1. Introduction

Supply chain security and product quality assurance are essential concerns for business infrastructure in Industry 4.0. Supply chain security has been defined as “the application of policies, procedures, and technology to protect supply chain assets [...] from theft, damage, or terrorism” (Closs and McGarrell, 2004: 8), while product quality can be described as: “the assurance of quality of a product by means of a system which will manage quality and the product (Baines, et al., 2006: 91).

Simulated risk assessments are the standard method by which an organization can measure the likelihood of any category of risk (Olsen & Wu, 2017), as this method “allows users to apply whatever probability distributions exist in their particular applications” (Olsen & Wu, 2008: 653) to implement a fully-customized model for the projection of future risk (Chan & Chan, 2006).

It is thus the intent of this report to carry out a simulated risk assessment of supply chain security and product quality as applied to the organization Pampered Pets. Historical and objective data will first be reviewed and interpreted, followed by a simulated risk assessment. Results and conclusions from the simulation will be analysed and discussed, and applicable mitigation suggestions will be recommended. Finally, a disaster recovery plan will be outlined.

2. Quality and Safety Risks

Threats to maintaining product quality and supply chain safety can be separated into ‘Operational’ and ‘Hazardous’ taxonomies (*Table 1,* Bischof et al., 2009; Power, 2005; EEU, 2022; EM-DAT, 2021; Mitre, 2021). A historical disaster risk analysis and cyber vulnerability severity analysis of these risk categories are undertaken in sections 2.1 and 2.2 to provide context for the simulated risk assessment and mitigation selection in sections 3.1, 4.1, and 4.2.

Table 1: Operational & Hazardous Risks

Operational Risks		Hazardous Risks	
Technological	Cyber security	Climatological	Drought
Technological	Machinery		Wildfires
	Transport/distribution	Geophysical	Earthquakes
Product Quality	Regional standards	Hydrological	Floods
	Raw materials		Landslides
		Meteorological	Storms
			Extreme temperatures

2.1 Historical Disaster Risk

EM-DAT, an international disaster database (2021), provided historical data to calculate the proportion of disaster occurrence in key EU agricultural areas between 1980 and 2021 (*Table 2*). It should be noted data from the UK was not available. Proportion and probability statistics were used to calculate disaster occurrence (see Appendix I).

Table 2: Natural and Man-Made Disasters 1980-2021

Disaster Category	**Country**					
	France	Germany	Greece	Italy	Netherlands	Romania
Climatological	1.45%	0.09%	1.45%	1.03%	0.00%	0.17%
Geophysical	0.09%	0.17%	2.22%	2.22%	0.09%	0.26%
Hydrological	5.39%	1.88%	2.22%	4.62%	0.34%	4.36%
Meteorological	8.04%	5.90%	1.28%	2.99%	2.82%	2.48%
Technological[1]	5.22%	3.85%	4.02%	7.10%	1.37%	1.80%
Total % (Country)	**20.19%**	**11.89%**	**11.21%**	**17.96%**	**4.62%**	**9.07%**

Disaster Category	**Country**				
	Poland	Portugal	Spain	UK	**Total % (Category)**
Climatological	0.26%	1.54%	1.88%	N/A	**7.87%**
Geophysical	0.09%	0.00%	0.17%	N/A	**5.30%**
Hydrological	1.28%	0.94%	2.74%	N/A	**23.78%**
Meteorological	3.59%	1.37%	2.91%	N/A	**31.39%**

1. ‘Technological’ refers to industrial machinery, modes of transportation, etc. See section 2.2 for cyber threat analysis.

Technological	1.88%	1.28%	5.13%	N/A	**31.65%**
Total % (Country)	**7.10%**	**5.13%**	**12.83%**	**N/A**	**100.00%**

Probability of disaster occurrence/day: 8%

The following results were significant:

- Highest disaster occurrence by country: France (20.19%)
- Highest disaster occurrence by category: technological (31.65%)
- Probability of disaster occurrence on an individual day: 8%

2.2 Cyber Security Vulnerabilities

Mitre's CAPEC Supply Chain taxonomy (2021) provided objective data to determine which cyber vulnerabilities specific to the supply chain have the highest severity and likelihood of occurrence (Table 3). TOPSIS was used to calculate the total severity, as this method computes the normalized ranking of objective data (*Çelikbilek & Tüysüz, 2020*, see Appendix II) .

The following results were significant:

- Most frequent attack types: information disclosure, data tampering
- Attacks with the highest severity (Pi score): leveraging/manipulating configuration search file paths, WSDL scanning
- Top ten total attack surface (supply chain): 12.66%

Table 3: TOPSIS Pi Top Ten

Vulnerability	**STRIDE**	**Pi**	**Percentage**
Leveraging/Manipulating Configuration File Search Paths	T	1	1.27%
WSDL Scanning (var. 1)	I	0.91	1.27%
WSDL Scanning (var. 2)	I	0.83	1.27%
Directory Indexing (var. 1)	I	0.82	1.27%
Bluetooth Impersonation AttackS (BIAS)	S, E	0.82	1.27%
Repo Jacking	T, I	0.82	1.27%

Collect Data from Registries	I	0.76	1.27%
Collect Data from Screen Capture	I	0.76	1.27%
Metadata Spoofing	S	0.76	1.27%
Altered Component Firmware (var. 3)	T, E	0.73	1.27%
Total Attack Surface:			**12.66%**

3. Pampered Pets' Simulated Risk Assessment

For Pampered Pets, the Monte Carlo Simulation (MCS) model was chosen to perform the risk assessment, as MCS provides "sets of assumptions concerning the relationship among model components" (Olsen & Wu, 2017: 70) which "allows making literally any assumption" (ibid: 73) necessary for organizational risk compliance.

The following parameters to the equation were assigned (see Appendix III):

- A Normal Probability Distribution
- 8 risk factors chosen from Operational and Hazardous taxonomies
- 90% confidence intervals for risk factors

The following assumptions were made:

- Subjective probability weightings
- Breadth of risk factor categories utilized

3.1 Assessment Results

The following results were significant:

- Highest potential disruption cost: Cloud server breach (£2,458,486.01)
- Highest subjective risk probability: warehouse distribution – orders (66%)
- Highest quantitative risk probability: supply chain disruption – ingredients (7%)
- A Cloud server breach would comprise 91.3% of the total potential disruption cost

Table 4: Monte Carlo Simulation – Product Quality & Supply Chain Risk

Risk Category	Target	Impact ($)	Timeframe	Subjective Probability	Quantitative Probability
Cloud server breach	Inventory	£2,458,486.01	>24 months	20%	5%
Supply chain disruption	Ingredients	£54,470.46	<12 months	10%	7%
Warehouse disruption	Orders	£93,423.34	<12 months	66%	5%
Warehouse disruption	Machine failure	£362,304.74	<18 months	10%	1%
Cloud server breach	Supplier info	£95,763.21	>24 months	5%	4%
Warehouse disruption	Power outage	£122,324.88	< 24 months	3%	5%
Supply chain disruption	Flooding	£341,853.60	>36 months	7%	5%
Supply chain disruption	Drought	£231,815.70	>48 months	2%	4%

Avg. Subjective Probability	Avg. Quantitative Probability	Potential Disruption Cost
15.3%	4.45%	£2,693,846.51

Accordingly, the following can be inferred as essential components of product quality/supply chain security:

- Cloud server security
- Data integrity
- Order distribution assurance
- Quality ingredient assurance

These components will thus inform the focus of the risk mitigation suggestions in the following section.

4. Risk Mitigation

4.1 Natural and Man-Made Disaster Mitigation

MCS was performed to determine the optimal ratio for uninterrupted supply chain performance in the event of a natural or man-made disaster (see Appendix IV). The following assumptions have been applied:

- Main inventory/vendor locations are within the UK/EU
- The supply chain should have very little performance variance
- Alternate warehouse locations should ensure equivalent product quality

Table 5: Pampered Pets Inventory Simulation - Policies

Policy	Reorder Point	Order Quantity	Parameters for MCS Simulation	
1	5000	8000	Mean Unit Demand	4500
2	4000	8000	Fixed Order Cost	£50
3	5500	100	Unit Cost	£1
4	6000	9100	Sales Price	£5
5	800	300	Holding Cost	£1
6	6000	400	Salvage Value	£3
7	500	500		

Table 6: Monte Carlo Simulation – Inventory

Policy	Mean Profit	Sales Revenue	Order Cost	Holding Cost	Out-of-Stock
1	£230,075.88	£432,268	£104, 650	£108,015	0%
2	£230,599.23	£536,030	£104,650	£84,496	8%
3	£230,960.33	£57,000	£3,600	£4,957	92%
4	£**231,867.46**	£**540,335**	£**109,800**	£**178,415**	**0%**
5	£230,749.71	£78,500	£8,050	£4,857	92%
6	£230,837.02	£73,200	£10,800	£5,257	92%
7	£230,506.15	£100,500	£12,650	£4857	92%

Policy	Risk of Loss	Overall Rating
4	0%	Best
2	33%	Middle
3	200%	Worst

Policy 4, with a reorder point of 6000 and a order quantity of 9100, had the following optimal characteristics:

- Highest mean profit: £231,867.46
- Lowest Out-Of-Stock rating: 0%
- Lowest Risk of Loss rating: 0%

Thus this policy would perform most adequately in the event a warehouse source is lost and production were required to increase at a second location.

Table 7: SMART Calculation – Supplier by Country

Supplier Country	Crop Output (€M)	Crop Price	Animal Output (€M)	Animal Price
France	**€47,973.66**	**€128.30**	**€26,847.40**	**€112.80**
Germany	€29,698.62	€129.30	€25,917.59	€116.50
Greece	€8,725.22	€156.10	€2,455.55	€125.80
Italy	**€34,283.10**	**€124.30**	**€16,353.91**	**€113.70**
Netherlands	€15,671.56	€118.70	€10,954.00	€113.50
Poland	€13,620.87	€131.10	€13,584.02	€117.20
Portugal	€6,072.62	€126.60	€3,053.82	€115.20
Romania	€15,028.32	€334.50	€4,245.42	€287.30
Spain	**€34,999.84**	**€121.40**	**€20,478.57**	**€116.10**
UK	€9,803.06	€164.40	€16,574.00	€150.10

Supplier Country	Organic Crops (tonne)	Organic Livestock (head)	Disaster Rate	SMART Score
France	**692,243.00**	**860,308.00**	**20.19%**	**75.49**
Germany	0.00	861,272.00	11.89%	63.25
Greece	152,118.00	163,066.00	11.21%	35.00
Italy	**968,425.00**	**397,187.00**	**17.96%**	**71.18**
Netherlands	19,591.00	76,069.00	4.62%	55.24
Poland	315,269.00	31,102.00	7.10%	46.70
Portugal	0.00	92,673.00	5.13%	41.83
Romania	229,794.00	19,870.00	9.07%	23.16
Spain	**382,153.00**	**219,769.00**	**12.83%**	**62.31**
UK	129,297.00	300,788.00	N/A	28.50

Rank	Country	SMART Rating
1	France	75.49
2	Italy	71.18
3	Spain	62.31

A SMART analysis (see Appendix IV) was conducted on the agriculture industry of ten key EU states with a data combination of Eurostat's (2022) and the historical disaster rate calculated in section 2.1 to determine an optimal second location (Table 7). Significant desirability factors include:

- High count of organic crops (Italy: 968,425) and livestock (France: 860,308)
- High crop and animal output (France: €47,973.66, €26,847.40)
- Low crop (Spain: €121.40) and animal (France: €112.8) prices

It should be noted, however, that these countries showed higher rates of disaster occurrence. Still, given the geographical distance between these locations and the main Pampered Pets' warehouse, these should serve well to diversify the supply chain area to reduce risk.

4.2 Cyber Security Risk Mitigations

Cyber security mitigations are more technical in nature, involving recommendations from the CAPEC ATT&CK taxonomy (Mitre, 2021). Relevant attack categories and proposed mitigations are listed in Table 8.

Table 8: CAPEC Mitigation Recommendations

Attack Category	Mitigation recommendations
Excavation	• Reduce error/response, only necessary warnings • Remove all non-essential information
Hardware Integrity Attack	• No unauthorized access to the system
Malicious Logic Insertion	• Use Anti-Virus software to detect/isolate viruses • Cease operation of compromised applications
Manipulation During Distribution	• Cross-check all vendor shipping sources • Tamper-evident packaging

Metadata Spoofing	• Validate authors, timestamps, statistics • Authenticate open-source code/products • Leverage automated testing techniques
Modification During Manufacture	• Ensure the authenticity of digital certificates • Buy hardware only from trusted vendors • Implement configuration management security practices
Resource Location Spoofing	• Monitor application activity log for unauthorized use
Software Integrity Attack	• Validate software updates before installation • Implement DAWG and KPTI • Disable ‘Copy-on-Write’ between Cloud VMs

4. Disaster Recovery

Disaster recovery (DR) in the event of a natural disaster or security breach can allow a business to “[replicate an] application state between two data centres; if the primary data centre becomes unavailable, then the backup site can takeover” (Cecchet et al., 2010: 1). There are a number of benefits with and repercussions without the implementation of a DR plan (Table 9).

Table 9: DR Benefits & Repercussions

Benefits With	Repercussions Without
GDPR Compliance	GDPR non-compliance
Continued operation	Loss of sales/revenue
Fast resumption of service	Regulation penalties
Lowered Cost and hazard risk	Loss of contract/penalties
Increase in trustworthiness	Loss of trustworthiness

Given the specification of <1 minute RTO and <1 minute RPO, the use of VMWare to consolidate virtual data (Figure 1) is recommended in coordination with Amazon’s AWS and Pampered Pets’ current local system (Figure 2). Table 10 demonstrates the reasoning behind this recommendation (VMWare, n.d.a; Amazon, n.d.a).

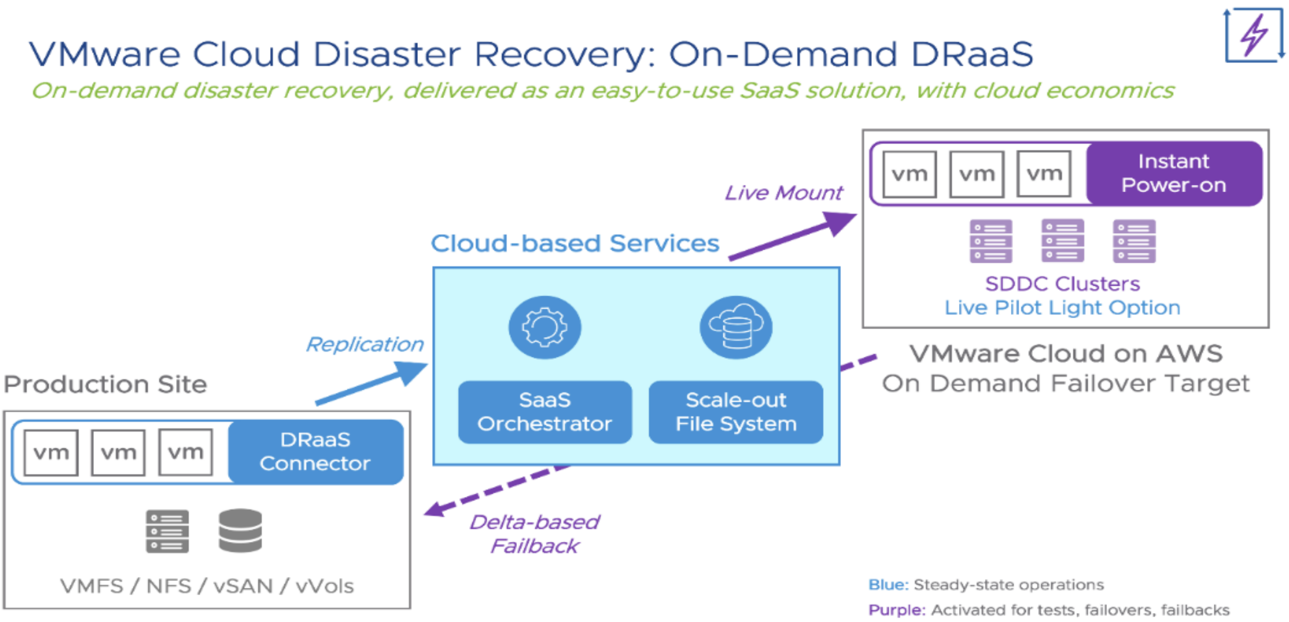

Figure 1: VMWare Cloud Recovery Scheme (VMWare, n.d.b.)

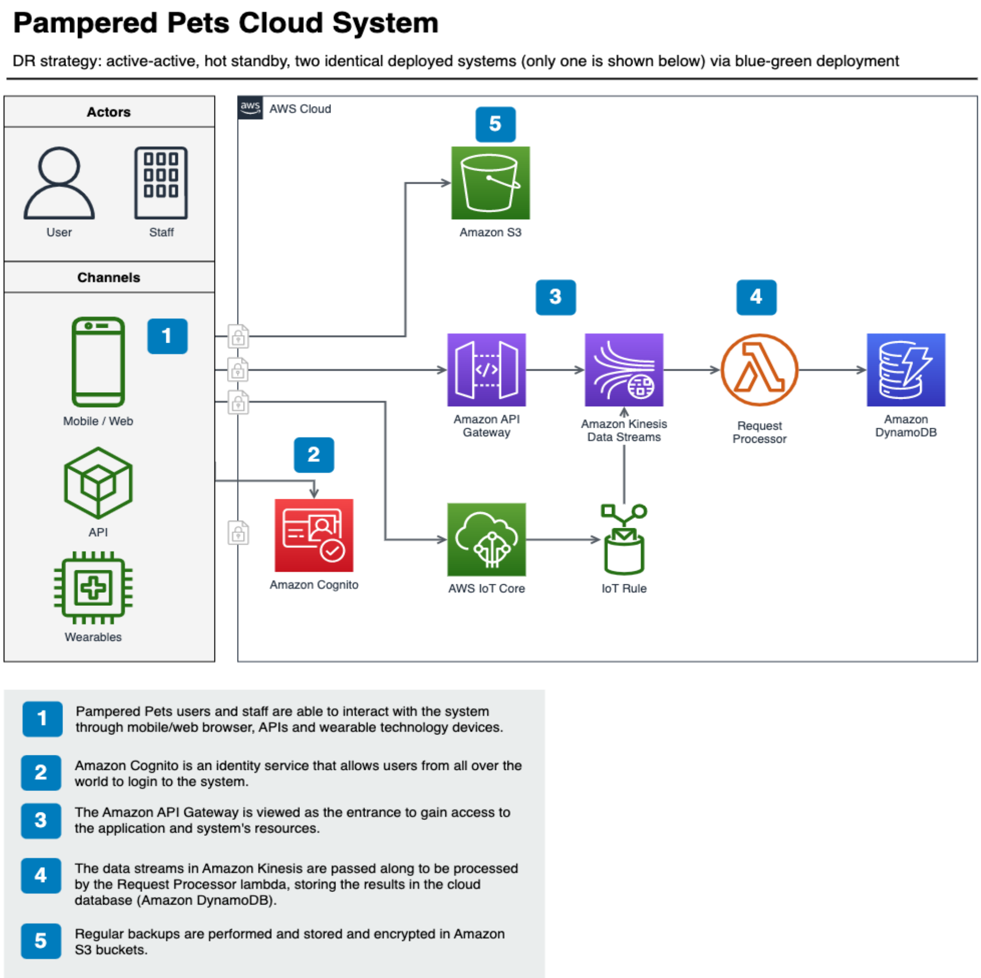

Figure 2: Pampered Pets' AWS/Cloud Structure

Table 10: Benefits of VMWare & Amazon AWS Utilization

VMWare	Amazon AWS
Virtual Machine creation	Cross-Cloud service with VMWare
Local and Cloud storage options	Cognito ID service
Less Bandwidth/electricity use	API Gateway
Lowered IT costs	Kinesis data streams
Instant company asset replication	Dynamo DB cloud database
Snapshot recovery	S3 bucket storage and encryption
Active-Active/Hot-Standby capability	Active-Active/Hot-Standby capability

Having an Active-Active/Hot-Standby server will allow a <1 minute recovery for both RTO and RPO. In addition, VMWare implements a detailed data protection lifecycle (*Figure 3*), along with three key areas of GDPR compliance (*Figure 4*). This combination satisfies several GDPR requirements of organization supply chain management (GDPR, 2018, VMWare, 2017).

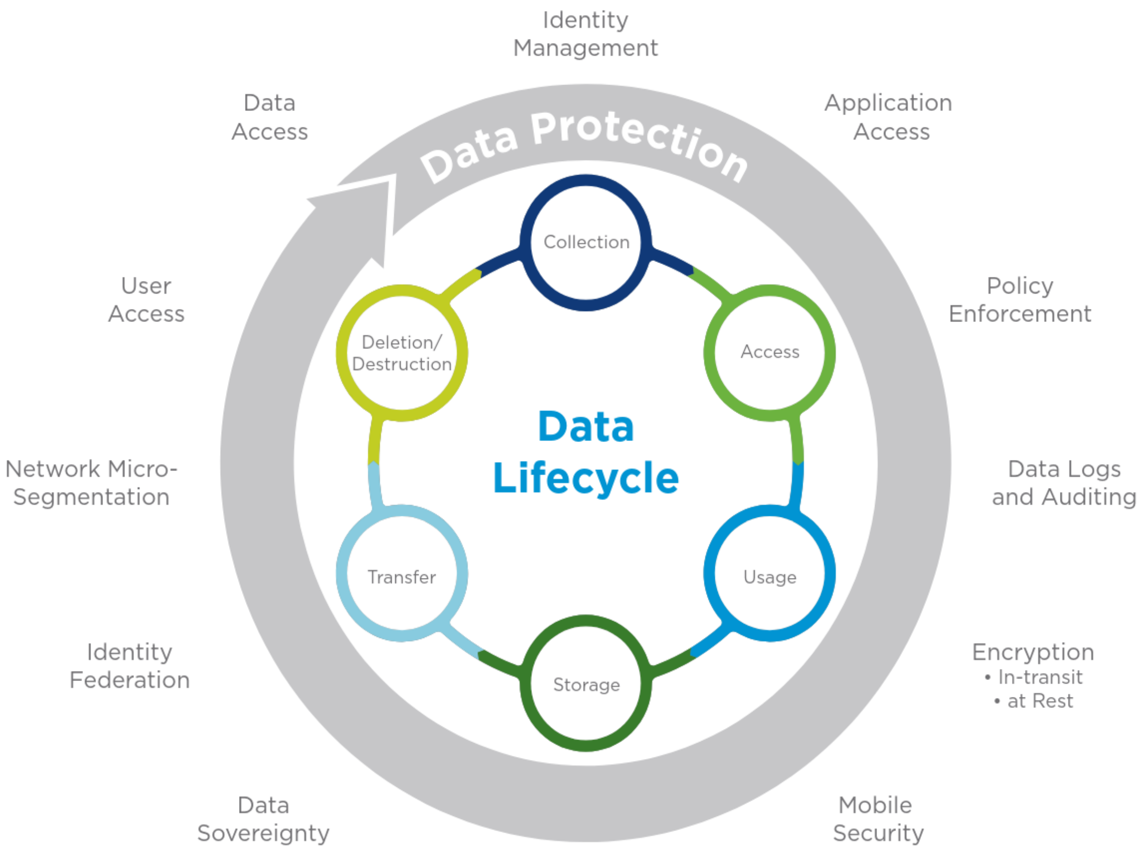

Figure 3: GDPR Compliant Data Lifecycle (VMWare, 2017)

Figure 4: GDPR Compliance -- 3 Key Areas (VMWare, 2017)

Amazon AWS utilizes a similar compliance program (Table 11), which enables a comprehensive security scheme compatible with diverse needs (AWS, 2022). It should be noted that AWS employs a “shared responsibility security model,” (AWS, 2022: 3) which requires customers to set many data privacy settings independently, is thus dependent on end-user settings and must be cross-examined to be fully GDPR compliant (GDPR, 2018, AWS, 2022).

Table 11: Amazon AWS GDPR Compliance

AWS Compliance Framework	
The CISPE code of conduct	Custom permissions settings
Data access controls	Custom boundaries for regional service access
Identity & access management	Application access controls
Temporary tokens (AWS STS)	Application monitoring and logging
Multi-factor authentication	Data encryption

5. End Summary

Supply chain safety and product quality are essential aspects of risk management. In this report, a simulated risk assessment performed on Pampered Pets found elevated levels of risk concerning Cloud server security, data integrity, order distribution assurance, and quality ingredient assurance. Relevant mitigation suggestions, including optimal order/restock ratios and alternative warehouse locations, were discussed. In addition, a Disaster Recovery plan with <1 minute RTO and RPO was outlined along with relevant GDPR compliance.

6. Appendices

6.1. Appendix I

To find the proportion and probability of the disaster data, the following steps were performed:

1. Isolate and index each country dataset (Figure 5)

2. Sum the various categories of disaster by subtype and country using =COUNTIF (Figures 6 & 7)

3. Sum the subcategories into main categories by country (Figures 8 & 9).

4. Calculate the disaster proportion by country using P=C/T, if P = proportion, C = disaster category, T = total disasters (Figures 10 & 11).

	B	E	F	G	H	K	L	M	N	AR	AS
1	EM-DAT, CRED / UCLouvain,										
2	www.emdat.be										
3	2022-12-02										
4	Fri, 02 Dec 2022 05:56:33 C										
5	Custom request										
6	2345										
7	Year	Disaster Group	Disaster Subgroup	Disaster Type	Disaster Subtype	Country	ISO	Region	Continent	Total Damages ('000 US$)	Total Damages, Adjusted ('000 US
8	1982	Natural	Climatological	Drought	Drought	France	FRA	Western Europe	Europe	0	0
9	1989	Natural	Climatological	Drought	Drought	France	FRA	Western Europe	Europe	1600000	3497323
10	1991	Natural	Climatological	Drought	Drought	France	FRA	Western Europe	Europe	0	0
11	1997	Natural	Climatological	Drought	Drought	France	FRA	Western Europe	Europe	10000	16881
12	2022	Natural	Climatological	Drought	Drought	France	FRA	Western Europe	Europe	0	0
13	2019	Natural	Geophysical	Earthquake	Ground movement	France	FRA	Western Europe	Europe	0	0
14	1985	Natural	Meteorological	Extreme temperature	Cold wave	France	FRA	Western Europe	Europe	0	0
15	1990	Natural	Meteorological	Extreme temperature	Heat wave	France	FRA	Western Europe	Europe	0	0
16	1991	Natural	Meteorological	Extreme temperature	Cold wave	France	FRA	Western Europe	Europe	0	0
17	1991	Natural	Meteorological	Extreme temperature	Cold wave	France	FRA	Western Europe	Europe	772000	1535987
18	1997	Natural	Meteorological	Extreme temperature	Cold wave	France	FRA	Western Europe	Europe	0	0
19	2003	Natural	Meteorological	Extreme temperature	Heat wave	France	FRA	Western Europe	Europe	4400000	6481178
20	2005	Natural	Meteorological	Extreme temperature	Cold wave	France	FRA	Western Europe	Europe	0	0
21	2005	Natural	Meteorological	Extreme temperature	Severe winter conditions	France	FRA	Western Europe	Europe	0	0
22	2006	Natural	Meteorological	Extreme temperature	Heat wave	France	FRA	Western Europe	Europe	0	0
23	2008	Natural	Meteorological	Extreme temperature	Cold wave	France	FRA	Western Europe	Europe	0	0
24	2009	Natural	Meteorological	Extreme temperature	Severe winter conditions	France	FRA	Western Europe	Europe	0	0

Figure 5: EM-DAT Country Data

	France	Germany	Greece	Italy		Netherlands
Drought	=COUNTIF($G$8:$G$243, "Drought")	=COUNTIF($G$244:$G$382, "Drought")	=COUNTIF($G$383:$G$513, "Drought")	=COUNTIF($G$514:$G$724, "Drought")		=COUNTIF($G$726:$G$779, "Drought")
Earthquake	=COUNTIF($G$8:$G$243, "Earthquake")	=COUNTIF($G$244:$G$382, "Earthquake")	=COUNTIF($G$383:$G$513, "Earthquake")	=COUNTIF($G$514:$G$724, "Earthquake")		=COUNTIF($G$726:$G$779, "Earthquake")
Extreme Temperature	=COUNTIF($G$8:$G$243, "Extreme temperature")	=COUNTIF($G$244:$G$382, "Extreme temperature")	=COUNTIF($G$383:$G$513, "Extreme temperature")	=COUNTIF($G$514:$G$724, "Extreme temperature")		=COUNTIF($G$726:$G$779, "Extreme temperature")
Flood	=COUNTIF($G$8:$G$243, "flood")	=COUNTIF($G$244:$G$382, "flood")	=COUNTIF($G$383:$G$513, "flood")	=COUNTIF($G$514:$G$724, "flood")		=COUNTIF($G$726:$G$779, "flood")
Landslide	=COUNTIF($G$8:$G$243, "landslide")	=COUNTIF($G$244:$G$382, "landslide")	=COUNTIF($G$383:$G$513, "landslide")	=COUNTIF($G$514:$G$724, "landslide")		=COUNTIF($G$726:$G$779, "landslide")
Industrial Accident	=COUNTIF($G$8:$G$243, "industrial accident")	=COUNTIF($G$244:$G$382, "industrial accident")	=COUNTIF($G$383:$G$513, "industrial accident")	=COUNTIF($G$514:$G$724, "industrial accident")		=COUNTIF($G$726:$G$779, "industrial accident")
Transport Accident	=COUNTIF($G$8:$G$243, "transport accident")	=COUNTIF($G$244:$G$382, "transport accident")	=COUNTIF($G$383:$G$513, "transport accident")	=COUNTIF($G$514:$G$724, "transport accident")		=COUNTIF($G$726:$G$779, "transport accident")
Storm	=COUNTIF($G$8:$G$243, "storm")	=COUNTIF($G$244:$G$382, "storm")	=COUNTIF($G$383:$G$513, "storm")	=COUNTIF($G$514:$G$724, "storm")		=COUNTIF($G$726:$G$779, "storm")
Wildfire	=COUNTIF($G$8:$G$243, "wildfire")	=COUNTIF($G$244:$G$382, "wildfire")	=COUNTIF($G$383:$G$513, "wildfire")	=COUNTIF($G$514:$G$724, "wildfire")		=COUNTIF($G$726:$G$779, "wildfire")
Miscellaneous accident	###	###	###	###		###
Total Damage	=SUM($AR$8:$AR$243)	=SUM($AR$244:$AR$382)	=SUM($AR$383:$AR$513)	=SUM($AR$514:$AR$724)		=SUM($AR$726:$AR$779)
Total Damage Adjusted	=SUM($AS$8:$AS$243)	=SUM($AS$244:$AS$382)	=SUM($AS$383:$AS$513)	=SUM($AS$514:$AS$724)		=SUM($AS$726:$AS$779)
	Romania	Poland	Portugal	Spain	UK	Total:
Drought	=COUNTIF($G$923:$G$1028, "Drought")	=COUNTIF($G$780:$G$862, "Drought")	=COUNTIF($G$863:$G$922, "Drought")	=COUNTIF($G$1029:$G$1178, "Drought")	=0	=SUM(BD$8:BN$8)
Earthquake	=COUNTIF($G$923:$G$1028, "Earthquake")	=COUNTIF($G$780:$G$862, "Earthquake")	=COUNTIF($G$863:$G$922, "Earthquake")	=COUNTIF($G$1029:$G$1178, "Earthquake")	=0	=SUM(BD$9:BN$9)
Extreme Temperature	###	=COUNTIF($G$780:$G$862, "Extreme temperature")	=COUNTIF($G$863:$G$922, "Extreme temperature")	###	=0	=SUM(BD$10:BN$10)
Flood	=COUNTIF($G$923:$G$1028, "flood")	=COUNTIF($G$780:$G$862, "flood")	=COUNTIF($G$863:$G$922, "flood")	=COUNTIF($G$1029:$G$1178, "flood")	=0	=SUM(BD$11:BN$11)
Landslide	=COUNTIF($G$923:$G$1028, "landslide")	=COUNTIF($G$780:$G$862, "landslide")	=COUNTIF($G$863:$G$922, "landslide")	=COUNTIF($G$1029:$G$1178, "landslide")	=0	=SUM(BD$12:BN$12)
Industrial Accident	=COUNTIF($G$923:$G$1028, "industrial accident")	=COUNTIF($G$780:$G$862, "industrial accident")	=COUNTIF($G$863:$G$922, "industrial accident")	=COUNTIF($G$1029:$G$1178, "industrial accident")	=0	=SUM(BD$13:BN$13)
Transport Accident	=COUNTIF($G$923:$G$1028, "transport accident")	=COUNTIF($G$780:$G$862, "transport accident")	=COUNTIF($G$863:$G$922, "transport accident")	=COUNTIF($G$1029:$G$1178, "transport accident")	=0	=SUM(BD$14:BN$14)
Storm	=COUNTIF($G$923:$G$1028, "storm")	=COUNTIF($G$780:$G$862, "storm")	=COUNTIF($G$863:$G$922, "storm")	=COUNTIF($G$1029:$G$1178, "storm")	=0	=SUM(BD$15:BN$15)
Wildfire	=COUNTIF($G$923:$G$1028, "wildfire")	=COUNTIF($G$780:$G$862, "wildfire")	=COUNTIF($G$863:$G$922, "wildfire")	=COUNTIF($G$1029:$G$1178, "wildfire")	=0	=SUM(BD$16:BN$16)
Miscellaneous accident	###	###	###	###	=0	=SUM(BD$17:BN$17)
Total Damage	=SUM($AR$923:$AR$1028)	=SUM($AR$780:$AR$862)	=SUM($AR$863:$AR$922)	=SUM($AR$1029:$AR$1178)	=0	=SUM(BD$18:BN$18)
Total Damage Adjusted	=SUM($AS$923:$AS$1028)	=SUM($AS$780:$AS$862)	=SUM($AS$863:$AS$922)	=SUM($AS$1029:$AS$1178)	=0	=SUM(BD$19:BN$19)

Figure 6: =COUNTIF Excel Formula

	France	Germany	Greece	Italy	Netherlands	Romania	Poland	Portugal	Spain	UK	Total:
Drought	5	0	1	5	0	2	1	4	4	0	22
Earthquake	1	2	26	26	1	3	1	0	2	0	62
Extreme Temperature	21	13	8	11	8	19	19	6	9	0	114
Flood	56	21	26	43	4	50	15	11	31	0	257
Landslide	7	1	0	11	0	1	0	0	1	0	21
Industrial Accident	10	13	2	4	4	6	6	0	8	0	53
Transport Accident	33	25	41	64	7	11	11	12	44	0	248
Storm	73	56	7	24	25	10	23	10	25	0	253
Wildfire	12	1	16	7	0	0	2	14	18	0	70
Miscellaneous accident	18	7	4	15	5	4	5	3	8	0	69
Total Damage	$52,019,100.00	$99,486,505.00	$13,393,059.00	$90,719,063.00	$5,938,411.00	$3,639,918.00	$8,427,050.00	$7,925,636.00	$42,187,404.00	$0.00	$323,736,146.00
Total Damage Adjusted	$78,039,966.00	$124,954,550.00	$23,166,669.00	$169,588,681.00	$9,984,450.00	$5,108,409.00	$12,906,564.00	$11,292,149.00	$76,506,301.00	$0.00	$511,547,739.00

Figure 7: =COUNTIF Results

BU	BV	BW	BX	BY	BZ	CA	CB
				# of days in 20 years:	=(365*40)+10		
				Probability of disaster occurance:	=(CB15)/BZ5		
	France	Germany	Greece	Italy	Netherlands	Total by Category	
Climatological	=SUM(BD$8,BD$16)	=SUM(BE$8,BE$16)	=SUM(BF$8,BF$16)	=SUM(BG$8,BG$16)	=SUM(BI$8,BI$16)	=SUM(BV9:BZ9)	
Geophysical	=SUM(BD$9)	=SUM(BE$9)	=SUM(BF$9)	=SUM(BG$9)	=SUM(BI$9)	=SUM(BV10:BZ10)	
Hydrological	=SUM(BD$11,BD$12)	=SUM(BE$11,BE$12)	=SUM(BF$11,BF$12)	=SUM(BG$11,BG$12)	=SUM(BI$11,BI$12)	=SUM(BV11:BZ11)	
Meteorilogical	=SUM(BD$10,BD$15)	=SUM(BE$10,BE$15)	=SUM(BF$10,BF$15)	=SUM(BG$10,BG$15)	=SUM(BI$10,BI$15)	=SUM(BV12:BZ12)	
technological	=SUM(BD$13,BD$14,BD$17)	=SUM(BE$13,BE$14,BE$17)	=SUM(BF$13,BF$14,BF$17)	=SUM(BG$13,BG$14,BG$17)	=SUM(BI$13,BI$14,BI$17)	=SUM(BV13:BZ13)	
Total by Country	=SUM(BV9:BV13)	=SUM(BW9:BW13)	=SUM(BX9:BX13)	=SUM(BY9:BY13)	=SUM(BZ9:BZ13)	=SUM(CA9:CA13)	
						TOTAL:	=SUM(CA14,CA22)
	Romania	Poland	Portugal	Spain	UK	Total by Category	
Climatological	=SUM(BD$22,BD$30)	=SUM(BE$22,BE$30)	=SUM(BF$22,BF$30)	=SUM(BG$22,BG$30)	N/A	=SUM(BV17:BZ17)	
Geophysical	=SUM(BD$23)	=SUM(BE$23)	=SUM(BF$23)	=SUM(BG$23)	N/A	=SUM(BV18:BZ18)	
Hydrological	=SUM(BD$25,BD$26)	=SUM(BE$25,BE$26)	=SUM(BF$25,BF$26)	=SUM(BG$25,BG$26)	N/A	=SUM(BV19:BZ19)	
Meteorilogical	=SUM(BD$24,BD$29)	=SUM(BE$24,BE$29)	=SUM(BF$24,BF$29)	=SUM(BG$24,BG$29)	N/A	=SUM(BV20:BZ20)	
technological	=SUM(BD$27,BD$28,BD$31)	=SUM(BE$27,BE$28,BE$31)	=SUM(BF$27,BF$28,BF$31)	=SUM(BG$27,BG$28,BG$31)	N/A	=SUM(BV21:BZ21)	
Total by Country	=SUM(BV17:BV21)	=SUM(BW17:BW21)	=SUM(BX17:BX21)	=SUM(BY17:BY21)	N/A	=SUM(CA17:CA21)	

Figure 8: Category Totals Excel Formula

BU	BV	BW	BX	BY	BZ	CA	CB
				# of days in 20 years:	14610		
				Probability of disaster occurance:	0.0800136892539357		
	France	Germany	Greece	Italy	Netherlands	Total by Category	
Climatological	17	1	17	12	0	47	
Geophysical	1	2	26	26	1	56	
Hydrological	63	22	26	54	4	169	
Meteorilogical	94	69	15	35	33	246	
technological	61	45	47	83	16	252	
Total by Country	236	139	131	210	54	770	
						TOTAL:	1,169.00
	Romania	Poland	Portugal	Spain	UK	Total by Category	
Climatological	2	3	18	22	N/A	45	
Geophysical	3	1	0	2	N/A	6	
Hydrological	51	15	11	32	N/A	109	
Meteorilogical	29	42	16	34	N/A	121	
technological	21	22	15	60	N/A	118	
Total by Country	106	83	60	150	N/A	399	

Figure 9: Category Totals Results

	France	Germany	Greece	Italy	Netherlands	Total % (Category)	
Climatological	=(BV9/$CB$15)	=(BW9/$CB$15)	=(BX9/$CB$15)	=(BY9/$CB$15)	=(BZ9/$CB$15)	=SUM(BV25:BZ25)	=SUM(CA25+CA33)
Geophysical	=(BV10/$CB$15)	=(BW10/$CB$15)	=(BX10/$CB$15)	=(BY10/$CB$15)	=(BZ10/$CB$15)	=SUM(BV26:BZ26)	=SUM(CA26+CA34)
Hydrological	=(BV11/$CB$15)	=(BW11/$CB$15)	=(BX11/$CB$15)	=(BY11/$CB$15)	=(BZ11/$CB$15)	=SUM(BV27:BZ27)	=SUM(CA27+CA35)
Meteorilogical	=(BV12/$CB$15)	=(BW12/$CB$15)	=(BX12/$CB$15)	=(BY12/$CB$15)	=(BZ12/$CB$15)	=SUM(BV28:BZ28)	=SUM(CA28+CA36)
technological	=(BV13/$CB$15)	=(BW13/$CB$15)	=(BX13/$CB$15)	=(BY13/$CB$15)	=(BZ13/$CB$15)	=SUM(BV29:BZ29)	=SUM(CA29+CA37)
Total % (Country)	=SUM(BV25:BV29)	=SUM(BW25:BW29)	=SUM(BX25:BX29)	=SUM(BY25:BY29)	=SUM(BZ25:BZ29)	=SUM(CA25:CA29)	
						TOTAL:	=SUM(CA30,CA38)
	Romania	Poland	Portugal	Spain	UK	Total % (Category)	
Climatological	=(BV17/$CB$15)	=(BW17/$CB$15)	=(BX17/$CB$15)	=(BY17/$CB$15)	N/A	=SUM(BV33:BZ33)	
Geophysical	=(BV18/$CB$15)	=(BW18/$CB$15)	=(BX18/$CB$15)	=(BY18/$CB$15)	N/A	=SUM(BV34:BZ34)	
Hydrological	=(BV19/$CB$15)	=(BW19/$CB$15)	=(BX19/$CB$15)	=(BY19/$CB$15)	N/A	=SUM(BV35:BZ35)	
Meteorilogical	=(BV20/$CB$15)	=(BW20/$CB$15)	=(BX20/$CB$15)	=(BY20/$CB$15)	N/A	=SUM(BV36:BZ36)	
technological	=(BV21/$CB$15)	=(BW21/$CB$15)	=(BX21/$CB$15)	=(BY21/$CB$15)	N/A	=SUM(BV37:BZ37)	
Total % (Country)	=SUM(BV33:BV37)	=SUM(BW33:BW37)	=SUM(BX33:BX37)	=SUM(BY33:BY37)	N/A	=SUM(BV38:BZ38)	

Figure 10: Category Percentage by Country Excel Formula

	France	Germany	Greece	Italy	Netherlands	Total % (Category)	
Climatological	1.45%	0.09%	1.45%	1.03%	0.00%	4.02%	7.87%
Geophysical	0.09%	0.17%	2.22%	2.22%	0.09%	4.79%	5.30%
Hydrological	5.39%	1.88%	2.22%	4.62%	0.34%	14.46%	23.78%
Meteorilogical	8.04%	5.90%	1.28%	2.99%	2.82%	21.04%	31.39%
technological	5.22%	3.85%	4.02%	7.10%	1.37%	21.56%	31.65%
Total % (Country)	20.19%	11.89%	11.21%	17.96%	4.62%	65.87%	
						TOTAL:	100.00%
	Romania	Poland	Portugal	Spain	UK	Total % (Category)	
Climatological	0.17%	0.26%	1.54%	1.88%	N/A	3.85%	
Geophysical	0.26%	0.09%	0.00%	0.17%	N/A	0.51%	
Hydrological	4.36%	1.28%	0.94%	2.74%	N/A	9.32%	
Meteorilogical	2.48%	3.59%	1.37%	2.91%	N/A	10.35%	
technological	1.80%	1.88%	1.28%	5.13%	N/A	10.09%	
Total % (Country)	9.07%	7.10%	5.13%	12.83%	N/A	34.13%	

Figure 11: Category Percentage by Country Results

6.2. Appendix II

The TOPSIS calculation for CAPEC Supply Chain attack severity in Section 2.2 involves 7 steps (Mathew, 2018):

- Calculate the normalized matrix
- Calculate the weighted normalized matrix
- Calculate the ideal worst value (V-)
- Calculate the ideal best value (V+)
- Calculate the Euclidean distance from the ideal best (S+)
- Calculate the Euclidean distance from the ideal worst (S-)
- Calculate the Performance Score (Pi)

To perform this analysis on Excel, the following steps were undertaken

6.2.1. Calculating the Normalized Matrix

1. CAPEC data was collected and indexed according to the 'Attack Likelihood', 'Attack Severity', and 'Skill Level Required' of a vulnerability (Figure 12)
2. Each Severity is assigned a number on a scale of 5-0, Very-High - Very Low. Each rating is then squared (Figure 13 & 14)
3. A sum of the squares for each category are found (Figure 15)

4. The Normalized Matrix equation (x/(s)^.05) is then performed on individual category scores, where x = AL/TS/SR scores and s = the summed square root, finding the Normalized Matrix (figure 16 & 17)

	A	B	C	D
1	**Supply Chain**			
2	**Vulnerability**	**Attack Likeliho**	**Typical Sever**	**Skills Requir**
3	WSDL Scanning	high	high	low
4	USB Memory Attacks	low	high	n/a
5	TypoSquatting	low	medium	low
6	System Build Data Maliciously Altered	low	high	n/a
7	Symlink Attack	low	high	high
8	Symlink Attack	low	high	low
9	SoundSquatting	low	medium	low
10	Software Development Tools Maliciously Altered	low	high	high
11	Signing Malicious Code	n/a	very high	n/a
12	Server Functionality Compromise	low	high	n/a
13	Search Order Hijacking	n/a	medium	medium

Figure 12: CAPEC Supply Chain Vulnerability Index

	B	C	D	E	F	G	H	
1								
2	**Attack Likeliho**	**Typical Sever**	**Skills Requir**	**AL Score**	**AL Square**	**TS Score**	**TS Square**	
3	high	high	low	=IFS(B3="very high",5,B3="high",4,B3="medium",3,B3="low",2,B3="very low",1,B3="n/a", 0)	=E3^2	=IFS(C3="very high",5,C3="high",4,C3="medium",3,C3="low",2,C3="very low",1,C3="n/a", 0)	=(G3^2)	=IFS
4	low	high	n/a	=IFS(B4="very high",5,B4="high",4,B4="medium",3,B4="low",2,B4="very low",1,B4="n/a", 0)	=(E4^2)	=IFS(C4="very high",5,C4="high",4,C4="medium",3,C4="low",2,C4="very low",1,C4="n/a", 0)	=(G4^2)	=IFS
5	low	medium	low	=IFS(B5="very high",5,B5="high",4,B5="medium",3,B5="low",2,B5="very low",1,B5="n/a", 0)	=(E5^2)	=IFS(C5="very high",5,C5="high",4,C5="medium",3,C5="low",2,C5="very low",1,C5="n/a", 0)	=(G5^2)	=IFS
6	low	high	n/a	=IFS(B6="very high",5,B6="high",4,B6="medium",3,B6="low",2,B6="very low",1,B6="n/a", 0)	=(E6^2)	=IFS(C6="very high",5,C6="high",4,C6="medium",3,C6="low",2,C6="very low",1,C6="n/a", 0)	=(G6^2)	=IFS
7	low	high	high	=IFS(B7="very high",5,B7="high",4,B7="medium",3,B7="low",2,B7="very low",1,B7="n/a", 0)	=(E7^2)	=IFS(C7="very high",5,C7="high",4,C7="medium",3,C7="low",2,C7="very low",1,C7="n/a", 0)	=(G7^2)	=IFS
8	low	high	low	=IFS(B8="very high",5,B8="high",4,B8="medium",3,B8="low",2,B8="very low",1,B8="n/a", 0)	=(E8^2)	=IFS(C8="very high",5,C8="high",4,C8="medium",3,C8="low",2,C8="very low",1,C8="n/a", 0)	=(G8^2)	=IFS
9	low	medium	low	=IFS(B9="very high",5,B9="high",4,B9="medium",3,B9="low",2,B9="very low",1,B9="n/a", 0)	=(E9^2)	=IFS(C9="very high",5,C9="high",4,C9="medium",3,C9="low",2,C9="very low",1,C9="n/a", 0)	=(G9^2)	=IFS
10	low	high	high	=IFS(B10="very high",5,B10="high",4,B10="medium",3,B10="low",2,B10="very low",1,B10="n/a", 0)	=(E10^2)	=IFS(C10="very high",5,C10="high",4,C10="medium",3,C10="low",2,C10="very low",1,C10="n/a", 0)	=(G10^2)	=IFS(D1
11	n/a	very high	n/a	=IFS(B11="very high",5,B11="high",4,B11="medium",3,B11="low",2,B11="very low",1,B11="n/a", 0)	=(E11^2)	=IFS(C11="very high",5,C11="high",4,C11="medium",3,C11="low",2,C11="very low",1,C11="n/a", 0)	=(G11^2)	=IFS(D1
12	low	high	n/a	=IFS(B12="very high",5,B12="high",4,B12="medium",3,B12="low",2,B12="very low",1,B12="n/a", 0)	=(E12^2)	=IFS(C12="very high",5,C12="high",4,C12="medium",3,C12="low",2,C12="very low",1,C12="n/a", 0)	=(G12^2)	=IFS(D1
13	n/a	medium	medium	=IFS(B13="very high",5,B13="high",4,B13="medium",3,B13="low",2,B13="very low",1,B13="n/a", 0)	=(E13^2)	=IFS(C13="very high",5,C13="high",4,C13="medium",3,C13="low",2,C13="very low",1,C13="n/a", 0)	=(G13^2)	=IFS(D1
14	medium	medium	n/a	=IFS(B14="very high",5,B14="high",4,B14="medium",3,B14="low",2,B14="very low",1,B14="n/a", 0)	=(E14^2)	=IFS(C14="very high",5,C14="high",4,C14="medium",3,C14="low",2,C14="very low",1,C14="n/a", 0)	=(G14^2)	=IFS(D1
15	n/a	n/a	n/a	=IFS(B15="very high",5,B15="high",4,B15="medium",3,B15="low",2,B15="very low",1,B15="n/a", 0)	=(E15^2)	=IFS(C15="very high",5,C15="high",4,C15="medium",3,C15="low",2,C15="very low",1,C15="n/a", 0)	=(G15^2)	=IFS(D1
16	n/a	high	medium	=IFS(B16="very high",5,B16="high",4,B16="medium",3,B16="low",2,B16="very low",1,B16="n/a", 0)	=(E16^2)	=IFS(C16="very high",5,C16="high",4,C16="medium",3,C16="low",2,C16="very low",1,C16="n/a", 0)	=(G16^2)	=IFS(D1
17	low	high	high	=IFS(B17="very high",5,B17="high",4,B17="medium",3,B17="low",2,B17="very low",1,B17="n/a", 0)	=(E17^2)	=IFS(C17="very high",5,C17="high",4,C17="medium",3,C17="low",2,C17="very low",1,C17="n/a", 0)	=(G17^2)	=IFS(D1
18	medium	medium	medium	=IFS(B18="very high",5,B18="high",4,B18="medium",3,B18="low",2,B18="very low",1,B18="n/a", 0)	=(E18^2)	=IFS(C18="very high",5,C18="high",4,C18="medium",3,C18="low",2,C18="very low",1,C18="n/a", 0)	=(G18^2)	=IFS(D1
19	medium	medium	high	=IFS(B19="very high",5,B19="high",4,B19="medium",3,B19="low",2,B19="very low",1,B19="n/a", 0)	=(E19^2)	=IFS(C19="very high",5,C19="high",4,C19="medium",3,C19="low",2,C19="very low",1,C19="n/a", 0)	=(G19^2)	=IFS(D1
20	low	high	high	=IFS(B20="very high",5,B20="high",4,B20="medium",3,B20="low",2,B20="very low",1,B20="n/a", 0)	=(E20^2)	=IFS(C20="very high",5,C20="high",4,C20="medium",3,C20="low",2,C20="very low",1,C20="n/a", 0)	=(G20^2)	=IFS(D2
21	medium	high	low	=IFS(B21="very high",5,B21="high",4,B21="medium",3,B21="low",2,B21="very low",1,B21="n/a", 0)	=(E21^2)	=IFS(C21="very high",5,C21="high",4,C21="medium",3,C21="low",2,C21="very low",1,C21="n/a", 0)	=(G21^2)	=IFS(D2
22	n/a	medium	n/a	=IFS(B22="very high",5,B22="high",4,B22="medium",3,B22="low",2,B22="very low",1,B22="n/a", 0)	=(E22^2)	=IFS(C22="very high",5,C22="high",4,C22="medium",3,C22="low",2,C22="very low",1,C22="n/a", 0)	=(G22^2)	=IFS(D2
23	n/a	n/a	n/a	=IFS(B23="very high",5,B23="high",4,B23="medium",3,B23="low",2,B23="very low",1,B23="n/a", 0)	=(E23^2)	=IFS(C23="very high",5,C23="high",4,C23="medium",3,C23="low",2,C23="very low",1,C23="n/a", 0)	=(G23^2)	=IFS(D2
24	low	high	high	=IFS(B24="very high",5,B24="high",4,B24="medium",3,B24="low",2,B24="very low",1,B24="n/a", 0)	=(E24^2)	=IFS(C24="very high",5,C24="high",4,C24="medium",3,C24="low",2,C24="very low",1,C24="n/a", 0)	=(G24^2)	=IFS(D2
25	low	high	high	=IFS(B25="very high",5,B25="high",4,B25="medium",3,B25="low",2,B25="very low",1,B25="n/a", 0)	=(E25^2)	=IFS(C25="very high",5,C25="high",4,C25="medium",3,C25="low",2,C25="very low",1,C25="n/a", 0)	=(G25^2)	=IFS(D2

Figure 13: Excel formula for Severity Rating and Squared Value

	A	B	C	D	E	F	G	H	I	J
1	**Supply Chain**									
2	**Vulnerability**	**Attack Likeliho**	**Typical Sever**	**Skills Requir**	**AL Score**	**AL Square**	**TS Score**	**TS Square**	**SR Score**	**SR Square**
3	WSDL Scanning	high	high	low	4	16	4	16	4	16
4	USB Memory Attacks	low	high	n/a	2	4	4	16	0	0
5	TypoSquatting	low	medium	low	2	4	3	9	4	16
6	System Build Data Maliciously Altered	low	high	n/a	2	4	4	16	0	0
7	Symlink Attack	low	high	high	2	4	4	16	2	4
8	Symlink Attack	low	high	low	2	4	4	16	4	16
9	SoundSquatting	low	medium	low	2	4	3	9	4	16
10	Software Development Tools Maliciously Altered	low	high	high	2	4	4	16	2	4
11	Signing Malicious Code	n/a	very high	n/a	0	0	5	25	0	0
12	Server Functionality Compromise	low	high	n/a	2	4	4	16	0	0
13	Search Order Hijacking	n/a	medium	medium	0	0	3	9	3	9

Figure 14: Severity Rating and Squared Value

	A	B	C	D	E	F	G	H	I	J
61	Detect Unpublisized Web Pages	n/a	low	n/a	0	0	2	4	0	0
62	Design for FPGA Maliciously Altered	low	high	high	2	4	4	16	2	4
63	Cross Domain Search Timing	n/a	medium	low	0	0	3	9	4	16
64	Conunterfeit Hardware Component Inserted During Product Assembly	low	high	high	2	4	4	16	2	4
65	Collect Data from Screen Capture	medium	medium	low	3	9	3	9	4	16
66	Collect Data from Registeries	medium	medium	low	3	9	3	9	4	16
67	Collect Data from Clipboard	low	low	high	2	4	2	4	2	4
68	Cellular Rougue Base Station	n/a	low	low	0	0	2	4	4	16
69	Capture Credentials via Keylogger	n/a	high	n/a	0	0	4	16	0	0
70	Bypassing ATA Password Security	n/a	n/a	n/a	0	0	0	0	0	0
71	Bluetooth Impersonation AttackS (BIAS)	medium	high	low	3	9	4	16	4	16
72	BitSquatting	low	medium	low	2	4	3	9	4	16
73	ASIC with Malicious Functionality	low	high	high	2	4	4	16	2	4
74	Alternate of a Software Update	medium	high	n/a	3	9	4	16	0	0
75	Altered Installed BIOS	low	high	high	2	4	4	16	2	4
76	Altered Component Firmware	low	very high	low	2	4	5	25	4	16
77	Altered Component Firmware	low	very high	medium	2	4	5	25	3	9
78	Altered Component Firmware	low	very high	high	2	4	5	25	2	4
79	Square sum					378		1026		450

Figure 15: Sum of the Square Values

L	M	N
=1/3	=1/3	=1/3
AL Score	TS Score	SR Score
=(E3/(($F$79)^0.5))	=(G3/($H$79^0.5))	=(I3/$J$79^0.5)
=(E4/(($F$79)^0.5))	=(G4/($H$79^0.5))	=(I4/$J$79^0.5)
=(E5/(($F$79)^0.5))	=(G5/($H$79^0.5))	=(I5/$J$79^0.5)
=(E6/(($F$79)^0.5))	=(G6/($H$79^0.5))	=(I6/$J$79^0.5)
=(E7/(($F$79)^0.5))	=(G7/($H$79^0.5))	=(I7/$J$79^0.5)
=(E8/(($F$79)^0.5))	=(G8/($H$79^0.5))	=(I8/$J$79^0.5)
=(E9/(($F$79)^0.5))	=(G9/($H$79^0.5))	=(I9/$J$79^0.5)
=(E10/(($F$79)^0.5))	=(G10/($H$79^0.5))	=(I10/$J$79^0.5)
=(E11/(($F$79)^0.5))	=(G11/($H$79^0.5))	=(I11/$J$79^0.5)
=(E12/(($F$79)^0.5))	=(G12/($H$79^0.5))	=(I12/$J$79^0.5)
=(E13/(($F$79)^0.5))	=(G13/($H$79^0.5))	=(I13/$J$79^0.5)
=(E14/(($F$79)^0.5))	=(G14/($H$79^0.5))	=(I14/$J$79^0.5)
=(E15/(($F$79)^0.5))	=(G15/($H$79^0.5))	=(I15/$J$79^0.5)
=(E16/(($F$79)^0.5))	=(G16/($H$79^0.5))	=(I16/$J$79^0.5)

Figure 16: Normalized Excel Formula

L	M	N
0.333333333333333	0.333333333333333	0.333333333333
AL Score	TS Score	SR Score
0.205737799949456	0.124878108210893	0.188561808316
0.102868899974728	0.124878108210893	0
0.102868899974728	0.093658581158169	0.188561808316
0.102868899974728	0.124878108210893	0
0.102868899974728	0.124878108210893	0.094280904158
0.102868899974728	0.124878108210893	0.188561808316
0.102868899974728	0.093658581158169	0.188561808316
0.102868899974728	0.124878108210893	0.094280904158
0	0.156097635263616	0
0.102868899974728	0.124878108210893	0
0	0.093658581158169	0.141421356237
0.154303349962092	0.093658581158169	0
0	0	0
0	0.124878108210893	0.141421356237

Figure 17: Normalized Matrix Score

6.2.2 Calculating the Weighted Normalized Matrix

1. Weights for Attack Likelihood, Typical Severity, and Skills Required are assigned to the Normalized Matrix categories (Figure 12 & 13). For this calculation, each have the weight 1/3.

2. AL/TS/SR Scores are then multiplied by the assigned weight to find the weighted Normalized Matrix score (Figure 18 & 19)

P	Q	R
AL Weighted	TS Weighted	SR Weighted
=(L3*$L$1)	=(M3*$M$1)	=(N3*$N$1)
=(L4*$L$1)	=(M4*$M$1)	=(N4*$N$1)
=(L5*$L$1)	=(M5*$M$1)	=(N5*$N$1)
=(L6*$L$1)	=(M6*$M$1)	=(N6*$N$1)
=(L7*$L$1)	=(M7*$M$1)	=(N7*$N$1)
=(L8*$L$1)	=(M8*$M$1)	=(N8*$N$1)
=(L9*$L$1)	=(M9*$M$1)	=(N9*$N$1)
=(L10*$L$1)	=(M10*$M$1)	=(N10*$N$1)
=(L11*$L$1)	=(M11*$M$1)	=(N11*$N$1)
=(L12*$L$1)	=(M12*$M$1)	=(N12*$N$1)
=(L13*$L$1)	=(M13*$M$1)	=(N13*$N$1)
=(L14*$L$1)	=(M14*$M$1)	=(N14*$N$1)
=(L15*$L$1)	=(M15*$M$1)	=(N15*$N$1)
=(L16*$L$1)	=(M16*$M$1)	=(N16*$N$1)
=(L17*$L$1)	=(M17*$M$1)	=(N17*$N$1)
=(L18*$L$1)	=(M18*$M$1)	=(N18*$N$1)
=(L19*$L$1)	=(M19*$M$1)	=(N19*$N$1)
=(L20*$L$1)	=(M20*$M$1)	=(N20*$N$1)

Figure 18: Weighted Excel Formula

P	Q	R
AL Weighted	TS Weighted	SR Weighted
0.0685792666498186	0.0416260360702975	0.0628539361054709
0.0342896333249093	0.0416260360702975	0
0.0342896333249093	0.0312195270527231	0.0628539361054709
0.0342896333249093	0.0416260360702975	0
0.0342896333249093	0.0416260360702975	0.0314269680527354
0.0342896333249093	0.0416260360702975	0.0628539361054709
0.0342896333249093	0.0312195270527231	0.0628539361054709
0.0342896333249093	0.0416260360702975	0.0314269680527354
0	0.0520325450878719	0
0.0342896333249093	0.0416260360702975	0
0	0.0312195270527231	0.0471404520791032
0.051434449987364	0.0312195270527231	0
0	0	0
0	0.0416260360702975	0.0471404520791032
0.0342896333249093	0.0416260360702975	0.0314269680527354
0.051434449987364	0.0312195270527231	0.0471404520791032
0.051434449987364	0.0312195270527231	0.0314269680527354
0.0342896333249093	0.0416260360702975	0.0314269680527354

Figure 19: Weighted N. Matrix Score

6.3.3 Calculating the Ideal Best/Worst Values

1. Calculating the ideal best (V+) and ideal worst (V-) values use a variation of the same equation (Figure 20). The transposition of this equation into an Excel formula is demonstrated in Figure 21, wherein the maximum and minimum AL/TS/SR scores are obtained.

   It should be noted that ideal best scores can be as high as 1 and ideal worst scores can be as low as 0.

$$S_i^+ = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^+ \right)^2 \right]^{0.5}$$

$$S_i^- = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^- \right)^2 \right]^{0.5}$$

Figure 20: Vi+/- Equation (Matthew, 2018)

V+	=MAX(P3:P78)	=MAX(Q3:Q78)	=MAX(R3:R78)
V-	=MIN(P3:P78)	=MIN(Q3:Q78)	=MIN(R3:R78)

Figure 21: Ideal Best/Worst Value Excel Formula

V+	0.0685792666498186	0.0520325450878719	0.0628539361054709
V-	0	0	0

Figure 22: Ideal Best/Worst Value Scores

6.3.4 Calculating the Euclidean Distance from the Ideal Best/Worst Values

1. Calculating Euclidean Distance for ideal best and worst values uses a variation of the same equation (Figures 23 & 24).

$$S_i^+ = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^+ \right)^2 \right]^{0.5}$$

$$S_i^- = \left[\sum_{j=1}^{m} \left(V_{ij} - V_j^- \right)^2 \right]^{0.5}$$

Figure 23: Euclidean Distance Equation (Matthew, 2018)

2. The Weighted AL/TS/SR scores are subtracted from V+/V-. This result is then squared

3. The squared sum of the three categories are added together and then squared by 0.5

4. The resulting number represents the Euclidean distance (figure 25)

T	U	V	W	X
Si+	**Si-**	**Pi**	**Occurance**	**Percentage**
`=((P3-$P$80)^2+(Q3-$Q$80)^2+(R3-$R$80)^2)^0.5`	`=((P3-$P$81)^2+(Q3-$Q$81)^2+(R3-$R$81)^2)^0.5`	**=(U3/(T3+U3))**	=COUNTIF(V3:V78,V3)	=(W3/76)
`=((P4-$P$80)^2+(Q4-$Q$80)^2+(R4-$R$80)^2)^0.5`	`=((P4-$P$81)^2+(Q4-$Q$81)^2+(R4-$R$81)^2)^0.5`	=(U4/(T4+U4))	=COUNTIF(V4:V79,V4)	=(W4/76)
`=((P5-$P$80)^2+(Q5-$Q$80)^2+(R5-$R$80)^2)^0.5`	`=((P5-$P$81)^2+(Q5-$Q$81)^2+(R5-$R$81)^2)^0.5`	=(U5/(T5+U5))	=COUNTIF(V5:V80,V5)	=(W5/76)
`=((P6-$P$80)^2+(Q6-$Q$80)^2+(R6-$R$80)^2)^0.5`	`=((P6-$P$81)^2+(Q6-$Q$81)^2+(R6-$R$81)^2)^0.5`	=(U6/(T6+U6))		
`=((P7-$P$80)^2+(Q7-$Q$80)^2+(R7-$R$80)^2)^0.5`	`=((P7-$P$81)^2+(Q7-$Q$81)^2+(R7-$R$81)^2)^0.5`	=(U7/(T7+U7))	=COUNTIF(V7:V82,V7)	=(W7/76)
`=((P8-$P$80)^2+(Q8-$Q$80)^2+(R8-$R$80)^2)^0.5`	`=((P8-$P$81)^2+(Q8-$Q$81)^2+(R8-$R$81)^2)^0.5`	=(U8/(T8+U8))	=COUNTIF(V8:V83,V8)	=(W8/76)
`=((P9-$P$80)^2+(Q9-$Q$80)^2+(R9-$R$80)^2)^0.5`	`=((P9-$P$81)^2+(Q9-$Q$81)^2+(R9-$R$81)^2)^0.5`	=(U9/(T9+U9))		
`=((P10-$P$80)^2+(Q10-$Q$80)^2+(R10-$R$80)^2)^0.5`	`=((P10-$P$81)^2+(Q10-$Q$81)^2+(R10-$R$81)^2)^0.5`	=(U10/(T10+U10))		
`=((P11-$P$80)^2+(Q11-$Q$80)^2+(R11-$R$80)^2)^0.5`	`=((P11-$P$81)^2+(Q11-$Q$81)^2+(R11-$R$81)^2)^0.5`	=(U11/(T11+U11))	=COUNTIF(V11:V86,V11)	=(W11/76)
`=((P12-$P$80)^2+(Q12-$Q$80)^2+(R12-$R$80)^2)^0.5`	`=((P12-$P$81)^2+(Q12-$Q$81)^2+(R12-$R$81)^2)^0.5`	=(U12/(T12+U12))		
`=((P13-$P$80)^2+(Q13-$Q$80)^2+(R13-$R$80)^2)^0.5`	`=((P13-$P$81)^2+(Q13-$Q$81)^2+(R13-$R$81)^2)^0.5`	=(U13/(T13+U13))	=COUNTIF(V13:V88,V13)	=(W13/76)
`=((P14-$P$80)^2+(Q14-$Q$80)^2+(R14-$R$80)^2)^0.5`	`=((P14-$P$81)^2+(Q14-$Q$81)^2+(R14-$R$81)^2)^0.5`	=(U14/(T14+U14))	=COUNTIF(V14:V89,V14)	=(W14/76)
`=((P15-$P$80)^2+(Q15-$Q$80)^2+(R15-$R$80)^2)^0.5`	`=((P15-$P$81)^2+(Q15-$Q$81)^2+(R15-$R$81)^2)^0.5`	=(U15/(T15+U15))	=COUNTIF(V15:V90,V15)	=(W15/76)
`=((P16-$P$80)^2+(Q16-$Q$80)^2+(R16-$R$80)^2)^0.5`	`=((P16-$P$81)^2+(Q16-$Q$81)^2+(R16-$R$81)^2)^0.5`	=(U16/(T16+U16))	=COUNTIF(V16:V91,V16)	=(W16/76)
`=((P17-$P$80)^2+(Q17-$Q$80)^2+(R17-$R$80)^2)^0.5`	`=((P17-$P$81)^2+(Q17-$Q$81)^2+(R17-$R$81)^2)^0.5`	=(U17/(T17+U17))		
`=((P18-$P$80)^2+(Q18-$Q$80)^2+(R18-$R$80)^2)^0.5`	`=((P18-$P$81)^2+(Q18-$Q$81)^2+(R18-$R$81)^2)^0.5`	=(U18/(T18+U18))	=COUNTIF(V18:V93,V18)	=(W18/76)
`=((P19-$P$80)^2+(Q19-$Q$80)^2+(R19-$R$80)^2)^0.5`	`=((P19-$P$81)^2+(Q19-$Q$81)^2+(R19-$R$81)^2)^0.5`	=(U19/(T19+U19))	=COUNTIF(V19:V94,V19)	=(W19/76)

Figure 24: Si+, Si-, Pi, Occurrence, & Percentage Excel Formulas

T	U	V	W	X
Si+	**Si-**	**Pi**	**Occurance**	**Percentage**
0.0104065090175744	0.101913983226559	**0.90734986279302**	1	1.32%
0.0723511690813646	0.0539305649189997	0.42706544494269	3	3.95%
0.0401118520301439	0.0781092510968007	0.66070480676304	5	6.58%
0.0723511690813646	0.0539305649189997	0.42706544494269		
0.047662655239477	0.062419229036172	0.56702544153289	21	27.63%
0.0358339836396902	0.0828198232093806	0.69799549975441	1	1.32%
0.0401118520301439	0.0781092510968007	0.66070480676304		
0.047662655239477	0.062419229036172	0.56702544153289		
0.0930254432839615	0.0520325450878719	0.35870168662821	2	2.63%
0.0723511690813646	0.0539305649189997	0.42706544494269		
0.0733703694566496	0.0565409682585816	0.4352273577732	1	1.32%
0.0683940329419989	0.0601677780452158	0.46800661551975	1	1.32%
0.106588549321674	0	0	4	5.26%
0.071121901158551	0.0628883860593348	0.46928028709531	1	1.32%
0.047662655239477	0.062419229036172	0.56702544153289		
0.031209614518086	0.0764354874199189	0.71006934866335	1	1.32%

Figure 25: Si+/-, Pi, Occurrence & Percentage

6.3.5 Calculating the Performance Score (Pi) and Percentage

1. Calculating the performance score involves the equation P = B/(W+B) (*Figure 24*). This equation will result in a decimal number between 1 and 0, 1 signifying the best rank and 0 signifying the worst (*Figure 25*).

2. Calculating the percentage provides the rate of occurrence of an individual attack. This calculation can be performed with the equation P = A/T, where P = percentage, A = the individual attack, and T = the total attack count, which is 76 (Figures 24 & 25).

6.3 Appendix III

The Monte Carlo simulation () was used to simulate both a quantitative risk probability and an optimal reorder uptake point for limited supply chain disruption in the event of a natural or man-made disaster.

6.3.1 Calculating the Probability of Risk Occurrence

1. Find the quantitative probability (*Figure 26*)

    - Identify 8 risk IDs and their contributing factors
    - Randomly sample each risk 3 times and record the average for each
    - Run this average in the Monte Carlo Simulation for 1000 repetitions
    - Record the MIN and MAX variables using =COUNTIF for value/ratio matching to find the probability

2. Calculate the 90% Confidence Interval (*Figure 26)*

    - Use a lognormal distribution to calculate the mean and standard deviation from the lower and upper ranges
    - Find the financial impact using =lognorm.inv(rand()(lower range,Upper range)
        - Lognormal distributions can be used on large positive number sets that may skew in one direction

    - Results for these formulae can be seen in Figures 27, 28 & 29.

3. Calculations with Yasai

    - There were two different inventory analyses:

◦ both contained 7 individual scenarios that ran through 5000 simulations (Figures 28 & 29)

- Different scenarios included:
    ◦ changes to product re-order quantities and re-order points in rolling stock numbers (Figure 27)
    ◦ Comparing re-order quantities and re-order points to one another to optimize the numbers for a mitigation scenario (Figure 28)

					(Financial impact) 90% CI of LR and UR	
Rand Prob Of Sub Prob	Quantitative Probability	distribution	LR and UR std.dev	LR and UR mean	lognormal rand distribution	Rand result of financial cost (zero when event did not occur)
=IF(RAND() < 0.2,1,0)	=R27	lognormal	=(LN(K6)-LN(I6))/3.29	=(LN(K6)+LN(I6))/2	=LOGNORM.INV(RAND(),P6,O6)	=IF(RAND()<0.2,LOGNORM.INV(RAND(),(LN(K6)+LN(I6))/2,(LN(K6)-LN(I6))/3.29),0)
=IF(RAND() < H7,1,0)	=R28	lognormal	=(LN(K7)-LN(I7))/3.29	=(LN(K7)+LN(I7))/2	=LOGNORM.INV(RAND(),P7,O7)	=IF(RAND()<H7,LOGNORM.INV(RAND(),(LN(K7)+LN(I7))/2,(LN(K7)-LN(I7))/3.29),0)
=IF(RAND() < H8,1,0)	=R29	lognormal	=(LN(K8)-LN(I8))/3.29	=(LN(K8)+LN(I8))/2	=LOGNORM.INV(RAND(),P8,O8)	=IF(RAND()<H8,LOGNORM.INV(RAND(),(LN(K8)+LN(I8))/2,(LN(K8)-LN(I8))/3.29),0)
=IF(RAND() < H9,1,0)	=R30	lognormal	=(LN(K9)-LN(I9))/3.29	=(LN(K9)+LN(I9))/2	=LOGNORM.INV(RAND(),P9,O9)	=IF(RAND()<H9,LOGNORM.INV(RAND(),(LN(K9)+LN(I9))/2,(LN(K9)-LN(I9))/3.29),0)
=IF(RAND() < H10,1,0)	=R31	lognormal	=(LN(K10)-LN(I10))/3.29	=(LN(K10)+LN(I10))/2	=LOGNORM.INV(RAND(),P10,O10)	=IF(RAND()<H10,LOGNORM.INV(RAND(),(LN(K10)+LN(I10))/2,(LN(K10)-LN(I10))/3.29),0)
=IF(RAND() < H11,1,0)	=R32	lognormal	=(LN(K11)-LN(I11))/3.29	=(LN(K11)+LN(I11))/2	=LOGNORM.INV(RAND(),P11,O11)	=IF(RAND()<H11,LOGNORM.INV(RAND(),(LN(K11)+LN(I11))/2,(LN(K11)-LN(I11))/3.29),0)
=IF(RAND() < H12,1,0)	=R33	lognormal	=(LN(K12)-LN(I12))/3.29	=(LN(K12)+LN(I12))/2	=LOGNORM.INV(RAND(),P12,O12)	=IF(RAND()<H12,LOGNORM.INV(RAND(),(LN(K12)+LN(I12))/2,(LN(K12)-LN(I12))/3.29),0)
=IF(RAND() < H13,1,0)	=R34	lognormal	=(LN(K13)-LN(I13))/3.29	=(LN(K13)+LN(I13))/2	=LOGNORM.INV(RAND(),P13,O13)	=IF(RAND()<H13,LOGNORM.INV(RAND(),(LN(K13)+LN(I13))/2,(LN(K13)-LN(I13))/3.29),0)
Average Quantitative prob:						Total potential distruption cost
	='probability range'!E17					=R6+R7+R8+R9+R10+R11+R12+R13
	from 1000 simulations of eac					

Risk ID	list of risks	What	When	Impact C	Impact I	Impact A	Subjective Probability	Lower range	Upper range
1	cloud server breach	inventory	>24 months	0	0.2	0.8	0.2	2000000	3000000
2	supply chain disruption	ingredients	<12 months	0	0.8	0.2	0.1	40000	60000
3	warehouse disruption	orders	<12 months	0.3	0.5	0.2	0.66	70000	105000
4	warehouse disruption	Machine Failure	<18 months	0	0	1	0.1	250000	380000
5	cloud server breach	supplier Information	>24 months	0.7	0.2	0.1	0.05	70000	155000
6	warehouse disruption	Power outage	< 24 months	0	0	1	0.03	90000	150000
7	supply chain disruption	Flooding	>36 months	0	0.1	0.9	0.07	240000	500000
8	supply chain disruption	Draught	>48 months	0	0.4	0.6	0.02	180000	260000
							e of all Subjective Probab		
							=SUM(H5:H12)/8		

Figures 26: Major Simulation Formulae

Pampered Pets Inventory Simulation

Mean demand	4500	**Parameters of ordering policies**			
			Policy	Reord pt	Ord quan
Fixed order cost	$50		1	5000	8000
Unit cost	$1		2	4000	8000
Sales price	$5		3	5500	100
Holding cost	$1		4	6000	9100
Salvage value	$3		5	800	300
			6	6000	400
Starting inventory	9100		7	500	500
Reorder point	6000				
Reorder quantity	9100				

Simulation of 24-month period

Month	Beginning Inv	Demand	Units Sold	End Inv	Order Size	Order Cost	Sales rev	Holding Cost	Out of Stock?	Probabilty
1	9100	4440	4440	4660	9100	$9,150	$22,200	$4,660	0	0%
2	13760	4502	4502	9258	0	$0	$22,510	$9,258	0	
3	9258	4462	4462	4796	9100	$9,150	$22,310	$4,796	0	
4	13896	4403	4403	9493	0	$0	$22,015	$9,493	0	
5	9493	4432	4432	5061	9100	$9,150	$22,160	$5,061	0	
6	14161	4443	4443	9718	0	$0	$22,215	$9,718	0	
7	9718	4425	4425	5293	9100	$9,150	$22,125	$5,293	0	
8	14393	4601	4601	9792	0	$0	$23,005	$9,792	0	
9	9792	4622	4622	5170	9100	$9,150	$23,110	$5,170	0	
10	14270	4553	4553	9717	0	$0	$22,765	$9,717	0	
11	9717	4532	4532	5185	9100	$9,150	$22,660	$5,185	0	
12	14285	4497	4497	9788	0	$0	$22,485	$9,788	0	
13	9788	4462	4462	5326	9100	$9,150	$22,310	$5,326	0	
14	14426	4445	4445	9981	0	$0	$22,225	$9,981	0	
15	9981	4585	4585	5396	9100	$9,150	$22,925	$5,396	0	
16	14496	4582	4582	9914	0	$0	$22,910	$9,914	0	
17	9914	4474	4474	5440	9100	$9,150	$22,370	$5,440	0	
18	14540	4373	4373	10167	0	$0	$21,865	$10,167	0	
19	10167	4527	4527	5640	9100	$9,150	$22,635	$5,640	0	
20	14740	4478	4478	10262	0	$0	$22,390	$10,262	0	
21	10262	4473	4473	5789	9100	$9,150	$22,365	$5,789	0	
22	14889	4581	4581	10308	0	$0	$22,905	$10,308	0	
23	10308	4513	4513	5795	9100	$9,150	$22,565	$5,795	0	
24	14895	4515	4515	10380	0	$0	$22,575	$10,380	0	
					Totals	$109,800	$539,600	######		

Salvage value	$31,140		
		Out of stock?	
Total profit	$278,611	0	

Figure 27: Optimal Results from a Order-Size/Re-Order Point

YASAI Simulation Output

Workbook	Executive Summary Project MCS.xlsx	**YASAI Version:**	3
Sheet	Inventory P-Pets	**Use Same Seed?**	Yes
Start Date	27/11/2022	**Random Number Seed:**	41839.44531
Start Time	11:37:19 AM		
Run Time (h:mm:ss)	00:04:39		
Scenarios:	7		
Sample Size:	5000		

Output Name	Scenario	Observations	Mean	Standard Deviation	Minimum	5th Percentile	10th Percentile	15th Percentile	20th Percentile
Out of stock?	1	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Out of stock?	2	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Out of stock?	3	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Out of stock?	4	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Out of stock?	5	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Out of stock?	6	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Out of stock?	7	5000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total profit	1	5000	230075.875	54397.626	165468.000	170982.600	172481.000	173738.400	174961.200
Total profit	2	5000	230599.225	54269.189	166105.000	171081.650	172529.000	173815.450	174990.400
Total profit	3	5000	230960.326	54432.202	166105.000	170981.650	172560.900	173883.550	175000.400
Total profit	4	5000	231867.461	54401.948	165637.000	170955.750	172532.400	173874.550	175042.400
Total profit	5	5000	230749.708	54342.207	165637.000	171104.850	172645.900	173953.250	175075.200
Total profit	6	5000	230837.021	54287.118	165217.000	170858.800	172455.900	173838.250	175090.800
Total profit	7	5000	230506.146	54371.164	165217.000	170985.900	172558.700	173846.250	175042.800

Zero chance of being out of stock while running 7 scenarios of different re-order quantities to support 1 location having down time and a HQ being able to maintain orders

Scenario 4 would provide the highest profits while ensuring minimal risk to product quality and availablity

Figure 28: Results of an Optimal Re-Order Yasai Simulation

Risk ID	list of risks	What	When	Impact C	Impact I	Impact A	Subjective Probability	90% Confidence Interval Lower range	90% Confidence Interval Upper range	Rand Prob Of Sub Prob	Quantitative Probability	distribution	LR and UR std.dev	LR and UR mean	(Financial impact) 90% CI of LR and UR lognormal rand distribution	Rand result of financial cost (zero when event did not occur)
1	cloud server breach	inventory	>24 months	0	0.2	0.8	0.2	$2,000,000.00	$ 3,000,000.00	0	5%	lognormal	0.123242	14.7114	$ 2,458,486.01	$ 2,298,351.63
2	supply chain disruption	ingredients	<12 months	0	0.8	0.2	0.1	$ 40,000.00	$ 60,000.00	0	7%	lognormal	0.123242	10.7994	$ 54,470.46	$ -
3	warehouse disruption	orders	<12 months	0.3	0.5	0.2	0.66	$ 70,000.00	$ 105,000.00	1	5%	lognormal	0.123242	11.359	$ 93,423.34	$ 98,735.79
4	warehouse disruption	Machine Failure	<18 months	0	0	1	0.1	$ 250,000.00	$ 380,000.00	0	1%	lognormal	0.127268	12.6386	$ 362,304.74	$ -
5	cloud server breach	supplier Information	>24 months	0.7	0.2	0.1	0.05	$ 70,000.00	$ 155,000.00	0	4%	lognormal	0.24162	11.5537	$ 95,763.21	$ -
6	warehouse disruption	Power outage	< 24 months	0	0	1	0.03	$ 90,000.00	$ 150,000.00	0	5%	lognormal	0.155266	11.663	$ 122,324.88	$ 85,315.10
7	supply chain disruption	Flooding	>36 months	0	0.1	0.9	0.07	$ 240,000.00	$ 500,000.00	0	5%	lognormal	0.223091	12.7554	$ 341,853.60	$ -
8	supply chain disruption	Draught	>48 months	0	0.4	0.6	0.02	$ 180,000.00	$ 260,000.00	0	4%	lognormal	0.11177	12.2846	$ 231,815.70	$ 211,443.98
				Average of all Subjective Probabilties			15.13%			Average Quantitative probabilty	4.45% (derived from 1000 simulations of each risk ID)					Total potential distruption cost $ 2,693,846.51

Figure 29: Results of a Quantitative Risk Yasai Simulation

6.4 Appendix IV

A SMART score was calculated from historical data of 10 key agricultural areas in the EU. As country participation can vary yearly, all data was used from the last applicable year and no data sources have more than a two-year report gap (Eurostats, 2022).

As SMART scoring involves subjective opinion of category importance and weight (Olsen & Wu, 2008), all decisions were assessed with product quality and supply chain safety as the benchmark. Calculating the SMART score on Excel required the following (Wk portfolio, 2021):

1. A Table must be created with data from the earliest available year with not more than a two-year report gap (Figure 30).

2. Each row in the category column must be given a subjective rank from 0-100, 0 being the worst and 100 being the best (Figure 31).

3. A subjective weight is given to each category, which is then standardized (Figure 32 & 33)

4. The standardized column weights are summed with the subjective row rankings (Figure 34 & 35), thus achieving the final weighted rank score.

	A	B	C	D	E	F	G	H
1	Country	Crop Output (Meuro)	Crop Price	Animal Output (Meuro)	Animal Price	Organic Crops (tonne)	Organic Livestock (head)	Disaster Count
2	France	€47,973.66	€128.30	€26,847.40	€112.80	692,243.00	860,308.00	236.00
3	Germany	€29,698.62	€129.30	€25,917.59	€116.50	0.00	861,272.00	139.00
4	Greece	€8,725.22	€156.10	€2,455.55	€125.80	152,118.00	163,066.00	131.00
5	Italy	€34,283.10	€124.30	€16,353.91	€113.70	968,425.00	397,187.00	210.00
6	Netherlands	€15,671.56	€118.70	€10,954.00	€113.50	19,591.00	76,069.00	54.00
7	Poland	€13,620.87	€131.10	€13,584.02	€117.20	315,269.00	31,102.00	106.00
8	Portugal	€6,072.62	€126.60	€3,053.82	€115.20	0.00	92,673.00	83.00
9	Romania	€15,028.32	€334.50	€4,245.42	€287.30	229,794.00	19,870.00	60.00
10	Spain	€34,999.84	€121.40	€20,478.57	€116.10	382,153.00	219,769.00	150.00
11	UK	€9,803.06	€164.40	€16,574.00	€150.10	129,297.00	300,788.00	N/A

Figure 30: Initial Eurostats Table

13	Country	Crop Output (Meuro)	Crop Price	Animal Output (Meuro)	Animal Price	Organic Crops (tonne)	Organic Livestock (head)	Disaster Count
14	**France**	**100.00**	**75.00**	**100.00**	**100.00**	**70.00**	**90.00**	**5.00**
15	Germany	60.00	70.00	95.00	75.00	5.00	100.00	50.00
16	Greece	10.00	40.00	15.00	55.00	25.00	25.00	55.00
17	**Italy**	**85.00**	**85.00**	**70.00**	**94.00**	**100.00**	**50.00**	**10.00**
18	Netherlands	40.00	100.00	50.00	95.00	0.00	10.00	100.00
19	Poland	30.00	60.00	60.00	70.00	40.00	5.00	70.00
20	Portugal	0.00	80.00	0.00	81.00	0.00	15.00	85.00
21	Romania	35.00	0.00	30.00	0.00	30.00	0.00	95.00
22	**Spain**	**90.00**	**90.00**	**85.00**	**76.00**	**50.00**	**35.00**	**40.00**
23	UK	15.00	30.00	75.00	30.00	20.00	40.00	0.00

Figure 31: Ranked Eurostats Table

Figure 32: Category Weights

Attributes	Weights	Standard Weights
Crop Output (Meuro)	35	=(M14/$M$21)*100
Crop Price	85	=(M15/$M$21)*100
Animal Output (Meuro)	40	=(M16/$M$21)*100
Animal Price	90	=(M17/$M$21)*100
Disaster %	70	=(M18/$M$21)*100
Organic Crops (tonne)	95	=(M19/$M$21)*100
Organic Livestock (head)	100	=(M20/$M$21)*100
Total:	=SUM(M14:M20)	=SUM(N14:N20)

Attributes	Weights	Standard Weights
Crop Output (Meuro)	35	6.79611650485437
Crop Price	85	16.504854368932
Animal Output (Meuro)	40	7.76699029126214
Animal Price	90	17.4757281553398
Disaster %	70	13.5922330097087
Organic Crops (tonne)	95	18.4466019417476
Organic Livestock (head)	100	19.4174757281553
Total:	515	100

Figure 33: Category Weight Results

13	Country	Crop Output (Meuro)	Crop Price	Animal Output (Meuro)	Animal Price	Organic Crops (tonne)	Organic Livestock (head)	Disaster Count	Total	Total II
14	**France**	**100.00**	**75.00**	**100.00**	**100.00**	**70.00**	**90.00**	**5.00**	**=SUMPRODUCT(B14:H14,$B$24:$H$24)**	**=I14/100**
15	Germany	60.00	70.00	95.00	75.00	5.00	100.00	50.00	=SUMPRODUCT(B15:H15,$B$24:$H$24)	=I15/100
16	Greece	10.00	40.00	15.00	55.00	25.00	25.00	55.00	=SUMPRODUCT(B16:H16,$B$24:$H$24)	=I16/100
17	**Italy**	**85.00**	**85.00**	**70.00**	**94.00**	**100.00**	**50.00**	**10.00**	**=SUMPRODUCT(B17:H17,$B$24:$H$24)**	**=I17/100**
18	Netherlands	40.00	100.00	50.00	95.00	0.00	10.00	100.00	=SUMPRODUCT(B18:H18,$B$24:$H$24)	=I18/100
19	Poland	30.00	60.00	60.00	70.00	40.00	5.00	70.00	=SUMPRODUCT(B19:H19,$B$24:$H$24)	=I19/100
20	Portugal	0.00	80.00	0.00	81.00	0.00	15.00	85.00	=SUMPRODUCT(B20:H20,$B$24:$H$24)	=I20/100
21	Romania	35.00	0.00	30.00	0.00	30.00	0.00	95.00	=SUMPRODUCT(B21:H21,$B$24:$H$24)	=I21/100
22	**Spain**	**90.00**	**90.00**	**85.00**	**76.00**	**50.00**	**35.00**	**40.00**	**=SUMPRODUCT(B22:H22,$B$24:$H$24)**	**=I22/100**
23	UK	15.00	30.00	75.00	30.00	20.00	40.00	0.00	=SUMPRODUCT(B23:H23,$B$24:$H$24)	=I23/100
24	St. Weights	=N14	=N15	=N16	=N17	=N19	=N20	=N18		

Figure 32: Total Weighted Score Formula

13	Country	Crop Output (Meuro)	Crop Price	Animal Output (Meuro)	Animal Price	Organic Crops (tonne)	Organic Livestock (head)	Disaster Count	Total	Total II
14	**France**	**100.00**	**75.00**	**100.00**	**100.00**	**70.00**	**90.00**	**5.00**	**7548.54**	**75.49**
15	Germany	60.00	70.00	95.00	75.00	5.00	100.00	50.00	6325.24	63.25
16	Greece	10.00	40.00	15.00	55.00	25.00	25.00	55.00	3500.00	35.00
17	**Italy**	**85.00**	**85.00**	**70.00**	**94.00**	**100.00**	**50.00**	**10.00**	**7118.45**	**71.18**
18	Netherlands	40.00	100.00	50.00	95.00	0.00	10.00	100.00	5524.27	55.24
19	Poland	30.00	60.00	60.00	70.00	40.00	5.00	70.00	4669.90	46.70
20	Portugal	0.00	80.00	0.00	81.00	0.00	15.00	85.00	4182.52	41.83
21	Romania	35.00	0.00	30.00	0.00	30.00	0.00	95.00	2315.53	23.16
22	**Spain**	**90.00**	**90.00**	**85.00**	**76.00**	**50.00**	**35.00**	**40.00**	**6231.07**	**62.31**
23	UK	15.00	30.00	75.00	30.00	20.00	40.00	0.00	2849.51	28.50
24	St. Weights	6.80	16.50	7.77	17.48	18.45	19.42	13.59		

Figure 33: Total Weighted Score Results

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