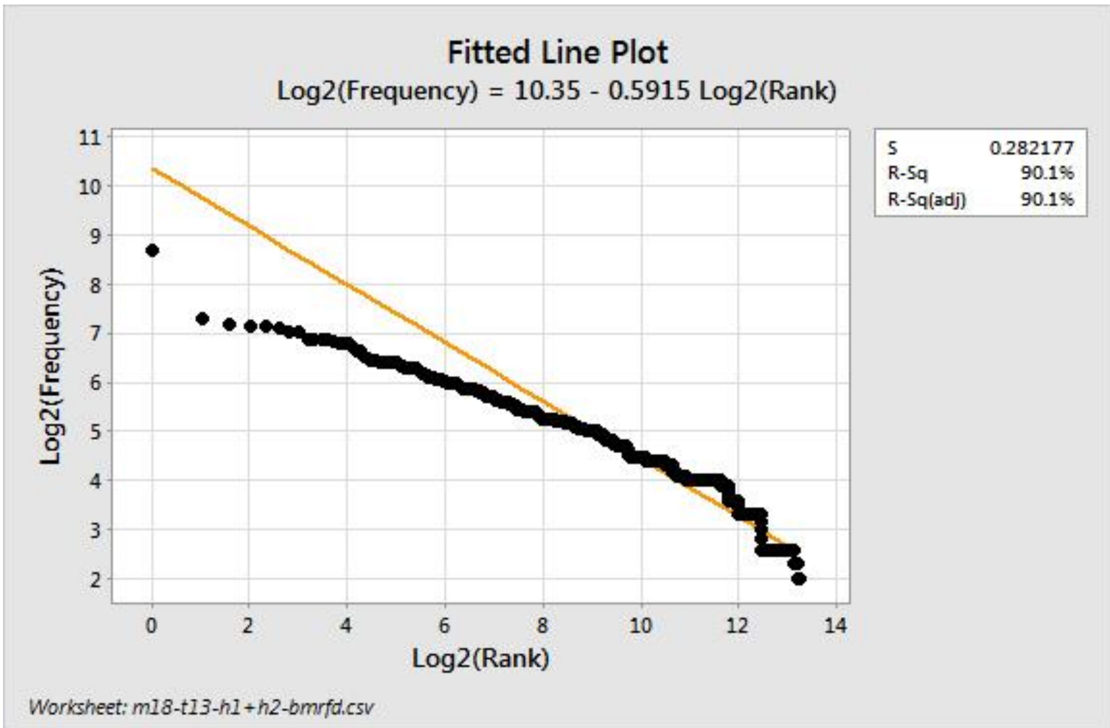

Fitted Line Plot
Log2(Frequency) = 11.61 - 0.6957 Log2(Rank)
S 0.605431
R-Sq 73.2%
R-Sq(adj) 73.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta-h1+h2-rarfd.csv

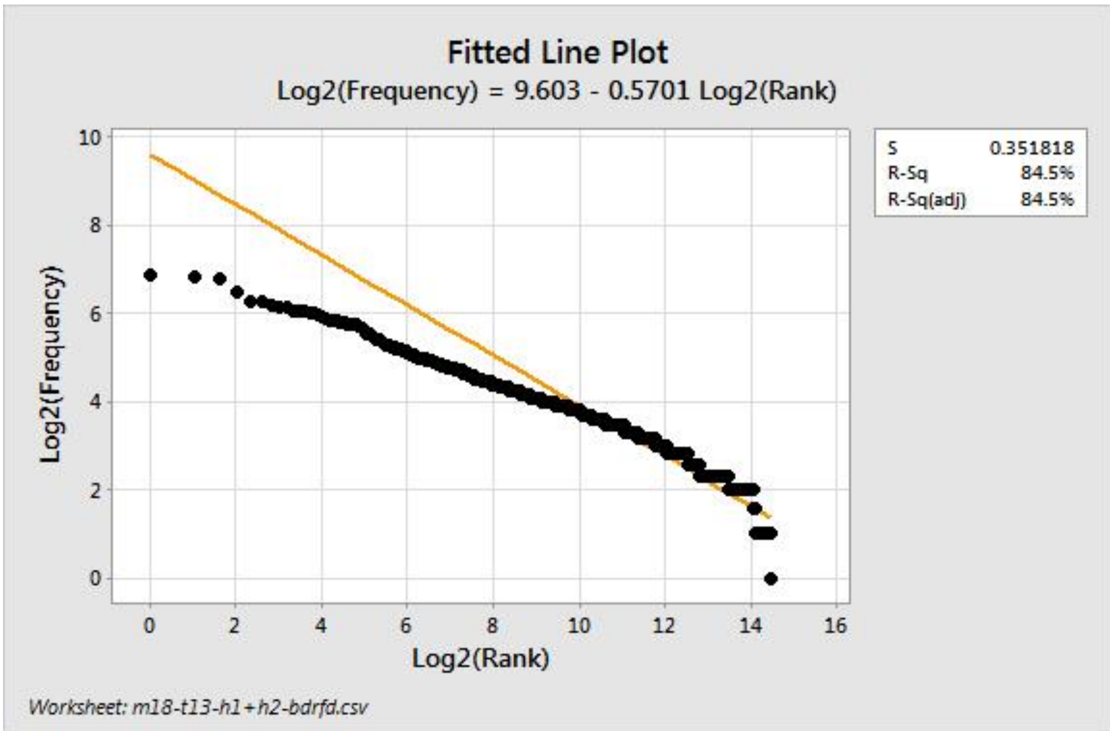

Fitted Line Plot
Log2(Frequency) = 10.52 - 0.6272 Log2(Rank)
S 0.451218
R-Sq 80.0%
R-Sq(adj) 80.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 11.50 - 0.7386 Log2(Rank)
S 0.423140
R-Sq 86.4%
R-Sq(adj) 86.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta-h1+h2-rdrfd.csv

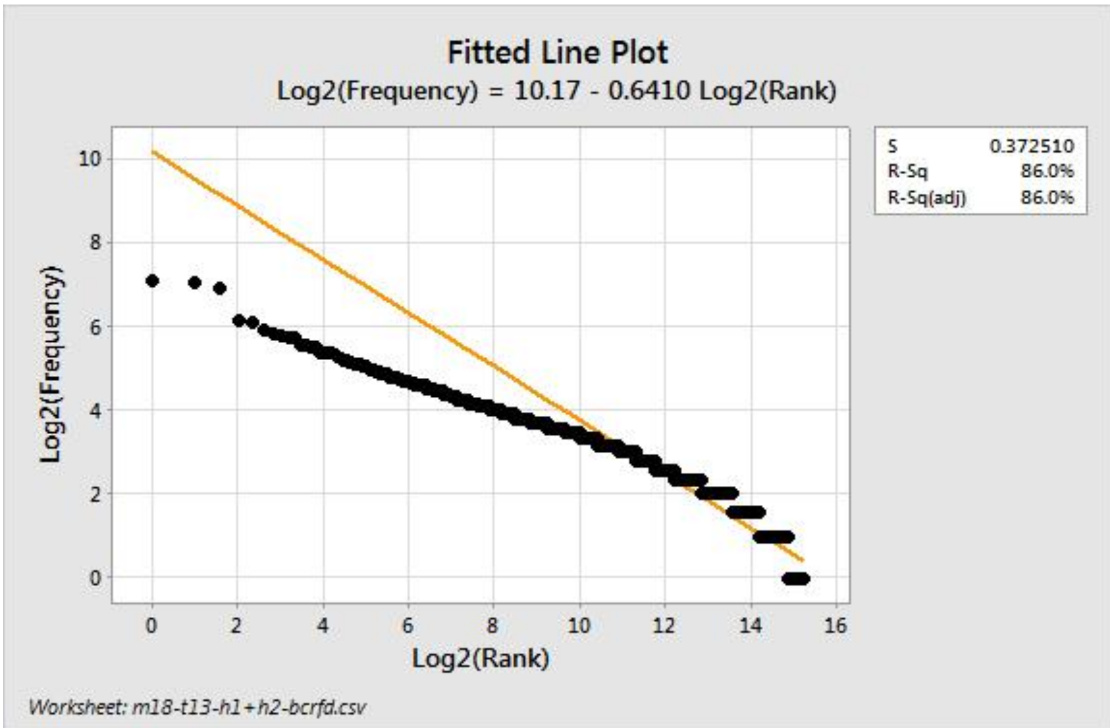

Fitted Line Plot
Log2(Frequency) = 10.39 - 0.6591 Log2(Rank)
S 0.365359
R-Sq 87.1%
R-Sq(adj) 87.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 14.41 - 0.9790 Log2(Rank)
S 1.28272
R-Sq 54.6%
R-Sq(adj) 54.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13-h1+h2-barfd.csv

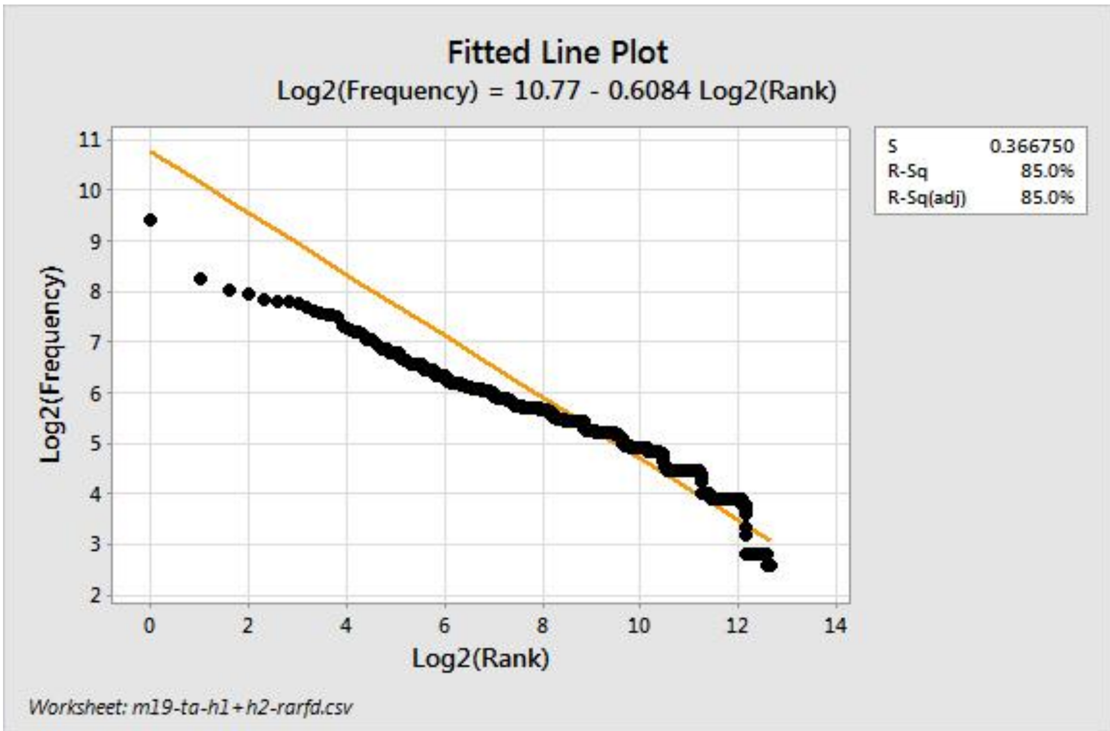

Fitted Line Plot
Log2(Frequency) = 10.35 - 0.5915 Log2(Rank)
S 0.282177
R-Sq 90.1%
R-Sq(adj) 90.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13-h1+h2-bmrfd.csv

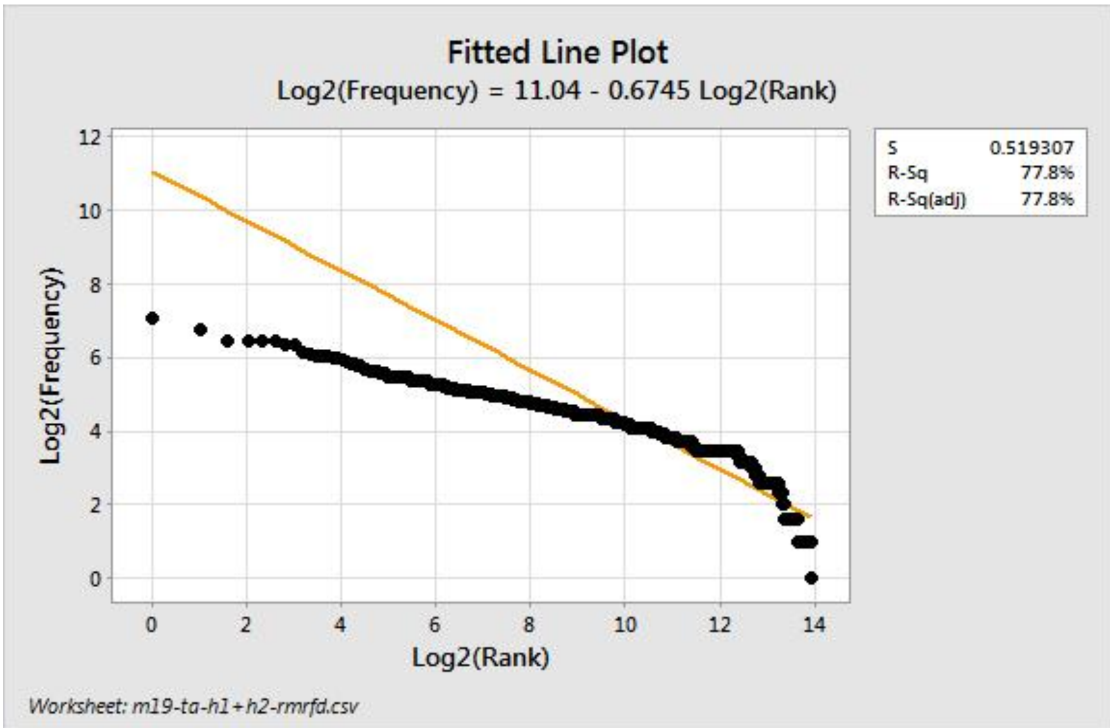


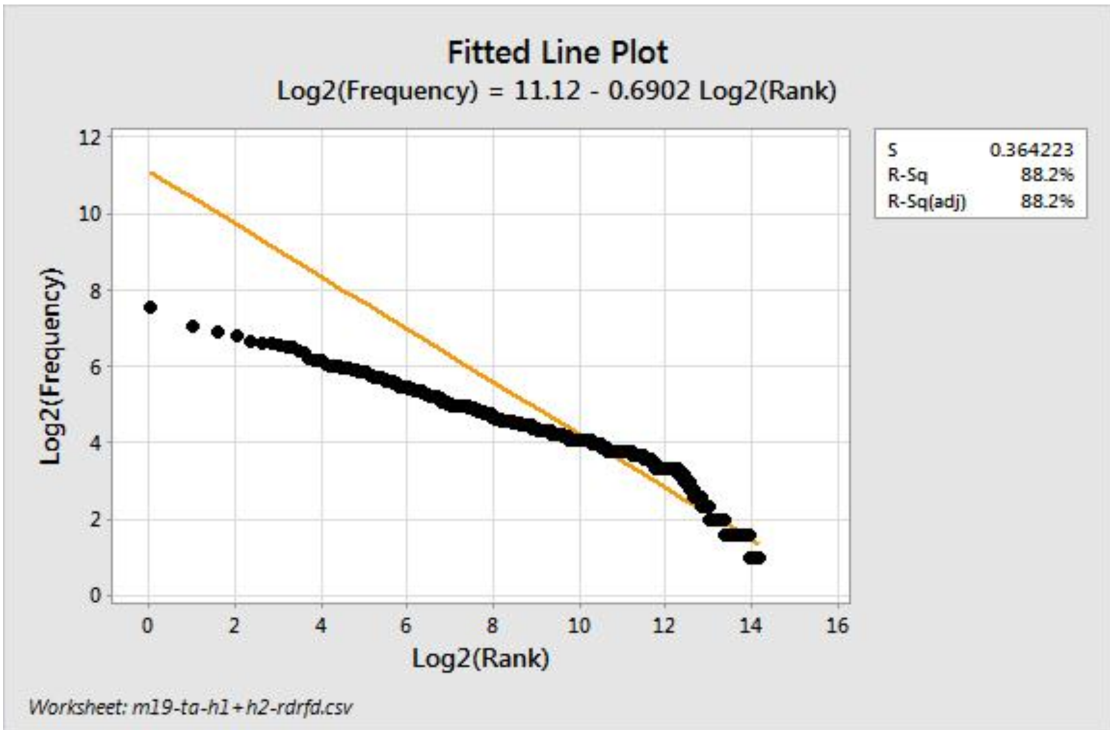
Fitted Line Plot
Log2(Frequency) = 9.603 - 0.5701 Log2(Rank)
S 0.351818
R-Sq 84.5%
R-Sq(adj) 84.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13-h1+h2-bdrfd.csv

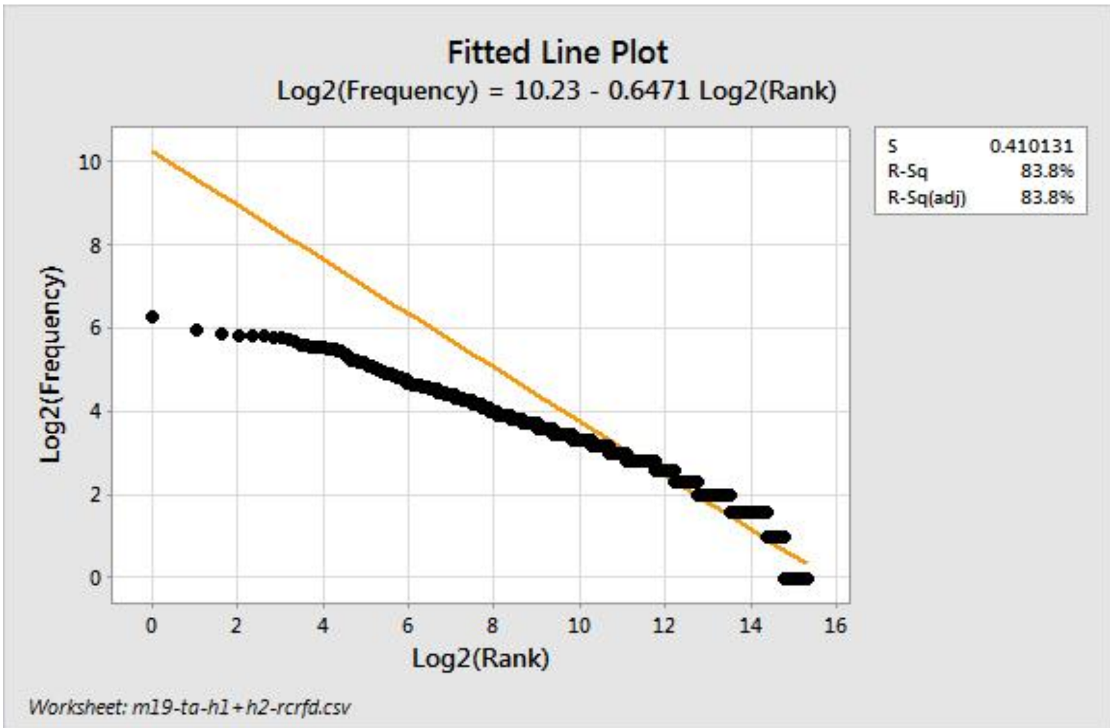


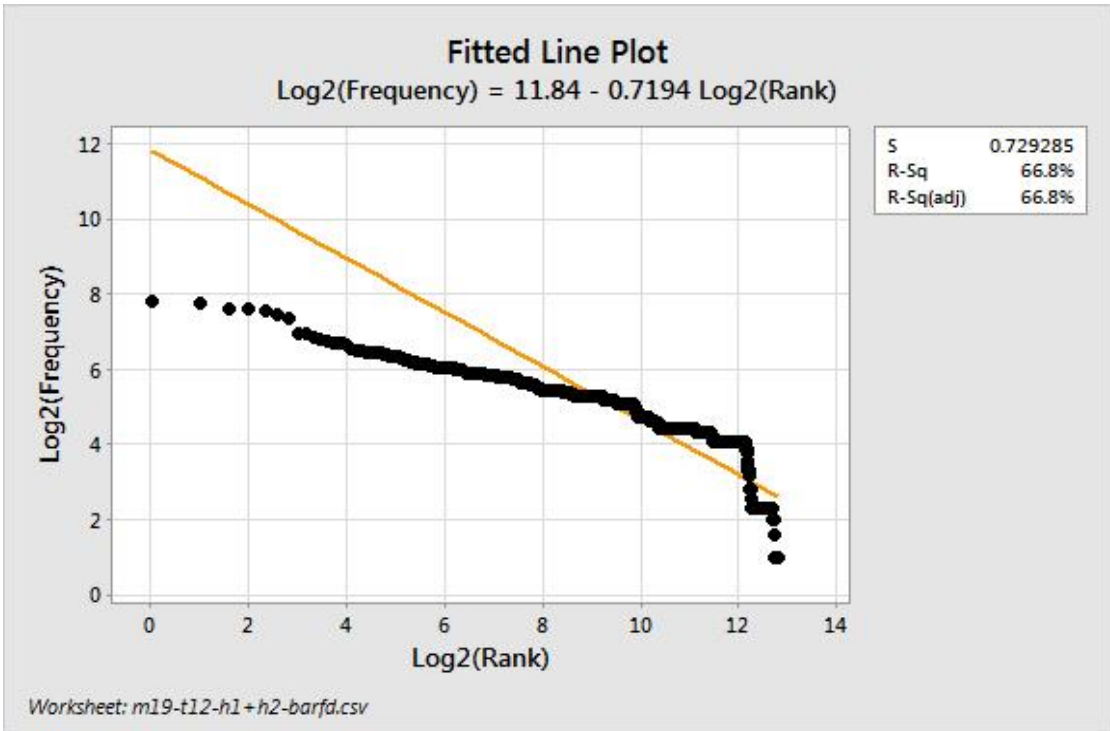
Fitted Line Plot
Log2(Frequency) = 10.17 - 0.6410 Log2(Rank)
S 0.372510
R-Sq 86.0%
R-Sq(adj) 86.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m18-t13-h1+h2-bcrfd.csv

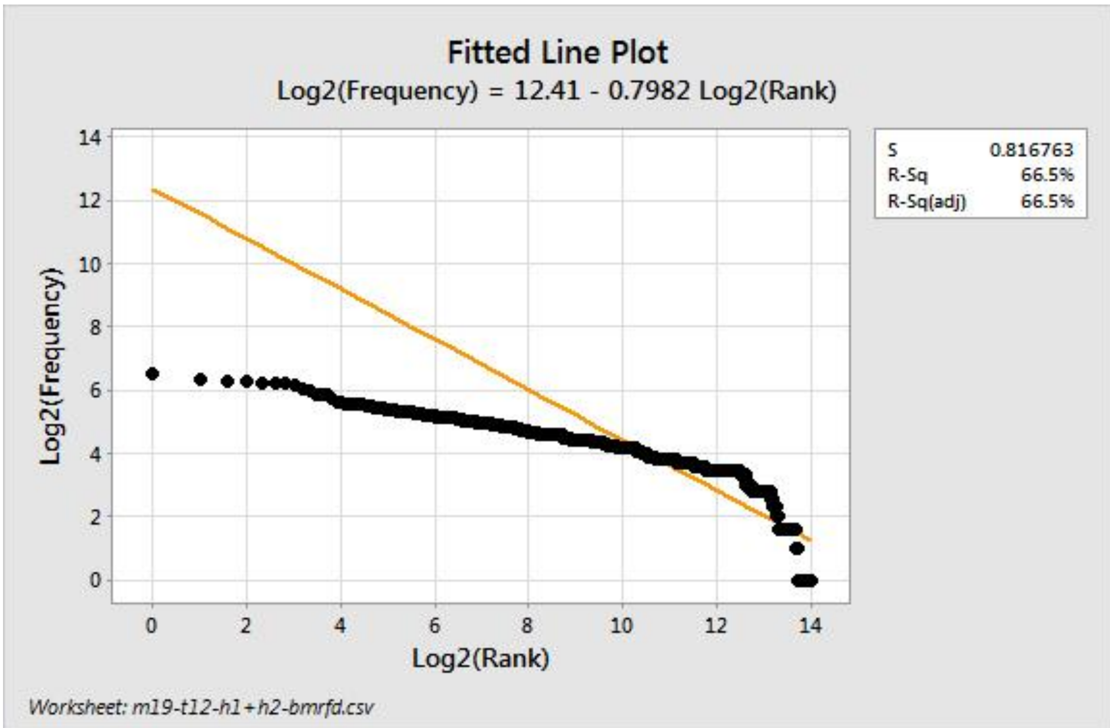

Fitted Line Plot
Log2(Frequency) = 10.77 - 0.6084 Log2(Rank)
S 0.366750
R-Sq 85.0%
R-Sq(adj) 85.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta-h1+h2-rarfd.csv

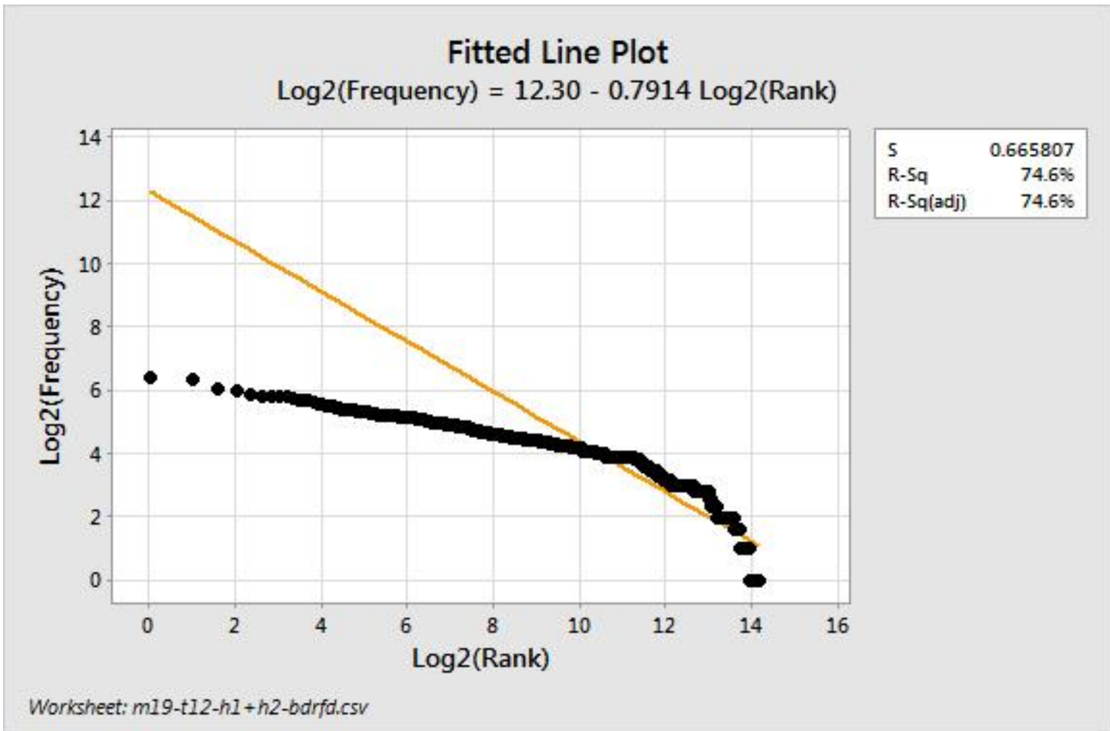

Fitted Line Plot
Log2(Frequency) = 11.04 - 0.6745 Log2(Rank)
S 0.519307
R-Sq 77.8%
R-Sq(adj) 77.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta-h1+h2-rmrfd.csv

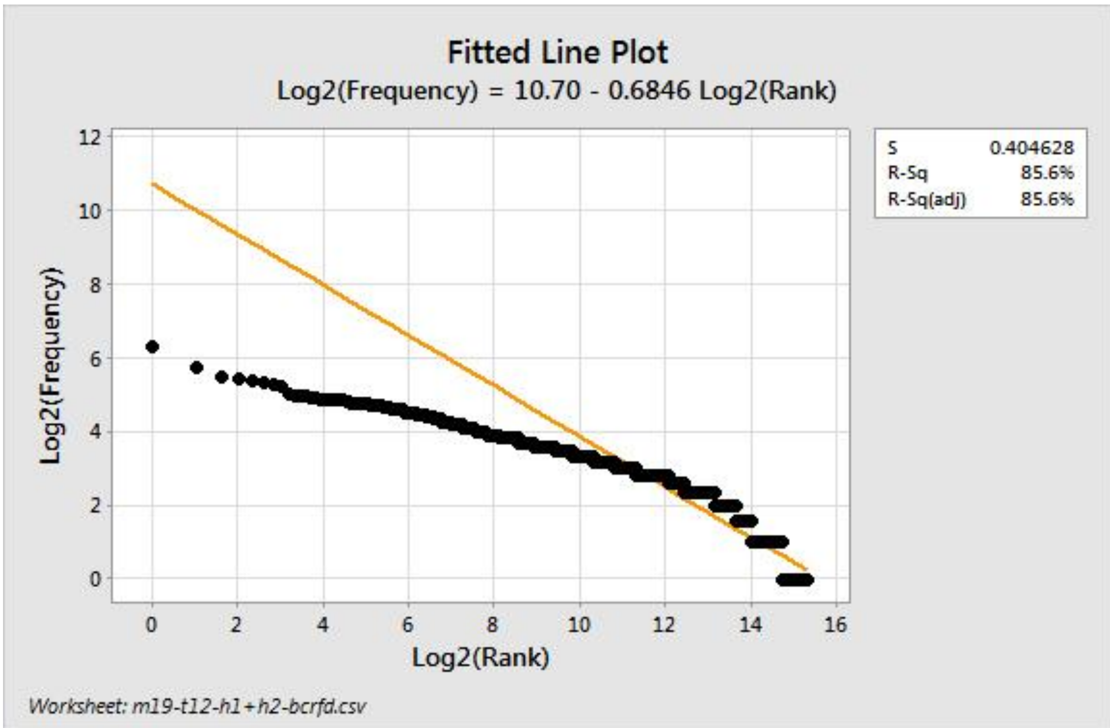

Fitted Line Plot
Log2(Frequency) = 11.12 - 0.6902 Log2(Rank)
S 0.364223
R-Sq 88.2%
R-Sq(adj) 88.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta-h1+h2-rdrfd.csv

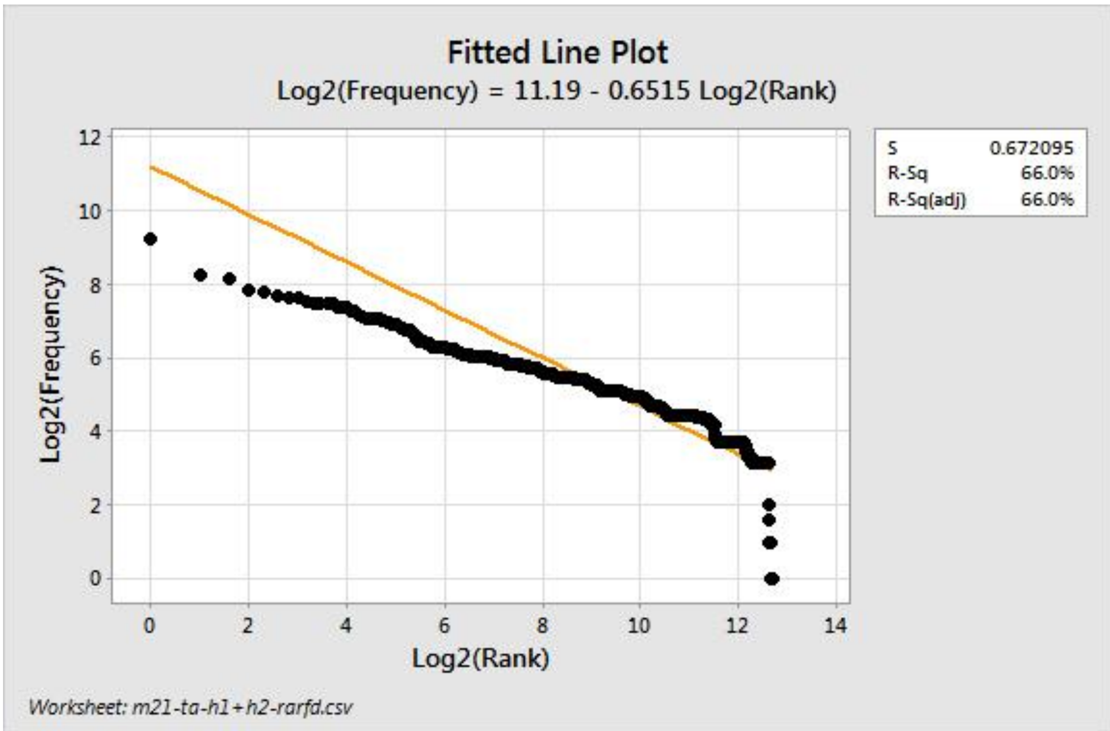

Fitted Line Plot
Log2(Frequency) = 10.23 - 0.6471 Log2(Rank)
S 0.410131
R-Sq 83.8%
R-Sq(adj) 83.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-ta-h1+h2-rcrfd.csv

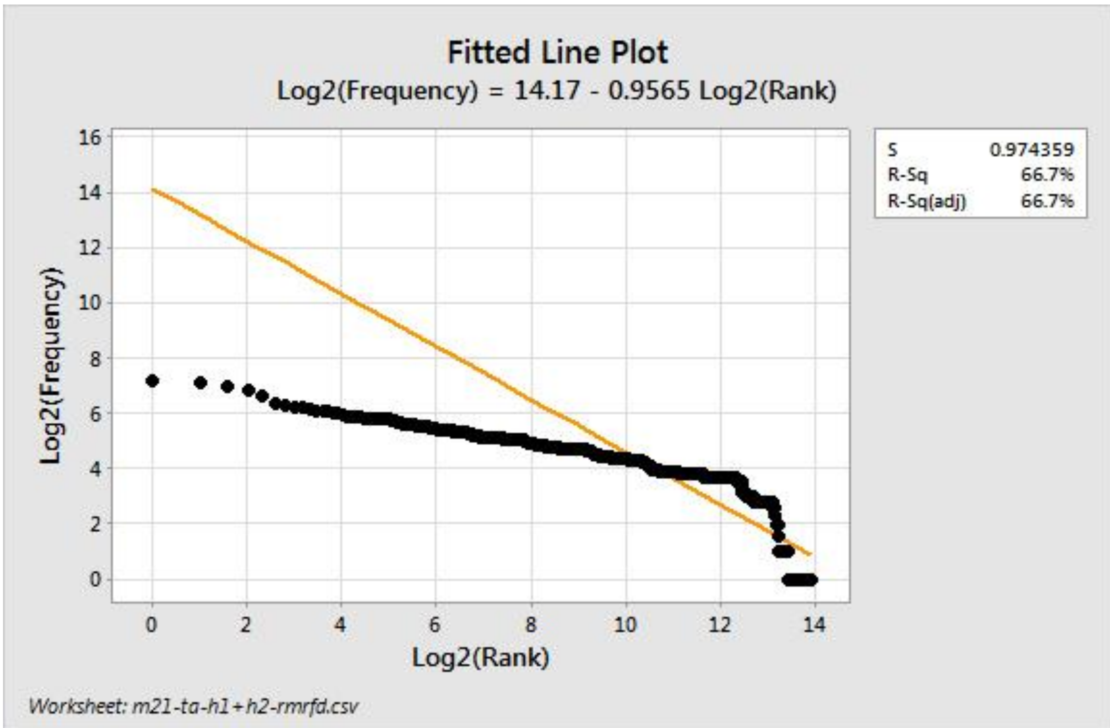

Fitted Line Plot
Log2(Frequency) = 11.84 - 0.7194 Log2(Rank)
S 0.729285
R-Sq 66.8%
R-Sq(adj) 66.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12-h1+h2-barfd.csv

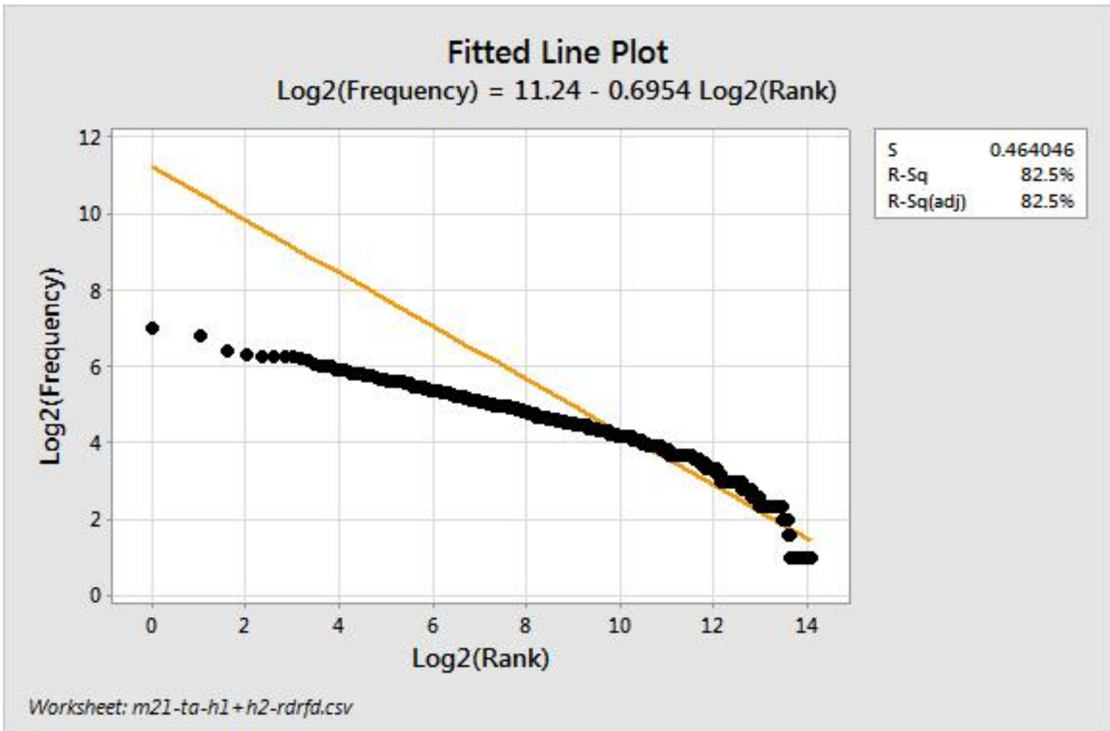

Fitted Line Plot
Log2(Frequency) = 12.41 - 0.7982 Log2(Rank)
S 0.816763
R-Sq 66.5%
R-Sq(adj) 66.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12-h1+h2-bmrfd.csv

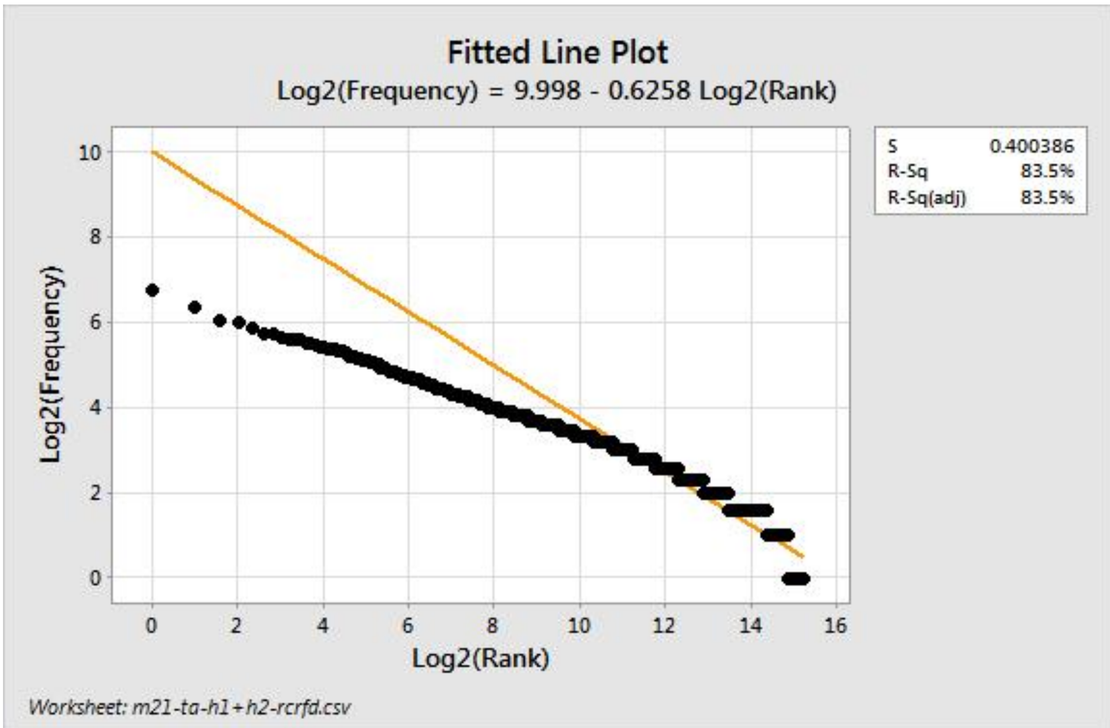

Fitted Line Plot
Log2(Frequency) = 12.30 - 0.7914 Log2(Rank)
S 0.665807
R-Sq 74.6%
R-Sq(adj) 74.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12-h1+h2-bdrfd.csv

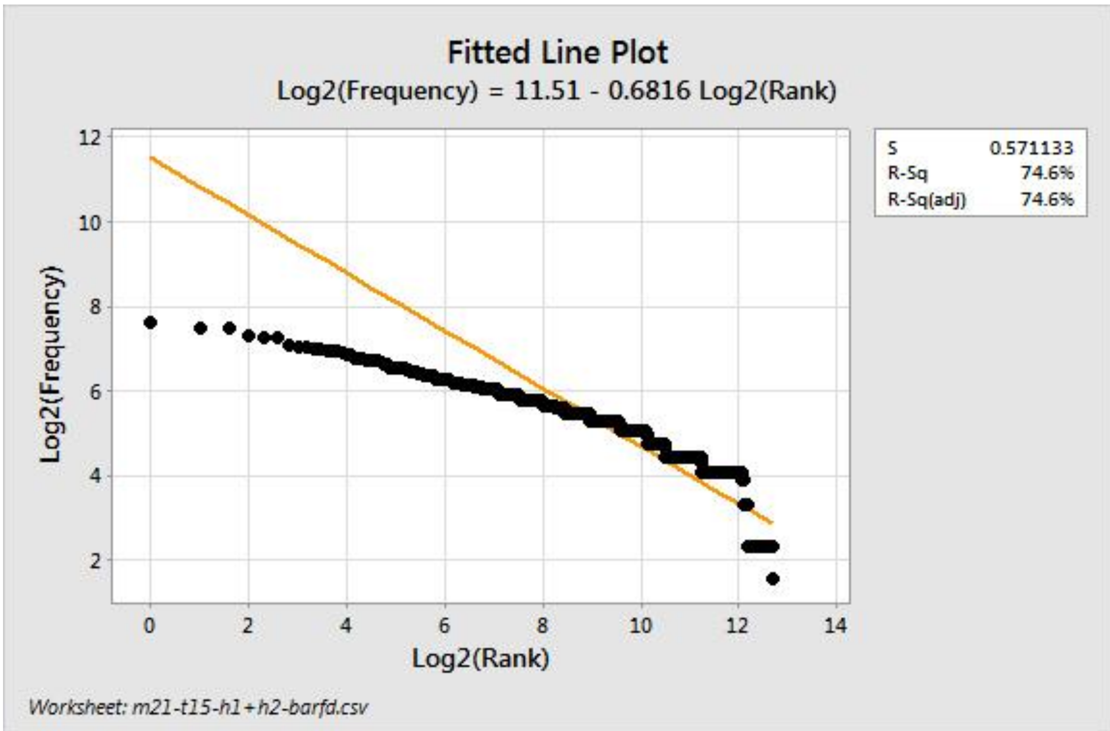

Fitted Line Plot
Log2(Frequency) = 10.70 - 0.6846 Log2(Rank)
S 0.404628
R-Sq 85.6%
R-Sq(adj) 85.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m19-t12-h1+h2-bcrfd.csv

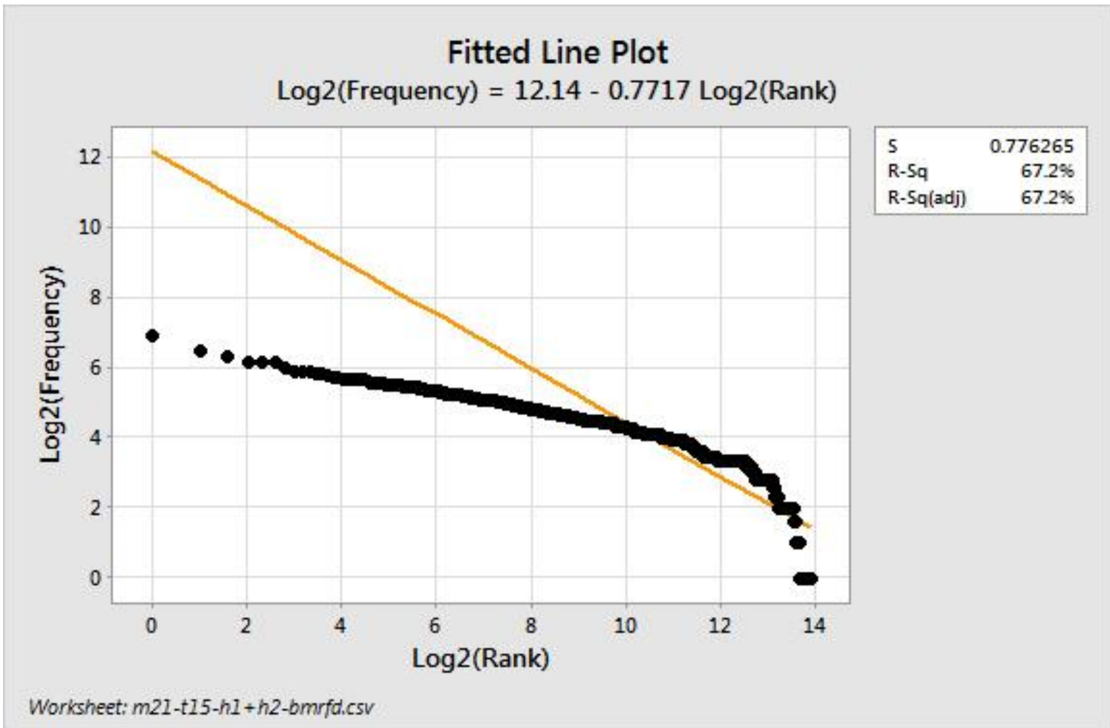

Fitted Line Plot
Log2(Frequency) = 11.19 - 0.6515 Log2(Rank)
S 0.672095
R-Sq 66.0%
R-Sq(adj) 66.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-ta-h1+h2-rarfd.csv

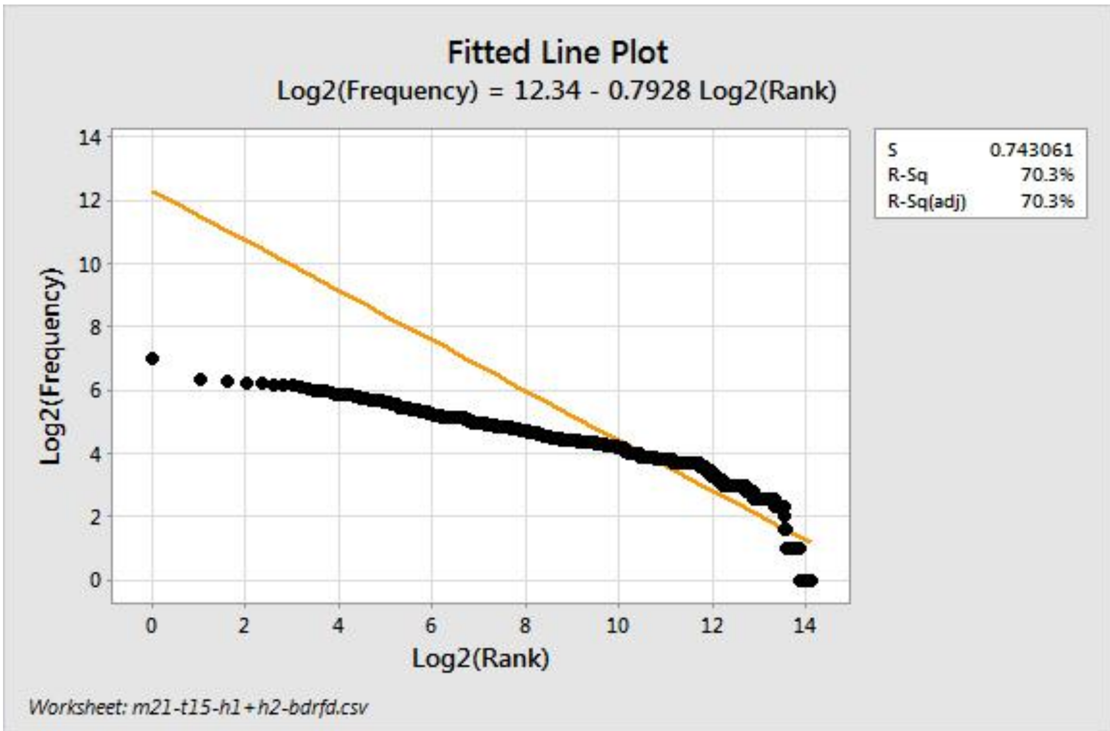

Fitted Line Plot
Log2(Frequency) = 14.17 - 0.9565 Log2(Rank)
S 0.974359
R-Sq 66.7%
R-Sq(adj) 66.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-ta-h1+h2-rmrfd.csv

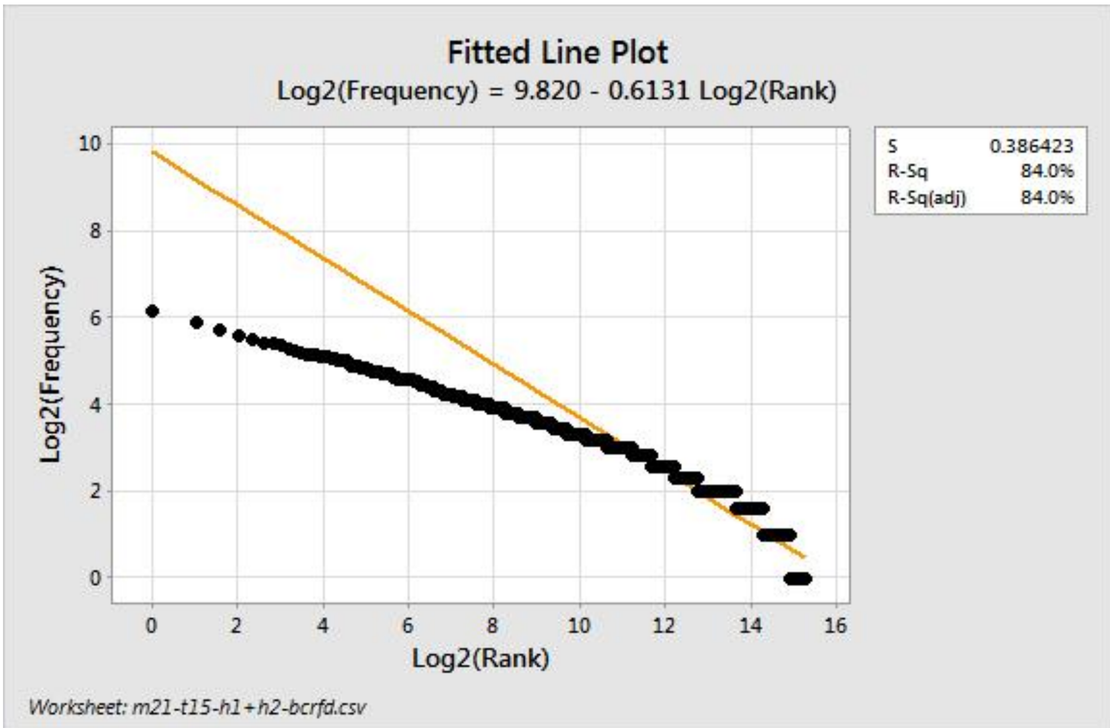

Fitted Line Plot
Log2(Frequency) = 11.24 - 0.6954 Log2(Rank)
S 0.464046
R-Sq 82.5%
R-Sq(adj) 82.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-ta-h1+h2-rdrfd.csv

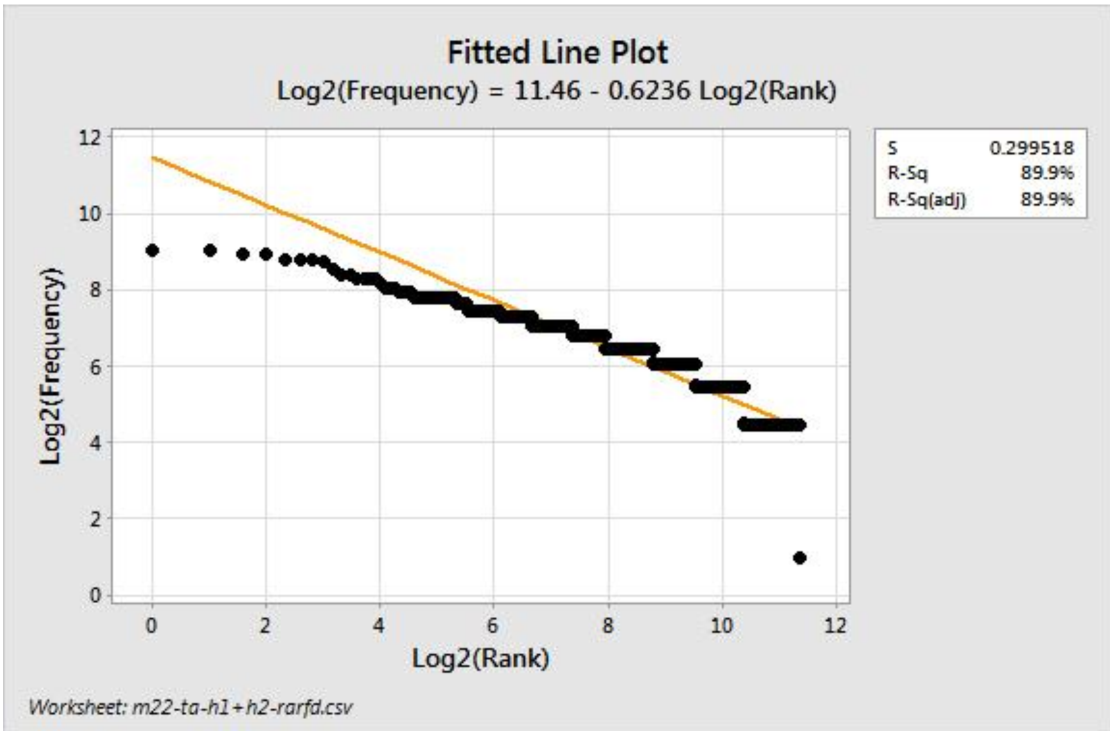

Fitted Line Plot
Log2(Frequency) = 9.998 - 0.6258 Log2(Rank)
S 0.400386
R-Sq 83.5%
R-Sq(adj) 83.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-ta-h1+h2-rcrfd.csv

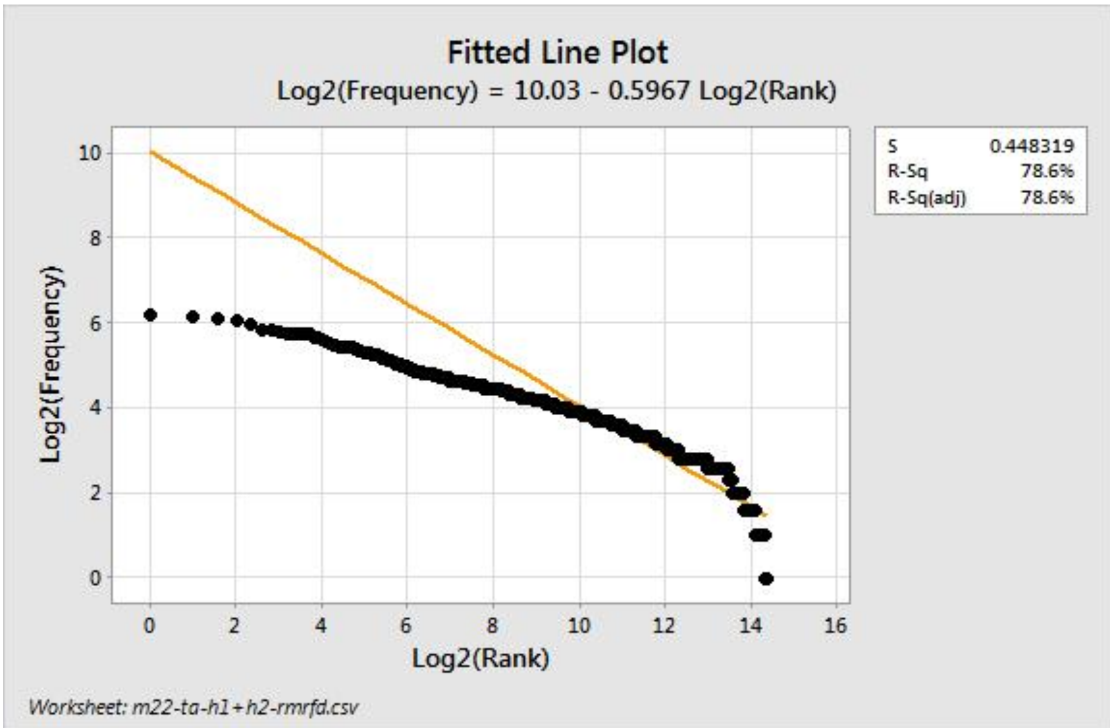

Fitted Line Plot
Log2(Frequency) = 11.51 - 0.6816 Log2(Rank)
S 0.571133
R-Sq 74.6%
R-Sq(adj) 74.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-t15-h1+h2-barfd.csv

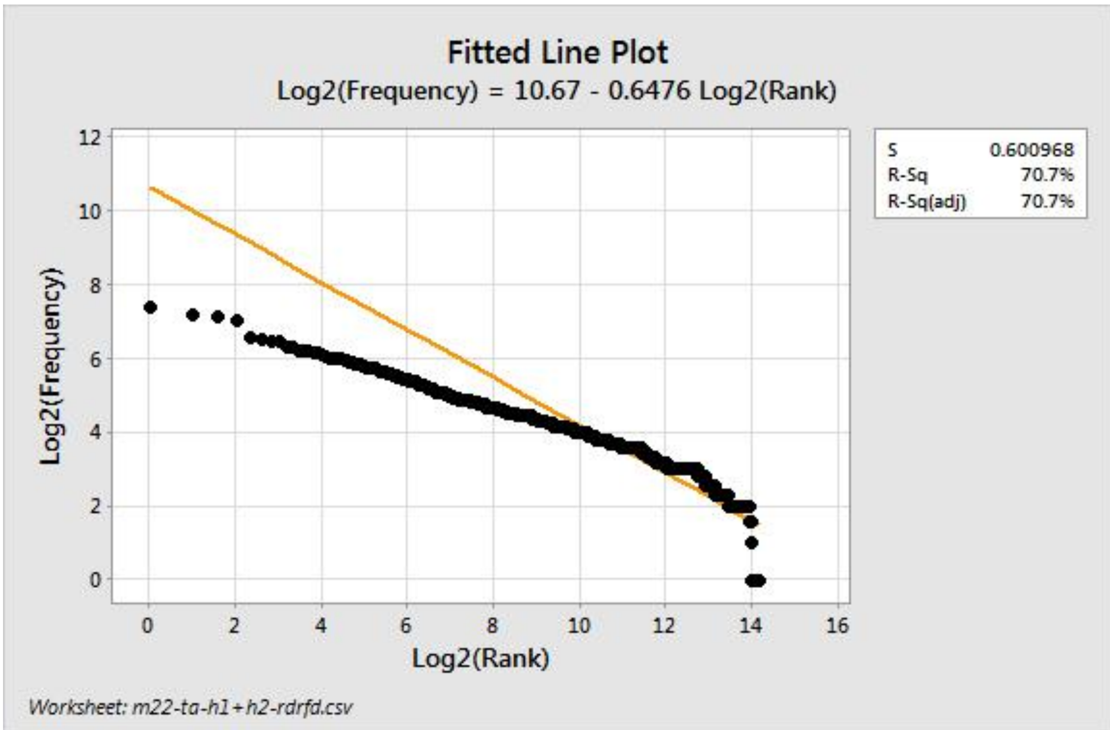

Fitted Line Plot
Log2(Frequency) = 12.14 - 0.7717 Log2(Rank)
S 0.776265
R-Sq 67.2%
R-Sq(adj) 67.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-t15-h1+h2-bmrfd.csv

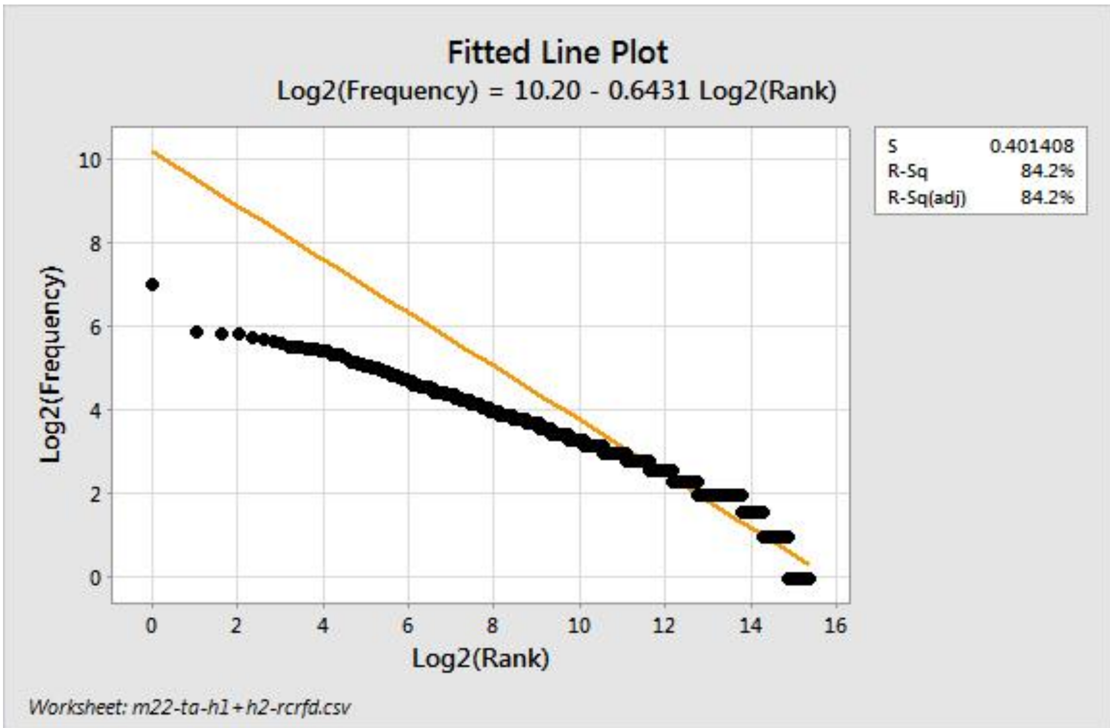

Fitted Line Plot
Log2(Frequency) = 12.34 - 0.7928 Log2(Rank)
S 0.743061
R-Sq 70.3%
R-Sq(adj) 70.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-t15-h1+h2-bdrfd.csv

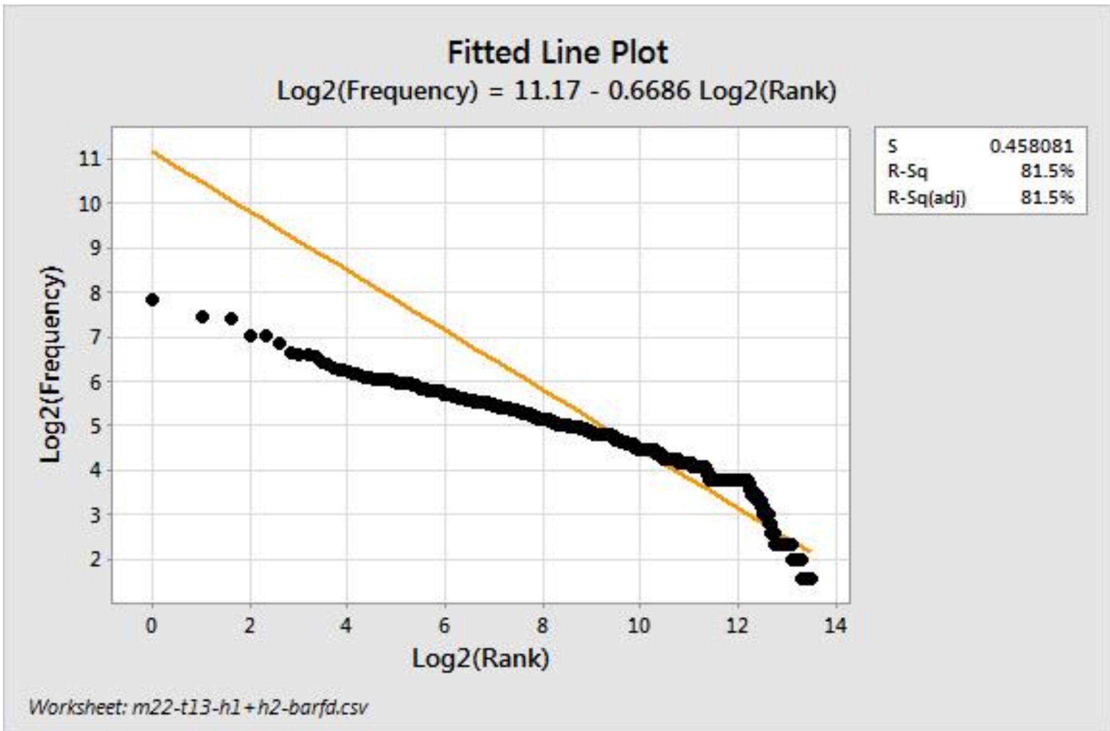

Fitted Line Plot
Log2(Frequency) = 9.820 - 0.6131 Log2(Rank)
S 0.386423
R-Sq 84.0%
R-Sq(adj) 84.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m21-t15-h1+h2-bcrfd.csv

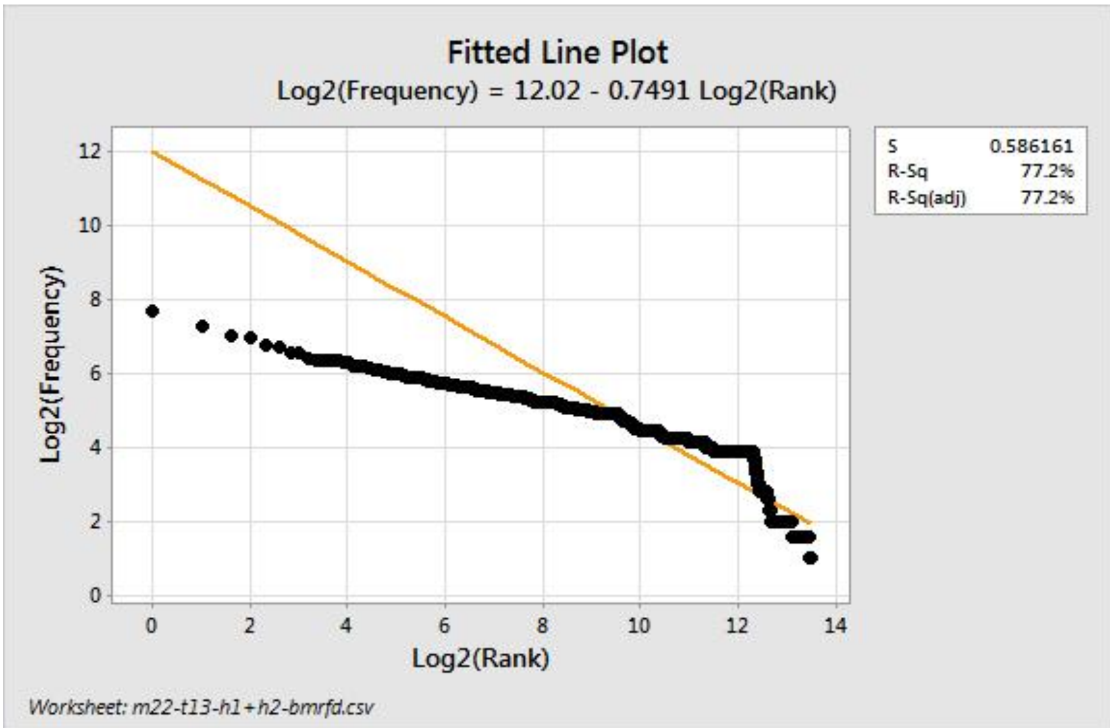

Fitted Line Plot
Log2(Frequency) = 11.46 - 0.6236 Log2(Rank)
S 0.299518
R-Sq 89.9%
R-Sq(adj) 89.9%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
Worksheet: m22-ta-h1+h2-rarfd.csv

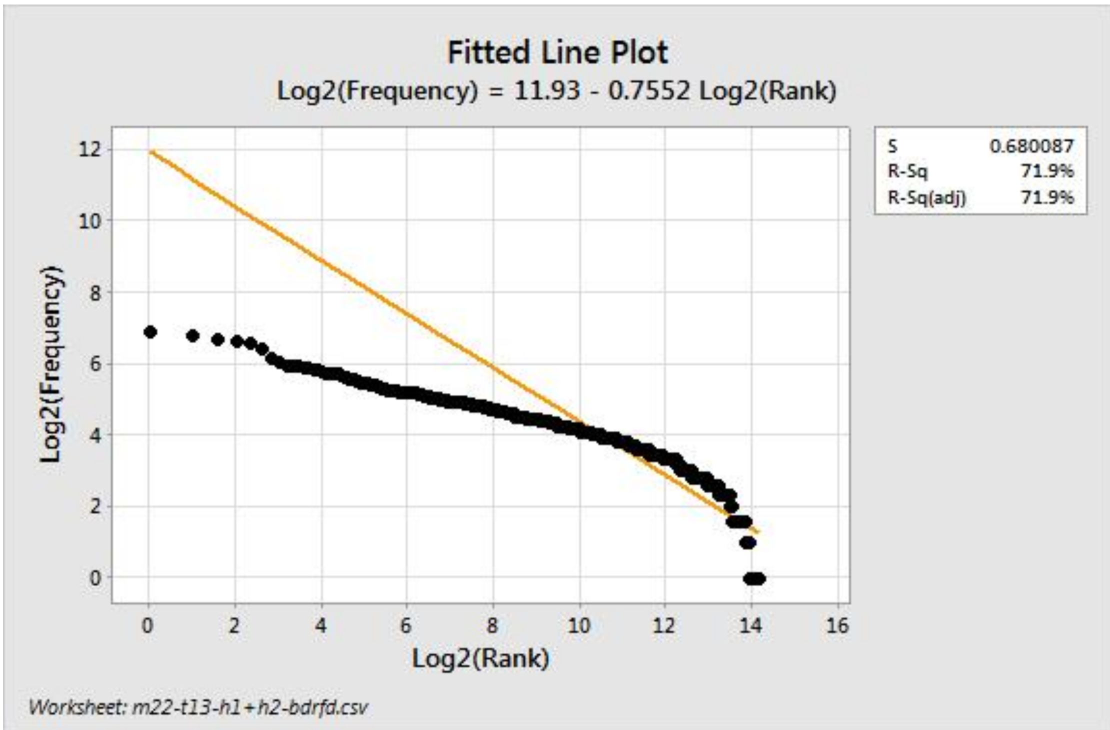

Fitted Line Plot
Log2(Frequency) = 10.03 - 0.5967 Log2(Rank)
S 0.448319
R-Sq 78.6%
R-Sq(adj) 78.6%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m22-ta-h1+h2-rmrfd.csv

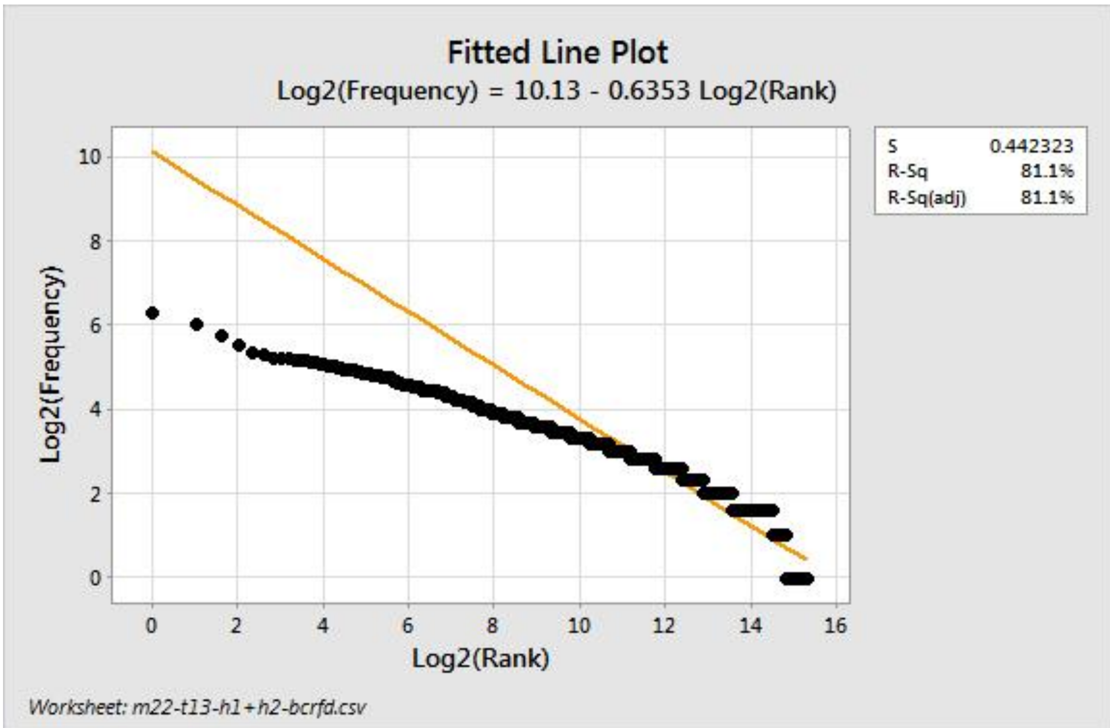

Fitted Line Plot
Log2(Frequency) = 10.67 - 0.6476 Log2(Rank)
S 0.600968
R-Sq 70.7%
R-Sq(adj) 70.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-ta-h1+h2-rdrfd.csv

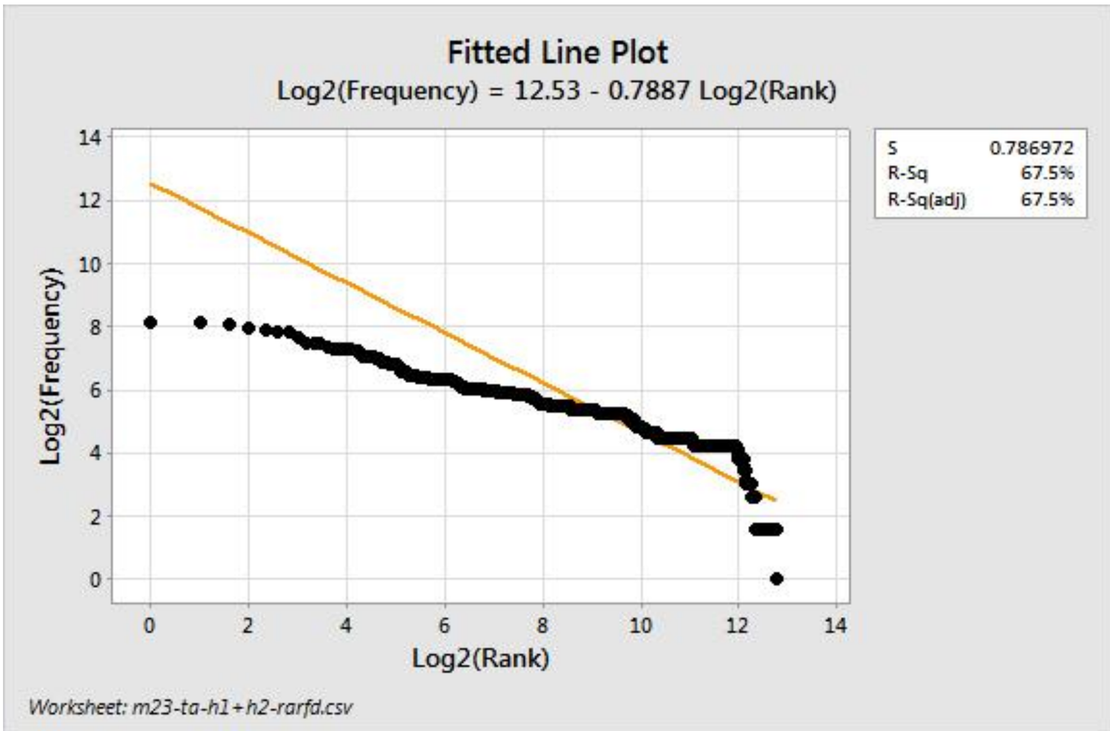

Fitted Line Plot
Log2(Frequency) = 10.20 - 0.6431 Log2(Rank)
S 0.401408
R-Sq 84.2%
R-Sq(adj) 84.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-ta-h1+h2-rcrfd.csv

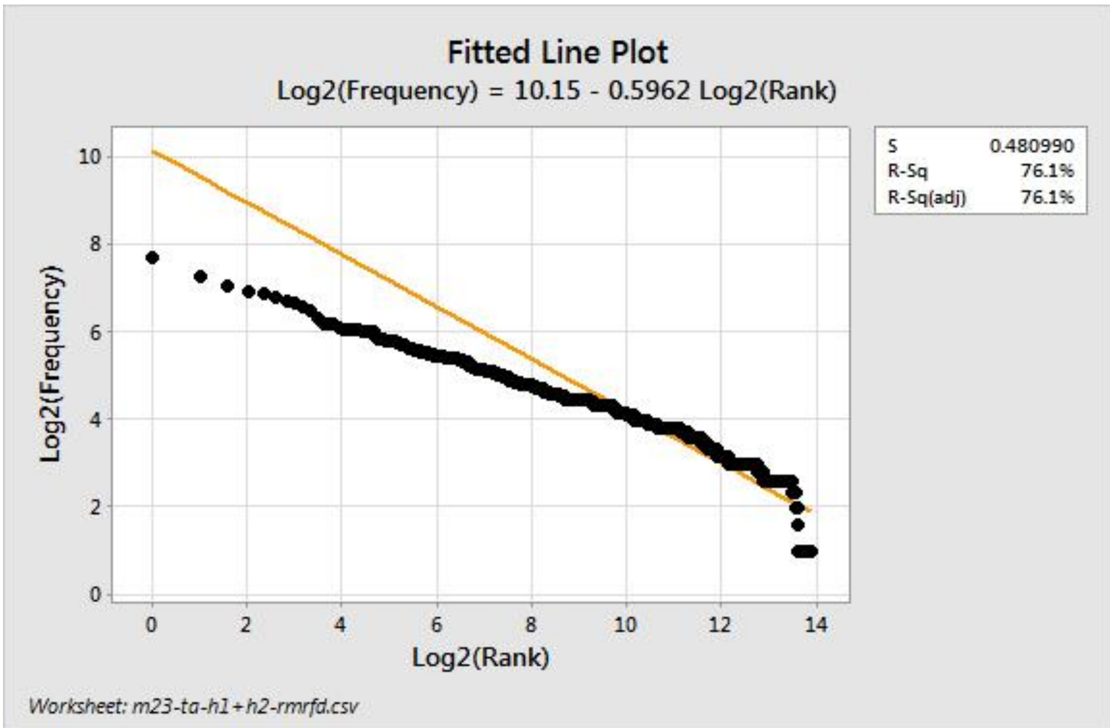

Fitted Line Plot
Log2(Frequency) = 11.17 - 0.6686 Log2(Rank)
S 0.458081
R-Sq 81.5%
R-Sq(adj) 81.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13-h1+h2-barfd.csv

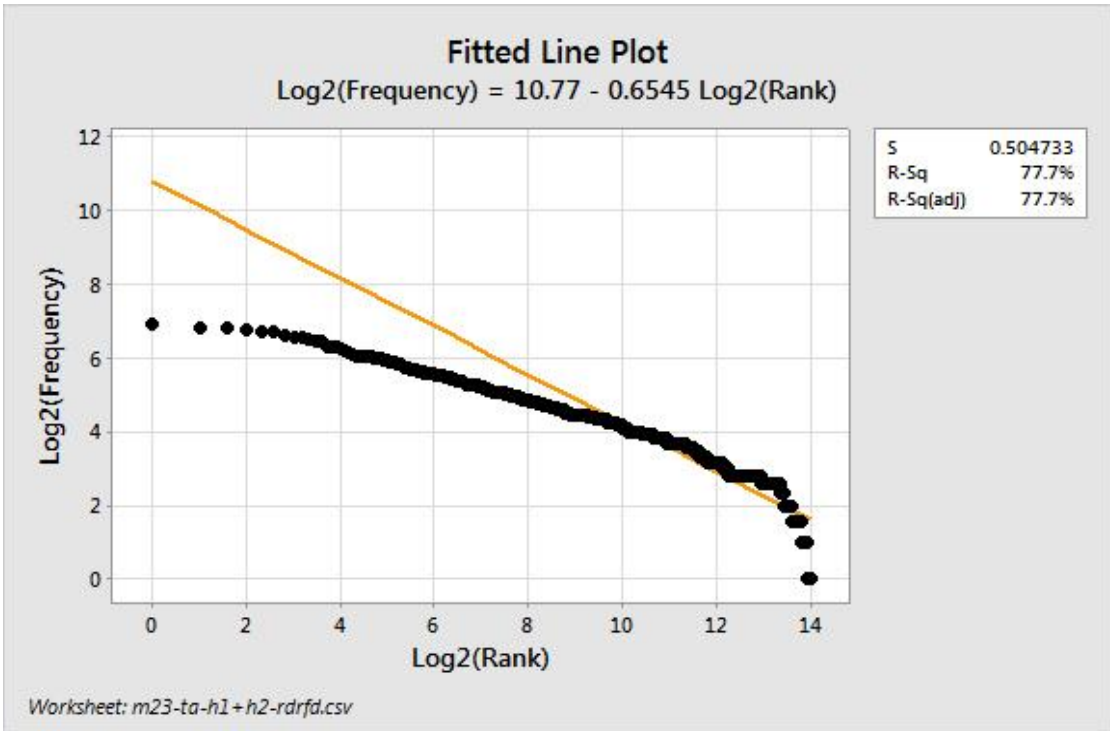

Fitted Line Plot
Log2(Frequency) = 12.02 - 0.7491 Log2(Rank)
S 0.586161
R-Sq 77.2%
R-Sq(adj) 77.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13-h1+h2-bmrfd.csv

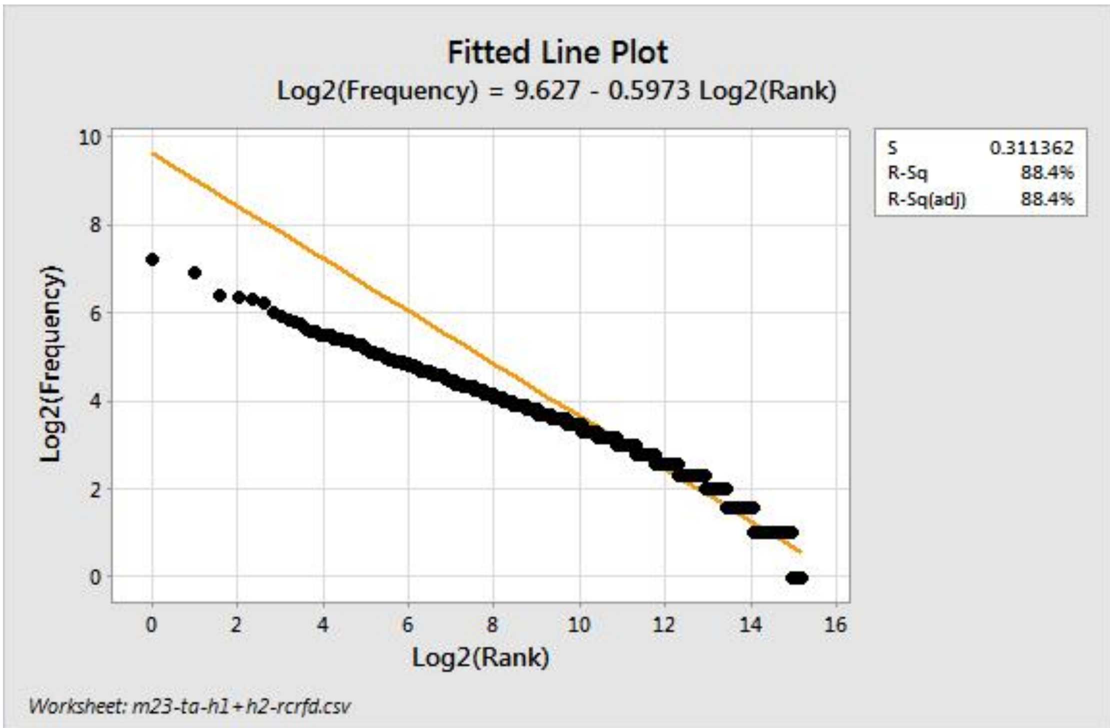

Fitted Line Plot
Log2(Frequency) = 11.93 - 0.7552 Log2(Rank)
S 0.680087
R-Sq 71.9%
R-Sq(adj) 71.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13-h1+h2-bdrfd.csv

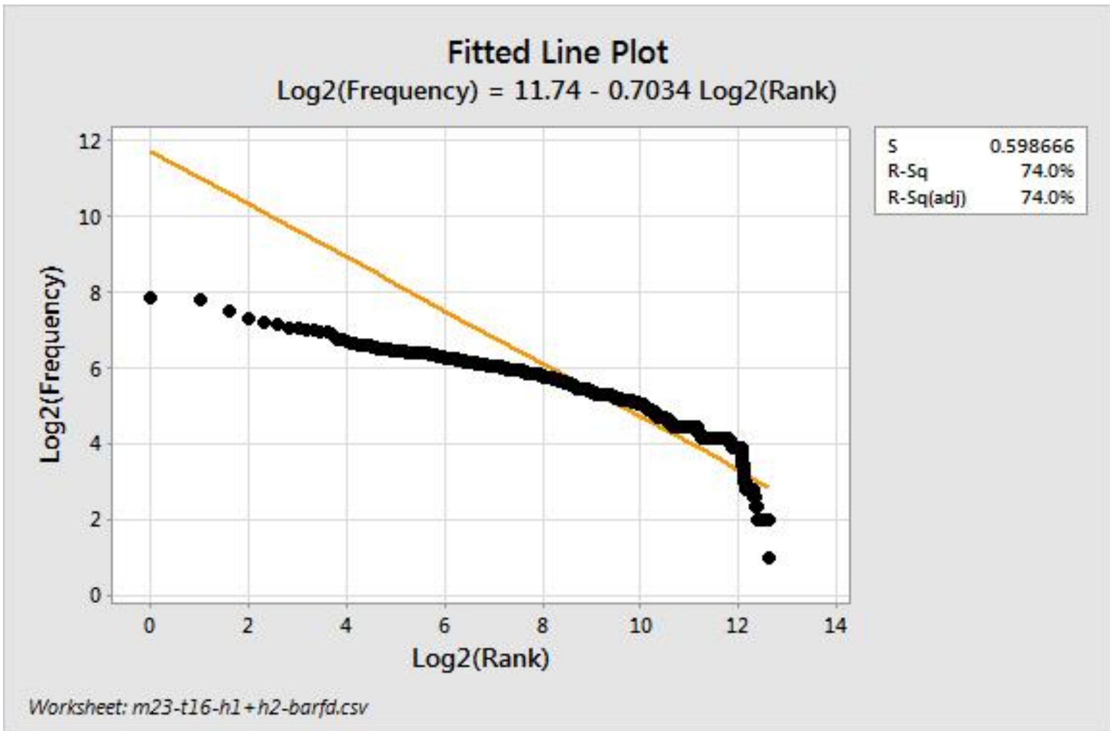

Fitted Line Plot
Log2(Frequency) = 10.13 - 0.6353 Log2(Rank)
S 0.442323
R-Sq 81.1%
R-Sq(adj) 81.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m22-t13-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 12.53 - 0.7887 Log2(Rank)
S 0.786972
R-Sq 67.5%
R-Sq(adj) 67.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta-h1+h2-rarfd.csv

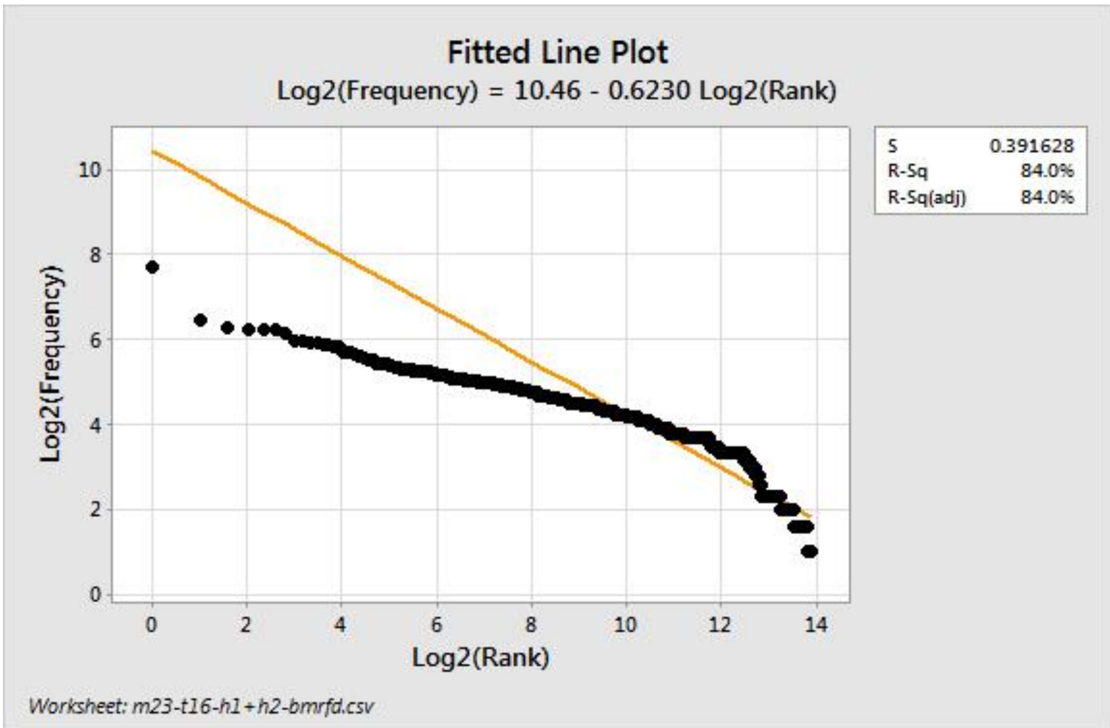

Fitted Line Plot
Log2(Frequency) = 10.15 - 0.5962 Log2(Rank)
S 0.480990
R-Sq 76.1%
R-Sq(adj) 76.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta-h1+h2-rmrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.77 - 0.6545 Log2(Rank)
S 0.504733
R-Sq 77.7%
R-Sq(adj) 77.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta-h1+h2-rdrfd.csv

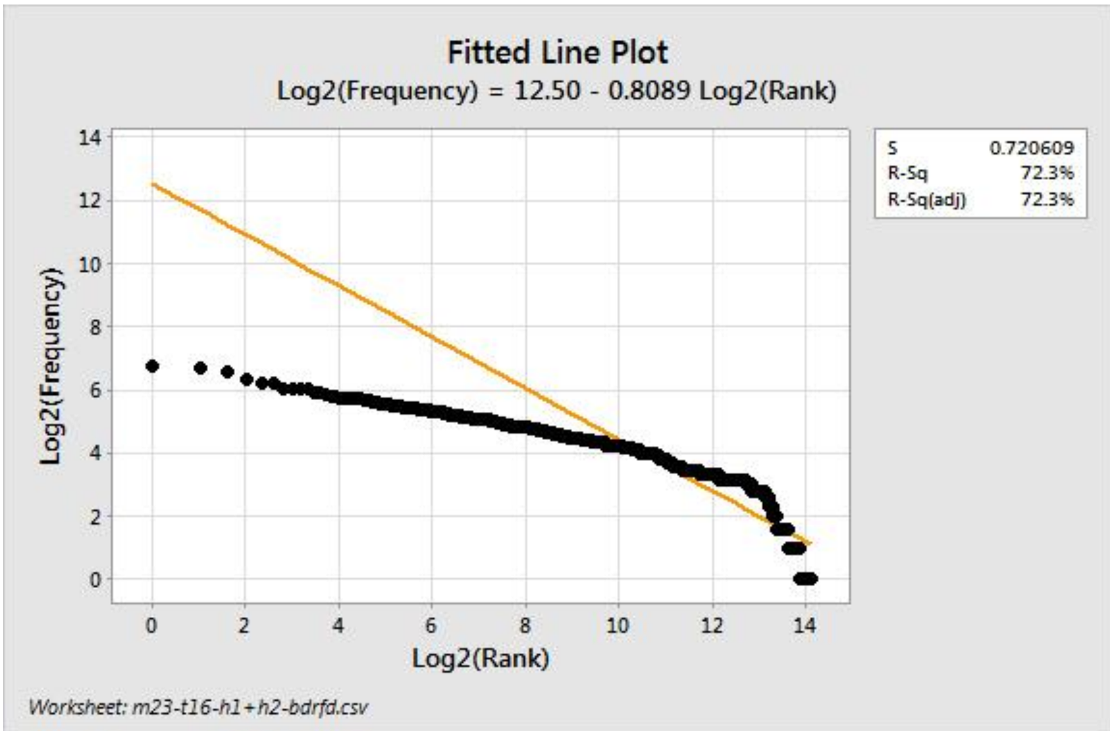

Fitted Line Plot
Log2(Frequency) = 9.627 - 0.5973 Log2(Rank)
S 0.311362
R-Sq 88.4%
R-Sq(adj) 88.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-ta-h1+h2-rcrfd.csv

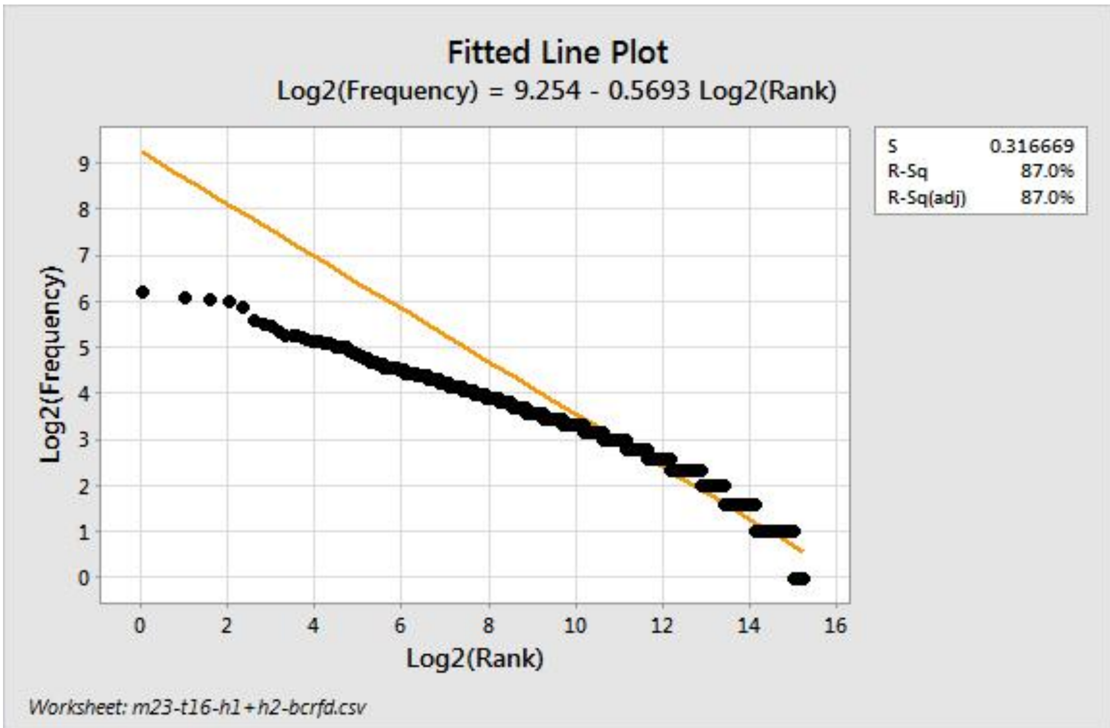


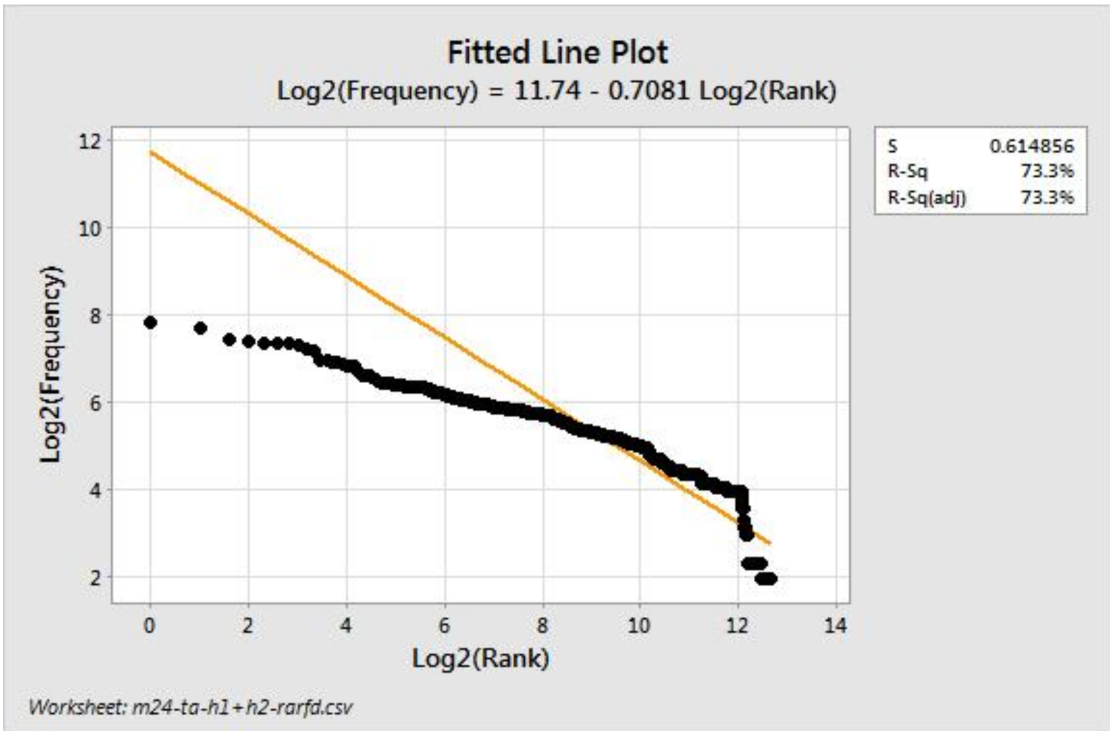
Fitted Line Plot
Log2(Frequency) = 11.74 - 0.7034 Log2(Rank)
S 0.598666
R-Sq 74.0%
R-Sq(adj) 74.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16-h1+h2-barfd.csv

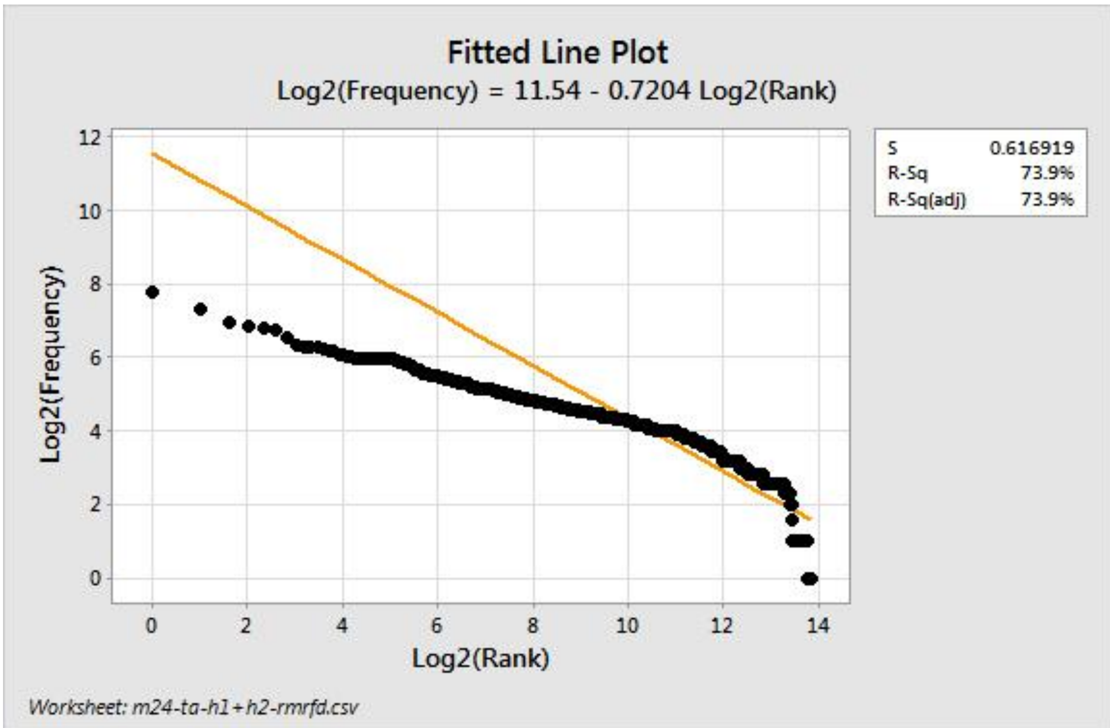


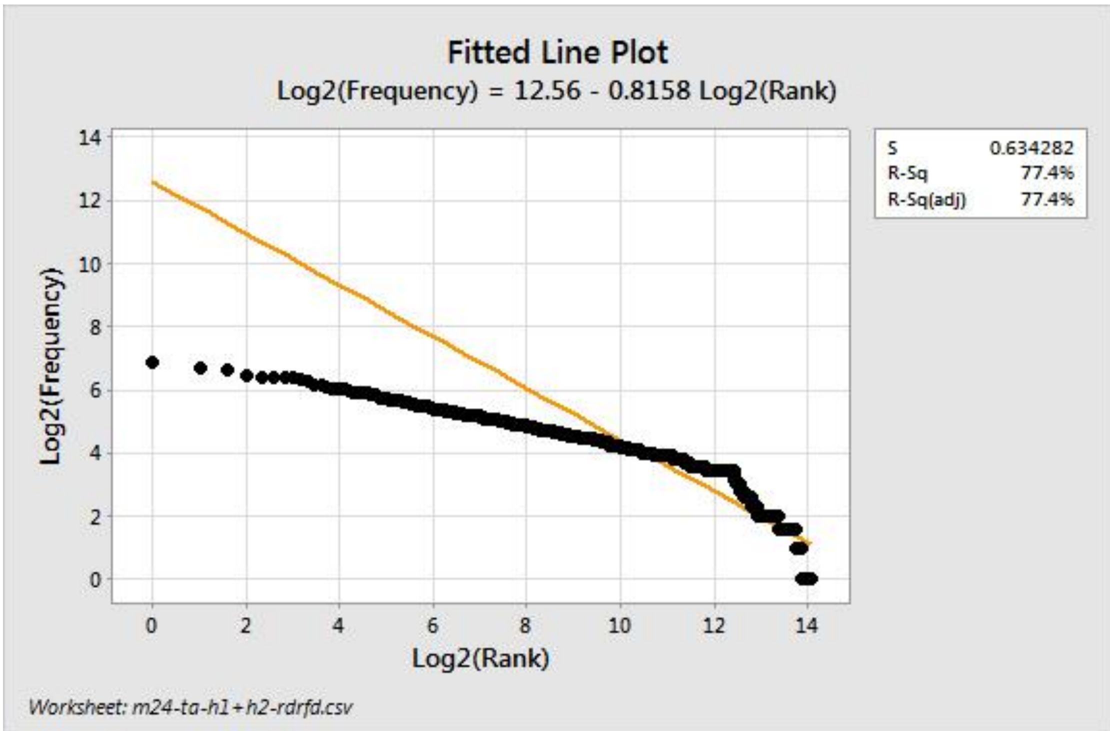
Fitted Line Plot
Log2(Frequency) = 10.46 - 0.6230 Log2(Rank)
S 0.391628
R-Sq 84.0%
R-Sq(adj) 84.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16-h1+h2-bmrfd.csv

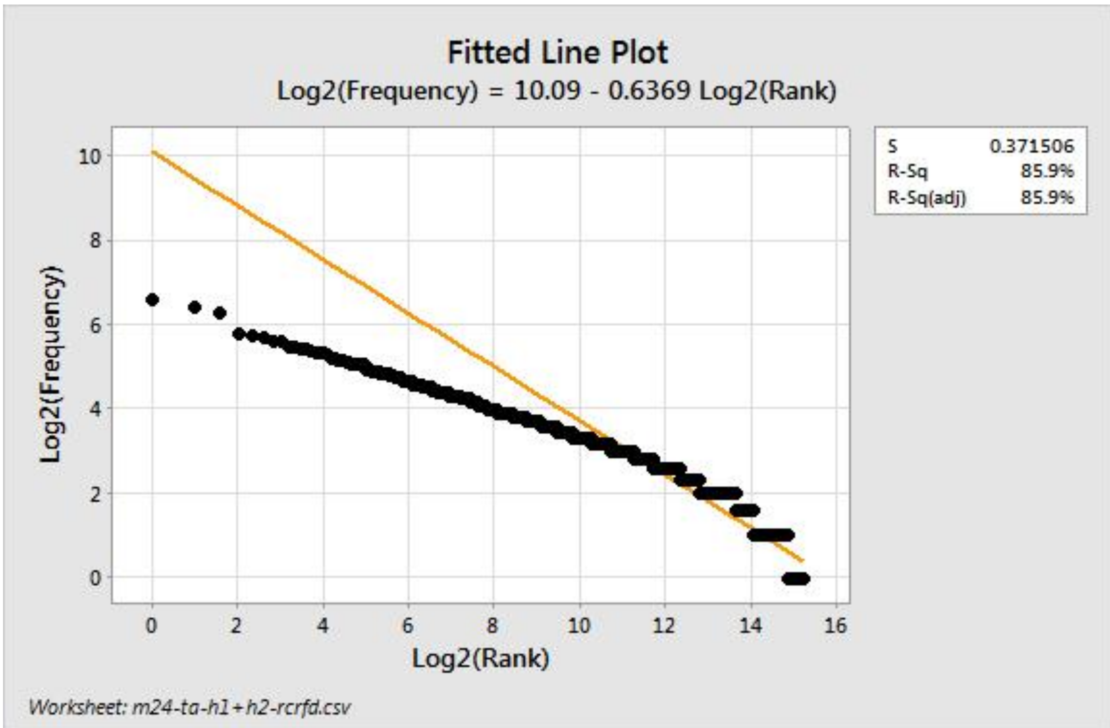

Fitted Line Plot
Log2(Frequency) = 12.50 - 0.8089 Log2(Rank)
S 0.720609
R-Sq 72.3%
R-Sq(adj) 72.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16-h1+h2-bdrfd.csv

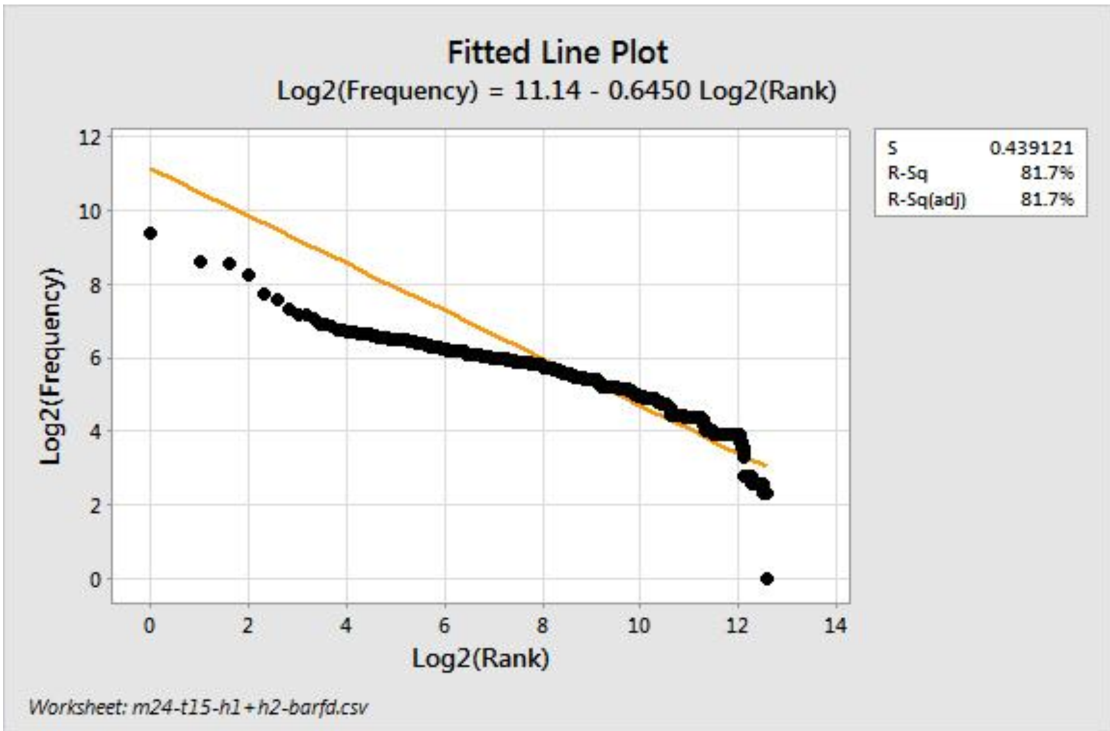

Fitted Line Plot
Log2(Frequency) = 9.254 - 0.5693 Log2(Rank)
S 0.316669
R-Sq 87.0%
R-Sq(adj) 87.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m23-t16-h1+h2-bcrfd.csv

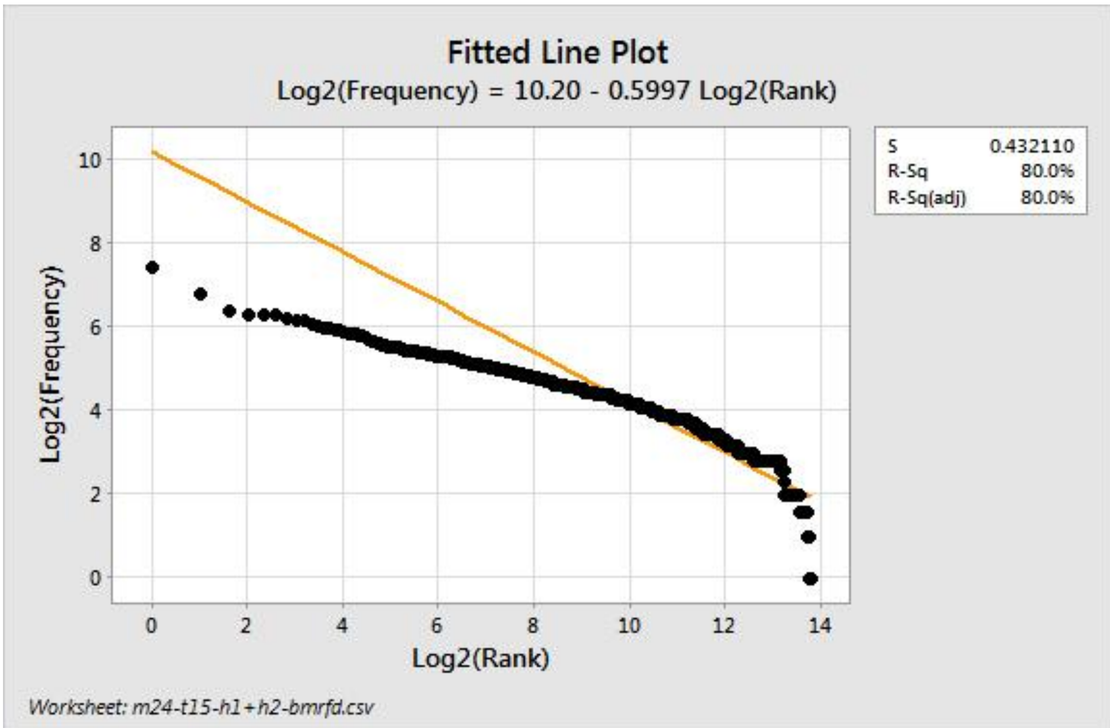

Fitted Line Plot
Log2(Frequency) = 11.74 - 0.7081 Log2(Rank)
S 0.614856
R-Sq 73.3%
R-Sq(adj) 73.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-ta-h1+h2-rarfd.csv

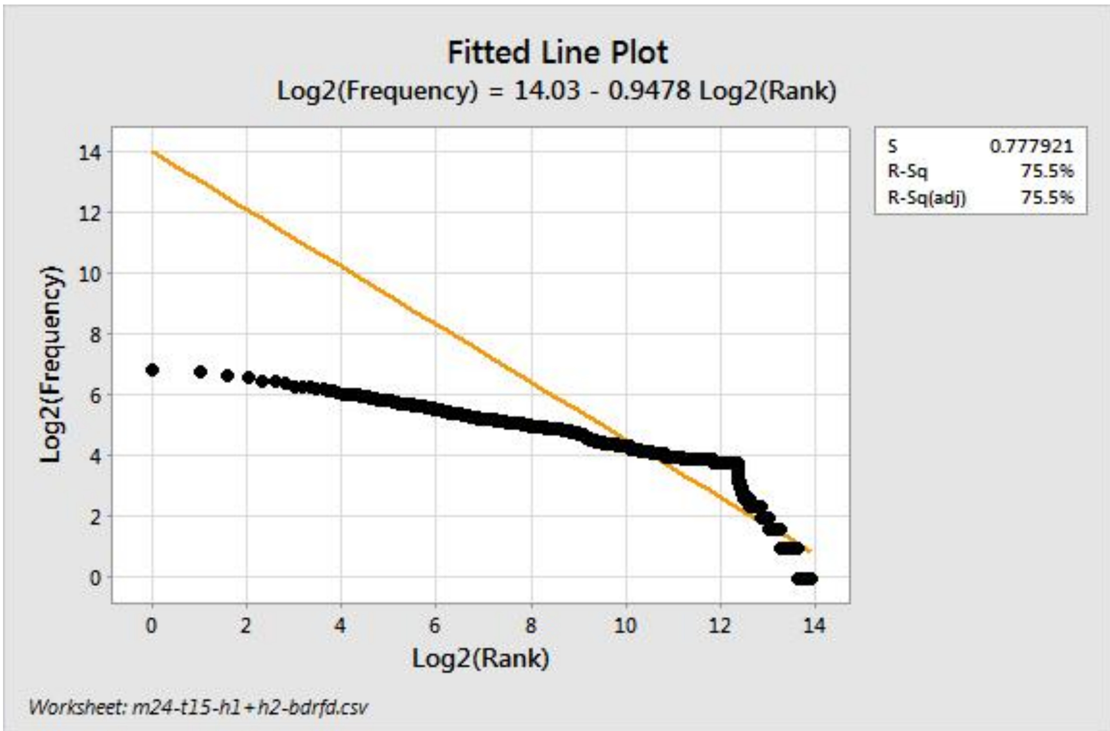

Fitted Line Plot
Log2(Frequency) = 11.54 - 0.7204 Log2(Rank)
S 0.616919
R-Sq 73.9%
R-Sq(adj) 73.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-ta-h1+h2-rmrfd.csv

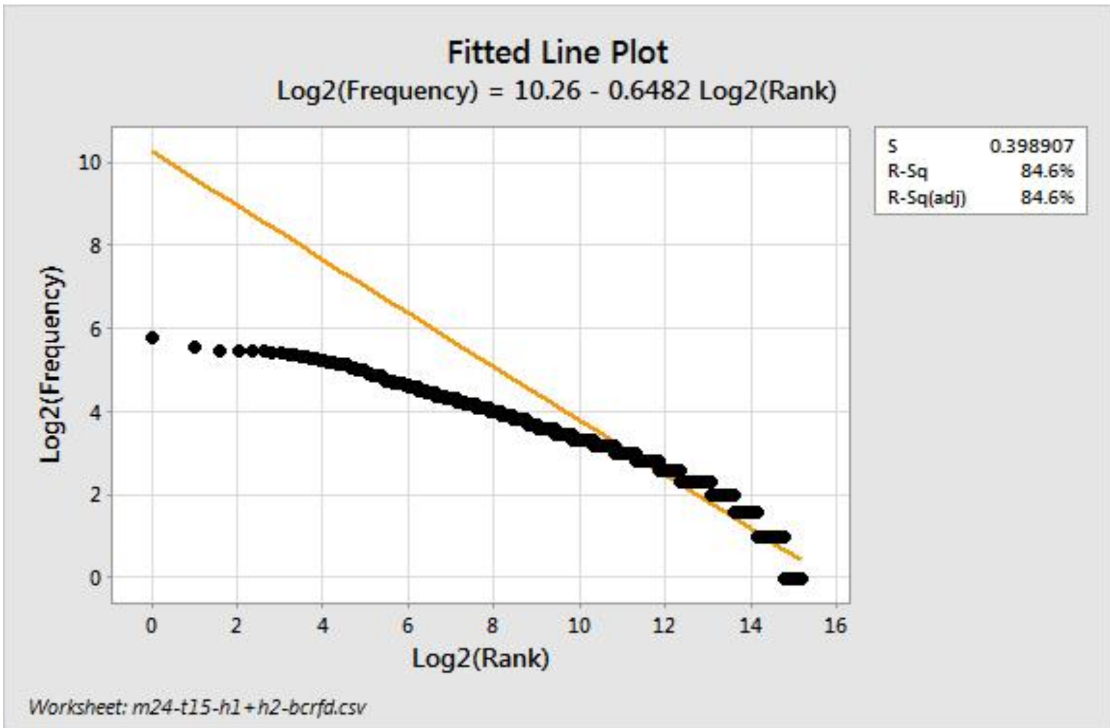

Fitted Line Plot
Log2(Frequency) = 12.56 - 0.8158 Log2(Rank)
S 0.634282
R-Sq 77.4%
R-Sq(adj) 77.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-ta-h1+h2-rdrfd.csv

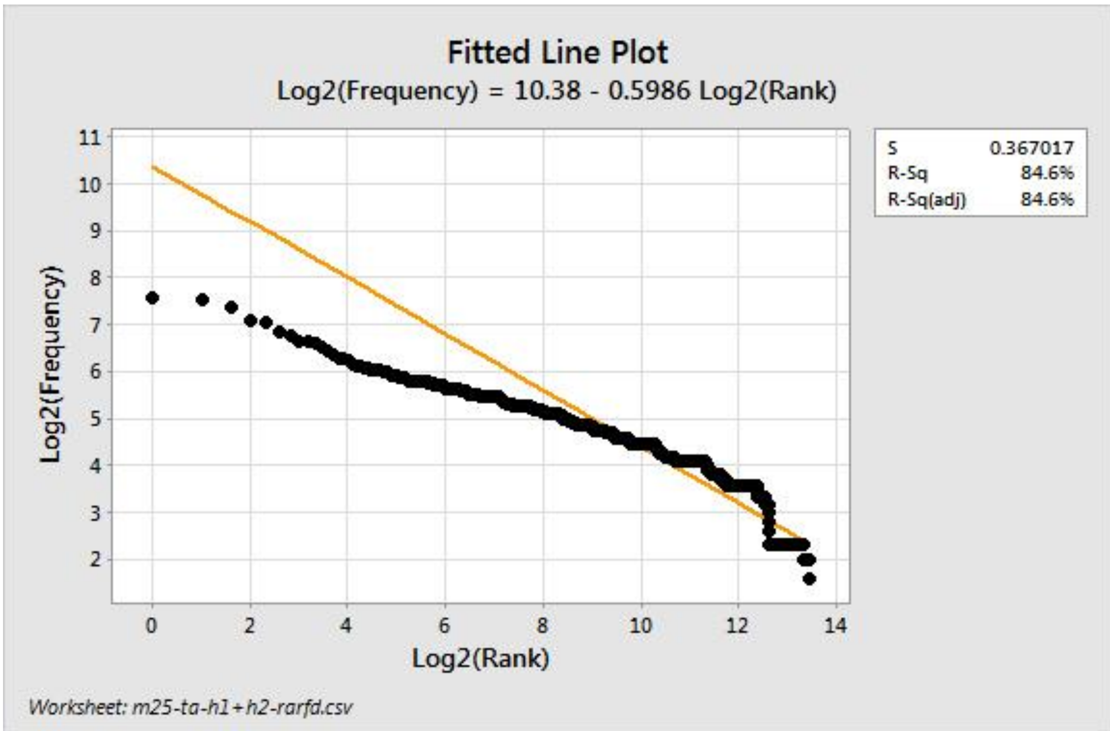

Fitted Line Plot
Log2(Frequency) = 10.09 - 0.6369 Log2(Rank)
S 0.371506
R-Sq 85.9%
R-Sq(adj) 85.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-ta-h1+h2-rcrfd.csv

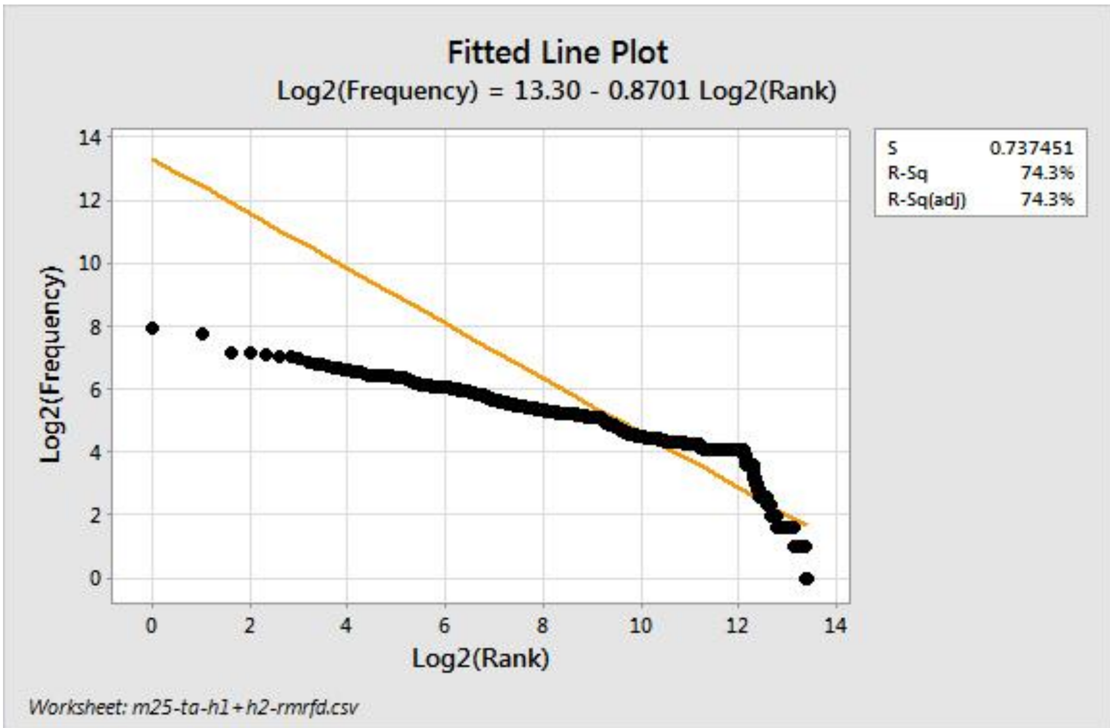

Fitted Line Plot
Log2(Frequency) = 11.14 - 0.6450 Log2(Rank)
S 0.439121
R-Sq 81.7%
R-Sq(adj) 81.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-t15-h1+h2-barfd.csv

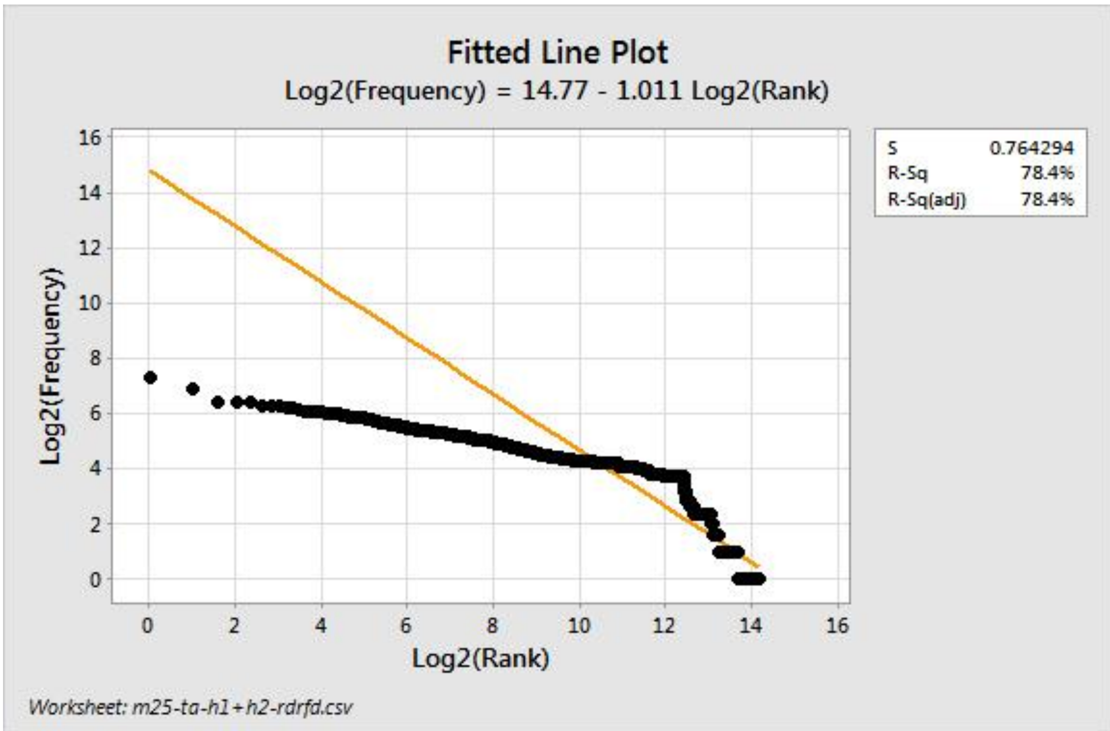

Fitted Line Plot
Log2(Frequency) = 10.20 - 0.5997 Log2(Rank)
S 0.432110
R-Sq 80.0%
R-Sq(adj) 80.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-t15-h1+h2-bmrfd.csv

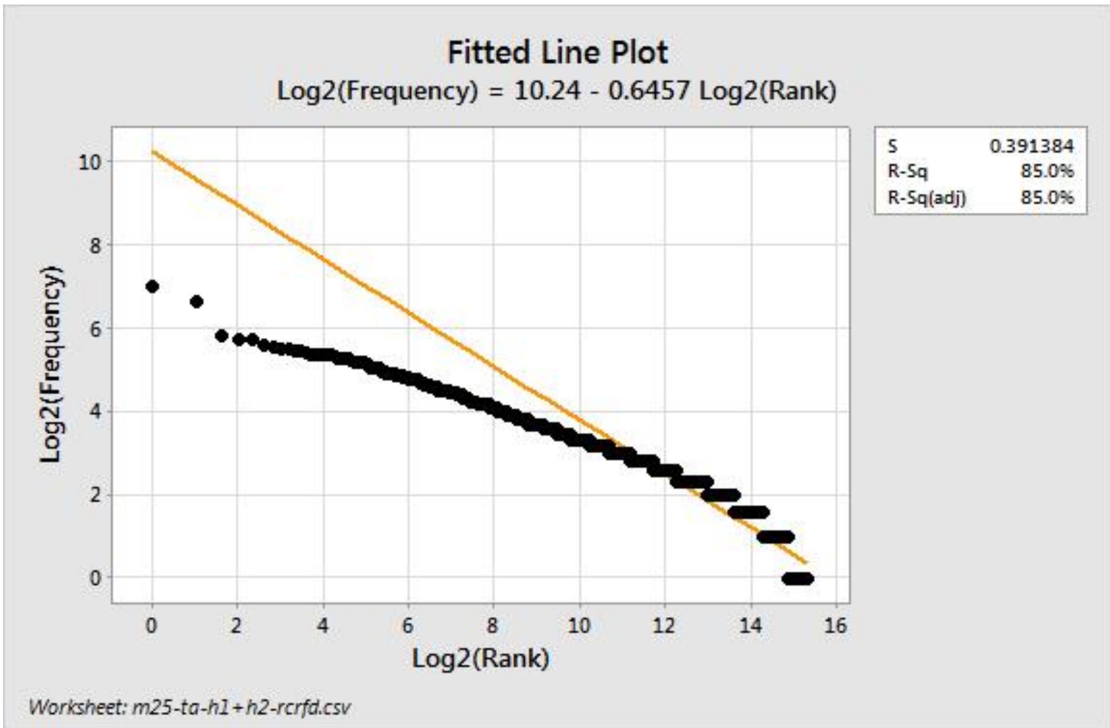

Fitted Line Plot
Log2(Frequency) = 14.03 - 0.9478 Log2(Rank)
S 0.777921
R-Sq 75.5%
R-Sq(adj) 75.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-t15-h1+h2-bdrfd.csv

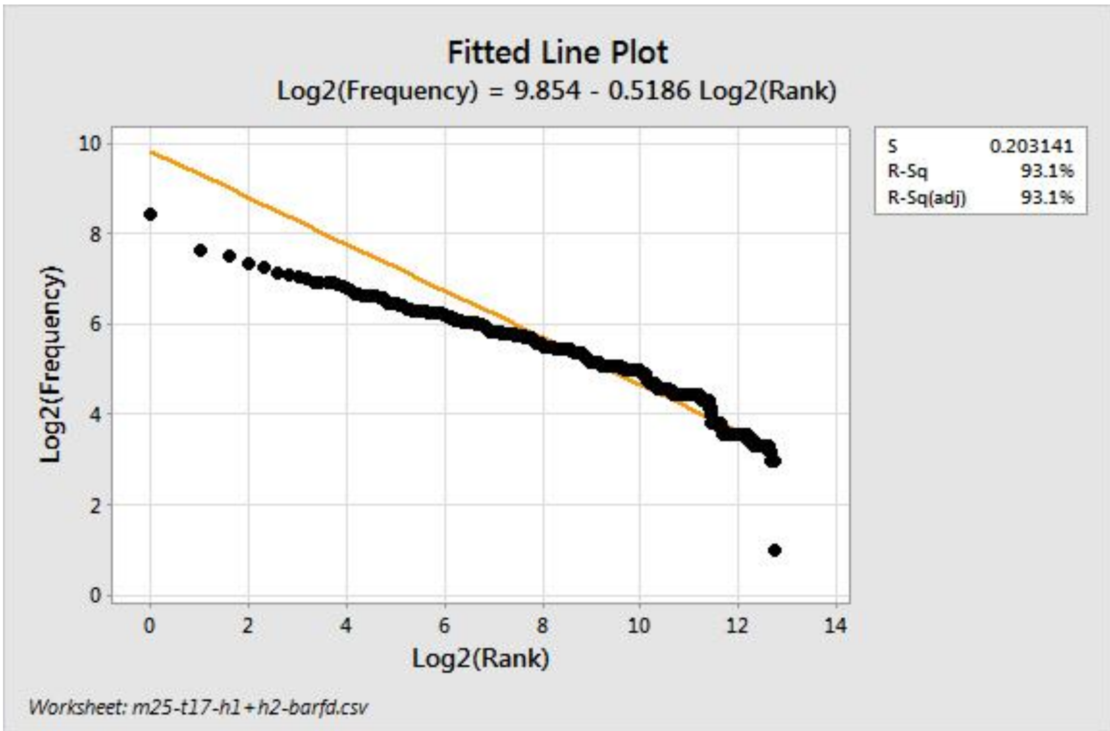

Fitted Line Plot
Log2(Frequency) = 10.26 - 0.6482 Log2(Rank)
S 0.398907
R-Sq 84.6%
R-Sq(adj) 84.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m24-t15-h1+h2-bcrfd.csv

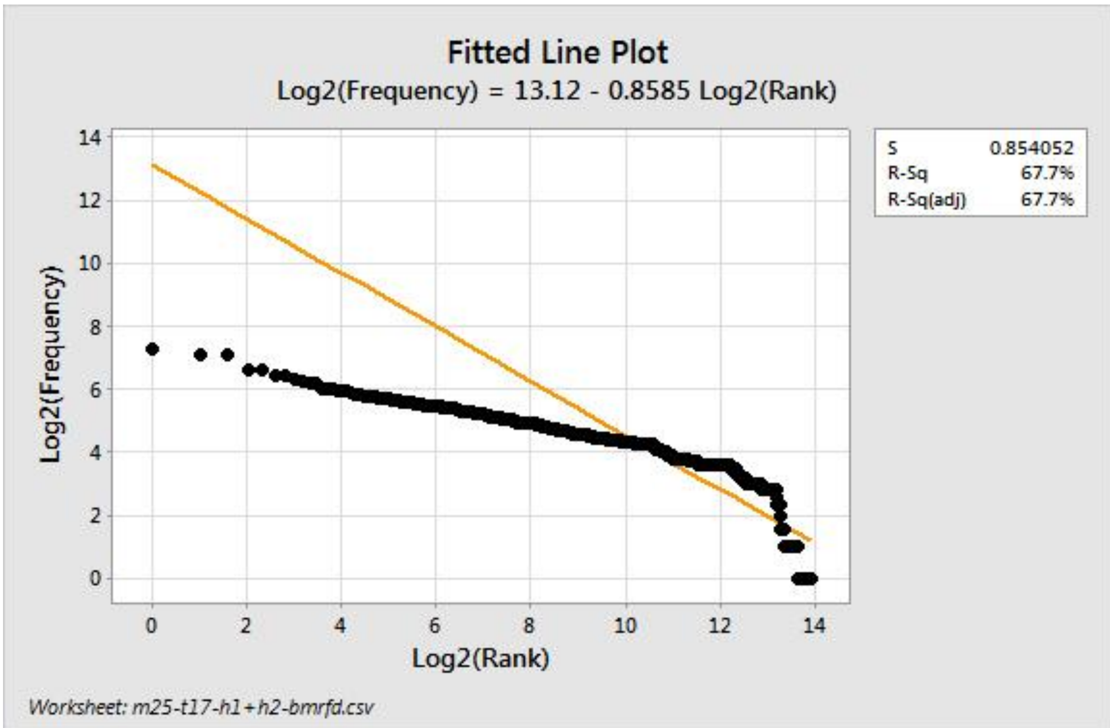

Fitted Line Plot
Log2(Frequency) = 10.38 - 0.5986 Log2(Rank)
S 0.367017
R-Sq 84.6%
R-Sq(adj) 84.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-ta-h1+h2-rarfd.csv

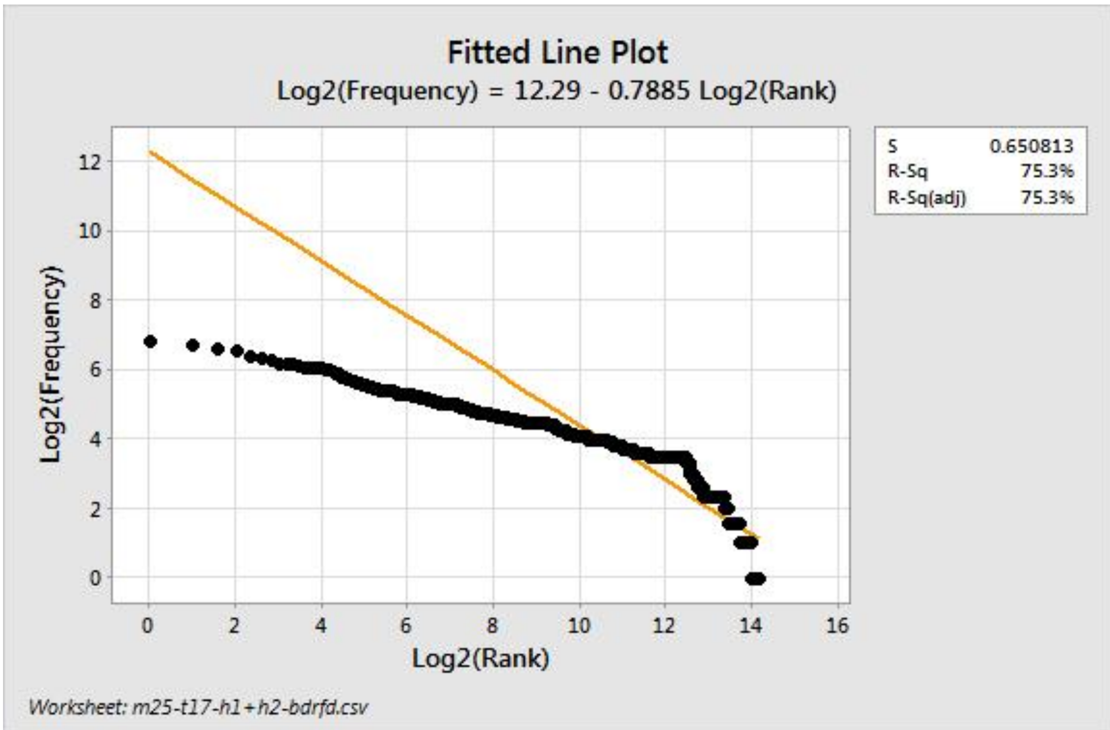

Fitted Line Plot
Log2(Frequency) = 13.30 - 0.8701 Log2(Rank)
S 0.737451
R-Sq 74.3%
R-Sq(adj) 74.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-ta-h1+h2-rmrfd.csv

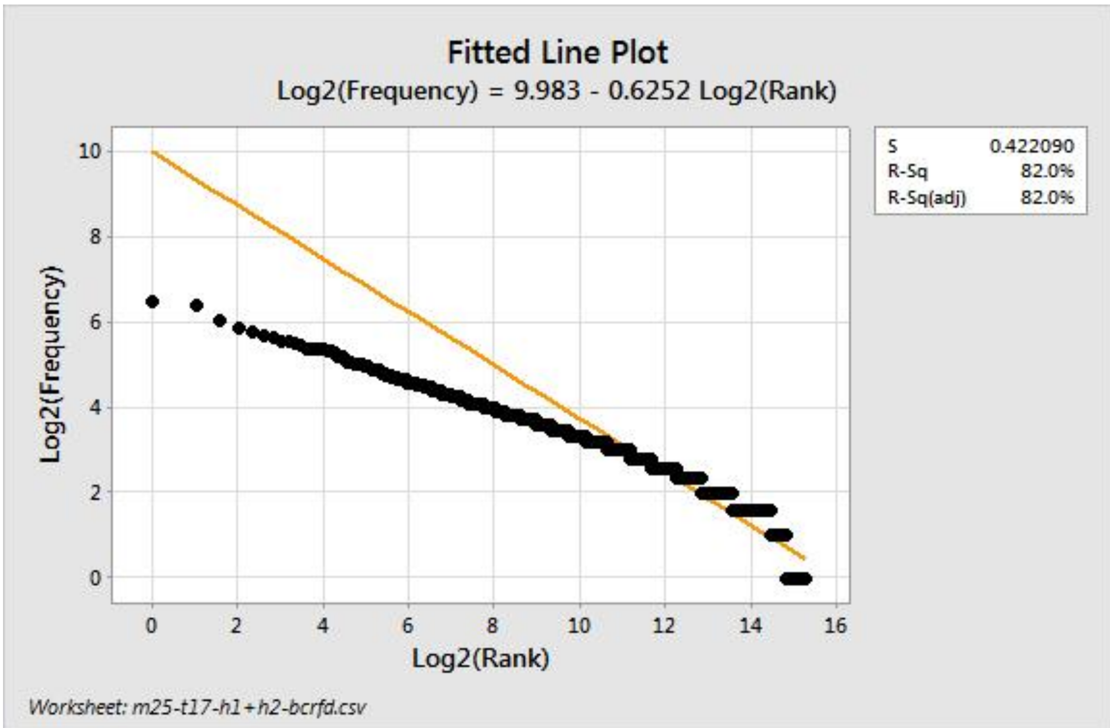

Fitted Line Plot
Log2(Frequency) = 14.77 - 1.011 Log2(Rank)
S 0.764294
R-Sq 78.4%
R-Sq(adj) 78.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-ta-h1+h2-rdrfd.csv

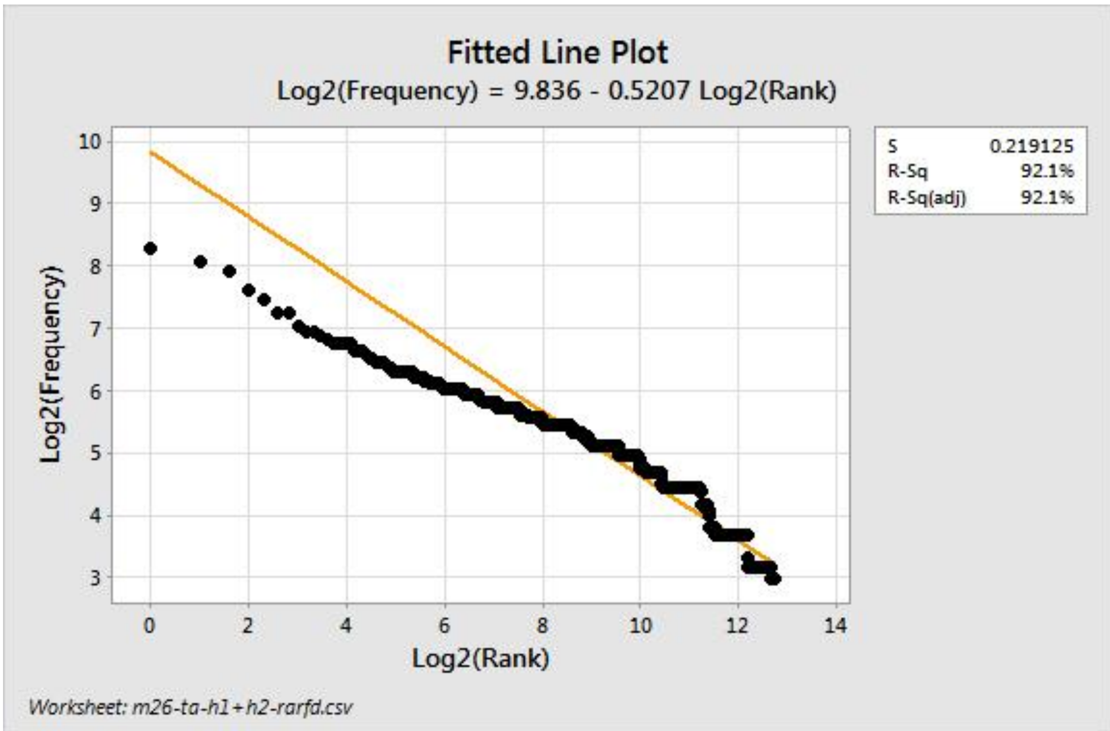

Fitted Line Plot
Log2(Frequency) = 10.24 - 0.6457 Log2(Rank)
S 0.391384
R-Sq 85.0%
R-Sq(adj) 85.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-ta-h1+h2-rcrfd.csv

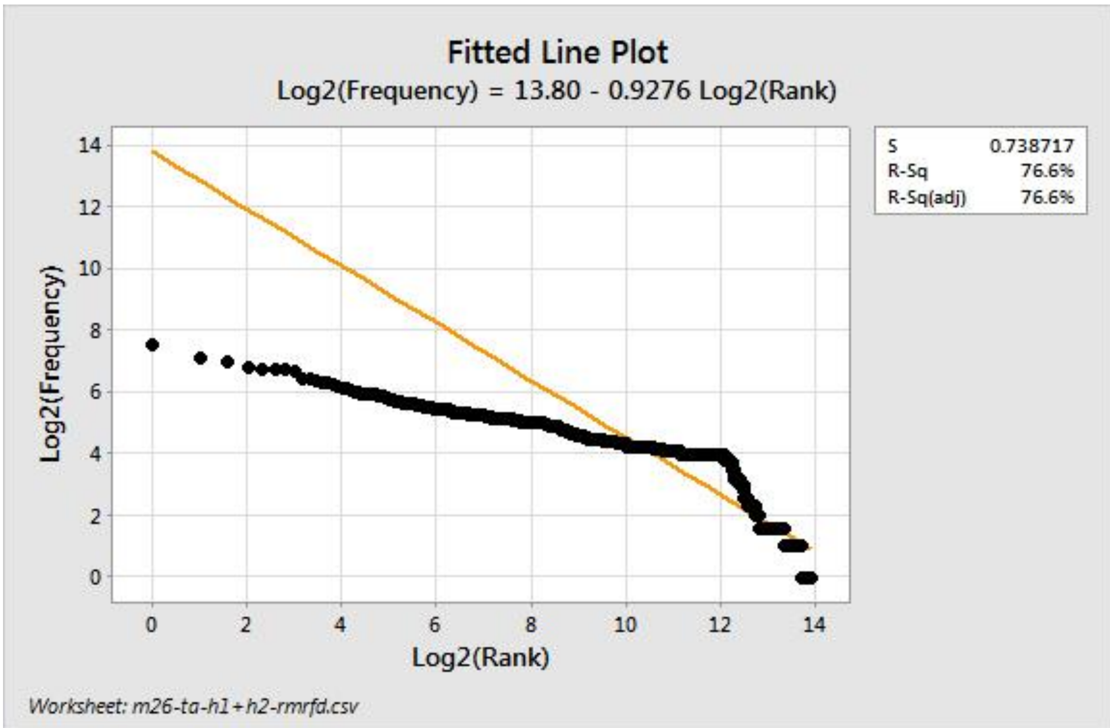

Fitted Line Plot
Log2(Frequency) = 9.854 - 0.5186 Log2(Rank)
S 0.203141
R-Sq 93.1%
R-Sq(adj) 93.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-t17-h1+h2-barfd.csv

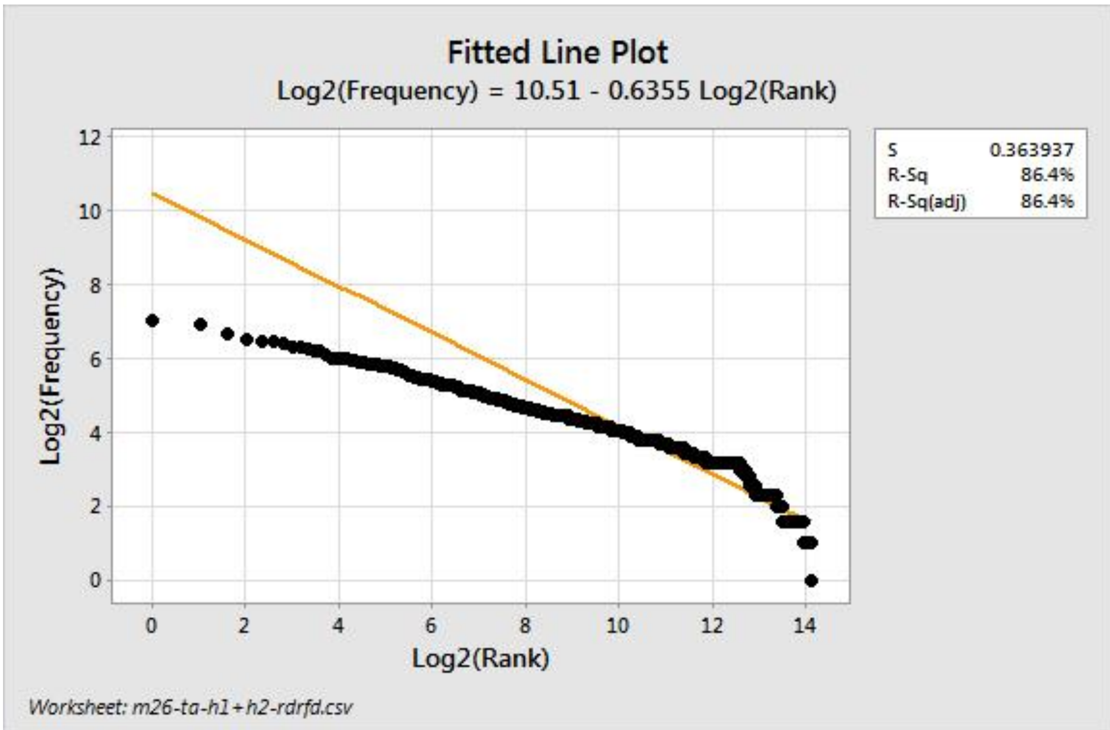

Fitted Line Plot
Log2(Frequency) = 13.12 - 0.8585 Log2(Rank)
S 0.854052
R-Sq 67.7%
R-Sq(adj) 67.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-t17-h1+h2-bmrfd.csv

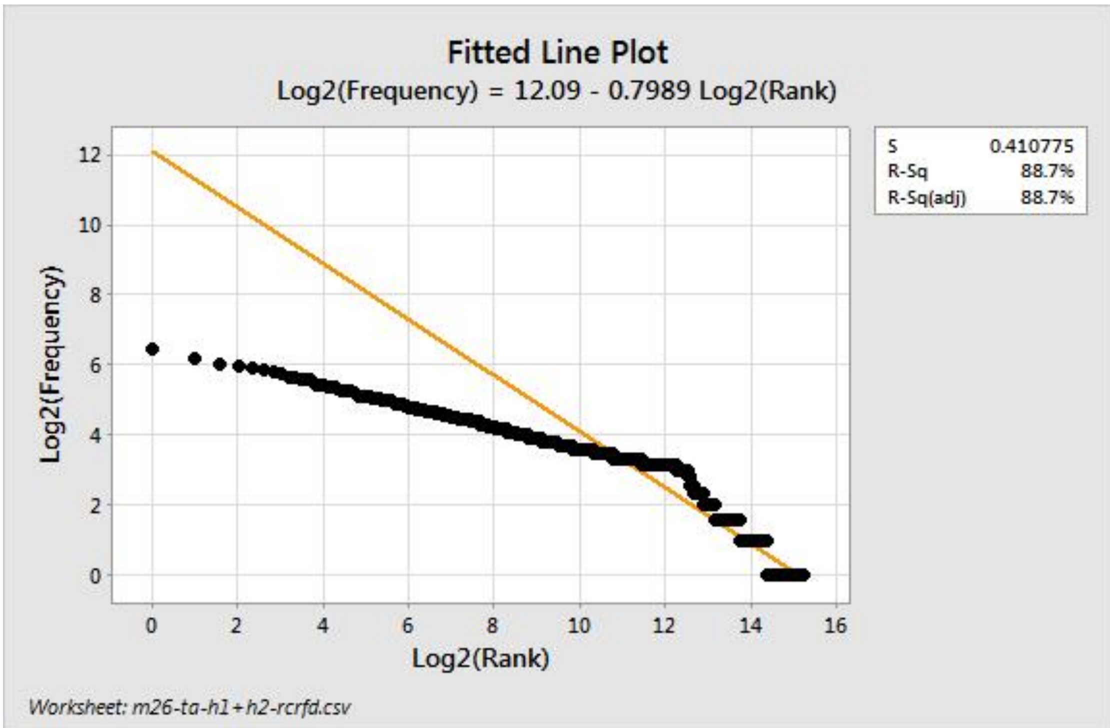

Fitted Line Plot
Log2(Frequency) = 12.29 - 0.7885 Log2(Rank)
S 0.650813
R-Sq 75.3%
R-Sq(adj) 75.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-t17-h1+h2-bdrfd.csv

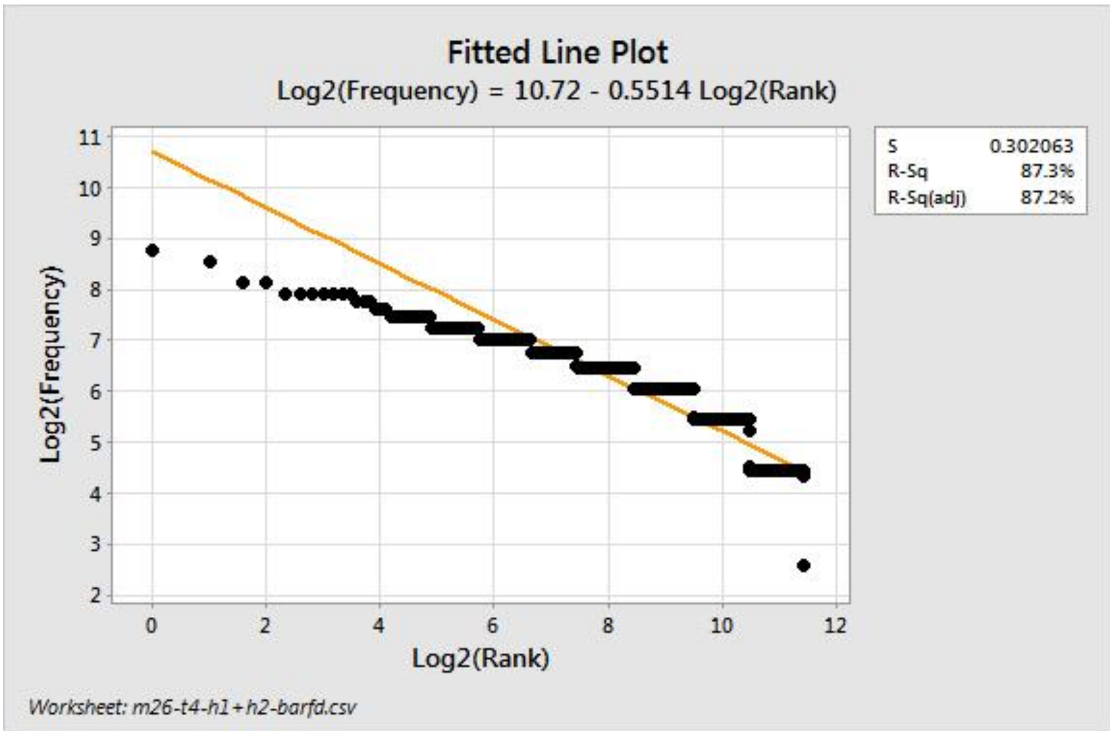

Fitted Line Plot
Log2(Frequency) = 9.983 - 0.6252 Log2(Rank)
S 0.422090
R-Sq 82.0%
R-Sq(adj) 82.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m25-t17-h1+h2-bcrfd.csv

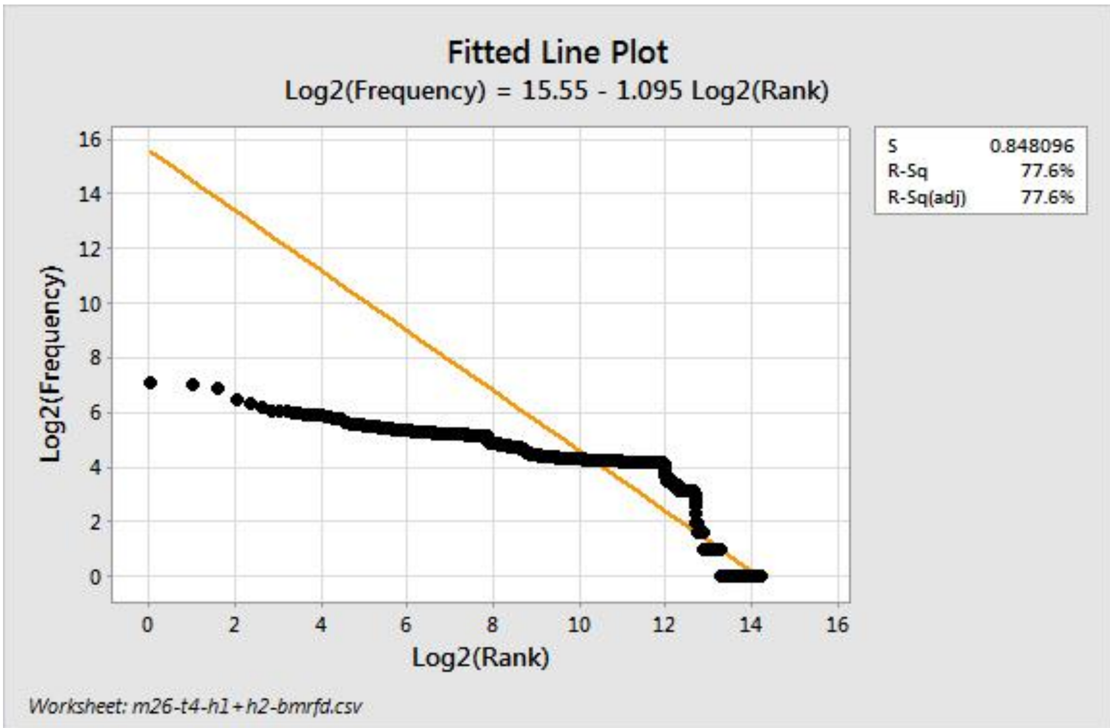

Fitted Line Plot
Log2(Frequency) = 9.836 - 0.5207 Log2(Rank)
S 0.219125
R-Sq 92.1%
R-Sq(adj) 92.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta-h1+h2-rarfd.csv

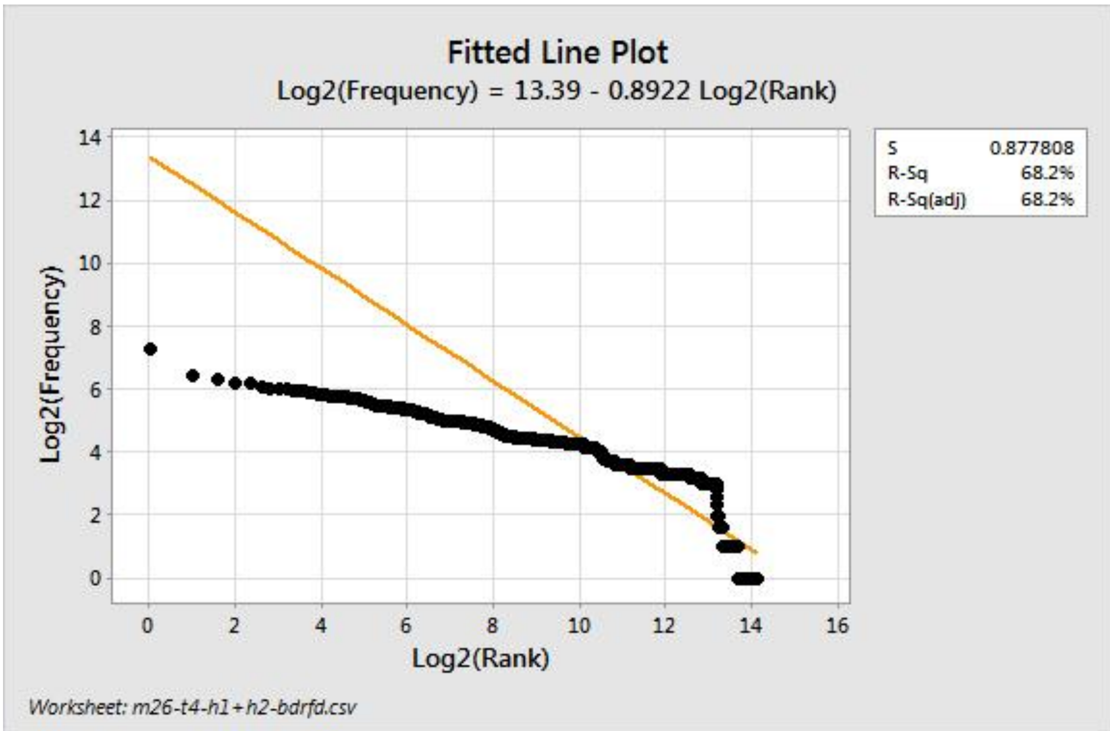

Fitted Line Plot
Log2(Frequency) = 13.80 - 0.9276 Log2(Rank)
S 0.738717
R-Sq 76.6%
R-Sq(adj) 76.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta-h1+h2-rmrfd.csv

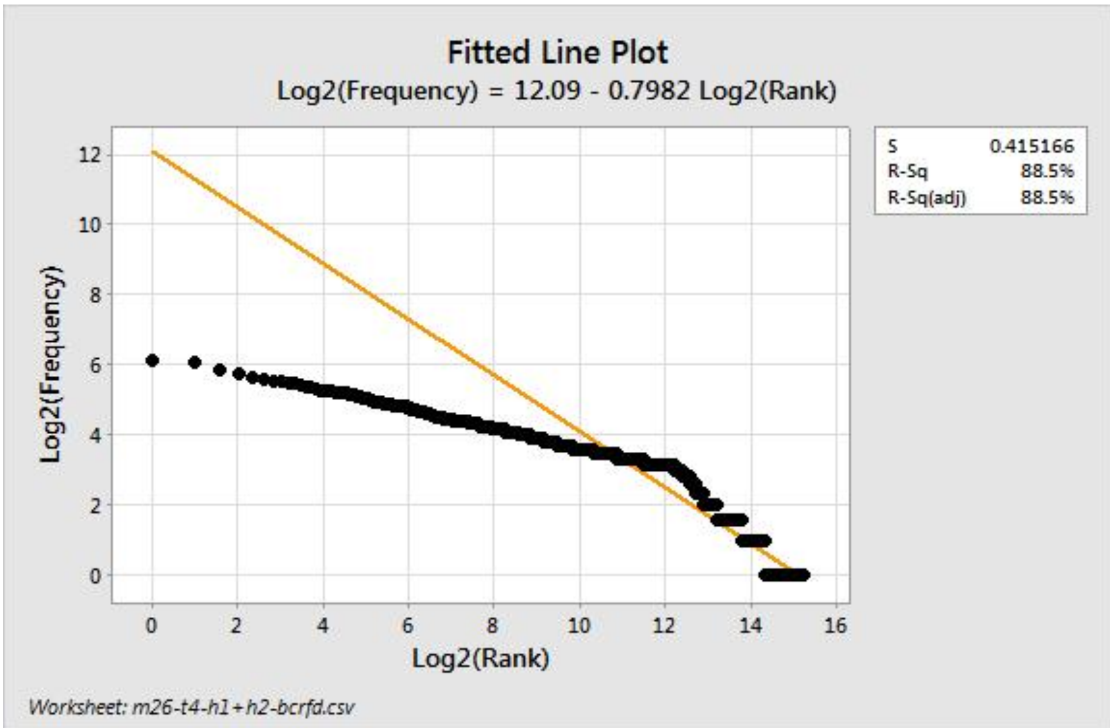

Fitted Line Plot
Log2(Frequency) = 10.51 - 0.6355 Log2(Rank)
S 0.363937
R-Sq 86.4%
R-Sq(adj) 86.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta-h1+h2-rdrfd.csv

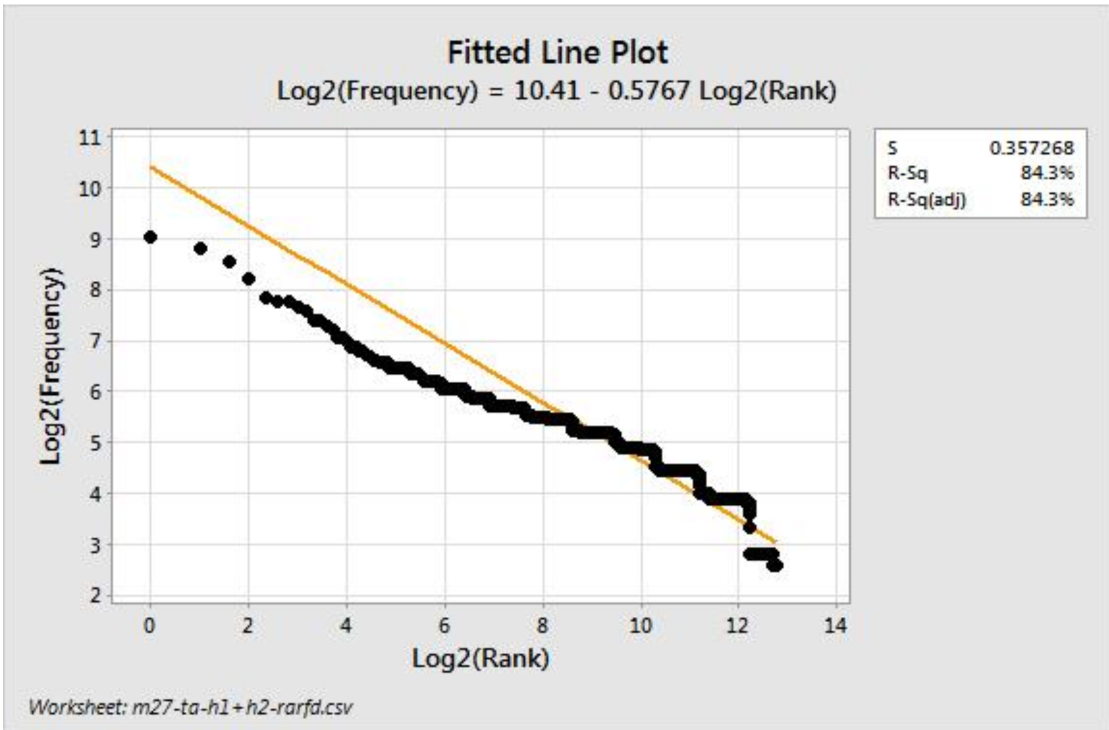

Fitted Line Plot
Log2(Frequency) = 12.09 - 0.7989 Log2(Rank)
S 0.410775
R-Sq 88.7%
R-Sq(adj) 88.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-ta-h1+h2-rcrfd.csv

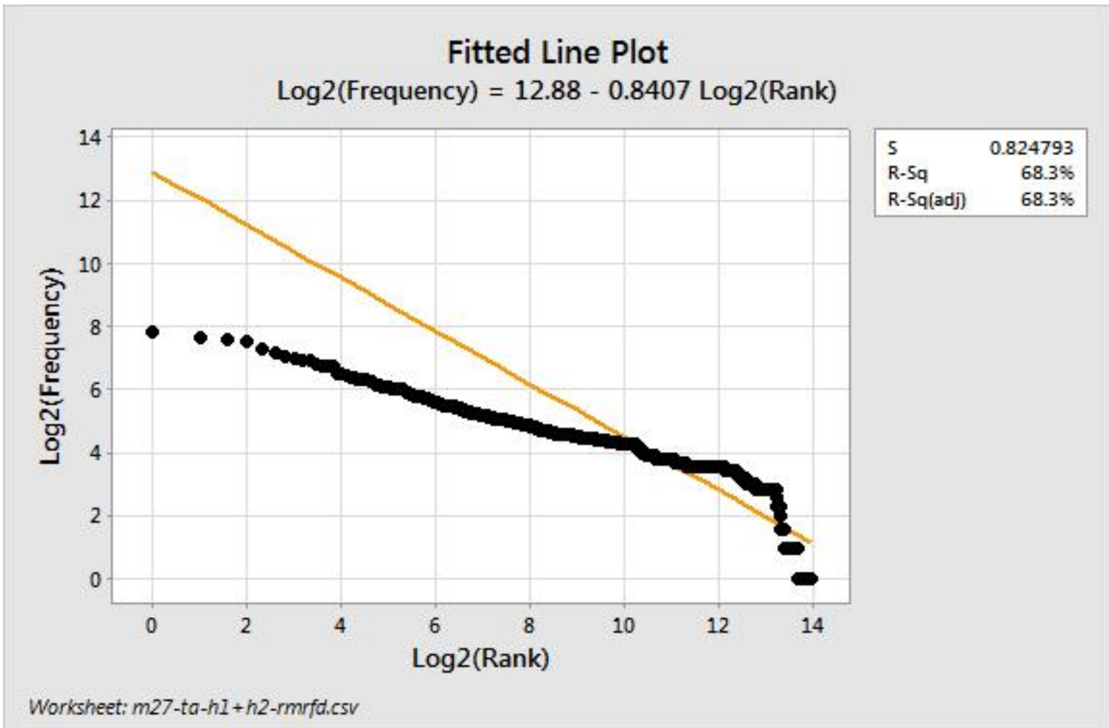

Fitted Line Plot
Log2(Frequency) = 10.72 - 0.5514 Log2(Rank)
S 0.302063
R-Sq 87.3%
R-Sq(adj) 87.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-t4-h1+h2-barfd.csv

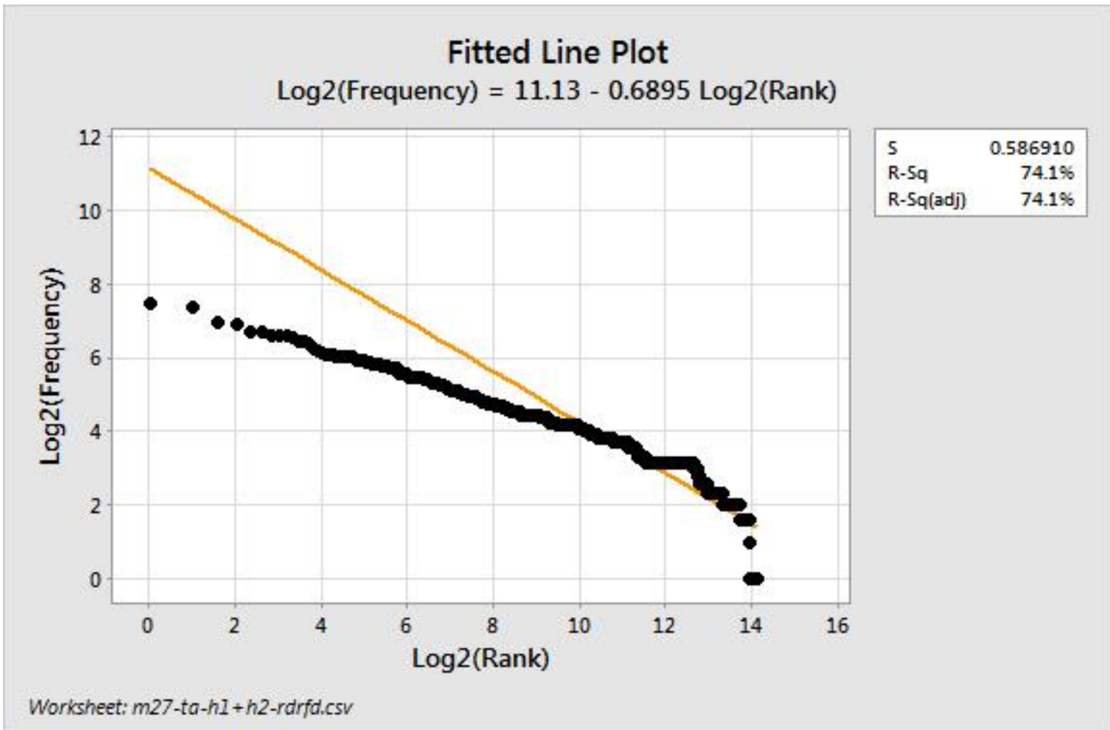

Fitted Line Plot
Log2(Frequency) = 15.55 - 1.095 Log2(Rank)
S 0.848096
R-Sq 77.6%
R-Sq(adj) 77.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m26-t4-h1+h2-bmrfd.csv

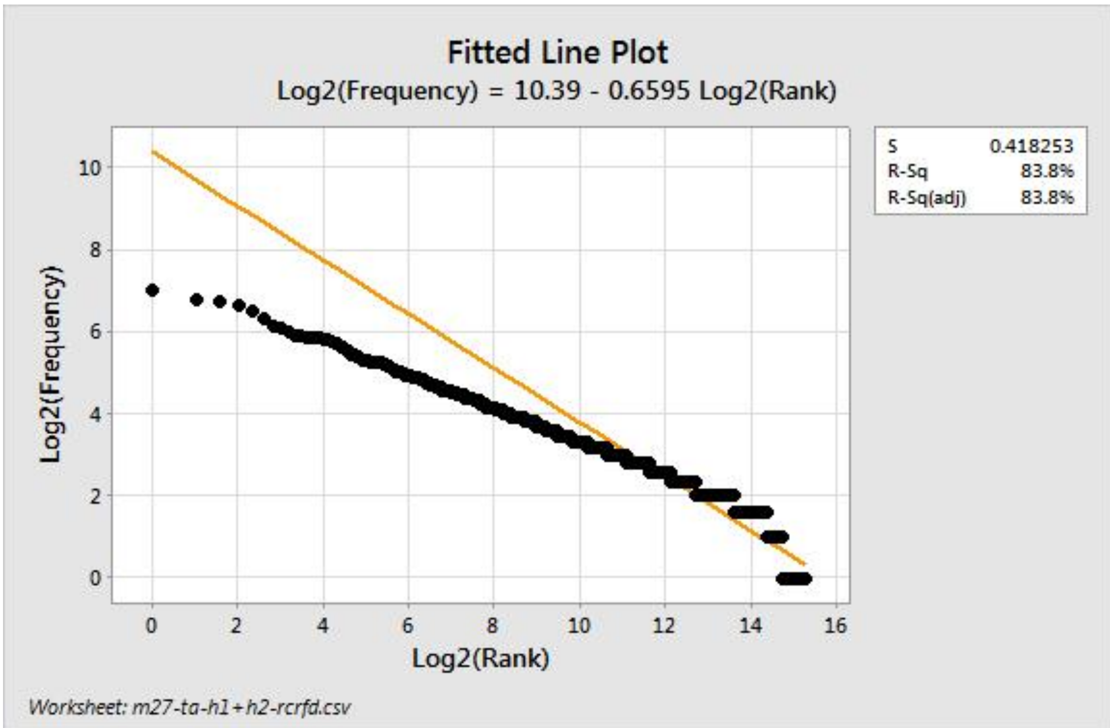

Fitted Line Plot
Log2(Frequency) = 13.39 - 0.8922 Log2(Rank)
S 0.877808
R-Sq 68.2%
R-Sq(adj) 68.2%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m26-t4-h1+h2-bdrfd.csv

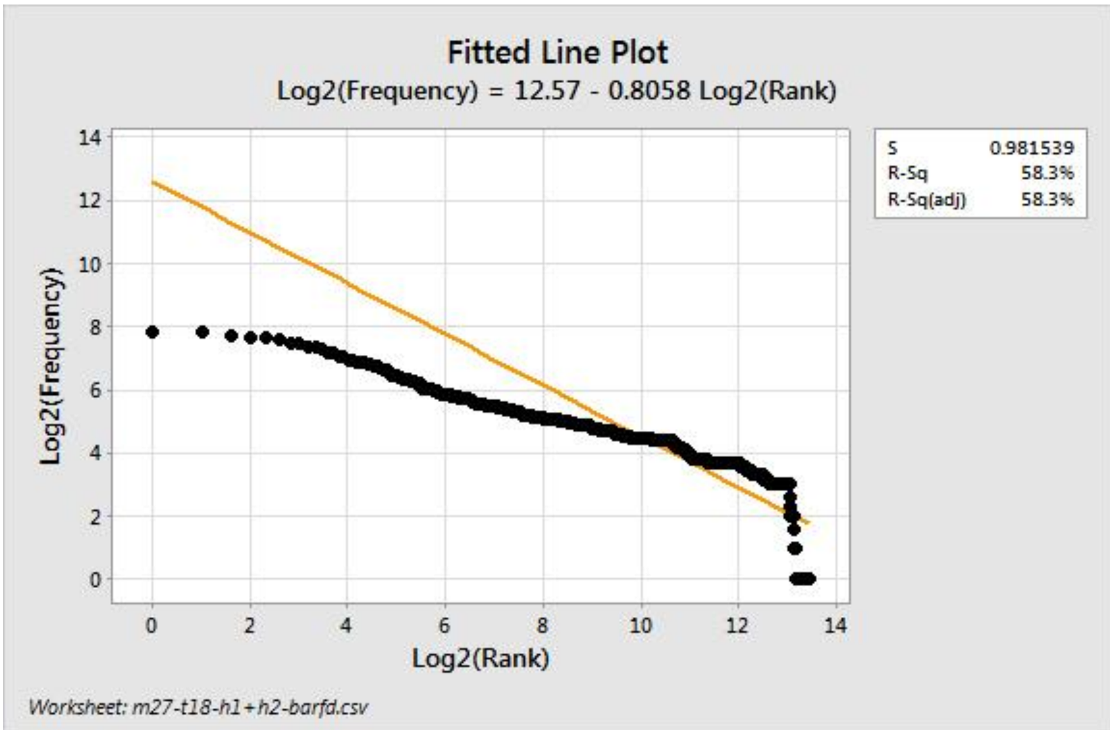

Fitted Line Plot
Log2(Frequency) = 12.09 - 0.7982 Log2(Rank)
S 0.415166
R-Sq 88.5%
R-Sq(adj) 88.5%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
16
Worksheet: m26-t4-h1+h2-bcrfd.csv

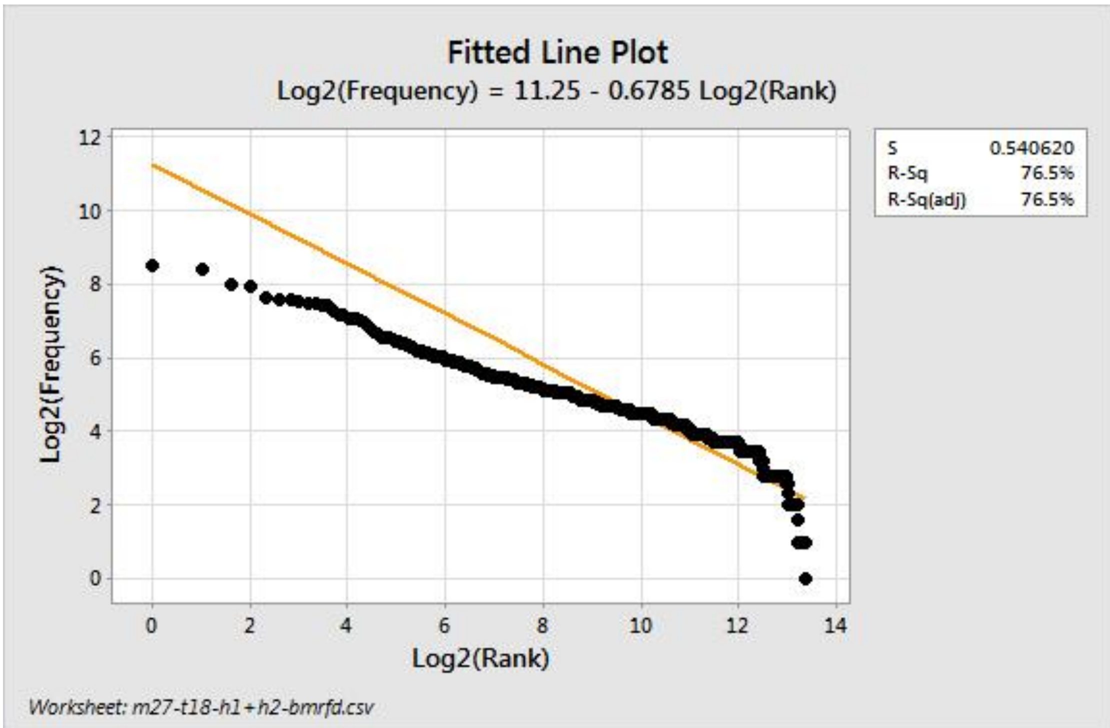

Fitted Line Plot
Log2(Frequency) = 10.41 - 0.5767 Log2(Rank)
S 0.357268
R-Sq 84.3%
R-Sq(adj) 84.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta-h1+h2-rarfd.csv

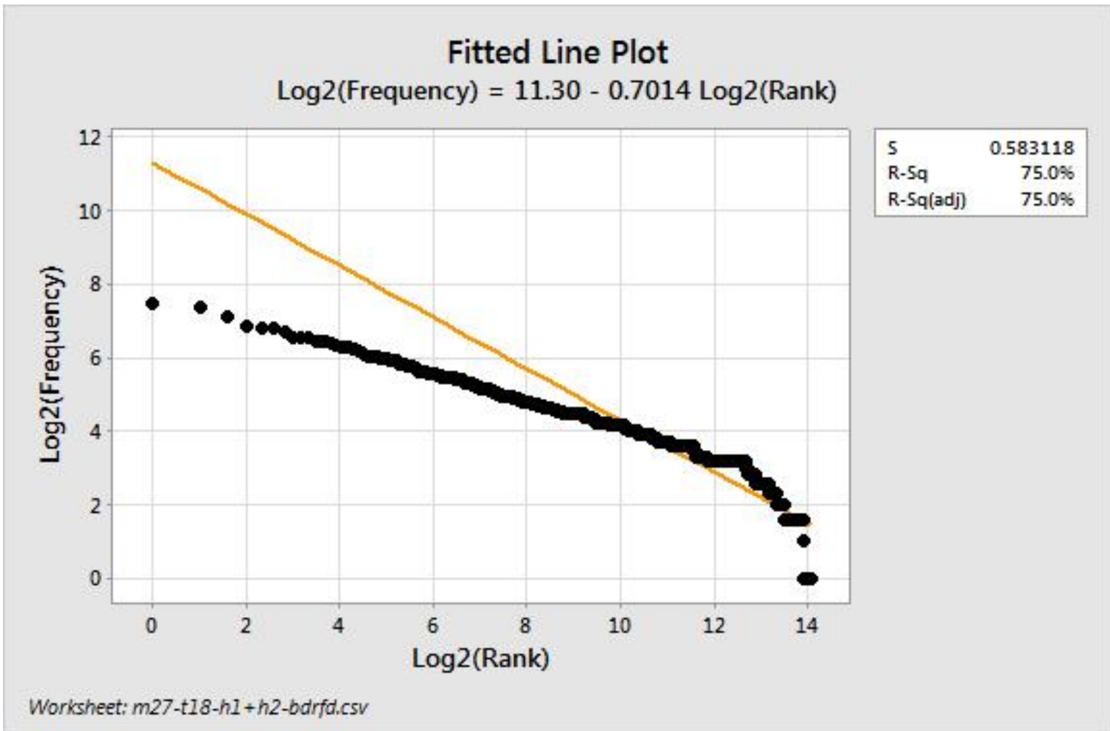

Fitted Line Plot
Log2(Frequency) = 12.88 - 0.8407 Log2(Rank)
S 0.824793
R-Sq 68.3%
R-Sq(adj) 68.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta-h1+h2-rmrfd.csv

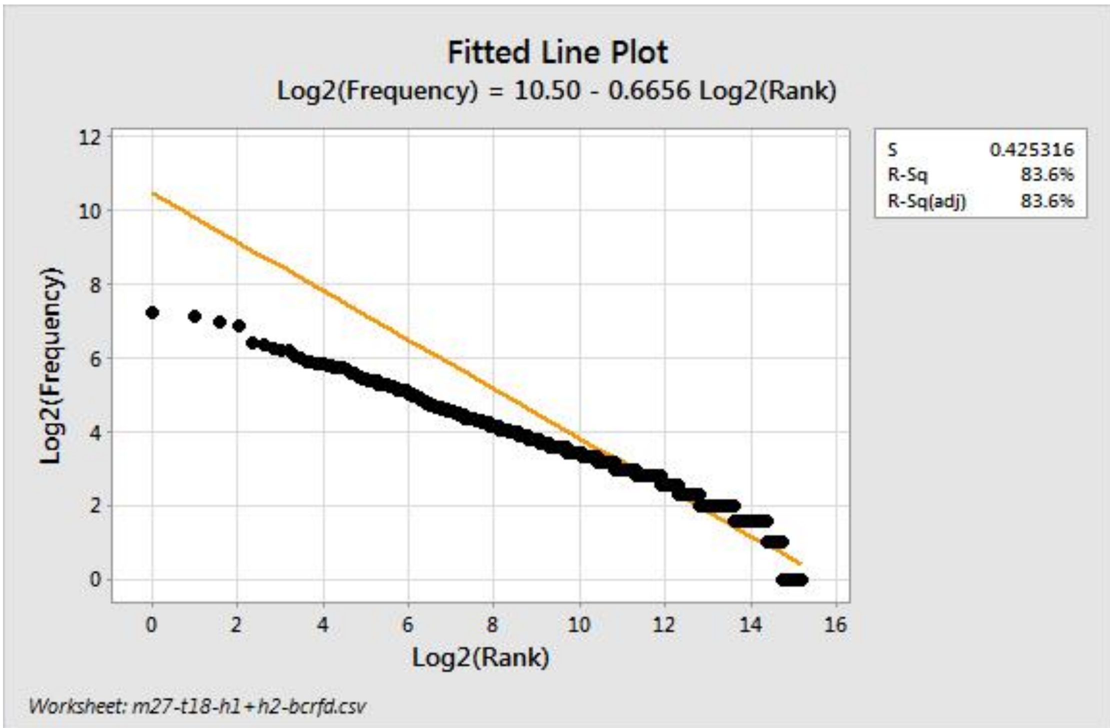

Fitted Line Plot
Log2(Frequency) = 11.13 - 0.6895 Log2(Rank)
S 0.586910
R-Sq 74.1%
R-Sq(adj) 74.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta-h1+h2-rdrfd.csv

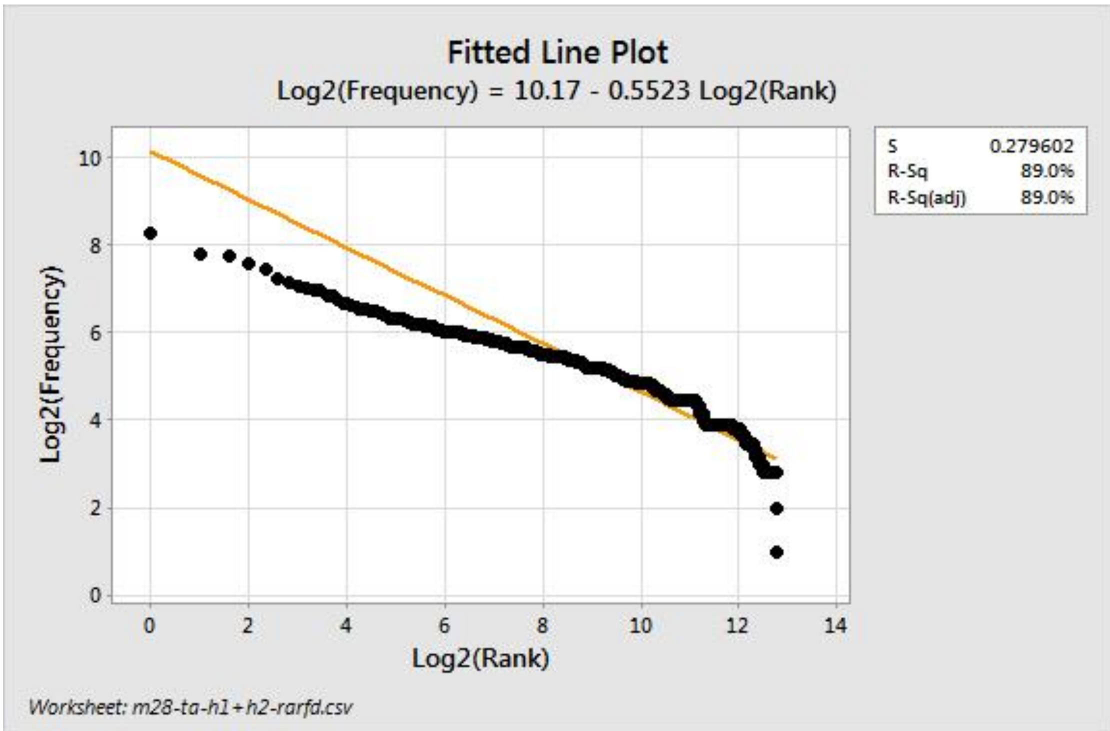

Fitted Line Plot
Log2(Frequency) = 10.39 - 0.6595 Log2(Rank)
S 0.418253
R-Sq 83.8%
R-Sq(adj) 83.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-ta-h1+h2-rcrfd.csv

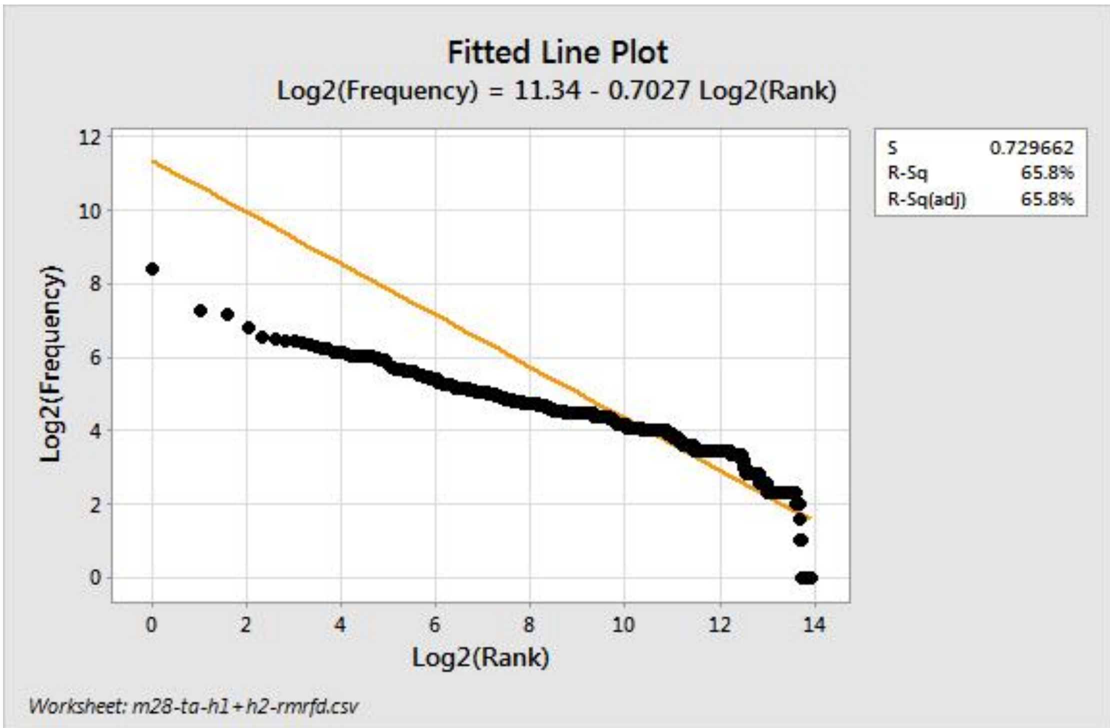

Fitted Line Plot
Log2(Frequency) = 12.57 - 0.8058 Log2(Rank)
S 0.981539
R-Sq 58.3%
R-Sq(adj) 58.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18-h1+h2-barfd.csv

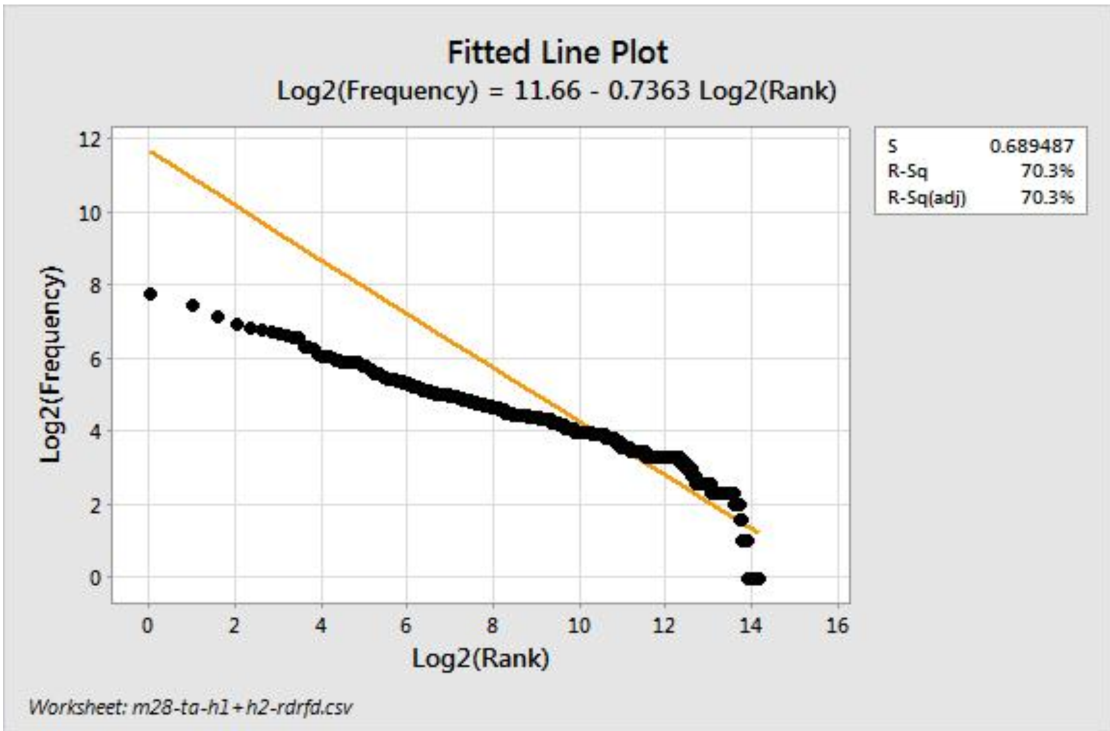

Fitted Line Plot
Log2(Frequency) = 11.25 - 0.6785 Log2(Rank)
S 0.540620
R-Sq 76.5%
R-Sq(adj) 76.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18-h1+h2-bmrfd.csv

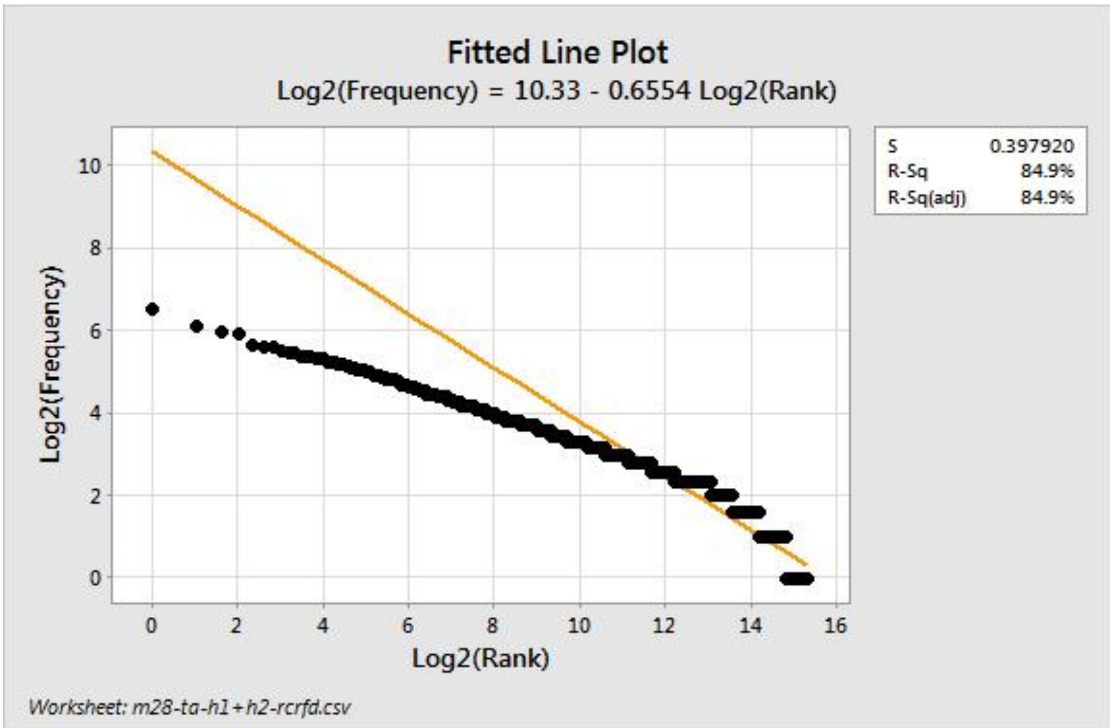

Fitted Line Plot
Log2(Frequency) = 11.30 - 0.7014 Log2(Rank)
S 0.583118
R-Sq 75.0%
R-Sq(adj) 75.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18-h1+h2-bdrfd.csv

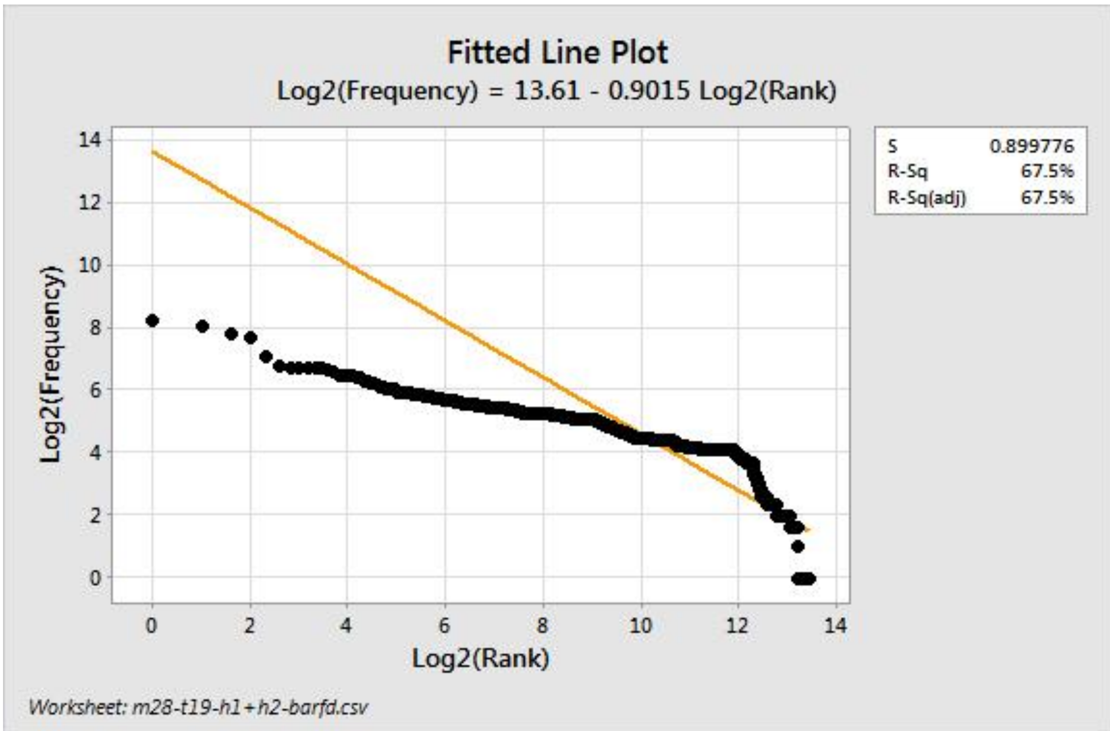

Fitted Line Plot
Log2(Frequency) = 10.50 - 0.6656 Log2(Rank)
S 0.425316
R-Sq 83.6%
R-Sq(adj) 83.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m27-t18-h1+h2-bcrfd.csv

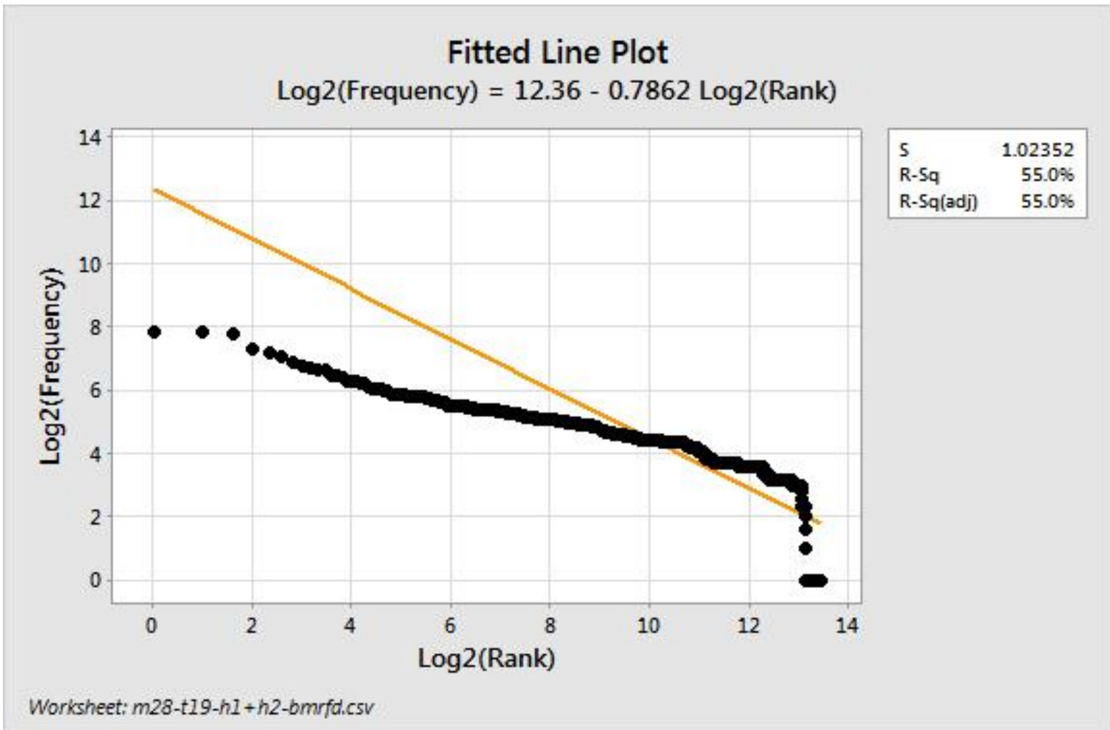

Fitted Line Plot
Log2(Frequency) = 10.17 - 0.5523 Log2(Rank)
S 0.279602
R-Sq 89.0%
R-Sq(adj) 89.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-ta-h1+h2-rarfd.csv

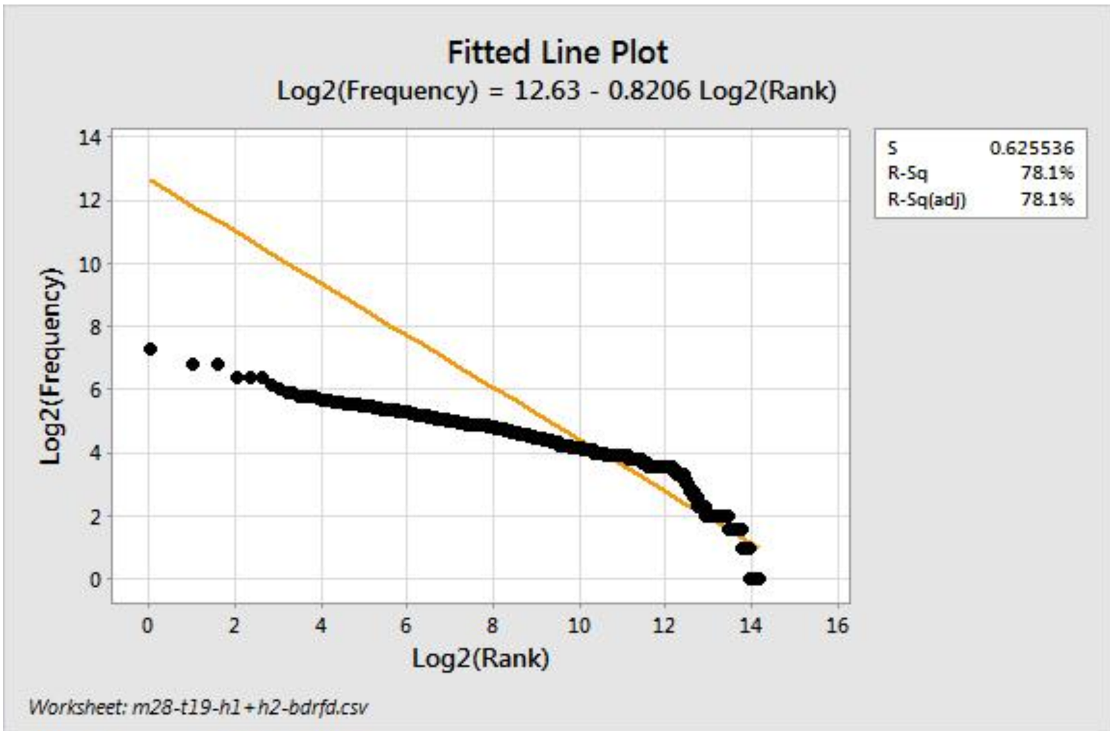

Fitted Line Plot
Log2(Frequency) = 11.34 - 0.7027 Log2(Rank)
S 0.729662
R-Sq 65.8%
R-Sq(adj) 65.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-ta-h1+h2-rmrfd.csv

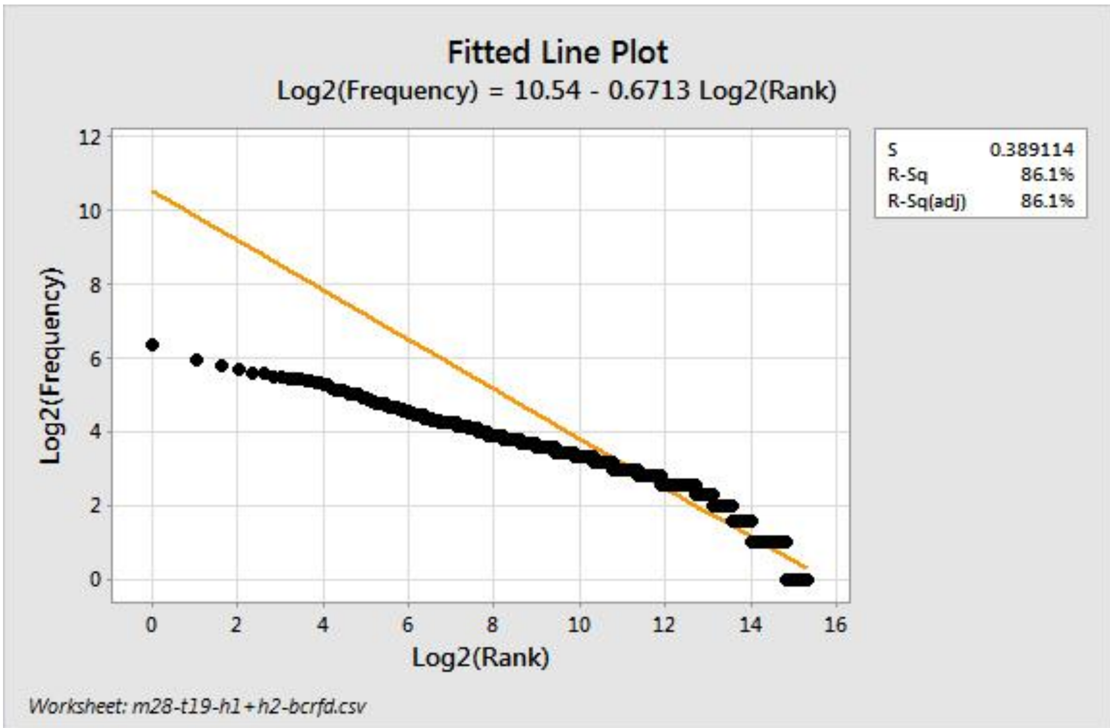

Fitted Line Plot
Log2(Frequency) = 11.66 - 0.7363 Log2(Rank)
S 0.689487
R-Sq 70.3%
R-Sq(adj) 70.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-ta-h1+h2-rdrfd.csv

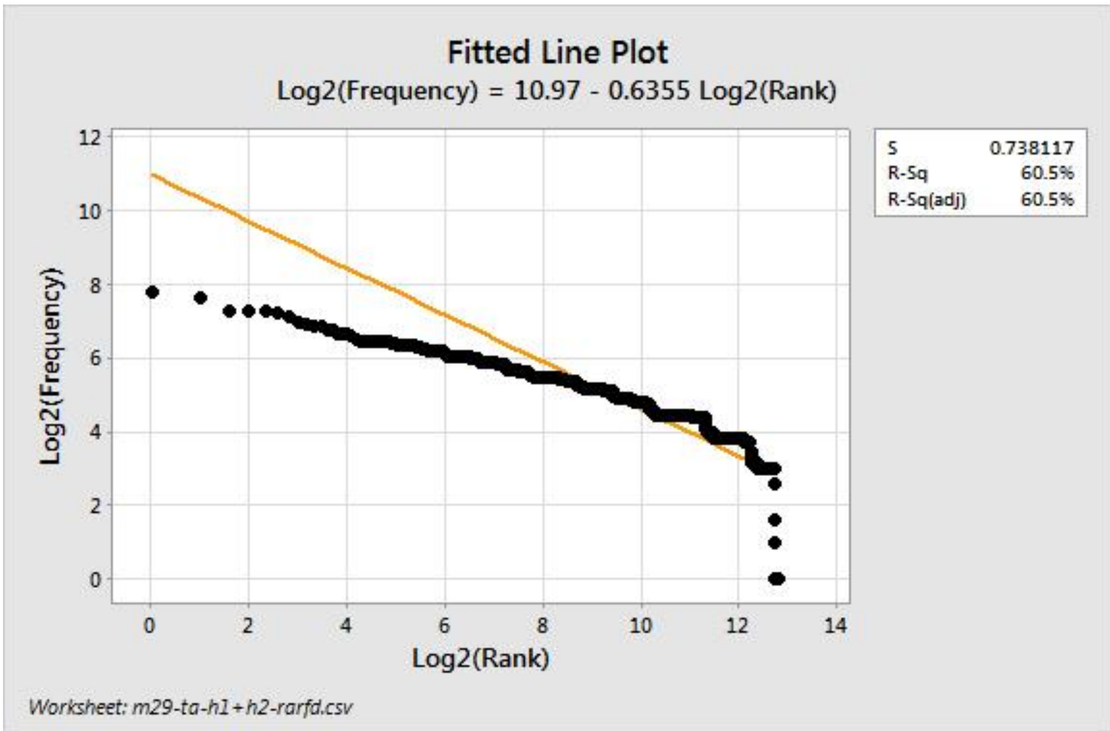

Fitted Line Plot
Log2(Frequency) = 10.33 - 0.6554 Log2(Rank)
S 0.397920
R-Sq 84.9%
R-Sq(adj) 84.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.61 - 0.9015 Log2(Rank)
S 0.899776
R-Sq 67.5%
R-Sq(adj) 67.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-t19-h1+h2-barfd.csv

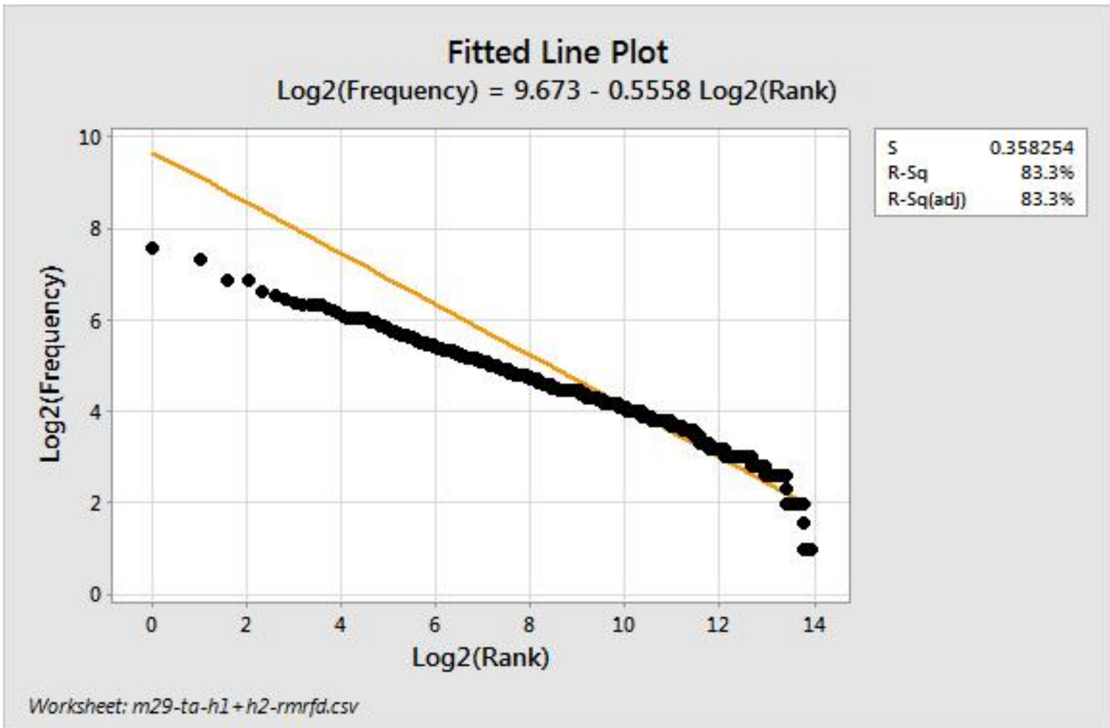

Fitted Line Plot
Log2(Frequency) = 12.36 - 0.7862 Log2(Rank)
S 1.02352
R-Sq 55.0%
R-Sq(adj) 55.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-t19-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 12.63 - 0.8206 Log2(Rank)
S 0.625536
R-Sq 78.1%
R-Sq(adj) 78.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-t19-h1+h2-bdrfd.csv

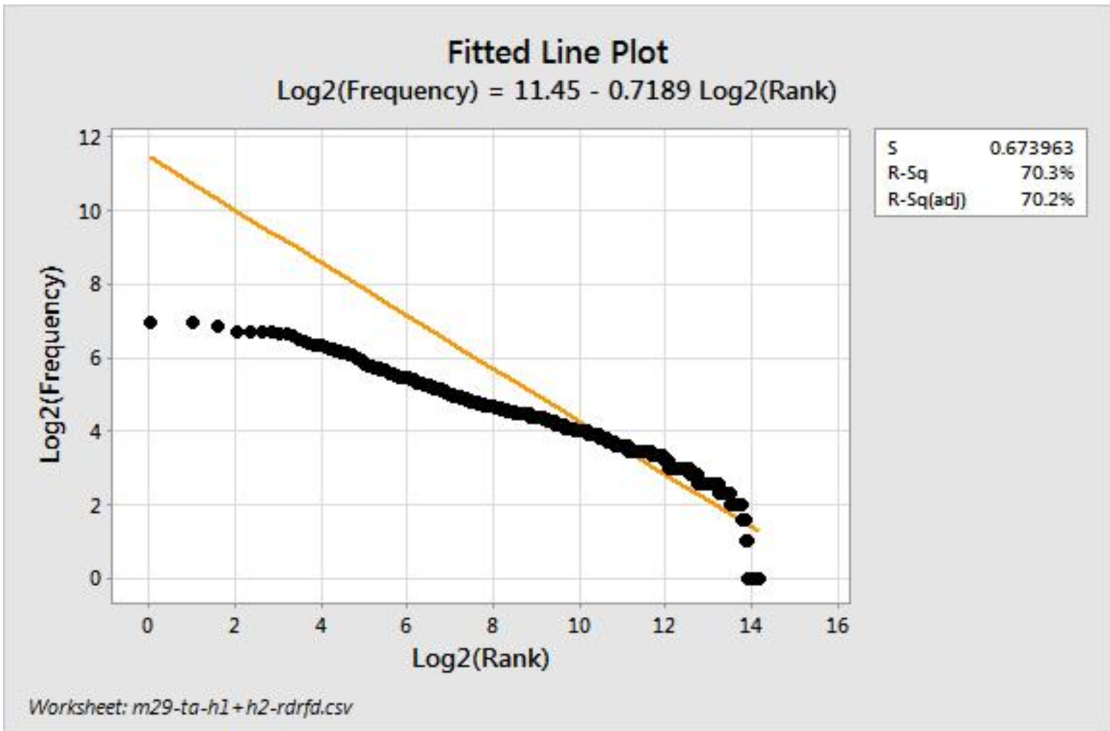

Fitted Line Plot
Log2(Frequency) = 10.54 - 0.6713 Log2(Rank)
S 0.389114
R-Sq 86.1%
R-Sq(adj) 86.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m28-t19-h1+h2-bcrfd.csv



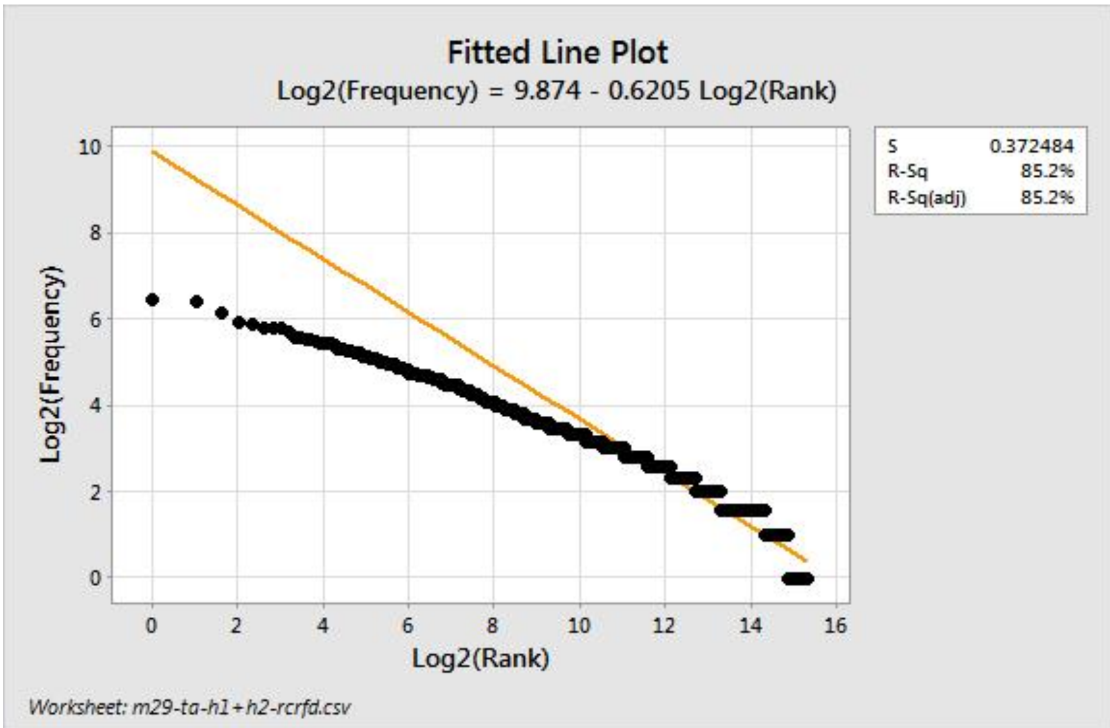
Fitted Line Plot
Log2(Frequency) = 10.97 - 0.6355 Log2(Rank)
S 0.738117
R-Sq 60.5%
R-Sq(adj) 60.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta-h1+h2-rarfd.csv



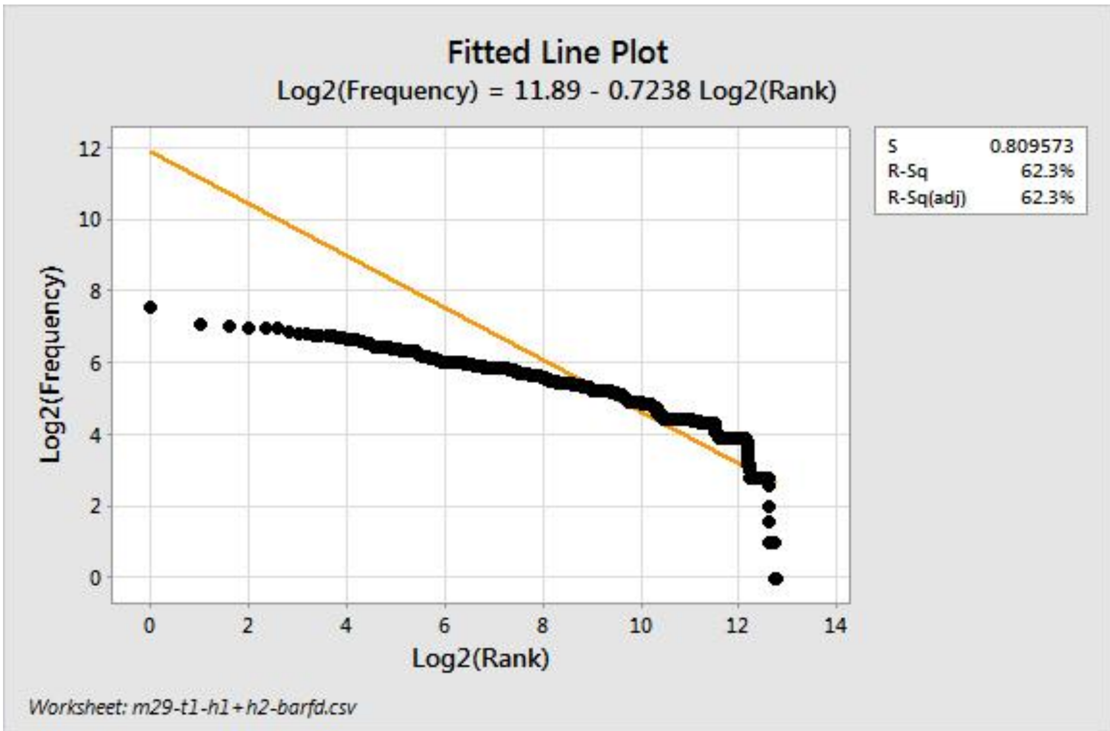
Fitted Line Plot
Log2(Frequency) = 9.673 - 0.5558 Log2(Rank)
S 0.358254
R-Sq 83.3%
R-Sq(adj) 83.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta-h1+h2-rmrfd.csv

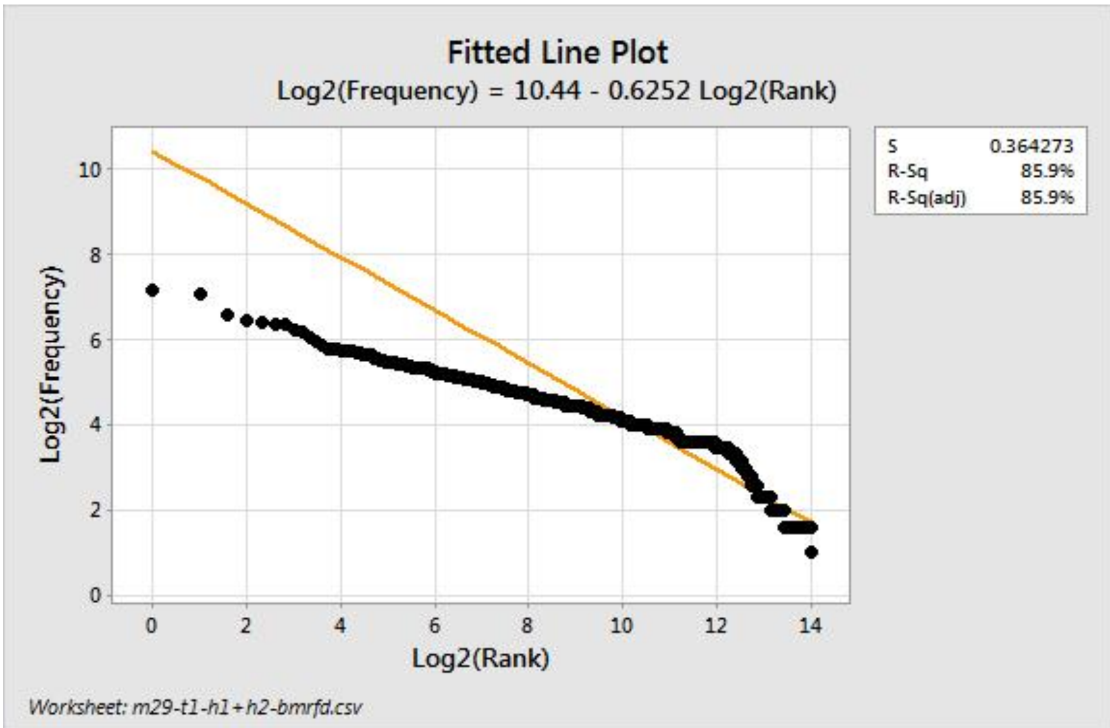


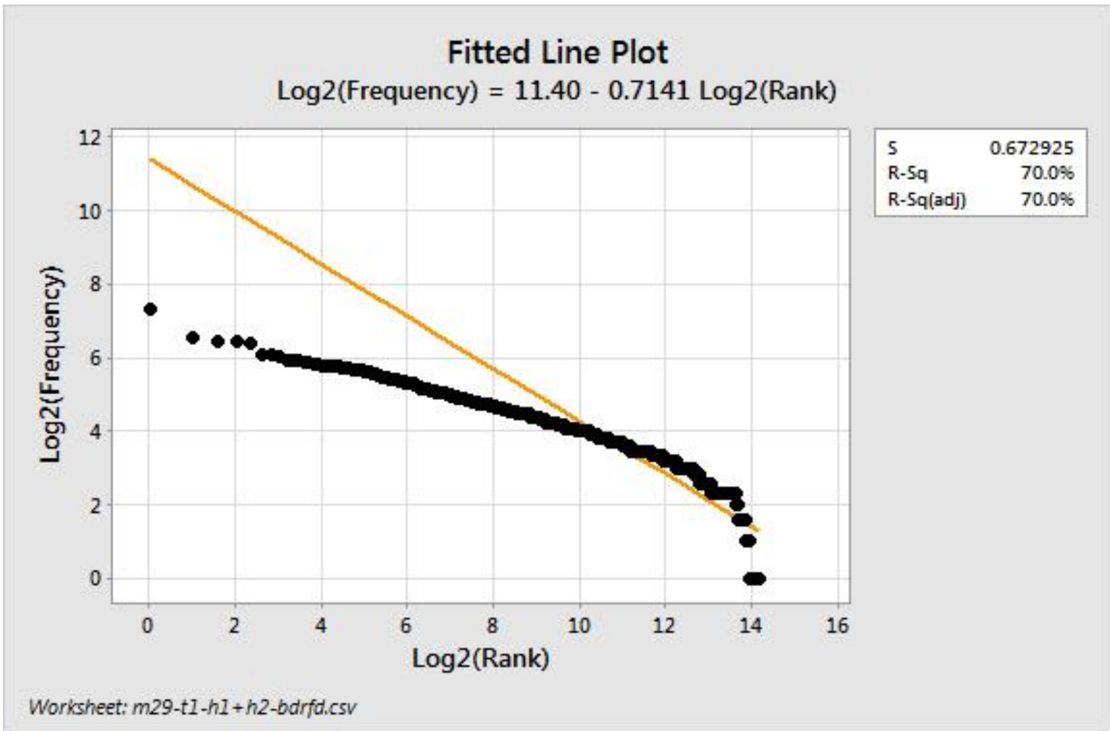
Fitted Line Plot
Log2(Frequency) = 11.45 - 0.7189 Log2(Rank)
S 0.673963
R-Sq 70.3%
R-Sq(adj) 70.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta-h1+h2-rdrfd.csv

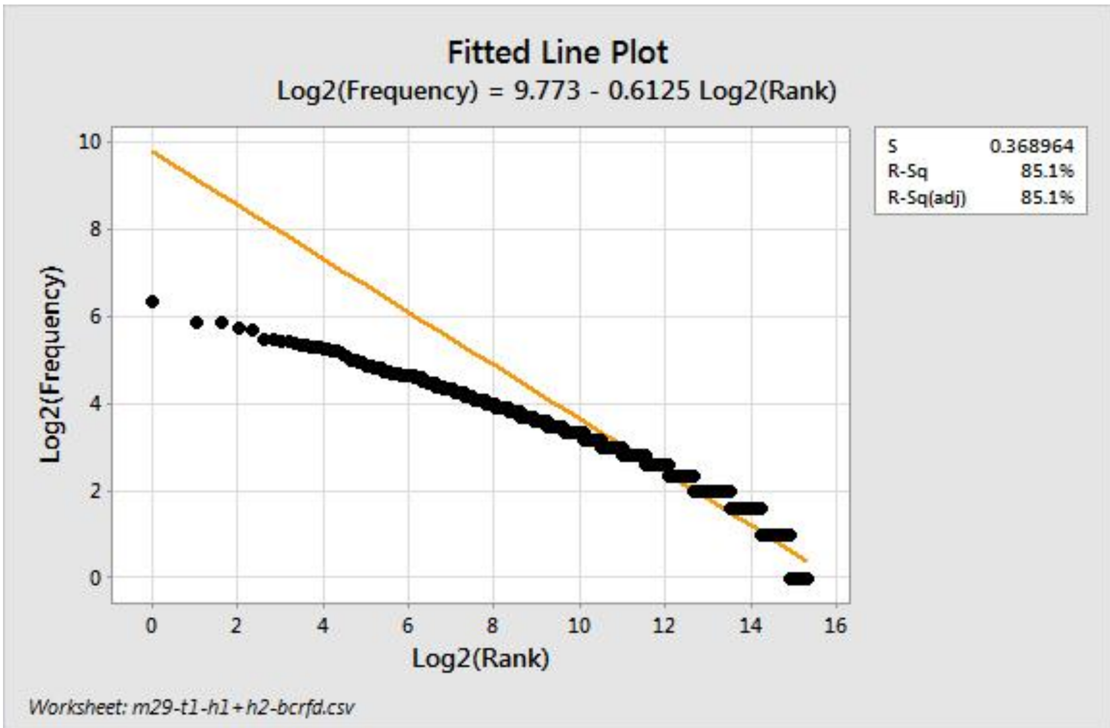


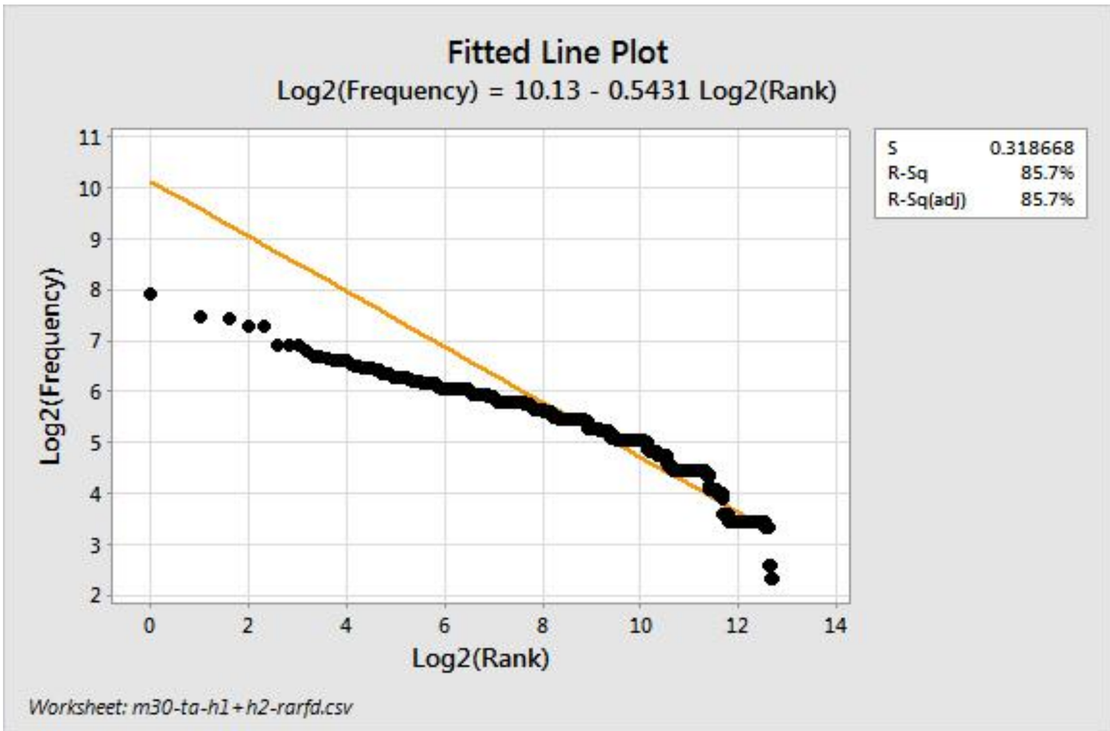
Fitted Line Plot
Log2(Frequency) = 9.874 - 0.6205 Log2(Rank)
S 0.372484
R-Sq 85.2%
R-Sq(adj) 85.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-ta-h1+h2-rcrfd.csv

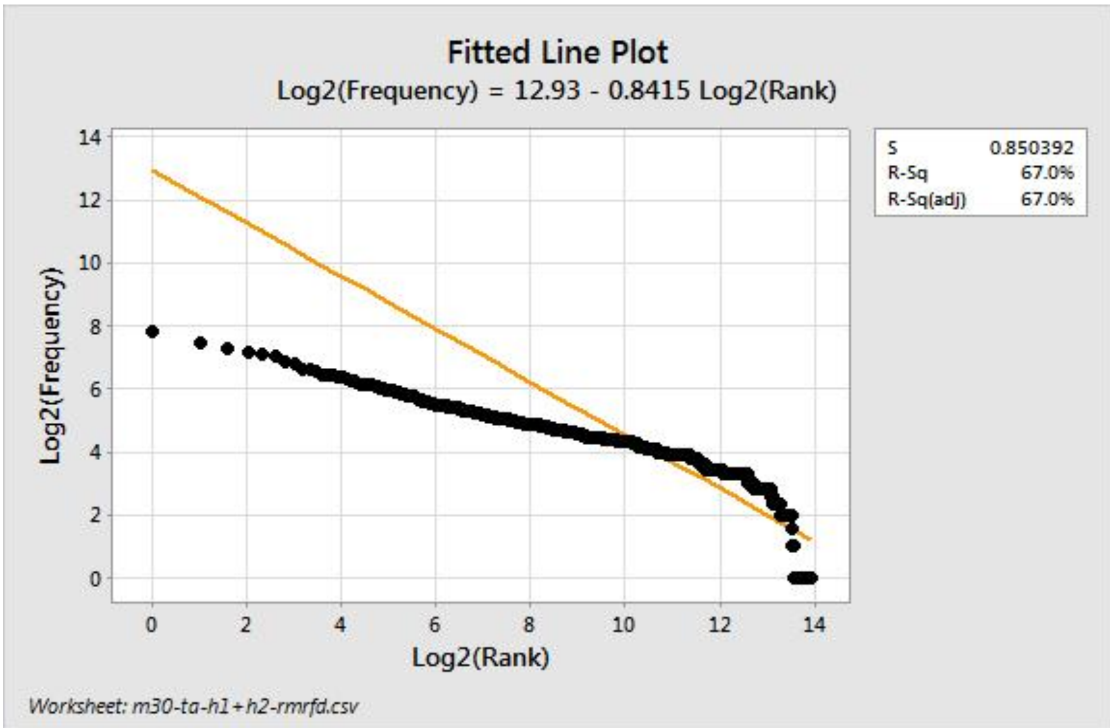

Fitted Line Plot
Log2(Frequency) = 11.89 - 0.7238 Log2(Rank)
S 0.809573
R-Sq 62.3%
R-Sq(adj) 62.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1-h1+h2-barfd.csv

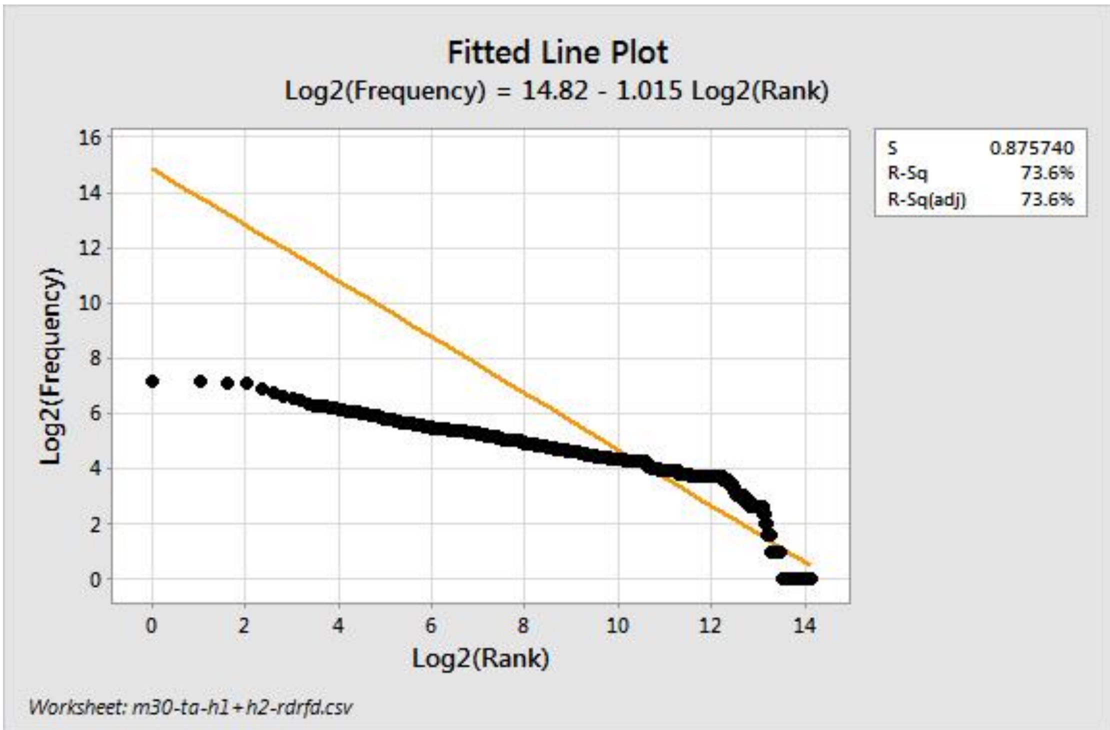

Fitted Line Plot
Log2(Frequency) = 10.44 - 0.6252 Log2(Rank)
S 0.364273
R-Sq 85.9%
R-Sq(adj) 85.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1-h1+h2-bmrfd.csv

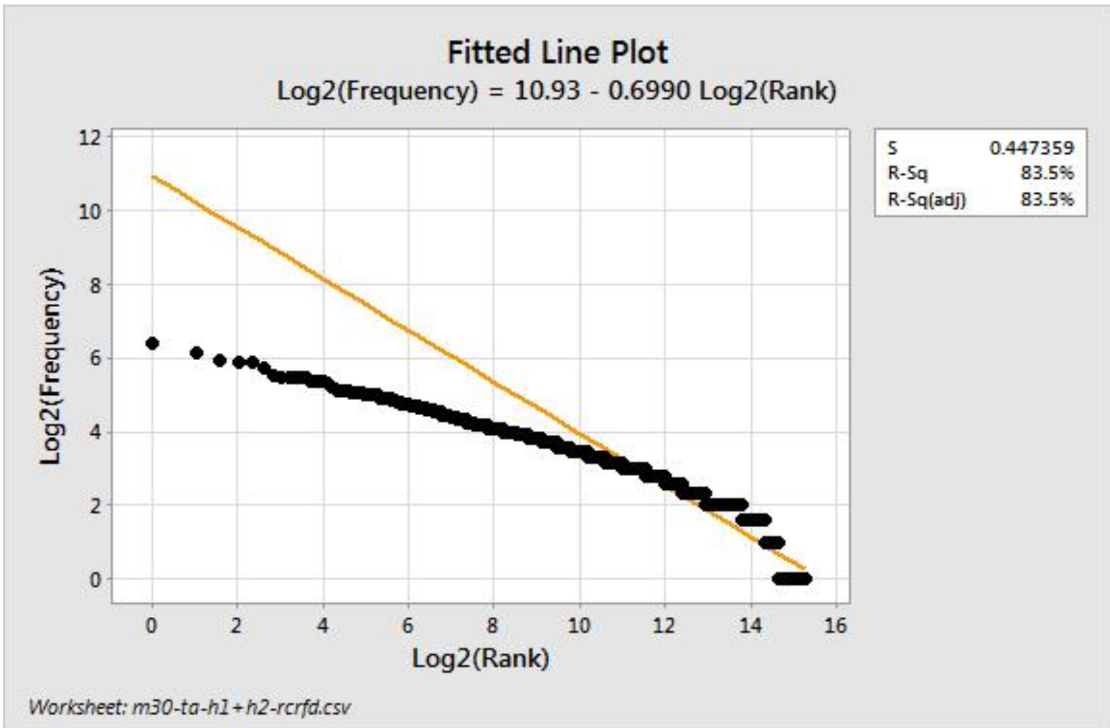

Fitted Line Plot
Log2(Frequency) = 11.40 - 0.7141 Log2(Rank)
S 0.672925
R-Sq 70.0%
R-Sq(adj) 70.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1-h1+h2-bdrfd.csv

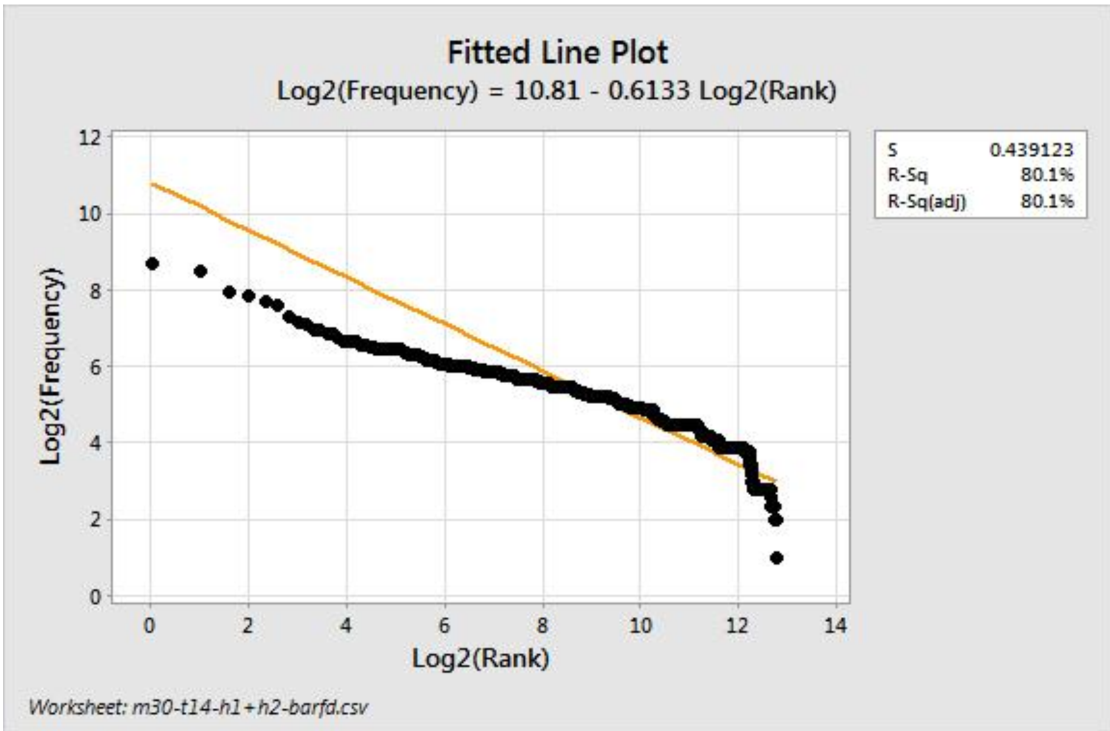

Fitted Line Plot
Log2(Frequency) = 9.773 - 0.6125 Log2(Rank)
S 0.368964
R-Sq 85.1%
R-Sq(adj) 85.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m29-t1-h1+h2-bcrfd.csv

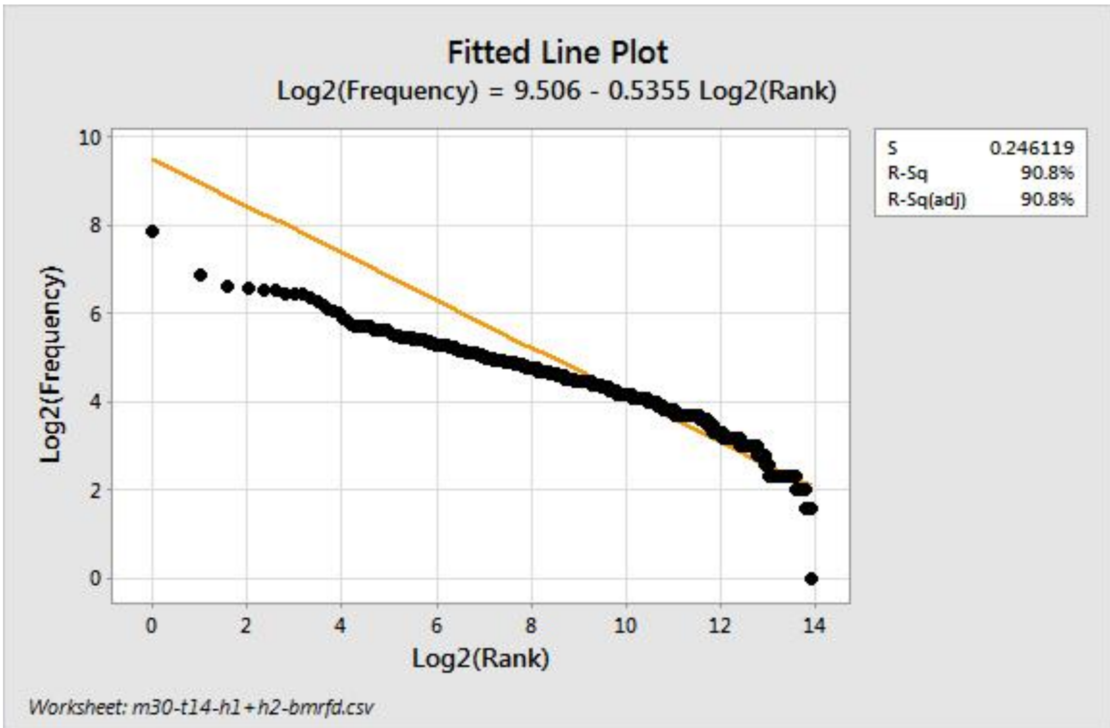

Fitted Line Plot
Log2(Frequency) = 10.13 - 0.5431 Log2(Rank)
S 0.318668
R-Sq 85.7%
R-Sq(adj) 85.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-ta-h1+h2-rarfd.csv

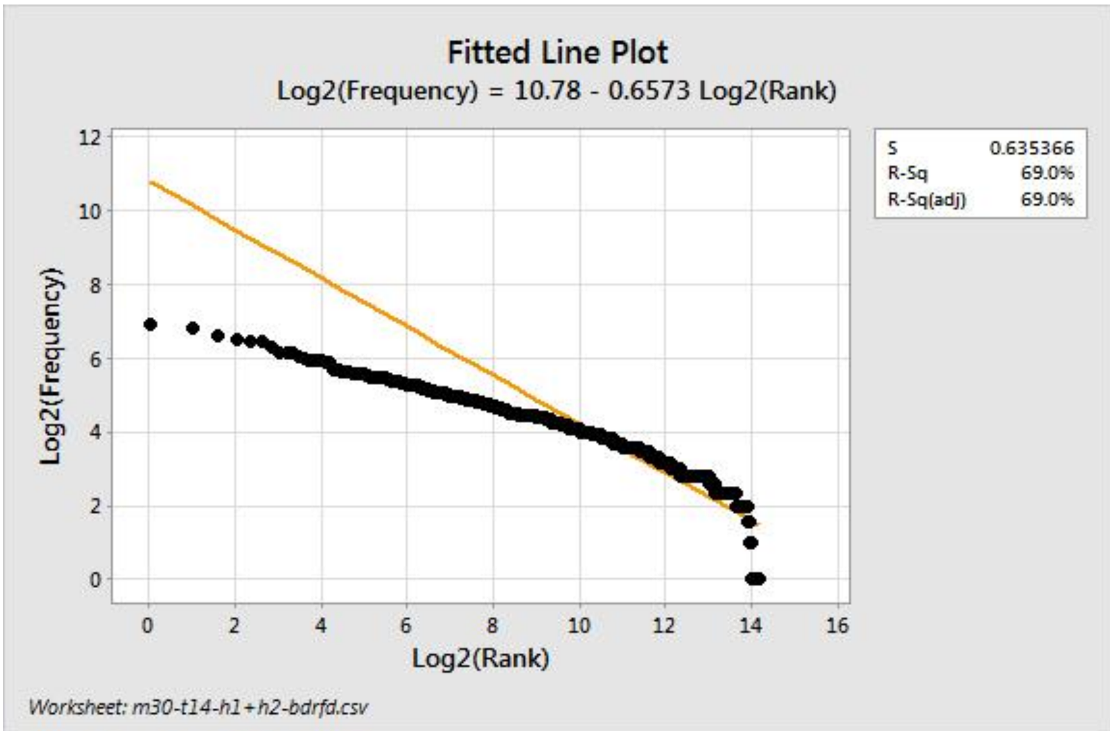

Fitted Line Plot
Log2(Frequency) = 12.93 - 0.8415 Log2(Rank)
S 0.850392
R-Sq 67.0%
R-Sq(adj) 67.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-ta-h1+h2-rmrfd.csv

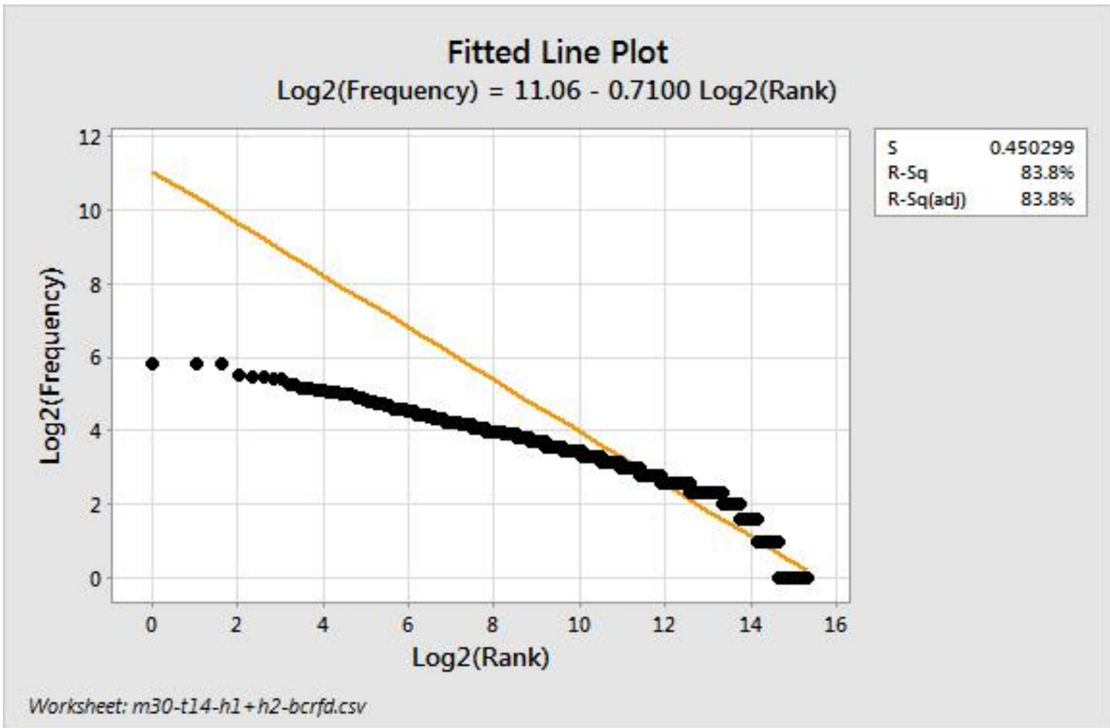

Fitted Line Plot
Log2(Frequency) = 14.82 - 1.015 Log2(Rank)
S 0.875740
R-Sq 73.6%
R-Sq(adj) 73.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-ta-h1+h2-rdrfd.csv

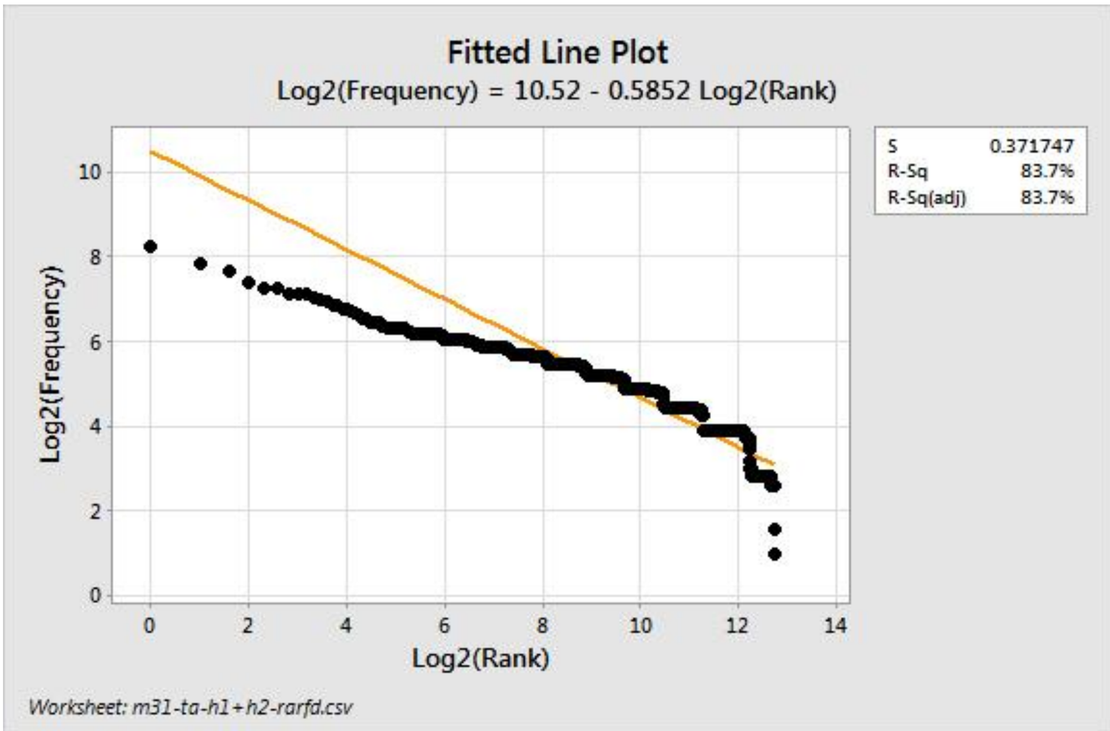

Fitted Line Plot
Log2(Frequency) = 10.93 - 0.6990 Log2(Rank)
S 0.447359
R-Sq 83.5%
R-Sq(adj) 83.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-ta-h1+h2-rcrfd.csv

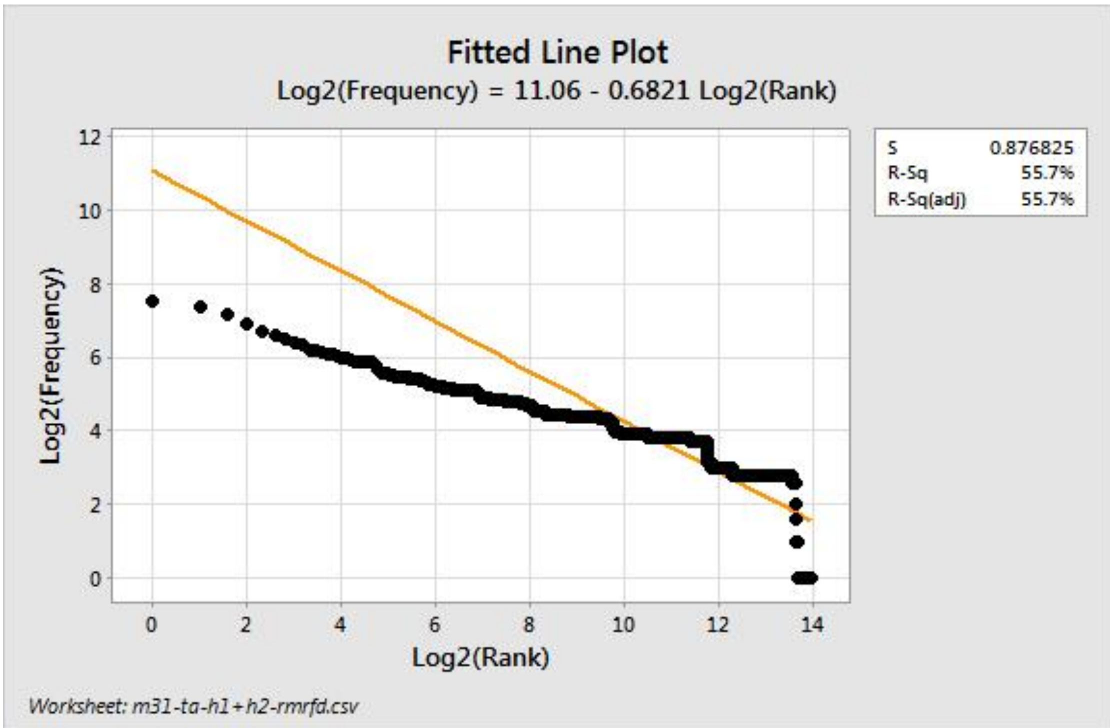

Fitted Line Plot
Log2(Frequency) = 10.81 - 0.6133 Log2(Rank)
S 0.439123
R-Sq 80.1%
R-Sq(adj) 80.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-t14-h1+h2-barfd.csv

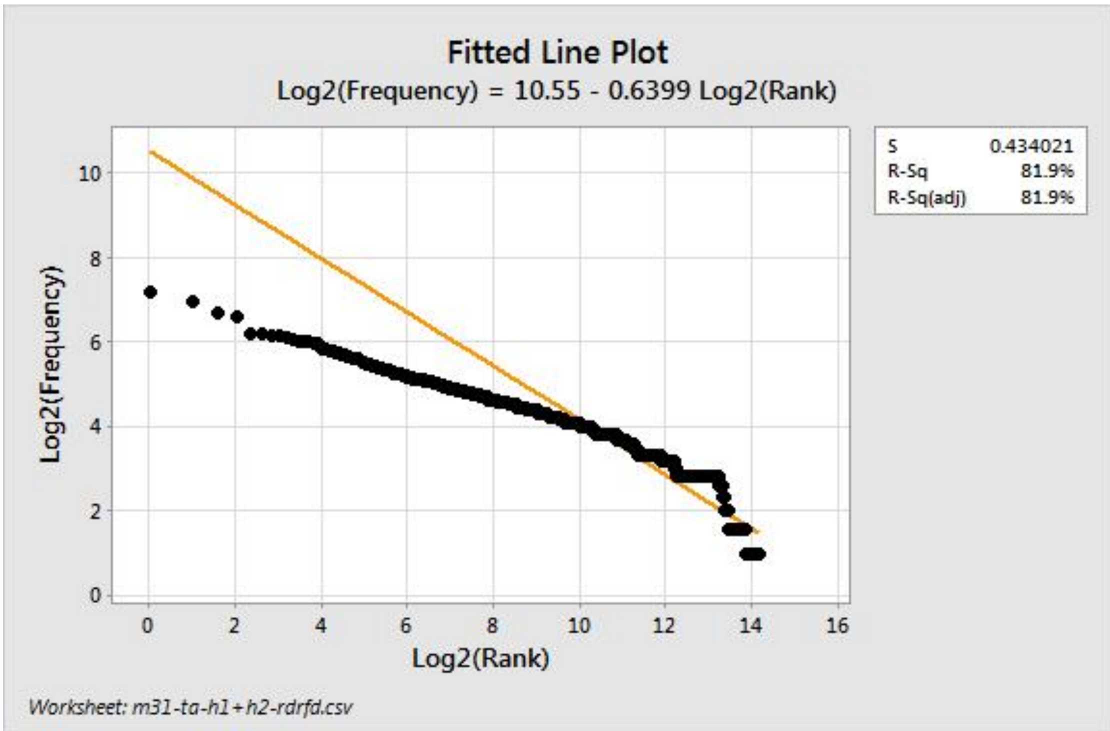

Fitted Line Plot
Log2(Frequency) = 9.506 - 0.5355 Log2(Rank)
S 0.246119
R-Sq 90.8%
R-Sq(adj) 90.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-t14-h1+h2-bmrfd.csv

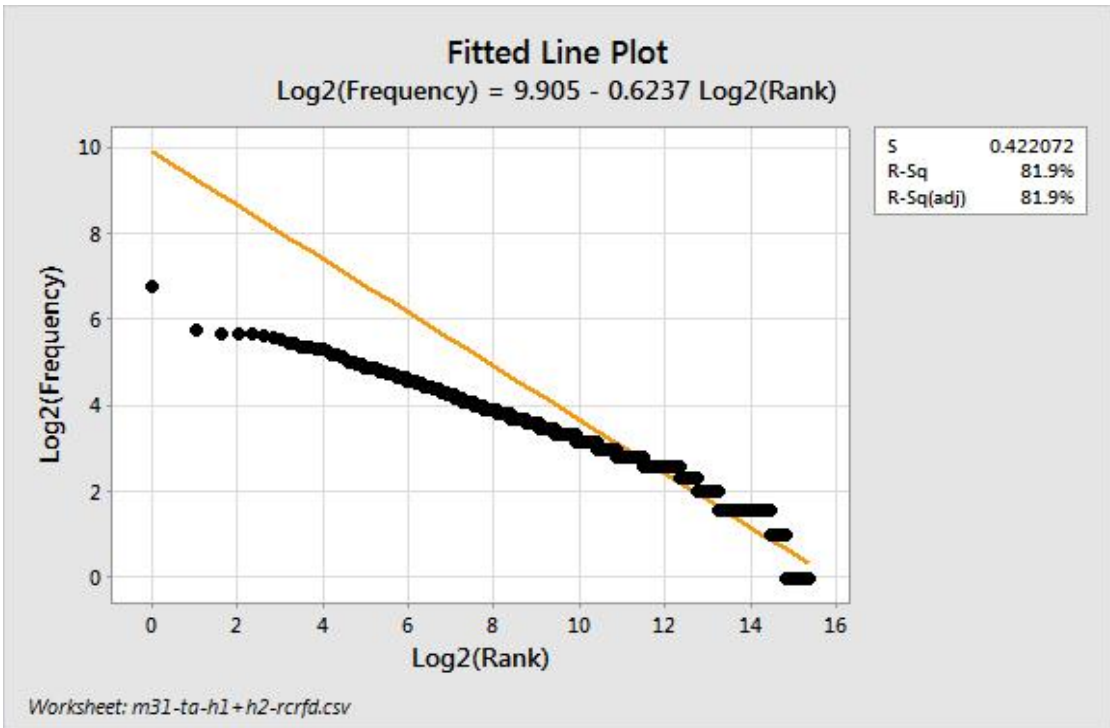

Fitted Line Plot
Log2(Frequency) = 10.78 - 0.6573 Log2(Rank)
S 0.635366
R-Sq 69.0%
R-Sq(adj) 69.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-t14-h1+h2-bdrfd.csv

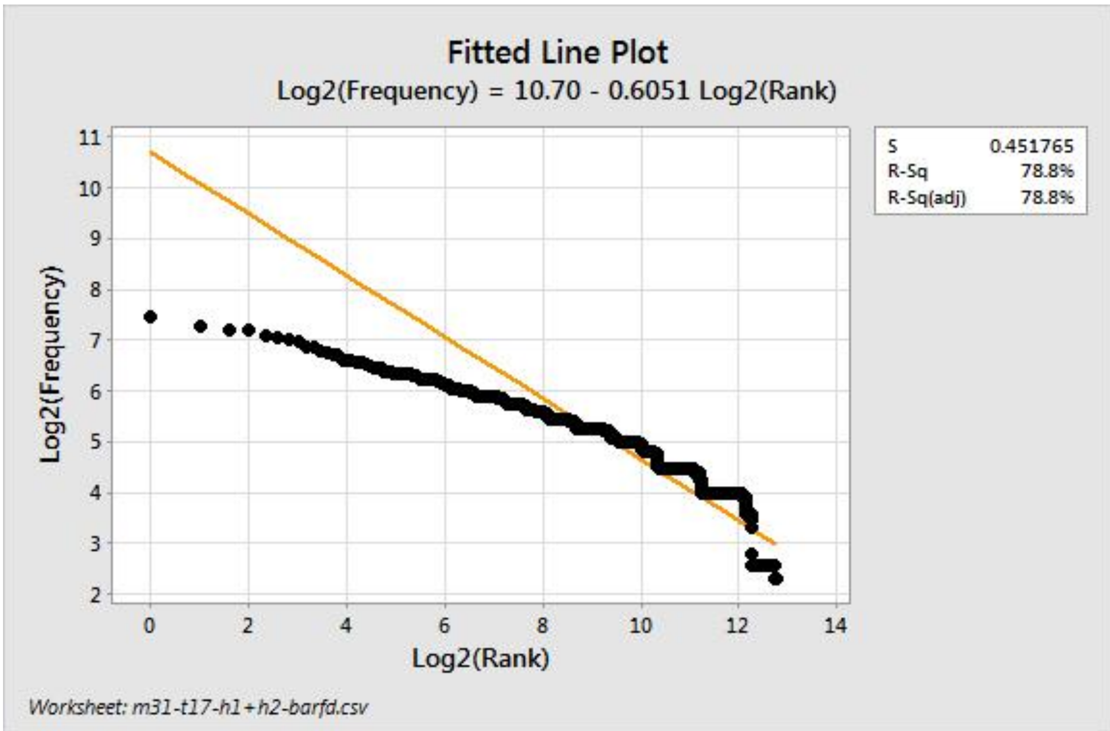

Fitted Line Plot
Log2(Frequency) = 11.06 - 0.7100 Log2(Rank)
S 0.450299
R-Sq 83.8%
R-Sq(adj) 83.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m30-t14-h1+h2-bcrfd.csv

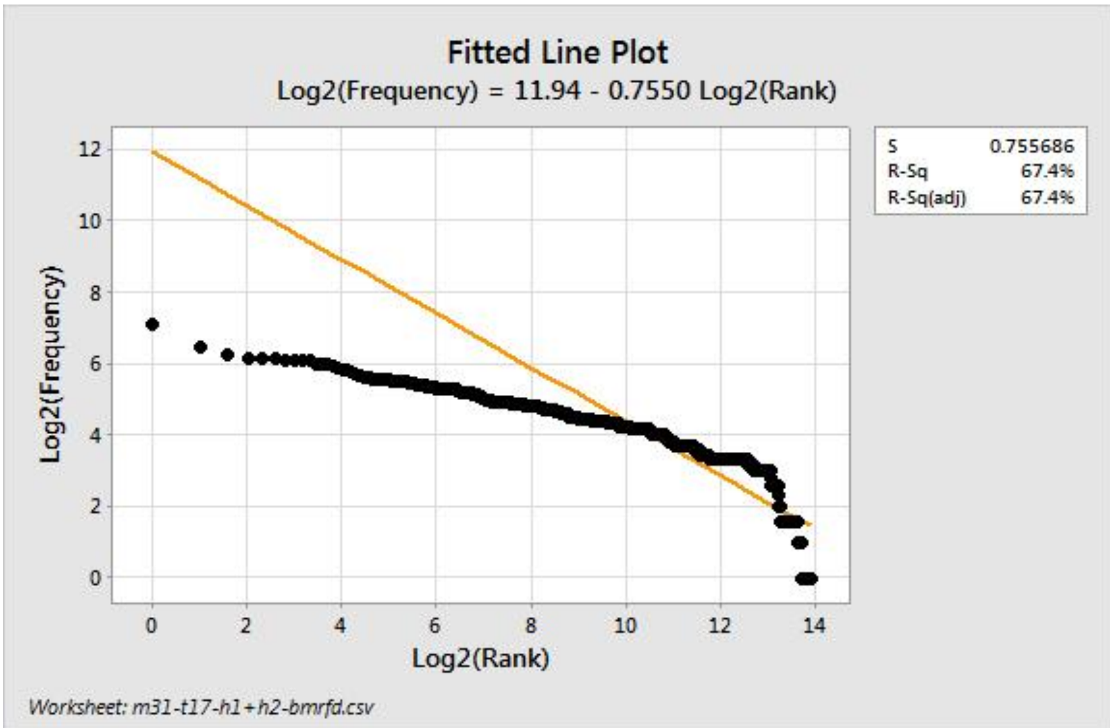

Fitted Line Plot
Log2(Frequency) = 10.52 - 0.5852 Log2(Rank)
S 0.371747
R-Sq 83.7%
R-Sq(adj) 83.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta-h1+h2-rarfd.csv

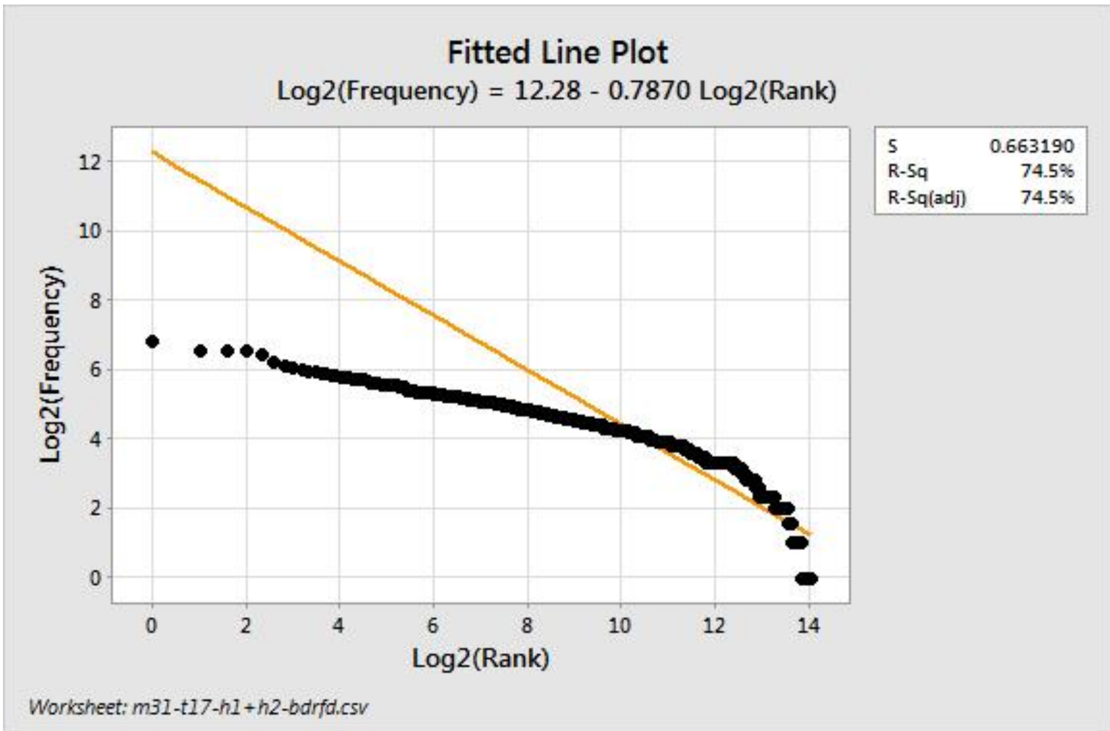

Fitted Line Plot
Log2(Frequency) = 11.06 - 0.6821 Log2(Rank)
S 0.876825
R-Sq 55.7%
R-Sq(adj) 55.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta-h1+h2-rmrfd.csv

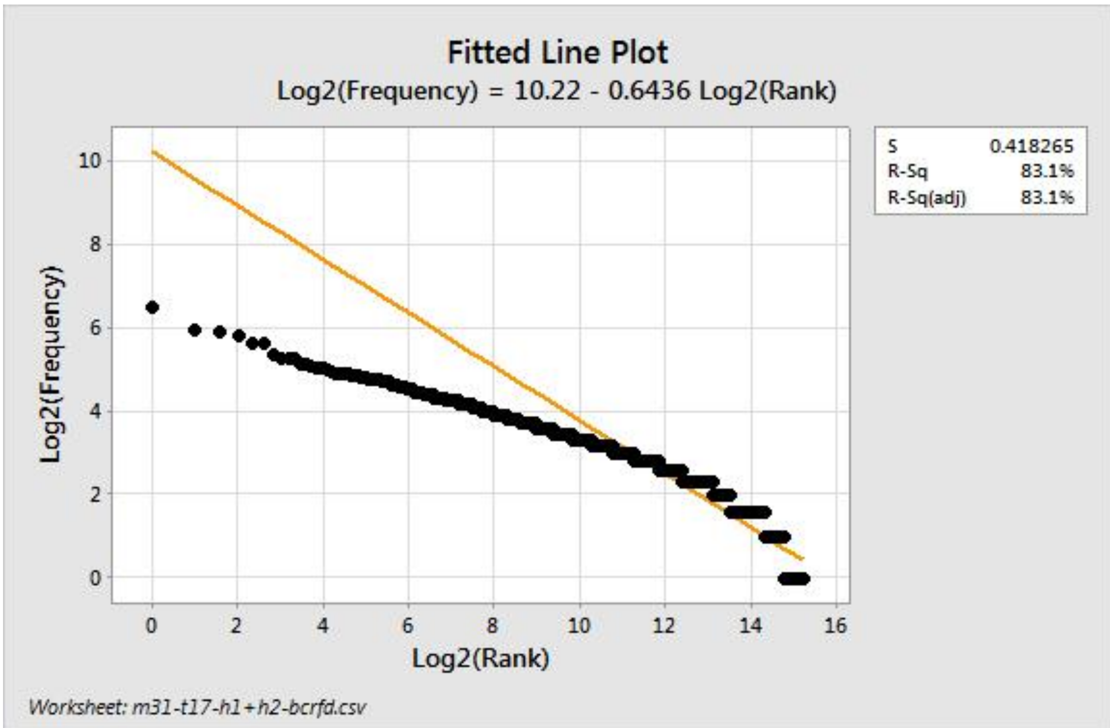

Fitted Line Plot
Log2(Frequency) = 10.55 - 0.6399 Log2(Rank)
S 0.434021
R-Sq 81.9%
R-Sq(adj) 81.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta-h1+h2-rdrfd.csv

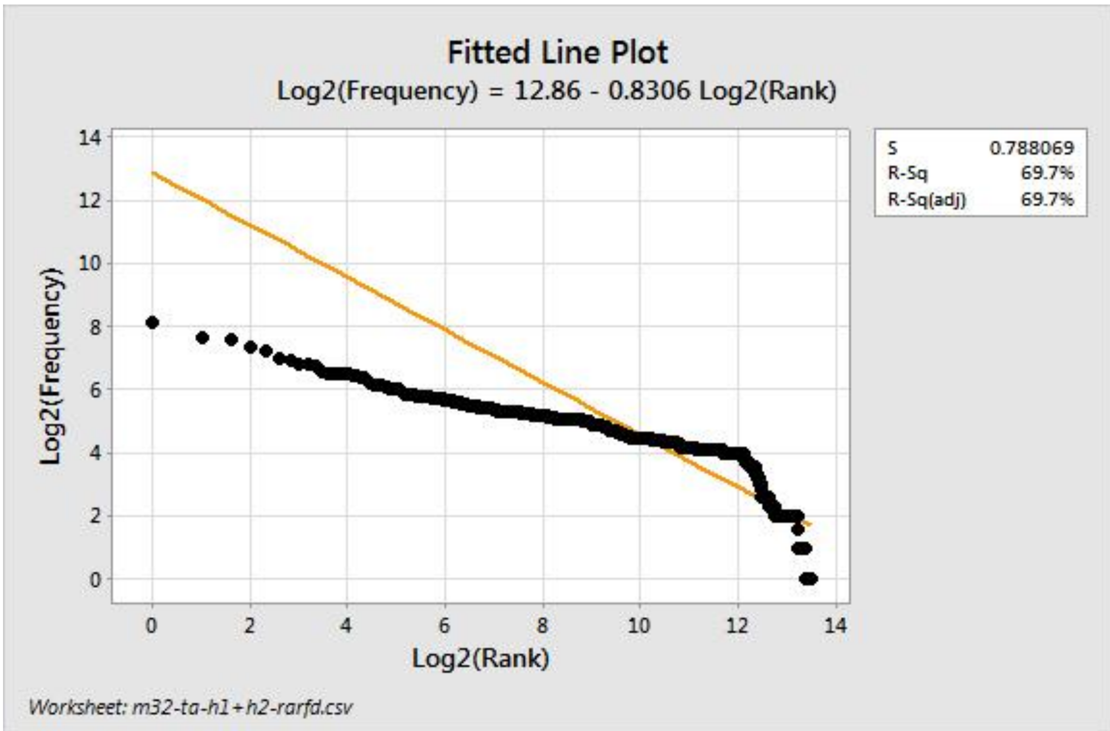

Fitted Line Plot
Log2(Frequency) = 9.905 - 0.6237 Log2(Rank)
S 0.422072
R-Sq 81.9%
R-Sq(adj) 81.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-ta-h1+h2-rcrfd.csv

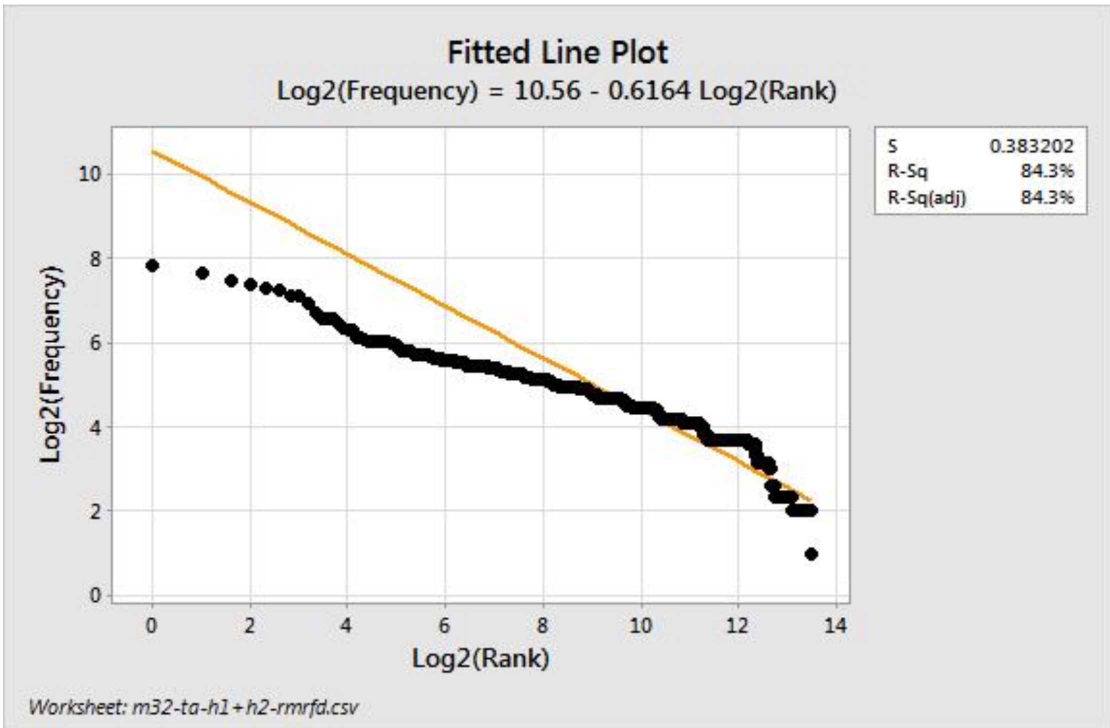

Fitted Line Plot
Log2(Frequency) = 10.70 - 0.6051 Log2(Rank)
S 0.451765
R-Sq 78.8%
R-Sq(adj) 78.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17-h1+h2-barfd.csv

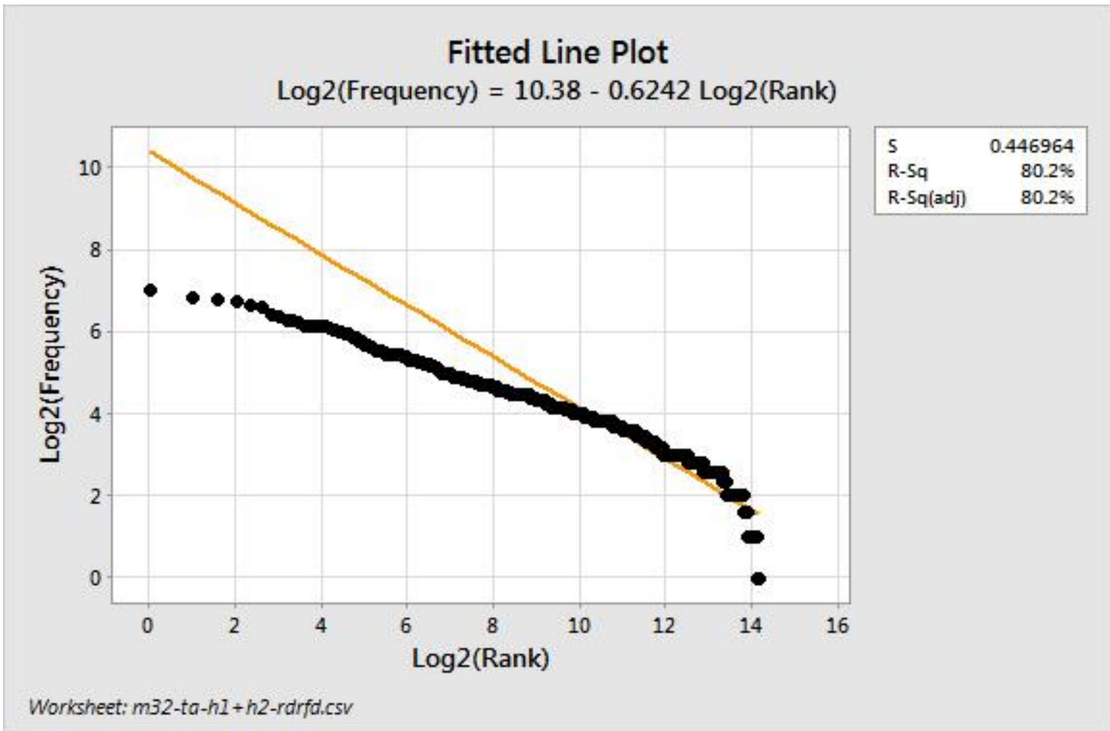

Fitted Line Plot
Log2(Frequency) = 11.94 - 0.7550 Log2(Rank)
S 0.755686
R-Sq 67.4%
R-Sq(adj) 67.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17-h1+h2-bmrfd.csv

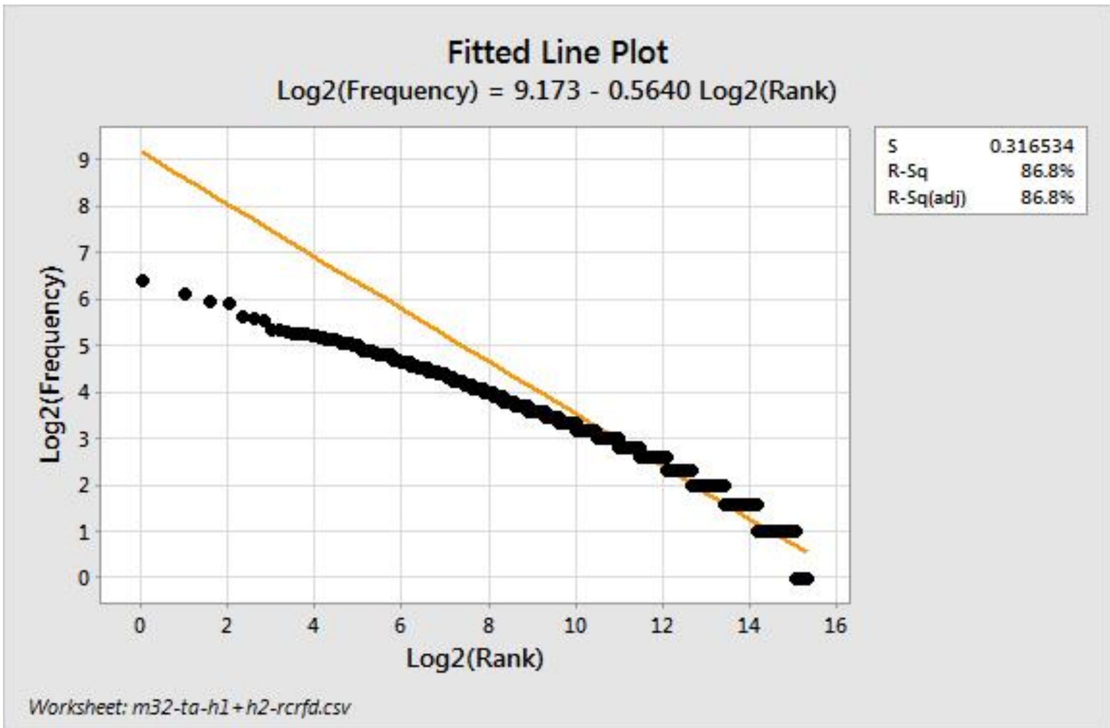

Fitted Line Plot
Log2(Frequency) = 12.28 - 0.7870 Log2(Rank)
S 0.663190
R-Sq 74.5%
R-Sq(adj) 74.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17-h1+h2-bdrfd.csv

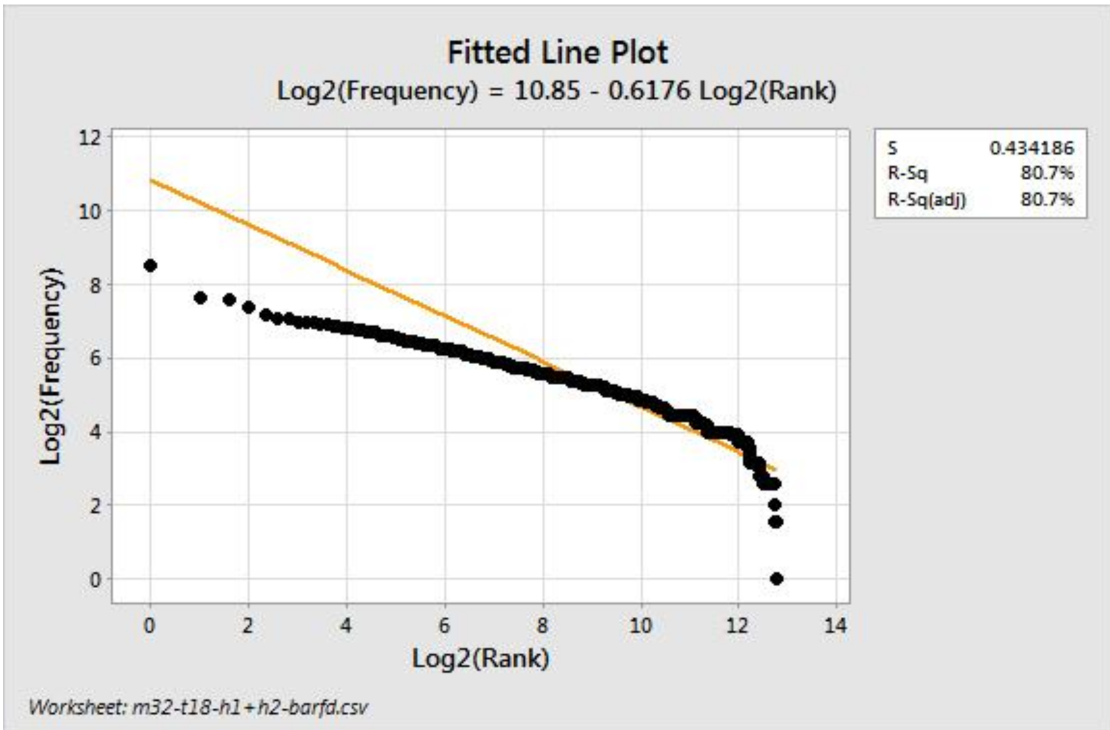

Fitted Line Plot
Log2(Frequency) = 10.22 - 0.6436 Log2(Rank)
S 0.418265
R-Sq 83.1%
R-Sq(adj) 83.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m31-t17-h1+h2-bcrfd.csv

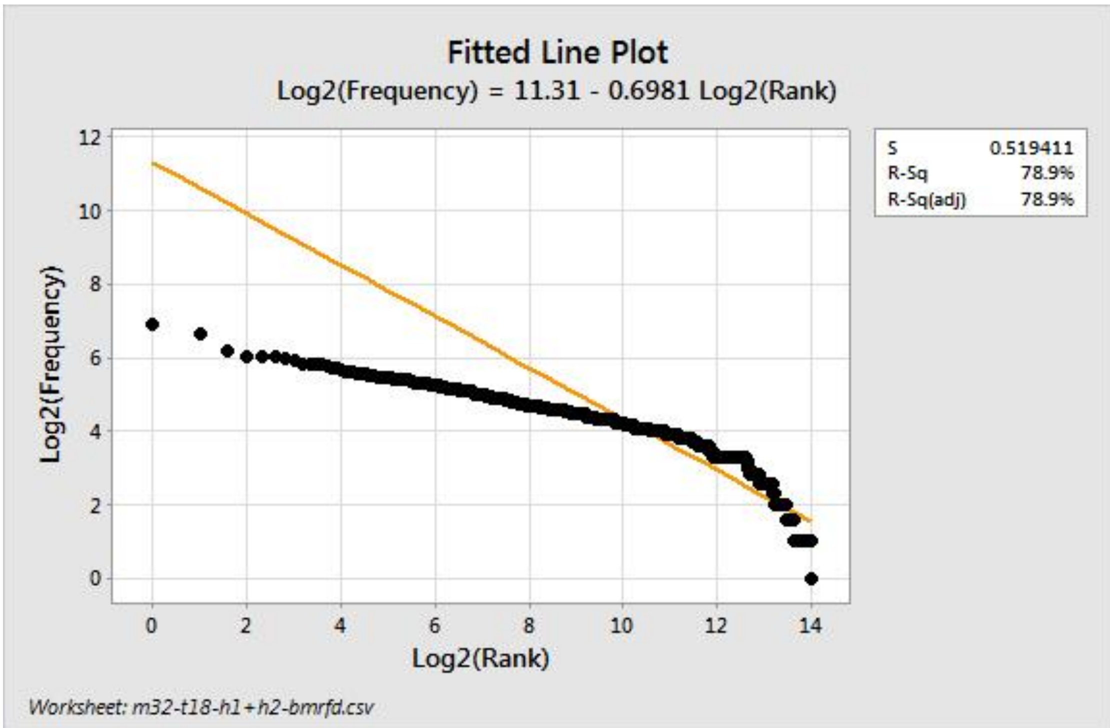

Fitted Line Plot
Log2(Frequency) = 12.86 - 0.8306 Log2(Rank)
S 0.788069
R-Sq 69.7%
R-Sq(adj) 69.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta-h1+h2-rarfd.csv

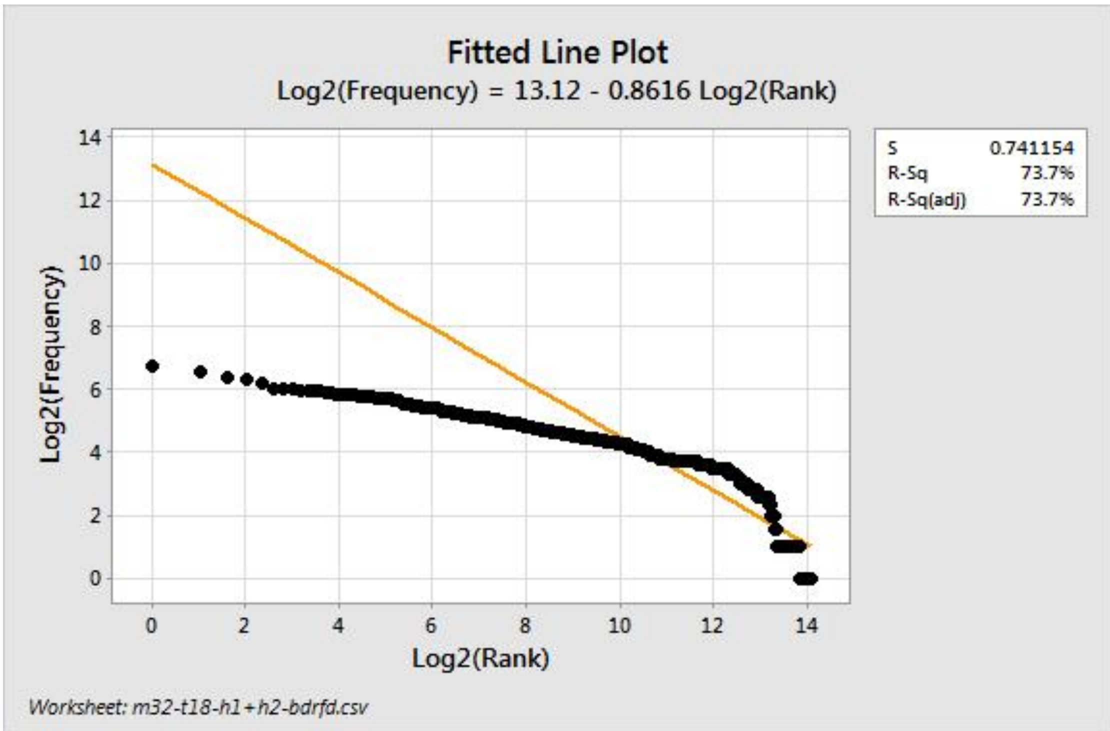

Fitted Line Plot
Log2(Frequency) = 10.56 - 0.6164 Log2(Rank)
S 0.383202
R-Sq 84.3%
R-Sq(adj) 84.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta-h1+h2-rmrfd.csv

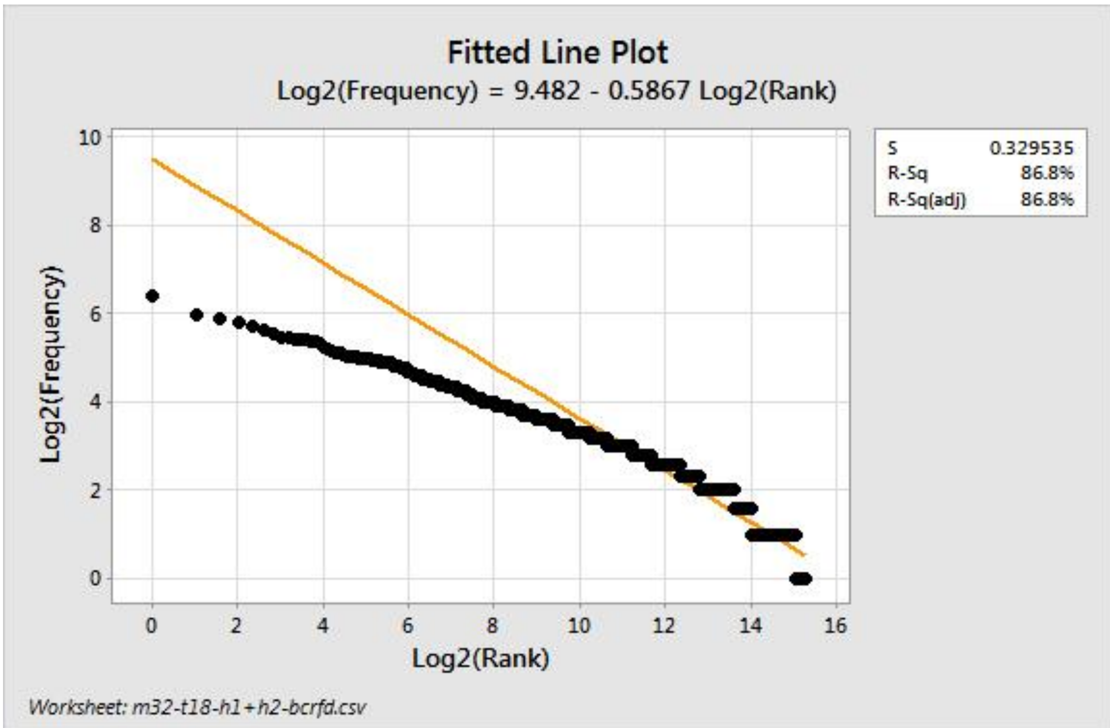

Fitted Line Plot
Log2(Frequency) = 10.38 - 0.6242 Log2(Rank)
S 0.446964
R-Sq 80.2%
R-Sq(adj) 80.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta-h1+h2-rdrfd.csv

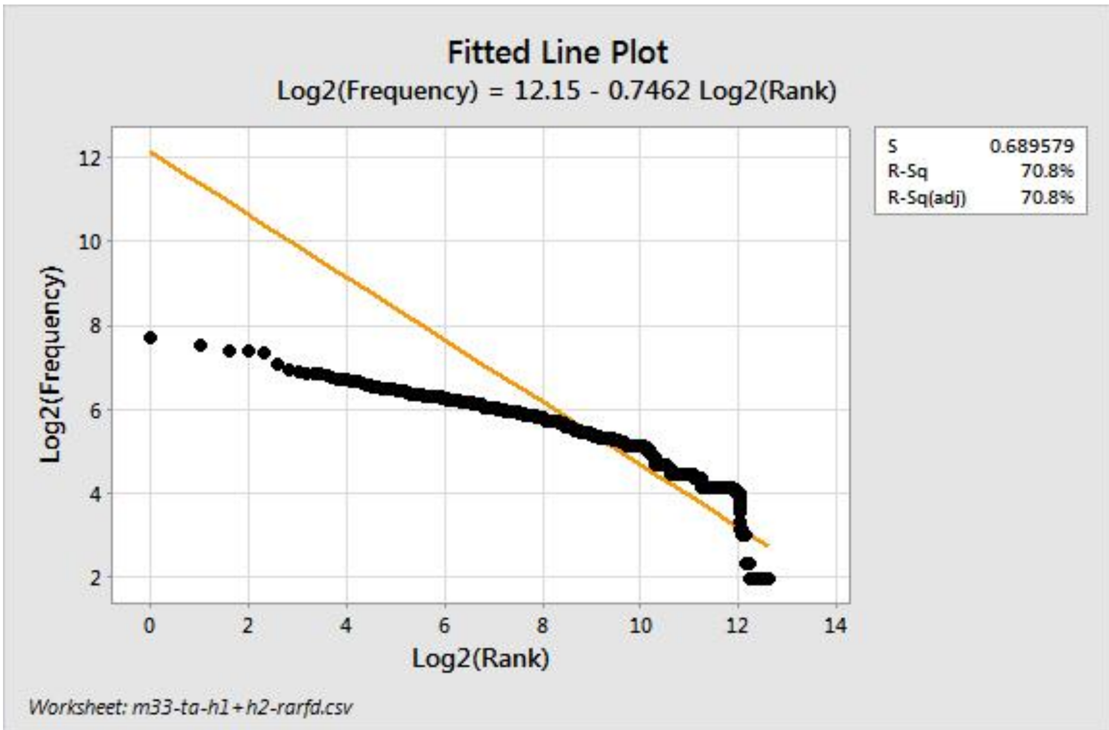

Fitted Line Plot
Log2(Frequency) = 9.173 - 0.5640 Log2(Rank)
S 0.316534
R-Sq 86.8%
R-Sq(adj) 86.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-ta-h1+h2-rcrfd.csv

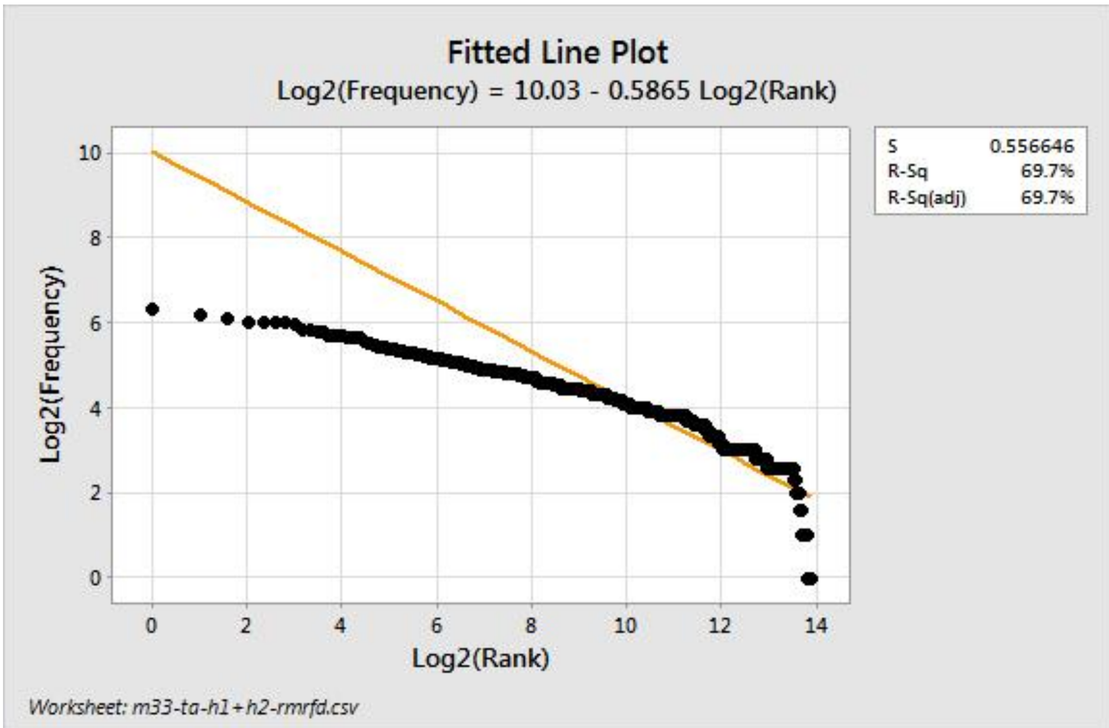

Fitted Line Plot
Log2(Frequency) = 10.85 - 0.6176 Log2(Rank)
S 0.434186
R-Sq 80.7%
R-Sq(adj) 80.7%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m32-t18-h1+h2-barfd.csv

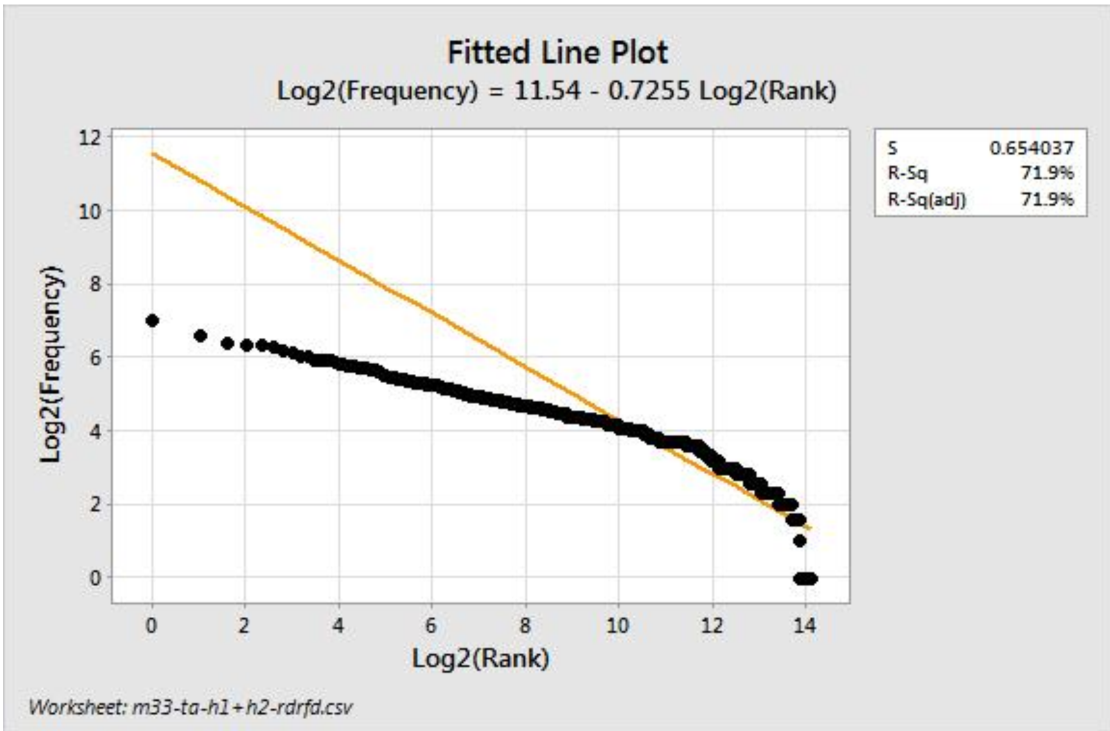

Fitted Line Plot
Log2(Frequency) = 11.31 - 0.6981 Log2(Rank)
S 0.519411
R-Sq 78.9%
R-Sq(adj) 78.9%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m32-t18-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.12 - 0.8616 Log2(Rank)
S 0.741154
R-Sq 73.7%
R-Sq(adj) 73.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-t18-h1+h2-bdrfd.csv

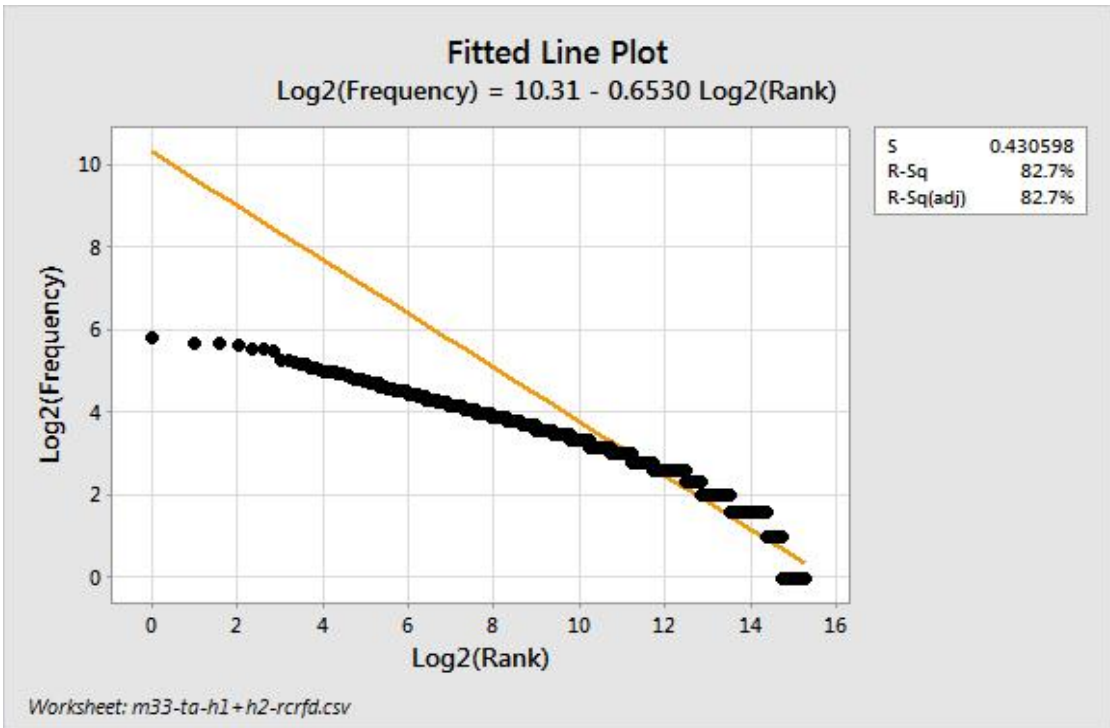

Fitted Line Plot
Log2(Frequency) = 9.482 - 0.5867 Log2(Rank)
S 0.329535
R-Sq 86.8%
R-Sq(adj) 86.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m32-t18-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 12.15 - 0.7462 Log2(Rank)
S 0.689579
R-Sq 70.8%
R-Sq(adj) 70.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta-h1+h2-rarfd.csv

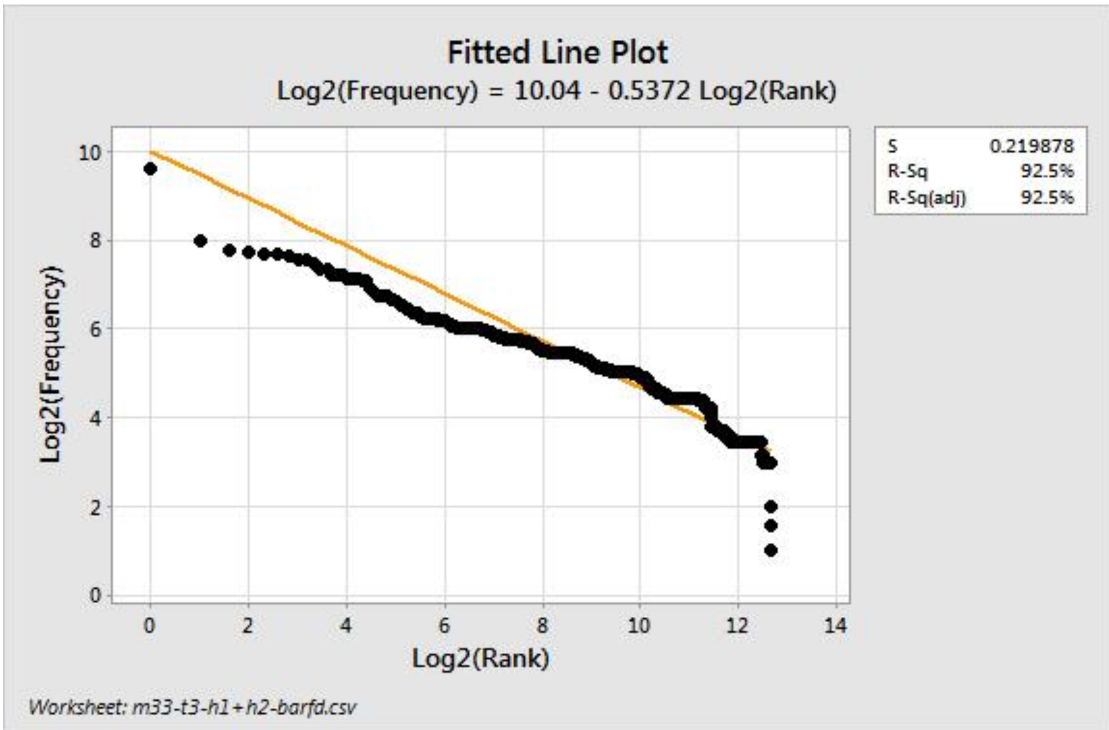

Fitted Line Plot
Log2(Frequency) = 10.03 - 0.5865 Log2(Rank)
S 0.556646
R-Sq 69.7%
R-Sq(adj) 69.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta-h1+h2-rmrfd.csv

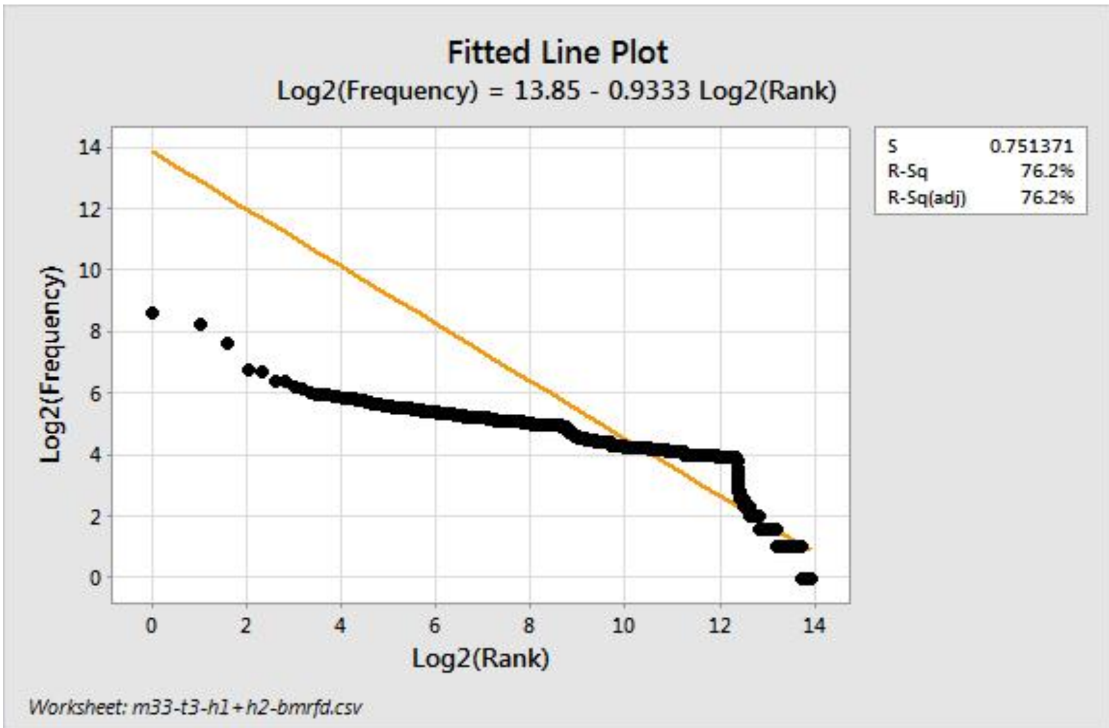


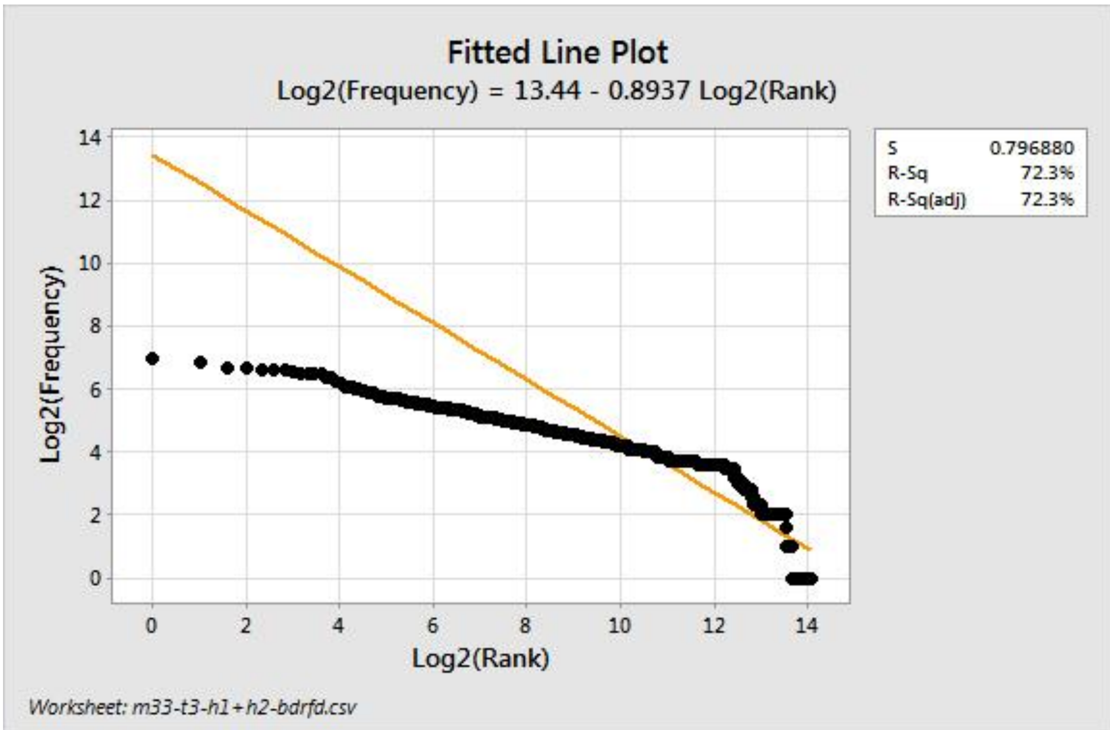
Fitted Line Plot
Log2(Frequency) = 11.54 - 0.7255 Log2(Rank)
S 0.654037
R-Sq 71.9%
R-Sq(adj) 71.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta-h1+h2-rdrfd.csv



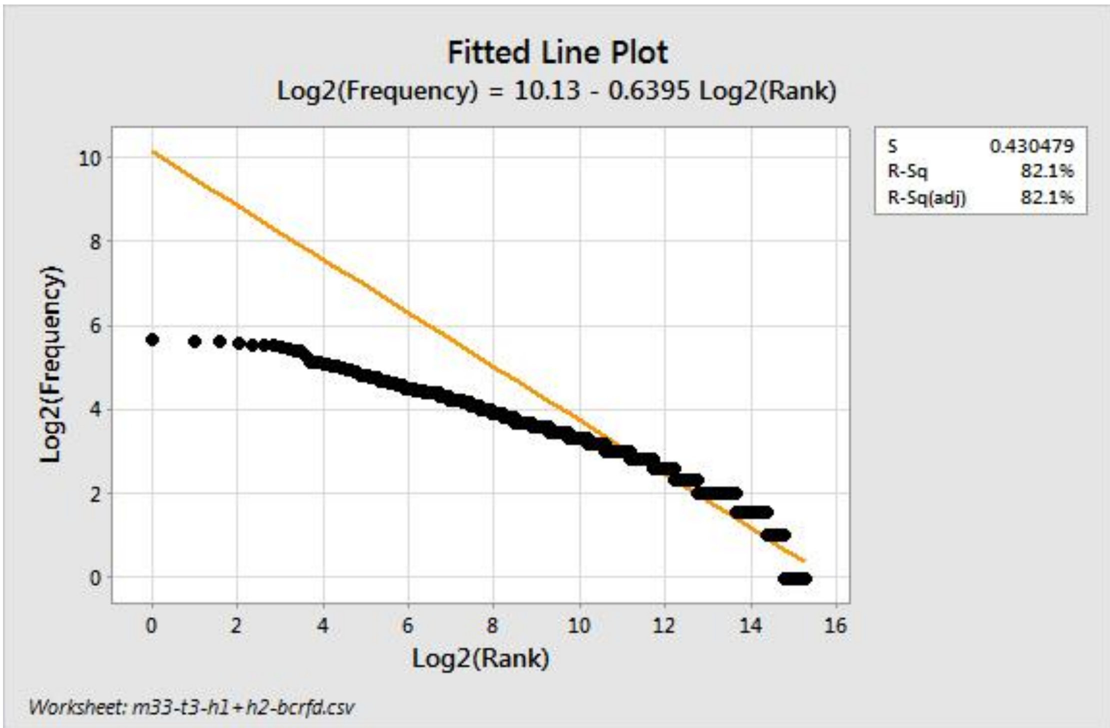
Fitted Line Plot
Log2(Frequency) = 10.31 - 0.6530 Log2(Rank)
S 0.430598
R-Sq 82.7%
R-Sq(adj) 82.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.04 - 0.5372 Log2(Rank)
S 0.219878
R-Sq 92.5%
R-Sq(adj) 92.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3-h1+h2-barfd.csv

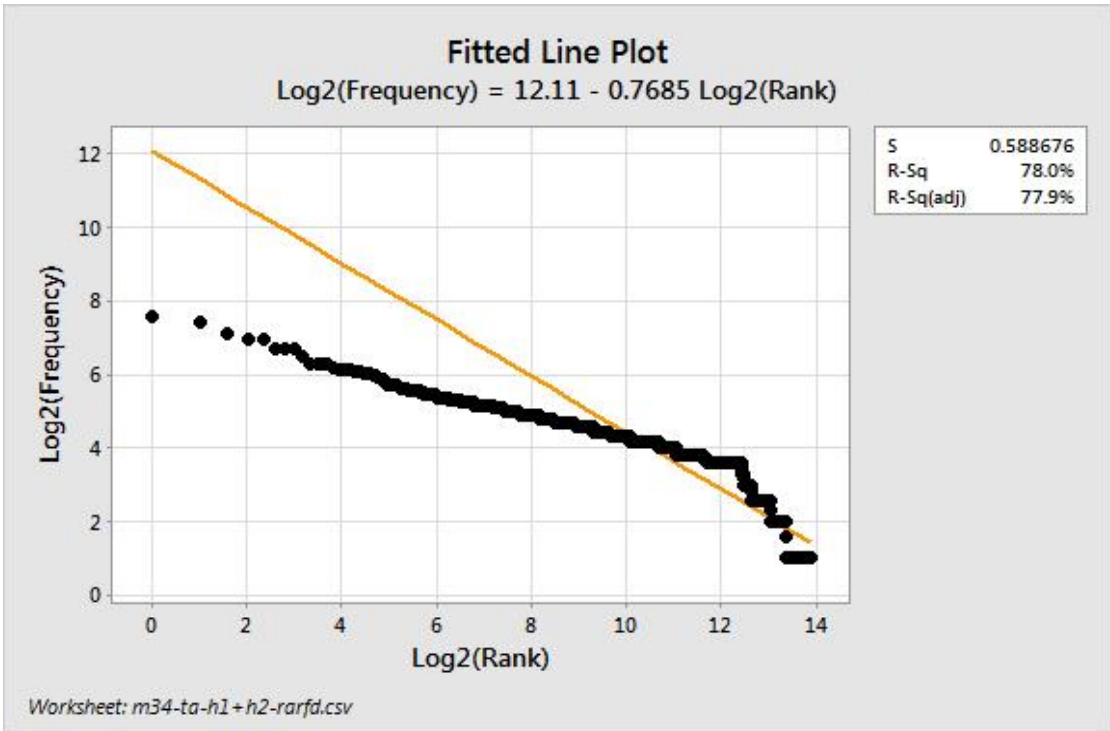

Fitted Line Plot
Log2(Frequency) = 13.85 - 0.9333 Log2(Rank)
S 0.751371
R-Sq 76.2%
R-Sq(adj) 76.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3-h1+h2-bmrfd.csv



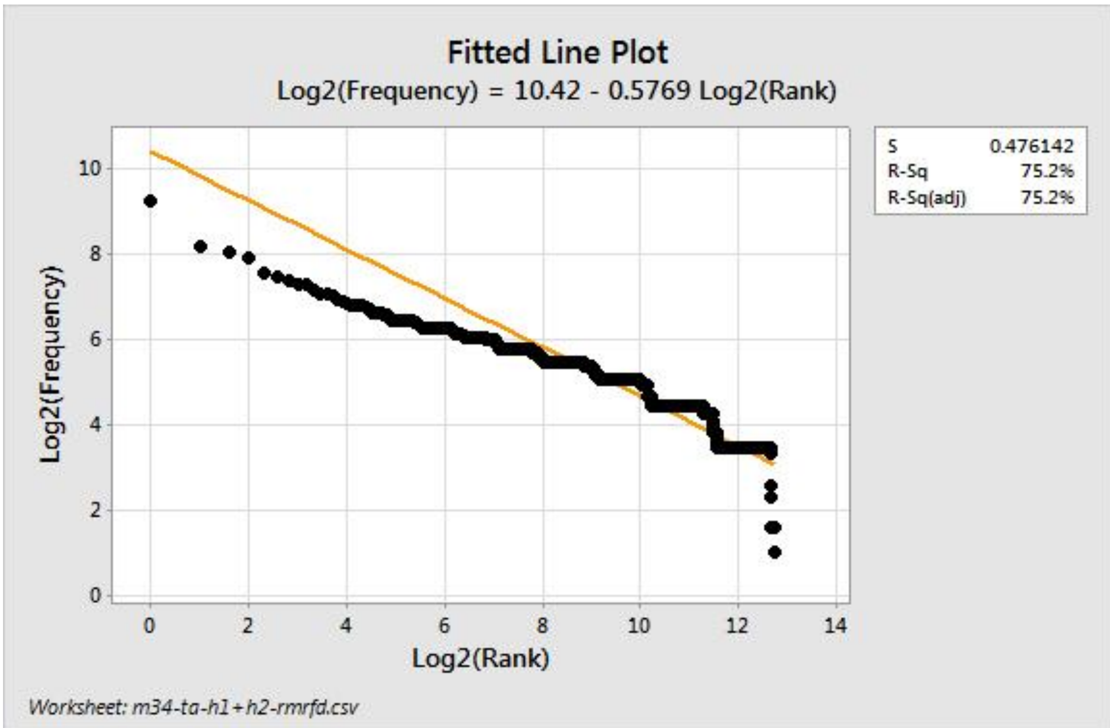
Fitted Line Plot
Log2(Frequency) = 13.44 - 0.8937 Log2(Rank)
S 0.796880
R-Sq 72.3%
R-Sq(adj) 72.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3-h1+h2-bdrfd.csv



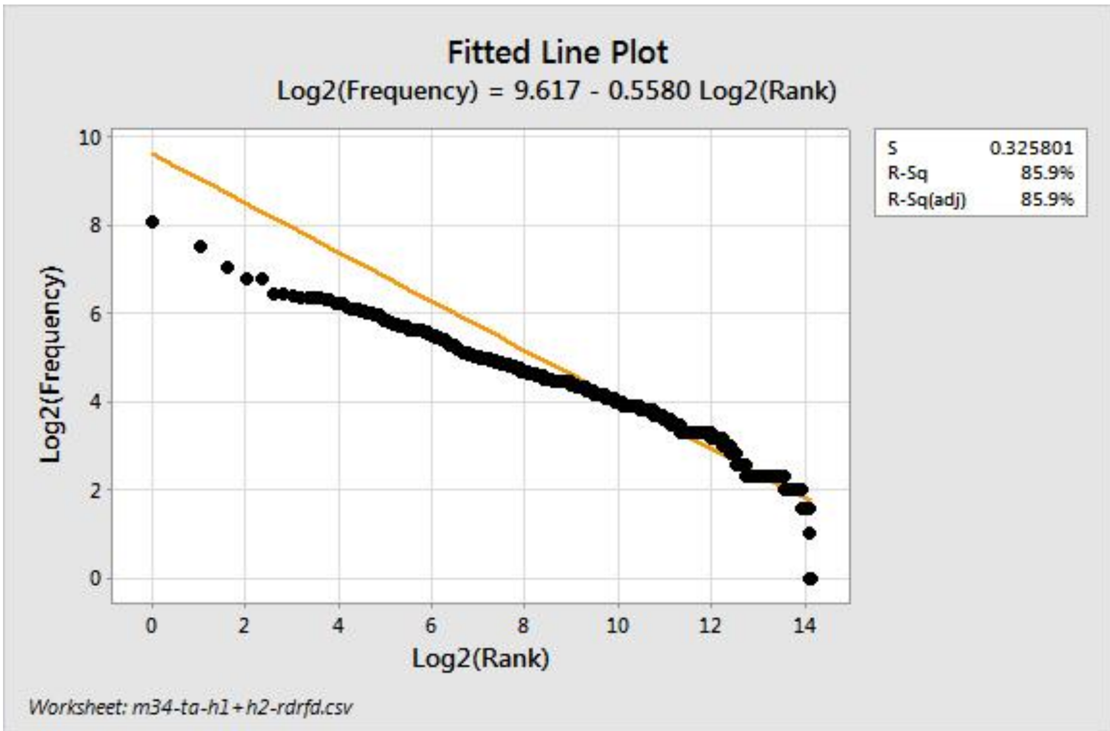
Fitted Line Plot
Log2(Frequency) = 10.13 - 0.6395 Log2(Rank)
S 0.430479
R-Sq 82.1%
R-Sq(adj) 82.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m33-t3-h1+h2-bcrfd.csv

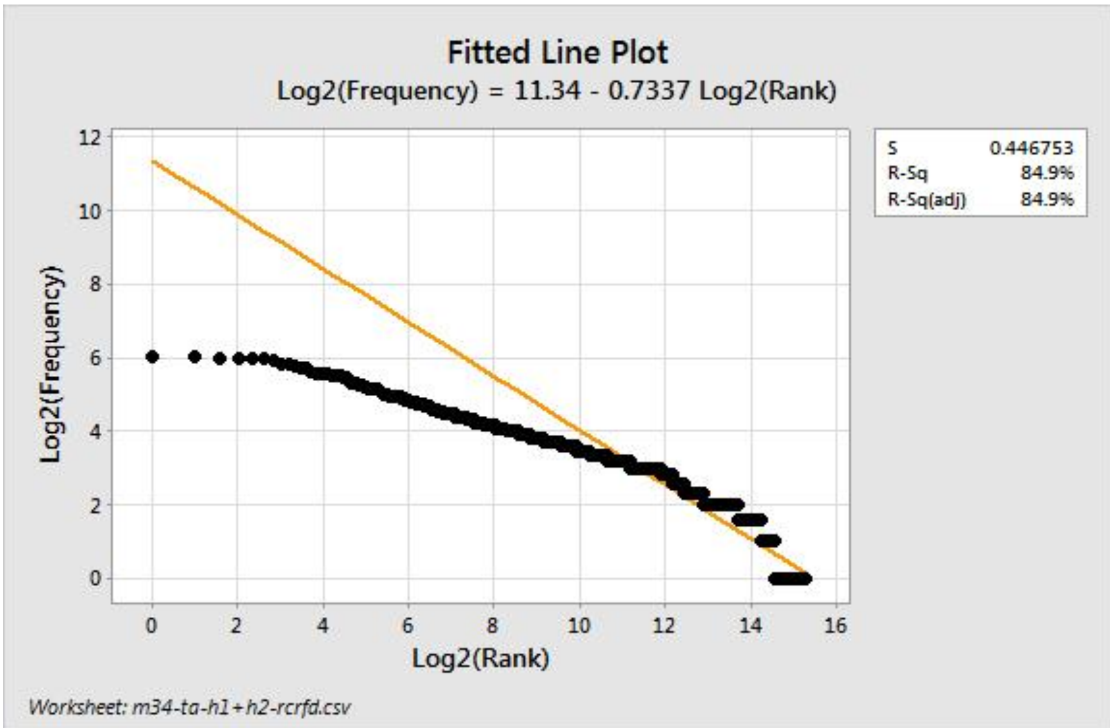


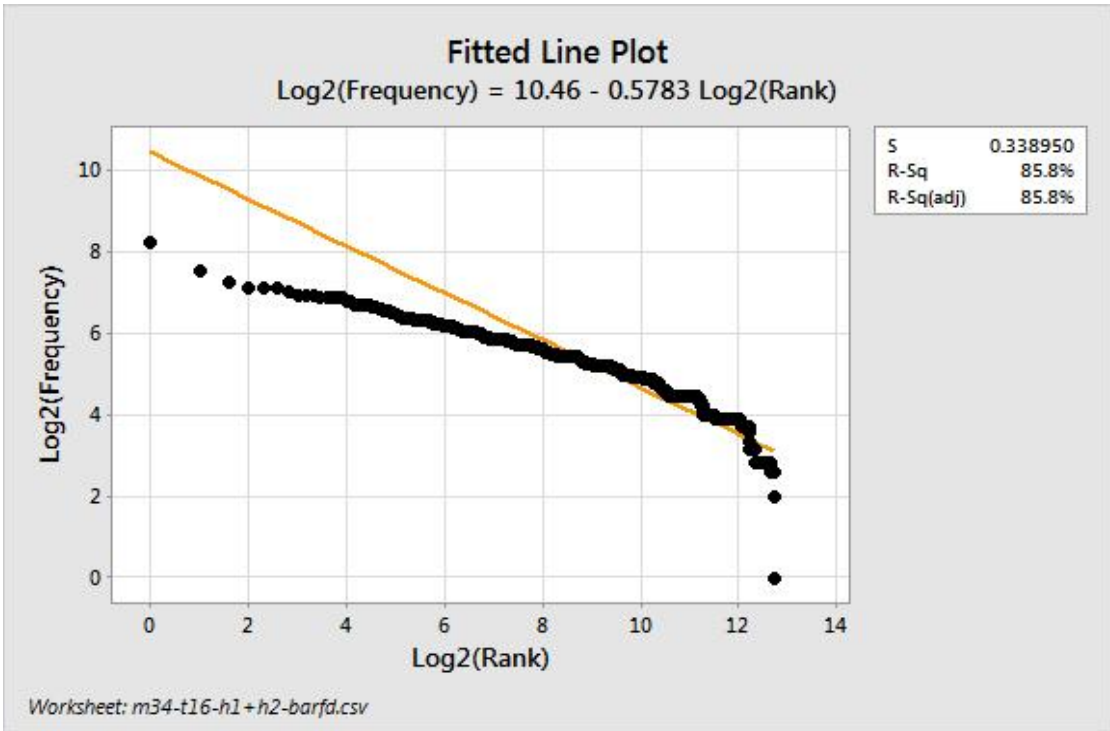
Fitted Line Plot
Log2(Frequency) = 12.11 - 0.7685 Log2(Rank)
S 0.588676
R-Sq 78.0%
R-Sq(adj) 77.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-ta-h1+h2-rarfd.csv

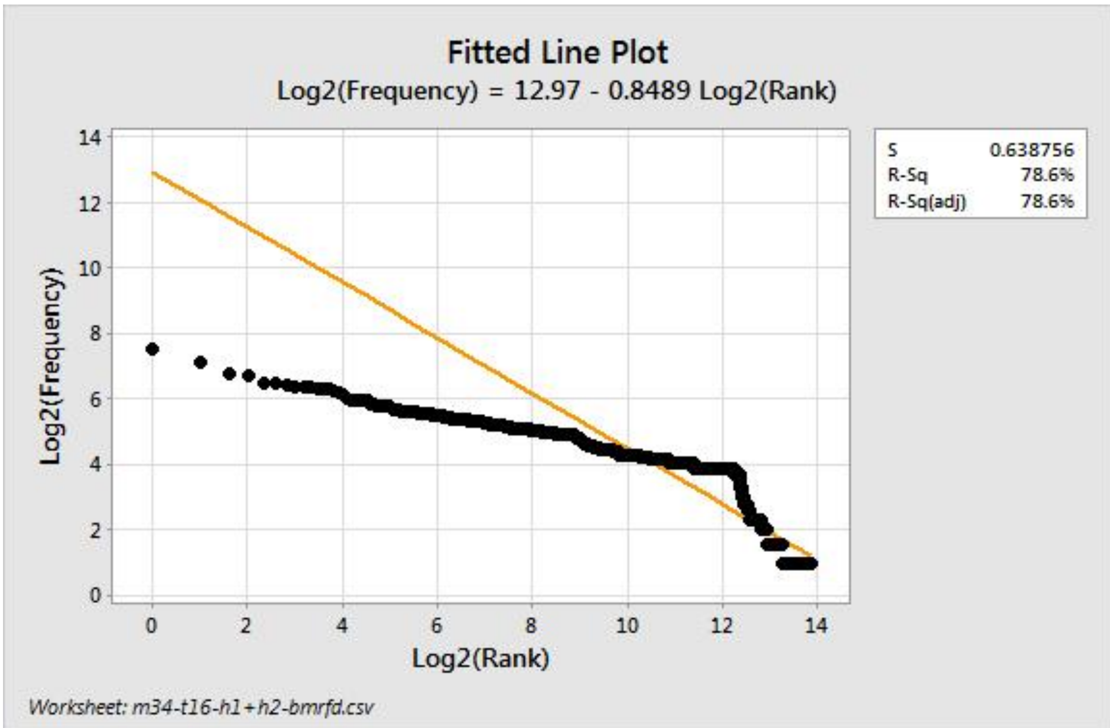


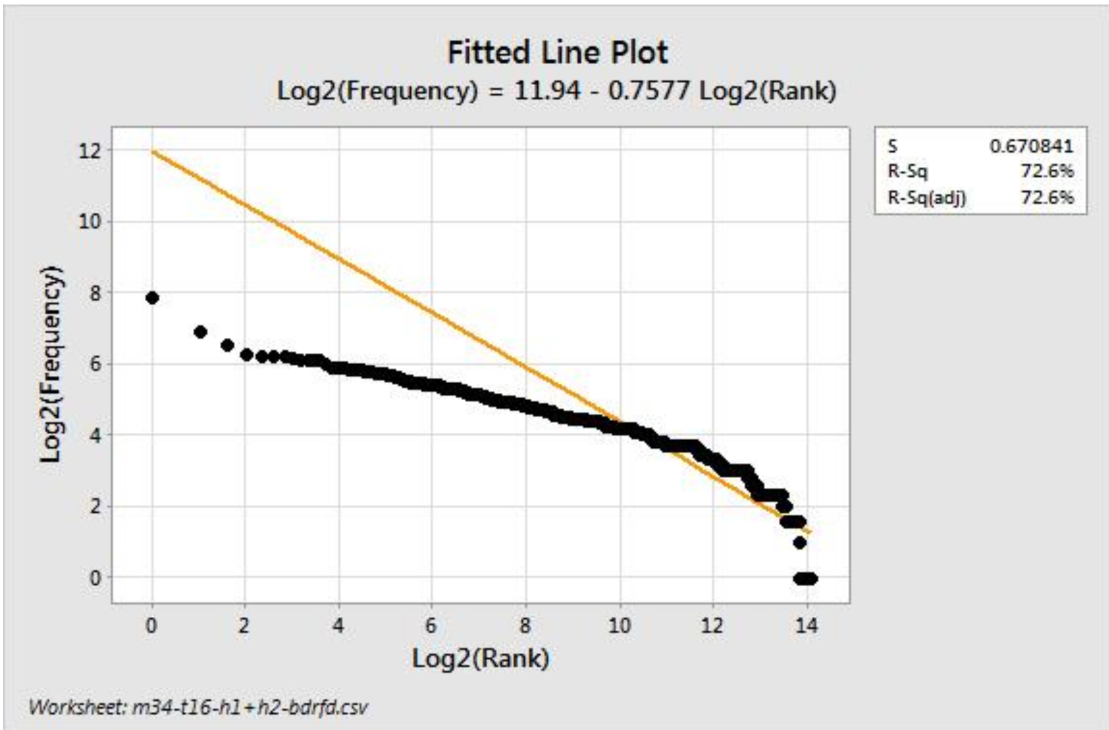
Fitted Line Plot
Log2(Frequency) = 10.42 - 0.5769 Log2(Rank)
S 0.476142
R-Sq 75.2%
R-Sq(adj) 75.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-ta-h1+h2-rmrfd.csv

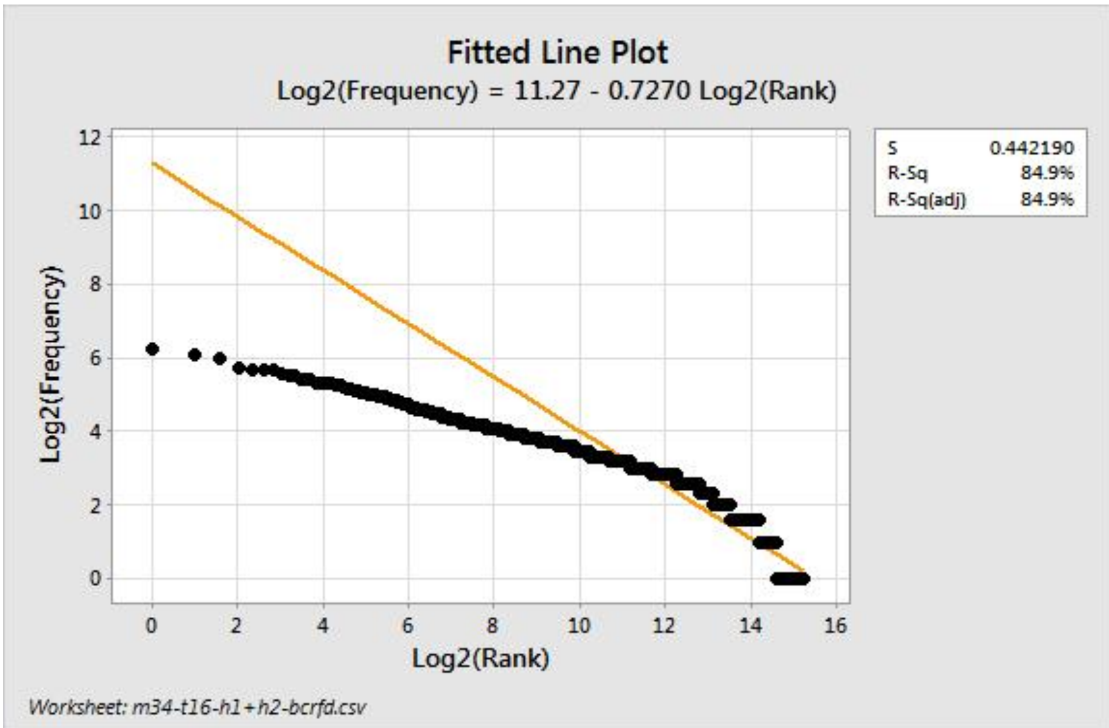

Fitted Line Plot
Log2(Frequency) = 9.617 - 0.5580 Log2(Rank)
S 0.325801
R-Sq 85.9%
R-Sq(adj) 85.9%
Log2(Frequency)
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Log2(Rank)
Worksheet: m34-ta-h1+h2-rdrfd.csv

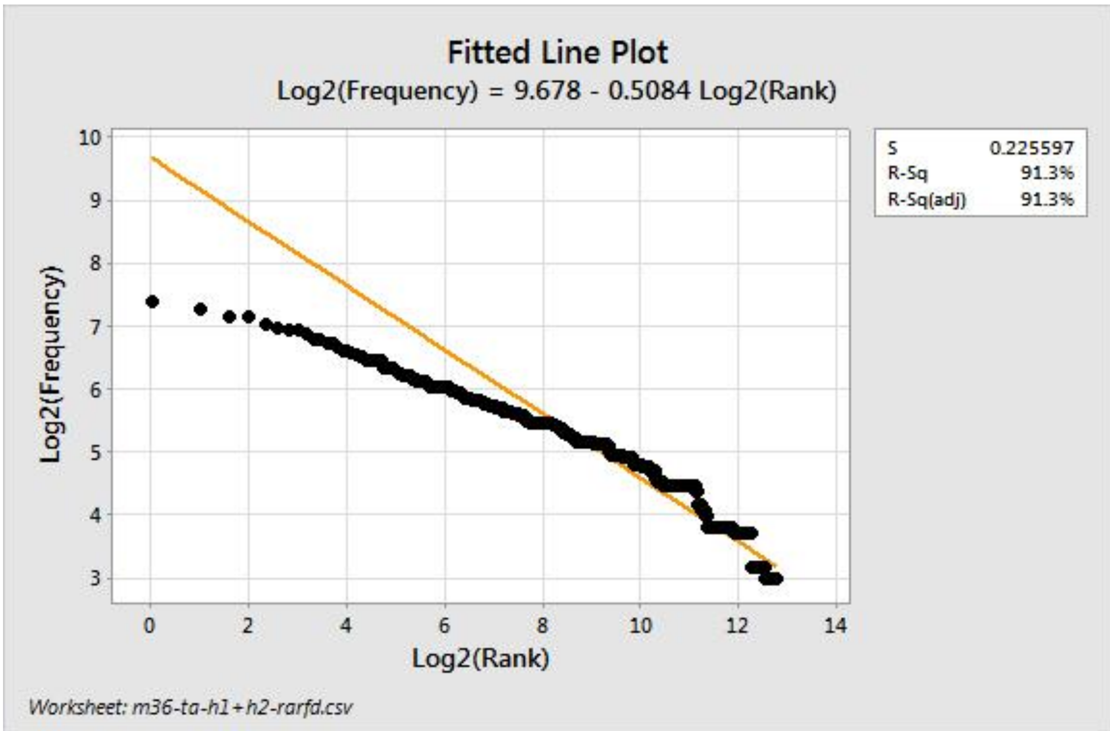

Fitted Line Plot
Log2(Frequency) = 11.34 - 0.7337 Log2(Rank)
S 0.446753
R-Sq 84.9%
R-Sq(adj) 84.9%
Log2(Frequency)
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
16
Log2(Rank)
Worksheet: m34-ta-h1+h2-rcrfd.csv

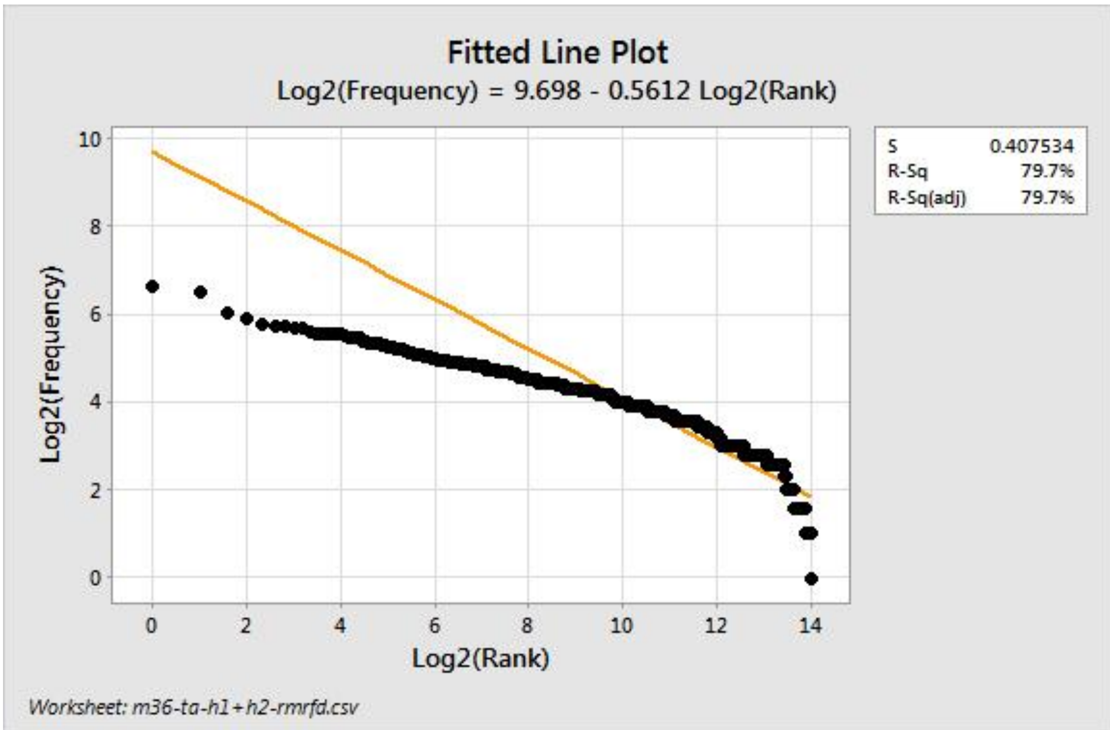

Fitted Line Plot
Log2(Frequency) = 10.46 - 0.5783 Log2(Rank)
S 0.338950
R-Sq 85.8%
R-Sq(adj) 85.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16-h1+h2-barfd.csv

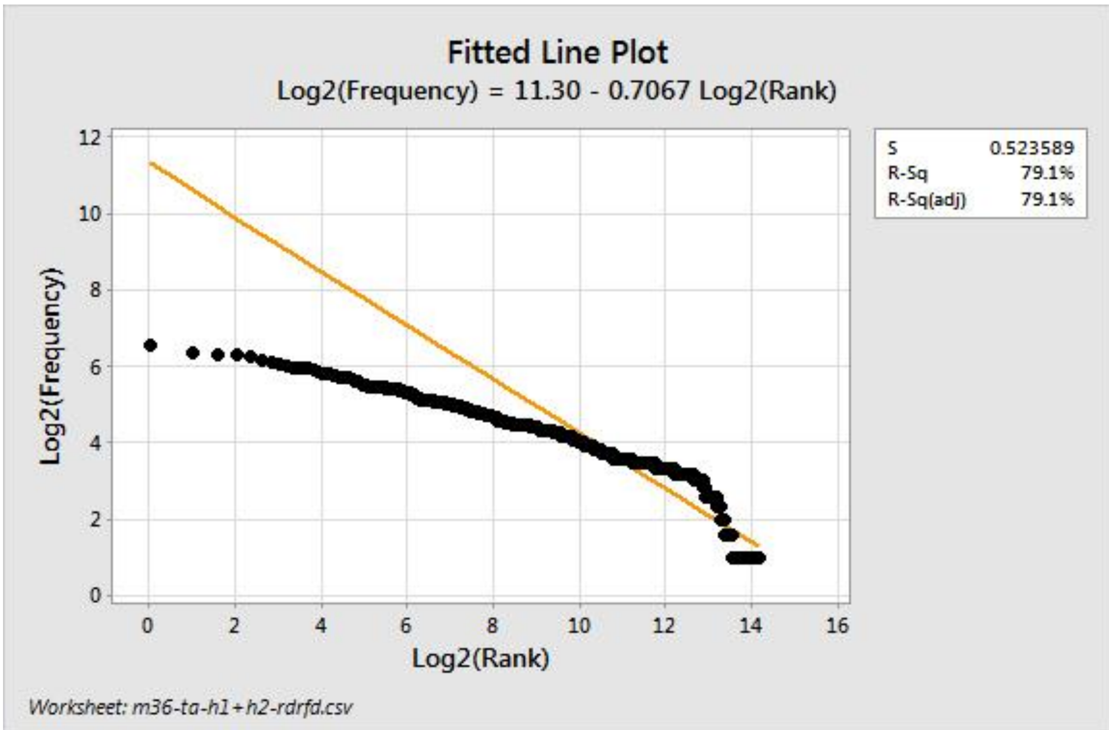

Fitted Line Plot
Log2(Frequency) = 12.97 - 0.8489 Log2(Rank)
S 0.638756
R-Sq 78.6%
R-Sq(adj) 78.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 11.94 - 0.7577 Log2(Rank)
S 0.670841
R-Sq 72.6%
R-Sq(adj) 72.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16-h1+h2-bdrfd.csv

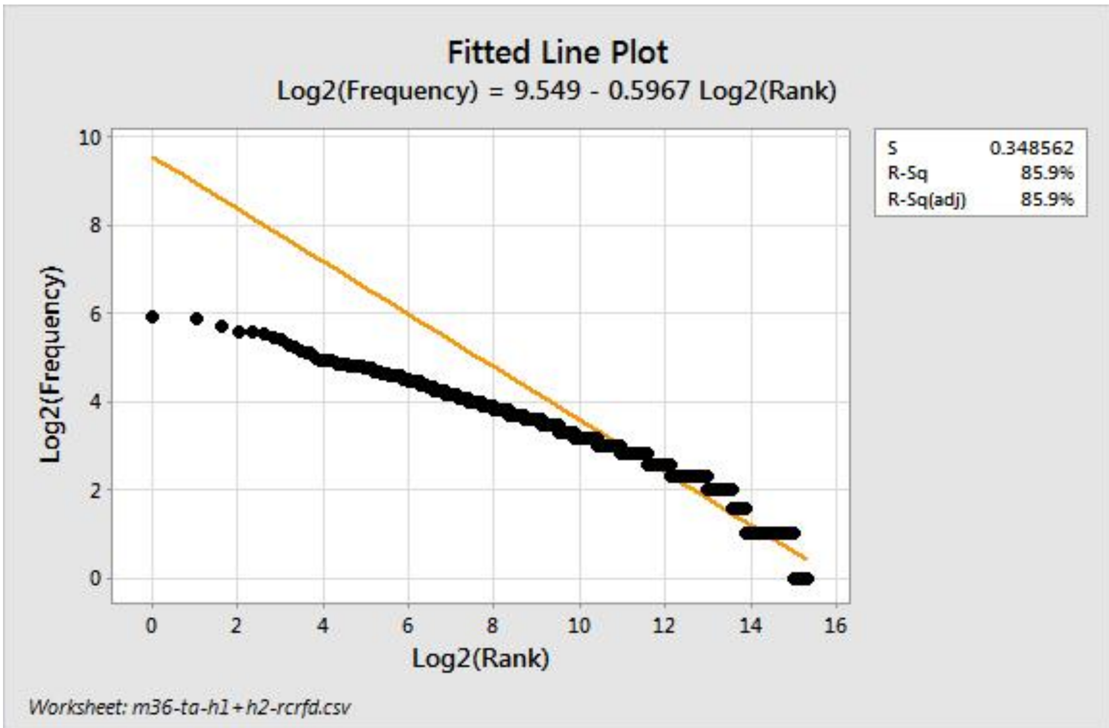

Fitted Line Plot
Log2(Frequency) = 11.27 - 0.7270 Log2(Rank)
S 0.442190
R-Sq 84.9%
R-Sq(adj) 84.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m34-t16-h1+h2-bcrfd.csv


Fitted Line Plot
Log2(Frequency) = 9.678 - 0.5084 Log2(Rank)
S 0.225597
R-Sq 91.3%
R-Sq(adj) 91.3%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-ta-h1+h2-rarfd.csv

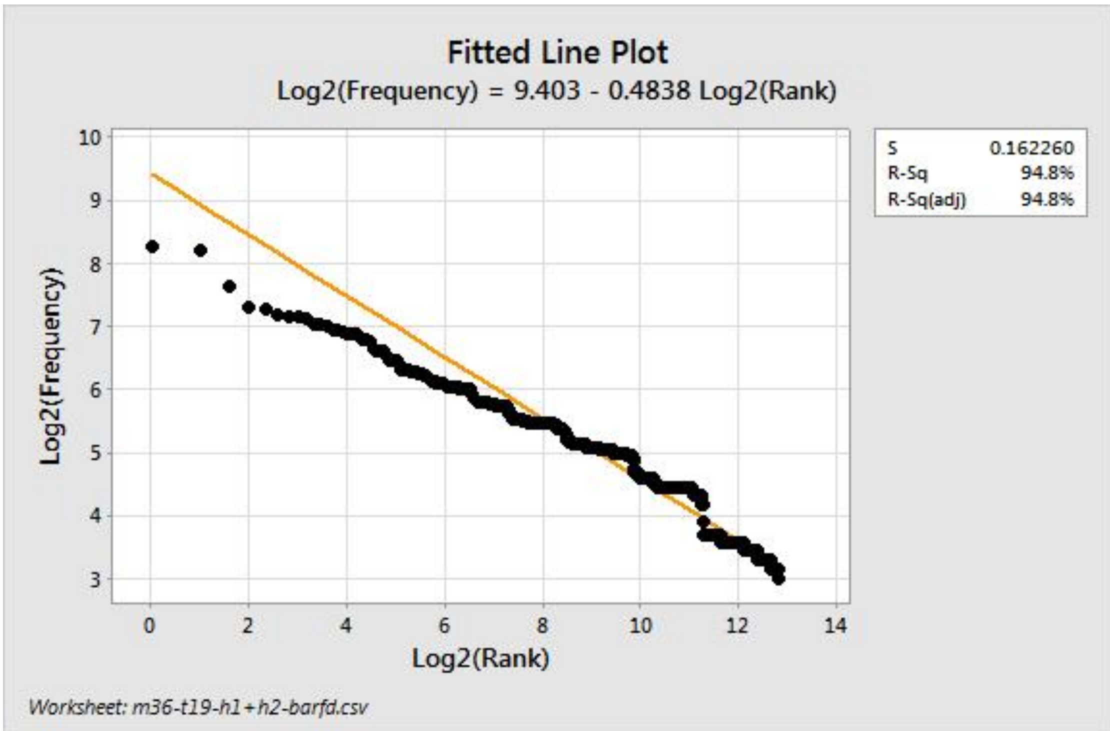

Fitted Line Plot
Log2(Frequency) = 9.698 - 0.5612 Log2(Rank)
S 0.407534
R-Sq 79.7%
R-Sq(adj) 79.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-ta-h1+h2-rmrfd.csv

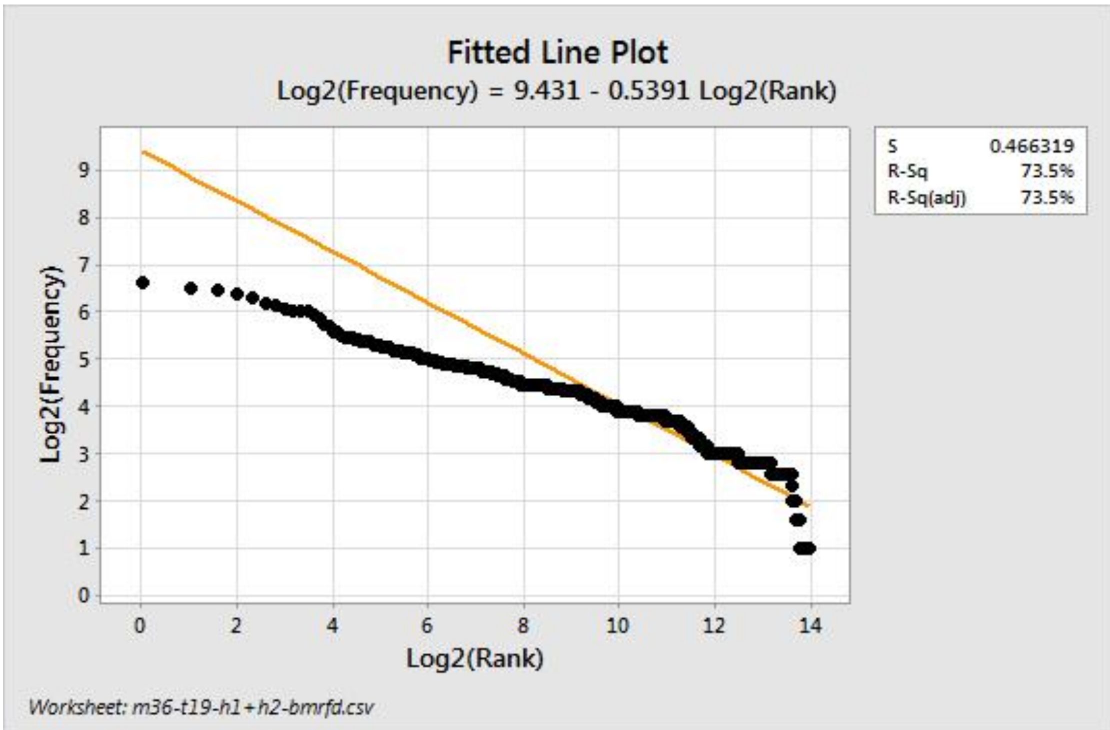


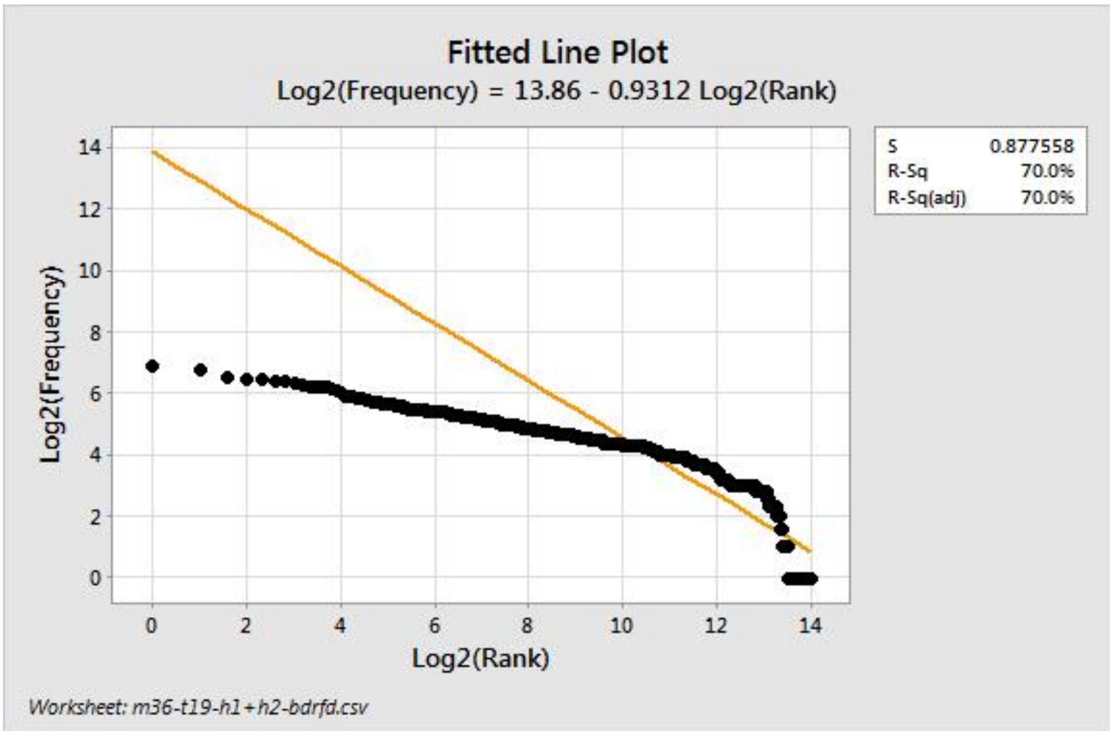
Fitted Line Plot
Log2(Frequency) = 11.30 - 0.7067 Log2(Rank)
S 0.523589
R-Sq 79.1%
R-Sq(adj) 79.1%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-ta-h1+h2-rdrfd.csv

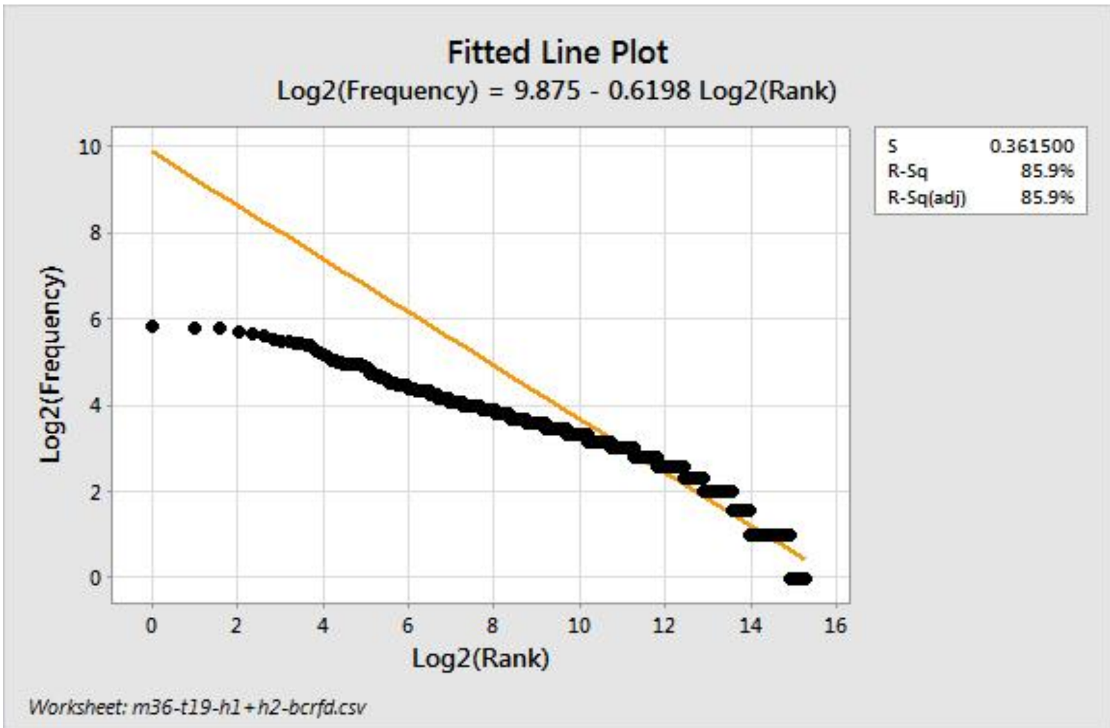


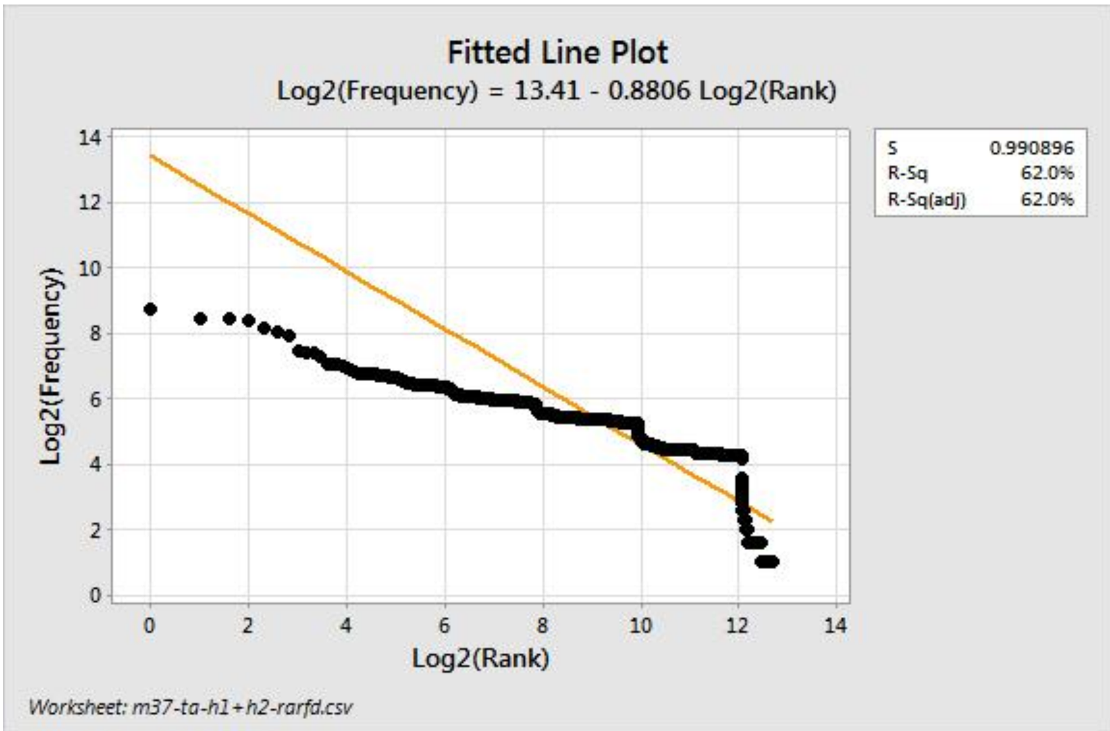
Fitted Line Plot
Log2(Frequency) = 9.549 - 0.5967 Log2(Rank)
S 0.348562
R-Sq 85.9%
R-Sq(adj) 85.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-ta-h1+h2-rcrfd.csv

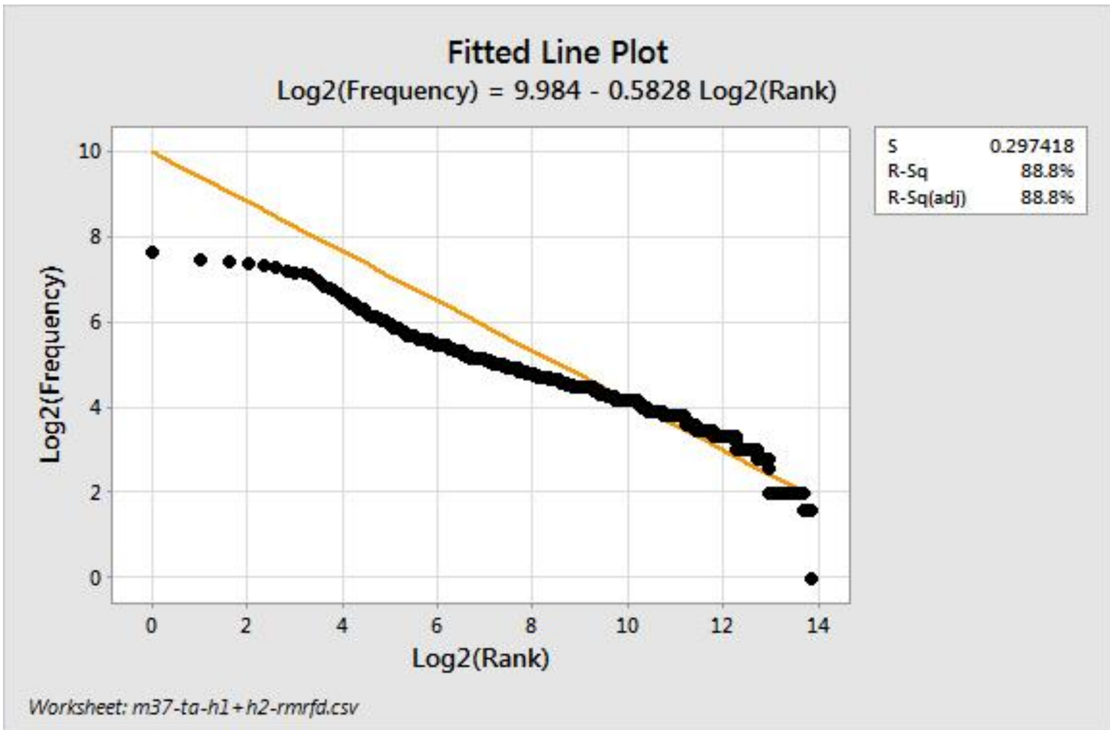

Fitted Line Plot
Log2(Frequency) = 9.403 - 0.4838 Log2(Rank)
S 0.162260
R-Sq 94.8%
R-Sq(adj) 94.8%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-t19-h1+h2-barfd.csv

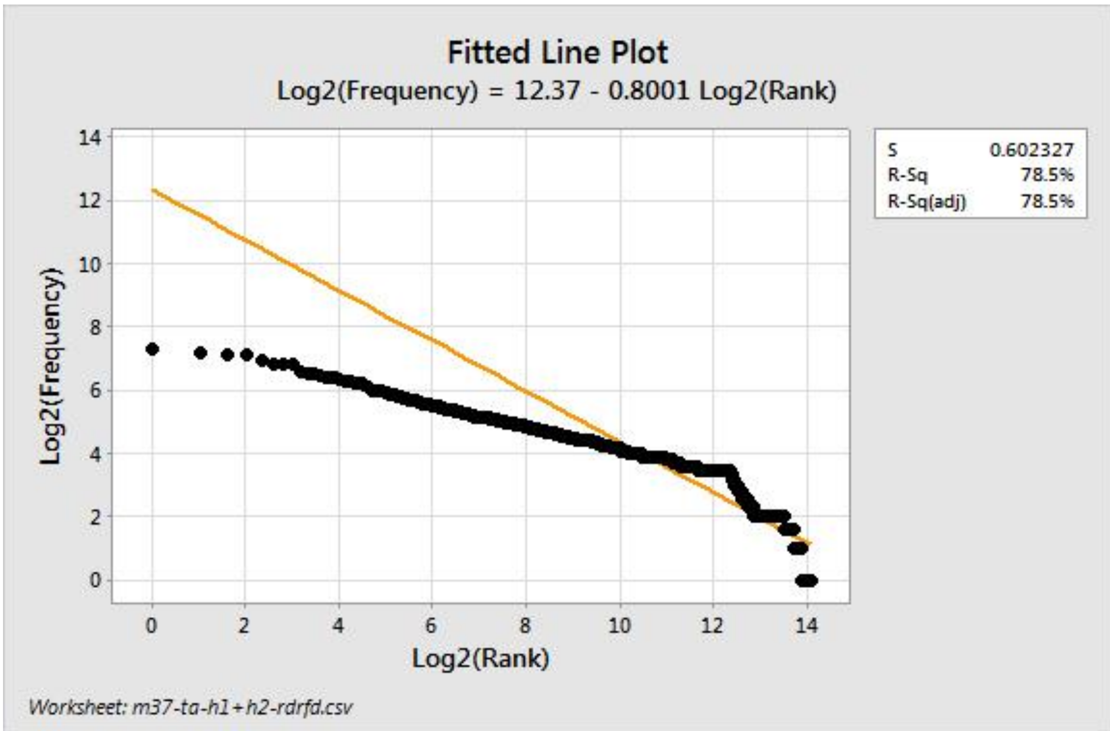

Fitted Line Plot
Log2(Frequency) = 9.431 - 0.5391 Log2(Rank)
S 0.466319
R-Sq 73.5%
R-Sq(adj) 73.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-t19-h1+h2-bmrfd.csv

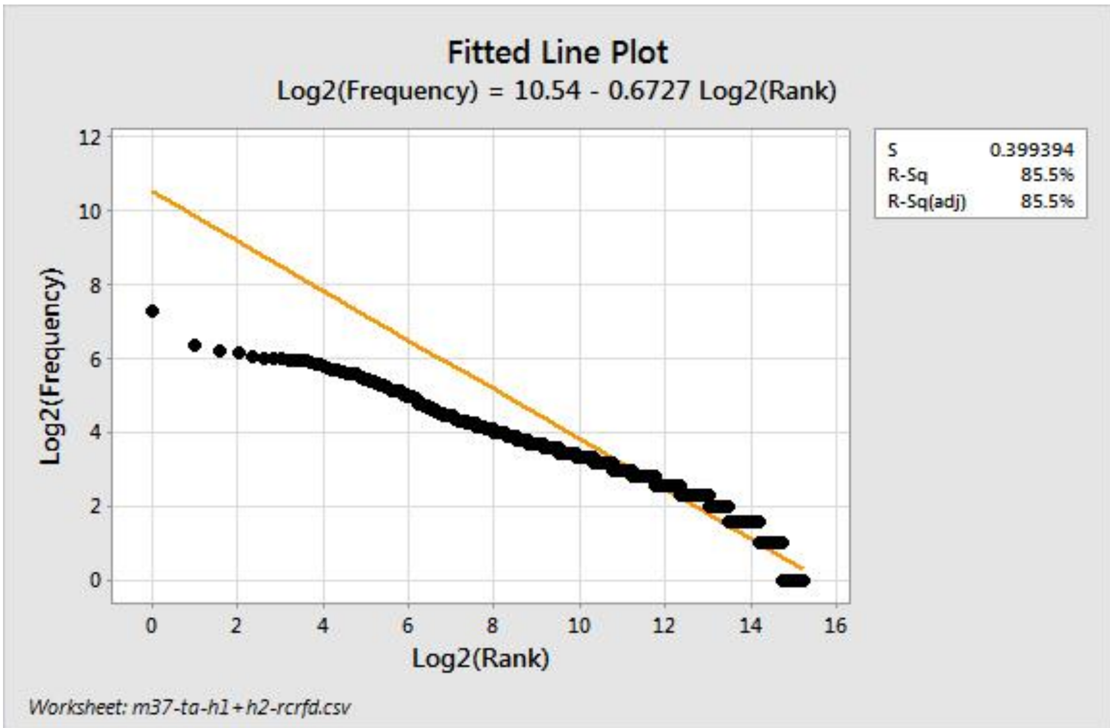

Fitted Line Plot
Log2(Frequency) = 13.86 - 0.9312 Log2(Rank)
S 0.877558
R-Sq 70.0%
R-Sq(adj) 70.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-t19-h1+h2-bdrfd.csv

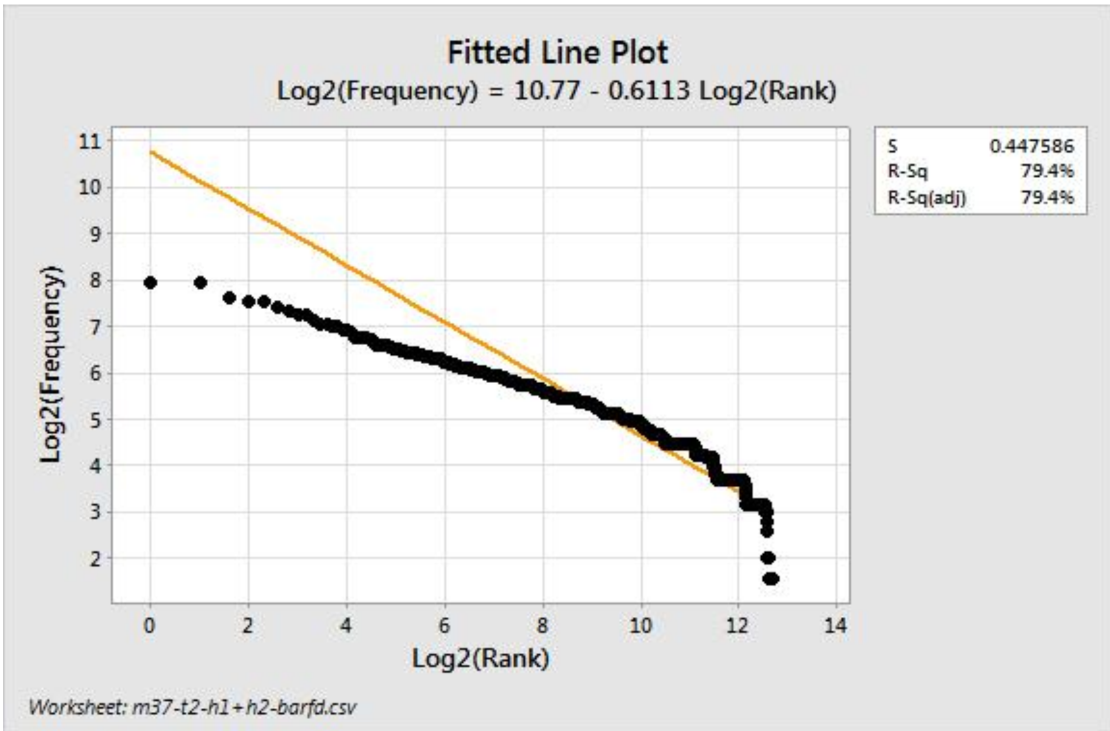

Fitted Line Plot
Log2(Frequency) = 9.875 - 0.6198 Log2(Rank)
S 0.361500
R-Sq 85.9%
R-Sq(adj) 85.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m36-t19-h1+h2-bcrfd.csv

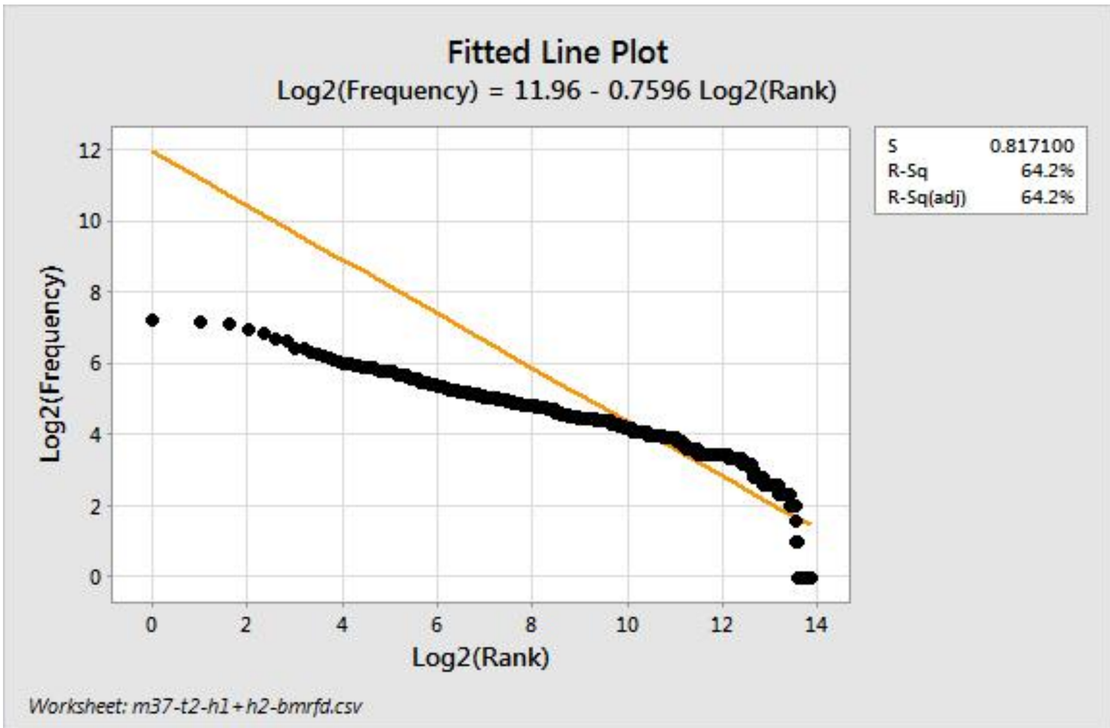

Fitted Line Plot
Log2(Frequency) = 13.41 - 0.8806 Log2(Rank)
S 0.990896
R-Sq 62.0%
R-Sq(adj) 62.0%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m37-ta-h1+h2-rarfd.csv

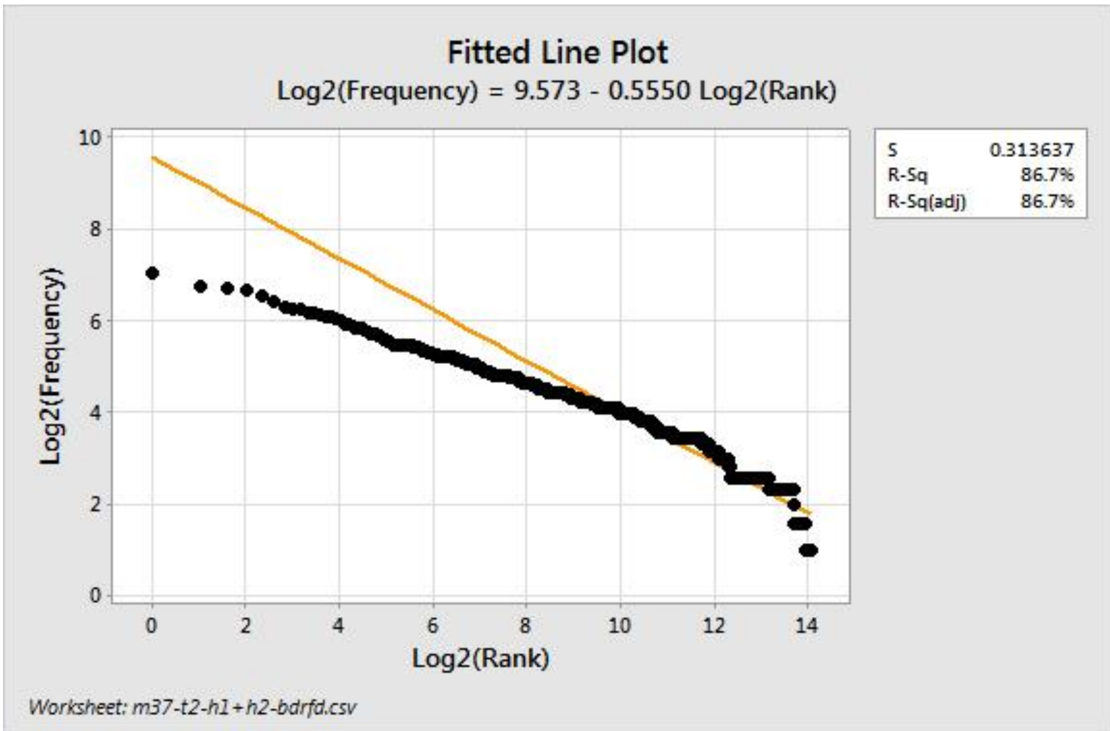

Fitted Line Plot
Log2(Frequency) = 9.984 - 0.5828 Log2(Rank)
S 0.297418
R-Sq 88.8%
R-Sq(adj) 88.8%
Log2(Frequency)
Log2(Rank)
0
2
4
6
8
10
12
14
Worksheet: m37-ta-h1+h2-rmrfd.csv

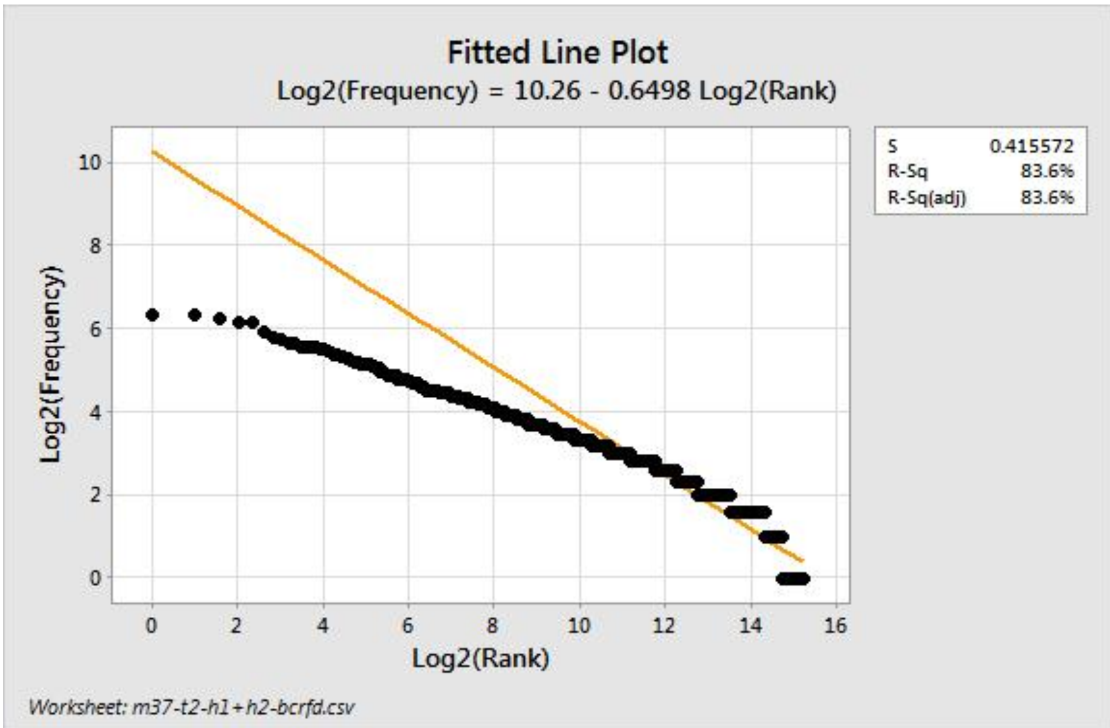

Fitted Line Plot
Log2(Frequency) = 12.37 - 0.8001 Log2(Rank)
S 0.602327
R-Sq 78.5%
R-Sq(adj) 78.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-ta-h1+h2-rdrfd.csv

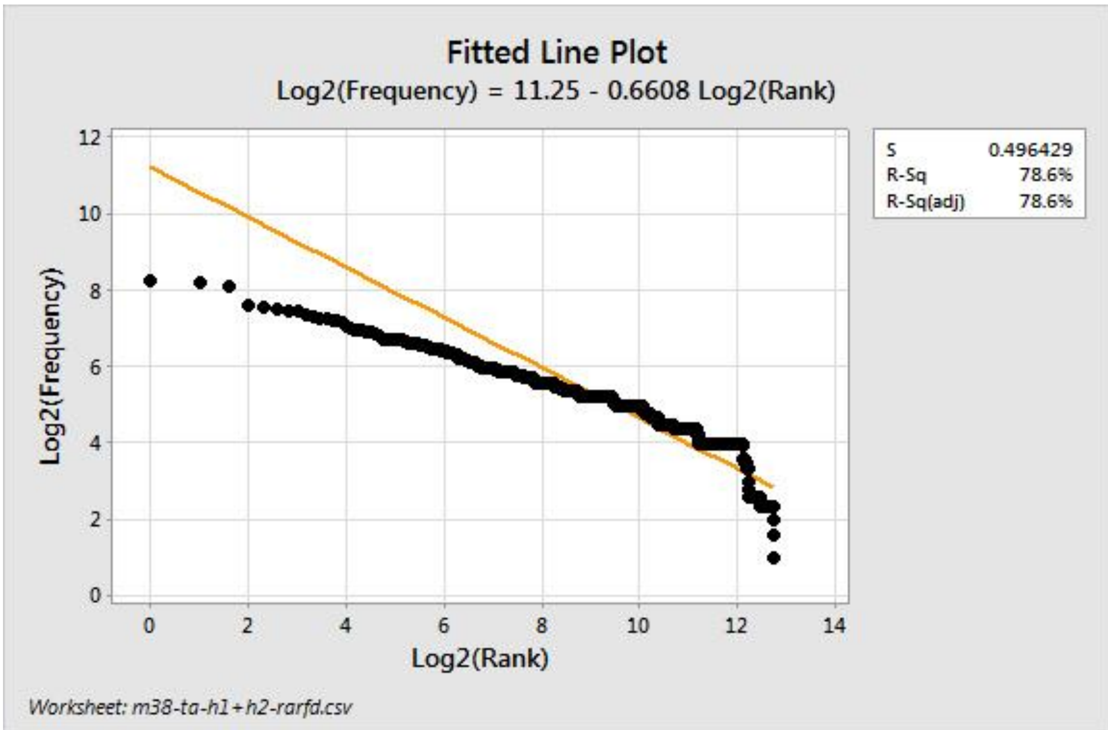

Fitted Line Plot
Log2(Frequency) = 10.54 - 0.6727 Log2(Rank)
S 0.399394
R-Sq 85.5%
R-Sq(adj) 85.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-ta-h1+h2-rcrfd.csv

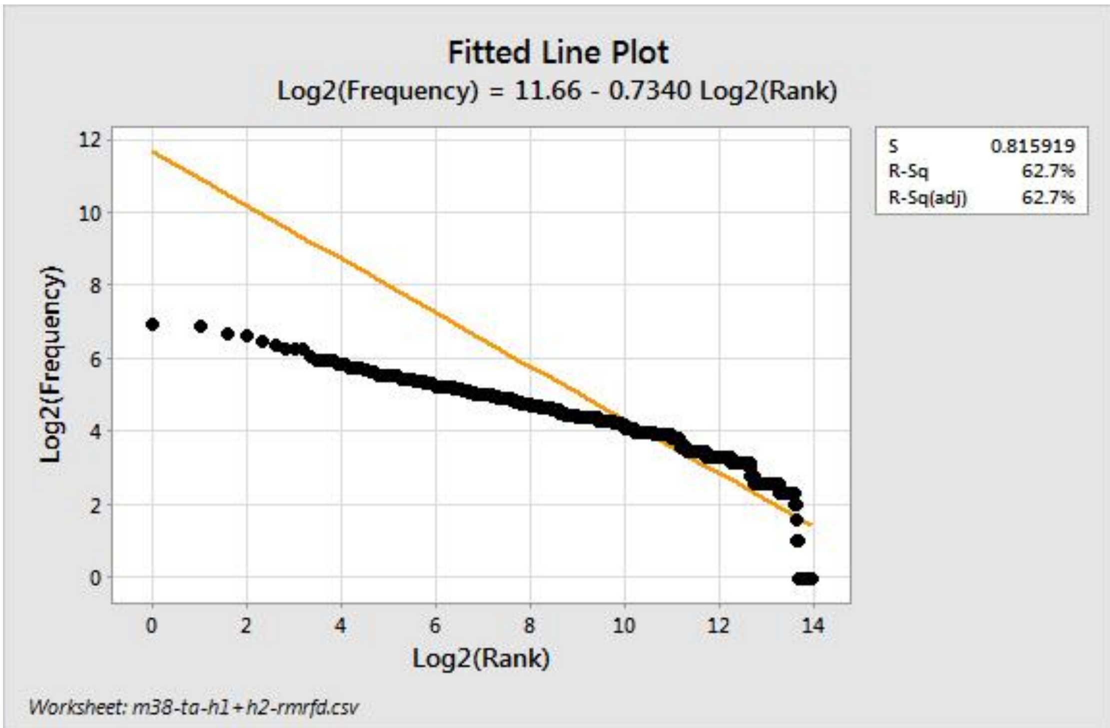

Fitted Line Plot
Log2(Frequency) = 10.77 - 0.6113 Log2(Rank)
S 0.447586
R-Sq 79.4%
R-Sq(adj) 79.4%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2-h1+h2-barfd.csv

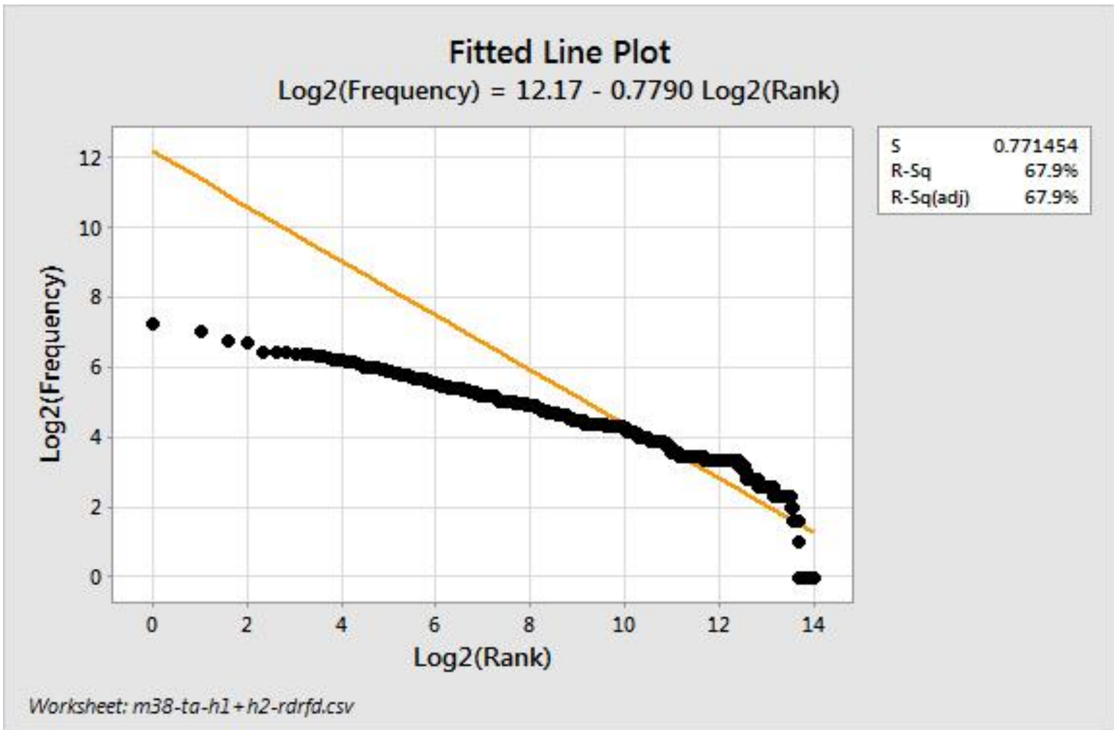

Fitted Line Plot
Log2(Frequency) = 11.96 - 0.7596 Log2(Rank)
S 0.817100
R-Sq 64.2%
R-Sq(adj) 64.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2-h1+h2-bmrfd.csv

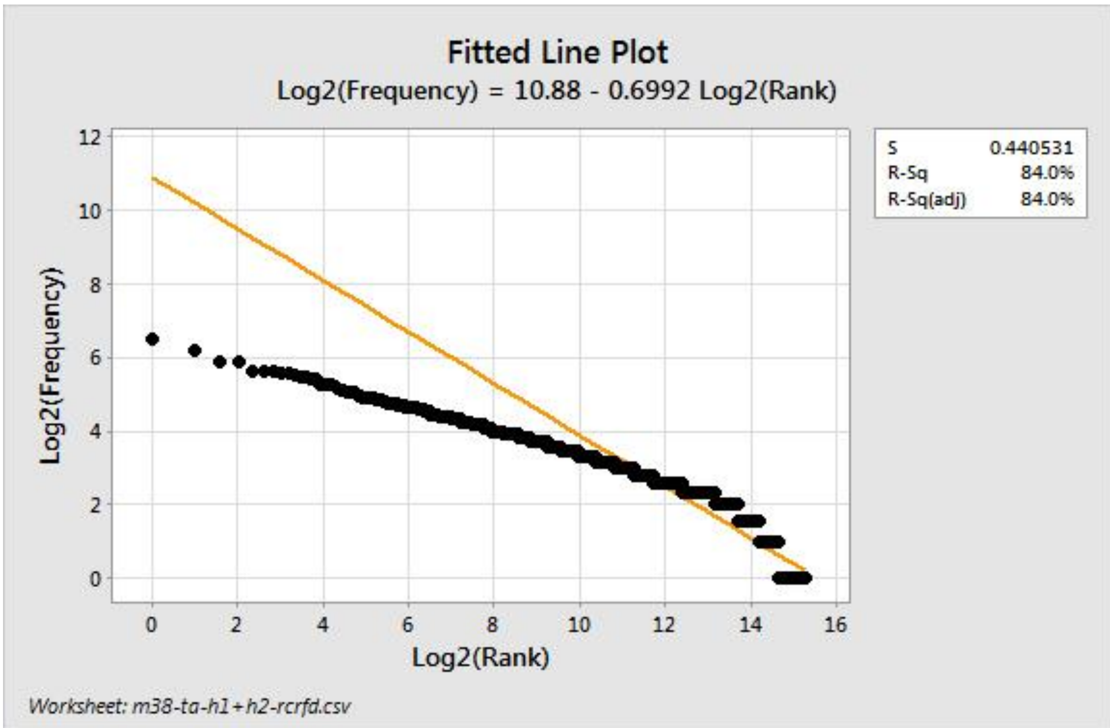

Fitted Line Plot
Log2(Frequency) = 9.573 - 0.5550 Log2(Rank)
S 0.313637
R-Sq 86.7%
R-Sq(adj) 86.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2-h1+h2-bdrfd.csv

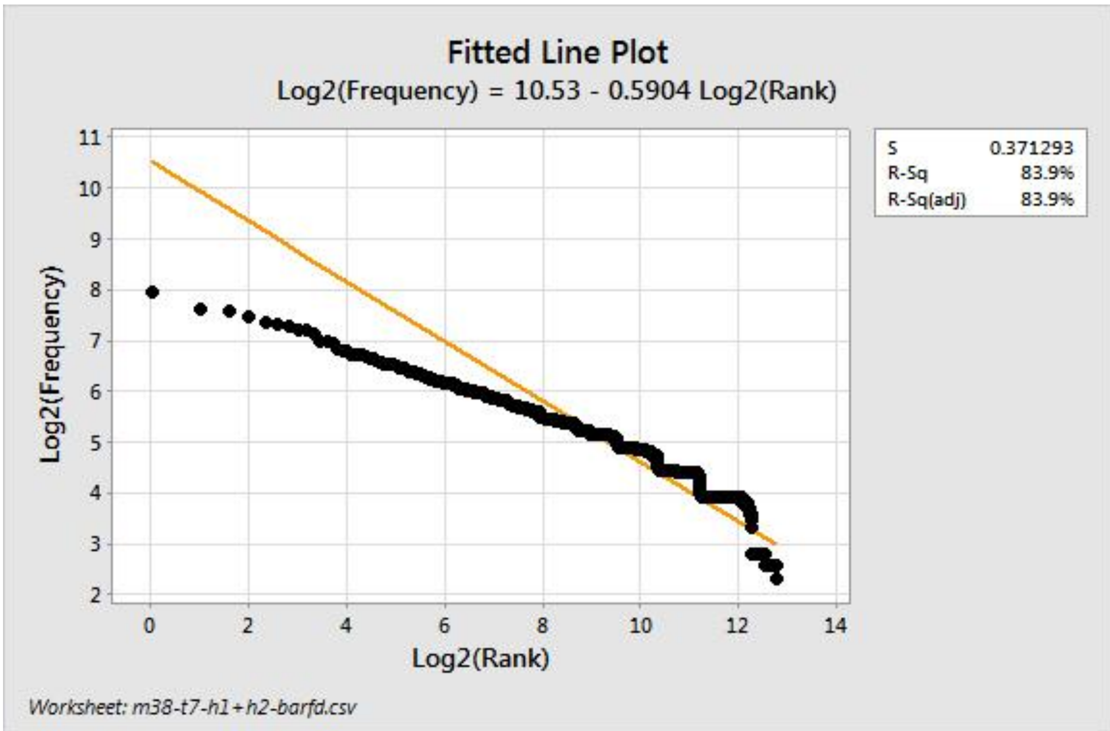

Fitted Line Plot
Log2(Frequency) = 10.26 - 0.6498 Log2(Rank)
S 0.415572
R-Sq 83.6%
R-Sq(adj) 83.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m37-t2-h1+h2-bcrfd.csv

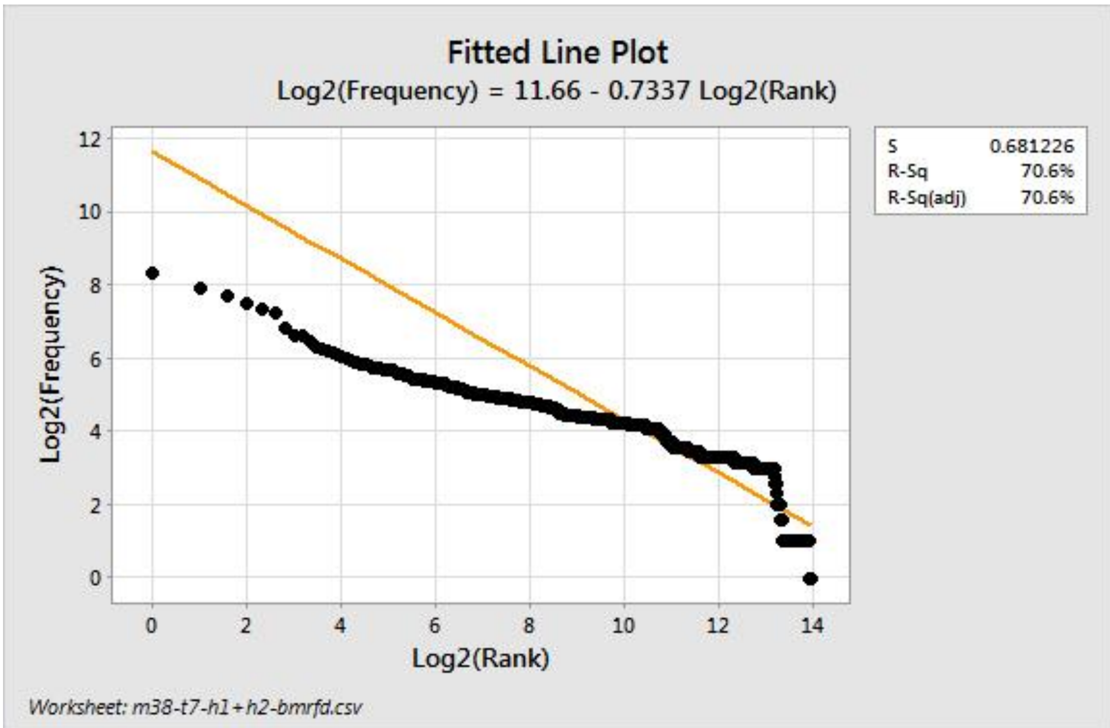

Fitted Line Plot
Log2(Frequency) = 11.25 - 0.6608 Log2(Rank)
S 0.496429
R-Sq 78.6%
R-Sq(adj) 78.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta-h1+h2-rarfd.csv

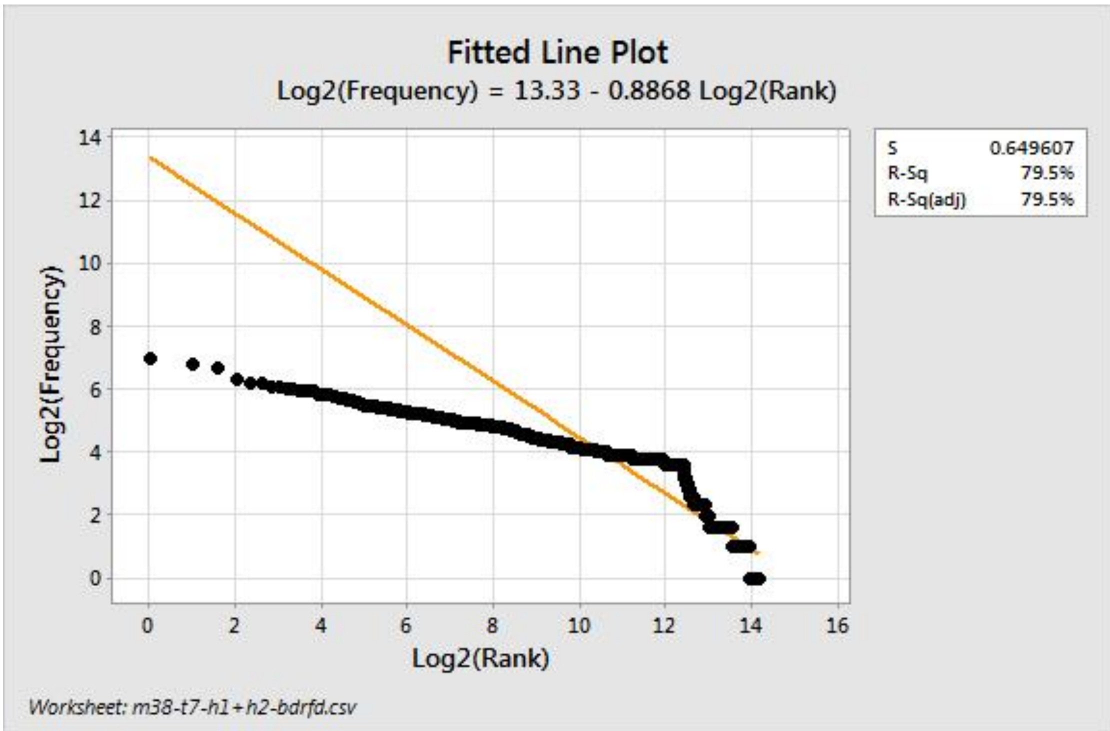

Fitted Line Plot
Log2(Frequency) = 11.66 - 0.7340 Log2(Rank)
S 0.815919
R-Sq 62.7%
R-Sq(adj) 62.7%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta-h1+h2-rmrfd.csv

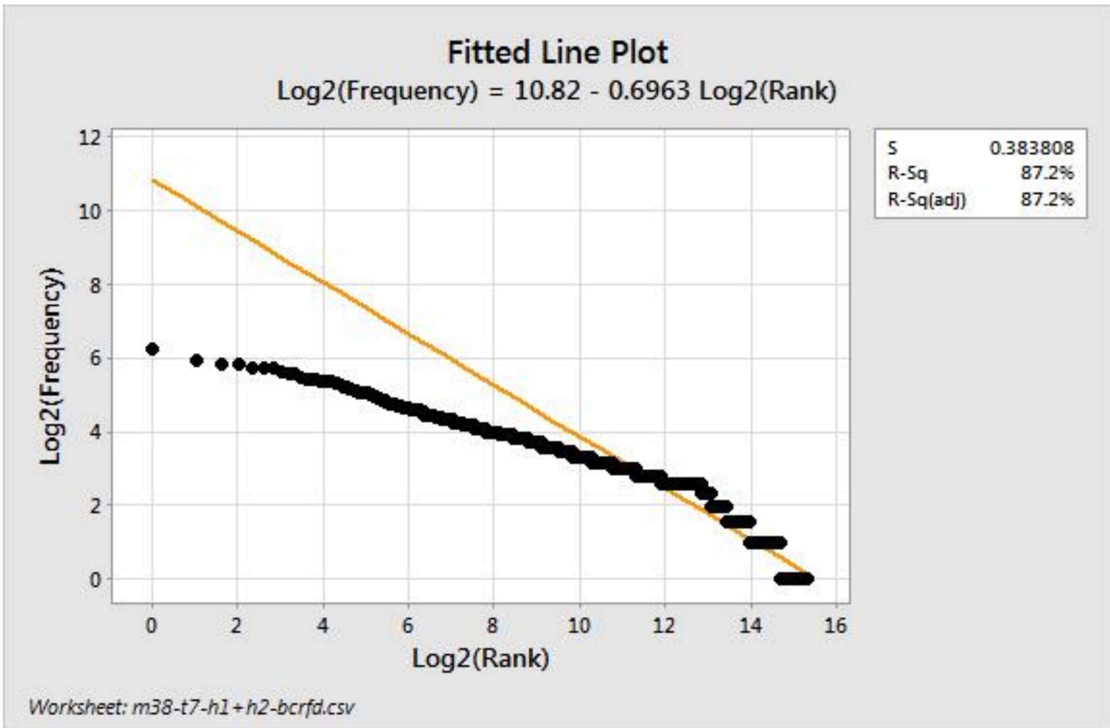

Fitted Line Plot
Log2(Frequency) = 12.17 - 0.7790 Log2(Rank)
S 0.771454
R-Sq 67.9%
R-Sq(adj) 67.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta-h1+h2-rdrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.88 - 0.6992 Log2(Rank)
S 0.440531
R-Sq 84.0%
R-Sq(adj) 84.0%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-ta-h1+h2-rcrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.53 - 0.5904 Log2(Rank)
S 0.371293
R-Sq 83.9%
R-Sq(adj) 83.9%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7-h1+h2-barfd.csv


Fitted Line Plot
Log2(Frequency) = 11.66 - 0.7337 Log2(Rank)
S 0.681226
R-Sq 70.6%
R-Sq(adj) 70.6%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7-h1+h2-bmrfd.csv


Fitted Line Plot
Log2(Frequency) = 13.33 - 0.8868 Log2(Rank)
S 0.649607
R-Sq 79.5%
R-Sq(adj) 79.5%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7-h1+h2-bdrfd.csv


Fitted Line Plot
Log2(Frequency) = 10.82 - 0.6963 Log2(Rank)
S 0.383808
R-Sq 87.2%
R-Sq(adj) 87.2%
Log2(Frequency)
Log2(Rank)
Worksheet: m38-t7-h1+h2-bcrfd.csv

Appendix 3 – Data underpinning Policy Characteristics Graphs

The data presented below in tabular form relates to an account of how many data points have been involved in the production of each type of Policy Characteristics graph as per Appendix 1,2, &3.

The trends presented by each of the graphs in each of the appendices are all the more thought provoking since the sample sizes are very large in all cases, but especially in the case of the actual dynamics depicted in Appendix 1.

Please note that Match 20 was excluded by Prozone by agreement in advance of their selection of the data utilised in this work and its issue to the author for confidential reasons.

		Appendix 1 Data			Appendix 2 Data				Optimisation Data		
Match	**Team**	**Lines in H1 Analysis**	**Lines in H2 Analysis**	**Lines in Combined H1 & H2 Analysis**	**Lines in Emergent Attack**	**Lines in Emergent Midfield**	**Lines in Emergent Defence**	**Lines in Emergent Whole Team**	**Lines in Optimal Attack**	**Lines in Optimal Midfield**	**Lines in Optimal Defence**
1	TA	198,791	195,092	325,711	7,035	15,363	19,091	40,964	35,493	43,174	39,798
	T1	197,332	200,620	320,639	7,317	15,987	18,565	41,214	N/a	N/a	N/a
2	TA	191,099	190,583	316,791	6,537	14,895	18,143	40,565	34,582	41,669	39,538
	T2	193,970	207,811	320,262	6,993	14,782	17,907	39,091	N/a	N/a	N/a
3	TA	181,351	181,323	317,669	6,119	14,572	16,766	39,931	34,453	42,600	36,490
	T3	193,899	197,095	313,937	6,928	14,796	15,913	36,892	N/a	N/a	N/a
4	TA	204,806	183,554	324,576	6,711	15,157	17,982	40,333	34,035	41,867	38,189
	T4	202,915	188,391	314,248	6,239	15,059	17,076	38,196	N/a	N/a	N/a
5	TA	189,695	205,030	321,247	6,873	15,344	17,676	39,774	34,444	42,695	38,941
	T5	192,257	197,516	320,666	6,909	14,982	17,962	39,494	N/a	N/a	N/a
6	TA	194,050	197,979	317,175	7,015	14,885	17,762	39,533	31,362	37,515	44,374
	T6	196,842	190,887	319,401	2,474	20,148	17,798	40,080	N/a	N/a	N/a
7	TA	187,678	190,068	309,551	6,551	15,030	17,698	38,944	35,201	40,896	40,170
	T7	190,312	194,049	305,893	6,585	10,640	22,500	39,335	N/a	N/a	N/a
8	TA	194,130	192,310	317,969	6,948	16,216	18,202	41,007	34,160	42,888	39,553
	T8	195,198	199,017	320,690	6,937	15,447	17,856	39,111	N/a	N/a	N/a
9	TA	187,398	188,070	315,626	N/a	N/a	N/a	N/a	N/a	N/a	N/a
	T9	177,672	185,292	297,820	N/a	N/a	N/a	N/a	N/a	N/a	N/a
10	TA	193,510	194,885	311,411	6,403	14,641	17,410	37,991	31,866	40,720	35,465
	T8	189,662	170,945	306,611	2,640	17,732	18,412	39,239	N/a	N/a	N/a
11	TA	185,874	187,475	312,010	10,959	11,033	17,186	39,047	38,322	38,471	37,593
	T9	186,935	196,357	310,111	6,041	15,496	17,055	37,970	N/a	N/a	N/a
12	TA	188,121	198,525	314,285	6,604	15,105	17,213	38,254	31,051	39,189	41,631
	T6	182,716	177,067	304,380	10,167	11,013	16,835	38,731	N/a	N/a	N/a

		Appendix 1 Data			Appendix 2 Data				Optimisation Data		
Match	**Team**	**Lines in H1 Analysis**	**Lines in H2 Analysis**	**Lines in Combined H1 & H2 Analysis**	**Lines in Emergent Attack**	**Lines in Emergent Midfield**	**Lines in Emergent Defence**	**Lines in Emergent Whole Team**	**Lines in Optimal Attack**	**Lines in Optimal Midfield**	**Lines in Optimal Defence**
13	TA	185,008	181,989	311,874	6,945	15,364	17,287	40,191	34,637	43,081	37,811
	T10	192,936	204,780	320,993	6,795	15,878	17,829	39,889	N/a	N/a	N/a
14	TA	190,340	200,661	321,655	6,936	15,914	18,493	41,520	35,951	44,320	40,095
	T11	203,981	204,154	327,755	6,993	15,368	18,783	40,223	N/a	N/a	N/a
15	TA	187,511	201,385	316,919	6,731	19,664	13,505	39,751	33,646	47,842	34,932
	T5	195,587	197,649	322,955	6,982	10,155	22,357	39,311	N/a	N/a	N/a
16	TA	191,911	202,255	319,822	6,882	15,343	17,840	39,134	35,578	43,823	39,950
	T12	191,690	202,266	321,562	6,926	15,611	19,033	41,769	N/a	N/a	N/a
17	TA	189,875	202,584	316,705	6,948	14,979	17,794	38,983	35,297	40,712	43,470
	T11	199,420	194,812	324,293	11,441	11,078	18,762	40,932	N/a	N/a	N/a
18	TA	192,393	197,855	312,656	6,924	14,744	29,304	38,619	34,971	37,221	37,474
	T13	191,272	177,898	306,061	6,526	9,733	22,444	38,708	N/a	N/a	N/a
19	TA	194,349	200,401	321,502	6,410	15,316	18,612	40,260	33,910	42,136	40,116
	T12	200,210	201,829	327,609	7,155	16,052	18,623	40,929	N/a	N/a	N/a
21	TA	192,363	201,059	315,968	6,595	15,146	17,184	38,256	33,442	41,471	38,512
	T15	187,927	193,215	322,161	6,539	15,204	17,411	39,652	N/a	N/a	N/a
22	TA	195,641	185,531	321,108	2,616	20,799	18,485	42,259	27,328	47,536	44,977
	T13	198,016	208,637	324,524	11,317	11,321	18,293	40,239	N/a	N/a	N/a
23	TA	181,162	193,338	304,387	6,922	14,933	16,254	37,136	33,093	40,081	40,201
	T16	182,749	197,523	310,882	6,272	14,993	17,342	38,638	N/a	N/a	N/a
24	TA	186,126	190,512	301,758	6,446	14,451	16,856	38,067	31,675	40,262	36,868
	T15	182,873	177,152	289,324	6,056	14,138	15,159	36,777	N/a	N/a	N/a

		Appendix 1 Data			Appendix 2 Data				Optimisation Data		
Match	**Team**	**Lines in H1 Analysis**	**Lines in H2 Analysis**	**Lines in Combined H1 & H2 Analysis**	**Lines in Emergent Attack**	**Lines in Emergent Midfield**	**Lines in Emergent Defence**	**Lines in Emergent Whole Team**	**Lines in Optimal Attack**	**Lines in Optimal Midfield**	**Lines in Optimal Defence**
25	TA	192,274	204,840	325,218	11,253	10,753	18,699	40,301	38,815	38,715	40,596
	T17	191,882	202,744	322,767	6,789	15,264	18,323	39,942	N/a	N/a	N/a
26	TA	188,374	195,116	311,478	6,672	15,188	17,325	38,466	32,277	40,650	38,010
	T4	193,826	193,336	317,253	2,746	19,077	17,801	38,609	N/a	N/a	N/a
27	TA	175,761	179,032	295,706	6,928	15,532	17,880	39,906	33,624	40,238	40,817
	T18	184,324	197,190	311,486	11,052	10,629	16,830	37,307	N/a	N/a	N/a
28	TA	192,330	196,248	322,160	6,902	15,328	18,252	40,719	35,876	41,584	42,302
	T19	195,851	209,418	324,673	11,075	11,090	18,559	40,140	N/a	N/a	N/a
29	TA	190,241	200,355	322,861	7,199	15,397	18,357	40,539	35,084	42,752	40,322
	T1	196,165	199,145	320,153	6,988	16,041	18,255	40,813	N/a	N/a	N/a
30	TA	195,706	201,155	319,940	6,631	15,358	17,777	39,421	35,597	42,597	38,817
	T14	197,376	190,633	318,811	7,034	14,998	18,225	40,359	N/a	N/a	N/a
31	TA	189,920	175,989	313,716	6,689	15,574	18,245	41,617	34,492	42,534	40,591
	T17	194,161	197,984	315,832	6,908	15,214	16,647	38,040	N/a	N/a	N/a
32	TA	191,267	196,993	321,716	11,345	11,271	18,374	40,713	38,649	39,004	39,906
	T18	194,541	205,449	321,026	6,961	15,943	17,225	39,489	N/a	N/a	N/a
33	TA	192,415	199,538	312,376	6,259	14,987	17,515	39,015	33,669	40,966	37,326
	T3	198,453	173,791	308,181	6,364	15,329	16,938	39,014	N/a	N/a	N/a
34	TA	187,297	188,676	304,480	14,989	6,810	17,762	38,903	41,167	33,705	38,677
	T16	190,529	187,677	304,305	6,761	14,635	17,221	38,106	N/a	N/a	N/a
35	TA	197,824	188,768	319,111	N/a	N/a	N/a	N/a	N/a	N/a	N/a
	T10	180,767	186,705	300,784	N/a	N/a	N/a	N/a	N/a	N/a	N/a
36	TA	193,059	195,507	320,891	7,012	16,086	18,244	40,986	33,489	42,564	38,300
	T19	192,311	192,974	311,201	7,074	16,082	16,017	39,116	N/a	N/a	N/a

		Appendix 1 Data			Appendix 2 Data				Optimisation Data		
Match	**Team**	**Lines in H1 Analysis**	**Lines in H2 Analysis**	**Lines in Combined H1 & H2 Analysis**	**Lines in Emergent Attack**	**Lines in Emergent Midfield**	**Lines in Emergent Defence**	**Lines in Emergent Whole Team**	**Lines in Optimal Attack**	**Lines in Optimal Midfield**	**Lines in Optimal Defence**
37	TA	186,011	188,399	305,708	6,487	14,545	17,225	37,785	34,491	40,874	38,640
	T2	188,325	199,476	314,672	6,492	14,693	16,971	37,784	N/a	N/a	N/a
38	TA	191,150	182,046	308,016	6,800	15,702	16,223	39,148	34,222	42,546	36,956
	T7	195,380	193,769	316,931	7,017	15,476	18,768	41,139	N/a	N/a	N/a
	Total	**14,167,073**	**14,350,379**	**23,332,604**	**498,769**	**1,031,509**	**1,260,316**	**2,764,316**	**1,205,949**	**1,448,898**	**1,377,408**
	Min	**175,761**	**170,945**	**289,324**	**2,474**	**6,810**	**13,505**	**36,777**	**27,328**	**33,705**	**34,932**
	Max	**204,806**	**209,418**	**327,755**	**14,989**	**20,799**	**29,304**	**42,259**	**41,167**	**47,842**	**44,977**
	Mean	**191,447**	**193,924**	**315,305**	**7,125**	**14,736**	**18,005**	**39,490**	**34,456**	**41,397**	**39,355**

Please Note:

N/a – denotes omission of graph from appendix due to technical issue, but nevertheless included in Appendix 1 to preserve sample size.
N/a – denotes that optimised emergent data for Team A opponent omitted since only Team A's data is of interest so as to discern trend over season.

Appendix 4 – Regression Line Parameters for each Team in each Match

This appendix details the whole set of data used for each team in each match. An abridged version of this was presented in Section 5.1. (Actual Dynamics) on p.165 as per Table 2.

Each match is represented by six lines of data in this appendix.

- The sub set of the first two lines in each set of six refer to the regression line parameters for both teams involved during the first half of the match, and are highlighted in blue.
- The sub set of the second two lines in each set of six refer to the regression line parameters for both teams involved during the second half of the match, and are highlighted in green.
- The sub set of the third two lines in each set of six refer to the regression line parameters for both teams involved during the both halves of the match taken as a contiguous data set, and are highlighted in pink.

Please note that Match 20 was excluded by Prozone by agreement in advance of their selection of the data utilised in this work and its issue to the author for confidential reasons.

Also please note that that Matches 9 and 35 have been included here since there was no technical difficulty relating to their actual dynamics in contrast to when their emergent dynamics were analysed (and were hence omitted from Appendix 4).

Match File	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Success	Information Content	Team A Home or Away?
m1-ta-H1	7.87	0.46	89.20	10.80	2	26.41	H
m1-t1-H1	8.01	0.47	89.60	10.40	0	26.63	
m1-ta-H2	8.45	0.50	90.40	9.60	1	27.66	H
m1-t1-H2	8.24	0.48	90.10	9.90	0	27.16	
m1-ta-H1 + H2	10.06	0.56	91.40	8.60	3	33.54	H
m1-t1-H1 + H2	10.22	0.57	91.10	8.90	0	34.07	
m2-ta- H1	7.79	0.46	89.00	11.00	1	26.38	H
m2-t2- H1	7.61	0.45	88.50	11.50	0	26.03	
m2-ta- H2	8.42	0.49	90.50	9.50	0	27.68	H
m2-t2- H2	7.54	0.44	88.40	11.60	1	25.88	
m2-ta- H1 + H2	9.84	0.54	89.90	10.10	1	33.44	H
m2-t2- H1 + H2	9.69	0.54	89.20	10.80	1	33.15	
m3-ta- H1	8.21	0.48	89.60	10.40	0	27.48	A
m3-t3- H1	7.61	0.45	88.40	11.60	0	26.06	
m3-ta- H2	8.90	0.52	91.30	8.70	0	28.94	A
m3-t3- H2	8.15	0.48	89.90	10.10	0	27.08	
m3-ta- H1 + H2	9.87	0.55	90.20	9.80	0	33.41	A
m3-t3- H1 + H2	9.96	0.55	90.00	10.00	0	33.74	
m4-ta- H1	8.48	0.49	90.50	9.50	2	27.80	A
m4-t4- H1	8.36	0.49	90.30	9.70	1	27.71	
m4-ta- H2	8.83	0.52	91.30	8.70	0	28.44	A
m4-t4- H2	8.11	0.48	89.80	10.20	1	26.92	
m4-ta- H1 + H2	10.37	0.57	91.60	8.40	2	34.58	A
m4-t4- H1 + H2	10.34	0.57	91.60	8.40	2	34.74	
m5-ta- H1	7.91	0.46	89.40	10.60	0	26.46	H
m5-t5- H1	7.79	0.46	89.20	10.80	1	26.15	
m5-ta- H2	8.19	0.48	89.90	10.10	0	27.13	H
m5-t5- H2	8.58	0.50	90.80	9.20	0	27.94	
m5-ta- H1 + H2	10.04	0.56	90.80	9.20	0	33.68	H
m5-t5- H1 + H2	10.11	0.56	91.20	8.80	1	33.71	
m6-ta- H1	7.97	0.47	89.50	10.50	1	26.64	A
m6-t6- H1	7.87	0.46	89.30	10.70	2	26.32	
m6-ta- H2	8.22	0.48	90.00	10.00	0	27.04	A
m6-t6- H2	8.59	0.50	90.80	9.20	0	27.87	
m6-ta- H1 + H2	10.13	0.56	90.80	9.20	1	33.89	A
m6-t6- H1 + H2	10.10	0.56	90.90	9.10	2	33.71	
m7-ta- H1	7.99	0.47	89.70	10.30	0	26.59	A
m7-t7- H1	7.79	0.46	89.10	10.90	0	26.29	
m7-ta- H2	9.28	0.54	92.00	8.00	0	29.70	A
m7-t7- H2	9.00	0.53	91.50	8.50	0	29.16	
m7-ta- H1 + H2	10.50	0.58	91.50	8.50	0	35.22	A
m7-t7- H1 + H2	10.49	0.58	91.10	8.90	0	35.53	

Match File	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Success	Information Content	Team A Home or Away?
m8-ta- H1	8.32	0.49	90.20	9.80	1	27.38	A
m8-t8- H1	8.27	0.49	90.20	9.80	0	27.21	
m8-ta- H2	8.76	0.51	91.10	8.90	2	28.39	A
m8-t8- H2	8.51	0.50	90.50	9.50	0	27.65	
m8-ta- H1 + H2	10.44	0.58	91.50	8.50	3	34.74	A
m8-t8- H1 + H2	10.41	0.58	91.80	8.20	0	34.50	
m9-ta- H1	8.20	0.48	90.00	10.00	0	27.08	A
m9-t9- H1	7.78	0.46	89.10	10.90	1	26.01	
m9-ta- H2	8.50	0.50	90.70	9.30	0	27.63	A
m9-t9- H2	7.80	0.46	89.20	10.80	2	25.99	
m9-ta- H1 + H2	10.08	0.56	91.40	8.60	0	33.50	A
m9-t9- H1 + H2	9.81	0.55	91.00	9.00	3	32.45	
m10-ta-H1	8.15	0.48	89.90	10.10	0	26.92	H
m10-t8- H1	7.89	0.46	89.40	10.60	1	26.41	
m10-ta- H2	8.30	0.49	90.20	9.80	1	27.36	H
m10-t8- H2	8.53	0.50	90.80	9.20	0	27.84	
m10-ta- H1 + H2	10.32	0.57	91.30	8.70	1	34.52	H
m10-t8- H1 + H2	9.85	0.55	91.00	9.00	1	32.86	
m11-ta- H1	8.12	0.48	89.90	10.10	0	26.84	H
m11-t9- H1	8.00	0.47	89.60	10.40	0	26.66	
m11-ta- H2	8.70	0.51	91.00	9.00	1	28.26	H
m11-t9- H2	8.23	0.48	90.10	9.90	0	27.18	
m11-ta- H1 + H2	10.18	0.57	91.40	8.60	1	33.90	H
m11-t9- H1 + H2	10.21	0.57	91.50	8.50	0	33.99	
m12-ta- H1	8.42	0.50	90.30	9.70	1	27.42	H
m12-t6- H1	8.33	0.49	90.20	9.80	1	27.20	
m12-ta- H2	8.27	0.48	90.20	9.80	0	27.12	H
m12-t6- H2	8.37	0.49	90.50	9.50	0	27.25	
m12-ta- H1 + H2	10.38	0.58	92.00	8.00	1	34.30	H
m12-t6- H1 + H2	10.09	0.56	91.90	8.10	1	33.17	
m13-ta- H1	8.36	0.49	90.30	9.70	1	27.57	A
m13-t10- H1	8.02	0.47	89.70	10.30	0	26.68	
m13-ta- H2	9.30	0.55	92.10	7.90	0	29.71	A
m13-t10- H2	8.14	0.48	89.80	10.20	1	27.11	
m13-ta- H1 + H2	10.37	0.57	91.30	8.70	1	34.79	A
m13-t10- H1 + H2	10.11	0.56	90.70	9.30	1	34.03	
m14-ta- H1	8.38	0.49	90.30	9.70	1	27.49	A
m14-t11- H1	7.67	0.45	88.80	11.20	0	26.02	
m14-ta- H2	8.30	0.48	90.20	9.80	0	27.49	A
m14-t11- H2	8.16	0.48	89.90	10.10	2	27.18	
m14-ta- H1 + H2	10.16	0.56	90.60	9.40	1	34.26	A
m14-t11- H1 + H2	9.98	0.55	90.20	9.80	2	33.78	

Match File	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Success	Information Content	Team A Home or Away?
m15-ta- H1	8.04	0.47	89.70	10.30	0	26.68	A
m15-t5- H1	7.61	0.45	88.70	11.30	2	25.80	
m15-ta- H2	7.89	0.46	89.30	10.70	1	26.38	A
m15-t5- H2	8.10	0.48	89.80	10.20	1	26.74	
m15-ta- H1 + H2	9.96	0.55	90.70	9.30	1	33.28	A
m15-t5- H1 + H2	9.81	0.54	90.70	9.30	3	32.76	
m16-ta- H1	8.23	0.48	90.10	9.90	0	27.08	H
m16-t12- H1	8.25	0.48	90.20	9.80	2	27.23	
m16-ta- H2	8.01	0.47	89.60	10.40	2	26.71	H
m16-t12- H2	8.10	0.47	89.30	10.70	2	27.15	
m16-ta- H1 + H2	10.19	0.56	91.10	8.90	2	34.08	H
m16-t12- H1 + H2	10.05	0.55	89.90	10.10	4	34.08	
m17-ta- H1	8.28	0.49	90.10	9.90	0	27.31	H
m17-t11- H1	7.86	0.46	89.20	10.80	2	26.43	
m17-ta- H2	7.91	0.46	89.30	10.70	1	26.54	H
m17-t11- H2	8.35	0.49	90.20	9.80	1	27.46	
m17-ta- H1 + H2	10.19	0.57	91.30	8.70	1	34.06	H
m17-t11- H1 + H2	9.94	0.55	90.20	9.80	3	33.57	
m18-ta- H1	7.98	0.47	89.60	10.40	0	26.56	H
m18-t13- H1	8.02	0.47	89.70	10.30	0	26.64	
m18-ta- H2	8.44	0.49	90.50	9.50	1	27.61	H
m18-t13- H2	8.56	0.51	90.90	9.10	0	27.70	
m18-ta- H1 + H2	10.29	0.57	90.90	9.10	1	34.48	H
m18-t13- H1 + H2	10.12	0.56	91.30	8.70	0	33.63	
m19-ta- H1	7.84	0.46	89.20	10.80	0	26.31	A
m19-t12- H1	7.51	0.44	88.40	11.60	1	25.74	
m19-ta- H2	7.96	0.47	89.50	10.50	1	26.53	A
m19-t12- H2	7.84	0.46	89.10	10.90	1	26.38	
m19-ta- H1 + H2	9.91	0.55	90.70	9.30	1	33.18	A
m19-t12- H1 + H2	9.70	0.54	90.20	9.80	2	32.70	
m21-ta- H1	7.95	0.47	89.50	10.50	1	26.56	H
m21-t15- H1	8.25	0.49	90.20	9.80	2	27.08	
m21-ta- H2	8.03	0.47	89.60	10.40	1	26.76	H
m21-t15- H2	8.36	0.49	90.40	9.60	0	27.52	
m21-ta- H1 + H2	10.09	0.56	90.70	9.30	2	33.86	H
m21-t15- H1 + H2	9.96	0.55	91.10	8.90	2	33.29	
m22-ta- H1	8.09	0.47	89.80	10.20	3	26.86	A
m22-t13- H1	7.96	0.47	89.60	10.40	1	26.57	
m22-ta- H2	8.94	0.52	91.30	8.70	0	29.07	A
m22-t13- H2	7.88	0.46	89.10	10.90	1	26.63	
m22-ta- H1 + H2	10.18	0.56	90.90	9.10	3	34.15	A
m22-t13- H1 + H2	10.06	0.56	90.20	9.80	2	33.94	

Match File	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Success	Information Content	Team A Home or Away?
m23-ta- H1	8.31	0.49	90.30	9.70	0	27.30	H
m23-t16- H1	8.28	0.49	90.20	9.80	0	27.26	
m23-ta- H2	8.30	0.49	90.20	9.80	0	27.34	H
m23-t16- H2	8.14	0.48	89.80	10.20	0	27.05	
m23-ta- H1 + H2	10.32	0.57	91.60	8.40	0	34.38	H
m23-t16- H1 + H2	10.09	0.56	90.30	9.70	0	33.99	
m24-ta- H1	8.18	0.48	89.90	10.10	0	27.28	A
m24-t15- H1	8.13	0.48	89.90	10.10	0	27.00	
m24-ta- H2	8.50	0.50	90.60	9.40	3	27.83	A
m24-t15- H2	8.28	0.49	90.40	9.60	1	27.10	
m24-ta- H1 + H2	10.29	0.57	90.20	9.80	3	35.10	A
m24-t15- H1 + H2	10.17	0.57	90.50	9.50	1	34.35	
m25-ta- H1	8.03	0.47	89.60	10.40	1	26.76	H
m25-t17- H1	8.02	0.47	89.70	10.30	0	26.69	
m25-ta- H2	8.12	0.47	89.80	10.20	0	26.81	H
m25-t17- H2	8.17	0.48	89.90	10.10	2	27.01	
m25-ta- H1 + H2	9.99	0.55	90.50	9.50	1	33.48	H
m25-t17- H1 + H2	10.05	0.56	90.80	9.20	2	33.61	
m26-ta- H1	7.94	0.47	89.50	10.50	0	26.50	H
m26-t4- H1	7.70	0.45	89.00	11.00	0	25.95	
m26-ta- H2	8.09	0.47	89.80	10.20	0	26.79	H
m26-t4- H2	8.19	0.48	90.10	9.90	0	26.99	
m26-ta- H1 + H2	10.03	0.56	90.80	9.20	0	33.53	H
m26-t4- H1 + H2	9.88	0.55	90.60	9.40	0	33.07	
m27-ta- H1	8.331	0.4916	90.2	9.80	1	27.34	H
m27-t18- H1	8.45	0.50	90.20	9.80	0	27.45	
m27-ta-H2	8.377	0.4917	90.4	9.60	0	27.52	H
m27-t18- H2	8.03	0.47	89.70	10.30	0	26.70	
m27-ta- H1 + H2	10.17	0.5651	91.6	8.40	1	33.90	H
m27-t18- H1 + H2	10.27	0.57	92.00	8.00	0	33.93	
m28-ta- H1	7.85	0.46	89.30	10.70	1	26.35	A
m28-t19- H1	7.60	0.45	88.60	11.40	0	25.97	
m28-ta- H2	8.28	0.48	90.20	9.80	0	27.24	A
m28-t19- H2	7.64	0.45	88.70	11.30	0	25.99	
m28-ta- H1 + H2	9.87	0.55	90.40	9.60	1	33.18	A
m28-t19- H1 + H2	9.73	0.54	89.50	10.50	0	33.04	
m29-ta- H1	8.07	0.47	89.80	10.20	1	26.74	A
m29-t1- H1	7.79	0.46	89.10	10.90	1	26.19	
m29-ta- H2	7.87	0.46	89.20	10.80	0	26.23	A
m29-t1- H2	7.93	0.46	89.30	10.70	1	26.42	
m29-ta- H1 + H2	9.88	0.55	91.00	9.00	1	32.85	A
m29-t1- H1 + H2	9.92	0.55	90.30	9.70	2	33.16	

Match File	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Success	Information Content	Team A Home or Away?
m30-ta- H1	8.15	0.48	89.90	10.10	0	26.90	H
m30-t14- H1	8.03	0.47	89.60	10.40	0	26.76	
m30-ta- H2	7.99	0.47	89.50	10.50	0	26.70	H
m30-t14- H2	8.54	0.50	90.70	9.30	1	27.92	
m30-ta- H1 + H2	10.15	0.56	91.10	8.90	0	33.94	H
m30-t14- H1 + H2	10.14	0.56	90.60	9.40	1	34.09	
m31-ta- H1	8.07	0.47	89.50	10.50	0	26.97	A
m31-t17- H1	7.85	0.46	89.30	10.70	0	26.41	
m31-ta- H2	8.95	0.53	91.30	8.70	0	28.73	A
m31-t17- H2	8.13	0.48	89.90	10.10	1	27.01	
m31-ta- H1 + H2	9.97	0.55	90.40	9.60	0	33.53	A
m31-t17- H1 + H2	10.05	0.56	90.60	9.40	1	33.85	
m32-ta- H1	7.96	0.47	89.50	10.50	1	26.51	A
m32-t18- H1	7.75	0.45	89.10	10.90	0	26.12	
m32-ta- H2	8.36	0.49	90.40	9.60	0	27.54	A
m32-t18- H2	7.97	0.47	89.50	10.50	2	26.68	
m32-ta- H1 + H2	9.95	0.55	90.60	9.40	1	33.49	A
m32-t18- H1 + H2	9.95	0.55	90.40	9.60	2	33.55	
m33-ta- H1	7.80	0.46	89.40	10.60	0	24.50	H
m33-t3- H1	7.49	0.44	88.20	11.80	1	25.75	
m33-ta- H2	8.17	0.48	89.90	10.10	0	27.00	H
m33-t3- H2	8.83	0.52	91.30	8.70	0	28.37	
m33-ta- H1 + H2	10.12	0.56	90.10	9.90	0	34.11	H
m33-t3- H1 + H2	9.95	0.55	90.60	9.40	1	33.45	
m34-ta- H1	7.99	0.47	89.50	10.50	1	26.72	A
m34-t16- H1	7.84	0.46	89.00	11.00	1	26.39	
m34-ta- H2	8.80	0.52	91.20	8.80	0	28.42	A
m34-t16- H2	8.84	0.52	91.30	8.70	2	28.57	
m34-ta- H1 + H2	10.37	0.58	91.10	8.90	1	34.81	A
m34-t16- H1 + H2	10.37	0.58	90.90	9.10	3	34.86	
m35-ta- H1	7.65	0.45	88.70	11.30	1	26.07	H
m35-t10- H1	7.99	0.47	89.60	10.40	0	26.72	
m35-ta- H2	8.49	0.50	90.50	9.50	2	27.43	H
m35-t10- H2	8.20	0.48	89.9	10.10	0	26.94	
m35-ta- H1 + H2	9.97	0.55	91.10	8.90	3	33.21	H
m35-t10- H1 + H2	10.12	0.5618	91.2	8.80	0	33.76	
m36-ta- H1	7.76	0.46	89.10	10.90	0	26.08	H
m36-t19- H1	7.44	0.44	88.2	11.80	0	25.51	
m36-ta- H2	8.02	0.47	89.60	10.40	1	26.67	H
m36-t19- H2	7.90	0.46	89.3	10.70	1	26.39	
m36-ta- H1 + H2	9.76	0.54	90.40	9.60	1	32.74	H
m36-t19- H1 + H2	9.66	0.53	89.8	10.20	1	32.58	

Match File	Y Intercept	Gradient	Regression Coefficient	Disorganisation	Success	Information Content	Team A Home or Away?
m37-ta- H1	8.02	0.47	89.70	10.30	0	26.73	A
m37-t2- H1	8.00	0.47	89.70	10.30	2	26.53	
m37-ta- H2	8.15	0.48	89.90	10.10	0	27.08	A
m37-t2- H2	7.62	0.45	88.70	11.30	1	25.97	
m37-ta- H1 + H2	10.02	0.56	90.70	9.30	0	33.73	A
m37-t2- H1 + H2	9.80	0.54	90.20	9.80	3	33.05	
m38-ta- H1	8.00	0.47	89.60	10.40	0	26.62	H
m38-t7- H1	8.06	0.47	89.70	10.30	1	26.87	
m38-ta- H2	8.00	0.47	89.60	10.40	1	26.43	H
m38-t7- H2	8.24	0.48	90.10	9.90	0	27.32	
m38-ta- H1 + H2	9.91	0.55	91.10	8.90	1	32.96	H
m38-t7- H1 + H2	10.08	0.56	90.50	9.50	1	34.03	

Appendix 5 – Actual Dynamics and Match Outcomes

The following tests were carried out for Team A's actual dynamics. This is to say that the regression lines associated with the scatter plots of the actual player movement about the pitch as recorded by the Prozone 3 system.

	All Matches			
	Half 1		Half 2	
	Home	Away	Home	Away
Goals Scored	A1	B1	A4	B4
Goals Conceded	A2	B2	A5	B5
Goal Difference	A3	B3	A6	B6

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.747
R Square	0.559
Adjusted R Square	0.433
Standard Error	0.457
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	3.705	0.926	4.431	0.016
Residual	14.000	2.927	0.209		
Total	18.000	6.632			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	441.779	119.428	3.699	0.002	185.632	697.927	185.632	697.927
Y Intercept	11.521	8.692	1.326	0.206	-7.121	30.164	-7.121	30.164
Gradient	27.059	143.385	0.189	0.853	-280.471	334.589	-280.471	334.589
Regression Coefficient	-5.921	1.584	-3.738	0.002	-9.317	-2.524	-9.317	-2.524
Information Content	-0.599	0.435	-1.375	0.191	-1.532	0.335	-1.532	0.335

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	0.98	0.97	1.00		
Information Content	0.80	0.82	0.69	1.00	
Goals Scored	-0.16	-0.15	-0.30	0.04	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.399
R Square	0.160
Adjusted R Square	-0.081
Standard Error	0.799
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.696	0.424	0.665	0.627
Residual	14.000	8.935	0.638		
Total	18.000	10.632			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-91.043	208.673	-0.436	0.669	-538.603	356.517	-538.603	356.517
Y Intercept	12.762	15.188	0.840	0.415	-19.812	45.336	-19.812	45.336
Gradient	-220.667	250.533	-0.881	0.393	-758.006	316.671	-758.006	316.671
Regression Coefficient	1.031	2.767	0.372	0.715	-4.904	6.965	-4.904	6.965
Information Content	0.032	0.761	0.042	0.967	-1.599	1.664	-1.599	1.664

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	0.98	0.97	1.00		
Information Content	0.80	0.82	0.69	1.00	
Goals Conceded	0.27	0.25	0.30	0.10	1.00

A1

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
1.00	1.00	7.87	0.46	89.20	26.41	2
1.00	1.00	7.79	0.46	89.00	26.38	1
1.00	1.00	7.91	0.46	89.40	26.46	0
1.00	1.00	8.15	0.48	89.90	26.92	0
1.00	1.00	8.12	0.48	89.90	26.84	0
1.00	1.00	8.42	0.50	90.30	27.42	1
1.00	1.00	8.23	0.48	90.10	27.08	0
1.00	1.00	8.28	0.49	90.10	27.31	0
1.00	1.00	7.98	0.47	89.60	26.56	0
1.00	1.00	7.95	0.47	89.50	26.56	1
1.00	1.00	8.31	0.49	90.30	27.30	0
1.00	1.00	8.03	0.47	89.60	26.76	1
1.00	1.00	7.94	0.47	89.50	26.50	0
1.00	1.00	8.33	0.49	90.2	27.34	1
1.00	1.00	8.15	0.48	89.90	26.90	0
1.00	1.00	7.80	0.46	89.40	24.50	0
1.00	1.00	7.65	0.45	88.70	26.07	1
1.00	1.00	7.76	0.46	89.10	26.08	0
1.00	1.00	8.00	0.47	89.60	26.62	0

A2

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
1.00	1.00	7.87	0.46	89.20	26.41	0
1.00	1.00	7.79	0.46	89.00	26.38	0
1.00	1.00	7.91	0.46	89.40	26.46	1
1.00	1.00	8.15	0.48	89.90	26.92	1
1.00	1.00	8.12	0.48	89.90	26.84	0
1.00	1.00	8.42	0.50	90.30	27.42	1
1.00	1.00	8.23	0.48	90.10	27.08	2
1.00	1.00	8.28	0.49	90.10	27.31	2
1.00	1.00	7.98	0.47	89.60	26.56	0
1.00	1.00	7.95	0.47	89.50	26.56	2
1.00	1.00	8.31	0.49	90.30	27.30	0
1.00	1.00	8.03	0.47	89.60	26.76	0
1.00	1.00	7.94	0.47	89.50	26.50	0
1.00	1.00	8.33	0.49	90.2	27.34	0
1.00	1.00	8.15	0.48	89.90	26.90	0
1.00	1.00	7.80	0.46	89.40	24.50	1
1.00	1.00	7.65	0.45	88.70	26.07	0
1.00	1.00	7.76	0.46	89.10	26.08	0
1.00	1.00	8.00	0.47	89.60	26.62	1

A3

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
1.00	1.00	7.87	0.46	89.20	26.41	2
1.00	1.00	7.79	0.46	89.00	26.38	1
1.00	1.00	7.91	0.46	89.40	26.46	-1
1.00	1.00	8.15	0.48	89.90	26.92	-1
1.00	1.00	8.12	0.48	89.90	26.84	0
1.00	1.00	8.42	0.50	90.30	27.42	0
1.00	1.00	8.23	0.48	90.10	27.08	-2
1.00	1.00	8.28	0.49	90.10	27.31	-2
1.00	1.00	7.98	0.47	89.60	26.56	0
1.00	1.00	7.95	0.47	89.50	26.56	-1
1.00	1.00	8.31	0.49	90.30	27.30	0
1.00	1.00	8.03	0.47	89.60	26.76	1
1.00	1.00	7.94	0.47	89.50	26.50	0
1.00	1.00	8.33	0.49	90.2	27.34	1
1.00	1.00	8.15	0.48	89.90	26.90	0
1.00	1.00	7.80	0.46	89.40	24.50	-1
1.00	1.00	7.65	0.45	88.70	26.07	1
1.00	1.00	7.76	0.46	89.10	26.08	0
1.00	1.00	8.00	0.47	89.60	26.62	-1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.609
R Square	0.370
Adjusted R Square	0.191
Standard Error	0.961
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	7.604	1.901	2.059	0.141
Residual	14.000	12.923	0.923		
Total	18.000	20.526			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	532.822	250.952	2.123	0.052	-5.416	1071.061	-5.416	1071.061
Y Intercept	-1.241	18.265	-0.068	0.947	-40.414	37.933	-40.414	37.933
Gradient	247.727	301.292	0.822	0.425	-398.480	893.934	-398.480	893.934
Regression Coefficient	-6.951	3.328	-2.089	0.055	-14.089	0.186	-14.089	0.186
Information Content	-0.631	0.915	-0.690	0.502	-2.593	1.331	-2.593	1.331

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	0.98	0.97	1.00		
Information Content	0.80	0.82	0.69	1.00	
Goal Difference	-0.28	-0.27	-0.38	-0.04	1.00

A4

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
2.00	1.00	8.45	0.50	90.40	27.66	1
2.00	1.00	8.42	0.49	90.50	27.68	0
2.00	1.00	8.19	0.48	89.90	27.13	0
2.00	1.00	8.30	0.49	90.20	27.36	1
2.00	1.00	8.70	0.51	91.00	28.26	1
2.00	1.00	8.27	0.48	90.20	27.12	0
2.00	1.00	8.01	0.47	89.60	26.71	2
2.00	1.00	7.91	0.46	89.30	26.54	1
2.00	1.00	8.44	0.49	90.50	27.61	1
2.00	1.00	8.03	0.47	89.60	26.76	1
2.00	1.00	8.30	0.49	90.20	27.34	0
2.00	1.00	8.12	0.47	89.80	26.81	0
2.00	1.00	8.09	0.47	89.80	26.79	0
2.00	1.00	8.38	0.49	90.4	27.52	0
2.00	1.00	7.99	0.47	89.50	26.70	0
2.00	1.00	8.17	0.48	89.90	27.00	0
2.00	1.00	8.49	0.50	90.50	27.43	2
2.00	1.00	8.02	0.47	89.60	26.67	1
2.00	1.00	8.00	0.47	89.60	26.43	1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.463
R Square	0.214
Adjusted R Square	-0.010
Standard Error	0.687
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.805	0.451	0.955	0.462
Residual	14.000	6.616	0.473		
Total	18.000	8.421			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	366.797	227.393	1.613	0.129	-120.912	854.506	-120.912	854.506
Y Intercept	11.226	14.041	0.799	0.437	-18.890	41.341	-18.890	41.341
Gradient	40.242	156.120	0.258	0.800	-294.602	375.085	-294.602	375.085
Regression Coefficient	-4.837	3.104	-1.558	0.142	-11.495	1.821	-11.495	1.821
Information Content	-1.564	2.037	-0.768	0.455	-5.932	2.805	-5.932	2.805

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.99	0.99	1.00		
Information Content	0.98	0.96	0.97	1.00	
Goals Scored	0.06	0.08	0.02	0.00	1.00

A5

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
2.00	1.00	8.45	0.50	90.40	27.66	0
2.00	1.00	8.42	0.49	90.50	27.68	1
2.00	1.00	8.19	0.48	89.90	27.13	0
2.00	1.00	8.30	0.49	90.20	27.36	0
2.00	1.00	8.70	0.51	91.00	28.26	0
2.00	1.00	8.27	0.48	90.20	27.12	0
2.00	1.00	8.01	0.47	89.60	26.71	2
2.00	1.00	7.91	0.46	89.30	26.54	1
2.00	1.00	8.44	0.49	90.50	27.61	0
2.00	1.00	8.03	0.47	89.60	26.76	0
2.00	1.00	8.30	0.49	90.20	27.34	0
2.00	1.00	8.12	0.47	89.80	26.81	2
2.00	1.00	8.09	0.47	89.80	26.79	0
2.00	1.00	8.38	0.49	90.4	27.52	0
2.00	1.00	7.99	0.47	89.50	26.70	1
2.00	1.00	8.17	0.48	89.90	27.00	0
2.00	1.00	8.49	0.50	90.50	27.43	0
2.00	1.00	8.02	0.47	89.60	26.67	1
2.00	1.00	8.00	0.47	89.60	26.43	0

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.555
R Square	0.308
Adjusted R Square	0.110
Standard Error	0.653
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	2.656	0.664	1.555	0.240
Residual	14.000	5.976	0.427		
Total	18.000	8.632			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-17.911	216.120	-0.083	0.935	-481.443	445.621	-481.443	445.621
Y Intercept	10.033	13.345	0.752	0.465	-18.590	38.655	-18.590	38.655
Gradient	-187.126	148.381	-1.261	0.228	-505.370	131.119	-505.370	131.119
Regression Coefficient	0.449	2.950	0.152	0.881	-5.878	6.777	-5.878	6.777
Information Content	-0.532	1.936	-0.275	0.787	-4.684	3.620	-4.684	3.620

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.99	0.99	1.00		
Information Content	0.98	0.96	0.97	1.00	
Goals Conceded	-0.45	-0.48	-0.45	-0.41	1.00

A6

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
2.00	1.00	8.45	0.50	90.40	27.66	1
2.00	1.00	8.42	0.49	90.50	27.68	-1
2.00	1.00	8.19	0.48	89.90	27.13	0
2.00	1.00	8.30	0.49	90.20	27.36	1
2.00	1.00	8.70	0.51	91.00	28.26	1
2.00	1.00	8.27	0.48	90.20	27.12	0
2.00	1.00	8.01	0.47	89.60	26.71	0
2.00	1.00	7.91	0.46	89.30	26.54	0
2.00	1.00	8.44	0.49	90.50	27.61	1
2.00	1.00	8.03	0.47	89.60	26.76	1
2.00	1.00	8.30	0.49	90.20	27.34	0
2.00	1.00	8.12	0.47	89.80	26.81	-2
2.00	1.00	8.09	0.47	89.80	26.79	0
2.00	1.00	8.38	0.49	90.4	27.52	0
2.00	1.00	7.99	0.47	89.50	26.70	-1
2.00	1.00	8.17	0.48	89.90	27.00	0
2.00	1.00	8.49	0.50	90.50	27.43	2
2.00	1.00	8.02	0.47	89.60	26.67	0
2.00	1.00	8.00	0.47	89.60	26.43	1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.630
R Square	0.397
Adjusted R Square	0.225
Standard Error	0.808
Observations	19.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	6.025	1.506	2.309	0.109
Residual	14.000	9.133	0.652		
Total	18.000	15.158			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	384.709	267.170	1.440	0.172	-188.315	957.732	-188.315	957.732
Y Intercept	1.193	16.497	0.072	0.943	-34.190	36.577	-34.190	36.577
Gradient	227.368	183.430	1.240	0.236	-166.050	620.785	-166.050	620.785
Regression Coefficient	-5.286	3.647	-1.449	0.169	-13.109	2.536	-13.109	2.536
Information Content	-1.032	2.393	-0.431	0.673	-6.164	4.101	-6.164	4.101

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.99	0.99	1.00		
Information Content	0.98	0.96	0.97	1.00	
Goal Difference	0.38	0.42	0.35	0.30	1.00

B1

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
1.00	2.00	8.21	0.48	89.60	27.48	0
1.00	2.00	8.48	0.49	90.50	27.80	2
1.00	2.00	7.97	0.47	89.50	26.64	1
1.00	2.00	7.99	0.47	89.70	26.59	0
1.00	2.00	8.32	0.49	90.20	27.38	1
1.00	2.00	8.20	0.48	90.00	27.08	0
1.00	2.00	8.36	0.49	90.30	27.57	1
1.00	2.00	8.38	0.49	90.30	27.49	1
1.00	2.00	8.04	0.47	89.70	26.68	0
1.00	2.00	7.84	0.46	89.20	26.31	0
1.00	2.00	8.09	0.47	89.80	26.86	3
1.00	2.00	8.18	0.48	89.90	27.28	0
1.00	2.00	7.85	0.46	89.30	26.35	1
1.00	2.00	8.07	0.47	89.80	26.74	1
1.00	2.00	8.07	0.47	89.50	26.97	0
1.00	2.00	7.96	0.47	89.50	26.51	1
1.00	2.00	7.99	0.47	89.50	26.72	1
1.00	2.00	8.02	0.47	89.70	26.73	0

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.753
R Square	0.566
Adjusted R Square	0.433
Standard Error	0.622
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	6.578	1.644	4.247	0.020
Residual	13.000	5.033	0.387		
Total	17.000	11.611			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*r 9*	*Upper 95.0%*
Intercept	-238.215	189.865	-1.255	0.232	-648.394	171.964	#	171.964
Y Intercept	24.286	11.538	2.105	0.055	-0.640	49.212	#	49.212
Gradient	-519.577	146.879	-3.537	0.004	-836.889	-202.265	#	-202.265
Regression Coefficient	3.273	2.338	1.400	0.185	-1.777	8.323	#	8.323
Information Content	-0.171	2.616	-0.065	0.949	-5.823	5.481	#	5.481

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.94	0.95	1.00		
Information Content	0.97	0.96	0.86	1.00	
Goals Scored	0.26	0.20	0.33	0.19	1.00

B2

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
1.00	2.00	8.21	0.48	89.60	27.48	0
1.00	2.00	8.48	0.49	90.50	27.80	1
1.00	2.00	7.97	0.47	89.50	26.64	2
1.00	2.00	7.99	0.47	89.70	26.59	0
1.00	2.00	8.32	0.49	90.20	27.38	0
1.00	2.00	8.20	0.48	90.00	27.08	1
1.00	2.00	8.36	0.49	90.30	27.57	0
1.00	2.00	8.38	0.49	90.30	27.49	0
1.00	2.00	8.04	0.47	89.70	26.68	2
1.00	2.00	7.84	0.46	89.20	26.31	1
1.00	2.00	8.09	0.47	89.80	26.86	1
1.00	2.00	8.18	0.48	89.90	27.28	0
1.00	2.00	7.85	0.46	89.30	26.35	0
1.00	2.00	8.07	0.47	89.80	26.74	1
1.00	2.00	8.07	0.47	89.50	26.97	0
1.00	2.00	7.96	0.47	89.50	26.51	0
1.00	2.00	7.99	0.47	89.50	26.72	1
1.00	2.00	8.02	0.47	89.70	26.73	2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.391
R Square	0.153
Adjusted R Square	-0.107
Standard Error	0.807
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.531	0.383	0.588	0.677
Residual	13.000	8.469	0.651		
Total	17.000	10.000			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-91.058	246.278	-0.370	0.718	-623.110	440.995	-623.110	440.995
Y Intercept	-0.054	14.966	-0.004	0.997	-32.385	32.278	-32.385	32.278
Gradient	-38.281	190.519	-0.201	0.844	-449.873	373.311	-449.873	373.311
Regression Coefficient	1.433	3.032	0.473	0.644	-5.118	7.984	-5.118	7.984
Information Content	-0.677	3.393	-0.200	0.845	-8.008	6.654	-8.008	6.654

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.94	0.95	1.00		
Information Content	0.97	0.96	0.86	1.00	
Goals Conceded	-0.26	-0.26	-0.16	-0.32	1.00

B3

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
1.00	2.00	8.21	0.48	89.60	27.48	0
1.00	2.00	8.48	0.49	90.50	27.80	1
1.00	2.00	7.97	0.47	89.50	26.64	-1
1.00	2.00	7.99	0.47	89.70	26.59	0
1.00	2.00	8.32	0.49	90.20	27.38	1
1.00	2.00	8.20	0.48	90.00	27.08	-1
1.00	2.00	8.36	0.49	90.30	27.57	1
1.00	2.00	8.38	0.49	90.30	27.49	1
1.00	2.00	8.04	0.47	89.70	26.68	-2
1.00	2.00	7.84	0.46	89.20	26.31	-1
1.00	2.00	8.09	0.47	89.80	26.86	2
1.00	2.00	8.18	0.48	89.90	27.28	0
1.00	2.00	7.85	0.46	89.30	26.35	1
1.00	2.00	8.07	0.47	89.80	26.74	0
1.00	2.00	8.07	0.47	89.50	26.97	0
1.00	2.00	7.96	0.47	89.50	26.51	1
1.00	2.00	7.99	0.47	89.50	26.72	0
1.00	2.00	8.02	0.47	89.70	26.73	-2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.583
R Square	0.340
Adjusted R Square	0.137
Standard Error	1.031
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	7.125	1.781	1.676	0.215
Residual	13.000	13.819	1.063		
Total	17.000	20.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-147.157	314.596	-0.468	0.648	-826.800	532.486	-826.800	532.486
Y Intercept	24.340	19.117	1.273	0.225	-16.961	65.640	-16.961	65.640
Gradient	-481.296	243.369	-1.978	0.070	-1007.064	44.472	-1007.064	44.472
Regression Coefficient	1.840	3.873	0.475	0.643	-6.528	10.208	-6.528	10.208
Information Content	0.506	4.335	0.117	0.909	-8.859	9.871	-8.859	9.871

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	0.99	1.00			
Regression Coefficient	0.94	0.95	1.00		
Information Content	0.97	0.96	0.86	1.00	
Goal Difference	0.37	0.33	0.35	0.36	1.00

B4

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
2.00	2.00	8.90	0.52	91.30	28.94	0
2.00	2.00	8.83	0.52	91.30	28.44	0
2.00	2.00	8.22	0.48	90.00	27.04	0
2.00	2.00	9.28	0.54	92.00	29.70	0
2.00	2.00	8.76	0.51	91.10	28.39	2
2.00	2.00	8.50	0.50	90.70	27.63	0
2.00	2.00	9.30	0.55	92.10	29.71	0
2.00	2.00	8.30	0.48	90.20	27.49	0
2.00	2.00	7.89	0.46	89.30	26.38	1
2.00	2.00	7.96	0.47	89.50	26.53	1
2.00	2.00	8.94	0.52	91.30	29.07	0
2.00	2.00	8.50	0.50	90.60	27.83	3
2.00	2.00	8.28	0.48	90.20	27.24	0
2.00	2.00	7.87	0.46	89.20	26.23	0
2.00	2.00	8.95	0.53	91.30	28.73	0
2.00	2.00	8.36	0.49	90.40	27.54	0
2.00	2.00	8.80	0.52	91.20	28.42	0
2.00	2.00	8.15	0.48	89.90	27.08	0

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.317
R Square	0.101
Adjusted R Square	-0.176
Standard Error	0.922
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.236	0.309	0.364	0.830
Residual	13.000	11.042	0.849		
Total	17.000	12.278			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-4.005	214.309	-0.019	0.985	-466.992	458.983	-466.992	458.983
Y Intercept	22.506	24.147	0.932	0.368	-29.662	74.673	-29.662	74.673
Gradient	-304.238	286.796	-1.061	0.308	-923.823	315.347	-923.823	315.347
Regression Coefficient	0.262	2.810	0.093	0.927	-5.808	6.332	-5.808	6.332
Information Content	-2.120	2.923	-0.725	0.481	-8.436	4.196	-8.436	4.196

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	1.00	1.00	1.00		
Information Content	0.99	0.99	0.99	1.00	
Goals Scored	-0.14	-0.15	-0.14	-0.14	1.00

B5

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
2.00	2.00	8.90	0.52	91.30	28.94	0
2.00	2.00	8.83	0.52	91.30	28.44	1
2.00	2.00	8.22	0.48	90.00	27.04	0
2.00	2.00	9.28	0.54	92.00	29.70	0
2.00	2.00	8.76	0.51	91.10	28.39	0
2.00	2.00	8.50	0.50	90.70	27.63	2
2.00	2.00	9.30	0.55	92.10	29.71	1
2.00	2.00	8.30	0.48	90.20	27.49	2
2.00	2.00	7.89	0.46	89.30	26.38	1
2.00	2.00	7.96	0.47	89.50	26.53	1
2.00	2.00	8.94	0.52	91.30	29.07	1
2.00	2.00	8.50	0.50	90.60	27.83	1
2.00	2.00	8.28	0.48	90.20	27.24	0
2.00	2.00	7.87	0.46	89.20	26.23	1
2.00	2.00	8.95	0.53	91.30	28.73	1
2.00	2.00	8.36	0.49	90.40	27.54	2
2.00	2.00	8.80	0.52	91.20	28.42	2
2.00	2.00	8.15	0.48	89.90	27.08	1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.411
R Square	0.169
Adjusted R Square	-0.086
Standard Error	0.756
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.513	0.378	0.662	0.629
Residual	13.000	7.431	0.572		
Total	17.000	8.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	-244.199	175.811	-1.389	0.188	-624.016	135.619	-624.016	135.619
Y Intercept	-16.910	19.810	-0.854	0.409	-59.706	25.887	-59.706	25.887
Gradient	127.716	235.277	0.543	0.596	-380.569	636.000	-380.569	636.000
Regression Coefficient	3.240	2.305	1.406	0.183	-1.739	8.220	-1.739	8.220
Information Content	1.142	2.398	0.476	0.642	-4.039	6.323	-4.039	6.323

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	1.00	1.00	1.00		
Information Content	0.99	0.99	0.99	1.00	
Goals Conceded	-0.17	-0.16	-0.14	-0.17	1.00

B6

Half	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
2.00	2.00	8.90	0.52	91.30	28.94	0
2.00	2.00	8.83	0.52	91.30	28.44	-1
2.00	2.00	8.22	0.48	90.00	27.04	0
2.00	2.00	9.28	0.54	92.00	29.70	0
2.00	2.00	8.76	0.51	91.10	28.39	2
2.00	2.00	8.50	0.50	90.70	27.63	-2
2.00	2.00	9.30	0.55	92.10	29.71	-1
2.00	2.00	8.30	0.48	90.20	27.49	-2
2.00	2.00	7.89	0.46	89.30	26.38	0
2.00	2.00	7.96	0.47	89.50	26.53	0
2.00	2.00	8.94	0.52	91.30	29.07	-1
2.00	2.00	8.50	0.50	90.60	27.83	2
2.00	2.00	8.28	0.48	90.20	27.24	0
2.00	2.00	7.87	0.46	89.20	26.23	-1
2.00	2.00	8.95	0.53	91.30	28.73	-1
2.00	2.00	8.36	0.49	90.40	27.54	-2
2.00	2.00	8.80	0.52	91.20	28.42	-2
2.00	2.00	8.15	0.48	89.90	27.08	-1

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.331
R Square	0.109
Adjusted R Square	-0.165
Standard Error	1.294
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	2.676	0.669	0.400	0.806
Residual	13.000	21.768	1.674		
Total	17.000	24.444			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*Upper 95.0%*
Intercept	240.194	300.903	0.798	0.439	-409.867	890.255	-409.867	890.255
Y Intercept	39.415	33.904	1.163	0.266	-33.831	112.661	-33.831	112.661
Gradient	-431.953	402.678	-1.073	0.303	-1301.887	437.980	-1301.887	437.980
Regression Coefficient	-2.978	3.945	-0.755	0.464	-11.501	5.545	-11.501	5.545
Information Content	-3.262	4.105	-0.795	0.441	-12.130	5.605	-12.130	5.605

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	1.00	1.00	1.00		
Information Content	0.99	0.99	0.99	1.00	
Goal Difference	0.00	-0.01	-0.01	0.01	1.00

Appendix 6 – Emergent Dynamics and Match Outcomes

The following tests were carried out for Team A's emergent dynamics. This is to say that the regression lines associated with the scatter plots of the emergent policy centroids, as determined by the movement of each player as recorded by the Prozone 3 system, that correspond to the emergent policies of Attack, Midfield, Defence and Whole team.

	Subgroup (VSM Recursion) Centroid							
	Attack		Midfield		Defence		Whole Team	
	Home	Away	Home	Away	Home	Away	Home	Away
Goals Scored	D1	D4	E1	E4	F1	F4	G1	G4
Goals Conceded	D2	D5	E2	E5	F2	F5	G2	G5
Goal Difference	D3	D6	E3	E6	F3	F6	G3	G6

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.89	-0.88	1.00		
Information Content	-0.32	-0.38	0.12	1.00	
Goals Scored	-0.01	-0.01	-0.04	-0.04	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.216
R Square	0.046
Adjusted R Square	-0.247
Standard Error	0.896
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	0.508	0.127	0.158	0.956
Residual	13.000	10.436	0.803		
Total	17.000	10.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-12.258	35.695	-0.343	0.737	-89.372	64.857	-89.372	64.857
Y Intercept	5.175	9.854	0.525	0.608	-16.113	26.462	-16.113	26.462
Gradient	-56.255	102.382	-0.549	0.592	-277.438	164.928	-277.438	164.928
Regression Coefficient	-0.035	0.051	-0.688	0.503	-0.144	0.075	-0.144	0.075
Information Content	-0.034	0.054	-0.643	0.532	-0.150	0.081	-0.150	0.081

D1

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m1	ta	a	1.00	9.67	0.50	93.90	153.18	3
m2	ta	a	1.00	12.04	0.74	70.90	152.63	1
m5	ta	a	1.00	9.68	0.50	93.10	154.34	0
m10	ta	a	1.00	11.56	0.69	80.20	153.66	1
m11	ta	a	1.00	13.46	0.89	72.80	106.65	1
m12	ta	a	1.00	9.96	0.53	96.00	151.92	1
m16	ta	a	1.00	12.59	0.79	68.10	151.21	2
m17	ta	a	1.00	9.65	0.50	94.00	152.75	1
m18	ta	a	1.00	11.61	0.70	73.20	147.93	1
m21	ta	a	1.00	11.19	0.65	66.00	154.73	2
m23	ta	a	1.00	12.53	0.79	67.50	146.60	0
m25	ta	a	1.00	10.38	0.60	84.60	109.71	1
m26	ta	a	1.00	9.84	0.52	92.10	152.61	0
m27	ta	a	1.00	10.41	0.58	84.30	150.04	1
m30	ta	a	1.00	10.13	0.54	85.70	158.28	0
m33	ta	a	1.00	12.15	0.75	70.80	156.46	0
m36	ta	a	1.00	9.68	0.51	91.30	148.14	1
m38	ta	a	1.00	11.25	0.66	78.60	148.88	1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.89	-0.88	1.00		
Information Content	-0.32	-0.38	0.12	1.00	
Goals Conceded	0.01	0.01	-0.11	0.07	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.267
R Square	0.071
Adjusted R Square	-0.214
Standard Error	1.223
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.497	0.374	0.250	0.904
Residual	13.000	19.448	1.496		
Total	17.000	20.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	34.277	48.727	0.703	0.494	-70.991	139.546	-70.991	139.546
Y Intercept	-7.396	13.451	-0.550	0.592	-36.455	21.663	-36.455	21.663
Gradient	72.727	139.761	0.520	0.612	-229.209	374.663	-229.209	374.663
Regression Coefficient	-0.041	0.069	-0.595	0.562	-0.191	0.108	-0.191	0.108
Information Content	0.035	0.073	0.480	0.639	-0.123	0.193	-0.123	0.193

D2

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m1	ta	a	1.00	9.67	0.50	93.90	153.18	0
m2	ta	a	1.00	12.04	0.74	70.90	152.63	1
m5	ta	a	1.00	9.68	0.50	93.10	154.34	1
m10	ta	a	1.00	11.56	0.69	80.20	153.66	1
m11	ta	a	1.00	13.46	0.89	72.80	106.65	0
m12	ta	a	1.00	9.96	0.53	96.00	151.92	1
m16	ta	a	1.00	12.59	0.79	68.10	151.21	4
m17	ta	a	1.00	9.65	0.50	94.00	152.75	3
m18	ta	a	1.00	11.61	0.70	73.20	147.93	0
m21	ta	a	1.00	11.19	0.65	66.00	154.73	2
m23	ta	a	1.00	12.53	0.79	67.50	146.60	0
m25	ta	a	1.00	10.38	0.60	84.60	109.71	2
m26	ta	a	1.00	9.84	0.52	92.10	152.61	0
m27	ta	a	1.00	10.41	0.58	84.30	150.04	0
m30	ta	a	1.00	10.13	0.54	85.70	158.28	1
m33	ta	a	1.00	12.15	0.75	70.80	156.46	1
m36	ta	a	1.00	9.68	0.51	91.30	148.14	1
m38	ta	a	1.00	11.25	0.66	78.60	148.88	1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.89	-0.88	1.00		
Information Content	-0.32	-0.38	0.12	1.00	
Goal Difference	-0.02	-0.01	0.08	-0.10	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.275
R Square	0.076
Adjusted R Square	-0.209
Standard Error	1.300
Observations	18.000

ANOVA

	df	SS	MS	F	Significance F
Regression	4.000	1.801	0.450	0.266	0.894
Residual	13.000	21.977	1.691		
Total	17.000	23.778			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-46.535	51.799	-0.898	0.385	-158.440	65.370	-158.440	65.370
Y Intercept	12.571	14.299	0.879	0.395	-18.321	43.462	-18.321	43.462
Gradient	-128.982	148.572	-0.868	0.401	-449.953	191.989	-449.953	191.989
Regression Coefficient	0.006	0.074	0.085	0.933	-0.153	0.165	-0.153	0.165
Information Content	-0.070	0.078	-0.894	0.387	-0.237	0.098	-0.237	0.098

D3

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m1	ta	a	1.00	9.67	0.50	93.90	153.18	3
m2	ta	a	1.00	12.04	0.74	70.90	152.63	0
m5	ta	a	1.00	9.68	0.50	93.10	154.34	-1
m10	ta	a	1.00	11.56	0.69	80.20	153.66	0
m11	ta	a	1.00	13.46	0.89	72.80	106.65	1
m12	ta	a	1.00	9.96	0.53	96.00	151.92	0
m16	ta	a	1.00	12.59	0.79	68.10	151.21	-2
m17	ta	a	1.00	9.65	0.50	94.00	152.75	-2
m18	ta	a	1.00	11.61	0.70	73.20	147.93	1
m21	ta	a	1.00	11.19	0.65	66.00	154.73	0
m23	ta	a	1.00	12.53	0.79	67.50	146.60	0
m25	ta	a	1.00	10.38	0.60	84.60	109.71	-1
m26	ta	a	1.00	9.84	0.52	92.10	152.61	0
m27	ta	a	1.00	10.41	0.58	84.30	150.04	1
m30	ta	a	1.00	10.13	0.54	85.70	158.28	-1
m33	ta	a	1.00	12.15	0.75	70.80	156.46	-1
m36	ta	a	1.00	9.68	0.51	91.30	148.14	0
m38	ta	a	1.00	11.25	0.66	78.60	148.88	0

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.83	-0.85	1.00		
Information Content	-0.18	-0.27	0.31	1.00	
Goals Scored	-0.09	-0.13	0.16	0.39	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.464
R Square	0.216
Adjusted R Square	-0.046
Standard Error	1.038
Observations	17.000

ANOVA

	df	SS	MS	F	Significance F
Regression	4.000	3.553	0.888	0.825	0.534
Residual	12.000	12.917	1.076		
Total	16.000	16.471			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-22.157	22.388	-0.990	0.342	-70.937	26.622	-70.937	26.622
Y Intercept	5.283	5.530	0.955	0.358	-6.766	17.331	-6.766	17.331
Gradient	-52.429	55.257	-0.949	0.361	-172.824	67.966	-172.824	67.966
Regression Coefficient	0.003	0.038	0.084	0.934	-0.080	0.086	-0.080	0.086
Information Content	-0.012	0.026	-0.474	0.644	-0.068	0.044	-0.068	0.044

D4

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m3	ta	a	2.00	9.94	0.52	89.10	163.44	0
m4	ta	a	2.00	10.99	0.63	69.50	158.61	2
m6	ta	a	2.00	9.47	0.49	92.90	151.48	1
m7	ta	a	2.00	12.66	0.79	69.70	156.52	0
m8	ta	a	2.00	10.41	0.57	89.80	155.45	3
m13	ta	a	2.00	9.61	0.50	92.40	154.50	1
m14	ta	a	2.00	9.83	0.52	93.50	155.24	1
m15	ta	a	2.00	15.79	1.13	53.00	145.74	1
m19	ta	a	2.00	10.77	0.61	85.00	156.87	1
m22	ta	a	2.00	11.46	0.62	89.90	263.74	3
m24	ta	a	2.00	11.74	0.71	73.30	152.49	3
m28	ta	a	2.00	10.17	0.55	89.00	151.26	1
m29	ta	a	2.00	10.97	0.64	60.50	145.61	1
m31	ta	a	2.00	10.52	0.59	83.70	153.33	0
m32	ta	a	2.00	12.86	0.83	69.70	106.35	1
m34	ta	a	2.00	12.11	0.77	78.00	87.27	1
m37	ta	a	2.00	13.41	0.88	62.00	149.17	0

D5

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m3	ta	a	2.00	9.94	0.52	89.10	163.44	0
m4	ta	a	2.00	10.99	0.63	69.50	158.61	2
m6	ta	a	2.00	9.47	0.49	92.90	151.48	2
m7	ta	a	2.00	12.66	0.79	69.70	156.52	0
m8	ta	a	2.00	10.41	0.57	89.80	155.45	0
m13	ta	a	2.00	9.61	0.50	92.40	154.50	1
m14	ta	a	2.00	9.83	0.52	93.50	155.24	2
m15	ta	a	2.00	15.79	1.13	53.00	145.74	3
m19	ta	a	2.00	10.77	0.61	85.00	156.87	2
m22	ta	a	2.00	11.46	0.62	89.90	263.74	2
m24	ta	a	2.00	11.74	0.71	73.30	152.49	1
m28	ta	a	2.00	10.17	0.55	89.00	151.26	0
m29	ta	a	2.00	10.97	0.64	60.50	145.61	2
m31	ta	a	2.00	10.52	0.59	83.70	153.33	1
m32	ta	a	2.00	12.86	0.83	69.70	106.35	2
m34	ta	a	2.00	12.11	0.77	78.00	87.27	3
m37	ta	a	2.00	13.41	0.88	62.00	149.17	3

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.83	-0.85	1.00		
Information Content	-0.18	-0.27	0.31	1.00	
Goals Conceded	0.49	0.50	-0.45	-0.18	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.512
R Square	0.262
Adjusted R Square	0.017
Standard Error	1.059
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	4.786	1.197	1.068	0.414
Residual	12.000	13.449	1.121		
Total	16.000	18.235			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	8.557	22.844	0.375	0.714	-41.216	58.330	-41.216	58.330
Y Intercept	-1.993	5.643	-0.353	0.730	-14.287	10.301	-14.287	10.301
Gradient	22.444	56.383	0.398	0.698	-100.403	145.292	-100.403	145.292
Regression Coefficient	-0.007	0.039	-0.181	0.860	-0.092	0.078	-0.092	0.078
Information Content	0.008	0.026	0.291	0.776	-0.049	0.064	-0.049	0.064

D6

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m3	ta	a	2.00	9.94	0.52	89.10	163.44	0
m4	ta	a	2.00	10.99	0.63	69.50	158.61	0
m6	ta	a	2.00	9.47	0.49	92.90	151.48	-1
m7	ta	a	2.00	12.66	0.79	69.70	156.52	0
m8	ta	a	2.00	10.41	0.57	89.80	155.45	3
m13	ta	a	2.00	9.61	0.50	92.40	154.50	0
m14	ta	a	2.00	9.83	0.52	93.50	155.24	-1
m15	ta	a	2.00	15.79	1.13	53.00	145.74	-2
m19	ta	a	2.00	10.77	0.61	85.00	156.87	-1
m22	ta	a	2.00	11.46	0.62	89.90	263.74	1
m24	ta	a	2.00	11.74	0.71	73.30	152.49	2
m28	ta	a	2.00	10.17	0.55	89.00	151.26	1
m29	ta	a	2.00	10.97	0.64	60.50	145.61	-1
m31	ta	a	2.00	10.52	0.59	83.70	153.33	-1
m32	ta	a	2.00	12.86	0.83	69.70	106.35	-1
m34	ta	a	2.00	12.11	0.77	78.00	87.27	-2
m37	ta	a	2.00	13.41	0.88	62.00	149.17	-3

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.83	-0.85	1.00		
Information Content	-0.18	-0.27	0.31	1.00	
Goal Difference	-0.41	-0.44	0.43	0.39	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.578
R Square	0.334
Adjusted R Square	0.111
Standard Error	1.412
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	11.969	2.992	1.502	0.263
Residual	12.000	23.914	1.993		
Total	16.000	35.882			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-30.715	30.461	-1.008	0.333	-97.085	35.655	-97.085	35.655
Y Intercept	7.276	7.524	0.967	0.353	-9.118	23.669	-9.118	23.669
Gradient	-74.873	75.184	-0.996	0.339	-238.685	88.938	-238.685	88.938
Regression Coefficient	0.010	0.052	0.198	0.847	-0.103	0.123	-0.103	0.123
Information Content	-0.020	0.035	-0.567	0.581	-0.095	0.056	-0.095	0.056

E1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.60	-0.60	1.00		
Information Content	-0.01	-0.03	0.17	1.00	
Goals Scored	0.41	0.41	-0.40	0.02	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.484
R Square	0.235
Adjusted R Square	-0.001
Standard Error	0.803
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	2.567	0.642	0.996	0.444
Residual	13.000	8.377	0.644		
Total	17.000	10.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-14.263	24.343	-0.586	0.568	-66.854	38.328	-66.854	38.328
Y Intercept	5.072	7.890	0.643	0.532	-11.974	22.118	-11.974	22.118
Gradient	-55.232	88.045	-0.627	0.541	-245.442	134.978	-245.442	134.978
Regression Coefficient	-0.021	0.031	-0.688	0.504	-0.088	0.046	-0.088	0.046
Information Content	-0.023	0.054	-0.427	0.676	-0.139	0.093	-0.139	0.093

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m1	ta	m	1.00	12.41	0.80	61.90	87.53	3
m2	ta	m	1.00	11.30	0.70	83.70	87.12	1
m5	ta	m	1.00	9.46	0.53	90.80	88.11	0
m10	ta	m	1.00	10.14	0.60	86.40	88.17	1
m11	ta	m	1.00	10.90	0.65	80.20	108.52	1
m12	ta	m	1.00	11.45	0.71	78.30	85.66	1
m16	ta	m	1.00	14.93	1.03	70.20	85.54	2
m17	ta	m	1.00	13.09	0.86	67.90	87.94	1
m18	ta	m	1.00	10.52	0.63	80.00	88.62	1
m21	ta	m	1.00	14.17	0.96	66.70	85.73	2
m23	ta	m	1.00	10.15	0.60	76.10	87.93	0
m25	ta	m	1.00	13.30	0.87	74.30	110.33	1
m26	ta	m	1.00	13.80	0.93	76.60	83.23	0
m27	ta	m	1.00	12.88	0.84	68.30	84.39	1
m30	ta	m	1.00	12.93	0.84	67.00	86.78	0
m33	ta	m	1.00	10.03	0.59	69.70	87.46	0
m36	ta	m	1.00	9.70	0.56	79.70	82.86	1
m38	ta	m	1.00	11.66	0.73	62.70	83.65	1

E2

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.60	-0.60	1.00		
Information Content	-0.01	-0.03	0.17	1.00	
Goals Conceded	0.51	0.51	-0.20	0.00	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.535
R Square	0.287
Adjusted R Square	0.067
Standard Error	1.072
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	6.005	1.501	1.306	0.319
Residual	13.000	14.940	1.149		
Total	17.000	20.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	10.038	32.510	0.309	0.762	-60.195	80.271	-60.195	80.271
Y Intercept	-4.560	10.537	-0.433	0.672	-27.324	18.204	-27.324	18.204
Gradient	55.407	117.580	0.471	0.645	-198.609	309.424	-198.609	309.424
Regression Coefficient	0.019	0.041	0.465	0.650	-0.070	0.109	-0.070	0.109
Information Content	0.025	0.072	0.351	0.731	-0.129	0.180	-0.129	0.180

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m1	ta	m	1.00	12.41	0.80	61.90	87.53	0
m2	ta	m	1.00	11.30	0.70	83.70	87.12	1
m5	ta	m	1.00	9.46	0.53	90.80	88.11	1
m10	ta	m	1.00	10.14	0.60	86.40	88.17	1
m11	ta	m	1.00	10.90	0.65	80.20	108.52	0
m12	ta	m	1.00	11.45	0.71	78.30	85.66	1
m16	ta	m	1.00	14.93	1.03	70.20	85.54	4
m17	ta	m	1.00	13.09	0.86	67.90	87.94	3
m18	ta	m	1.00	10.52	0.63	80.00	88.62	0
m21	ta	m	1.00	14.17	0.96	66.70	85.73	2
m23	ta	m	1.00	10.15	0.60	76.10	87.93	0
m25	ta	m	1.00	13.30	0.87	74.30	110.33	2
m26	ta	m	1.00	13.80	0.93	76.60	83.23	0
m27	ta	m	1.00	12.88	0.84	68.30	84.39	0
m30	ta	m	1.00	12.93	0.84	67.00	86.78	1
m33	ta	m	1.00	10.03	0.59	69.70	87.46	1
m36	ta	m	1.00	9.70	0.56	79.70	82.86	1
m38	ta	m	1.00	11.66	0.73	62.70	83.65	1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.60	-0.60	1.00		
Information Content	-0.01	-0.03	0.17	1.00	
Goal Difference	-0.20	-0.20	-0.09	0.01	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.390
R Square	0.152
Adjusted R Square	-0.108
Standard Error	1.245
Observations	18.000

ANOVA

	df	SS	MS	F	Significance F
Regression	4.000	3.625	0.906	0.585	0.679
Residual	13.000	20.153	1.550		
Total	17.000	23.778			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-24.301	37.758	-0.644	0.531	-105.871	57.270	-105.871	57.270
Y Intercept	9.632	12.238	0.787	0.445	-16.807	36.070	-16.807	36.070
Gradient	-110.639	136.561	-0.810	0.432	-405.661	184.384	-405.661	184.384
Regression Coefficient	-0.041	0.048	-0.843	0.414	-0.145	0.063	-0.145	0.063
Information Content	-0.048	0.083	-0.577	0.573	-0.227	0.131	-0.227	0.131

E3

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m1	ta	m	1.00	12.41	0.80	61.90	87.53	3
m2	ta	m	1.00	11.30	0.70	83.70	87.12	0
m5	ta	m	1.00	9.46	0.53	90.80	88.11	-1
m10	ta	m	1.00	10.14	0.60	86.40	88.17	0
m11	ta	m	1.00	10.90	0.65	80.20	108.52	1
m12	ta	m	1.00	11.45	0.71	78.30	85.66	0
m16	ta	m	1.00	14.93	1.03	70.20	85.54	-2
m17	ta	m	1.00	13.09	0.86	67.90	87.94	-2
m18	ta	m	1.00	10.52	0.63	80.00	88.62	1
m21	ta	m	1.00	14.17	0.96	66.70	85.73	0
m23	ta	m	1.00	10.15	0.60	76.10	87.93	0
m25	ta	m	1.00	13.30	0.87	74.30	110.33	-1
m26	ta	m	1.00	13.80	0.93	76.60	83.23	0
m27	ta	m	1.00	12.88	0.84	68.30	84.39	1
m30	ta	m	1.00	12.93	0.84	67.00	86.78	-1
m33	ta	m	1.00	10.03	0.59	69.70	87.46	-1
m36	ta	m	1.00	9.70	0.56	79.70	82.86	0
m38	ta	m	1.00	11.66	0.73	62.70	83.65	0

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
Y Intercept	1.00				
Gradient	0.62	1.00			
Regression Coefficient	-0.21	-0.32	1.00		
Information Content	0.17	-0.18	0.01	1.00	
Goals Scored	0.06	0.05	0.14	-0.15	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.239
R Square	0.057
Adjusted R Square	-0.257
Standard Error	1.138
Observations	17.000

ANOVA

	df	SS	MS	F	Significance F
Regression	4.000	0.938	0.235	0.181	0.944
Residual	12.000	15.532	1.294		
Total	16.000	16.471			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.196	3.965	0.049	0.961	-8.444	8.835	-8.444	8.835
Y Intercept	0.044	0.139	0.318	0.756	-0.258	0.347	-0.258	0.347
Gradient	0.002	3.283	0.001	0.999	-7.151	7.156	-7.151	7.156
Regression Coefficient	0.018	0.033	0.564	0.583	-0.053	0.090	-0.053	0.090
Information Content	-0.010	0.017	-0.573	0.577	-0.048	0.028	-0.048	0.028

E4

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m3	ta	m	2.00	11.13	0.68	63.10	89.24	0
m4	ta	m	2.00	12.81	0.83	80.50	88.81	2
m6	ta	m	2.00	14.08	0.95	74.40	86.66	1
m7	ta	m	2.00	11.24	0.69	79.10	89.74	0
m8	ta	m	2.00	10.91	0.66	76.50	86.22	3
m13	ta	m	2.00	9.17	0.51	94.30	88.98	1
m14	ta	m	2.00	13.88	0.93	78.60	84.07	1
m15	ta	m	2.00	0.96	0.59	79.70	71.63	1
m19	ta	m	2.00	11.04	0.67	77.80	86.38	1
m22	ta	m	2.00	10.03	0.60	78.60	71.30	3
m24	ta	m	2.00	11.54	0.72	73.90	87.67	3
m28	ta	m	2.00	11.34	0.70	65.80	86.23	1
m29	ta	m	2.00	9.67	0.56	83.30	86.12	1
m31	ta	m	2.00	11.06	0.68	55.70	85.15	0
m32	ta	m	2.00	10.56	0.62	84.30	108.60	1
m34	ta	m	2.00	10.42	0.58	75.20	152.41	1
m37	ta	m	2.00	9.98	0.58	88.80	87.85	0

E5

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m3	ta	m	2.00	11.13	0.68	63.10	89.24	0
m4	ta	m	2.00	12.81	0.83	80.50	88.81	2
m6	ta	m	2.00	14.08	0.95	74.40	86.66	2
m7	ta	m	2.00	11.24	0.69	79.10	89.74	0
m8	ta	m	2.00	10.91	0.66	76.50	86.22	0
m13	ta	m	2.00	9.17	0.51	94.30	88.98	1
m14	ta	m	2.00	13.88	0.93	78.60	84.07	2
m15	ta	m	2.00	0.96	0.59	79.70	71.63	3
m19	ta	m	2.00	11.04	0.67	77.80	86.38	2
m22	ta	m	2.00	10.03	0.60	78.60	71.30	2
m24	ta	m	2.00	11.54	0.72	73.90	87.67	1
m28	ta	m	2.00	11.34	0.70	65.80	86.23	0
m29	ta	m	2.00	9.67	0.56	83.30	86.12	2
m31	ta	m	2.00	11.06	0.68	55.70	85.15	1
m32	ta	m	2.00	10.56	0.62	84.30	108.60	2
m34	ta	m	2.00	10.42	0.58	75.20	152.41	3
m37	ta	m	2.00	9.98	0.58	88.80	87.85	3

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	0.62	1.00			
Regression Coefficient	-0.21	-0.32	1.00		
Information Content	0.17	-0.18	0.01	1.00	
Goals Conceded	-0.31	-0.09	0.43	0.23	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.659
R Square	0.435
Adjusted R Square	0.246
Standard Error	0.927
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	7.927	1.982	2.307	0.118
Residual	12.000	10.308	0.859		
Total	16.000	18.235			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-5.383	3.230	-1.666	0.122	-12.421	1.656	-12.421	1.656
Y Intercept	-0.229	0.113	-2.022	0.066	-0.475	0.018	-0.475	0.018
Gradient	4.390	2.675	1.641	0.127	-1.438	10.218	-1.438	10.218
Regression Coefficient	0.053	0.027	1.986	0.070	-0.005	0.111	-0.005	0.111
Information Content	0.025	0.014	1.771	0.102	-0.006	0.056	-0.006	0.056

E6

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m3	ta	m	2.00	11.13	0.68	63.10	89.24	0
m4	ta	m	2.00	12.81	0.83	80.50	88.81	0
m6	ta	m	2.00	14.08	0.95	74.40	86.66	-1
m7	ta	m	2.00	11.24	0.69	79.10	89.74	0
m8	ta	m	2.00	10.91	0.66	76.50	86.22	3
m13	ta	m	2.00	9.17	0.51	94.30	88.98	0
m14	ta	m	2.00	13.88	0.93	78.60	84.07	-1
m15	ta	m	2.00	0.96	0.59	79.70	71.63	-2
m19	ta	m	2.00	11.04	0.67	77.80	86.38	-1
m22	ta	m	2.00	10.03	0.60	78.60	71.30	1
m24	ta	m	2.00	11.54	0.72	73.90	87.67	2
m28	ta	m	2.00	11.34	0.70	65.80	86.23	1
m29	ta	m	2.00	9.67	0.56	83.30	86.12	-1
m31	ta	m	2.00	11.06	0.68	55.70	85.15	-1
m32	ta	m	2.00	10.56	0.62	84.30	108.60	-1
m34	ta	m	2.00	10.42	0.58	75.20	152.41	-2
m37	ta	m	2.00	9.98	0.58	88.80	87.85	-3

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	0.62	1.00			
Regression Coefficient	-0.21	-0.32	1.00		
Information Content	0.17	-0.18	0.01	1.00	
Goal Difference	0.26	0.10	-0.21	-0.27	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.505
R Square	0.255
Adjusted R Square	0.006
Standard Error	1.493
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	9.138	2.285	1.025	0.433
Residual	12.000	26.744	2.229		
Total	16.000	35.882			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.578	5.203	1.072	0.305	-5.759	16.915	-5.759	16.915
Y Intercept	0.273	0.182	1.498	0.160	-0.124	0.670	-0.124	0.670
Gradient	-4.388	4.308	-1.018	0.329	-13.775	4.999	-13.775	4.999
Regression Coefficient	-0.034	0.043	-0.803	0.437	-0.128	0.059	-0.128	0.059
Information Content	-0.035	0.023	-1.536	0.151	-0.085	0.015	-0.085	0.015

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.13	-0.11	1.00		
Information Content	-0.05	-0.08	-0.47	1.00	
Goals Scored	-0.08	-0.09	-0.17	-0.12	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.465
R Square	0.216
Adjusted R Square	-0.025
Standard Error	0.812
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	2.369	0.592	0.898	0.493
Residual	13.000	8.575	0.660		
Total	17.000	10.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-29.550	27.850	-1.061	0.308	-89.717	30.616	-89.717	30.616
Y Intercept	13.398	9.639	1.390	0.188	-7.425	34.221	-7.425	34.221
Gradient	-152.247	108.880	-1.398	0.185	-387.468	82.975	-387.468	82.975
Regression Coefficient	-0.042	0.046	-0.920	0.374	-0.140	0.057	-0.140	0.057
Information Content	-0.137	0.081	-1.694	0.114	-0.311	0.038	-0.311	0.038

F1

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m1	ta	d	1.00	10.86	0.67	72.40	75.13	3
m2	ta	d	1.00	11.55	0.73	73.00	75.42	1
m5	ta	d	1.00	10.61	0.64	79.70	78.98	0
m10	ta	d	1.00	12.12	0.78	80.00	76.62	1
m11	ta	d	1.00	14.82	1.02	78.70	76.19	1
m12	ta	d	1.00	12.98	0.85	80.10	76.89	1
m16	ta	d	1.00	11.63	0.73	73.30	78.72	2
m17	ta	d	1.00	12.34	0.79	74.00	77.81	1
m18	ta	d	1.00	11.50	0.74	86.40	52.33	1
m21	ta	d	1.00	11.24	0.70	82.50	77.45	2
m23	ta	d	1.00	10.77	0.65	77.70	82.22	0
m25	ta	d	1.00	14.77	1.01	78.40	73.15	1
m26	ta	d	1.00	10.51	0.64	86.40	77.74	0
m27	ta	d	1.00	11.13	0.69	74.10	76.95	1
m30	ta	d	1.00	14.82	1.02	73.60	76.51	0
m33	ta	d	1.00	11.54	0.73	71.90	77.12	0
m36	ta	d	1.00	11.30	0.71	79.10	74.46	1
m38	ta	d	1.00	12.17	0.78	67.90	81.16	1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.13	-0.11	1.00		
Information Content	-0.05	-0.08	-0.47	1.00	
Goals Conceded	0.15	0.13	-0.25	0.22	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.8442
R Square	0.7127
Adjusted R Square	0.6243
Standard Error	0.6804
Observations	18.0000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.0000	14.9268	3.7317	8.0616	0.0017
Residual	13.0000	6.0177	0.4629		
Total	17.0000	20.9444			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*er !*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-119.9544	23.3305	-5.1415	0.0002	-170.3569	#	-170.3569	-69.5518
Y Intercept	42.8119	8.0745	5.3021	0.0001	25.3680	#	25.3680	60.2558
Gradient	-482.4898	91.2110	-5.2898	0.0001	-679.5393	#	-679.5393	-285.4403
Regression Coefficient	-0.0089	0.0382	-0.2319	0.8202	-0.0913	#	-0.0913	0.0736
Information Content	-0.2933	0.0675	-4.3432	0.0008	-0.4392	#	-0.4392	-0.1474

F2

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m1	ta	d	1.00	10.86	0.6659	72.4	75.13	0
m2	ta	d	1.00	11.55	0.727	73	75.42	1
m5	ta	d	1.00	10.61	0.641	79.7	78.98	1
m10	ta	d	1.00	12.12	0.7766	80	76.62	1
m11	ta	d	1.00	14.82	1.02	78.7	76.19	0
m12	ta	d	1.00	12.98	0.8521	80.1	76.89	1
m16	ta	d	1.00	11.63	0.7286	73.3	78.72	4
m17	ta	d	1.00	12.34	0.793	74	77.81	3
m18	ta	d	1.00	11.5	0.7386	86.4	52.33	0
m21	ta	d	1.00	11.24	0.6954	82.5	77.45	2
m23	ta	d	1.00	10.77	0.6545	77.7	82.22	0
m25	ta	d	1.00	14.77	1.011	78.4	73.15	2
m26	ta	d	1.00	10.51	0.6355	86.4	77.74	0
m27	ta	d	1.00	11.13	0.6895	74.1	76.95	0
m30	ta	d	1.00	14.82	1.015	73.6	76.51	1
m33	ta	d	1.00	11.54	0.7255	71.9	77.12	1
m36	ta	d	1.00	11.3	0.7067	79.1	74.46	1
m38	ta	d	1.00	12.17	0.779	67.9	81.16	1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.13	-0.11	1.00		
Information Content	-0.05	-0.08	-0.47	1.00	
Goal Difference	-0.20	-0.18	0.12	-0.29	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.6206
R Square	0.3851
Adjusted R Square	0.1959
Standard Error	1.0605
Observations	18.0000

ANOVA

	df	SS	MS	F	Significance F
Regression	4.0000	9.1565	2.2891	2.0353	0.1485
Residual	13.0000	14.6213	1.1247		
Total	17.0000	23.7778			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	90.4041	36.3666	2.4859	0.0273	11.8388	168.9695	11.8388	168.9695
Y Intercept	-29.4139	12.5862	-2.3370	0.0361	-56.6047	-2.2230	-56.6047	-2.2230
Gradient	330.2430	142.1758	2.3228	0.0371	23.0909	637.3951	23.0909	637.3951
Regression Coefficient	-0.0331	0.0595	-0.5556	0.5879	-0.1616	0.0955	-0.1616	0.0955
Information Content	0.1568	0.1053	1.4894	0.1602	-0.0706	0.3842	-0.0706	0.3842

F3

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m1	ta	d	1.00	10.86	0.67	72.40	75.13	3
m2	ta	d	1.00	11.55	0.73	73.00	75.42	0
m5	ta	d	1.00	10.61	0.64	79.70	78.98	-1
m10	ta	d	1.00	12.12	0.78	80.00	76.62	0
m11	ta	d	1.00	14.82	1.02	78.70	76.19	1
m12	ta	d	1.00	12.98	0.85	80.10	76.89	0
m16	ta	d	1.00	11.63	0.73	73.30	78.72	-2
m17	ta	d	1.00	12.34	0.79	74.00	77.81	-2
m18	ta	d	1.00	11.50	0.74	86.40	52.33	1
m21	ta	d	1.00	11.24	0.70	82.50	77.45	0
m23	ta	d	1.00	10.77	0.65	77.70	82.22	0
m25	ta	d	1.00	14.77	1.01	78.40	73.15	-1
m26	ta	d	1.00	10.51	0.64	86.40	77.74	0
m27	ta	d	1.00	11.13	0.69	74.10	76.95	1
m30	ta	d	1.00	14.82	1.02	73.60	76.51	-1
m33	ta	d	1.00	11.54	0.73	71.90	77.12	-1
m36	ta	d	1.00	11.30	0.71	79.10	74.46	0
m38	ta	d	1.00	12.17	0.78	67.90	81.16	0

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.23	-0.23	1.00		
Information Content	-0.03	-0.05	0.01	1.00	
Goals Scored	0.24	0.25	-0.33	-0.05	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.484
R Square	0.235
Adjusted R Square	-0.020
Standard Error	1.025
Observations	17.000

ANOVA

	df	SS	MS	F	Significance F
Regression	4.000	3.865	0.966	0.920	0.484
Residual	12.000	12.606	1.050		
Total	16.000	16.471			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	34.206	25.033	1.366	0.197	-20.336	88.748	-20.336	88.748
Y Intercept	-10.097	8.373	-1.206	0.251	-28.340	8.145	-28.340	8.145
Gradient	115.758	94.821	1.221	0.246	-90.839	322.355	-90.839	322.355
Regression Coefficient	-0.060	0.048	-1.243	0.238	-0.164	0.045	-0.164	0.045
Information Content	0.055	0.082	0.674	0.513	-0.123	0.233	-0.123	0.233

F4

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m3	ta	d	2.00	9.92	0.58	86.00	80.92	0
m4	ta	d	2.00	15.31	1.06	78.60	76.10	2
m6	ta	d	2.00	13.89	0.93	79.60	76.09	1
m7	ta	d	2.00	11.73	0.74	85.70	79.22	0
m8	ta	d	2.00	11.78	0.75	82.90	78.41	3
m13	ta	d	2.00	12.47	0.80	80.80	79.71	1
m14	ta	d	2.00	12.27	0.78	77.10	76.84	1
m15	ta	d	2.00	12.15	0.77	76.00	92.64	1
m19	ta	d	2.00	11.12	0.69	88.20	74.33	1
m22	ta	d	2.00	10.67	0.65	70.70	77.40	3
m24	ta	d	2.00	12.56	0.82	77.40	77.64	3
m28	ta	d	2.00	11.66	0.74	70.30	75.60	1
m29	ta	d	2.00	11.45	0.72	70.30	74.85	1
m31	ta	d	2.00	10.55	0.64	81.90	75.80	0
m32	ta	d	2.00	10.38	0.62	80.20	76.40	1
m34	ta	d	2.00	9.62	0.56	85.90	78.23	1
m37	ta	d	2.00	12.37	0.80	78.50	76.34	0

F5

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m3	ta	d	2.00	9.92	0.58	86.00	80.92	0
m4	ta	d	2.00	15.31	1.06	78.60	76.10	2
m6	ta	d	2.00	13.89	0.93	79.60	76.09	2
m7	ta	d	2.00	11.73	0.74	85.70	79.22	0
m8	ta	d	2.00	11.78	0.75	82.90	78.41	0
m13	ta	d	2.00	12.47	0.80	80.80	79.71	1
m14	ta	d	2.00	12.27	0.78	77.10	76.84	2
m15	ta	d	2.00	12.15	0.77	76.00	92.64	3
m19	ta	d	2.00	11.12	0.69	88.20	74.33	2
m22	ta	d	2.00	10.67	0.65	70.70	77.40	2
m24	ta	d	2.00	12.56	0.82	77.40	77.64	1
m28	ta	d	2.00	11.66	0.74	70.30	75.60	0
m29	ta	d	2.00	11.45	0.72	70.30	74.85	2
m31	ta	d	2.00	10.55	0.64	81.90	75.80	1
m32	ta	d	2.00	10.38	0.62	80.20	76.40	2
m34	ta	d	2.00	9.62	0.56	85.90	78.23	3
m37	ta	d	2.00	12.37	0.80	78.50	76.34	3

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.23	-0.23	1.00		
Information Content	-0.03	-0.05	0.01	1.00	
Goals Conceded	0.10	0.10	-0.15	0.14	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.298
R Square	0.089
Adjusted R Square	-0.215
Standard Error	1.177
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.625	0.406	0.293	0.877
Residual	12.000	16.611	1.384		
Total	16.000	18.235			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	20.344	28.735	0.708	0.492	-42.265	82.953	-42.265	82.953
Y Intercept	-6.998	9.611	-0.728	0.480	-27.940	13.943	-27.940	13.943
Gradient	79.906	108.846	0.734	0.477	-157.249	317.061	-157.249	317.061
Regression Coefficient	-0.030	0.055	-0.549	0.593	-0.150	0.090	-0.150	0.090
Information Content	0.082	0.094	0.878	0.397	-0.122	0.286	-0.122	0.286

F6

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m3	ta	d	2.00	9.92	0.58	86.00	80.92	0
m4	ta	d	2.00	15.31	1.06	78.60	76.10	0
m6	ta	d	2.00	13.89	0.93	79.60	76.09	-1
m7	ta	d	2.00	11.73	0.74	85.70	79.22	0
m8	ta	d	2.00	11.78	0.75	82.90	78.41	3
m13	ta	d	2.00	12.47	0.80	80.80	79.71	0
m14	ta	d	2.00	12.27	0.78	77.10	76.84	-1
m15	ta	d	2.00	12.15	0.77	76.00	92.64	-2
m19	ta	d	2.00	11.12	0.69	88.20	74.33	-1
m22	ta	d	2.00	10.67	0.65	70.70	77.40	1
m24	ta	d	2.00	12.56	0.82	77.40	77.64	2
m28	ta	d	2.00	11.66	0.74	70.30	75.60	1
m29	ta	d	2.00	11.45	0.72	70.30	74.85	-1
m31	ta	d	2.00	10.55	0.64	81.90	75.80	-1
m32	ta	d	2.00	10.38	0.62	80.20	76.40	-1
m34	ta	d	2.00	9.62	0.56	85.90	78.23	-2
m37	ta	d	2.00	12.37	0.80	78.50	76.34	-3

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.23	-0.23	1.00		
Information Content	-0.03	-0.05	0.01	1.00	
Goal Difference	0.09	0.09	-0.12	-0.13	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.199
R Square	0.039
Adjusted R Square	-0.281
Standard Error	1.695
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	1.415	0.354	0.123	0.971
Residual	12.000	34.467	2.872		
Total	16.000	35.882			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	13.862	41.393	0.335	0.743	-76.326	104.050	-76.326	104.050
Y Intercept	-3.099	13.845	-0.224	0.827	-33.264	27.067	-33.264	27.067
Gradient	35.852	156.792	0.229	0.823	-305.768	377.473	-305.768	377.473
Regression Coefficient	-0.029	0.079	-0.371	0.717	-0.202	0.143	-0.202	0.143
Information Content	-0.027	0.135	-0.202	0.843	-0.321	0.267	-0.321	0.267

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
Y Intercept	1.00				
Gradient	0.53	1.00			
Regression Coefficient	0.15	0.06	1.00		
Information Content	-0.21	-0.16	0.06	1.00	
Goals Scored	-0.12	0.20	-0.31	0.00	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.445
R Square	0.198
Adjusted R Square	-0.049
Standard Error	0.822
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	2.166	0.541	0.802	0.545
Residual	13.000	8.779	0.675		
Total	17.000	10.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	10.809	11.948	0.905	0.382	-15.003	36.621	-15.003	36.621
Y Intercept	-0.283	0.318	-0.889	0.390	-0.969	0.404	-0.969	0.404
Gradient	1.887	1.534	1.231	0.240	-1.426	5.201	-1.426	5.201
Regression Coefficient	-0.101	0.086	-1.176	0.261	-0.287	0.085	-0.287	0.085
Information Content	0.013	0.223	0.059	0.954	-0.468	0.494	-0.468	0.494

G1

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m1	ta	c	1.00	10.45	0.66	81.50	41.90	3
m2	ta	c	1.00	9.62	0.60	85.70	41.14	1
m5	ta	c	1.00	9.91	0.06	85.80	42.61	0
m10	ta	c	1.00	9.19	0.57	88.90	42.92	1
m11	ta	c	1.00	11.98	0.79	90.00	41.55	1
m12	ta	c	1.00	10.40	0.66	87.00	42.55	1
m16	ta	c	1.00	10.32	0.65	86.80	43.45	2
m17	ta	c	1.00	10.62	0.67	84.70	43.18	1
m18	ta	c	1.00	10.39	0.66	87.10	42.60	1
m21	ta	c	1.00	10.00	0.63	83.50	43.55	2
m23	ta	c	1.00	9.63	0.60	88.40	44.05	0
m25	ta	c	1.00	10.24	0.65	85.00	42.16	1
m26	ta	c	1.00	12.09	0.80	88.70	41.54	0
m27	ta	c	1.00	10.39	0.66	83.80	41.76	1
m30	ta	c	1.00	10.93	0.70	83.50	42.89	0
m33	ta	c	1.00	10.31	0.65	82.70	42.08	0
m36	ta	c	1.00	9.55	0.60	85.90	40.44	1
m38	ta	c	1.00	10.88	0.70	84.00	41.76	1

	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
Y Intercept	1.00				
Gradient	0.53	1.00			
Regression Coefficient	0.15	0.06	1.00		
Information Content	-0.21	-0.16	0.06	1.00	
Goals Conceded	-0.20	-0.08	-0.16	0.38	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.437
R Square	0.191
Adjusted R Square	-0.058
Standard Error	1.142
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	3.998	0.999	0.767	0.566
Residual	13.000	16.947	1.304		
Total	17.000	20.944			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-9.806	16.601	-0.591	0.565	-45.669	26.057	-45.669	26.057
Y Intercept	-0.188	0.442	-0.425	0.678	-1.142	0.766	-1.142	0.766
Gradient	0.433	2.131	0.203	0.842	-4.170	5.037	-4.170	5.037
Regression Coefficient	-0.077	0.120	-0.647	0.529	-0.336	0.181	-0.336	0.181
Information Content	0.453	0.310	1.463	0.167	-0.216	1.121	-0.216	1.121

G2

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m1	ta	c	1.00	10.45	0.66	81.50	41.90	0
m2	ta	c	1.00	9.62	0.60	85.70	41.14	1
m5	ta	c	1.00	9.91	0.06	85.80	42.61	1
m10	ta	c	1.00	9.19	0.57	88.90	42.92	1
m11	ta	c	1.00	11.98	0.79	90.00	41.55	0
m12	ta	c	1.00	10.40	0.66	87.00	42.55	1
m16	ta	c	1.00	10.32	0.65	86.80	43.45	4
m17	ta	c	1.00	10.62	0.67	84.70	43.18	3
m18	ta	c	1.00	10.39	0.66	87.10	42.60	0
m21	ta	c	1.00	10.00	0.63	83.50	43.55	2
m23	ta	c	1.00	9.63	0.60	88.40	44.05	0
m25	ta	c	1.00	10.24	0.65	85.00	42.16	2
m26	ta	c	1.00	12.09	0.80	88.70	41.54	0
m27	ta	c	1.00	10.39	0.66	83.80	41.76	0
m30	ta	c	1.00	10.93	0.70	83.50	42.89	1
m33	ta	c	1.00	10.31	0.65	82.70	42.08	1
m36	ta	c	1.00	9.55	0.60	85.90	40.44	1
m38	ta	c	1.00	10.88	0.70	84.00	41.76	1

G3

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m1	ta	c	1.00	10.45	0.66	81.50	41.90	3
m2	ta	c	1.00	9.62	0.60	85.70	41.14	0
m5	ta	c	1.00	9.91	0.06	85.80	42.61	-1
m10	ta	c	1.00	9.19	0.57	88.90	42.92	0
m11	ta	c	1.00	11.98	0.79	90.00	41.55	1
m12	ta	c	1.00	10.40	0.66	87.00	42.55	0
m16	ta	c	1.00	10.32	0.65	86.80	43.45	-2
m17	ta	c	1.00	10.62	0.67	84.70	43.18	-2
m18	ta	c	1.00	10.39	0.66	87.10	42.60	1
m21	ta	c	1.00	10.00	0.63	83.50	43.55	0
m23	ta	c	1.00	9.63	0.60	88.40	44.05	0
m25	ta	c	1.00	10.24	0.65	85.00	42.16	-1
m26	ta	c	1.00	12.09	0.80	88.70	41.54	0
m27	ta	c	1.00	10.39	0.66	83.80	41.76	1
m30	ta	c	1.00	10.93	0.70	83.50	42.89	-1
m33	ta	c	1.00	10.31	0.65	82.70	42.08	-1
m36	ta	c	1.00	9.55	0.60	85.90	40.44	0
m38	ta	c	1.00	10.88	0.70	84.00	41.76	0

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	0.53	1.00			
Regression Coefficient	0.15	0.06	1.00		
Information Content	-0.21	-0.16	0.06	1.00	
Goal Difference	0.11	0.21	-0.07	-0.36	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.400
R Square	0.160
Adjusted R Square	-0.098
Standard Error	1.239
Observations	18.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	3.812	0.953	0.621	0.656
Residual	13.000	19.966	1.536		
Total	17.000	23.778			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	20.615	18.018	1.144	0.273	-18.312	59.541	-18.312	59.541
Y Intercept	-0.095	0.479	-0.198	0.846	-1.130	0.940	-1.130	0.940
Gradient	1.454	2.313	0.629	0.540	-3.543	6.451	-3.543	6.451
Regression Coefficient	-0.024	0.130	-0.183	0.857	-0.304	0.256	-0.304	0.256
Information Content	-0.440	0.336	-1.309	0.213	-1.165	0.286	-1.165	0.286

G4

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Scored
m3	ta	c	2.00	10.31	0.65	81.30	41.63	0
m4	ta	c	2.00	12.78	0.86	86.50	41.42	2
m6	ta	c	2.00	10.53	0.67	85.10	42.49	1
m7	ta	c	2.00	10.00	0.62	87.70	43.88	0
m8	ta	c	2.00	10.75	0.68	84.10	42.51	3
m13	ta	c	2.00	10.89	0.70	84.00	42.42	1
m14	ta	c	2.00	9.83	0.61	86.50	41.91	1
m15	ta	c	2.00	9.71	0.61	85.90	41.66	1
m19	ta	c	2.00	10.23	0.65	83.80	41.52	1
m22	ta	c	2.00	10.20	0.64	84.20	41.12	3
m24	ta	c	2.00	10.09	0.64	85.90	42.41	3
m28	ta	c	2.00	10.33	0.66	84.90	41.17	1
m29	ta	c	2.00	9.87	0.62	85.20	41.07	1
m31	ta	c	2.00	9.91	0.62	81.90	40.41	0
m32	ta	c	2.00	9.17	0.56	86.80	41.74	1
m34	ta	c	2.00	11.34	0.73	84.90	42.55	1
m37	ta	c	2.00	10.54	0.67	85.50	42.48	0

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Scored*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.01	-0.01	1.00		
Information Content	0.09	0.06	0.48	1.00	
Goals Scored	0.23	0.22	0.14	-0.05	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.504
R Square	0.254
Adjusted R Square	0.005
Standard Error	1.012
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	4.178	1.045	1.020	0.436
Residual	12.000	12.292	1.024		
Total	16.000	16.471			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-30.365	22.445	-1.353	0.201	-79.269	18.540	-79.269	18.540
Y Intercept	17.524	10.821	1.620	0.131	-6.052	41.101	-6.052	41.101
Gradient	-211.135	132.712	-1.591	0.138	-500.289	78.020	-500.289	78.020
Regression Coefficient	0.332	0.213	1.559	0.145	-0.132	0.797	-0.132	0.797
Information Content	-0.942	0.575	-1.637	0.128	-2.196	0.312	-2.196	0.312

G5

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goals Conceded
m3	ta	c	2.00	10.31	0.65	81.30	41.63	0
m4	ta	c	2.00	12.78	0.86	86.50	41.42	2
m6	ta	c	2.00	10.53	0.67	85.10	42.49	2
m7	ta	c	2.00	10.00	0.62	87.70	43.88	0
m8	ta	c	2.00	10.75	0.68	84.10	42.51	0
m13	ta	c	2.00	10.89	0.70	84.00	42.42	1
m14	ta	c	2.00	9.83	0.61	86.50	41.91	2
m15	ta	c	2.00	9.71	0.61	85.90	41.66	3
m19	ta	c	2.00	10.23	0.65	83.80	41.52	2
m22	ta	c	2.00	10.20	0.64	84.20	41.12	2
m24	ta	c	2.00	10.09	0.64	85.90	42.41	1
m28	ta	c	2.00	10.33	0.66	84.90	41.17	0
m29	ta	c	2.00	9.87	0.62	85.20	41.07	2
m31	ta	c	2.00	9.91	0.62	81.90	40.41	1
m32	ta	c	2.00	9.17	0.56	86.80	41.74	2
m34	ta	c	2.00	11.34	0.73	84.90	42.55	3
m37	ta	c	2.00	10.54	0.67	85.50	42.48	3

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goals Conceded*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.01	-0.01	1.00		
Information Content	0.09	0.06	0.48	1.00	
Goals Conceded	0.07	0.09	0.29	-0.12	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.433
R Square	0.187
Adjusted R Square	-0.084
Standard Error	1.111
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	3.414	0.853	0.691	0.612
Residual	12.000	14.821	1.235		
Total	16.000	18.235			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.669	24.647	-0.027	0.979	-54.369	53.031	-54.369	53.031
Y Intercept	-3.024	11.882	-0.254	0.803	-28.912	22.865	-28.912	22.865
Gradient	38.890	145.727	0.267	0.794	-278.622	356.402	-278.622	356.402
Regression Coefficient	0.259	0.234	1.106	0.291	-0.251	0.769	-0.251	0.769
Information Content	-0.335	0.632	-0.529	0.606	-1.711	1.042	-1.711	1.042

G6

Match File	Team	Type	Team A Home or Away?	Y Intercept	Gradient	Regression Coefficient	Information Content	Goal Difference
m3	ta	c	2.00	10.31	0.65	81.30	41.63	0
m4	ta	c	2.00	12.78	0.86	86.50	41.42	0
m6	ta	c	2.00	10.53	0.67	85.10	42.49	-1
m7	ta	c	2.00	10.00	0.62	87.70	43.88	0
m8	ta	c	2.00	10.75	0.68	84.10	42.51	3
m13	ta	c	2.00	10.89	0.70	84.00	42.42	0
m14	ta	c	2.00	9.83	0.61	86.50	41.91	-1
m15	ta	c	2.00	9.71	0.61	85.90	41.66	-2
m19	ta	c	2.00	10.23	0.65	83.80	41.52	-1
m22	ta	c	2.00	10.20	0.64	84.20	41.12	1
m24	ta	c	2.00	10.09	0.64	85.90	42.41	2
m28	ta	c	2.00	10.33	0.66	84.90	41.17	1
m29	ta	c	2.00	9.87	0.62	85.20	41.07	-1
m31	ta	c	2.00	9.91	0.62	81.90	40.41	-1
m32	ta	c	2.00	9.17	0.56	86.80	41.74	-1
m34	ta	c	2.00	11.34	0.73	84.90	42.55	-2
m37	ta	c	2.00	10.54	0.67	85.50	42.48	-3

	Y Intercept	*Gradient*	*Regression Coefficient*	*Information Content*	*Goal Difference*
Y Intercept	1.00				
Gradient	1.00	1.00			
Regression Coefficient	-0.01	-0.01	1.00		
Information Content	0.09	0.06	0.48	1.00	
Goal Difference	0.10	0.09	-0.11	0.05	1.00

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.371
R Square	0.138
Adjusted R Square	-0.150
Standard Error	1.606
Observations	17.000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.000	4.934	1.234	0.478	0.751
Residual	12.000	30.948	2.579		
Total	16.000	35.882			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-29.696	35.615	-0.834	0.421	-107.294	47.902	-107.294	47.902
Y Intercept	20.548	17.170	1.197	0.254	-16.861	57.958	-16.861	57.958
Gradient	-250.025	210.578	-1.187	0.258	-708.834	208.785	-708.834	208.785
Regression Coefficient	0.073	0.338	0.217	0.832	-0.663	0.810	-0.663	0.810
Information Content	-0.607	0.913	-0.665	0.519	-2.597	1.382	-2.597	1.382

Appendix 7 – Match replay Software

The following software was written in pure Java using the Processing Integrated Development Environment to facilitate match replay from the data files provided by Prozone. It was developed using an iterative, rapid application development methodology and although the software has served its purpose in this work, it does require further development work to bypass the need to hard code certain values in the executable code prior to each match being played back.

This is more of a future nicety to be incorporated and certainly does not detract from the results that it produces in its current form.

```
//Computer Code written in support of PhD Thesis: On Self Organising Cyberdynamic Policy (September 2016)

//Mark Evans B.Sc.(Hons), M.Sc.

//PhD Researcher in Applied Cybernetics

//Department of Computer Science

//Faculty of Engineering & Technology

//Liverpool John Moores University

//James Parsons Building

//Byrom Street

//Liverpool

//L3 3AF

//Copyright (c) 2014-16 Mark R. Evans (unless otherwise stated)



//This is the main program code to re-create a football pitch and to read in player positions from a supplied target file.

//The player positions from the file are supplied to software agents that represent players, and the necessary interconnecting

//edges between them are computed and drawn. The centroids of functional polygons within the team (subgroups of players) is also

//computed and drawn and their dynamically varying positions are recorded to various destination files for post match analysis.

//The program uses three other classes: Hungarian Algorithm, Player and mreMunkresArray6

//The Hungarian Algorithm Class is an implementation of that algorithm in Java, written by Kevin L. Stern (attribution in class code - see that
code) for policy allocation aspect of research (not in final thesis)

//The Player class is that to describe a software agent that represents a real football player.
```

//mreMunkresArray6 is a class that describes a subroutine to handle the differences in distance between A,M,D on Red Team to A,M,D on Blue Team in conjunction with this particular application of the Hungarian Algorithm.

```
import controlP5.*;                             //importing GUI controls library

import java.io.*;


ControlP5 cp5;                                  //declaration of control object


boolean showRed;                                //show red team overall policy polygon flag

boolean showRedAttack;                          //show red team attack policy polygon flag

boolean showRedMidfield;                        //show red team midfield policy polygon flag

boolean showRedDefence;                         //show red team defence policy polygon flag


boolean showBlue;                               //show blue team overall policy polygon flag

boolean showBlueAttack;                         //show blue team attack policy polygon flag

boolean showBlueMidfield;                       //show blue team midfield policy polygon flag

boolean showBlueDefence;                        //show blue team defence policy polygon flag


int nplayers = 11;                              //number of players

Player [] red = new Player[nplayers];           //red team array

Player [] blue = new Player[nplayers];          //blue team array
```

```
double [][] x_distances= new double[3][3];     //two diemnsional array to handle store X coordinates of Attack, Midfield & Defence policy
                                               centroids

double [][] y_distances = new double[3][3];    //two diemnsional array to handle store Y coordinates of Attack, Midfield & Defence policy
                                               centroids


double [][] x_preservation = new double[3][3]; //two dimensional array to preserve signed value content of x_distances array

double [][] y_preservation = new double[3][3]; //two dimensional array to preserve signed value content of y_distances array


double [][] x_preservation2 = new double[3][3];

double [][] y_preservation2 = new double[3][3];


double xTempCheck;                             //temporary variable to allow conversion from negative to positive when normalising array prior to
                                               passing to allocation algorithm

double yTempCheck;                             //temporary variable to allow conversion from negative to positive when normalising array prior to
                                               passing to allocation algorithm


//*******************************************************************************************************************

//The array to handle the differences in distance for  between

//A,M,D on Red Team to A,M,D on Blue Team in the X direction:


//*******************************************************************************************************************
```

```
//Suspect this is not required:

double[][] myArray = {  {74, 76, 46},
                     {12, 59, 17},
                     {60, 91, 48} };
//**********************************************************************************************************************

//The array to handle the differences in distance for  between
//A,M,D on Red Team to A,M,D on Blue Team in the Y direction:

//**********************************************************************************************************************
//Suspect this is not required:

double[][] myArray2 = {  {79, 95, 18},
                     {14, 24, 3},
                     {9, 47, 87} };
//**********************************************************************************************************************
//Suspect this is not required:
/*int[][] myAssignments = new int[3][3];
int[][] myAssignments2 =  new int[3][3];*/
//**********************************************************************************************************************
//Suspect this is not required:
```

```
/*int[] xResult = new int[3];
int[] yResult = new int[3];*/
//*****************************************************************************************************************
//Suspect this is not required:

String[] flag = {"A","M","D"};                  //one dimensional array to apply appropriate flag to output data
                                                //'A' - Attack ; 'M' - Midfield ; 'D' - Defence
//*************************************************************************************************************
//HungarianAlgorithm algorithm;
//HungarianAlgorithm algorithm2;
//*************************************************************************************************************

mreMunkresArray6 allocations;                    //declaration of Munkres object

BufferedReader reader;                           //declaration of buffered reader object for file read
String line;                                     //declaration of string variable for line data

int x;                                           //x coordinate of a player in file record
int y;                                           //y coordinate of a player in file record
int playerNo;                                    //player number of player (shirt number) in file record
int team;                                        //team number of team in file record
int timestamp;                                   //timestamp of file record i.e. time at which laser reading taken
```

```
int conversionFactorX = 1000/105;           //geometry conversion factors from real world to model coordinates
int conversionFactorY = 647/68;

                                            //for the red team:

int sumXRed;                                //variable to store sum of red team x coordinate
int sumYRed;                                //variable to store sum of red team y coordinate

int sumXRedAttack;                          //variable to store sum of red team (Attack functionaries) x coordinate
int sumYRedAttack;                          //variable to store sum of red team (Attack functionaries) y coordinate

int sumXRedMidfield;                        //variable to store sum of red team (Midfield functionaries) x coordinate
int sumYRedMidfield;                        //variable to store sum of red team (Midfield functionaries) y coordinate

int sumXRedDefence;                         //variable to store sum of red team (Defence functionaries) x coordinate
int sumYRedDefence;                         //variable to store sum of red team (Defence functionaries) y coordinate

                                            //for the blue team:

int sumXBlue;                               //variable to store sum of blue team x coordinate
int sumYBlue;                               //variable to store sum of blue team y coordinate
```

```
int sumXBlueAttack;                 //variable to store sum of blue team (Attack functionaries) x coordinate
int sumYBlueAttack;                 //variable to store sum of blue team (Attack functionaries) y coordinate

int sumXBlueMidfield;               //variable to store sum of blue team (Midfield functionaries) x coordinate
int sumYBlueMidfield;               //variable to store sum of blue team (Midfield functionaries) y coordinate

int sumXBlueDefence;                //variable to store sum of blue team (Defence functionaries) x coordinate
int sumYBlueDefence;                //variable to store sum of blue team (Defence functionaries) y coordinate

                                    //for the red team:

PShape redTeam;                     //declaration of pshape object for red team overall policy polygon
PShape redTeamAttack;               //declaration of pshape object for red team attack policy polygon
PShape redTeamMidfield;             //declaration of pshape object for red team midfield policy polygon
PShape redTeamDefence;              //declaration of pshape object for red team defence policy polygon

PShape blueTeam;                    //declaration of pshape object for blue team overall policy polygon
PShape blueTeamAttack;              //declaration of pshape object for blue team attack policy polygon
PShape blueTeamMidfield;            //declaration of pshape object for blue team midfield policy polygon
PShape blueTeamDefence;             //declaration of pshape object for blue team defence policy polygon
```

```
PImage pitch;                          //image of pitch for use as background

PrintWriter redOutput;                 //declaration of print writer object for red team centroid data (Whole team)
PrintWriter redAttack;                 //declaration of print writer object for red team centroid data (Attack function)
PrintWriter redMidfield;               //declaration of print writer object for red team centroid data (Midfield function)
PrintWriter redDefence;                //declaration of print writer object for red team centroid data (Defence function)

PrintWriter blueOutput;                //declaration of print writer object for blue team centroid data (Whole team)
PrintWriter blueAttack;                //declaration of print writer object for blue team centroid data (Attack function)
PrintWriter blueMidfield;              //declaration of print writer object for blue team centroid data (Midfield function)
PrintWriter blueDefence;               //declaration of print writer object for blue team centroid data (Defence function)


PrintWriter optimalAttack;             //declaration of print writer object for optimally adjusted attack centroid coordinates
PrintWriter optimalMidfield;           //declaration of print writer object for optimally adjusted midfield centroid coordinates
PrintWriter optimalDefence;            //declaration of print writer object for optimally adjusted defence centroid coordinates

PrintWriter A;                         //declaration of print writer object for writing allocations based on magnitude only for attack
function
PrintWriter M;                         //declaration of print writer object for writing allocations based on magnitude only for midfield
function
PrintWriter D;                         //declaration of print writer object for writing allocations based on magnitude only for defence
function
```

```
PrintWriter signedAttack;            //declaration of print writer object for Writing signed values from the preserved arrays to allow
                                     integrity checking for attack function

PrintWriter signedMidfield;          //declaration of print writer object for Writing signed values from the preserved arrays to allow
                                     integrity checking for midfield function

PrintWriter signedDefence;           //declaration of print writer object for Writing signed values from the preserved arrays to allow
                                     integrity checking for defence function


PrintWriter auditLog;                //declaration of print writer object for writing the audit log to allow integrity check of system
                                     arithmetic output



double optimisedAttackX;             //declaration of variable to compute optimised attack coordinates in x direction

double optimisedAttackY;             //declaration of variable to compute optimised attack coordinates in y direction


double optimisedMidfieldX;           //declaration of variable to compute optimised midfield coordinates in x direction

double optimisedMidfieldY;           //declaration of variable to compute optimised midfield coordinates in y direction


double optimisedDefenceX;            //declaration of variable to compute optimised defence coordinates in x direction

double optimisedDefenceY;            //declaration of variable to compute optimised defence coordinates in y direction



void setup()                         //commence setup...
```

```
{
   size(1280,819);                             //window size to contain model


   smooth();                                   //smoothing animation
   stroke(0);                                  //line colour is white


   //initialising all elements in x and y 2d arrays to zero


   for(int i=0; i<3 ;i++)                      //outer loop
   {
     for(int j=0; j<3; j++)                    //inner loop
     {
      x_distances[i][j] = 0;                   //allocations
      y_distances[i][j] = 0;


     }                                         //end inner loop


   }                                           //end outer loop




  for(int i=0; i< nplayers; i++)               //for every player involved...
```

```
{
    red[i] = new Player(255,0,0);            //create nplayer x player objects for red team array
    blue[i] = new Player(0,0,255);           //create nplayer x player objects for blue team array
}

reader = createReader("general2.csv");       //create reader for source data file

PFont myFont = createFont("Times",8);        //create font and size for text labels
textFont(myFont);                            //apply font specified

pitch = loadImage("Pitch2.jpg");             //load background image

                                             //show red team overall policy polygon button...
 cp5 = new ControlP5(this);                  //adding GUI controls as required
 cp5.addButton("displayRed").setValue(0)     //associated method i.e. do method if selected
  .setPosition(140,750).setSize(110,19)      //position
  .setLabel("Show Red Team")                 //caption
  .setColorBackground(0xffff0000)            //background colour (always have to use hex. rgb is a no go.
```

```
 .setColorActive(0xffff0000);
 //0xff660000
 //#ff0d00
                                                //show red team attack policy polygon button...
cp5 = new ControlP5(this);                      //adding GUI controls as required
cp5.addButton("displayRedAttack").setValue(0)   //associated method i.e. do method if selected
 .setPosition(260,750).setSize(110,19)          //position
 .setLabel("Show Red Team Attack")              //caption
 .setColorBackground(0xffff0000)                //background colour (always have to use hex. rgb is a no go.
 .setColorActive(0xffff0000);

                                                //show red team midfield policy polygon button...
 cp5 = new ControlP5(this);                     //adding GUI controls as required
cp5.addButton("displayRedMidfield").setValue(0) //associated method i.e. do method if selected
 .setPosition(380,750).setSize(110,19)          //position
 .setLabel("Show Red Team Midfield")            //caption
 .setColorBackground(0xffff0000)                //background colour (always have to use hex. rgb is a no go.
 .setColorActive(0xffff0000);


                                                //show red team defence policy polygon button...
 cp5 = new ControlP5(this);                     //adding GUI controls as required
```

```
 cp5.addButton("displayRedDefence").setValue(0)  //associated method i.e. do method if selected
  .setPosition(500,750).setSize(110,19)          //position
  .setLabel("Show Red Team Defence")             //caption
  .setColorBackground(0xffff0000)                //background colour (always have to use hex. rgb is a no go.
  .setColorActive(0xffff0000);



                                                 //show blue team overall policy polygon button...
cp5 = new ControlP5(this);
 cp5.addButton("displayBlue").setValue(0)
  .setPosition(1030,750).setSize(110,19)
  .setLabel("Show Blue Team");

                                                 //show blue team attack policy polygon button...

cp5 = new ControlP5(this);
 cp5.addButton("displayBlueAttack").setValue(0)
  .setPosition(910,750).setSize(110,19)
  .setLabel("Show Blue Team Attack");



                                                 //show blue team midfield policy polygon button...
```

```
cp5 = new ControlP5(this);
 cp5.addButton("displayBlueMidfield").setValue(0)
  .setPosition(790,750).setSize(110,19)
  .setLabel("Show Blue Team Midfield");


                                                  //show blue team defence policy polygon button...
cp5 = new ControlP5(this);
 cp5.addButton("displayBlueDefence").setValue(0)
  .setPosition(670,750).setSize(110,19)
  .setLabel("Show Blue Team Defence");


 //specify target files for centroid data to be written to

redOutput= createWriter("data/redCentroidData.txt");                 //whole Red team centroid
redAttack= createWriter("data/redAttackCentroidData.txt");           //attack centroid for Red Team
redMidfield= createWriter("data/redMidfieldCentroidData.txt");       //Midfield centroid for Red Team
redDefence= createWriter("data/redDefenceCentroidData.txt");         //Defence centroid for Red Team


blueOutput = createWriter("data/blueCentroidData.txt");              //whole Blue team centroid
```

```
blueAttack= createWriter("data/blueAttackCentroidData.txt");         //attack centroid for Blue Team
blueMidfield= createWriter("data/blueMidfieldCentroidData.txt");     //Midfield centroid for Blue Team
blueDefence= createWriter("data/blueDefenceCentroidData.txt");       //Defence centroid for Blue Team


//writing optimally adjusted policy centroid coordinates to relevant files pending post run analysis

optimalAttack = createWriter("data/optimalAttack.txt");              //optimally adjusted attack centroid coordinates to be written here
optimalMidfield = createWriter("data/optimalMidfield.txt");          //optimally adjusted midfield centroid coordinates to be written here
optimalDefence = createWriter("data/optimalDefence.txt");            //optimally adjusted defence centroid coordinates to be written here

//writing allocations based on magnitude only to relevant files for reference purposes

A = createWriter("data/MREAttackOptimals.txt");                      //attack centroid allocations
M = createWriter("data/MREMidfieldOptimals.txt");                    //midfield centroid allocations
D = createWriter("data/MREDefenceOptimals.txt");                     //defence centroid allocations

//Writing signed values from the preserved arrays to allow integrity checking

signedAttack = createWriter("data/MREsignedAttack.txt");             //attack centroid signed values
signedMidfield = createWriter("data/MREsignedMidfield.txt");         //midfield centroid signed values
signedDefence = createWriter("data/MREsignedDefence.txt");           //defence centroid signed values
```

```
 auditLog = createWriter("data/auditLog.txt");                          //audit log output destination file

}                                               //end setup

void draw()                                     //commence draw loop (equivalent to main() method in java)
{

  background(pitch);                            //applying pitch image to background

  try                                           //if there is a line to read in the source file...
  {
    line = reader.readLine();                   //read the line.
  }

  catch (IOException e)                         //if there is no line to read in the source file...
  {
    e.printStackTrace();                        //we have an error, so print the stack trace to locate it.
    line = null;                                //line is set to null since we don't have one to read.
  }

  if (line == null)                             //if we have no line to read...
```

```
{
                                             //Stop reading because of an error or file is empty

  noLoop();                                  //do not loop i.e. do not allow draw() to loop

  redOutput.close();                         //close centroid data writer streams
  blueOutput.close();

}

else                                         //if we get this far, then we have one or more lines in the file...
{
  String[] pieces = split(line,",");         //The source files will be comma separated, so need to split by the comma delimiter
                                             //and we are reading each line.

  //assiging split data in the array to variables required:

  x = int(pieces[4]);                        //the index in the square brackets corresponds to the column in the data file
  y = int(pieces[5]);
  team = int(pieces[2]);
  playerNo = int(pieces[3]);
```

```
timestamp = int(pieces[1]);



    if(team==0)  //if the team no parameter that has been read from the file is 0...
    {
      //assiging read-in position to sprite on screen that represents player:

      red[playerNo-1].setXPos((width/2)+(x*conversionFactorX));     //x-coordinate
      red[playerNo-1].setYPos((height/2) + (y*conversionFactorY));  //y coordinate

    }

    if(team==1)  //as above, but for team 1
    {
      blue[playerNo-1].setXPos((width/2)+(x*conversionFactorX));
      blue[playerNo-1].setYPos((height/2)+(y*conversionFactorY));

    }



    for(int j = 0; j<11; j++)  //for every player involved...
       {
```

```
if(showRed)  //testing truth value of 'showRed' parameter, and if true then...
{
//do this...
fill(0,0,0);//set text colour to black
text("X:"+(int)red[j].getXPos(),red[j].getXPos()+5,red[j].getYPos());         //red team member x coordinate
text("Y:"+(int)red[j].getYPos(),(red[j].getXPos()+5),red[j].getYPos()+10);    //red team member y coordinate
text("N:"+j,(red[j].getXPos())+5,red[j].getYPos()+20);                        //red team member array index number
}

//otherwise...

if(showBlue)  //testing truth value of 'showBlue@ paramter, and if true then...
{
//do this...



fill(0,0,0);//set text colour to black
text("X:"+(int)blue[j].getXPos(),blue[j].getXPos()+5,blue[j].getYPos());      //blue team member x coordinate
text("Y:"+(int)blue[j].getYPos(),(blue[j].getXPos()+5),blue[j].getYPos()+10); //blue team member y coordinate
text("N:"+j,(blue[j].getXPos())+5,blue[j].getYPos()+20);                      //blue team member array index number
```

```
 }

 //drawing a line between each player in the array

for(int d = 0; d <10; d++)  //for every player involved (note the array indexing carefully)
{
  if(showRed)  // testing truth of showRed parameter, and if true then...
  {
  //do this...
  stroke(255,0,0,10);  //set line colour to the same colour as the background (makes it invisible)
  line(red[d].getXPos(),red[d].getYPos(),red[d+1].getXPos(),red[d+1].getYPos());
   //we still need to update the line even if it is invisible though
  }

  if(showBlue) // testing truth of showBlue parameter, and if true then...
  {
  //do this...
  stroke(0,0,255,10);  //set line colour to the same colour as the background (makes it invisible)
  line(blue[d].getXPos(),blue[d].getYPos(),blue[d+1].getXPos(),blue[d+1].getYPos());
   //we still need to update the line even if it is invisible though
```

```
    }

}

  //joins first to last and closes polygon
  //similar to above, but relates exclusively to the last line in the polygon that serves to close it
  if(showRed)
  {
   stroke(255,0,0,10);
   line(red[10].getXPos(),red[10].getYPos(),red[0].getXPos(),red[0].getYPos());
  }

   if(showBlue)
  {
   stroke(0,0,255,10);
   line(blue[10].getXPos(),blue[10].getYPos(),blue[0].getXPos(),blue[0].getYPos());

  }
```

```
  sumXRed+=red[j].getXPos();      //accumulate X and Y cocordinates for each team
  sumYRed+=red[j].getYPos();

  sumXBlue+=blue[j].getXPos();
  sumYBlue+=blue[j].getYPos();

  if(showRed)
  {
    red[j].display();
  }

  if(showBlue)
  {
    blue[j].display();
  }


}

//for the red team:
```

```
//for the red team overall function...

beginShape(POLYGON);   //begin drawing a polygon

if(showRed)            //if true, then draw it as follows...
{
fill(255,0,0,25);      //fill it with a red colour that has an alpha (transparency) value of 25
}
else                   //otherwise...
{
 fill(125,0);          //if not true then set the polygon fill colour to be the same as the background colour
}


for(int k =0; k<11;k++)                       //for every player involved...
{
  vertex(red[k].getXPos(),red[k].getYPos());  //draw a polygon vertex at that player's location on the red team
}
 endShape(CLOSE);                             //finish drawing the red team's polygon


//for the red team attack function...
```

```
beginShape(POLYGON);   //begin drawing a polygon

if(showRedAttack)      //if true, then draw it as follows...
{
fill(184,250,140,90);  //fill it with a red colour that has an alpha (transparency) value of 50
}
else
{
 fill(125,0);          //if not true then set the polygon fill colour to be the same as the background colour
}



//for every player involved in the red team attack function...
{
  vertex(red[0].getXPos(),red[0].getYPos());    //draw a polygon vertex at that player's location on the red team
  vertex(red[1].getXPos(),red[1].getYPos());    //draw a polygon vertex at that player's location on the red team
  //vertex(red[2].getXPos(),red[2].getYPos());    //draw a polygon vertex at that player's location on the red team
  //vertex(red[3].getXPos(),red[3].getYPos());    //draw a polygon vertex at that player's location on the red team
  //vertex(red[8].getXPos(),red[8].getYPos());    //draw a polygon vertex at that player's location on the red team
  //vertex(red[9].getXPos(),red[9].getYPos());    //draw a polygon vertex at that player's location on the red team
  //vertex(red[10].getXPos(),red[10].getYPos());  //draw a polygon vertex at that player's location on the red team
```

```
              //calculating attack policy polygon centroid coordinates...

sumXRedAttack = red[0].getXPos()+red[1].getXPos();//+red[2].getXPos()+red[3].getXPos();//+red[10].getXPos();

sumYRedAttack = red[0].getYPos()+red[1].getYPos();//+red[2].getYPos()+red[3].getYPos();//+red[10].getYPos();




            }

             endShape(CLOSE);        //finish drawing the red team's attack function sub-polygon



             //for the red team midfield function...


             beginShape(POLYGON);  //begin drawing a polygon


            if(showRedMidfield)    //if true, then draw it as follows...

            {

            fill(250,140,247,90);  //fill it with a red colour that has an alpha (transparency) value of 75

            }

            else                   //otherwise...

            {
```

```
 fill(125,0);          //if not true then set the polygon fill colour to be the same as the background colour

}



//for every player involved in the midfield function...

{

  //vertex(red[1].getXPos(),red[1].getYPos());  //draw a polygon vertex at that player's location on the red team

  vertex(red[2].getXPos(),red[2].getYPos());  //draw a polygon vertex at that player's location on the red team

  vertex(red[3].getXPos(),red[3].getYPos());  //draw a polygon vertex at that player's location on the red team

  vertex(red[4].getXPos(),red[4].getYPos());  //draw a polygon vertex at that player's location on the red team

  vertex(red[5].getXPos(),red[5].getYPos());  //draw a polygon vertex at that player's location on the red team

  //vertex(red[6].getXPos(),red[6].getYPos());  //draw a polygon vertex at that player's location on the red team


  //calculating midfield policy polygon centroid coordinates...


  sumXRedMidfield = red[2].getXPos()+red[3].getXPos()+red[4].getXPos()+red[5].getXPos();

 //+red[6].getXPos();


  sumYRedMidfield = red[2].getYPos()+red[3].getYPos()+red[4].getYPos()+red[5].getYPos();

 //+red[6].getYPos();
```

```
}
 endShape(CLOSE);      //finish drawing the red team's midfield function sub-polygon



//for the red team defence function...


beginShape(POLYGON);  //begin drawing a polygon


if(showRedDefence)    //if true, then draw it as follows...
{
fill(249,133,8,90);   //fill it with a red colour that has an alpha (transparency) value of 75
}
else
{
fill(125,0);    //if not true then set the polygon fill colour to be the same as the background  colour
}



//for every player involved in the defence function...
{
  vertex(red[6].getXPos(),red[6].getYPos());  //draw a polygon vertex at that player's location on the red team
  vertex(red[7].getXPos(),red[7].getYPos());  //draw a polygon vertex at that player's location on the red team
```

```
  vertex(red[8].getXPos(),red[8].getYPos());  //draw a polygon vertex at that player's location on the red team

  vertex(red[9].getXPos(),red[9].getYPos());  //draw a polygon vertex at that player's location on the red team

  vertex(red[10].getXPos(),red[10].getYPos());  //draw a polygon vertex at that player's location on the red team

  //calculating defence policy polygon centroid coordinates...


  sumXRedDefence = red[6].getXPos()+red[7].getXPos()+red[8].getXPos()+red[9].getXPos()+red[10].getXPos();

  sumYRedDefence = red[6].getYPos()+red[7].getYPos()+red[8].getYPos()+red[9].getYPos()+red[10].getYPos();


}

 endShape(CLOSE);        //finish drawing the red team's defence function sub-polygon




 //for the blue team:


 //for the blue team overall function...


beginShape(POLYGON);    //begin drawing another polygon


if(showBlue)            //if true, then draw as follows...

{

fill(0,0,255,25);       //fill it with a blue colour that has an alpha (transparency) value of 25
```

```
}
else
{
  fill(125,0);    //if not true then set the polygon fill colour to be the same as the background colour
}

for(int m =0; m<11;m++)  //for every player involved...
{
   vertex(blue[m].getXPos(),blue[m].getYPos());
  //draw a polygon vertex at that player's loaction on the blue team
}
endShape(CLOSE);         //finish drawing the blue team's polygon



//for the blue team attack function...

 beginShape(POLYGON);   //begin drawing a polygon

if(showBlueAttack)      //if true, then draw it as follows...
{
fill(255,255,0,90);     //fill it with a red colour that has an alpha (transparency) value of 50
```

```
}
else
{
 fill(125,0);
 //if not true then set the polygon fill colour to be the same as the background colour
}


//for every player involved in the attack function...
{

  vertex(blue[0].getXPos(),blue[0].getYPos());
  //draw a polygon vertex at that player's location on the blue team

  vertex(blue[1].getXPos(),blue[1].getYPos());
  //draw a polygon vertex at that player's location on the blue team

  //vertex(blue[2].getXPos(),blue[2].getYPos());
  //draw a polygon vertex at that player's location on the blue team

  //vertex(blue[10].getXPos(),blue[10].getYPos());
  //draw a polygon vertex at that player's location on the blue team
```

```
  //calculating attack policy polygon centroid coordinates...

  sumXBlueAttack = blue[0].getXPos()+blue[1].getXPos();//+blue[2].getXPos();//+blue[10].getXPos();
  sumYBlueAttack = blue[0].getYPos()+blue[1].getYPos();//+blue[2].getYPos();//+blue[10].getYPos();
}
 endShape(CLOSE);        //finish drawing the blue team's attack function sub-polygon


 //for the blue team midfield function...

beginShape(POLYGON);    //begin drawing a polygon

if(showBlueMidfield)    //if true, then draw it as follows...
{
fill(0,255,247,90);     //fill it with a red colour that has an alpha (transparency) value of 50
}
else
{
 fill(125,0);
 //if not true then set the polygon fill colour to be the same as the background colour
}
```

```
//for every player involved in the midfield function...

{

  //vertex(blue[1].getXPos(),blue[1].getYPos());  //draw a polygon vertex at that player's location on the blue team

  vertex(blue[2].getXPos(),blue[2].getYPos());  //draw a polygon vertex at that player's location on the blue team

  vertex(blue[3].getXPos(),blue[3].getYPos());  //draw a polygon vertex at that player's location on the blue team

  vertex(blue[4].getXPos(),blue[4].getYPos());  //draw a polygon vertex at that player's location on the blue team

  vertex(blue[5].getXPos(),blue[5].getYPos());  //draw a polygon vertex at that player's location on the blue team

  //vertex(blue[6].getXPos(),blue[6].getYPos());  //draw a polygon vertex at that player's location on the blue team


  //calculating midfield policy polygon centroid coordinates...


  sumXBlueMidfield = blue[2].getXPos()+blue[3].getXPos()+blue[4].getXPos()+blue[5].getXPos();

  sumYBlueMidfield = blue[2].getYPos()+blue[3].getYPos()+blue[4].getYPos()+blue[5].getYPos();


}

 endShape(CLOSE);        //finish drawing the blue team's midfield function sub-polygon



 //for the blue team defence function...
```

```
beginShape(POLYGON);  //begin drawing a polygon

if(showBlueDefence)   //if true, then draw it as follows...
{
fill(154,0,255,90);   //fill it with a red colour that has an alpha (transparency) value of 50
}
else
{
 fill(125,0);
 //if not true then set the polygon fill colour to be the same as the background colour
}


//for every player involved in the defence function...
{
  //vertex(blue[5].getXPos(),blue[5].getYPos());  //draw a polygon vertex at that player's location on the blue team

  //vertex(blue[5].getXPos(),blue[5].getYPos());  //draw a polygon vertex at that player's location on the blue team
  vertex(blue[6].getXPos(),blue[6].getYPos());  //draw a polygon vertex at that player's location on the blue team
  vertex(blue[7].getXPos(),blue[7].getYPos());  //draw a polygon vertex at that player's location on the blue team
  vertex(blue[8].getXPos(),blue[8].getYPos());  //draw a polygon vertex at that player's location on the blue team
  vertex(blue[9].getXPos(),blue[9].getYPos());  //draw a polygon vertex at that player's location on the blue team
```

```
  vertex(blue[10].getXPos(),blue[10].getYPos());  //draw a polygon vertex at that player's location on the blue team

  //calculating defence policy polygon centroid coordinates...

    sumXBlueDefence = blue[6].getXPos()+blue[7].getXPos()+blue[8].getXPos()+blue[9].getXPos()+blue[10].getXPos();

  sumYBlueDefence = blue[6].getYPos()+blue[7].getYPos()+blue[8].getYPos()+blue[9].getYPos()+blue[10].getYPos();

}
 endShape(CLOSE);        //finish drawing the blue team's defence function sub-polygon




 //for the red team:

 //joining the centroid to the midpoint of each perimeter line of the overall policy polygon...

 for(int e=0; e <10; e++)
  {
   //drawing a line between the centroid and the midpoint of the lines joining each player in array
   if(showRed)
   {
```

```
      stroke(0,255,0,50);//draw this in green to differentiate

    }

    else

    {

      stroke(125,0);

     //if we have decided not to observe red team (showRed is false) then draw with same colour as background so as to make invisible

    }


     //calculate and draw line i.e. calculate the midpoint coordinates of polygon lines and draw a line from the centroid to each of
     them


     line( (( (red[e].getXPos())+(red[e+1].getXPos()) )/2),(( (red[e].getYPos())+(red[e+1].getYPos()) )/2),sumXRed/11,sumYRed/11);


   }


   //do the same for the line that closes the polygon

     line( (( (red[0].getXPos())+(red[10].getXPos()) )/2),(( (red[0].getYPos())+(red[10].getYPos()) )/2),sumXRed/11,sumYRed/11);




 //for the blue team:


 //identical to the above...i.e. for red team
```

```
//joining the centroid to the midpoint of each perimeter line of the overall policy polygon...


for(int f=0; f <10; f++)

  {

   //drawing a line between the centroid and the midpoint of the lines joining each player in array



   if(showBlue)

   {

     stroke(255,255,0,50);//draw this in yellow to differentiate

   }

   else

   {

     stroke(125,0);

   }

   //calculate and draw line

    line( (( (blue[f].getXPos())+(blue[f+1].getXPos()) )/2),(( (blue[f].getYPos())+(blue[f+1].getYPos())
    )/2),sumXBlue/11,sumYBlue/11);




  }


    line( (( (blue[0].getXPos())+(blue[10].getXPos()) )/2),(( (blue[0].getYPos())+(blue[10].getYPos()) )/2),sumXBlue/11,sumYBlue/11);
```

```
//for the centroid of each polygon...

//red team:

//entire team
    fill(255,0,0);
   //fill colour for red team centroid is red

    strokeWeight(4);
    //increase line weight to 4 from default setting of 1

    stroke(0,0,0);
    //line colour is black

    ellipse((sumXRed/11),(sumYRed/11),10,10);
    //draw circle to represent centroid for red team

    fill(255,255,255);
    //set fill colour to white
```

```
    text("WHOLE TEAM",(sumXRed/11)+10,(sumYRed/11)-10);
    //whole team centroid label


    text("X:"+(int)(sumXRed/11),(sumXRed/11)+10,(sumYRed/11));
    //create labels to display centroid coordinate data for red team

    text("Y:"+(int)(sumYRed/11),(sumXRed/11)+10,(sumYRed/11)+10);

    strokeWeight(1);
    //return line weight to default value

    noStroke();
    //switch stroke function off


//attack
    //sumXRedAttack = red[6].getXPos()+red[7].getXPos()+red[8].getXPos()+red[9].getXPos()+red[9].getYPos()+red[10].getXPos();
    //note: the above line was pasted in as a reminder of how many players are involved in the attach function so that the divisor
    //for the centroid calulations below is correct
```

```
fill(255,0,0);

//fill colour for red team attack centroid is red


strokeWeight(2);

//increasing line weight to 2 from default of 1. Sub policies have less line weight so they can be distinguished


stroke(255,255,255);

//line colour is white


ellipse((sumXRedAttack/2),(sumYRedAttack/2),10,10);

//draw circle to represent attack centroid for red team


fill(0,0,0);

//fill colour is set to black


text("ATTACK",(sumXRedAttack/2)+10,(sumYRedAttack/2)-10);

//attack centroid label


text("X:"+(int)(sumXRedAttack/2),(sumXRedAttack/2)+10,(sumYRedAttack/2));

//create labels to display attack centroid coordinate data for red team.

Divisor refers to number of players in attack formation
```

```
                text("Y:"+(int)(sumYRedAttack/2),(sumXRedAttack/2)+10,(sumYRedAttack/2)+10);

                strokeWeight(1);


                //return line weight to default value

                noStroke();


                //switch stroke function off


            //midfield

                //sumXRedMidfield = red[2].getXPos()+red[3].getXPos()+red[5].getXPos();


                //note: the above line was pasted in as a reminder of how many players are involved in the attach                function so that
the divisor for the centroid calulations below is correct


                fill(255,0,0);

               //fill colour for red team attack centroid is red


                strokeWeight(2);

                //increasing line weight to 2 from default of 1. Sub policies have less line weight so they can be distinguished


                stroke(255,255,255);

               //line colour is white
```

```
    ellipse((sumXRedMidfield/4),(sumYRedMidfield/4),10,10);
    //draw circle to represent midfield centroid for red team

    fill(0,0,0);
    //fill colour is set to black

    text("MIDFIELD",(sumXRedMidfield/4)+10,(sumYRedMidfield/4)-10);
    //midfield centroid label


    text("X:"+(int)(sumXRedMidfield/4),(sumXRedMidfield/4)+10,(sumYRedMidfield/4));
    //create labels to display centroid coordinate data for red team. Divisor refers to number of players in midfield formation

    text("Y:"+(int)(sumYRedMidfield/4),(sumXRedMidfield/4)+10,(sumYRedMidfield/4)+10);
    strokeWeight(1);
    //return line weight to default value

    noStroke();
    //switch stroke function off

//defence
    //sumXRedDefence = red[0].getXPos()+red[1].getXPos()+red[4].getXPos();
```

```
//note: the above line was pasted in as a reminder of how many players are involved in the attach                function so that the divisor for the centroid calulations below is correct

fill(255,0,0);

//fill colour for red team attack centroid is red

strokeWeight(2);

//increasing line weight to 2 from default of 1. Sub policies have less line weight so they can be distinguished

stroke(255,255,255);

//line colour is white

ellipse((sumXRedDefence/5),(sumYRedDefence/5),10,10);

//draw circle to represent defence centroid for red team

fill(0,0,0);

//fill colour is set to black

text("DEFENCE",(sumXRedDefence/5)+10,(sumYRedDefence/5)-10);

//defence centroid label

text("X:"+(int)(sumXRedDefence/5),(sumXRedDefence/5)+10,(sumYRedDefence/5));

//create labels to display centroid coordinate data for red team. Divisor refers to number of players in defence formation
```

```
            text("Y:"+(int)(sumYRedDefence/5),(sumXRedDefence/5)+10,(sumYRedDefence/5)+10);

            strokeWeight(1);
            //return line weight to default value

            noStroke();
            //switch stroke function off

        //need to write red centroid data to file here...

        //write red team centroid coordinates to nominated file:

//whole policy (x and y);attack policy (x and y); midfield policy (x and y); defence policy (x and y) respectively

//LEAVE:  redOutput.println((sumXRed/11) + "," +(sumYRed/11) + "," +(sumXRedAttack/5) + "," +(sumYRedAttack/5) + "," +(sumXRedMidfield/3) + ","
+(sumYRedMidfield/3)+ "," + (sumXRedDefence/3) + "," +(sumYRedDefence/3));

        //redOutput.println("("+   (sumXRed/11)         + "," +  (sumYRed/11)         + ")");
        //redAttack.println("("+   (sumXRedAttack/5)    + "," +  (sumYRedAttack/5)    + ")");
        //redMidfield.println("("+ (sumXRedMidfield/3)  + "," +  (sumYRedMidfield/3)  + ")");
```

```
//redDefence.println("("+  (sumXRedDefence/3)   + "," +  (sumYRedDefence/3)   + ")");

String redXWholeOutput  = str(sumXRed/11);                  //x coordinate of red team whole policy centroid
String redYWholeOutput  =str(sumYRed/11);                   //y coordinate of red team whole policy centroid
String redXAttackOutput =str(sumXRedAttack/2);              //x coordinate of red team attack policy centroid
String redYAttackOutput = str(sumYRedAttack/2);             //y coordinate of red team attack policy centroid
String redXMidfieldOutput = str(sumXRedMidfield/4);         //x coordinate of red team midfield policy centroid
String redYMidfieldOutput = str(sumYRedMidfield/4);         //y coordinate of red team midfield policy centroid
String redXDefenceOutput = str(sumXRedDefence/5);           //x coordinate of red team defence policy centroid
String redYDefenceOutput = str(sumYRedDefence/5);           //y coordinate of red team defence policy centroid

String redWhole = redXWholeOutput+","+redYWholeOutput;      //concatenating red x & y whole policy coordinates and assigning to string
                                                            variable

String redAttack1 = redXAttackOutput+","+redYAttackOutput;  //concatenating red x & y attack policy coordinates and assigning to
                                                            string variable

 String redMidfield1 = redXMidfieldOutput+","+redYMidfieldOutput;     //concatenating red x & y midfield policy coordinates and
                                                                      assigning to string variable

String redDefence1 = redXDefenceOutput+","+redYDefenceOutput;         //concatenating red x & y defence policy coordinates and
                                                                      assigning to string variable

redOutput.println(redWhole);                               //writing red x & y whole policy coordinates to file
```

```
redAttack.println(redAttack1);                          //writing red x & y attack policy coordinates to file
redMidfield.println(redMidfield1);                      //writing red x & y midfield policy coordinates to file
redDefence.println(redDefence1);                        //writing red x & y whole policy coordinates to file

noStroke();

//identical to the above, but for blue team...

//entire team
fill(0,0,255);                                  //fill colour for red team centroid is blue
strokeWeight(4);                                //increase line weight to 4 from default setting of 1
stroke(0,0,0);                                     //line colour is black
ellipse((sumXBlue/11),(sumYBlue/11),10,10);        //draw circle to represent centroid for blue team
fill(255,255,255);                                 //fill colour is set to white
text("WHOLE TEAM",(sumXBlue/11)+10,(sumYBlue/11)-10);  //whole team centroid label
text("X:"+(int)(sumXBlue/11),(sumXBlue/11)+11,(sumYBlue/11));    //create labels to display centroid coordinate data for blue team
text("Y:"+(int)(sumYBlue/11),(sumXBlue/11)+11,(sumYBlue/11)+10);
strokeWeight(1);                                   //return line weight to default value
noStroke();                                        //switch stroke function off
```

```
//attack

    //sumXBlueAttack = blue[7].getXPos()+blue[8].getXPos()+blue[9].getXPos()+blue[10].getXPos();

    //note: the above line was pasted in as a reminder of how many players are involved in the attach function so that the divisor

    //for the centroid calulations below is correct


    fill(0,0,255);                                  //fill colour for blue team attack centroid is blue

    strokeWeight(2);

    //increasing line weight to 2 from default of 1. Sub policies have less line weight so they can be distinguished

    stroke(255,255,255);                                        //line colour is white


    ellipse((sumXBlueAttack/2),(sumYBlueAttack/2),10,10);       //draw circle to represent attack centroid for blue team attack
                                                                centroid


    fill(0,0,0);                                                //fill colour is set to black


    text("ATTACK",(sumXBlueAttack/2)+10,(sumYBlueAttack/2)-10); //attack centroid label


    text("X:"+(int)(sumXBlueAttack/2),(sumXBlueAttack/2)+10,(sumYBlueAttack/2));

    //create labels to display centroid coordinate data for blue team. Divisor refers to number of players in attack formation


    text("Y:"+(int)(sumYBlueAttack/2),(sumXBlueAttack/2)+10,(sumYBlueAttack/2)+10);

    strokeWeight(1);                                              //return line weight to default value

    noStroke();                                                   //switch stroke function off
```

```
//midfield

    //sumXBlueMidfield = blue[4].getXPos()+blue[5].getXPos()+blue[6].getXPos();


    //note: the above line was pasted in as a reminder of how many players are involved in the attach function so that the divisor

    //for the centroid calulations below is correct


    fill(0,0,255);                              //fill colour for blue team midfield centroid is blue

    strokeWeight(2);                            //increasing line weight to 2 from default of 1. Sub policies have less line weight so
                                                they can be distinguished


    stroke(255,255,255);                        //line colour is  white

    ellipse((sumXBlueMidfield/4),(sumYBlueMidfield/4),10,10);    //draw circle to represent midfield centroid for blue team


    fill(0,0,0);                                                  //fill colour is set to black


    text("MIDFIELD",(sumXBlueMidfield/4)+10,(sumYBlueMidfield/4)-10);   //midfield centroid label


    text("X:"+(int)(sumXBlueMidfield/4),(sumXBlueMidfield/4)+10,(sumYBlueMidfield/4));

    //create labels to display centroid coordinate data for blue team. Divisor refers to number of players in midfield formation


    text("Y:"+(int)(sumYBlueMidfield/4),(sumXBlueMidfield/4)+10,(sumYBlueMidfield/4)+10);

    strokeWeight(1);                                             //return line weight to default value
```

```
    noStroke();                                              //switch stroke function off

//defence
    //sumXBlueDefence = blue[0].getXPos()+blue[1].getXPos()+blue[2].getXPos()+blue[3].getXPos();

    //note: the above line was pasted in as a reminder of how many players are involved in the attach function so that the divisor

    //for the centroid calulations below is correct

    fill(0,0,255);                               //fill colour for blue team defence centroid is blue

    strokeWeight(2);                  //increasing line weight to 2 from default of 1. Sub policies have less line weight so they can
                                      be distinguished

    stroke(255,255,255);              //line colour is white

    ellipse((sumXBlueDefence/5),(sumYBlueDefence/5),10,10);   //draw circle to represent defence centroid for blue team

    fill(0,0,0);                                             //set fill colour to black
    text("DEFENCE",(sumXBlueDefence/5)+10,(sumYBlueDefence/5)-10); //defence centroid label

    text("X:"+(int)(sumXBlueDefence/5),(sumXBlueDefence/5)+10,(sumYBlueDefence/5));
    //create labels to display centroid coordinate data for blue team. Divisor refers to number of players in defence formation
```

```
    text("Y:"+(int)(sumYBlueDefence/5),(sumXBlueDefence/5)+10,(sumYBlueDefence/5)+10);

    strokeWeight(1);                                          //return line weight to default value

    noStroke();                                               //switch stroke function off


//need to write blue centroid data to file here...

//blueOutput.println((sumXBlue/11)+","+(sumYBlue/11));//write blue team coordinates to file


//write blue team centroid coordinates to nominated file:


 //whole policy (x and y);attack policy (x and y); midfield policy (x and y); defence policy (x and y) respectively


 //LEAVE: blueOutput.println((sumXBlue/11) + "," +(sumYBlue/11) + "," +(sumXBlueAttack/4) + "," +(sumYBlueAttack/4) + ","
 +(sumXBlueMidfield/3) + "," +(sumYBlueMidfield/3)+ "," + (sumXBlueDefence/4) + "," +(sumYBlueDefence/4));


String blueXWholeOutput  = str(sumXBlue/11);      //x coordinate of blue team whole policy centroid

String blueYWholeOutput  =str(sumYBlue/11);       //y coordinate of blue team whole policy centroid

String blueXAttackOutput =str(sumXBlueAttack/2);  //x coordinate of blue team attack policy centroid

String blueYAttackOutput = str(sumYBlueAttack/2); //y coordinate of blue team attack policy centroid

String blueXMidfieldOutput = str(sumXBlueMidfield/4);//x coordinate of blue team midfield policy centroid

String blueYMidfieldOutput = str(sumYBlueMidfield/4); //y coordinate of blue team midfield policy centroid

String blueXDefenceOutput = str(sumXBlueDefence/5);   //x coordinate of blue team defence policy centroid

 String blueYDefenceOutput = str(sumYBlueDefence/5);   //y coordinate of blue team defence policy centroid
```

```
  String blueWhole = blueXWholeOutput+","+blueYWholeOutput;

  //concatenating blue x & y whole policy coordinates and assigning to string variable


  String blueAttack1 = blueXAttackOutput+","+blueYAttackOutput;

  //concatenating blue x & y attack policy coordinates and assigning to string variable


  String blueMidfield1 = blueXMidfieldOutput+","+blueYMidfieldOutput;

  //concatenating blue x & y midfield policy coordinates and assigning to string variable


  String blueDefence1 = blueXDefenceOutput+","+blueYDefenceOutput;

  //concatenating blue x & y defence policy coordinates and assigning to string variable


 blueOutput.println(blueWhole);              //writing blue x & y whole policy coordinates to file

 blueAttack.println(blueAttack1);            //writing blue x & y attack policy coordinates to file

 blueMidfield.println(blueMidfield1);        //writing blue x & y midfield policy coordinates to file

 blueDefence.println(blueDefence1);          //writing blue x & y defence policy coordinates to file



noStroke();


 //for computing x and y differences in Attack, Midfield & Defence functions (Policy Centroids)
```

```
//Conceptually, array encapsulates the following

//Note: Applies to X & Y Directions

//                Jobs

//          *  A  *  M  *  D  *

//      **********************

//      A   *  1  *  2 *   3  *

//   B  **********************

//   I  M   *  4  *  5  *  6  *

//   D  **********************

//      D   *  7   * 8  *  9  *

//      **********************

 //in the X direction:

 //'Value' in table below relates to number value in above matrix...

 //                  'Bid'            'Job'                    'Value'

   x_distances[0][0] = (sumXRedAttack/2)-(sumXBlueAttack/2);        //1
```

```
x_distances[0][1] = (sumXRedAttack/2)-(sumXBlueMidfield/4);      //2

x_distances[0][2] = (sumXRedAttack/2)-(sumXBlueDefence/5);       //3


x_distances[1][0] = (sumXRedMidfield/4)-(sumXBlueAttack/2);      //4

x_distances[1][1] = (sumXRedMidfield/4)-(sumXBlueMidfield/4);    //5

x_distances[1][2] = (sumXRedMidfield/4)-(sumXBlueDefence/5);     //6


x_distances[2][0] = (sumXRedDefence/5)-(sumXBlueAttack/2);       //7

x_distances[2][1] = (sumXRedDefence/5)-(sumXBlueMidfield/4);     //8

x_distances[2][2] = (sumXRedDefence/5)-(sumXBlueDefence/5);      //9


//array copy copies the first parameter (array) into the second parameter (array)

 arrayCopy(x_distances,x_preservation);  //taking a copy of the array to preserve the signage of the arithmetic in each element

//arrayCopy(x_preservation,x_distances);



for(int t = 0; t<3;t++)

{

   for(int s = 0; s<3;s++)

  {

     x_preservation2[t][s] = x_preservation[t][s];

  }
```

```
  }

  arrayCopy(myArray,x_distances);
//copying content of x_distances into myArray so allocations can be made

//for computing x and y differences in Attack, Midfield & Defence functions (Policy Centroids)

//in the Y direction:

//array representation is the same as described above...

//                    'Bid'              'Job'                  'Value'

  y_distances[0][0] = (sumYRedAttack/2)-(sumYBlueAttack/2);       //1
  y_distances[0][1] = (sumYRedAttack/2)-(sumYBlueMidfield/4);     //2
  y_distances[0][2] = (sumYRedAttack/2)-(sumYBlueDefence/5);      //3

  y_distances[1][0] = (sumYRedMidfield/4)-(sumYBlueAttack/2);     //4
  y_distances[1][1] = (sumYRedMidfield/4)-(sumYBlueMidfield/4);   //5
  y_distances[1][2] = (sumYRedMidfield/4)-(sumYBlueDefence/5);    //6

  y_distances[2][0] = (sumYRedDefence/5)-(sumYBlueAttack/2);      //7
```

```
      y_distances[2][1] = (sumYRedDefence/5)-(sumYBlueMidfield/4);     //8

      y_distances[2][2] = (sumYRedDefence/5)-(sumYBlueDefence/5);      //9


      arrayCopy(y_distances,y_preservation);

       //taking a copy of the array to preserve the signage of the arithmetic in each element


     //test @ 16/5

      for(int t = 0; t<3;t++)

      {

         for(int s = 0; s<3;s++)

        {

           y_preservation2[t][s] = y_preservation[t][s];

        }

      }



      arrayCopy(myArray2,y_distances);


//looping through both arrays and normalising to positive integers for all elements

//prior to passing array to Munkres algorithm for allocations to be made.


//Note: Munkres can handle negative values but this does not suit our purpose here.
```

```
//The reason for this is that it will,say, determine that a distance of -100 is to

//be allocated over a distance of +3. Although that is great for other purposes, it is no

//good here since we want to allocate a particular policy centroid to one of the opposing

//policy centroids by the magnitude of the distance that separates them. So in magnitude terms

//+3 has a smaller magnitue than -100, so +3 would be considered to be the lower of the two bids

//in our allocation scheme.


//We therefore cannot use signed values in the Munkres algorithm in our work when the allocations are made

//since this will result in a spatially inefficient allocation of the policy centroids.

//We have therefore preserved the array that may contain signed values as a result of computing the   differences

//in the x and y coordinates for each policy centroid. We have then looped through the main array and normalised all values to be a
   positive integer.


//The arrays have then been sent to Munkres for allocation and the allocations are

//then computed on a magnitude only basis. We then needed to get the correctly signed values that the magnitude allocations

//correspond to in the preserved arrays. Why? We have done this since the preserved array contains the sign data that is

//important when adjusting the exisiting policy node coordinates (Attack, Midfield or Defence as applicable) inside two dimensional
   space.


//We have captured the numeric values of the allocations for each policy node in both the x and y directions and then carried out a
   lookup

//for these values inside their respective 'preserved' arrays. We then read the value inside the preserved arrays as required and then
   use those
```

```
//to adjust the x and y coordinates of the relevant policy node to obtain the optimised signature for it i.e. one that is based on its
   current location

//and the number of options open to it at that point. The purpose of Munkres is to optimally allocate and coordinate an option to each
   of the policy

//nodes that is cost optimal for the entire system at all times (S3 & S2 functionality combined)



  auditLog.println();

  auditLog.println("--------------------------------------------------------------------------------------------------------------------
   -----------------------");

  auditLog.println("                                                                   New Set of Results Data:
   ");

  auditLog.println("--------------------------------------------------------------------------------------------------------------------
   -----------------------");

  auditLog.println();

  auditLog.println();



   auditLog.println("!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
   !!!!!!!!!!!!!!!!!!!!!!!!");

      //Checking (16/5/2014)

      for(int p = 0; p < 3; p++)       //outer loop

      {

        for(int q = 0; q < 3; q++)     //inner loop

        {
```

```
                    auditLog.println("X: "+"\t"+x_preservation[p][q]+"\t"+"Y: "+"\t"+y_preservation[p][q]);

                  }

                }

           auditLog.println("!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
           !!!!!!!!!!!!!!!!!!!!!!!!");

                auditLog.println();





//normalising x_distances and y_distances arrays to positive integers pending parameter pass to Munkres...


                for(int p = 0; p < 3; p++)       //outer loop

                {

                  for(int q = 0; q < 3; q++)     //inner loop

                  {

                    //for negative elements in x_distances array:


                    if(x_distances[p][q] < 0)          //if array element contains a negative value...
```

```
    {
      xTempCheck = x_distances[p][q];  //temporary variable
      xTempCheck = (xTempCheck)*(-1);  //negate temporary variable to make it positive

      x_distances[p][q] = xTempCheck;
     //assign negated temporary variable to array element so it contains a positive value
    }

    //for negative elements in y_distances array:

    if(y_distances[p][q] < 0)           //if array element contains a negative value...
    {
      yTempCheck = y_distances[p][q];   //temporary variable
      yTempCheck = (yTempCheck)*(-1);   //negate temporary variable to make it positive

      y_distances[p][q] = yTempCheck;
     //assign negated temporary variable to array element so it contains a positive value
    }

  }                               //end inner loop

}                                 //end outer loop
```

```
allocations = new mreMunkresArray6(x_distances,y_distances);

 //instantiate new Munkres object and pass normalised arrays as parameters

//allocations.run();

 //execute object functionality to make allocations as required




 auditLog.println("**************************************************************************************************************************
 *************************");

auditLog.println();

auditLog.println("X Distances:");

auditLog.println();

for(int r = 0; r<3;r++)

{

  auditLog.print("\t"+flag[r]+"(B)");

}


auditLog.println();

for(int r =0; r<3;r++)

{

  auditLog.print(flag[r]+"(R)"+"\t");

  for(int s = 0; s<3;s++)
```

```
    {
      auditLog.print(x_distances[r][s]+"\t");
    }
    auditLog.println();
  }

  auditLog.println();



  auditLog.println("--- X Preservation ---");
  auditLog.println();
  for(int r =0; r<3;r++)
  {
    for(int s = 0; s<3;s++)
    {
      //print(x_preservation2[r][s]+"\t");
      auditLog.print(x_preservation2[r][s]+"\t");
    }
    auditLog.println();
  }
```

```
auditLog.println();

 auditLog.println("*******************************************************************************************************************
 ************************");

auditLog.println();

auditLog.println("Y Distances:");

auditLog.println();

for(int r = 0; r<3;r++)

{

  auditLog.print("\t"+flag[r]+"(B)");

}


auditLog.println();

for(int r =0; r<3;r++)

{

  auditLog.print(flag[r]+"(R)"+"\t");

  for(int s = 0; s<3;s++)

  {

    auditLog.print(y_distances[r][s]+"\t");

  }

  auditLog.println();

}
```

```
auditLog.println();

auditLog.println("--- Y Preservation ---");

auditLog.println();

for(int r =0; r<3;r++)

{

  for(int s = 0; s<3;s++)

  {

    auditLog.print(y_preservation2[r][s]+"\t");

  }

  auditLog.println();

}


auditLog.println();

 auditLog.println("*******************************************************************************************************************
 ************************");


allocations.run();


//The Munkres algorithm will have made the allocations on the basis of magnitude only. This is important since to have just let signed
  values

//in (e.g. -100) would have caused it to return -100 as a better allocation than, say, +3. In spatial terms +3 is the lower cost hence
  that should have been
```

```
//the allocation given the choice between it and -100. It is a lower cost to the system to move forward, say, three miles than it is
  to, say, move backwards

//100 miles. The allocations made by the Munkres object will have now been completed and are accessible from this code.



//We needed to get the spatial allocation (the signed values that still sit in the x_preservation and y_preservation arrays) that
  directly correspond

//to the allocations returned in magnitude terms from the allocation algorithm for the reasons outlined above....



//So...



//loop through x_preservation array




for(int w=0; w<3;w++)

{

  //row 0: attack

  double temp2 = x_preservation[0][w];

    //assign array element value to temporary variable

   if(((temp2)%(allocations.optimalXAttackOutput))==0)

 //do a modulus check on the temporary variable and the corresponding value



{


 //returned by the Munkres object in magnitude terms...if it is 0 then there is a match at those element coordinates...
```

```
    optimisedAttackX = (sumXRedAttack/2) + x_preservation2[0][w];
//computing an adjusted X coordinate for the attack policy based upon the signed value, not the magnitude

  }

  //row 1 = midfield
  double temp3 = x_preservation[1][w];
   //assign array element value to temporary variable

  if(((temp3)%(allocations.optimalXMidfieldOutput))==0)
   //do a modulus check on the temporary variable and the corresponding value

{
   //returned by the Munkres object in magnitude terms...if it is 0 then there is a match at those element coordinates...

    optimisedMidfieldX = (sumXRedMidfield/4) + x_preservation2[1][w];
   //computing an adjusted X coordinate for the midfield policy based upon the signed value, not the magnitude
  }

  //row 2 = defence
  double temp4 = x_preservation[2][w];
```

```
    //assign array element value to temporary variable

   if(((temp4)%(allocations.optimalXDefenceOutput))==0)
    //do a modulus check on the temporary variable and the corresponding value

   {
    //returned by the Munkres object in magnitude terms...if it is 0 then there is a match at those element coordinates...

     optimisedDefenceX = (sumXRedDefence/5) + x_preservation2[2][w];
    //computing an adjusted X coordinate for the defence policy based upon the signed value, not the magnitude
   }



}

 //loop through y_preservation array

for(int w=0; w<3;w++)
{
  //row 0: attack
  double temp5 = y_preservation[0][w];              //assign array element value to temporary variable
```

```
if(((temp5)%(allocations.optimalYAttackOutput))==0)
//do a modulus check on the temporary variable and the corresponding value
{
 //returned by the Munkres object in magnitude terms...if it is 0 then there is a match at those element coordinates...

  optimisedAttackY = (sumYRedAttack/2) + y_preservation2[0][w];
 //computing an adjusted Y coordinate for the attack policy based upon the signed value, not the magnitude
}

//row 1 = midfield
double temp6 = y_preservation[1][w];              //assign array element value to temporary variable

if(((temp6)%(allocations.optimalYMidfieldOutput))==0)
 //do a modulus check on the temporary variable and the corresponding value
{

 //returned by the Munkres object in magnitude terms...if it is 0 then there is a match at those element coordinates...

  optimisedMidfieldY = (sumYRedMidfield/4) + y_preservation2[1][w];
 //computing an adjusted Y coordinate for the midfield policy based upon the signed value, not the magnitude
}
```

```
   //row 2 = defence

   double temp7 = y_preservation[2][w];              //assign array element value to temporary variable


   if(((temp7)%(allocations.optimalYDefenceOutput))==0)

    //do a modulus check on the temporary variable and the corresponding value

   {

    //returned by the Munkres object in magnitude terms...if it is 0 then there is a match at those element coordinates...


     optimisedDefenceY = (sumYRedDefence/5) + y_preservation2[2][w];

    //computing an adjusted Y coordinate for the defence policy based upon the signed value, not the magnitude

   }




}



 auditLog.println("*******************************************************************************************************************
 ************************");

auditLog.println();

auditLog.println("Signed Allocations based upon value positions in 'Allocations By Magnitude' Matrix:");

auditLog.println();

auditLog.println("X Att. (Signed):   "+((optimisedAttackX)-(sumXRedAttack/2)));

auditLog.println("Y Att. (Signed):   "+((optimisedAttackY)-(sumYRedAttack/2)));
```

```
 auditLog.println();

 auditLog.println("X Mid. (Signed): "+((optimisedMidfieldX)-(sumXRedMidfield/4)));

 //println("Y Midfield (Signed): "+((optimisedMidfieldY)-(sumYRedMidfield/3)));

 //println("Y Midfield (Signed): "+(optimisedMidfieldY)+"\t"+(sumYRedMidfield/3)+"\t"+((optimisedMidfieldY)-(sumYRedMidfield/3)));

 auditLog.println("Y Mid. (Signed): "+((optimisedMidfieldY)-(sumYRedMidfield/4)));

 auditLog.println();

 auditLog.println("X Def. (Signed):  "+((optimisedDefenceX)-(sumXRedDefence/5)));

 auditLog.println("Y Def. (Signed):  "+((optimisedDefenceY)-(sumYRedDefence/5)));

 auditLog.println();


//We now need to prepare the results of the above calculations for output to the relevant target files...

//Note: we add the variables inside the output strings.

//In doing this it means that any negative value that are present will be automatically deducted...


 //These are arithmetic expressions to give the signed values in the preservation arrays as per the above loop structure (temp variables
 5,6 & 7)

//The intention here is to capture these to a file so that post run integrity tests can be done.


 String MRESigned_Attack = ("("+((optimisedAttackX)-(sumXRedAttack/2))+","+((optimisedAttackY)-(sumYRedAttack/2))+")");


 String MRESigned_Midfield = ("("+((optimisedMidfieldX)-(sumXRedMidfield/4))+","+((optimisedMidfieldY)-(sumYRedMidfield/4))+")");


 String MRESigned_Defence = ("("+((optimisedDefenceX)-(sumXRedDefence/5))+","+((optimisedDefenceY)-(sumYRedDefence/5))+")");
```

```
String MRE_Test_Attack_X = ("Current Att."+"\t"+"(X):"+"\t"+(sumXRedAttack/2)+"\t"+"Allocated Adj. (X): "+"\t"+((optimisedAttackX)-(sumXRedAttack/2))+"\t"+"Optimised Current Att."+"\t"+"(X):"+"\t"+(optimisedAttackX));

String MRE_Test_Attack_Y = ("Current Att."+"\t"+"(Y):"+"\t"+(sumYRedAttack/2)+"\t"+"Allocated Adj. (Y): "+"\t"+((optimisedAttackY)-(sumYRedAttack/2))+"\t"+"Optimised Current Att."+"\t"+"(Y):"+"\t"+(optimisedAttackY));

String MRE_Test_Midfield_X = ("Current Mid."+"\t"+"(X):"+"\t"+(sumXRedMidfield/4)+"\t"+"Allocated Adj. (X): "+"\t"+((optimisedMidfieldX)-(sumXRedMidfield/4))+"\t"+"Optimised Current Mid."+"\t"+"(X):"+"\t"+(optimisedMidfieldX));

String MRE_Test_Midfield_Y = ("Current Mid."+"\t"+"(Y):"+"\t"+(sumYRedMidfield/4)+"\t"+"Allocated Adj. (Y): "+"\t"+((optimisedMidfieldY)-(sumYRedMidfield/4))+"\t"+"Optimised Current Mid."+"\t"+"(Y):"+"\t"+(optimisedMidfieldY));

String MRE_Test_Defence_X = ("Current Def."+"\t"+"(X):"+"\t"+(sumXRedDefence/5)+"\t"+"Allocated Adj. (X): "+"\t"+((optimisedDefenceX)-(sumXRedDefence/5))+"\t"+"Optimised Current Def."+"\t"+"(X):"+"\t"+(optimisedDefenceX));

String MRE_Test_Defence_Y = ("Current Def."+"\t"+"(Y):"+"\t"+(sumYRedDefence/5)+"\t"+"Allocated Adj. (Y): "+"\t"+((optimisedDefenceY)-(sumYRedDefence/5))+"\t"+"Optimised Current Def."+"\t"+"(Y):"+"\t"+(optimisedDefenceY));

String optimallyAdjustedAttack=("("+optimisedAttackX+","+optimisedAttackY+")");

String optimallyAdjustedMidfield=("("+optimisedMidfieldX+","+optimisedMidfieldY+")");

String optimallyAdjustedDefence=("("+optimisedDefenceX+","+optimisedDefenceY+")");

auditLog.println();
```

```
auditLog.println("***************************************************************************************************************************************
**********************");

auditLog.println();

auditLog.println("Adjustments to A,M,D Policy Vector Coordinates using Signed Allocations:");

auditLog.println();

auditLog.println(MRE_Test_Attack_X);

auditLog.println(MRE_Test_Attack_Y);

auditLog.println();

auditLog.println(MRE_Test_Midfield_X);

auditLog.println(MRE_Test_Midfield_Y);

auditLog.println();

auditLog.println(MRE_Test_Defence_X);

auditLog.println(MRE_Test_Defence_Y);

auditLog.println();

auditLog.println("***************************************************************************************************************************************
**********************");

auditLog.println();

auditLog.println("Writing to file:");

auditLog.println();

auditLog.println("A"+";"+optimallyAdjustedAttack);

auditLog.println("M"+";"+optimallyAdjustedMidfield);

auditLog.println("D"+";"+optimallyAdjustedDefence);
```

```
auditLog.println();

auditLog.println("--------------------------------------------------------------------------------------------------------------------
----------------------");

auditLog.println("                                                      End of Set of Results Data
");

auditLog.println("--------------------------------------------------------------------------------------------------------------------
----------------------");

auditLog.println();

auditLog.println();



 //Here we are writing the output of the Munkres object  to files for reference purposes...

 //Note: These values will be allocations made in terms of magnitude only as explained above


 String MREAttackOptimals = allocations.attackOutput;

 String MREMidfieldOptimals = allocations.midfieldOutput;

 String MREDefenceOptimals = allocations.defenceOutput;


 //The optimally adjusted policy centroid coordinates (to be analysed as final output) are:


 String attackOptimalOutput = ("("+optimisedAttackX+","+optimisedAttackY+")");

 String midfieldOptimalOutput = ("("+optimisedMidfieldX+","+optimisedMidfieldY+")");

 String defenceOptimalOutput = ("("+optimisedDefenceX+","+optimisedDefenceY+")");
```

```
//writing allocations based on magnitude only to relevant files for reference purposes

A.println(MREAttackOptimals);
M.println(MREMidfieldOptimals);
D.println(MREDefenceOptimals);

//Writing signed values from the preserved arrays to allow integrity checking

signedAttack.println(MRESigned_Attack);
signedMidfield.println(MRESigned_Midfield);
signedDefence.println(MRESigned_Defence);

//****************************************************************************************************
//Data to be used in Final Analysis:

//writing optimally adjusted policy centroid coordinates to relevant files pending post run analysis

optimalAttack.println(attackOptimalOutput);
optimalMidfield.println(midfieldOptimalOutput);
optimalDefence.println(defenceOptimalOutput);

//***************************************************************************************************
```

```
allocations = null;  //removing allocations (Munkres) object from memory pending next pass of draw() loop

redOutput.flush();  //actually writing the bytes to the file to record centroid data for red team
redAttack.flush();
redMidfield.flush();
redDefence.flush();

blueOutput.flush(); //actually writing the bytes to the file to record centroid data for blue team
blueAttack.flush();
blueMidfield.flush();
blueDefence.flush();

//A.flush();          //actually writing the bytes to the file to record allocations by magnitude
//M.flush();
//D.flush();

//signedAttack.flush();  //actually writing the bytes to the file to record signed values from preserved arrays
//signedMidfield.flush();
//signedDefence.flush();

//optimalAttack.flush();   //actually writing the bytes to the file to record optimised centroid data for each function
```

```
            //optimalMidfield.flush();

            //optimalDefence.flush();


            sumXRed=0;  //resetting cumulative totals for x and y coordinates for each player on each team, pending next pass of loop

            sumYRed=0;


            sumXBlue=0;

            sumYBlue=0;




            //printing a line of data to the console for monitoring

            //println("Timestamp: "+" "+timestamp+" "+"Team: "+" "+team+" "+"PlayerNo: "+" "+playerNo+" "+"xPos: "+" "+x+" "+"yPos: "+y);

            //println("***************************************************************************************************************");


  }


}                                              //end draw loop




//methods


public void displayRed(int val)              //toggle: display red team overall policy polygon
```

```
{
  showRed = !showRed;
}

public void displayRedAttack(int val)        //toggle: display red team attack policy polygon
{
  showRedAttack = !showRedAttack;
}

public void displayRedMidfield(int val)      //toggle: display red team midfield policy polygon
{
  showRedMidfield = !showRedMidfield;
}

public void displayRedDefence(int val)       //toggle: display red team defence policy polygon
{
  showRedDefence = !showRedDefence;
}



public void displayBlue(int val)             //toggle: display blue team overall policy polygon
```

```
{
  showBlue = !showBlue;
}

public void displayBlueAttack(int val)       //toggle: display blue team attack policy polygon
{
  showBlueAttack = !showBlueAttack;
}

public void displayBlueMidfield(int val)     //toggle: display blue team midfield policy polygon
{
  showBlueMidfield = !showBlueMidfield;
}

public void displayBlueDefence(int val)      //toggle: display blue team defence policy polygon
{
  showBlueDefence = !showBlueDefence;
}
```

```
//Computer Code written in support of PhD Thesis: On Self Organising Cyberdynamic Policy (September 2016)

//Mark Evans B.Sc.(Hons), M.Sc.

//PhD Researcher in Applied Cybernetics

//Department of Computer Science

//Faculty of Engineering & Technology

//Liverpool John Moores University

//James Parsons Building

//Byrom Street

//Liverpool

//L3 3AF

//Copyright (c) 2014-16 Mark R. Evans (unless otherwise stated)


//https://github.com/KevinStern/software-and-
algorithms/blob/master/src/main/java/blogspot/software_and_algorithms/stern_library/optimization/HungarianAlgorithm.java


//package blogspot.software_and_algorithms.stern_library.optimization;


import java.util.Arrays;


/* Copyright (c) 2012 Kevin L. Stern

*

* Permission is hereby granted, free of charge, to any person obtaining a copy

* of this software and associated documentation files (the "Software"), to deal
```

```
* in the Software without restriction, including without limitation the rights
* to use, copy, modify, merge, publish, distribute, sublicense, and/or sell
* copies of the Software, and to permit persons to whom the Software is
* furnished to do so, subject to the following conditions:
*
* The above copyright notice and this permission notice shall be included in
* all copies or substantial portions of the Software.
*
* THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR
* IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
* FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE
* AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
* LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM,
* OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE
* SOFTWARE.
*/

/**
* An implementation of the Hungarian algorithm for solving the assignment
* problem. An instance of the assignment problem consists of a number of
* workers along with a number of jobs and a cost matrix which gives the cost of
* assigning the i'th worker to the j'th job at position (i, j). The goal is to
```

```
* find an assignment of workers to jobs so that no job is assigned more than
* one worker and so that no worker is assigned to more than one job in such a
* manner so as to minimize the total cost of completing the jobs.
* <p>
*
* An assignment for a cost matrix that has more workers than jobs will
* necessarily include unassigned workers, indicated by an assignment value of
* -1; in no other circumstance will there be unassigned workers. Similarly, an
* assignment for a cost matrix that has more jobs than workers will necessarily
* include unassigned jobs; in no other circumstance will there be unassigned
* jobs. For completeness, an assignment for a square cost matrix will give
* exactly one unique worker to each job.
* <p>
*
* This version of the Hungarian algorithm runs in time O(n^3), where n is the
* maximum among the number of workers and the number of jobs.
*
* @author Kevin L. Stern
*/
public class HungarianAlgorithm
{
  private final double[][] costMatrix;
```

```
private final int rows, cols, dim;
private final double[] labelByWorker, labelByJob;
private final int[] minSlackWorkerByJob;
private final double[] minSlackValueByJob;
private final int[] matchJobByWorker, matchWorkerByJob;
private final int[] parentWorkerByCommittedJob;
private final boolean[] committedWorkers;

/**
* Construct an instance of the algorithm.
*
* @param costMatrix
* the cost matrix, where matrix[i][j] holds the cost of
* assigning worker i to job j, for all i, j. The cost matrix
* must not be irregular in the sense that all rows must be the
* same length.
*/
public HungarianAlgorithm(double[][] costMatrix)    //constructor for Hungarian Algorithm
{
  this.dim = Math.max(costMatrix.length, costMatrix[0].length);
  this.rows = costMatrix.length;
  this.cols = costMatrix[0].length;
```

```
 this.costMatrix = new double[this.dim][this.dim];

 for (int w = 0; w < this.dim; w++)
 {
   if (w < costMatrix.length)
   {
     if (costMatrix[w].length != this.cols)
     {
       throw new IllegalArgumentException("Irregular cost matrix");
     }

     this.costMatrix[w] = Arrays.copyOf(costMatrix[w], this.dim);
   }

   else
   {
   this.costMatrix[w] = new double[this.dim];
   }
}

 labelByWorker = new double[this.dim];
 labelByJob = new double[this.dim];
```

```
  minSlackWorkerByJob = new int[this.dim];

  minSlackValueByJob = new double[this.dim];

  committedWorkers = new boolean[this.dim];

  parentWorkerByCommittedJob = new int[this.dim];

  matchJobByWorker = new int[this.dim];

  Arrays.fill(matchJobByWorker, -1);

  matchWorkerByJob = new int[this.dim];

  Arrays.fill(matchWorkerByJob, -1);


}


/**

* Compute an initial feasible solution by assigning zero labels to the

* workers and by assigning to each job a label equal to the minimum cost

* among its incident edges.

*/


protected void computeInitialFeasibleSolution()

{

  for (int j = 0; j < dim; j++)

  {

    labelByJob[j] = Double.POSITIVE_INFINITY;
```

```
  }

  for (int w = 0; w < dim; w++)
  {
    for (int j = 0; j < dim; j++)
    {
      if (costMatrix[w][j] < labelByJob[j])
      {
        labelByJob[j] = costMatrix[w][j];
      }
    }
  }
}//end computeInitialFeasibleSolution method

/**
* Execute the algorithm.
*
* @return the minimum cost matching of workers to jobs based upon the
* provided cost matrix. A matching value of -1 indicates that the
* corresponding worker is unassigned.
*/
```

```
public int[] execute()
{
  /*
  * Heuristics to improve performance: Reduce rows and columns by their
  * smallest element, compute an initial non-zero dual feasible solution
  * and create a greedy matching from workers to jobs of the cost matrix.
  */

  reduce();
  computeInitialFeasibleSolution();
  greedyMatch();

  int w = fetchUnmatchedWorker();

  while (w < dim)
  {
    initializePhase(w);
    executePhase();
    w = fetchUnmatchedWorker();
  }
```

```
    int[] result = Arrays.copyOf(matchJobByWorker, rows);

    for (w = 0; w < result.length; w++)
    {
      if (result[w] >= cols)
      {
        result[w] = -1;
      }
    }

    return result;
}//end execute mtehod

 /**
 * Execute a single phase of the algorithm. A phase of the Hungarian
 * algorithm consists of building a set of committed workers and a set of
 * committed jobs from a root unmatched worker by following alternating
 * unmatched/matched zero-slack edges. If an unmatched job is encountered,
 * then an augmenting path has been found and the matching is grown. If the
 * connected zero-slack edges have been exhausted, the labels of committed
 * workers are increased by the minimum slack among committed workers and
```

```
* non-committed jobs to create more zero-slack edges (the labels of
* committed jobs are simultaneously decreased by the same amount in order
* to maintain a feasible labeling).
* <p>
*
* The runtime of a single phase of the algorithm is O(n^2), where n is the
* dimension of the internal square cost matrix, since each edge is visited
* at most once and since increasing the labeling is accomplished in time
* O(n) by maintaining the minimum slack values among non-committed jobs.
* When a phase completes, the matching will have increased in size.
*/


protected void executePhase()
{
  while (true)
  {
    int minSlackWorker = -1, minSlackJob = -1;
    double minSlackValue = Double.POSITIVE_INFINITY;

    for (int j = 0; j < dim; j++)
    {
```

```
  if (parentWorkerByCommittedJob[j] == -1)
  {
    if (minSlackValueByJob[j] < minSlackValue)
    {
      minSlackValue = minSlackValueByJob[j];
      minSlackWorker = minSlackWorkerByJob[j];
      minSlackJob = j;
    }
  }
}

if (minSlackValue > 0)
{
  updateLabeling(minSlackValue);
}

parentWorkerByCommittedJob[minSlackJob] = minSlackWorker;

if (matchWorkerByJob[minSlackJob] == -1)
{
  /*
  * An augmenting path has been found.
```

```
  */
  int committedJob = minSlackJob;
  int parentWorker = parentWorkerByCommittedJob[committedJob];

  while (true)
  {
    int temp = matchJobByWorker[parentWorker];
    match(parentWorker, committedJob);
    committedJob = temp;

    if (committedJob == -1)
    {
      break;
    }

    parentWorker = parentWorkerByCommittedJob[committedJob];
  }

  return;
}

else
```

```
{

/*
* Update slack values since we increased the size of the
* committed workers set.
*/

int worker = matchWorkerByJob[minSlackJob];
committedWorkers[worker] = true;

for (int j = 0; j < dim; j++)
{
  if (parentWorkerByCommittedJob[j] == -1)
  {
    double slack = costMatrix[worker][j]
    - labelByWorker[worker] - labelByJob[j];

    if (minSlackValueByJob[j] > slack)
    {
      minSlackValueByJob[j] = slack;
      minSlackWorkerByJob[j] = worker;
    }
```

```
      }
    }
   }
  }
}//end executePhase method



/**
*
* @return the first unmatched worker or {@link #dim} if none.
*/

protected int fetchUnmatchedWorker()
{
  int w;
  for (w = 0; w < dim; w++)
  {
    if (matchJobByWorker[w] == -1)
    {
      break;
    }
```

```
  }

  return w;
}//end fetchUnmatchedWorker method

/**
* Find a valid matching by greedily selecting among zero-cost matchings.
* This is a heuristic to jump-start the augmentation algorithm.
*/


protected void greedyMatch()
{
  for (int w = 0; w < dim; w++)
  {
    for (int j = 0; j < dim; j++)
    {
      if (matchJobByWorker[w] == -1
      && matchWorkerByJob[j] == -1
      && costMatrix[w][j] - labelByWorker[w] - labelByJob[j] == 0)
      {
        match(w, j);
```

```
      }
    }
  }
}//end greedyMatch method



/**
* Initialize the next phase of the algorithm by clearing the committed
* workers and jobs sets and by initializing the slack arrays to the values
* corresponding to the specified root worker.
*
* @param w
* the worker at which to root the next phase.
*/


protected void initializePhase(int w)
{
  Arrays.fill(committedWorkers, false);
  Arrays.fill(parentWorkerByCommittedJob, -1);
  committedWorkers[w] = true;
```

```
  for (int j = 0; j < dim; j++)
  {
    minSlackValueByJob[j] = costMatrix[w][j] - labelByWorker[w]
    - labelByJob[j];
    minSlackWorkerByJob[j] = w;
  }

}//end initialisePhase method



/**
* Helper method to record a matching between worker w and job j.
*/

protected void match(int w, int j)
{
  matchJobByWorker[w] = j;
  matchWorkerByJob[j] = w;
}//end match method
```

```
/**
* Reduce the cost matrix by subtracting the smallest element of each row
* from all elements of the row as well as the smallest element of each
* column from all elements of the column. Note that an optimal assignment
* for a reduced cost matrix is optimal for the original cost matrix.
*/


protected void reduce()
{
  for (int w = 0; w < dim; w++)
  {
    double min = Double.POSITIVE_INFINITY;

    for (int j = 0; j < dim; j++)
    {
      if (costMatrix[w][j] < min)
      {
        min = costMatrix[w][j];
      }
    }
```

```
  for (int j = 0; j < dim; j++)
  {
      costMatrix[w][j] -= min;
  }

}

double[] min = new double[dim];

for (int j = 0; j < dim; j++)
{
  min[j] = Double.POSITIVE_INFINITY;
}

for (int w = 0; w < dim; w++)
{
  for (int j = 0; j < dim; j++)
  {
    if (costMatrix[w][j] < min[j])
    {
      min[j] = costMatrix[w][j];
    }
```

```
    }
  }

  for (int w = 0; w < dim; w++)
  {
    for (int j = 0; j < dim; j++)
    {
      costMatrix[w][j] -= min[j];
    }
  }
}//end reduce method

/**
* Update labels with the specified slack by adding the slack value for
* committed workers and by subtracting the slack value for committed jobs.
* In addition, update the minimum slack values appropriately.
*/

protected void updateLabeling(double slack)
{
  for (int w = 0; w < dim; w++)
  {
```

```
      if (committedWorkers[w])
      {
        labelByWorker[w] += slack;
      }
    }

    for (int j = 0; j < dim; j++)
    {
      if (parentWorkerByCommittedJob[j] != -1)
      {
        labelByJob[j] -= slack;
      }

      else
      {
        minSlackValueByJob[j] -= slack;
      }
    }
  }//end updateLabeling method
  }//end class
//Computer Code written in support of PhD Thesis: On Self Organising Cyberdynamic Policy (September 2016)
//Mark Evans B.Sc.(Hons), M.Sc.
```

```
//PhD Researcher in Applied Cybernetics
//Department of Computer Science
//Faculty of Engineering & Technology
//Liverpool John Moores University
//James Parsons Building
//Byrom Street
//Liverpool
//L3 3AF
//Copyright (c) 2014-16 Mark R. Evans (unless otherwise stated)


class Player
{
  int diameter = 5;  //diameter of player sprite
  int red;           //value of red in player sprite colour channel 0-255
  int green;         //value of green in player sprite colour channel 0-255
  int blue;

  //position
  int xpos = 0;      //player sprite x coordinate
  int ypos = 0;      //player sprite y coordinate
```

```
//speed
float xspeed=1;    //player sprite x speed
float yspeed=1;    //player sprite y speed

Player(int r,int g, int b)  //constructor for player sprite
{
  red = r;                  //red colour value
  green = g;                //green colour value
  blue = b;                 //blue colour value
}

void display()              //method to display player
{
  fill(red,green,blue);     //set player sprite colour

  ellipse(int(getXPos()),int(getYPos()),diameter,diameter);   //draw ellipse at x and y coordinates
}
```

```
  void setXPos(int xposition)  //set x coordinate
  {
    xpos = xposition;
  }//end method

  void setYPos(int yposition) //set y coordinate
  {
     ypos = yposition;
  }//end method

  int getXPos()              //get x coordinate
  {
    return xpos;
  }//end method

  int getYPos()              //get y coordinate
  {
    return ypos;
  }//end method


}//end class
```

```
//Computer Code written in support of PhD Thesis: On Self Organising Cyberdynamic Policy (September 2016)

//Mark Evans B.Sc.(Hons), M.Sc.

//PhD Researcher in Applied Cybernetics

//Department of Computer Science

//Faculty of Engineering & Technology

//Liverpool John Moores University

//James Parsons Building

//Byrom Street

//Liverpool

//L3 3AF

//Copyright (c) 2014-16 Mark R. Evans (unless otherwise stated)



//The array to handle the differences in distance for  between A,M,D on Red Team to A,M,D on Blue Team


class mreMunkresArray6

{


  int[][] myAssignments = new int[3][3];        //set up array to handle assignments for x direction

  int[][] myAssignments2 =  new int[3][3];      //set up array to handle assignments for y direction


  int[] xResult = new int[3];                   //set up array to handle results for x direction
```

```
  int[] yResult = new int[3];                     //set up array to handle results for y direction

  String[] flag = {"A","M","D"};                  //set up flag for results 'A' - Attack, 'M' - Midfield. 'D' - Defence



  HungarianAlgorithm algorithm;                   //declare HungarianAlgorithm object to handle x values

  HungarianAlgorithm algorithm2;                  //declare HungarianAlgorithm object to handle x values



  String attackOutput;                            //declare String variable to handle optimised attack output

  String midfieldOutput;                          //declare String variable to handle optimised midfield output

  String defenceOutput;                           //declare String variable to handle optimised defence output


  double optimalXAttackOutput;                    //declare double variable so can use x direction component of attackOutput in calculations
elsewhere

  double optimalYAttackOutput;                    //declare double variable so can use y direction component of attackOutput in calculations
elsewhere


  double optimalXMidfieldOutput;                  //declare double variable so can use x direction component of midfieldOutput in calculations
elsewhere

  double optimalYMidfieldOutput;                  //declare double variable so can use y direction component of midfieldOutput in calculations
elsewhere


  double optimalXDefenceOutput;                   //declare double variable so can use x direction component of defenceOutput in calculations
elsewhere
```

```
  double optimalYDefenceOutput;                 //declare double variable so can use y direction component of defenceOutput in calculations
elsewhere



  mreMunkresArray6(double xArray[][],double yArray[][])  //constructor of Munkres

  {

      algorithm = new HungarianAlgorithm(xArray);        //instantiate a new HungarianAlgorithm object by passing xArray as a parameter

      algorithm2 = new HungarianAlgorithm(yArray);       //instantiate a new HungarianAlgorithm object by passing yArray as a parameter

  }




  void run()                                             //execute Munkres

  {

    for(int i = 0; i<1; i++)

    {


        myAssignments[i] = algorithm.execute();          //assign the output of the x array hungarian algorithm to the first element of
MyAssignments

        myAssignments2[i] = algorithm2.execute();        //assign the output of the y array hungarian algorithm to the first element of
MyAssignments2


        arrayCopy(myAssignments[i],xResult);             //copy the content of MyAssignments Array to xResult Array
```

```
    arrayCopy(myAssignments2[i],yResult);            //copy the content of MyAssignments Array to yResult Array

}

// println(" ");                                        //blank line printed to console
// println(xResult);                                    //xResult Array printed to console
// println(" ");                                        //blank line printed to console
// println(yResult);                                    //yResult Array printed to console
//  println(" ");                                       //blank line printed to console

for(int i = 0; i<3; i++)                               //for each row in the XResults Array
{
  int test = xResult[i];
  //println(myArray[i][xResult[i]]);                   //print the allocations made to the console
}

//println("******* ");                                  //print a spacer line to the console

for(int i = 0; i<3; i++)                               //for each row in the YResults Array
{
  int test2 = yResult[i];
  //println(myArray2[i][yResult[i]]);                  //print the allocations made to the console
```

```
    }

     //println("******* ");                                  //print a spacer line to the console

     auditLog.println("Allocations (by Magnitude Only): A - Attack ; M - Midfield ; D -Defence");

     auditLog.println();

     for(int i = 0; i<3; i++)                            //for each row in both xResults and YResults Arrays...

     {

       //print to the console the optimal x allocations for Attack, Midfield and Defence alongside the optimal y allocations for Attack. Midfield
 and Defence

       auditLog.println( flag[i]+ ";" + "(" + (myArray[i][xResult[i]]) + "," +(myArray2[i][yResult[i]])+ ")");

     }

     auditLog.println();

     auditLog.println();

     //split and assign optimal x and y allocations to appropriate variables so they can be used in file writing streams

     attackOutput =   ( flag[0]+ ";" + "(" + (myArray[0][xResult[0]]) + "," +(myArray2[0][yResult[0]])+ ")");

     midfieldOutput = ( flag[1]+ ";" + "(" + (myArray[1][xResult[1]]) + "," +(myArray2[1][yResult[1]])+ ")");

     defenceOutput =  ( flag[2]+ ";" + "(" + (myArray[2][xResult[2]]) + "," +(myArray2[2][yResult[2]])+ ")");
```

```
  //split and assign optimal x and y allocations to apporopriate variables so they can be used in calculations elsewhere

  optimalXAttackOutput=(myArray[0][xResult[0]]);

  optimalYAttackOutput=(myArray2[0][yResult[0]]);


  optimalXMidfieldOutput=(myArray[1][xResult[1]]);

  optimalYMidfieldOutput=(myArray2[1][yResult[1]]);


  optimalXDefenceOutput=(myArray[2][xResult[2]]);

  optimalYDefenceOutput=(myArray2[2][yResult[2]]);

}//end run method

}//end class
```