Master’s Thesis

Submitted to:
Reykjavik University
School of Business

INVESTMENT MANAGEMENT

INSURANCE ENVIRONMENT IN A VIRTUAL WORLD
Calculations and implementation of insurance schemes in
EVE-Online

Grettir Jóhannesson
Þorvaldur Símon Kristjánsson

15.05.2013

Supervisor
Dr. Kannoo Ravindran
Assistant supervisor
Róbert Ragnar Grönqvist

Reykjavik, May 2013

Acknowledgement

First off we would like to express our deepest appreciation to our instructors Dr. Kannoo Ravindran and Róbert Ragnar Grönqvist for their valuable guidance and assistance.

Second we would like to thank Eyjólfur Guðmundsson, Pétur Jóhannes Óskarsson and Kjartan Þór Halldórsson from CCP for their efforts and time spent on assisting us with this thesis.

Furthermore we would like to acknowledge Eyþór Stefánsson and Guðmundur Magnússon for 16 hours of nonstop fun on simulations.

Finally a special thanks to Garðar Hólm Kjartansson and Garðar Þorsteinn Guðgeirsson at TM for their valuable insights into insurance modeling and their interest in our thesis.

Abstract

The insurance system in EVE-Online has been fundamentally unchanged for a decade and is not fully utilized by all players. By updating the insurance system with risk factors included, could be the first step in implementing more financial elements into the game. New calculation methods are performed on hypothetical data and recommendations on implementing are presented. The data was generated and simulated to replicate a sample set of 2,500 characters. The generalized linear model is proposed as the ideal vessel for incorporating new risk factors as it able to work with various types of distributions. By introducing new methods of calculation to the current system, a more realistic insurance contract will be introduced. The result of this will enable CCP to introduce additional insurance products for its players, as well as further broadening the research environment for academics and researchers that want to test theory and evaluate behavioral patterns.

Keywords: CCP, EVE-Online, Generalized linear model, GLM, insurance, risk factors

Declaration of Research Work Integrity

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature of any degree. This thesis is the result of our own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. A bibliography is appended.

By signing the present document we confirm and agree that we have read RU‘s ethics code of conduct and fully understand the consequences of violating these rules in regards of our thesis.

Data and place ID number Signature

Data and place ID number Signature

Table of content

List of figures, tables and equations

List of abbreviations

- **AIC –** Akaike Information Criterion
- **A-D –** Anderson-Darling
- **Bn** - Billion
- **BLUE** - Best Linear Unbiased Estimator
- **C -** Coverage
- **CDF –** Cumulative Distribution Function
- **ECDF –** Explained Cumulative Distribution Function
- **ESS –** Explained Sum of Squares
- **EU –** European Union
- **GEV –** Generalized Extreme Value
- **GLM –** Generalized Linear Model
- **HQ –** Headquarters
- **HQIC –** Hannan-Quinn Information Criterion
- **ISK –** InterStellar Kredits
- **K** - Cost
- **K-S –** Kolmogorov-Smirnov
- **M –** Million
- **MMO** - Massively Multiplayer Online Game
- **MMORPG** - Massively Multiplayer Online Roleplaying Games
- **MV –** Market Value
- **NPC –** Non-playing Character
- **OLS** - Ordinary Least Squares
- **PC -** Personal Computer
- **PDF –** Probability Distribution Function
- **PS3** - PlayStation3
- **R2 –** R-squared
- **RSS** – Residual sum of squares
- **SIC –** Schwartz Information Criterion
- **T1 –** First Generation Technology
- **T2 –** Second Generation Technology
- **T3 –** Third Generation Technology
- **TSS –** Total Sum of Squares

1. Introduction

An insurance contract is in its essence a transfer of risk. The insured transfers his risk or at least part of it to an insurance company that charges a premium. The insured fears a certain risk occurrence and if he is not insured he runs the risk of losing both the asset and take a financial blow. If insured the insurer ensures that the consequences of this risk occurrence will be limited (Yves YT Thiery & Caroline CV Van Schoubroeck, 2006). To understand the future evolution of insurance contracts into virtual worlds, one must first appreciate the development of insurance history in real life.

1.1. History

Insurance history can be traced back to before the birth of Christ, however the beginning of modern insurance, as we know it, dates back to the year 1666 and the great fires of London, where 80% of the city lay in ruin. Great wealth was destroyed by fire, roughly two-thirds of the total assets of the English empire. From those ashes rose two entities; the first fire brigade and the world's first insurance company (Klein, 2001). In the late 1680s a man named Edward Lloyd opened up a coffee house in Tower Street, London. The establishment became a popular hangout for ship owners, captains and merchants, hence a good source for the latest news in the shipping industry. This led to the establishment becoming the preferred location for parties to insure their ships and cargo, and individuals willing to underwrite those ventures. This was the birth of Lloyd's insurance market, which is still today a leading insurance market for marine and other specialized types of insurance.

The first mutual insurance company in the United States, The Friendly Society of Mutual Insuring of Homes against Fire, was founded in 1735 in Charleston but only lasted for 6 years until a major fire put it out of business (America, 2009). Later joint-stock insurance companies emerged in the marine sector in the United States, with the first successful formed in 1792, The Insurance Company of North America. It sold not only fire insurance, but also marine and life insurance. Joint-stock companies grew in popularity, as they did not rely on funding from one individual, but from many underwriters. They also maintained more fixed capital than mutual insurance companies which primarily relied on premium income, and was therefore able to sustain larger amounts or more extreme events with their reserve funding. By 1810, more than 70 joint-stock companies had been formed in the United States, primarily focusing on the marine insurance sector (Baranoff, 2010).

In 1883, Chancellor of Germany, Otto von Bismarck implemented a health insurance bill that provided health care for large segments of German workers. The following year he managed to successfully pass an accident insurance bill. The program was placed in the hands of an organization that established central and bureaucratic insurance offices to perform the administration of the insurance program. The program eventually replaced the health care bill previously in place, and it paid for medical treatment and pension of up to two-thirds of earned wages if the worker was fully disabled (Holborn, 1982).

In June 1992 the European Union (EU) introduced a system where an insurance company, with their head office in a EU membership country, could open up branches and conduct business anywhere in the EU. The aim of the EU is for insurance holders to find an insurance plan that is best suited for them (The European Union, 1992). A new challenge emerged in 2011 that affected insurance companies, as sovereign debt problems arose within a number of countries in the EU. Severe losses were realized in the insurance sectors from sovereign debt securities as countries in the Euro area faced financial problems and possible bankruptcy (Financial Affairs Division, 2012).

1.2. Premiums and risk

To be able to enter into an agreement with an insurance company one has to pay a premium as mentioned above. The premium can vary between individuals based on how risky they are or how risky the social group they are a part of is perceived. Statistical information is vital for insurance companies to be able to calculate appropriate premium for individuals or groups. Fundamentally everyone is supposed to pay the same premium in relation to risk, e.g. the premium for a young person buying life insurance is less than for an older person, as the likelihood of mortality is obviously different for each (Lehtonen & Liukko, 2011). The insurance companies pool together all of the premiums and, simply put, this pool of premiums is used to pay out claims when they occur (Yves YT Thiery & Caroline CV Van Schoubroeck, 2006). In fact though most of us pay premiums on insurance contracts in one way or another, e.g. car and health insurance, one might not realize that they are in fact paying for other people's mishaps. In other words, if you are lucky in life and avoid mishaps and accidents that would otherwise involve insurance claims, the premiums that you paid over your lifetime went into compensating others people's mishaps as well. The statistical analysis of insurance companies ensures that accident prone individuals are required to pay higher premiums to compensate for their risky past (Baker, 2002). When people are insured it does, to some degree, encourage them to behave in a more risky manner. The negative consequences of the risk occurrence that they feared before has in a way been transferred to another entity so people are more willing to take risks (Baker & McElrath, 1996).

1.3. Objectives

The objective of the thesis is to introduce a more realistic calculation method for pricing insurance contracts in EVE-Online. The purpose is to further improve a realistic virtual world with more sophisticated financial elements, mainly insurance related. EVE-Online revolves around destruction of ships, so if a more realistic insurance contract system is implemented it could encourage players to take more risk and enjoy the game even more than before, they can transfer the risk of losing valuables over to another entity.

Once this is achieved it is expected that the next wave of development will revolve around the regulation of financial markets.

2. EVE-Online

EVE-Online is an online multiplayer game created by CCP, an Icelandic game developer, and was officially launched May 2003 in North-America and Europe ("OUR HISTORICAL TIMELINE," n.d.). The universe that CCP created is a player driven economy set in a fictional space environment. Players can customize their characters, male or female, from four major races; the Amarr, Caldari, Gallante, and Minmatar. There exist a fifth dominant race called Jovian, though that race is still obscured and hidden, supposedly with technology far superior to those available to players currently within the game.

EVE-Online is a massively multiplayer online game (MMO), where participants all play in the same universe called New Eden. CCP has created a niche for their game within the online gaming genre, as most other massively multiplayer online roleplaying games (MMORPG) are played on multiple servers containing merely several thousand players. EVE-Online is played on one server consisting of every subscriber to the game, over 500,000 so far ("EVE ONLINE SURPASSES 500,000 SUBSCRIBERS WORLDWIDE," 2013). The game follows a sandbox theme where players fully control what they want to accomplish with their playing time ("FIND YOUR PATH IN THE SANDBOX," n.d.). There is no grinding of level advancement required, however the character advancement system is based upon a real-time skill training, which occurs even if the player is not logged online. All ships and equipment can be built, bought or sold via the active market in the game, which is driven by supply and demand.

The universe consist of 7,500 solar systems, hereafter referred to as systems, each of which can contain stations, planets, moons, asteroid belts, complexes, and possibly hidden wormholes. These systems are interconnected with stargates that enable players to jump their ships between systems and travel great distances in a blink of an eye ("One Universe, Limitless Potential," n.d.).

2.1. New to EVE-Online

Players start with no assets, save for a rookie ship equipped with a mining laser and a small gun, the essentials to start making your mark on the game. Players can have difficulty in establishing wealth or assets without assistance from other players. Therefore, teamwork and interaction can be crucial and the push or lack thereof might make or break the new players in the game. There is a need for new blood in the game, as older and more experienced players still need new recruits to assist with various projects and manual labor. New players will have skills available to fill those roles and then later on work their way up the ranks. Therefore, there will always be room for more players in all infrastructures of the universe.

When a player has become established and worked out what he likes most about the elements within, then he will have to choose what in-game profession and activities he feels will be most profitable and enjoyable for him. Miner, manufacturer, trader, pirate, bounty hunter or fighter, the sandbox environment enables you as a player to venture down many paths or just focus on one. The environment that CCP has created provides a platform for players of different personalities with different goals, resulting in an economy vibrant with activities.

2.2. Game setting

The systems within the game have different varying levels of danger and are ranked by different security statuses, ranging from 0.0 to 1.0, with 1.0 being the safest system and 0.0 being the most dangerous. The status itself is a good indicator of what kind of threat level a player can expect when flying through a system. Systems with a 0.1 to 0.4 security status will be dangerous, as other players can attack you if they desire, though not in close proximity to stations or stargates, as they are equipped with guns and will engage the aggressors, within the protected area (“SENTRY GUNS,” n.d.). Systems with security status 0.0 are a kill or be killed areas, and have no consequences for hostile activities other than loss of ship and valuables. What separates the 0.1 to 0.4 systems from the 0.0 systems is that they incur a standings loss for the hostile initiating players, while that does not happen in 0.0 systems. Safe systems, hereafter referred to as empire space, range from 0.5 to 1.0 and players can be sure they will not be engaged in battle relative to the status of each system (“SYSTEM SECURITY,” n.d.).

In empire space resides a police regime called CONCORD, which was founded by the five major races to ease tension and provide secure systems were players can conduct trade and business. CONCORD responds to hostile activity, engages the aggressor and takes them down. Response time does vary as the security status of systems lowers towards the slowest response time in 0.5 systems, meaning that CONCORD will react to hostile actions in 0.5 space relatively slower than to 1.0 space (“CONCORD (MECHANICS),” n.d.).

2.3. Goals

There exists no goal or end game effectively in EVE-Online. The sandbox theme and the science fiction setting that CCP has created are supposed to be a virtual reality for players to enter and socialize with their friends and strangers. Whether a player wishes to become rich, famous, infamous or a behind the scene puppet master, everything is possible in that sense. You can create your own destiny, however difficult that may be. Players will compare themselves with other players, in wealth, kills or known achievements, but all value is in the eye of the beholder. Reputation is important for players to make connections in the game, e.g. as fighting prowess or market integrity. Players will become infamous for stealing or breaking up alliances, however memory is short and changing ones name can easily help in erasing past dirty deeds.

2.4. Market environment

There exists only one form of currency in the game, InterStellar Kredits or ISK (“GLOSSARY,” n.d.). There is no form of a banking system, therefore no risk-free rate for players to invest their ISK. There are a couple of markets in EVE-Online, the commodity market and the contract market, which fulfill the trading needs of the entire market.

2.4.1. Commodities market

There is a commodities market that has been in existence since the game was launched in 2003, and has fundamentally been unchanged since then. Initially CCP had an active involvement in trading on the market, being counterparty to every trade that players wished to make, either buying or selling. This was a crucial move on CCP’s half as this helped build credibility and the functionality of the market place, ensuring that the market would be a vital tool in building wealth and increasing the gaming experience of players. Now the market consists of over 8,000 tradable goods, built, bought and sold by players with no involvement from CCP, creating a real economy where wealth is transferrable from one player to another. With an average of 11 trades per second and peaking at 14 trades per second, this economy has grown into a larger market than the whole Icelandic economy (Guðmundsson, 2012).

2.4.2. Contracts market

Additional to the commodities market there is another market that is used for characters to bypass trading taxes and commissions; it is called the contract market. This market is used by characters to sell expensive items as well as packages of many items, all of which the seller does not have to pay any fee for the transaction. This market within the contract market is called item exchange. Since there is no fee, there is no assurance on risk involved with the trade. If characters do not thoroughly inspect the contract details, they could be scammed for the amount paid or item received. This market is very active, but also very risky with many individuals trying to take advantage of uninformed characters. Characters can also auction off items in the contract market, setting reserve and buyout prices. The third type of contract market variety is a courier mission contracts. This system has been scarcely used as it is flawed in the sense that all risk involved is transferred over to the courier mission taker, with the seller of the mission requiring the courier taker to pay large sums in collateral prior to the courier mission. If the courier taker is attacked and destroyed he will not only lose the collateral, but also his ship, modules and delivery package.

2.5. Skills

In order to fly ships, players will need to spend time in training their character. That includes basic piloting skills; maneuvering, armor or shield capabilities and offensive skills, in the form of gunnery or missile launcher operation. These skills take time depending on the type and level needed to train a skill, with time taken to study them being from 15 minutes to 5 hours just to reach level one of a certain skill type. There are five levels for each skill trainable in the game, and most often a level four or five is needed for one skill for the player to be eligible to train other skills related to the original one. As can be seen, a great deal of time goes into training and planning, and all in real life timing. If you need for instance 20 days to achieve level five in a skill, it will not finish until twenty days later, exactly. Players do not need to be logged on for the training to proceed, they just need to activate the skill and could theoretically log off after that and arrive twenty days later.

There are 16 skill groups in the skill tree and each of them has a large number of sub skills. Skill training time will vary depending on attribute level of character, and there are 5 attribute each character has: *charisma*, *intelligence*, *memory*, *perception* and *willpower*. All skills have a primary attribute that affects training most, and then there is a secondary attribute that has less effect on the time needed to train (“Attributes in EVE,” n.d.).

There are ways to improve attributes of a character. That is done by installing implants into the character. See section 2.10 for further details.

2.6. Materials

There are many things that come into play when a module is manufactured in EVE-Online. There are different tech levels for most of the modules and therefore different production cycles and materials needed.

There are eight base materials that are mined from different asteroids in a system. There can be many different asteroid belts within each system. The rare asteroids contain higher end materials, which are more valuable and are found in lower security space, thus making those materials more difficult to acquire. There are 16 different asteroids that all have different buildups of base materials, as can be seen in Figure 2.1 below.

When a player has mined the ore from the asteroid he has to refine it in stations to extract the base materials out. It depends on the skill level of the player on how efficiently he can extract the material from the ore collected. After the player has refined the ore he can start producing modules or ships given he has the necessary blueprint (“ORE,” n.d.):

Material	Veldspar	Scordite	Pyroxeres	Plagioclase	Omber	Kernite	Jaspet	Hemorphite
Tritanium	100%	67%	82%	25%	42%	25%	20%	24%
Pyerite		33%	6%	50%	17%		20%	
Mexallon			12%	25%		50%	40%	
Isogen					42%	25%		24%
Nocxium			1%				20%	48%
Zydrine							1%	3%
Megacite								
Morphite								

Material	Hedbergite	Gneiss	Dark Ochre	Crokite	Spodumain	Bistot	Arkanor	Mercoxit
Tritanium		20%	25%	25%	71%		38%	
Pyerite					14%	25%		
Mexallon		20%						
Isogen	65%	40%						
Nocxium	32%		50%	25%				
Zydrine	3%	20%	25%	50%		50%	21%	
Megacite					14%	25%	42%	
Morphite								100%

Figure 2.1: Asteroid yield

Tech 1 (hereafter referred to as T1) commodities consist of different quantities of base materials and players need different amounts to manufacture them depending on their skill level. The higher the skills at production and efficiency, the more cost efficient the production will become.

To be able to produce more advanced tech levels, such as tech 2 and tech 3 (hereafter referred to as T2 and T3), additional materials are required such as alloys and compounds which are found when fighting more advanced non-playing characters (NPC) ships, different types of gas extracted from gas clouds, and ice materials extracted from ice belts. There are also planetary materials that are extracted off planets and players can also salvage materials from ship wrecks, both NPC and player owned ships. This further extends the manufacturing chain, making higher tech ships very arduous in construction.

All manufacturing steps require different skill sets that need to be trained to improve efficiency. However, players need to specialize in order to focus production of advanced modules as to make their manufacturing more efficient, with respect to time and material usage. Interaction and planning between different manufacturers is crucial to produce large quantities of modules and ships. Players will be hard pressed to fulfill every stage of the manufacturing cycle of high end commodities; few manage the task all by themselves.

2.7. Evolution

EVE-Online has had 18 major additions added to the game in its lifetime; the first one, Castor, launched in December 2003. Castor was the first major content addition, including conquerable stations in deep space, NPC mission running and second generation equipment components being added ("CASTOR," 2003). Conquerable stations in deep space enabled the explorers and fighters of the game to venture into the unknown and establish their own base of operation to defend and fight over, because the greatest riches of the game are to be found in the most hostile of places. Mission running enables solo players or small group of friends to receive payments from NPCs in exchange for running mission for them, ensuring that players are not dependent on other players to enjoy the game ("THE EVE EXPANSIONS," n.d.).

2.7.1. Notable expansions and additions to EVE-Online

Exodus (Nov 2004), originally codenamed Shiva, adding the player owned stations enabling alliances and corporations to claim sovereignty over systems and regions ("EXODUS," 2004).

Red Moon Rising (Dec 2005) with CCP's focus on attracting more international players by adding four new player outlooks that had more of an Asian resemblance and also a boost in starting skill points. The expansion also included over 20 new ships, mostly expensive T2 ships and also the largest ships in the game, capital ships, including carriers, motherships and titans ("RED MOON RISING," 2005).

Trinity (Dec 2007) expansion offered players new types of ships, along with more advanced versions of the ships already in the game ("TRINITY," 2007).

Quantum Rise (Nov 2008) had new technology implement to the smoothness and quality of the server itself, adding hardware to reduce lag and streamline the communication between server and client. Lag and client crash to desktop was a major issue that CCP had to tackle as the player experience would greatly diminish if the servers were not reliable in heavily populated systems (“QUANTUM RISE,” 2008).

Apocrypha (March 2009) expansion enabled players to queue their training, so that they did not have to log on to the game at shorter intervals to reset training on another skill when one skill finished training. The training queue is limited to 24 hours, however, there is the possibility of adding a skill that takes a longer time to finish if it starts before the training queue is full, and otherwise it would be impossible to train skills that last longer (“APOCRYPHA,” 2009).

Crucible (Nov 2011) focused on refining the game and elements that were already within, improving the user interface, better graphics etc. With Crucible also featured a new tier (tiers are the levels within each ship type) of battlecruisers to the game (“CRUCIBLE,” 2011).

Retribution (Dec 2012) is the latest expansion focusing on improving the bounty hunter system and an addition called Crimewatch, enabling other players to see if another player is conducting criminal activities in the system they are currently residing and can therefore take actions (“RETRIBUTION,” 2012).

Almost every expansion that CCP has launched has been a successful addition, increasing the player base and subscribers to the game. Although, one expansion **Incarna**, led to a decrease in player base, as CCP tried to implement an new addition where players could leave their spaceships and walk around in their station headquarters (HQ) (“INCARNA,” 2011). This is part of CCP’s future vision of enabling players to interact visibly in stations. This new addition did not sit well with players and subsequently halted CCP’s further advancement with the idea of players interacting in first person in stations. CCP’s growth has been steady with their game, and they have been relatively successful with each new layer on top of the next (Dumitrescu, n.d.).

2.7.2. Dust 514

Additionally, in January 2013 CCP launched its first console game called Dust 514 and was in the process the first gaming developer to connect two gaming platforms together, a personal computer (PC) and a gaming console. While EVE-Online is played on the PC, Dust 514 is played on a PlayStation3 (PS3) and both games are supposed to influence one another as they happen simultaneously in the EVE universe. Dust 514 takes place on planets in systems while EVE players fight and play above and around the planets (Ásgrímsson, 2013).

2.8. Ships

EVE-Online revolves around space travel, combat, and industrialism, therefore, the fundamental tool that every player needs is a ship to fly around the universe. There are many varieties of ships and they range from a tiny little pod with no accessories up to a huge Titan, a warship designed for destruction and the centerpiece of great armadas. The ships vary in design and utility, and each of the four races have specialties in their ships, e.g. the Caldari favor missiles and railguns, while the Amarrians have designed lasers to bring about destruction of their enemies. There certainly is no ”best ship“ in the game, as players preferences are very different and each pilot uses his ship in his own way, though the ships are usually designed for certain activities or warfare. A mining ship is not used to fight other ships and speedy frigates (small ships) are not usually used for mining or transportation of a large amount of goods. Players will therefore have to specialize their training and/or take more precious training time to achieve the prerequisites to fly the ships they desire.

2.8.1. Ship types

There are basically eight different types of ship groups in EVE-Online:

1) **Capital ships –** There are many variations of capital ships within the game. They can be used in siege battles, fleet fights or even as massive transportation vessels. The biggest ship is a capital ship, the Titan. Titans are the most expensive ships; with a going price around 90 billion ISK.

2) **Mining Barges –** Ships solely designed to excavate ore, ice or gas from their corresponding asteroid belts. The T1 mining barges cost from 8M to 35M ISK, while the T2 variation costs from 130M to 200M ISK.
3) **Battleships –** Large warships, though also used as mining ships as they have many slots to improve the utility of the ships. Battleships are expensive and were originally the top tier ships in the game. There have been many changes and now there are T2 variations available costing more than their T1 counterparts. Battleships tend to have good damage outputs and are able to defend themselves with superior armor and shields compared to their smaller counterparts. T1 cost around 90 to 150M ISK.
4) **Industrial ships –** These ships are mainly used as transportation ships and mining vessels. They lack the defensive capabilities for solo flight in hostile area, so players tend to have backup from other players flying ships more suited for combat. The T2 variations of the industrial ships are called Transportation ships and they are more expensive, costing up to 150M ISK.
5) **Battlecruisers –** Medium sized ships with great defensive and/or offensive capabilities. They have the ability to take battleship type defenses or offenses, meaning if they focus on one the other will not be achieved. The T1 battlecruisers cost from 40M to 100M ISK, while their T2 counterparts, command ships, are much more expensive, and therefore much more deadly rivals, costing from 200M ISK to 300M ISK.
6) **Destroyers –** Small sized ships designed for quick damage or to tackle hostile ships. They are viewed as the anti-frigate gun or missile ship. The standard issue destroyer T1 cost around 1M to 1.5M ISK. The T2 variation is called an interdictor and is mainly sought after for their tackling capabilities, the most efficient ships in that aspect. They cost around 30M to 40M ISK.
7) **Cruisers –** Medium sized ships, built to pack a punch in fights, though usually lacking the defensive capabilities to withstand barrages from bigger ships. The T1 is relatively cheap to build or buy, while the T2 version is 10 to 15 times more expensive. There are T3 versions of cruisers available, and those ships are hard to build and expensive, they are about 30 to 40 times more expensive than their T1 counterparts. T1 cost around 7 to 15M ISK.
8) **Frigates –** Small ships which are used for skirmishes and to tackle larger ships, as they are fast and very maneuverable. T1 versions of frigates tend to be easily produced and

cheap, however, T2 variations are much more expensive as they require higher grade of content. T1 versions tend to be expendable, while the higher grade versions are still expensive enough that pilots take precautions when fighting in them.

2.9. Modules

All ships in the game have any or all of the following, high, medium and low slots, as well as rigging slots. These slots are what players use to fit their ships with offensive, defensive and mobility gear that suits their playing style. The number of slots range from zero to eight for the high, medium and low slots, while the rigging slots are at max three. An example can be seen in Figure 2.2 where that ship has seven high slots, four medium slots, six low slots and three rigging slots.

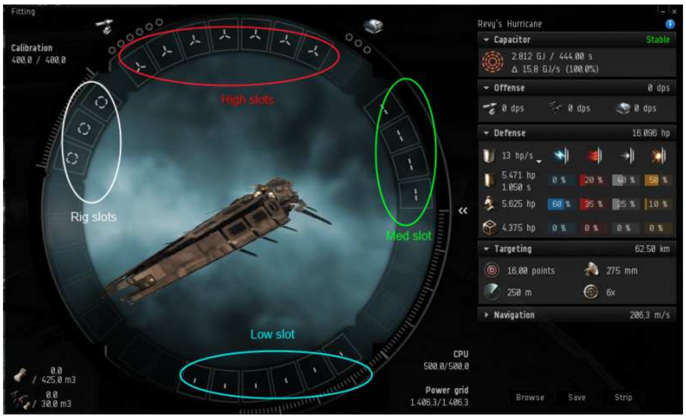


Figure 2.2: Hurricane fitting

2.9.1. Ship fitting options

High slots – Offensive capabilities of ships are mainly installed into the high slots of each ship, guns and launchers, or even modules that render the opposing ship neutralized. There are modules that are more defensive minded that fit into the high slot; they are more of the utility nature of repairing other ships or transferring energy.

Medium slots – Medium slots provide the most variety to add to your ship, whether it is speed, tackling modules, defensive (shield boosting or hardening) or even offensive electronic warfare.

Low slots – Defensive elements are installed into the low slots that factor into improving or hardening the armor of the ship. Low slot also deals with the electronics and power of the ship, as modules that improve on those elements are also installed in low slots. Upgrades to guns and launchers are also installed into low slots.

2.9.2. Rigs

The rigs are not interchangeable; meaning that once they have been installed the only way for them to come off is by destroying them and making them unusable on another ship. Rigs are improvements on elements of the ship, offensive, defensive, or mobility. They tend to have some other drawbacks from the improvements they give, like making you less maneuverable while improving your flat out speed ("RIGS," n.d.).

2.9.3. Drones

Some ships provide space for utilizing drones for attack or defense. Some races specialize in those elements for their ships, however, not all ships have room for drones. Drones are therefore not fitted into any slot in the ship, but rather launched from a drone bay, if one exists ("DRONES," n.d.).

2.10. Implants

When a character is generated at the start of his career, the owner must assign attributes to his character. As mentioned in section 2.5 each skill has a primary and secondary attribute associated with it, making a character with a high score in the corresponding attribute more apt at training that particular skill. Since those attributes are set after character creation the only way to affect them and increase is by installing implants into one of ten implant slot that the character has. These slots all affect specific attributes or skills for each character, so there is no way of have two identical implants installed into one character.

There are many levels of attribute implants and each increasing one attribute per implant, see Table 2.1. The attribute implants cost from 100,000 ISK all the way to 115M ISK, so they can become very valuable commodities for characters. There are also more specific implants available that increase attributes either +2 or +3 as well as piloting, defensive or offensive capabilities ("IMPLANTS," n.d.). Those implants are even pricier than the basic attribute implants, ranging from 100M ISK to 1.4Bn ISK ("Jita Snapshot," n.d.).

Table 2.1: Implant Type

Limited	+1 attribute increase
Limited Beta	+2 attribute increase
Basic	+3 attribute increase
Standard	+4 attribute increase
Improved	+5 attribute increase

Implants that only improve character skills at certain aspects of EVE-Online and do not affect attributes are called skill hardwiring. These implants improve on very specific skills and the variety of skill hardwiring for each implant slot is great, ranging from slot 6 to slot 10. Pricing is hard to pinpoint, however, they can cost from 10,000 ISK all the way up to a couple of billion ISK.

2.11. Insurance system

The insurance system in the game has been unchanged since its installment. As ships and modules have evolved, the insurance system has not kept pace with the rising prices and advancements in technology. An insurance contract is valid for 12 weeks and ships are the only eligible underlying insurable asset.

There are six different insurance coverage to choose from:

1. 50% = Basic
2. 60% = Standard
3. 70% = Bronze
4. 80% = Silver
5. 90% = Gold
6. 100% = Platinum

All ships are 40% covered by default ("INSURANCE," n.d.). The payouts of contracts are calculated from the 90 day average price of the eight base materials. It does not take into account market value of components or total value of modules needed to produce the ship. Calculations are therefore simple and not covering the real market value of ships (Halldórsson, 2013).

There are a few ways to lose the insurance players buy without getting their payouts. If they repackage their ship they forfeit the insurance. If they trade, sell or make a contract on the ship to other players, if the ship is put into a corporation hangar (unless it is insured by the corporation itself) and if CONCORD destroys the ship because of a criminal behavior of the player (“INSURANCE,” n.d.).

As it is set up today the insurance system is ran by CCP and does not produce a profit. Players only have one insurance scheme to choose from, i.e. to insure the ship hull. However, modules fitted on a ship can be more expensive than the actual ship and there are no ways for players to hedge their risk by insuring modules. Players with more advanced space ships tend to not even bother with insuring them because of the skewness of payout and fair market value.

The insurance system has been a part of the game for a long time. First time players use it to insure their basic ships but as time progresses, players accumulate more skills, and start flying more advanced ships and use more advanced modules. The insurance system, therefore, has the potential to evolve further and offer a variety of insurance schemes to players. Different insurance schemes could hypothetically enable players to run an insurance company, hence adding another dimension to the game.

2.11.1. Basic contract calculations

Contract Payout (C):

Equation 2.1: Contract payout

$$C = \sum_{i=1}^{8} \left(\text{Base}_i \times \text{Price}_i\right) \times \text{Coverage}_n \quad , \quad \{\text{n: } 50\%, 60\%, \ldots, 100\%\}$$

Where C is the contract payout, $Base_i$ is the quantity of the base materials needed to build a ship, $Price_i$ is the 90-day average price associated with each of the materials, $Coverage_n$ is the level of coverage the player wishes to insure the ship for.

Base Premium (P):

Equation 2.2: Base premium

$$P = \left(C \times Coverage_n\right) \times 30\% \times \frac{m}{6} \quad , \quad \{\text{n: } 50\%, 60\%, \ldots, 100\%; \ \text{m:} 1, 2, \ldots, 6\}$$

where P is the premium to be paid for the contract, C is the contract payout, $Coverage_n$ is the coverage level of the contract, 30% is the cost for a 100% contract, m is the level of cost for each contract. Each contract has different cost, as shown in Table 2.2.

Table 2.2: Insurance

m = 1	50% coverage
m = 2	60% coverage
m = 3	70% coverage
m = 4	80% coverage
m = 5	90% coverage
m = 6	100% coverage

2.11.1.1. Example 1: Raven

A player owning a blueprint for a T1 battleship, e.g. a Raven, will need materials to construct it. These materials can vary depending on the skill level of the manufacturer, however, in this example it is assumed that the player has perfect manufacturing skills and there are no wasted materials (“RAVEN BLUEPRINT,” n.d.). The Table 2.3 shows the materials and quantities required for the construction of the ship Raven (“Jita Snapshot,” n.d.).

Table 2.3: Raven construction

Symbol	Name	Materials needed (Raven)	Price*	Total
T	Tritanium	8,335,395	6.00	50,012,370
P	Pyerite	2,084,282	15.97	33,285,984
M	Mexallon	522,143	61.23	31,970,816
I	Isogen	130,371	155.96	20,332,661
N	Nocxium	32,555	864.42	28,141,193
Z	Zydrine	7,766	905.01	7,028,308
ME	Megacyte	2,479	2799.99	6,941,175
			Total	177,712,507

**Median price from www.eve-central.com*

To insure the Raven, which had (as of March 7^{th}) the going rate of 157.4M ISK (median main market hub price), the player will need to pay, using Equation 2.1 and 2.2, the following premium to receive a hypothetical 100% payout:

Contract payout

$$C_{Raven} = \begin{pmatrix} 8,335,395_T \times 6.00_{\text{price T}} + 2,084,282_P \times 15.97_{\text{price P}} + \\ 522,143_M \times 61.23_{\text{price M}} + 130,371_I \times 155.96_{\text{price I}} + \\ 32,555_N \times 864.42_{\text{price N}} + 7,766_Z \times 905.01_{\text{price Z}} + \\ 2,479_{ME} \times 2,799.99_{\text{price ME}} \end{pmatrix} \times 100\%$$

$$C_{Raven} = 177,712,507 \text{ ISK}$$

Premium

$$P = (177,712,507 \times 100\%) \times 30\% \times \frac{6}{6}$$

$$P = 53,313,752 \text{ ISK}$$

As Table 2.3 shows, with the median prices of underlying commodities needed to build the Raven, the value ends up being close to 178M ISK and with a 100% payout amounting to 178M ISK. When compared to the going rate of Ravens on the market, 157.4M ISK, it would seem that insuring is netting a profit for players buying insurance and losing their ships, that is not the case as the premium paid for the insurance negates that profit.

2.11.1.2. Example 2: Golem:

To construct a Golem, a T2 variation of the Raven, requires a fully built Raven, plus some additional higher technology material. The value of the Raven is presented in Table 2.3, which gives the average price of the underlying base materials. The following example shows how the price differs between a Golem and a Raven, with respect to the huge gap in payouts. Golem can only be insured as the basic hull, which is a Raven per se. Additional construction material are required, none of which include any of the base materials which are the fundamental instruments when pricing the T1 variation (“GOLEM BLUEPRINT,” n.d.).

Table 2.4: Golem construction

Type	Quantity	Price	Total price
Raven	1	177,646,034	177,646,034
Construction Blocks	300	10,096	3,028,800
Gravimetric Sensor Cluster	633	21,006	13,296,798
Gravitron Reactor Unit	165	38,488	6,350,520
Magpulse Thruster	275	16,598	4,564,450
Morphite	715	8,700	6,220,500
Quantum Microprocessor	4,400	35,597	156,626,800
Scalar Capacitor Unit	2,200	37,051	81,512,200
Sustained Shield Emitter	2,783	19,498	54,262,934
Titanium Diborite Armor Plate	27,500	8,100	222,750,000
		Total	726,259,036

It can be seen in Table 2.4, that the value of a Golem differs immensely from the value of a Raven, see Table 2.3. The Golem building cost is around 726M ISK, while the Raven cost is around 178M ISK, resulting in around 549M ISK difference. There is no way for a player to insure the value difference between these two ships, the only maximum payoff available for the Golem is the same as for the Raven.

3. Data

Like in the real world, each in EVE-Online has his own way of playing the game, exhibiting different levels of risk taking behavior. The authors of this thesis believe that there are nine risk factors that could potentially affect the pricing of an insurance contract in the game. The risk factors can be gathered for each character in the game, and are therefore universal. The data being assessed is all hypothetical; a data set was created for each variable depending on the experience of the authors as players' in-game. It could therefore be bias towards their experience and should not be interpret as actual data extracted from the game. An appropriate distribution of each risk factor is set up and simulated 2,500 times to mimic the behavior pattern of 2,500 characters. Some factors give indications on how a player behaves in-game, e.g. security status of a character ranges from -10.0 to 5.0, as the security status gets lower the character is more inclined towards hostile behavior. A character with a very low security standing is expected to behave in more of a criminal manner, hence a greater risk of losing his assets. It is also possible to see where each player spends his time in the universe; each system is ranked from 0.0 to 1.0, with 0.0 being the riskiest. Each player can jump from system to system; an average is generated over the period. When using the average of systems visited it can be seen where characters spend most of their time, and with lower security status of a system the more risk the player exhibits. A more detailed description on each risk factor can be seen in section 3.1.

3.1. Risk factors

3.1.1. Character security status [x1]

Character security status is a factor that affects the pricing of the insurance contract with respect to how dangerous a character is in the game. If the security status is negative, then the character is more prone to dangerous activities than a character with a positive security status. The distribution of security status in-game is bound from -10.0 to 5.0.

3.1.2. Characters bounty prize [x2]

Characters bounty prize is a factor that should affect the insurance pricing, increasing the likelihood of insurance claim with respect to that a bounty is in place. A character with a bounty in place has increased likelihood of being shot down and that likelihood increases with a higher amount placed on his head. If the prize is high, the likelihood of him being shot down increases and thereby the premium should be higher. Information gathered from CCP suggests that only 4% of characters in the game have a bounty placed on their heads (CCP Punkturis, 2013). Though a small portion of the population has a bounty in place, it should still be a significant risk factor to evaluate.

3.1.3. Solar system traveled [x3]

Solar system traveled will represent data on characters that show where they spend their time in the EVE universe. The security status of each system in the game is ranked from 1.0 to 0.0, where 0.0 is the most dangerous area. The distribution is thereby bound within those extremes. It can be seen that if the number generated for a character is low, the character presents a behavior of being in hostile areas, hence a greater risk of losing his ship and assets. The security status can, however, be broken into sections, as some areas are relatively safe, while others are just warzones. Threat level of solar system security status was described in section 2.2.

3.1.4. Number of ships lost [x4]

Number of ships lost is a clear indicator of the risk involved in insuring a characters ship in the future. Over an observed period the higher the number of ships lost, should correspond to a higher premium paid. All ships; irrelevant to whether they are insured or not, factor into this variable, as the number represents the characters tendency to lose ships.

3.1.5. Number of ships destroyed [x5]

Number of ships destroyed is an indicator on how aggressive the character is in fighting other characters in the game. Therefore, the higher number suggests that he is involved in more fights and thereby increasing the likelihood of his own ship being destroyed. This risk factor will likely have significance in pricing of insurance premiums.

3.1.6. Corporation in war [x6]

Corporation in war or not, will give an overview of how many players are involved in a war against another corporation or alliance in the game, thereby increasing the likelihood that they will be engaged in fights anywhere in the universe. Empire space (safe space) is no longer an area that is completely secure for the character. Hopefully this data series will represent some significance for the model.

3.1.7. Insurance claimed [x7]

The number of insurance claimed by a character is an important factor in the modeling of the premium pricing. Claims over an observed period will therefore be a clear indicator of the propensity for disaster that the character exhibits. Insurances claimed will give an indication of the probability of a contract being exercised.

The ratio between claims and premiums represents the dependent variable in the regression, see section 5.2 for further details.

3.1.8. Premiums paid [x8]

Premiums paid present the researchers with the estimated number of contracts sold during the viewed period. Premiums are not a risk factor; however, the data is important to evaluate other risk factors used in the regression. The ratio between claims and premiums paid, as well as ships lost and premiums paid, are good indicators for evaluating.

3.1.9. Ship group type [x9]

Ship group type will indicate what variety of ship a character is using and losing. This will give the indication of which ships are more likely of being destroyed. Though each group type has numerous variations within, different resistance levels or abilities, the group type should give the model a coefficient that either reduces or increases the premium of ship insurance. The ship groups are as follows (more details in section 2.8.1):

1. Capital ships
2. Mining Barges
3. Battleships
4. Industrial ships
5. Battlecruisers
6. Destroyers
7. Cruisers
8. Frigates

Each ship in the game present different abilities of evading danger or surviving combat, therefore there needs to be a different risk factor incorporated for each when pricing insurance instruments. The order is based upon the likelihood of ship group type being destroyed at any given instance.

3.2. Cholesky decomposition

Cholesky decomposition is a method used when correlating different data sets together. The data needs to be set up in a way that it has a chance to be correlated with Cholesky, i.e. the data is all positive. Data was therefore rescaled such that higher numbers represent higher risk levels and the data is scaled in a way that all numbers are positive. As seen in sections 4.1 and 4.3; character security status is inverted and rescaled from 0.0 to 15.0 where higher numbers represent greater risk and solar system visited is inverted and rescaled from 0.0 to 10.0, for easier readability and data manipulation, so the higher numbers represent greater risk. Although Cholesky decomposition was not applied on the data set, the data was rescaled such that it can be applied if needed.[1]

[1] For further information on Cholesky decomposition see (Greene, 2003)

4. Simulation

All data sets being evaluated are hypothetical; to be able to make appropriate data sets to each risk factor based on the experience of several players of EVE-Online to determine how the factors are distributed. A few steps needed to be taken before appropriate distribution was found. Some risk factors were also rescaled such that the higher numbers represent more risk for all factors. Some risk factors have recognizable distributions; however for those that do not, steps were taken to replicate what distribution is most likely suitable based on EVE-Online experience of thesis authors'. When the data had been replicated a distribution fitting tool was applied to find the most suited distribution available to the behavior of the data in question.[2] The fitting tool uses different parameter estimation methods for different probability distributions; least squares method, method of L-moments, method of moments and maximum likelihood method ("Distribution Fitting - What Parameter Estimation Methods Are Used in EasyFit?," n.d.). The data was then simulated 2,500 times to replicate the behavior pattern of 2,500 characters.

Please note that this data set does not represent the real data from the game, this data set is solely a replication of authors and several other players experience of EVE-Online. All statistical tests on the data will not be statistically significant because of the fact that it is hypothetical. However, appropriate test for the insurance model will be addressed to show how it will affect in practice the true outcome if the data is extracted from EVE-Online.

4.1. Character security status [x1]

Table 4.1: Character security status probabilities

Character security status (subjective view)

Bins			Prob.	Cumulative
0,0	to	5,0	60%	60%
5,1	to	7,4	17%	77%
7,5	to	9,9	13%	90%
10,0	to	12,5	5%	95%
12,5	to	14,9	3%	98%
15,0	to	15,0	2%	100%

[2] For further information on the fitting tool, see http://www.mathwave.com/easyfitxl-distribution-fitting-excel.html

Character security status spans from -10 to 5, where the lower numbers represent more risk. It was therefore rescaled from 0 to 15 where 15 represent the highest level of risk. The subjective view of the authors' experience playing EVE-Online is represented in Table 4.1, where probabilities are determined for each bin, with the bulk of the characters fall in the 0 to 9.9 bins or 90%. Only 10% of characters are represented in bins 10 to 15, the ones that are most likely to be risk seeking. These bins where then simulated 2,500 times and then run through a fitting program that recognized it as a Johnson SB distribution. Parameters used to replicate the desired distribution of the data; skewness γ of 1.0126, excess δ of 0.95346, scale λ of 19.619, and location ζ of -0.69111. After the parameters where determined the data was simulated 2,500 times with Johnson SB distribution, see Figure 4.1. Character security status has a mean of 5.408, a median of 5 and a standard deviation of 3.45. As can be seen it is skewed to the left where most players have security status of 0 to 5.

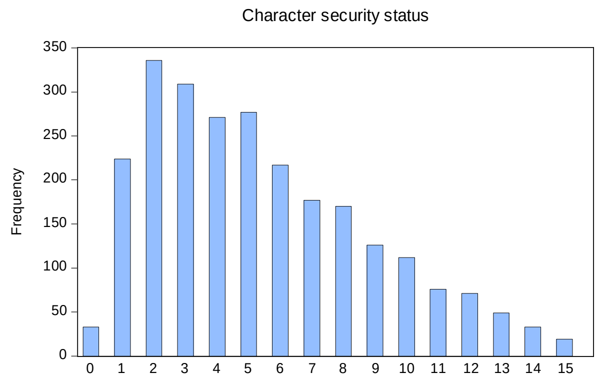


Figure 4.1: Character security status distribution

4.2. Character bounty prize [x2]

Table 4.2: Character bounty prize probabilities

Character bounty prize				
Bins			**Prob.**	**Cumulative**
0 ISK	to	0 ISK	95%	95,0%
100.000 ISK	to	10.000.000 ISK	2%	97,0%
10.000.000 ISK	to	100.000.000 ISK	2%	98,5%
100.000.000 ISK	to	1.000.000.000 ISK	1%	99,3%
1.000.000.000 ISK	to	10.000.000.000 ISK	1%	99,9%
10.000.000.000 ISK	to	100.000.000.000 ISK	0%	100,0%

Six bins where made to represent the character bounty prize. As mentioned in section 3.1.2 only around 4% of characters has a bounty prize on their heads. Therefore 95% of the population is placed in the zero bins and spread the rest down to a maximum bounty prize of 100,000,000,000 where there is 0.1% of the total population as seen in Table 4.2. It was clear that a distribution that handles extremes would be well suited to represent the character bounty prize factor. These bins where replicated 2,500 times and the outcome put through the distribution fitting tool. Gumbel Max distribution was the most likely distribution with a scale parameter, σ, of 100,000,000 and a location parameter, μ, of -300,000,000. The character bounty prize was then simulated with Gumbel Max distribution 2,500 times, see Figure 4.2: Character bounty prize distribution. As mentioned above most players do not have any bounty prizes on their head which explains why Figure 4.2: Character bounty prize distribution is almost all in the zero range.

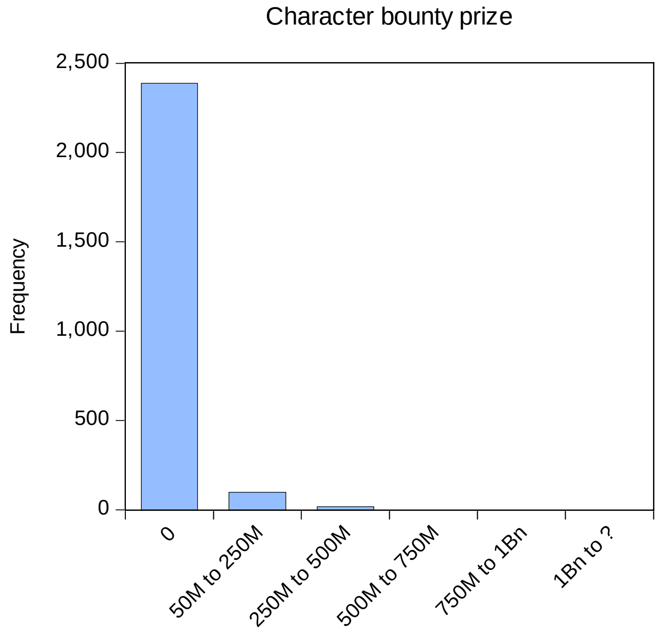


Figure 4.2: Character bounty prize distribution

4.3. Solar system visited [x3]

Table 4.3: Solar system visited probabilities

Solar system visited (subjective view)				
Bins			Prob.	Cumulative
10,0	to	10,0	15%	15%
6,0	to	9,0	8%	23%
0,0	to	5,0	77%	100%

Solar system security status span from 0.0 to 1.0 were 0.0 is high risk space. The data was rescaled, from 0.0 to 10.0, where 10.0 represent the highest risk areas. Bins were made that represent how the data would most likely look. It is believed that the majority of characters spend their time in more safe space from 0.0 to 5.0, or 77% of the population. It is also assumed that more character spend their time in 10.0 space rather than 6.0 to 9.0. Data series were simulated 2,500 times with emphasis on the information from the bins in Table 4.3. A distribution fitting tool was applied to find out most likely distribution that behaves similar to expectations. Generalized extreme value is most suitable to represent the data, with a shape parameter, κ, of 0.0544, a scale parameter, σ, of 2.3418 and finally a location parameter, μ, of 2.1. The data was then simulated 2,500 times using GEV distribution with above parameters. Figure 4.3 shows how the data is distributed with a mean of 4.0392, median of 4.000, and a standard deviation of 2.801. As expected most characters spend their time in more safe space, most of them spend their time in systems 2.0 to 4.0.

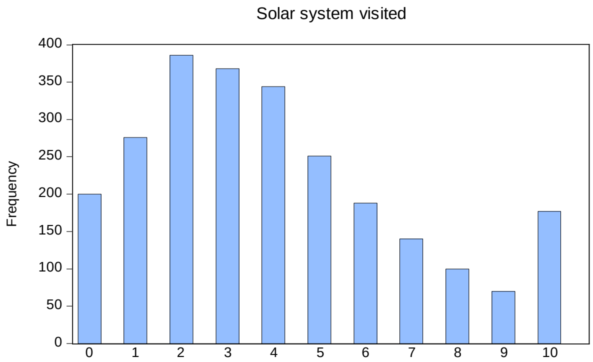


Figure 4.3: Solar system visited distribution

4.4. Number of ships lost [x4]

Table 4.4: Number of ships lost probabilities

Number of ships lost (subjective view)		
# Ships lost	**Prob.**	**Cumulative**
0	70%	70%
1	21%	91%
2	6%	97%
3	2%	99%
4	1%	100%
5	0%	100%

Number of ships lost is as before a subjective view of how the probabilities disperse, as seen in Table 4.4. The distribution fitting tool is applied and the goodness of fit tests suggested the Poisson distribution with a $\lambda = 0.4236$. Most players will likely not lose their ships over the period, or 70% of the population and 30% will lose at least one or more ships. The data was then simulated 2,500 times to replicate the distribution. Figure 4.4 show the distribution with a mean of 0.42, median of 0.000, and a standard deviation of 0.892. For further details see Appendix III – Data fitting results.

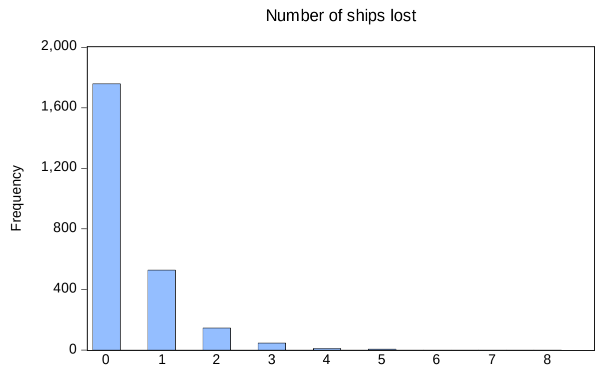


Figure 4.4: Number of ships lost distribution

4.5. Number of ships destroyed [x5]

Table 4.5: Number of ships destroyed probabilities

Number of ships destroyed (subjective view)		
# Ships destroyed	**Prob.**	**Cumulative**
0	67%	67%
1	27%	94%
2	5%	99%
3	1%	100%

Number of ships destroyed is as before a subjective view of how the probabilities disperse, as seen in Table 4.5. The distribution fitting tool is applied and the goodness of fit tests suggested the Poisson distribution with a $\lambda = 0.3912$. The data was then created by simulating 2,500 times and the data has a mean of 0.39, median of 0.000, and standard deviation of 0.620. The distribution estimates that around 67% of characters will not destroy another characters ship during the observed period, while 26% of them will destroy at least 1 ship. 32% of characters will destroy one or more ships during the period, as can be seen in Figure 4.5. For further details see Appendix III – Data fitting results.

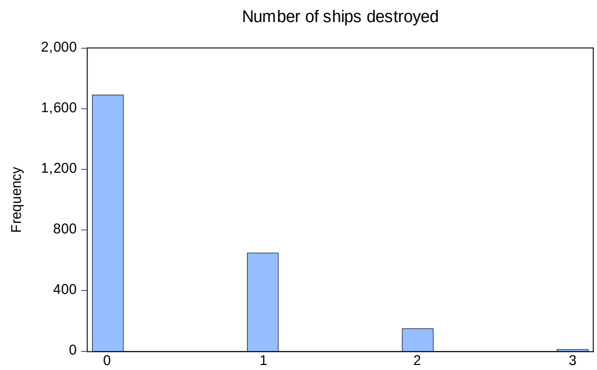


Figure 4.5: Number of ships destroyed distribution

4.6. Corporation in a war or not [x6]

Table 4.6: Corporation in war or not probabilities

Corporation in war or not (subjective view)		
War or not	**Prob.**	**Cumulative**
No	95%	95%
Yes	5%	100%

Suppose the probability of the risk factor x_6, corporation in a war or not, has a success probability rate, p, of 0.05. Success indicates that a corporation is in war and failure that it is not at war. The simulation is run 2,500 times to emulate the results of as many characters in EVE-Online. Then a distribution fitting tool is applied to find out the most likely distribution and Figure 4.6 illustrates recommended distribution, the Bernoulli distribution. Corporation in a war or not has a mean of 0.049, median of 0.000, and a standard deviation of 0.216. For further details see Appendix III – Data fitting results.

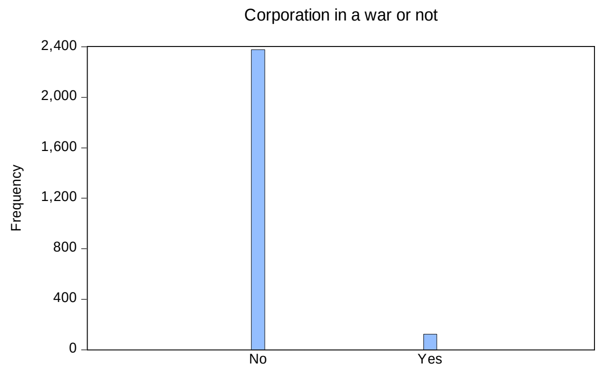


Figure 4.6: Corporation in war or not distribution

4.7. Insurance claimed [x7]

Table 4.7: Insurance claimed probabilities

Insurance claimed (subjective view)

# Claims	Prob.	Cumulative
0	74,1%	74,1%
1	22,2%	96,3%
2	3,3%	99,6%
3	0,3%	100,0%

The number of insurance claimed is as before a subjective view of how the probabilities disperse, as seen in Table 4.6. The distribution fitting tool is applied and the goodness of fit tests suggested the Poisson distribution with a $\lambda = 0.2956$ .The simulation was run 2,500 times to represent as many characters over the observed period. About 75% of characters will not claim any insurance payouts during the observed period, while 25% will claim one or more contracts. Figure 4.7 illustrates the distribution of insurance claimed with a mean of 0.296, median of 0.000, and a standard deviation of 0.554. For further details see Appendix III – Data fitting results.

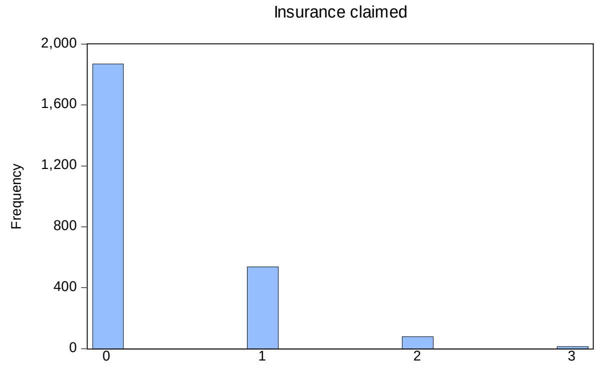


Figure 4.7: Insurance claimed distribution

4.8. Premiums paid [x8]

Table 4.8: Premiums paid probabilities

Premiums paid (subjective view)

# Premiums	Prob.	Cumulative
0	33,3%	33,3%
1	36,6%	69,9%
2	20,1%	90,0%
3	7,4%	97,4%
4	2,0%	99,5%
5	0,4%	99,9%
6	0,1%	100,0%

The number of premiums paid is as before a subjective view of how the probabilities disperse, as seen in Table 4.8. The distribution fitting tool is applied and the goodness of fit tests suggested the Poisson distribution with a $\lambda = 1.0784$. This will confirm that the occurrence of buying an insurance contract must exceed the event of claiming insurance. The data is simulated 2,500 times to represent characters buying insurance contracts, with around 35% of characters not buying any insurance over the observed period. On the other hand around 55% of characters buy one to two insurance contracts over the period. Figure 4.8 shows how the data is distributed over a number of occurrences with a mean of 1.078, median of 1.000, and a standard deviation of 1.065. For further details see Appendix III – Data fitting results.

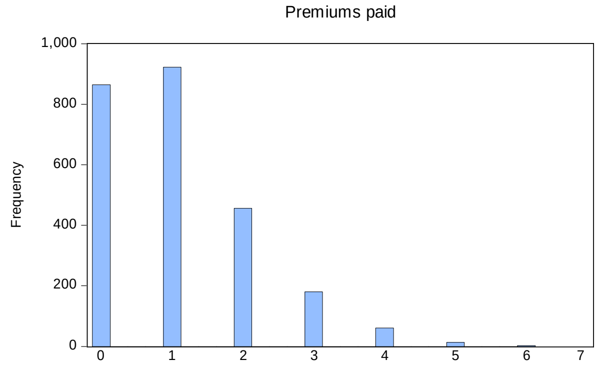


Figure 4.8: Premiums paid distribution

4.9. Ship group type [x9]

Table 4.9: Ship group type probabilities

Ship group type (informal survey)		
Group	**Prob.**	**Cumulative**
1	0,7%	0,7%
2	1,8%	2,5%
3	5,1%	7,6%
4	4,8%	12,4%
5	9,4%	21,8%
6	15,8%	37,6%
7	21,3%	58,9%
8	41,1%	100,0%

Ship group types are categorized as previously mentioned in section 2.8.1. Figure 4.9 shows the distribution of ship group type over the observed period. An informal survey on kills via an open source killboard site, www.battleclinic.com, found an ordering of the likelihood of ship group type being destroyed at any given moment ("Kill Board," n.d.). Frigates show the highest probability of being destroyed in combat, followed by cruisers and then destroyers. Surprisingly battleships seem to show resilience and are less likely of being destroyed, contrary to what was expected, however, it should be noted that large battles will of course show outliers and anomalies from the probability distribution estimated for the data to be generated. When the data was simulated 2,500 times, frigates are destroyed over 40% of the time and cruisers around 20% of the time.

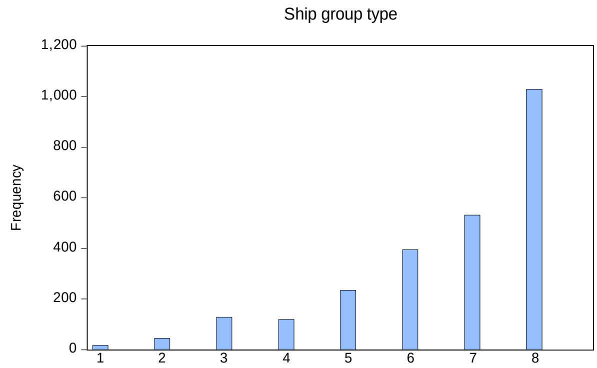


Figure 4.9: Ship group type distribution

5. Insurance modeling

There are many models available that insurance companies can use to value their contracts. Simple regression models can be used to check basic behavior patterns of sample data. However, simple regression models do not all allow for non-normal distributions in the modeling phase. Ordinary least squares (OLS) regression is widely used in statistics but to be able to use OLS analysis the data needs to fit the criteria of best linear unbiased estimator, usually called B.L.U.E, that means that the data cannot be highly correlated and it is also preferred to be normally distributed. When insurance data is evaluated, the data is often correlated and not normally distributed. A normally distributed probability model would be an inadequate fit for data that is correlated and is non-normally distributed as is with most risk outputs that insurance companies have to evaluate. OLS analysis is, therefore, not suited and a need for a more flexible model is required. Therefore, it was decided to focus on the generalized linear model (GLM).

5.1. Generalized Linear Model

Generalized linear model, hereafter referred to as GLM, is used by insurance companies to price premiums and evaluate risk factors; GLM is an extension of the linear models. It handles other probability distributions besides normally distributed, e.g. Poisson, Bernoulli, and geometric probability distributions to mention a few. Insurance data can be correlated, simple linear models are therefore not practical because of the influence variables have on each other. GLM evaluates and generates the best linear fit through the non-normal data and estimates the optimal multipliers for each risk factor (Ohlsson & Johansson, 2010).

GLM attempts, like other regression models, to fit a regression line through the data minimizing the sum of squares with the help of a link function (Rutherford, 2001). The same statistical tests are used to find out if the variables are significant and belong in the model or not. F-test and Chi-Square test can be run to check for differences when attempting to simplify the model by, for example, excluding one variable from the data set.

5.1.1. GLM modeling process

In his article "INTRODUCING THE GENERALIZED LINEAR MODELS" Jong-Hwan Yoo shows the process on finding the "best" model available. In his opinion the best way to model with GLM is both to simplify the model and complicate it. These methods ensure that the best fit model will be produced. There are mainly four steps when modeling with GLM (Yoo, n.d.).

1) Set up an unrestrained model:

First step is to include all variables that are expected to affect the outcome. It is important to start with a wide range of information to make sure all relevant data is initially included, thereby understanding the importance of each variable and their relevance.

2) Statistical tests:

Run univariate tests on the model, e.g. variable significance; check each variable and decide which will be included in the model. Run F-test and Chi-Square test to test the significance of the whole model, see 6 Statistical tests.

Simplify:

Simplify the model by, e.g. excluding variables that are statistically insignificant, without affecting its true outcome.

3) Interaction tests:

Run interaction test between the remaining variables to check for Simpson's paradox.

Variables being evaluated have different data sets and can take distinguish direction usually called a trend. Simpson's paradox can occur when two data sets are combined and the aggregated data trends in a different direction, rather than when evaluated separately (Wagner, 1982).

4) **Repeat:**

Repeat the steps above to find the most stable and significant model to use.

5.1.2. <u>Link function</u>

Since GLM can handle many different distributions a link function has to be introduced. In most regular linear regression models the data is normally distributed so the mean of the distribution falls on the regressed line. The link function is a way to link together the mean of different distributions within the GLM to minimize the sum of squares of the data. Link function is therefore a way to link together a dependent variable that is nonlinear to the other variables being evaluated. There are two different distributions that are commonly used to estimate insurance data, Gamma distribution is used to evaluate severity and Poisson distribution is used for frequency data (Yoo, n.d.). The dependent variable can be linked with various distribution functions. In insurance Poisson and Gamma link functions are commonly used, with $g(u)$ representing the link function.

Equation 5.1: Link function

$$E(Y) = g(u) = \beta_0 + \beta_1 + ... + \beta_j x_j + \varepsilon$$

5.2. Dependent variable

The loss ratio is used to find the proportional relationship between claims and premiums. Insurance companies do their best to make sure that the loss ratio is as low as possible, preferably staying below the 100% mark so that premiums collected cover the claims paid ("loss ratio," n.d.).

The loss ratio y is used as a dependent variable and evaluated with all risk factors included. The outcome shows the potential loss ratio for each character over the period. The loss ratio is then used as a proportional risk load when pricing the correct premium to charge each character.

Equation 5.2: GLM input

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_9 x_9 + \varepsilon$$

Where

$$y = \frac{\sum_{t=0}^{T} x_7(t,T)}{\sum_{t=0}^{T} x_8(t,T)} = \text{loss ratio}$$; representing the dependent variable.

Where x_1 to x_9 are the risk factors mentioned in section 3.1, and each corresponding beta the slope. The model will solve for the beta vectors and minimize the sum of squared residuals, then after simulation the GLM will give a final regression:

Equation 5.3: GLM output

$$\hat{y} = c + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_9 x_9$$

6. Statistical tests

Statistical tests must be run alongside the insurance modeling process. These tests are run to ensure that the optimal model will be chosen at conclusion of the process. Residual testing, goodness of fit and variable significance are things that need to be evaluated. The tests will be broken down into sections, starting with residual evaluation, then testing how good the model fits the data outputs, which includes measuring the significance of each risk loading variable.

6.1. Residuals

There are classical assumptions that must be met for the model to be the best available. Here the focus will be on two, one regarding serial correlation (autocorrelation) and one regarding variance.[3] First step when evaluating the residuals is to plot up the residuals to get a feel for how they behave. If the residuals seem correlated to each other, they might either be autocorrelated or heteroscedastic. When the residuals are plotted it is preferred that the residuals resemble white noise, which would give indications of a good regression fit of the model.

6.1.1. Durbin-Watson

The Durbin-Watson test is well suited to check the residuals of the model for serial correlation. The test checks if there exist a first-order serial correlation in the residuals. [4]

Equation 6.1: Durbin-Watson statistic

$$d = \frac{\sum_{2}^{T}\left(e_t - e_{t-1}\right)^2}{\sum_{1}^{T} e_t^2}$$

Where the Durbin-Watson statistic value is d and the residuals e from the GLM regression and T is the number of observations.

[3] For further information on the classical assumptions, see (Studenmund, 2011)
[4] For further information on the Durbin-Watson test see (Durbin & Watson, 1950)

After the d has been found, an upper value, d_U, and lower value, d_L, critical values of d are found from e.g. statistical tables (Studenmund, 2011).

If $d < d_L$ indicates that the residuals are likely autocorrelated.

If $d > d_U$ indicates that there is no autocorrelation.

If $d_L \geq d \leq d_U$ then the test is inconclusive.

6.1.2. White test

The White test tries to detect heteroscedasticity by running a regression with the squared residuals as the dependent variable. This test is generally thought of as the best test to check for heteroscedasticity, as it applies to all forms of heteroscedasticity (Studenmund, 2011). In his book "Using Econometrics: A PRACTICAL GUIDE" A.H. Studenmund suggests three steps when running the White test:

1. Calculate the residuals from the original estimated regression.
2. Use the squared residuals as the dependent variable, in a second equation that must include all previous explanatory variables from the original estimated regression. Additionally the equation must also include the squared values of the previous explanatory variables, as well as each variable multiplied with each other:

Equation 6.2: White's heteroscedasticity test

$$\varepsilon_i^2 = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{1i}^2 + \beta_4 X_{2i}^2 + \beta_5 X_{1i} X_{2i} + \upsilon_i$$

3. Finally test the overall significance of Equation 6.2 with a chi-square test, see section 6.2.4.

If the test results show heteroscedasticity, and the process of which explanatory variables should be included thought through, then some steps can be taken to fix for heteroscedasticity.[5]

6.2. Goodness of fit tests

Goodness of fit test shows how well the data fits the outputs of the regressed model. In other words it shows how far the data points are from the regression line; the closer they are to the line the better fit the model. Discussed below are some tests that are recommended to evaluate the level of suitability.

6.2.1. R-squared

R-squared (R^2) is probably one of the most commonly used measures of fit for a model. R^2 is the ratio of the explained sum of squares (ESS) to the total sum of squared (TSS). The higher R^2 is, the closer the estimated regressed equation fits the sample data being used ("Comparing fitted models using the SIC, HQIC or AIC information criteria," n.d.).

Equation 6.3: R-squared

$$R^2 = 1 - \frac{\sum e_i^2}{\sum \left(Y_i - \bar{Y}\right)^2} = \frac{ESS}{TSS}$$

R^2 must lie between the interval [0,1], where a value of 1 represents a perfect fit.

6.2.2. F-Test

Using a t-test to test a hypothesis for individual regression coefficients can be important, however it cannot be used to test multiple hypotheses simultaneously. That is where an F-test fits the purpose, as it can test a null hypothesis that contains many hypotheses or a single hypothesis on a group of coefficients (Studenmund, 2011). F-test places constraints or restrictions on an equation that is being tested. Using Equation 5.2, this would provide this hypothesis:

[5] For further information on remedies for heteroscedasticity, see (Studenmund, 2011).

$$H_0 : \beta_1 = \beta_2 = \ldots = \beta_9 = 0$$
$$H_1 : \text{ at least one coefficient is not equal to zero}$$

The null hypothesis assumes that all coefficients are equal to zero, suggesting that the mean value of y should be estimated with an ordinary sample mean. If the null hypothesis is rejected the data indicates that the mean value of y is not constant but varies in a way which is consistent with the model. The F-test will distinguish whether a constant mean or a variable mean best describes the variable y .[6]

6.2.3. Akaike information criterion

Akaike information criterion (AIC) is a statistical measure of fit, a method of comparing alternative specifications by adjusting the residual sum of squares (RSS) for a sample size and also the number of independent variables. AIC can therefore be used to measure if the improved fit caused by additional risk factors to the model is worth it, relative to increased complexity of the model with additional factors (Studenmund, 2011). There are other information criteria that could be used, such as Schwartz and Hannan-Quinn, however, the AIC is the least strict of the three, meaning it penalizes least degrees of freedom by having more parameters in the fitted model ("Comparing fitted models using the SIC, HQIC or AIC information criteria," n.d.).

Equation 6.4: Akaike information criterion

$$AIC = \left(\frac{2n}{n-k-1} \right) k - 2\ln\left[L_{\max} \right]$$

With n being number of observations, k number of parameters in the model and L_{MAX} the maximum value of the log-likelihood for the estimated model ("Comparing fitted models using the SIC, HQIC or AIC information criteria," n.d.) To use the information criterion one must estimate two alternative specifications for the model and then observe the AIC, or comparable information criterion, and the lower AIC of either is the better specification.

[6] For further information regarding F-test see (Studenmund, 2011)

6.2.4. Chi-Square

The chi-square test is a commonly used test, applicable to all distributions. The test deals with discrete data, contrary to the Kolmogorov-Smirnov test (Ross, 2006).The test is a way for analysts to evaluate whether a statistical model fits to some observed data. The computed test shows how close observed values are to expected (theoretical) values under some fitted distribution model with $\kappa - 1$ degrees of freedom.

Equation 6.5: Chi-Square test

$$X^2 = \sum \left(\frac{\left(\text{observed}_{data} - \text{expected}_{data}\right)^2}{\text{expected}_{data}} \right)$$

If the results of the chi-square goodness of fit test are large, it implies that the observed and expected values are not close and the model is an inappropriate fit to the observed data ("Chi-Square Goodness of Fit Test," n.d.).

6.2.5. The Kolmogorov-Smirnov

The Kolmogorov-Smirnov test (K-S) is a non-parametric test for continuous data and is used to test if a sample comes from a hypothesized continuous distribution. The K-S is based on the empirical cumulative distribution function (ECDF). Assuming a random sample $x_1, x_2, \dots, x_n$, and F_e is the ECDF defined as ("Goodness of Fit Tests," n.d.):

Equation 6.6: K-S expected CDF

$$F_e(x) = \frac{1}{n}\left[\#\ \text{of observations} \le x\right]$$

Meaning that F_e is the proportion of the observed values that are less than or equal to x (Ross, 2006). Given a null hypothesis, the test statistic for the K-S is as follows:

Equation 6.7: K-S test statistic

$$D \equiv \underset{x}{Max} \left| F_e(x) - F(x) \right|$$

H_0 : the data follows the specified distribution
H_1 : the data does not follow the specified distribution

If the test statistic (D) is greater than a critical value, obtained from a table depending on a pre-determined significance level, then the null hypothesis is rejected. [7] That would suggest that the data does not follow a specified distribution.

The K-S test has some limitations that make other tests more suitable for application, such as the Anderson-Darling test ("Kolmogorov-Smirnov Goodness-of-Fit Test," n.d.). It applies only to continuous data and is more sensitive near the center of the distribution, opposed to the tails. Distribution has to be fully specified. If the location, shape, and scale parameters are estimated from the data, which is typically done in simulation, the critical region of the K-S is no longer valid.

6.2.6. Anderson-Darling

The Anderson-Darling (A-D) is a more refined version of Kolmogorov-Smirnoff in testing the model for goodness of fit. It allows more weights in the tails of the distribution, the main body and the tails of the distribution get equal emphasis in the statistics ("Anderson-Darling (A-D) Statistic," n.d.)

The A-D statistic A_n^2 is defined as:

Equation 6.8: Anderson-Darling

$$A_n^2 = \int_{-\infty}^{\infty} \left| F_n(x) - F(x) \right|^2 \psi(x) f(x) dx$$

Where

$$\psi(x) = \frac{n}{F(x)\left(1 - F(x)\right)}$$

[7] For further information on significance table, see
http://www.cas.usf.edu/~cconnor/colima/Kolmogorov_Smirnov.htm

Where n is the number of data points, $F(x)$ the distribution function of the fitted distribution, $f(x)$ density function of the fitted distribution, $F_n(x)$ the empirical distribution function and $\psi(x)$ a weight function.

7. Premium pricing models

There are various models that insurance companies can choose from when pricing their insurance premiums. The models incorporating risk into the pricing of premiums in different ways. Here the focus is on the expected value premium principle to incorporate a risk loading factor into the pricing. Table 7.1 lists the various principles available.[8]

Table 7.1: Pricing models

Pricing models
Dutch premium
Esscher premium
Expected value premium
Exponential premium
Net premium
Principle of equivalent utility
Proportional hazards premium
Standard deviation premium
Swiss premium
Variance premium
Wang's premium

7.1. Expected value premium

The expected value premium principle, see Equation 7.1, builds upon the net premium principle, by incorporating a risk loading factor y, for $y > 0$. $H[X]$ depends on the cumulative distribution function of *X*, meaning that the premium of *X* will depend upon the property of the distribution and tail probability of *X*. *EX* is the expected payouts of the insurance contract in exchange for insuring the risk *X*. $H[X]$ is the premium excess of the expected payoff of the insurance (Young, 2004).

Equation 7.1: Expected value premium

$$H[X] = (1+y) * EX$$

If equation above is rearranged to get the premium of the contract, since $H[X]$ is the premium plus expected payout of contract, then premium [$\hat{p}$]:

[8] For further review on premium pricing principles see (Young, 2004)

Equation 7.2: Flat premium

$$\hat{p} = EX * \hat{y}$$

While the GLM will generate the risk loading factors that will ultimately form the variable $\hat{y}$ in the premium pricing formula, additional scaling variables must be implemented in Equation 7.1. The final equation for a premium pricing insurance is therefore:

Equation 7.3: Premium of ship insurance contract

$$p = MV \times C \times K \times \hat{y} \quad , \quad \hat{y} > 0$$

With MV, C and K being *market value of ship*, *coverage* and *cost* respectively.

7.2. Numerical example

Let us assume a contract with 100% coverage and the corresponding cost is equal to 30%, with the same ship Raven, as from example 2.11.1.1, valued at 178M ISK market value. The GLM will estimate multipliers for each risk factor and a value for the dependent variable. Standard deviation should be represented below each variable in brackets; since these numbers are hypothetical they are not presented.

$$\hat{y} = 0.9485 + 0.005x_1 + 0.008x_2 + 0.015x_3 + 0.03x_4 + 0.016x_5 + 0.0005x_6 + 0.005x_9$$

Now with these hypothetical inputs for an observed time period, see Table 7.2:

Table 7.2: Hypothetical regression inputs

Variable	Name	Inputs
x1	Character security status	15
x2	Character bounty price (scaled)	1
x3	Solar system traveled	10
x4	Number of ships lost	3
x5	Number of ships destroyed	7
x6	Corporation in war	1
x9	Ship group type	3

This generates $\hat{y} = 1.399$, this output is then used in Equation 7.3 giving the premium price, with above mentioned market value, coverage and cost:

$$p = 178\text{M ISK} \times 100\% \times 30\% \times 1.399 = 74,706,600 \text{ ISK}$$

From the previous example in section 2.11.1.1, where the premium for insuring a Raven cost around 53M ISK, now incorporating risk factors the price of the contract rises to around 75M ISK.

If the same comparison is done for the Golem, as seen in example 2.11.1.2, with a construction cost of 726M ISK (which is used as market value for illustrative purposes) the premium of insuring a Golem, with a 100% coverage and 30% cost, using the same inputs as the Raven above.

$$p = 726\text{M ISK} \times 100\% \times 30\% \times 1.399 = 304,810,917 \text{ ISK}$$

7.3. Payouts

The current insurance contract system in the game provides a payout of insurance claimed at the time of expiry. The payout price is dynamic, meaning that the payout is not set until contract is exercised (“INSURANCE,” n.d.). Premiums are fixed at time zero, however, the prices of the underlying materials fluctuate over time making the payout at exercise date uncertain. Therefore, the payout has a risk element that is not incorporated in the pricing of the premiums.

8. Other insurance schemes

For the past ten years the game has been evolving, new ships and modules have been introduced along with new tech levels. Because of this, new insurance schemes can be introduced into the game.

8.1. Module insurance

As mentioned in section 2.4.1 there are around 8,000 tradable goods in existence. Some of the modules are very expensive and players are likely willing to insure them. It can occur that the modules fitted onto a ship cost more than the ship itself. The calculation of these contracts would be very similar to the contracts on the ships. Risk factors would be the same; the more risky the character, higher premium should be paid. If a character wants to insure both ship and modules a relatively easy customization is performed onto the existing formula where the module insurance information is added into the calculations.

The same GLM output as in Equation 5.3 can be used as the risks involved will be connected to the ship being used to insure the module. It is assumed that the same theory will be applied to module insurance contracts, in respect to the contract being void, as with ship insurance contracts in EVE-Online.[9] If the module is removed from the ship, the contract will be void, as well as if the ship is repackaged. Characters will be able to see on their modules, fitted to ships, if they are in fact insured or not.

The module insurance would be an addition to the ship insurance, not a separate entity. In theory the calculations would be as follows:

Equation 8.1: Module insurance

$$\mathrm{Premium}_{\mathrm{ship+module}} = \left(\mathrm{MV}_{\mathrm{ship}} + \mathrm{MV}_{\mathrm{module}}\right) \times Coverage \times Cost \times \hat{y}$$

With $\hat{y}$ being the risk loading variable generated from the GLM.

[9] See http://wiki.eveonline.com/en/wiki/Insurance#Losing_insurance

8.2. Implant insurance

As mentioned in section 2.5, characters can have implants inserted in them to enhance certain attributes. These implants vary in value but the most sought after implants can be very expensive. If a character is killed when their pod is destroyed they lose all implants that they have in them. Because of that a new insurance scheme can be introduced, implant insurance. These calculations will be slightly different from those mentioned above. The risk factor that weighs most in implant insurance is the pod killings and the history of how often each character is shot down while flying a pod. Ship destruction plays a role as well but not as much as in the ships contract shown above. Character can lose a lot of ships but are able to get away in their pod unscathed.

In theory the model could look like this:

Equation 8.2: Implant regression

$$\text{Pods}_{\text{3M}}^{\text{lost}} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_6 x_6 + \varepsilon$$

Where the dependent variable is the number of pods lost over a 3 month period and the risk factors are similar to those mentioned in section 3.1 for x_1, x_2, x_3 and x_6, character security status, bounty on character, solar system visited and corporation in war or not, respectively. Other risk factors are not relevant when buying implant insurance.

8.3. Transportation Insurance

There exists a courier mission agreement under contracts in the game; however, it is not utilized by players because of the high risk to the character transporting the cargo. As the courier system is set up today the character that transports the goods has to pay high collateral to the owner of the goods. The owner usually sets the collateral higher than the total value of the goods in question, all the risk is therefore shifted to the transporter. If the transporter is attacked when moving the goods and loses the cargo, his collateral is forfeit and he loses his ship, while the owner of the goods retains the collateral.

Transportation insurance scheme could be introduced to attract players to use the courier part of the game. The system could be set up in a way that the character transporting the goods could buy insurance for the market value of delivered items. That in turn would ensure that the owner would be repaid the market value directly from the insurance company. The transporter would not have to put up collateral; he would buy an insurance contract that would cost a fraction of the collateral.

There are seven risk factors assumed to contribute most to the transportation insurance:

1. The route to the desired location, drop-off.
2. Security status of systems on route.
3. Ships lost over an observed period.
4. Ship type being used for transportation.
5. Value of cargo being transported.
6. Ship destruction on route in the past 24 hours, week, month etc.
7. Delivery time, 24 hours, week, month etc.

It is also important to note that some transportation will take more than one trip depending on the capacity of the ship being used to transport the goods. It is therefore important to multiply the number of trips to the risk factors mentioned above. One way to do so is to round up delivery package capacity divided with ship capacity to find out how often the transporter needs to take the same route.

Equation 8.3: Transportation insurance

$$\text{Premium}_{transportation} = \text{risk factors} \times \chi \times Cost$$

Where χ has to be an even number on the scale $\{1, \infty\}$:

$$\chi = \frac{\text{Delivery package capacity}}{\text{Ship capacity}}$$

If the χ is less than 1, and then the χ in Equation 8.3 is set to 1.

9. Next decade

Eve-Online reached its ten year anniversary in 2013. Over this first decade a lot of elements within the game have evolved, enriching the experience of its players. Introduction of new ships and modules alongside with new tech levels and enhanced gameplay has been the emphasis these first ten years. EVE-Online has potential to evolve even further by implementing exiting new sophisticated financial elements. New insurance schemes could be the first steps when introducing more financial elements into the economy. Next possible steps could take it even further with introduction of banks, stock, bond or forward/futures markets.

EVE-Online has potential to give academics what is needed when researching behavior patterns in financial decisions and test hypothetical scenarios that are hard to test in real life.

9.1. Implementation

The EVE-Online environment has been developing for a decade, with the current insurance system relatively unchanged. On the other hand players are familiar with the system and improving on the existing calculations will make the implementation of new insurance schematics easy. The implementation has to happen in stages, so not to disrupt both the utility of insurance for CCP, as well as enabling players to get acquainted with each new addition before installing a new one. This will ensure the familiarity and stability of the insurance system.

9.1.1. Groundwork

Before any further steps are taking on implementing what has been discussed in this thesis, it is important to address one fundamental risk factor that is already affecting the insurance system in EVE-Online. The stochastic price movements of underlying materials is the risk element that has not been included when pricing the insurance contracts, as fluctuations of those materials can either inflate or deflate the payout value at contract exercise. This situation could provide players with arbitrage opportunities if the volatility of price movements are high.

9.1.2. First stage

The important first step is to improve the current calculations and adding risk factors, generated from a character's playing behavior, into the premium calculations. The new system involves different premiums to be paid by each character in accordance with playing style. From the player's perspective, this new insurance system is not difficult to comprehend compared to the current insurance system.

Equation 7.3: Premium of ship insurance contract

$$p = MV \times C \times K \times \hat{y} \quad , \quad \hat{y} > 0$$

9.1.3. Second stage

The second insurance scheme recommended for introduction is the module insurance, where players can for the first time insure their modules. The modules insurance is an add-on onto the ship insurance system. Module calculations are added to the ship insurance formula to offer players to buy extra insurance on modules when insuring their ships. The scheme could be set up in a way that when a player removes a module from the ship, previously insured, he would forfeit his claim; however, the ship insurance will still be valid.

Equation 8.1: Module insurance

$$\mathrm{Premium}_{\mathrm{ship+module}} = \left(\mathrm{MV}_{\mathrm{ship}} + \mathrm{MV}_{\mathrm{module}}\right) \times Coverage \times Cost \times \hat{y}$$

9.1.4. Third stage

The third insurance scheme that can be implemented after the module insurance is transport insurance. A portion of players in EVE-Online are familiar with the courier missions available to them in the contract system. The product will make the courier missions a viable profession within the game, an added incentive for CCP to implement it.

10. Conclusion

The possibilities for the development of EVE-Online seem plenty from the researchers' point of view; this is naturally a result of CCP creating a great game that they've evolved at an even pace, with a thriving economy in a virtual setting. When researchers' ask themselves, will it be possible to implement a financial market into EVE-Online, and thereby further replicate a real world economy? Researchers think why not. What researchers have concluded is that implementing a financial market will require starting with the basic financial instrument insurance. New and improved ways to calculate insurance contracts is a good step to start the implementation process. These new calculation take into account risk factors that the old model did not, thus making it a more realistic for the players, as characters will have to pay different premiums depending on their characteristics, like in the real world. The research has shown that calculations of insurance, with additional risk factors, should be relatively easily implemented. CCP would be updating a system already in existence and not programming any new systems to the game. Steps that have been suggested above, with implementing in stages, should be in line with CCP's past improvements to the game.

Improved insurance, providing more practical payouts and incorporating character defining risk factors, should improve the frequency usage of the insurance market. Characters are able to insure more valuable ships and modules; this could in fact make the experience of the game even greater as characters might be more willing to take risk and thus taking part in other major entertainment aspect of EVE-Online.

When CCP has improved the insurance instruments, they have the possibility of open the door for player entry into the insurance market. With the required funding and financial backing, players should be able to run their own insurance company; given the necessary system programming is in place. This will enable CCP to gradually diminish their involvement in that particular market, and start focusing on new financial elements. Such as, banking, stock markets, forward markets to name a few. This will coincide with CCP's view of minimal involvement with the economy.

There are more aspects than just the entertainment value for characters. Future research value is tremendous, as with a fully functional financial market will open an avenue for researchers to test theory and behavior. Researchers would test a large sample population and receive instantly untainted data, where the results will not be affected by any reactive behavior by the test subjects.

EVE-Online recently celebrated its 10 year anniversary and has reached a player base of over 500,000 subscribers. The game has been constantly evolving, and it is the researchers' belief that improving the insurance market and focusing on implementing financial markets, in the future, is a good direction to take. Hopefully when looking back in 10 years, these suggestions would prove to have been beneficial in EVE-Online's further development.

Appendix I – Distributions

11. Distributions

The data used to price the premiums for the insurance contracts are not all normally distributed if any, and therefore a model had to be chosen that could incorporate different distributions. A generalized linear model (GLM) was deemed to fit the criteria for the regression. The distributions that are used to simulate the data for the regression are all different probability models, and will be discussed in more detail in sections 11.1 and 11.2.

11.1. Continuous distributions

In probability theory a distribution will be continuous when the random variable may take any value from negative infinity to positive infinity $-\infty \leq X \leq +\infty$. The following sections details the distributions that are continuous probability distributions.

11.1.1. Normal distribution

The normal distribution is the most recognizable and most used of all distributions. It has become the frame of reference for many probability problems that statisticians have faced in the past. The distribution is symmetrical and resembles a bell, hence the namesake bell shaped curve (Williams, n.d.).

The normal distribution describes response variable X that can take the value anywhere between $-\infty \leq X \leq \infty$, meaning that X can conceivable take on any value from minus infinity to plus infinity with probability greater than zero. 95% of all outcomes should lie between two standard deviations of the mean, in mathematical term: $P(\mu - 2\sigma \leq X \leq \mu + 2\sigma) = 95.44\%$

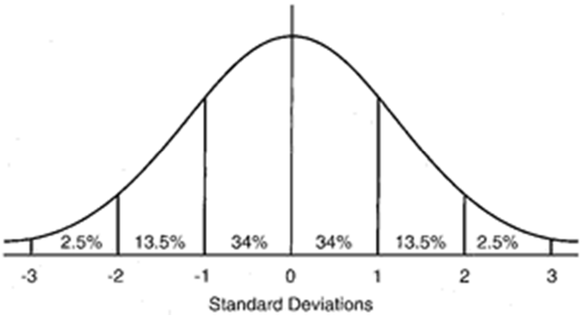


Figure 11.1: Normal distribution

A normal distribution might be able to properly represent some of the data being analyzed, to model insurance contract premiums; however other distributions are better representations for other types of data used.

11.1.2. Generalized extreme value

Generalized extreme value distribution, hereafter referred to as GEV, is part of the continuous probability distributions developed within extreme value theory to tie together three other extreme value distributions; Fréchet, Gumbel and Weibull. The GEV distribution is used as an approximation to model the max of long sequences of random variables (Embrechts, Klüppelberg, & Mikosch, 2011).

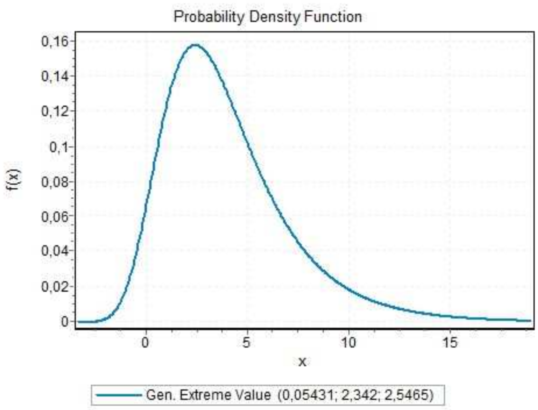


Figure 11.2: GEV distribution

The probability distribution function of GEV is calculated twofold; depending on the shape function, κ , being equal to zero or not:

Equation 11.1: GEV pdf

$$f(x)=\frac{1}{\sigma}a(x)^{\kappa+1}e^{-a(x)}$$

Where

$$a(x)=\begin{cases}\left(1+\left(\frac{x-\mu}{\sigma}\right)\kappa\right)^{-1/\kappa} & \text{if } \kappa\neq 0\\ e^{-(x-\mu)/\sigma} & \text{if } \kappa=0\end{cases}$$

With the cumulative distribution function:

Equation 11.2: GEV cdf

$$F(x)=e^{-a(x)}$$

The shape function within the GEV distribution controls the behavior of the distribution tail, however it also links the GEV to the three aforementioned extreme value distributions; when $\kappa>0$, $\kappa=0$, $\kappa<0$ corresponding to Fréchet, Gumbel, and Weibull respectively.

11.1.3. Gumbel Max

When working with extremes, Gumbel Max distribution is often used. It is very useful when modeling in hydrology, i.e. flooding predictions (Koutsoyiannis, 2004). Gumbel Max distribution, also known as type I distribution, has a location parameter μ and a scale parameter, σ, which are usually found with data fitting ("Extreme Value Max distribution," n.d.).[10]

[10] For more information about extreme values see (Embrechts, Klüppelberg, & Mikosch, 2011)

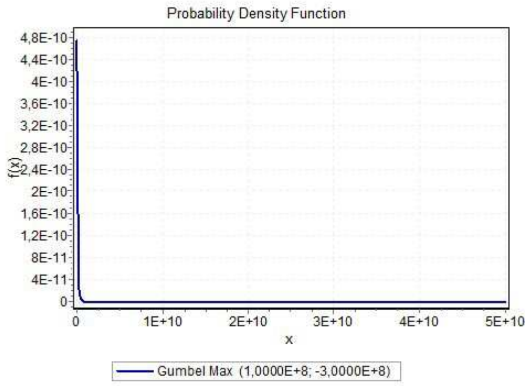


Figure 11.3: Gumbel Max distribution

The Gumbel max probability distribution function:

Equation 11.3: Gumbel Max pdf

$$f(s) = \frac{1}{\sigma}\exp\left(-z - \exp(-z)\right)$$

With the cumulative distribution function for the Gumbel max:

Equation 11.4: Gumbel Max cdf

$$F(x) = \exp\left(-\exp(-z)\right)$$

Where

$$z \equiv \frac{x-\mu}{\sigma}$$

11.1.4. Johnson SB

The Johnson SB distribution represents a bounded Johnson distribution with the following parameters for; location ξ, skewness γ, excess δ and scale λ, with two parameters being greater than zero $\gamma, \lambda > 0$.

The Johnson SB has been mainly used for estimating tree diameter distribution; it would seem that its low popularity stems from the relative difficulty in estimating the distribution parameters effectively (Siekierski, 1992). However, the distribution seems to be the best representation of one of the generated data string here used.

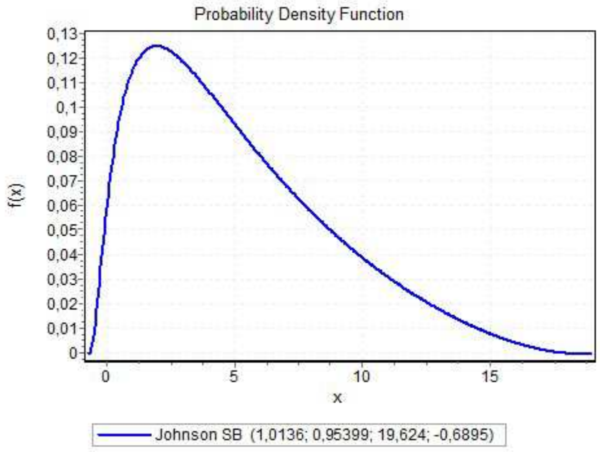


Figure 11.4: Johnson SB distribution

The Johnson SB probability distribution function:

Equation 11.5: Johnson SB pdf

$$f(x) = \frac{\delta}{\lambda\sqrt{2\pi}z(1-z)}\exp\left(-\frac{1}{2}\left(\gamma+\delta\ln\left(\frac{z}{1-z}\right)\right)^2\right)$$

Where

$$z \equiv \frac{x-\xi}{\lambda}$$

With the cumulative distribution function for the Johnson SB:

Equation 11.6: Johnson SB cdf

$$F(x) = \phi\left(\gamma+\delta\ln\left(\frac{z}{1-z}\right)\right)$$

With ϕ being the Laplace Integral (MathWave Technologies, n.d.):

Equation 11.7: Laplace Integral

$$\phi(x) = \frac{1}{\sqrt{2\pi}}\int_0^x e^{-t^2/2}dt$$

Researchers have received data from CCP, though not in time to evaluate and regress fully, however a comparison of distributions of generated data versus actual data of some factors is included below:

11.2. Discrete distributions

In probability theory a distribution will be discrete when the random variable may take any value from zero to positive infinity $0 \le X \le +\infty$. The following sections details the distributions that are discrete probability distributions.

11.2.1. Poisson

One type of distribution that will be used in the GLM is the Poisson distribution. When there is a response variable X that is in the form of a count, such as the number of times a certain event occurs over a given time period, e.g. how many ships a player loses over a three month period in the game, it is clear that all possible values range from zero to infinite and always a non-negative integer. Therefore, the response variable X possible values is denoted as such $\{X : 0,1,2,3,\ldots,n\}$, in theory the value of the response variable can be any non-negative integer and have no upper bound or limit.

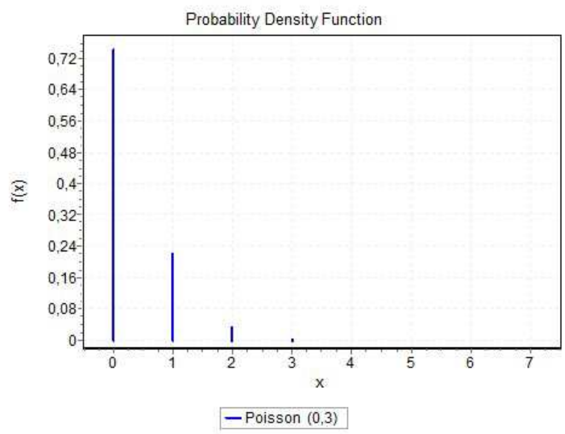


Figure 11.5: Poisson distribution

Figure 11.5 shows a Poisson distribution with a continuous event rate λ = 0.4. As can be seen a normally distributed model would be a useless approximation for data similar to this, therefore various types of distribution models must be considered. The advantage of the Poisson model is that the majority of events occur within a certain range and those events are always non-negative, unlike what a normally distributed model would express. What can also be seen is that event occurring more than, e.g. three times, is relatively uncommon and therefore the model shows that majority of events occur between zero and three times.

The Poisson probability distribution describes the probability that a random variable X takes the count of value in the range of zero to infinite, however the probability density function describes the probability that X takes on the value of x:

Equation 11.8: Poisson pdf

$$f(x) = P(X = x) = \frac{\mu^x e^{-\mu}}{x!} \quad , \; x=0,1,2,3,\ldots,\; \mu > 0$$

It can be shown that the mean and variance of X are both equal to μ .

As can be seen the average of all count values must be positive, therefore the mean of X will also be positive.

The variance of X or $\mathrm{var}(X) = \mu$, is a non-constant. Therefore, if X_1 and X_2 are both Poisson random variables, the only way that they can have the same variance is if they have the same mean (Davidian, n.d.).

11.2.2. Bernoulli

Another variety of distribution used is data that has only two values, yes or no, which will correspond to n = 1 or n = 0 respectively. An example would be data from EVE-Online on whether a player's corporation is currently involved in a war against another corporation. This declaration takes place with the corresponding requirements and both parties are therefore allowed to engage members of opposing corporation in space combat anywhere in the EVE universe without repercussions. This is a risk factor that has to be considered when pricing an insurance contract and if the data outputs are plotted there will be a string of binary data of 1s and 0s. A model that is only able to use the normal distribution is clearly a bad representation of the data. Therefore, a Bernoulli distribution comes into play.

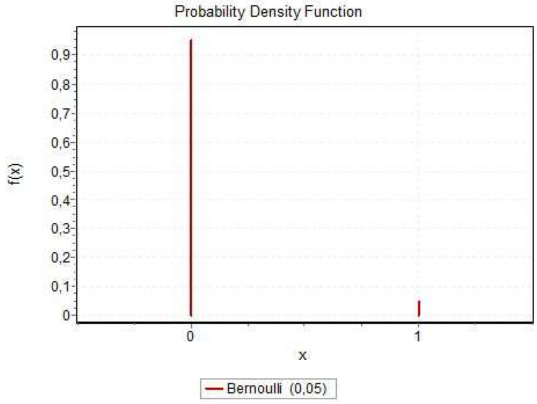


Figure 11.6: Bernoulli distribution

The distribution describes probabilities that a random variable X that describes whether an event, in the previous example, a declaration of war against another corporation, occurs or not. It can only take on two possible values (0,1), usually representing no or yes answers as can be seen in Figure 11.6. The probability density function is given by:

Equation 11.9: Bernoulli pdf

$$f(1) = P(X = 1) = \mu \ , \ f(0) = P(X = 0) = 1 - \mu$$
$$\text{for } 0 \le \mu \le 1$$

Since the extreme factors of μ = 0,1 are not very interesting outcomes, 0 < μ < 1 will be considered.

Equation 11.10: Bernoulli pdf 2

$$f(x) = P(X = x) = \mu^x (1-\mu)^{(1-x)} \ , 0 < \mu < 1 \ , x = (0,1)$$

It can be shown that the mean and variance of X are μ and $\mu(1-\mu)$ respectively.

The μ is also the probability of seeing the event (x = 1) and as a probability, it must be between 0 and 1, ergo the mean of X must lie between 0 and 1 as well.

While the variance of X is equal to $\operatorname{var}(X) = \mu(1-\mu)$, the variance of X is non-constant, therefore if X_1 and X_2 are both Bernoulli random variables, they can only have the same variance if they also have the same mean (Davidian, n.d.).

Appendix II – Data comparison

Real data was received during the final month of this thesis, and with work on hypothetical data finished; a decision was made to focus on the work already done and use real data for comparison. This was primarily decided as the data was not all usable, with the main deficiency that the sample was only on claimed insurance policies, not on expired contracts. New data was not requested as time constraints were the main concern at that point in time.

12. Data comparison

Data receive is used to compare with the generated hypothetical data, risk factors; character security status, character bounty prize, solar system visited, number of ships lost, number of ships destroyed, and corporation in war or not. The risk factors, insurance claimed and premiums paid, are not compared. Data was not received regarding ship group type, and is therefore not comparable.

12.1. Character security status [x1] comparison

Actual data received from CCP was rescaled in accordance with hypothetical data used, with 15 being equal to -5.0 and therefore bears the highest risk. As can be seen in Figure 12.1, the hypothetical data and actual data appear to be not similar. Another distribution has to be considered when working with the actual data from EVE-Online.

Figure 12.1: X1 data comparison

12.2. Character bounty prize [x2] comparison

As seen in Figure 12.2, the actual data and hypothetical data appear to be similar, even though character bounty prizes vary. This would suggest that the distribution for the hypothetical data can be used to represent the actual data from EVE-Online.

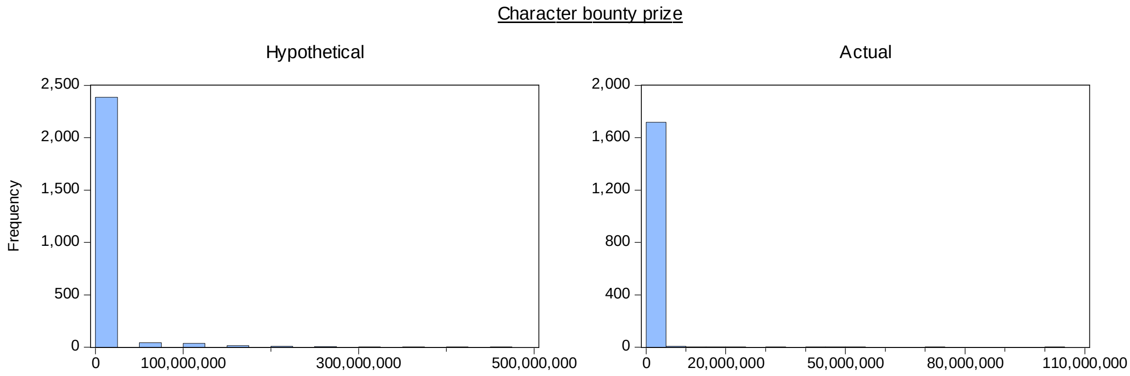


Figure 12.2: X2 data comparison

12.3. Solar system visited [x3] comparison

Solar system visited data received from CCP was rescaled in comparison with the data generated for the thesis. The highest number 10.0 represents 0.0 space, therefor being the most risky area. The data generated appears to be similar, to some degree, as can be seen in Figure 12.3. The distribution for the real data seems to have a higher peak, meaning a higher kurtosis, than the data generated for the thesis.

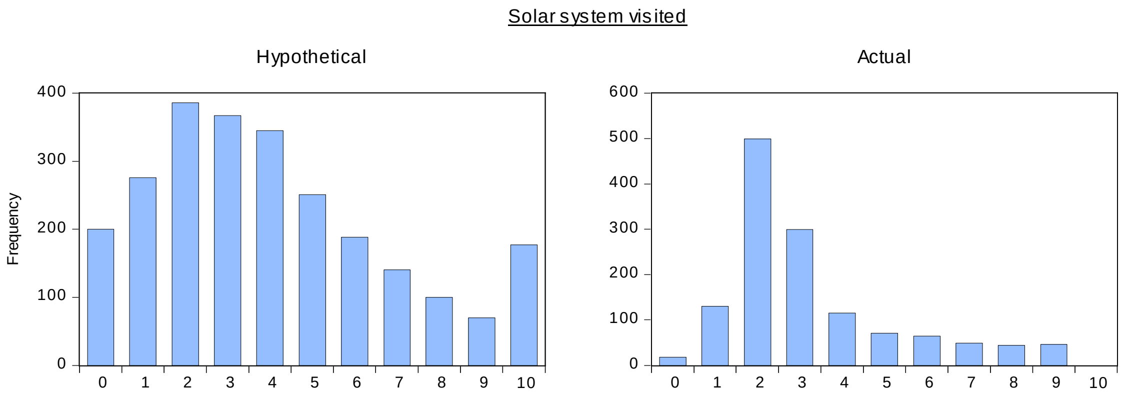


Figure 12.3: X3 data comparison

12.4. Number of ships lost [x4] comparison

Data generated for number of ships lost by a character appears to be correctly represented with a distribution that fits the actual data received. Figure 12.4 shows that actual and hypothetical data are close to identical.

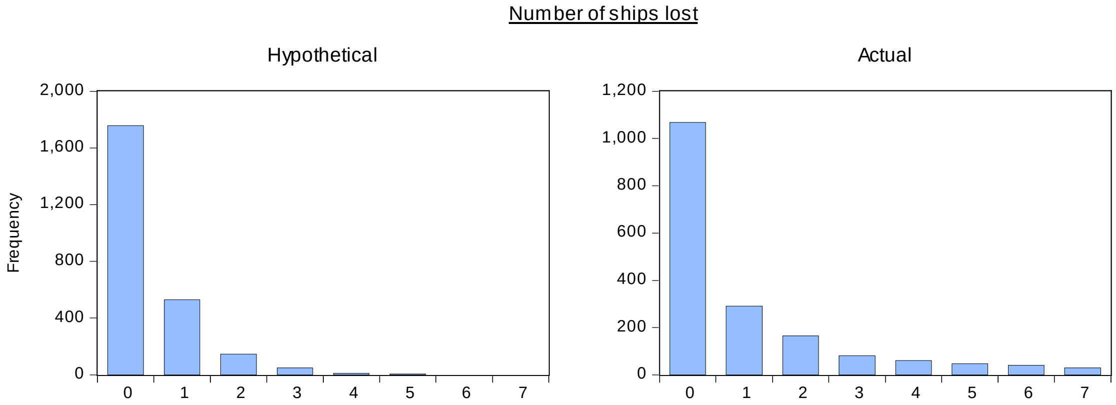


Figure 12.4: X4 data comparison

12.5. Number of ships destroyed [x5] comparison

The data generated for number of ships destroyed by a character appears to be similar to actual data received from CCP. The distribution for hypothetical data seen in Figure 12.5, can be used to represent actual data from the game, however, inputs will be different.

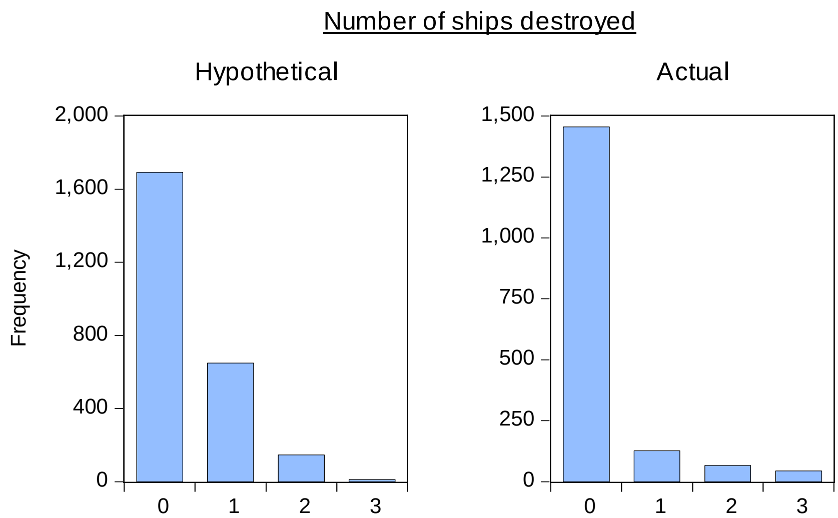


Figure 12.5: X5 data comparison

12.6. Corporation in war or not [x6] comparison

As Figure 12.6 shows the hypothetical and actual data appear to be similar, however, the number of wars in progress is greater than was expected. The distribution used for the hypothetical data can represent the actual data.

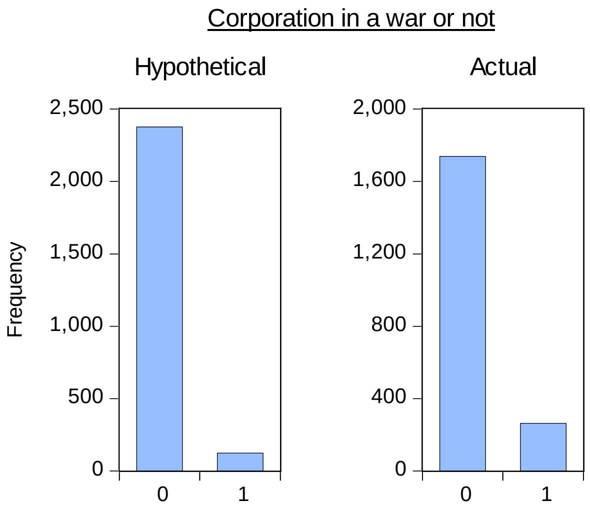


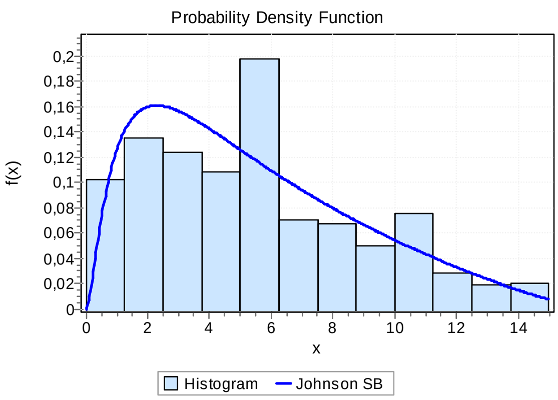
Figure 12.6: X6 data comparison

Appendix III – Data fitting results

13. Risk factors simulated

13.1. Character security status

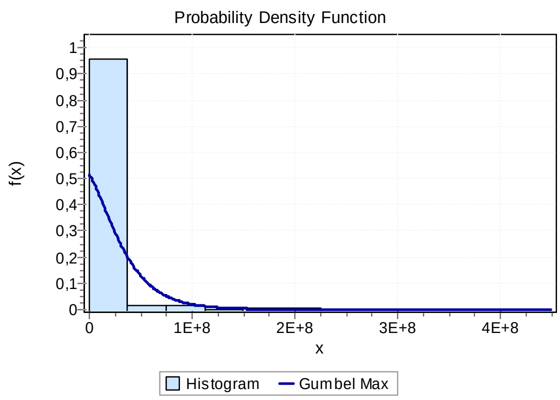
Table 13.1: X1 fitting results



Johnson SB	Continuous
Goodness of Fit	**Rank**
Kolmogorov Smirnov	1
Anderson Darling	1
Chi-Squared	2
Summary	
γ	0,85422
δ	0,89968
λ	17,128
ξ	0,04123

13.2. Character bounty prize

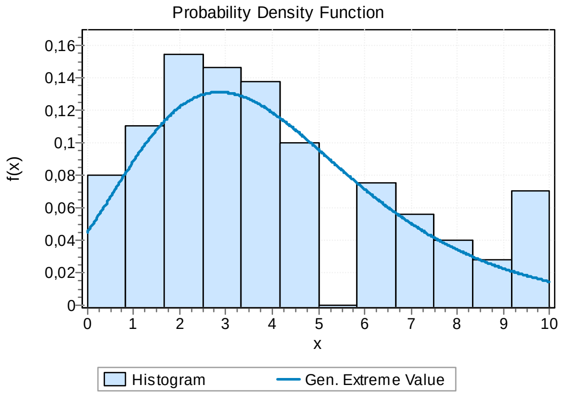
Table 13.2: X2 fitting results



Gumbel Max	Continuous
Goodness of Fit	**Rank**
Kolmogorov Smirnov	1
Anderson Darling	10
Chi-Squared	3
Summary	
σ	25.272.000,00
μ	-8.947.600,00

13.3. Solar system visited

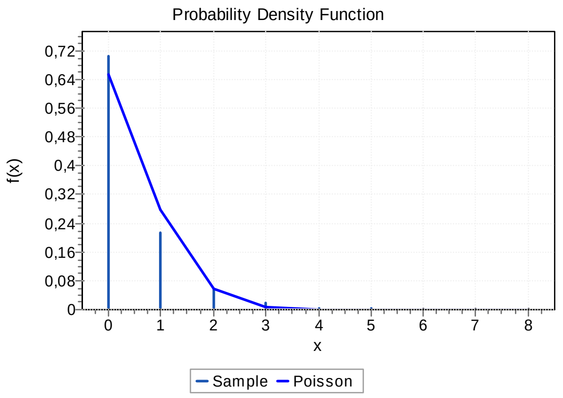
Table 13.3: X3 fitting results



Gen. Extreme Value	Continuous
Goodness of Fit	**Rank**
Kolmogorov Smirnov	1
Anderson Darling	1
Chi-Squared	11
Summary	
κ	-0,0362
σ	2,3331
μ	2,7705

13.4. Number of ships lost

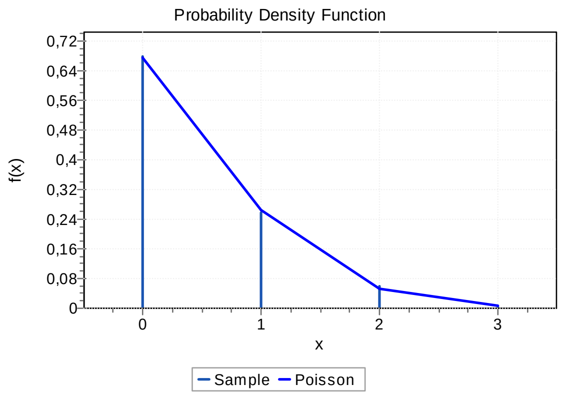
Table 13.4: X4 fitting results



Poisson	Discrete
Goodness of Fit	**Rank**
Kolmogorov Smirnov	1
Anderson Darling	1
Summary	
λ	0,4236

13.5. Number of ships destroyed

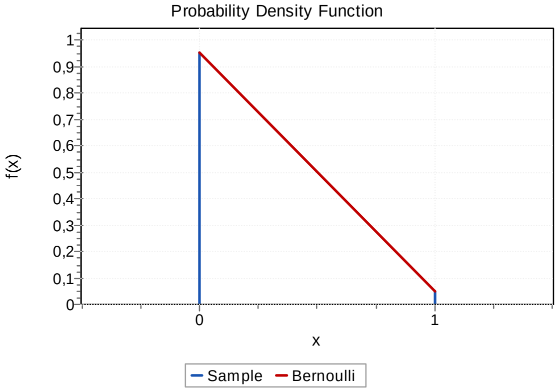
Table 13.5: X5 fitting results



Poisson	Discrete
Goodness of Fit	**Rank**
Kolmogorov Smirnov	3
Anderson Darling	2
Summary	
λ	0,3912

13.6. Corporation in war or not

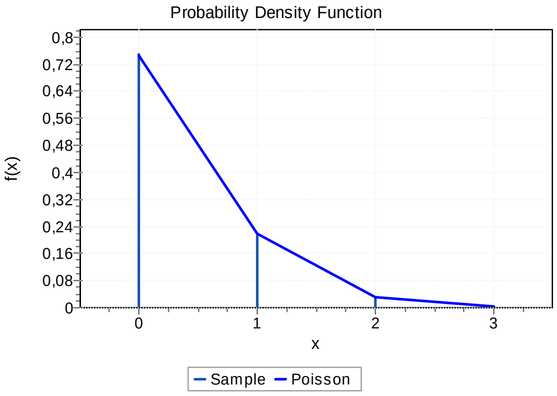
Table 13.6: X6 fitting results



Bernoulli	Discrete
Goodness of Fit	**Rank**
Kolmogorov Smirnov	1
Anderson Darling	3
Summary	
p	0,0492

13.7. Insurance claimed

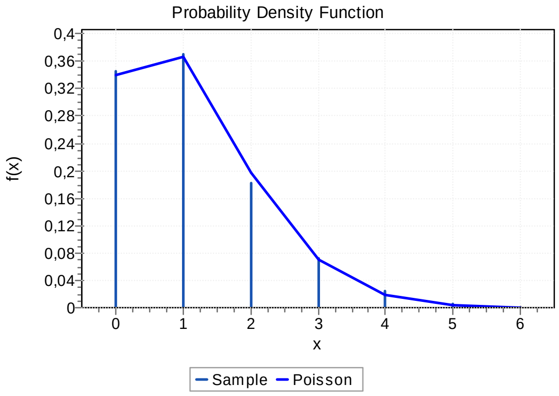
Table 13.7: X7 fitting results



Poisson	Discrete
Goodness of Fit	**Rank**
Kolmogorov Smirnov	2
Anderson Darling	2
Summary	
λ	0,2956

13.8. Premiums paid

Table 13.8: X8 fitting results



Poisson	Discrete
Goodness of Fit	**Rank**
Kolmogorov Smirnov	2
Anderson Darling	1
Summary	
λ	1,0784

Appendix IV – Further improvements

14. Future implementations

Here are possible further steps that can be taken if the thesis has been successfully implemented and the results are positive.

14.1. Implant insurance

A fourth insurance product to be implemented is an implant insurance scheme. Though there might not be a need for it at the moment, it may well be a welcome addition for players with great value installed into their characters, increasing the likelihood that they will be willing to risk their precious character into combat and other riskier situations. The implant insurance will provide increased entertainment value for some characters that need the safety net provided by insuring their clone, per se.

14.2. Forward thinking

The forward thinking would be to implement an environment for characters to start and run their own insurance companies, with the needed insurance funding and solvency issues. By adding the products available above and having the population familiarize themselves with the improved insurance system, CCP would provide an avenue for players to possibly run their own insurance company in the game and have a variety of products available for their clientele.

This would be the stage were CCP would be able to start gradually minimizing their involvement in the insurance market, given that players are successful at running privately owned insurance companies. This is in line with CCP's goal of minimal involvement with the economy, and by implementing the fifth stage they will have taken the first steps in creating a financial market in EVE-Online.

Bibliography

America, P. I. C. of. (2009). *The Documentary History of Insurance, 1000 B. C. - 1875 a. D.* Cornell University Library.

Anderson-Darling (A-D) Statistic. (n.d.). *VOSE SOFTWARE*. Retrieved April 21, 2013, from http://www.vosesoftware.com/ModelRiskHelp/index.htm#Analysing_and_using_data/Fitting_distributions/Comparing_fitted_models_using_the_SIC_HQIC_or_AIC_information_critereon.htm

APOCRYPHA. (2009, March 10). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/apocrypha/

Attributes in EVE. (n.d.). *EVE Online*. Retrieved February 27, 2013, from http://wiki.eveonline.com/en/wiki/Attributes_in_EVE

Ásgrímsson, Þ. (2013, November 1). CCP sameinar tvo leikjaheima. *mbl.is*. Retrieved March 7, 2013, from http://www.mbl.is/f/1724566/

Baker, T. (2002). Risk, insurance, and the social construction of responsibility. *Embracing risk: the changing culture of insurance and responsibility*, 33–51.

Baker, T., & McElrath, K. (1996). Whose Safety Net? Home Insurance and Inequality. *Law & Social Inquiry*, *21*(2), 229–264. doi:10.2307/828843

Baranoff, D. (2010, February 5). Fire Insurance in the United States. *EH.net*. Retrieved April 11, 2013, from http://eh.net/encyclopedia/article/baranoff.fire.final

CASTOR. (2003, December 18). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/castor/

CCP Punkturis. (2013, January 21). Team Super Friends runs some bounty numbers - EVE Community. *EVE Community*. Retrieved April 21, 2013, from http://community.eveonline.com/news/dev-blogs/team-super-friends-does-numbers/

Chi-Square Goodness of Fit Test. (n.d.). *yale.edu*. Retrieved April 16, 2013, from http://www.stat.yale.edu/Courses/1997-98/101/chigf.htm

Comparing fitted models using the SIC, HQIC or AIC information criteria. (n.d.). *VOSE SOFTWARE*. Retrieved April 16, 2013, from http://www.vosesoftware.com/ModelRiskHelp/index.htm#Analysing_and_using_data/Fitting_distributions/Comparing_fitted_models_using_the_SIC_HQIC_or_AIC_information_critereon.htm

CONCORD (MECHANICS). (n.d.). *EVE Online*. Retrieved February 28, 2013, from http://wiki.eveonline.com/en/wiki/CONCORD_(Mechanics)

CRUCIBLE. (2011, November 29). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/crucible/

Davidian, M. (n.d.). ST 732, Applied Longitudinal Data Analysis, Spring 2007. *NC STATE UNIVERSITY*. Retrieved April 3, 2013, from http://www.stat.ncsu.edu/people/davidian/courses/st732/

Distribution Fitting - What Parameter Estimation Methods Are Used in EasyFit? (n.d.). *mathwave*. Retrieved May 14, 2013, from http://www.mathwave.com/articles/distribution-fitting-methods.html

DRONES. (n.d.). *EVE Online*. Retrieved March 5, 2013, from http://wiki.eveonline.com/en/wiki/Drones

Dumitrescu, A. (n.d.). CCP Admits Failure of Incarna Expansion, Will Focus on Core Gamers. *SOFTPEDIA*. Retrieved March 3, 2013, from http://news.softpedia.com/news/CCP-Admits-Failure-of-Incarna-Expansion-Will-Focus-on-Core-Gamers-238512.shtml

Durbin, J., & Watson, G. S. (1950). Testing for Serial Correlation in Least Squares Regression: I. *Biometrika*, *37*(3/4), 409–428. doi:10.2307/2332391

Embrechts, P., Klüppelberg, C., & Mikosch, T. (2011). *Modelling Extremal Events: for Insurance and Finance* (Corrected.). Springer.

EVE ONLINE SURPASSES 500,000 SUBSCRIBERS WORLDWIDE. (2013, March 1). *CCP Games*. Retrieved March 1, 2013, from http://www.ccpgames.com/en/public-relations/press-releases/article/74405/eve-online-surpasses-500-000-subscribers-worldwide

EXODUS. (2004, November 17). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/exodus/

Extreme Value Max distribution. (n.d.). *VOSE SOFTWARE*. Retrieved April 10, 2013, from http://www.vosesoftware.com/ModelRiskHelp/index.htm#Distributions/Continuous_distributions/Extreme_Value_Max_distribution.htm

Financial Affairs Division. (2012). *Global Insurance Market Trends 2012* (Insurance) (p. 37). Paris: OECD. Retrieved from http://www.oecd.org/insurance/GlobalInsuranceMarketTrends2012.pdf

FIND YOUR PATH IN THE SANDBOX. (n.d.). *EVE Online*. Retrieved February 25, 2013, from http://www.eveonline.com/sandbox/

GLOSSARY. (n.d.). *EVE Online*. Retrieved April 30, 2013, from http://wiki.eveonline.com/en/wiki/Glossary

GOLEM BLUEPRINT. (n.d.). *EVE Online*. Retrieved February 27, 2013, from http://wiki.eveonline.com/en/wiki/Golem_Blueprint

Goodness of Fit Tests. (n.d.). *mathwave*. Retrieved April 21, 2013, from http://www.mathwave.com/articles/goodness_of_fit.html

Greene, W. H. (2003). *Econometric analysis / William H. Greene* (5th ed.). Upper Saddle River, NJ: Pearson Education.

Guðmundsson, E. (2012, December 12). First meeting.

Halldórsson, K. Þ. (2013, March 7). Data request meeting.

Holborn, H. (1982). *A History of Modern Germany, 1840-1945*. Princeton University Press.

IMPLANTS. (n.d.). *EVE Online*. Retrieved March 27, 2013, from http://wiki.eveonline.com/en/wiki/Implants

INCARNA. (2011, June 21). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/incarna/

INSURANCE. (n.d.). Retrieved February 28, 2013, from http://wiki.eveonline.com/en/wiki/Insurance

Jita Snapshot. (n.d.). *EVE-Central*. Retrieved February 10, 2013, from http://eve-central.com/

Kill Board. (n.d.). *BattleClinic*. Retrieved April 8, 2013, from http://eve.battleclinic.com/killboard/search.php

Klein, G. B. (2001, June 1). The Great Fire of London. *Risk & Insurance*. Retrieved April 11, 2013, from http://www.irmi.com/expert/articles/2001/klein06.aspx

Kolmogorov-Smirnov Goodness-of-Fit Test. (n.d.). *ENGINEERING STATISTICS HANDBOOK*. Retrieved April 21, 2013, from http://www.itl.nist.gov/div898/handbook/eda/section3/eda35g.htm

Koutsoyiannis, D. (2004). Statistics of extremes and estimation of extreme rainfall: I. Theoretical investigation/Statistiques de valeurs extrêmes et estimation de précipitations extrêmes: I. Recherche théorique. *Hydrological sciences journal*, *49*(4).

Lehtonen, T., & Liukko, J. (2011). The Forms and Limits of Insurance Solidarity. *Journal of Business Ethics*, *103*, 33–44. doi:http://dx.doi.org/10.1007/s10551-012-1221-x

loss ratio. (n.d.). *Risk & Insurance*. Retrieved April 23, 2013, from http://www.irmi.com/online/insurance-glossary/terms/l/loss-ratio.aspx

MathWave Technologies. (n.d.). *EasyFit*. Retrieved from http://www.mathwave.com/help/easyfit/html/appendix_a.html#std_normal_cdf

Ohlsson, E., & Johansson, B. (2010). *Non-Life Insurance Pricing with Generalized Linear Models* (2010th ed.). Springer.

One Universe, Limitless Potential. (n.d.). *EVE Online*. Retrieved February 25, 2013, from http://www.eveonline.com/universe/

ORE. (n.d.). *EVE Online*. Retrieved March 3, 2013, from http://wiki.eveonline.com/en/wiki/Item_Database:Manufacture_&_Research:Materials:Ore_&_Minerals_:Ore

OUR HISTORICAL TIMELINE. (n.d.). *CCP Games*. Retrieved February 25, 2013, from http://www.ccpgames.com/en/company/timeline

QUANTUM RISE. (2008, November 11). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/quantum-rise/

RAVEN BLUEPRINT. (n.d.). *EVE Online*. Retrieved February 27, 2013, from http://wiki.eveonline.com/en/wiki/Raven_Blueprint

RED MOON RISING. (2005, December 14). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/red-moon-rising/

RETRIBUTION. (2012, December 4). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/retribution/

RIGS. (n.d.). *EVE Online*. Retrieved March 5, 2013, from http://wiki.eveonline.com/en/wiki/Rigs

Ross, S. M. (2006). *Simulation, Fourth Edition* (4th ed.). Academic Press.

Rutherford, A. (2001). *Introducing Anova and Ancova: A GLM Approach*. SAGE.

SENTRY GUNS. (n.d.). *EVE Online*. Retrieved April 30, 2013, from http://wiki.eveonline.com/en/wiki/Sentry_guns

Siekierski, K. (1992). Comparison and Evaluation of Three Methods of Estimation of the Johnson Sb Distribution. *Biometrical Journal*, *34*(7), 879–895. doi:10.1002/bimj.4710340714

Studenmund, A. H. (2011). *Using econometrics : a practical guide / A. H. Studenmund* (6th ed.). Boston: Pearson.

SYSTEM SECURITY. (n.d.). *EVE Online*. Retrieved February 25, 2013, from http://wiki.eveonline.com/en/wiki/System_security

The European Union. (1992, June 18). Non-life insurance: third Directive. *Europa*. Retrieved April 11, 2013, from http://europa.eu/legislation_summaries/internal_market/single_market_services/financial_services_insurance/l24028b_en.htm

THE EVE EXPANSIONS. (n.d.). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/

TRINITY. (2007, December 12). *EVE Online*. Retrieved March 3, 2013, from http://www.eveonline.com/expansions/trinity/

Wagner, C. H. (1982). Simpson's Paradox in Real Life. *The American Statistician*, *36*(1), 46–48. doi:10.2307/2684093

Williams, R. (n.d.). Sociology Graduate Statistics I. *university of notre dame*. Retrieved March 20, 2013, from http://www3.nd.edu/~rwilliam/stats1/

Yoo, J.-H. (n.d.). INTRODUCING THE GENERALIZED LINEAR MODELS.

Young, V. R. (2004). Premium principles. *Encyclopedia of Actuarial Science*.

Yves YT Thiery, & Caroline CV Van Schoubroeck. (2006). Fairness and Equality in Insurance Classification*. *Geneva Papers on Risk & Insurance - Issues & Practice*, *31*(2), 190–211.