2022

EXECUTIVE SUMMARY

GROUP 5

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Executive Summary

This executive summary was created for Pampered pets and it is a sequel to the risk identification report. It is divided into six sections: potential risks, methodology, supply chain analysis, quality analysis, discussion, and Business Continuity/Disaster Recovery (BC/DR).

1. Potential risks

1.1 Potential risks

Rathore, Thakkar, and Jha (2017: 1275) have provided an extensive list of authors that studied supply chain risks (included in Appendix A). This executive summary follows the reasoning of Olson and Wu (2017: 31), which states that “the first focus is on the purpose of the business - the product”. Furthermore, the main characteristics to consider for a product are quality, meeting specifications, cost, and delivery (*Ibid*). Table 1.1 resumes Olson and Wu’s (2017: 32) table on risks’ value hierarchy in supply chain, plus the fourth column presents criteria that were chosen for the quantitative risk analysis.

Table 1.1 Value hierarchy for supply chain risk and criteria

Second Level	Third Level	Criteria
Quality		Work force ability to produce quality product
Cost	Price	Expected cost per unit
	Investment required	Acquisition and building cost
	Holding cost/service level trade-off	
On-time delivery		
Manufacturability	Outsourcing opportunity cost/risk trade-off	
	Ability to expand production	Expandability
	New technology breakthrough	
	Product obsolescence	
Deliverability	Transportation system	Transportation system reliability
	Insurance cost	Insurance structure
Communication	IS breakdown	Information system linkage
	Distorted information leading to bullwhip effect	
	Forecast accuracy	
	Integration	
	Viruses/bugs/hackers	
Flexibility	Agility of sources	Agility to change in demand
	Ability to replace sources as needed	
Safety	Plant disaster	
Labour	Risk of strikes, disputes	Work force propensity for labour dispute
Government	Customs and regulations	
		Governmental stability
War and Terrorism		
Overall economy	Economic downturn	
	Exchange rate risk	
Specific regional economy	Labour cost influence	
	Changes in competitive advantage	
		Tax structure
Specific market	Price fluctuation	
	Customer demand volatility	
	Customer payment	
	Uncontrollable disaster	Risk of disaster
	Diseases, epidemics	

1.2 Raw data

To execute a quantitative risk analysis, there is a need to possess valid data. Olson and Wu (2017) provided data for 10 options of potential sites for expanding production in new facilities. The locations are evaluated on 12 criteria that represent risks to the supply chain. Table 1.2 presents the associated data found in Olson and Wu (2017: 36).

Table 1.2 Plant siting data

Location	Acquisition and building cost	Expected cost per unit	Work force ability to produce quality product	Work force propensity for labor dispute	Transportation system reliability	Expandability	Agility to change in demand	Information system linkage	Insurance structure	Tax structure	Governmental stability	Risk of disaster
Alabama	$20 m	$5.50	High	Moderate	0.30	Good	2 mos	Very good	$400	$1000	Very good	Hurricane
Utah	$23 m	$5.60	High	Good	0.28	Poor	3 mos	Very good	$350	$1200	Very good	Drought
Oregon	$24 m	$5.40	High	Low	0.31	Moderate	1 mo	Very good	$450	$1500	Good	Flood
Mexico	$18 m	$3.40	Moderate	Moderate	0.25	Good	4 mos	Good	$300	$1800	Fair	Quake
Crete	$21 m	$6.20	High	Low	0.85	Poor	5 mos	Good	$600	$3500	Good	Quake
Indonesia	$15 m	$2.80	Moderate	Moderate	0.70	Fair	3 mos	Poor	$700	$800	Fair	Monsoon
Vietnam	$12 m	$2.50	Good	Good	0.75	Good	2 mos	Good	$600	$700	Good	Monsoon
India	$13 m	$3.00	Good	Good	0.80	Good	3 mos	Very good	$700	$900	Very good	Monsoon
China #1	$17 m	$3.10	Good	Good	0.60	Fair	2 mos	Very good	$800	$1200	Very good	Quake
China #2	$15 m	$3.20	Good	Good	0.55	Good	3 mos	Very good	$500	$1300	Very good	Quake

2. Methodology

2.1 Quantitative risk modelling approach

This executive summary runs quantitative risk modelling on two aspects: supply chain's analysis and quality's analysis. For the first analysis, two different variances for the Multiple-Criteria Decision Making (MCDM) are used to fortify the results' validity of adding new locations to the supply chain security. For the quality analysis, probabilities are calculated to establish if adding new sites might have an impact on the product, mainly the level of quality and the level of resilience to maintain the quality.

a) MCDM for supply chain analysis

- Simple Multiattribute Rating Theory (SMART):

  "The SMART method assigns the most important criterion a value of 1.0, and then assesses relative importance by considering the proportional worth to the best on the most important criterion" (Olson and Wu, 2017: 37).

- Risk assessment using Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

  "This method is based on the concept that the chosen alternative should have the shortest distance to Positive Ideal Solution (PIS) (the solution which minimises the cost criteria and maximises the benefit criteria) and the farthest distance to Negative Ideal Solution (NIS)" (Nădăban, Dzitac, and Dzitac, 2016: 826).

b) Probability from quality

- Conditional Probability

  This method evaluates the possibility of an outcome to happen, based on the existence of a previous outcome.

- Diachronic Bayes Theorem

  The Diachronic interpretation of Bayes Theorem gives us a way to update the probability of a hypothesis, considering some bodies of data. Sometimes, we can compute the prior based on background information.

When the set of hypotheses is mutually exclusive and collectively exhaustive, you can multiply the likelihoods by any factor, if you apply the same factor to the entire collective.

2.2 Standardised scores and prioritised criteria

Before starting the modelling there are two steps that need to be executed: The standardisation of the scoring for the selected locations and the prioritisation of the criteria. Using Olson and Wu's (2017: 38) data, table 2.1 provides standardised scoring for the selected criteria and table 2.2 shows the order of criteria desired to be used in the modelling.

Table 2.1 Standardised scores for plant siting data

Location	Acquisition and building cost		Expected cost per unit		Work force ability to produce quality product		Work force propensity for labor dispute		Transportation system reliability		Expandability		Agility to change in demand		Information system linkage		Insurance structure		Tax structure		Governmental stability		Risk of disaster	
Alabama	$20 m	0.60	$5.50	0.40	High	0.90	Moderate	0,3	0.30	0.90	Good	1	2 mos	0.8	Very good	1.0	$400	0,7	$1000	0,8	Very good	1.0	Hurricane	0.5
Utah	$23 m	0.30	$5.60	0.35	High	0.90	Good	0,8	0.28	0.95	Poor	0	3 mos	0.6	Very good	1.0	$350	0,8	$1200	0,7	Very good	1.0	Drought	0.9
Oregon	$24 m	0.10	$5.40	0.45	High	0.90	Low	0,1	0.31	0.86	Moderate	0,5	1 mo	1.00	Very good	1.0	$450	0,6	$1500	0,6	Good	0.8	Flood	0.8
Mexico	$18 m	0.70	$3.40	0.80	Moderate	0.40	Moderate	0,3	0.25	1.00	Good	1	4 mos	0.4	Good	0.7	$300	1	$1800	0,4	Fair	0.4	Quake	0.4
Crete	$21 m	0.50	$6.20	0.20	High	0.90	Low	0,1	0.85	0.30	Poor	0	5 mos	0.2	Good	0.7	$600	0,5	$3500	0	Good	0.8	Quake	0.3
Indonesia	$15 m	0.80	$2.80	0.90	Moderate	0.40	Moderate	0,3	0.70	0.55	Fair	0,3	3 mos	0.6	Poor	0.0	$700	0,3	$800	0,9	Fair	0.4	Monsoon	0.7
Vietnam	$12 m	0.90	$2.50	0.95	Good	0.60	Good	0,8	0.75	0.50	Good	1	2 mos	0.8	Good	0.7	$600	0,5	$700	1	Good	0.8	Monsoon	0.7
India	$13 m	0.85	$3.00	0.87	Good	0.60	Good	0,8	0.80	0.40	Good	1	3 mos	0.6	Very good	1.0	$700	0,3	$900	0,85	Very good	1.0	Monsoon	0.7
China #1	$17 m	0.75	$3.10	0.85	Good	0.60	Good	0,8	0.60	0.60	Fair	0,3	2 mos	0.8	Very good	1.0	$800	0,1	$1200	0,7	Very good	1.0	Quake	0.8
China #2	$15 m	0.80	$3.20	0.83	Good	0.60	Good	0,8	0.55	0.70	Good	1	3 mos	0.6	Very good	1.0	$500	0,55	$1300	0,65	Very good	1.0	Quake	0.4

Note that for the Disaster criterion, specifics for each locale can lead to different ratings for the same major risk category

Table 2.2 Prioritised criteria

	Criterion	Rating	Proportion
1.	Work force ability to produce quality product	1	0,167
2.	Expected cost per unit	0,8	0,133
3.	Risk of disaster	0,7	0,117
4.	Agility to change in demand	0,65	0,108
5.	Transportation system reliability	0,6	0,100
6.	Expandability	0,58	0,097
7.	Governmental stability	0,4	0,067
8.	Tax structure	0,35	0,058
9.	Insurance structure	0,32	0,053
10.	Acquisition and building cost	0,3	0,050

11.	Information system linkage	0,2	0,033
12.	Work force ability to produce quality product	0,1	0,017
Total		6	1,000

2.3 Assumptions

a) Financial constraints are not an issue

b) Pampered pets are exploring expanding in one or more of the 10 sites suggested above

c) Pampered pets agrees with the criteria selected for the quantitative risk's analysis

d) Pampered pets agrees with the order decided for the criteria selected for the quantitative risk's analysis

e) Olson and Wu's (2017: 36) data are still valid

f) Any assumed probabilities and subsequent calculations are from a perspective from an "ideal world scenario"

3. Supply chain analysis

3.1 Calculations

a) SMART modelling

Table 3.1 shows the previously agreed order of the criteria, as well as the ranking values, based on Olson and Wu's data (2017: 37-38), and the proportions for each criterion, as they are the results of the ranking on the total value of ranking. Table 3.2 represents the original raw data, the standardized scoring, and the weight, which is the result of the standardized score multiplied by the proportion of each criterion. The last column shows the total score of each location.

Table 3.1 SMART modelling

Location	Acquisition and building cost			Expected cost per unit			Work force ability to produce			Work force propensity for			Transportation system			Expandability			Agility to change in demand		
	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight
Alabama	$20 m	0,6	0,030	$5.50	0,4	0,053	High	0,9	0,150	Moderate	0,3	0,005	0.30	0,9	0,090	Good	1	0,097	2 mos	0,8	0,087
Utah	$23 m	0,3	0,015	$5.60	0,35	0,047	High	0,9	0,150	Good	0,8	0,013	0.28	0,95	0,095	Poor	0	0,000	3 mos	0,6	0,065
Oregon	$24 m	0,1	0,005	$5.40	0,45	0,060	High	0,9	0,150	Low	0,1	0,002	0.31	0,86	0,086	Moderate	0,5	0,048	1 mo	1	0,108
Mexico	$18 m	0,7	0,035	$3.40	0,8	0,107	Moderate	0,4	0,067	Moderate	0,3	0,005	0.25	1	0,100	Good	1	0,097	4 mos	0,4	0,043
Crete	$21 m	0,5	0,025	$6.20	0,2	0,027	High	0,9	0,150	Low	0,1	0,002	0.85	0,3	0,030	Poor	0	0,000	5 mos	0,2	0,022
Indonesia	$15 m	0,8	0,040	$2.80	0,9	0,120	Moderate	0,4	0,067	Moderate	0,3	0,005	0.70	0,55	0,055	Fair	0,3	0,029	3 mos	0,6	0,065
Vietnam	$12 m	0,9	0,045	$2.50	0,95	0,127	Good	0,6	0,100	Good	0,8	0,013	0.75	0,5	0,050	Good	1	0,097	2 mos	0,8	0,087
India	$13 m	0,85	0,043	$3.00	0,87	0,116	Good	0,6	0,100	Good	0,8	0,013	0.80	0,4	0,040	Good	1	0,097	3 mos	0,6	0,065
China #1	$17 m	0,75	0,038	$3.10	0,85	0,113	Good	0,6	0,100	Good	0,8	0,013	0.60	0,6	0,060	Fair	0,3	0,029	2 mos	0,8	0,087
China #2	$15 m	0,8	0,040	$3.20	0,83	0,111	Good	0,6	0,100	Good	0,8	0,013	0.55	0,7	0,070	Good	1	0,097	3 mos	0,6	0,065

Location	Information system linkage			Insurance structure			Tax structure			Governmental stability			Risk of disaster			Total	Rank
	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight	Raw data	Standard ized	Weight		
Alabama	Very good	1	0,033	$400	0,7	0,037	$1000	0,8	0,047	Very good	1	0,067	Hurricane	0,5	0,058	0,754	2
Utah	Very good	1	0,033	$350	0,8	0,043	$1200	0,7	0,041	Very good	1	0,067	Drought	0,9	0,105	0,674	7
Oregon	Very good	1	0,033	$450	0,6	0,032	$1500	0,6	0,035	Good	0,8	0,053	Flood	0,8	0,093	0,706	5
Mexico	Good	0,7	0,023	$300	1	0,053	$1800	0,4	0,023	Fair	0,4	0,027	Quake	0,4	0,047	0,627	8
Crete	Good	0,7	0,023	$600	0,5	0,027	$3500	0	0,000	Good	0,8	0,053	Quake	0,3	0,035	0,393	10
Indonesia	Poor	0	0,000	$700	0,3	0,016	$800	0,9	0,053	Fair	0,4	0,027	Monsoon	0,7	0,082	0,558	9
Vietnam	Good	0,7	0,023	$600	0,5	0,027	$700	1	0,058	Good	0,8	0,053	Monsoon	0,7	0,082	0,762	1
India	Very good	1	0,033	$700	0,3	0,016	$900	0,85	0,050	Very good	1	0,067	Monsoon	0,7	0,082	0,721	3
China #1	Very good	1	0,033	$800	0,1	0,005	$1200	0,7	0,041	Very good	1	0,067	Quake	0,8	0,093	0,679	6
China #2	Very good	1	0,033	$500	0,55	0,029	$1300	0,65	0,038	Very good	1	0,067	Quake	0,4	0,047	0,710	4

Table 3.2 Results from the SMART modelling

Location	Score	Rank
Vietnam	0,762	1
Alabama	0,754	2
India	0,721	3
China #2	0,710	4
Oregon	0,706	5
China #1	0,679	6
Utah	0,674	7
Mexico	0,629	8
Indonesia	0,562	9
Crete	0,463	10

b) Fuzzy TOPSIS modelling

Table 3.3 reuses the order of the criteria plus some sub-groups ranking for the most important criteria and the least important criteria. It gives more weight to the most important criteria. The values in the second column are based on Olson and Wu's data (2017: 42). The last column shows results from the total value of based on 1st divided by the based-on 1st's value.

Table 3.4 presents the original raw data, the standardised scoring, and the weight, which is the result of the standardised score multiplied by the proportion of each criterion. However, only the best location in each criterion can get the weight to be multiplied by its standardised score. The last column shows the total score of each location.

<u>Table 3.3 Fuzzy TOPSIS modelling</u>

Location	Acquisition and building cost			Expected cost per unit			Work force ability to produce quality product			Work force propensity for labor dispute			Transportation system reliability			Expandability			Agility to change in demand		
	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight
Alabama	$20 m	0,6		$5.50	0,4		High	0,9	0,115	Moderate	0,3		0.30	0,9		Good	1	0,096	2 mos	0,8	
Utah	$23 m	0,3		$5.60	0,35		High	0,9	0,115	Good	0,8	0,025	0.28	0,95		Poor	0		3 mos	0,6	
Oregon	$24 m	0,1		$5.40	0,45		High	0,9	0,115	Low	0,1		0.31	0,86		Moderate	0,5		1 mo	1	0,115
Mexico	$18 m	0,7		$3.40	0,8		Moderate	0,4		Moderate	0,3		0.25	1	0,115	Good	1	0,096	4 mos	0,4	
Crete	$21 m	0,5		$6.20	0,2		High	0,9	0,115	Low	0,1		0.85	0,3		Poor	0		5 mos	0,2	
Indonesia	$15 m	0,8		$2.80	0,9		Moderate	0,4		Moderate	0,3		0.70	0,55		Fair	0,3		3 mos	0,6	
Vietnam	$12 m	0,9	0,034	$2.50	0,95	0,121	Good	0,6		Good	0,8	0,025	0.75	0,5		Good	1	0,096	2 mos	0,8	
India	$13 m	0,85		$3.00	0,87		Good	0,6		Good	0,8	0,025	0.80	0,4		Good	1	0,096	3 mos	0,6	
China #1	$17 m	0,75		$3.10	0,85		Good	0,6		Good	0,8	0,025	0.60	0,6		Fair	0,3		2 mos	0,8	
China #2	$15 m	0,8		$3.20	0,83		Good	0,6		Good	0,8	0,025	0.55	0,7		Good	1	0,096	3 mos	0,6	

Location	Information system linkage			Insurance structure			Tax structure			Governmental stability			Risk of disaster			Total	Rank
	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight	Raw data	Standardized scores	Weight		
Alabama	Very good	1	0,032	$400	0,7		$1000	0,8		Very good	1	0,076	Hurricane	0,5		0,318	3
Utah	Very good	1	0,032	$350	0,8		$1200	0,7		Very good	1	0,076	Drought	0,9	0,115	0,363	1
Oregon	Very good	1	0,032	$450	0,6		$1500	0,6		Good	0,8		Flood	0,8		0,261	4
Mexico	Good	0,7		$300	1	0,051	$1800	0,4		Fair	0,4		Quake	0,4		0,261	4
Crete	Good	0,7		$600	0,5		$3500	0		Good	0,8		Quake	0,3		0,115	9
Indonesia	Poor	0		$700	0,3		$800	0,9		Fair	0,4		Monsoon	0,7		0,000	10
Vietnam	Good	0,7		$600	0,5		$700	1	0,064	Good	0,8		Monsoon	0,7		0,340	2
India	Very good	1	0,032	$700	0,3		$900	0,85		Very good	1	0,076	Monsoon	0,7		0,229	6
China #1	Very good	1	0,032	$800	0,1		$1200	0,7		Very good	1	0,076	Quake	0,8		0,134	8
China #2	Very good	1	0,032	$500	0,55		$1300	0,65		Very good	1	0,076	Quake	0,4		0,229	6

Table 3.4 Result from the Fuzzy TOPSIS modelling

Location	Score	Rank
Utah	0,363	1
Vietnam	0,340	2
Alabama	0,318	3
Oregon	0,261	4
Mexico	0,261	4
India	0,229	6
China #2	0,229	6
China #1	8,000	8
Crete	0,115	9
Indonesia	0,000	10

3.2 Results

After running the two MADMs, it is apparent that some locations are performing better than others. However, there is no consensus on a clear winner, so there is a need to proportionally evaluate their performance. For this part, instead of ranking the best location with a value of 1, and the worst with a value of 10, a reverse ranking was produced; the best location receives the value 9 and the worst, the value 0. Table 3.7 presents the new rankings according to the results and the reverse score for each location. Graphic 3.1 illustrates the average for each location according to their scores. Table 3.8 illustrates the best locations for a potential expansion in new sites of the supply chain.

Table 3.7 Ranking according to reverse score

Location	SMART method	Fuzzy TOPSIS method	Average	Ranking
Alabama	8	7	7,50	2
Utah	3	9	6,00	3
Oregon	5	6	5,50	4
Mexico	2	5	3,50	7
Crete	0	1	0,50	9
Indonesia	1	0	0,50	10
Vietnam	9	8	8,50	1
India	7	4	5,50	4
China #1	4	2	3,00	8
China #2	6	4	5,00	6

Graphic 3.1 Ranking according to reverse score

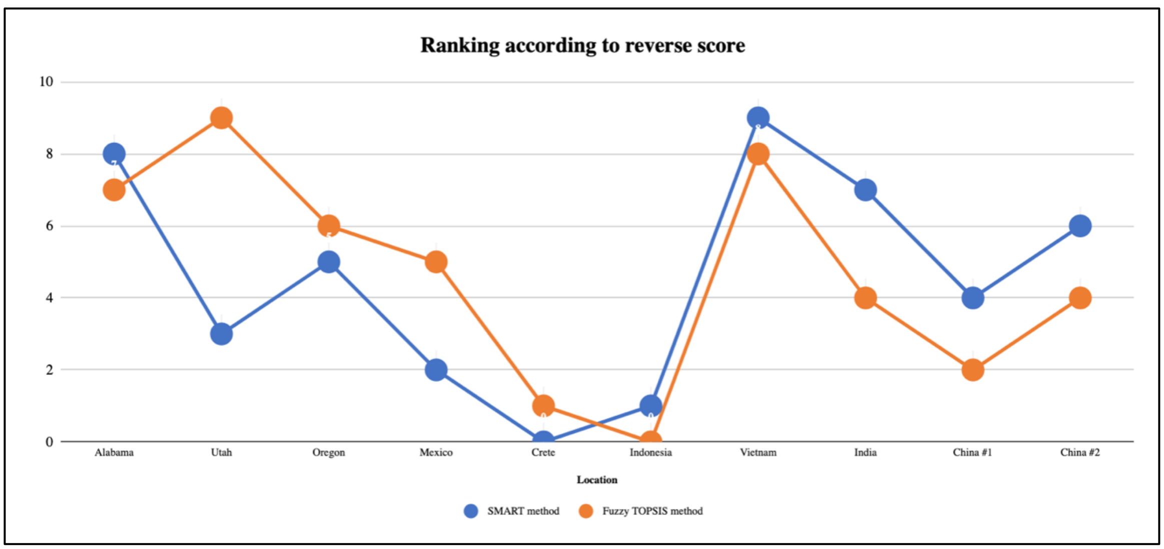

Table 3.8 Final result's ranking of the best sites

Rank	Location	Average
Best	Vietnam	8,50
2nd	Alabama	7,50
3rd	Utah	6,00
Correct	India + Oregon	5,50
Passable	China #2	5,00

4. Quality analysis

4.1 Calculations

a) Adding new sites – impact on level of quality

For the quality analysis the executive summary presents some probability calculations for two scenarios. Considering that Vietnam was the best site for expansion (according to the previous analysis) and that its standardised data for quality is 60% versus 90% for Alabama, Utah, or Oregon, the first scenario includes Vietnam as the first site, where the second scenario puts Vietnam at the fourth location. Table 4.1 shows the results for both scenarios. Note that calculation stops when the result reaches below 50%, which would indicate a change in the quality.

<u>Table 4.1 Results of adding new sites on the level of quality</u>

	Scenario 1: Vietnam as the first site					Scenario 2: Vietnam as the fourth site				
	Location	p(D|H) [Likelihood]	Proportion p(H) [prior]	Probability p(H)p(D|H)	Result p(D|H)	Location	p(D|H) [Likelihood]	Proportion p(H) [prior]	Probability p(H)p(D|H)	Result p(D|H)
1st site	Vietnam	60%	50%	(60)*100	60%	Alabama	90%	50%	(90)*100	90%
2nd site	Alabama	90%	25%	(60)*100+(90)*50	52,50%	Utah	90%	25%	(90)*100+(90)*50	67,50%
3rd site	Utah	90%	12,50%	(60)*100+(90)*50+(90)*	42,50%	Oregon	90%	12,50%	(90)*100+(90)*50+(90)*25	52,50%
4th site	Oregon	90%	6,25%			Vietnam	60%	6,25%	(90)*100+(90)*50+(90)*25+(60)*12,5	41,25%

b) Building resilience on the level of quality

The second aspect of quality analysed is the resilience level for the products' quality. Considering the results from the previous analysis, Vietnam is excluded from the following Bayesian's analysis, preferring the American sites, with 90% of chance of not change in the quality. Table 4.1

shows the Bayes theorem calculations, whereas Graphic 4.1 presents the resilience level increasing as new sites are added to the equation.

This is calculated using a simple formula (Downey, 2013: 23):

$$p(H|D) = \frac{p(H)p(D|H)}{p(D)}$$

Table 4.1 Result of adding new sites on building the resilience of quality

Case	p(H) [Prior]	p(D|H) Likelihood]	p(H)p(D|H)	p(H|D) [Result]
Alabama	0.5	90	45	0.9
	0.5	10	5	0.1
Utah	0.5	(90)(90)	162	0.987804878
	0.5	(10)(10)	2	0.012195122
Oregon	0.5	(90)(90)(90)	14580	0.998630137
	0.5	(10)(10)(10)	20	0.001369863

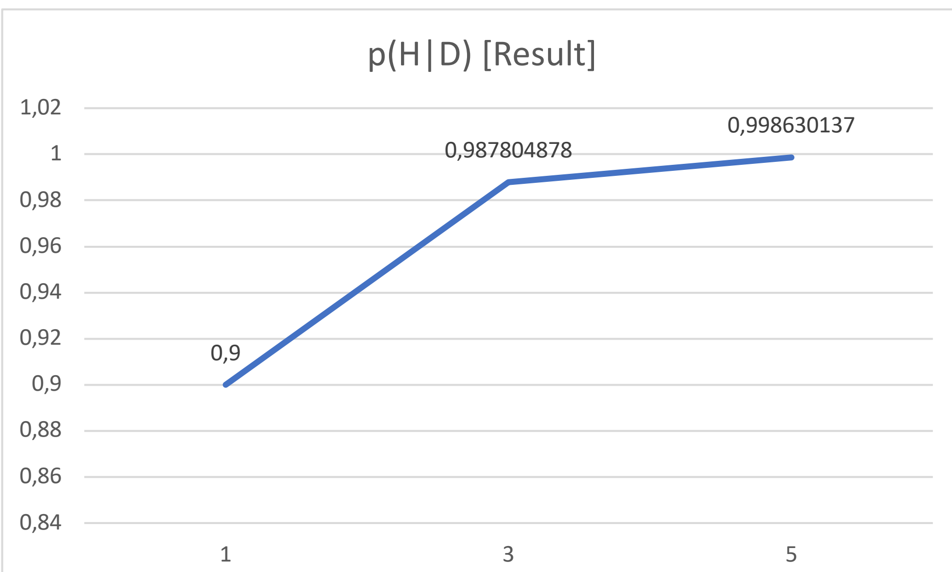

Figure 1: Increase in resilience with each new added site.

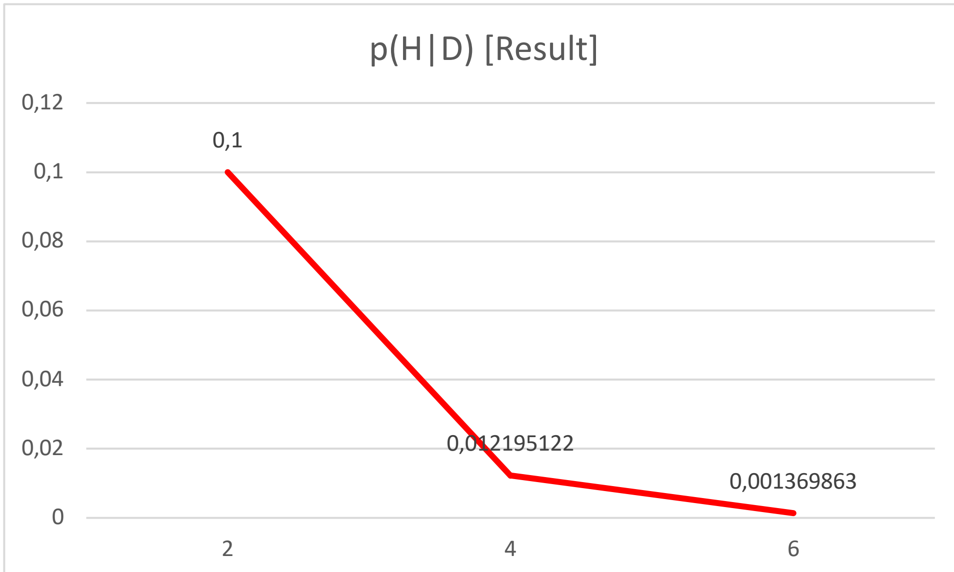

Figure 2: Reduction in fragility of supply chain with each added site

4.2 Results

As table 4.1 shows, if Vietnam is the first site to expand to, only one other site can be added to the supply chain, as the third site brings the probability to 42,5%, meaning there is more than 50% chance that the quality level would change. Comparatively, if Vietnam is the fourth site's option, there can be three sites to expand to, before falling under 50%, which would be Alabama, Utah, and Oregon. Additionally, the analysis on the resilience to maintain the level of quality shows that the more there are locations, the higher the chance to build resilience.

5. Discussion

5.1 Summary of results

After the supply chain analysis, it is evident that six strong sites have been identified to expand to, while ensuring the security of the global supply chain: Vietnam, Alabama, Utah, Oregon, India, and China #2. Following the quality analysis, it is evident that excluding Vietnam from the potential expansion sites ensures that Pampered Pets has a better chance to maintain their high-quality level of products.

5.2 Recommendations

As the supply chain and quality analysis demonstrates, Alabama, Utah, and Oregon should be considered as potential sites where to establish expanding facilities. According to the analysis, those locations ensure that supply chain security and quality would not be impacted negatively. However, according to the original raw data, an eye should be kept on some aspects for the American sites: acquisition and building cost, expected cost per unit, work force propensity for labour dispute, and expandability.

6. Business Continuity/Disaster Recovery (DR)

6.1 Introduction

This disaster recovery strategy enables both business continuity, which is concerned with the continuation of business activities in case of adverse events, and disaster recovery, which is focused on restoring access and infrastructure after a disaster. A resilient system needs to be developed to address both aspects and ensure the required uptime for the online shop as well as risks by local disasters in the areas identified in the analysis above.

6.2 Requirements

The business impact analysis has demonstrated that the online shop is a Critical Business Function (CBF) which should be available on a 24/7/365 basis with a recovery time objective (RTO) and a recovery point objective (RPO) of 1 minute as illustrated below:

Figure 3 Illustration of disaster recovery requirements

6.3 Solution Description

To address the stringent requirements, a warm standby multi cloud architecture which foresees mirroring data, and a failover mechanism is proposed. Such an architecture is typical for responding to stringent RTO and RPO requirements

(Alhazmi & Malaiya, 2013). Implementing DR in the cloud increases resilience but using a single cloud vendor comes with security challenges as there is reliance on the same infrastructure issues, software stacks and organisational failures, as well as the potential for vendor lock-in (Alshammari et al., 2017). All these aspects can be mitigated by utilising services from different cloud service providers to ensure additional resilience, vendor independence, and mechanisms for ensuring data security (Gu et al., 2014).

The solution proposed is vendor agnostic meaning that it can be implemented with any combination of reliable cloud vendors, examples could include Amazon, Google, and Microsoft. The proposed architecture consists initially of the primary active system (illustrated in green), hosting the online shop running in a cloud service provider (CSP) with dynamic scalability indicated in yellow as additional capacity is provisioned when necessary to respond to additional demand. The green system runs in the US region to ensure low latency and system performance.

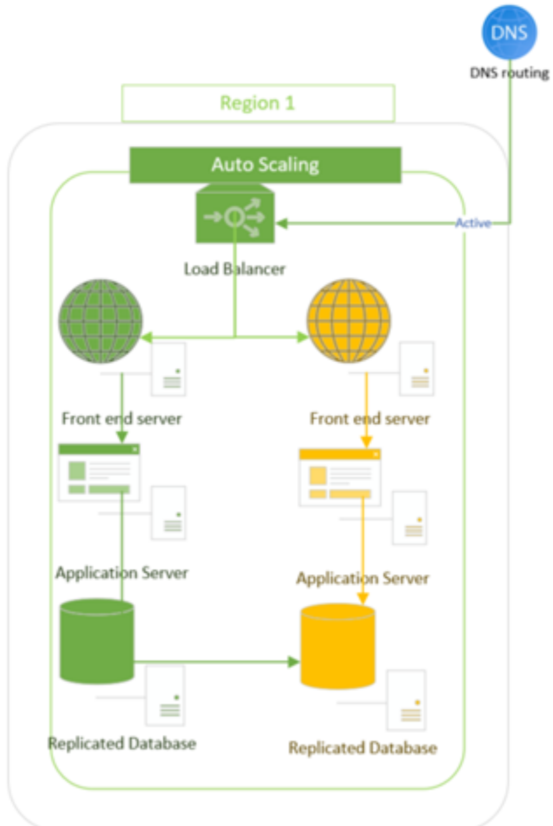

Figure 4 Primary production system (green system)

In case of a disaster, traffic will be routed to the warm standby system (illustrated below in blue), which operates in a different CSP and a different region. The blue system is always up and running but to save costs, it is only running with the minimum instances and services required to provide initial functionality in case of a disaster affecting the green system. Depending on the demand in place, the blue system will scale up dynamically to provide the necessary capacity. The user will not notice any impact in terms of functionality as the data will exist in the system already. Depending on the initial load placed on the blue system there might be a short performance penalty as the blue system scales up automatically to respond to the existing demand. The blue system runs in non-us region to mitigate the risk of a local disaster affecting both systems.

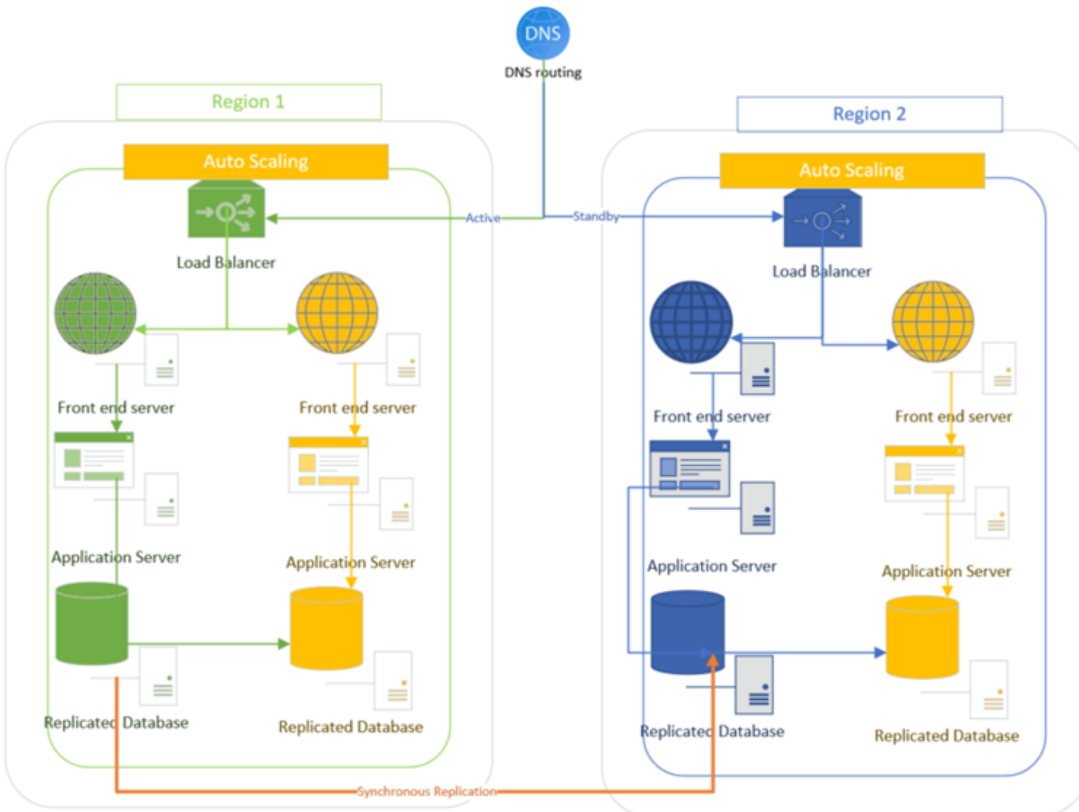

Figure 5 Illustration of the primary system (green) and secondary failover system (blue) including synchronous replication

This failover mechanism ensures business continuity and near zero downtime and data loss. Such as seamless transition is made possible through a mechanism of synchronous replication of the database which addresses the issue of replication latency in the cloud and ensures that the required RPO value is met (Alshammari et al., 2017). The synchronous replication mechanism is based on a concept employing three cloud providers like the concept proposed by Gu et al. (Gu et al., 2014). Data is replicated to ensure redundancy and security as data can be dispersed between CSPs and encrypted if necessary. The normal operation of the green system is illustrated below:

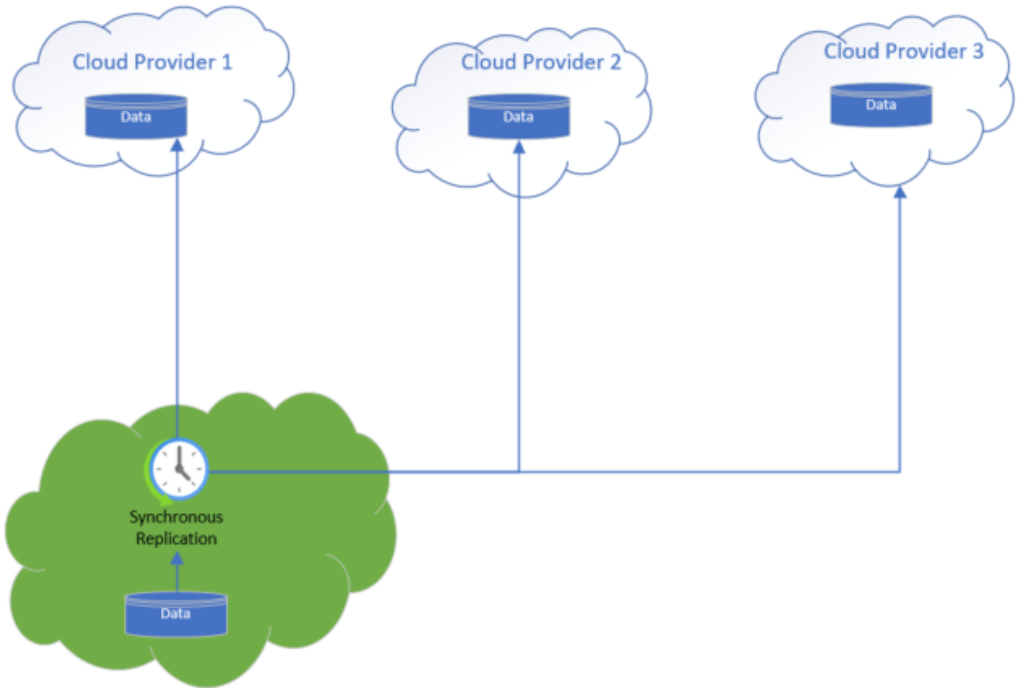

Figure 6 Synchronous replication mechanism from primary system to three cloud providers

Data is continuously synchronised to the failover (blue) system and therefore in case of a disaster data will be already available in the blue system to ensure business continuity:

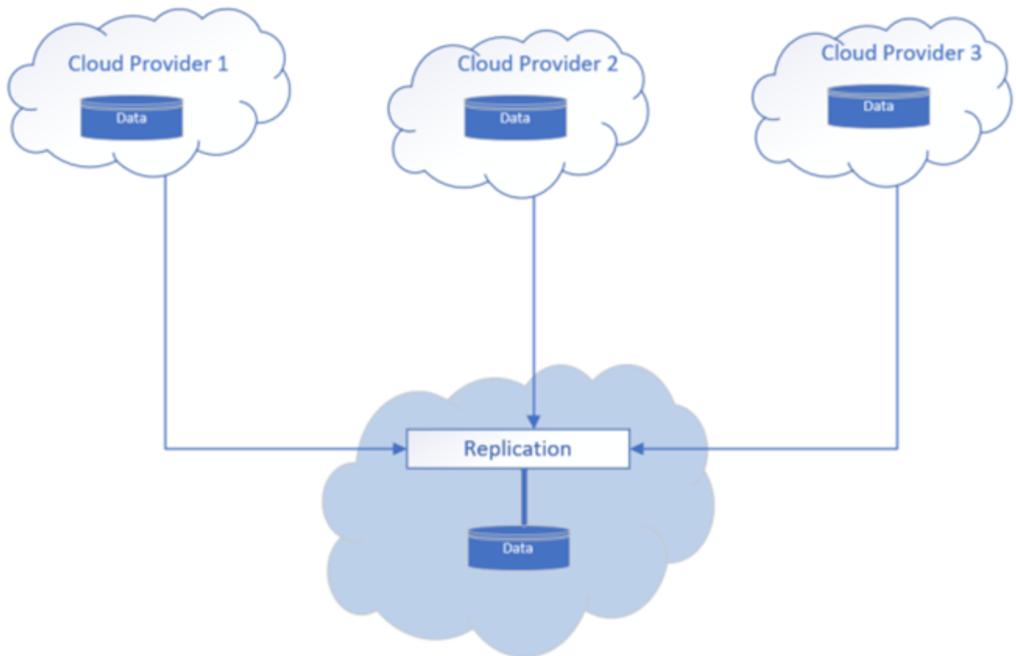

Figure 7 Synchronous replication to the secondary system

6.4 Vendor lock-in Considerations

CSPs offer vendor specific services based on proprietary technologies with specifications that vary from vendor to vendor including custom APIs and services. This often leads to a situation in which cloud users become dependent on a certain vendor for services due to lack of interoperability between providers and technical incompatibilities (Opara-Martins et al., 2014). In the multi cloud solution design proposed above the risk of vendor lock-in is mitigated by design as the integration and interoperability between CSPs is solved at the design stage by proposing a system which is interoperable in its concept by relying on basic infrastructure such as database replications instead of custom services and APIs provided by vendors.

6.5 Local BC/DR Design

To mitigate the local risks identified in the quantitative analysis, additional provisions are made for addressing local disasters. In the event of a disaster affecting the potentials locations in the geographical region of the United States, the online shop will be available, but potentially not able to reach the affected areas. This risk can be mitigated by relying on national infrastructure and using LTE modems to connect to the internet in case of local outages, or using commercial satellite internet providers such as Viasat, HughesNet, Skycasters or Starlink. Diesel generators can be used to ensure adequate power supply in case of outages.

Figure 8 Local BC/DR provisions to enable connectivity in case of local disasters

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Appendix A

Author(s)	Problem settings	Approach F/T	S	R	Risks covered	Techniques used	Description
Dong and Cooper (2016)	An orders-of-magnitude AHP supply chain risk assessment framework	✓			1. Earthquake 2. Financial Crisis 3. Supply interruptions 4. Inaccurate demand forecasts 5. Technology upgrades 6. Machine breakdowns	Orders-of-magnitude and AHP	Proposed the risk assessment framework to identify and analyse the risk and provided an effective proactive risk management tool which helps the researchers and managers to assess the risks
Heckmann *et al.* (2015)	A critical review of supply chain risk – definition, measure and modelling			✓	1. Network risk Location Assessment Stakeholder 2. Process risk SCOR (Supply chain operations reference-model) Organisational functions Logistical Operations	Review paper	Reviewed the existing methodologies for quantitative SCRM. Authors focused on supply chain risk definition and critical concepts
Ho *et al.* (2015)	Supply chain risk management: a literature review			✓	1. Macro risk factors 2. Micro risk factors 3. Demand risk factors 4. Manufacturing risk 5. factors Supply risk factors	Review paper	Reviewed and synthesised the extensive literature of SCRM
Radivojevic and Gajovic (2014)	Supply chain risk modelling by AHP and fuzzy-AHP methods	✓			1. Operational/technological risk 2. Economy/competition risk 3. Natural/hazard risk 4. Social risk 5. Legal/political risk	AHP and fuzzy-AHP	Developed the model which will help the managers and practitioners to make an effective decision and reduce the overall risk in the supply chain
Samvedi *et al.* (2013)	Quantification of risk in supply chain	✓	✓		1. Environmental risk, 2. Process risk, 3. Supply risk and 4. Demand risk	Fuzzy-AHP and fuzzy-TOPSIS	To deal with subjectivity and uncertainty, this paper provides a risk index for quantification of the risk in the supply chain
Diabat *et al.* (2012)	Supply chain risk management and its mitigation in a food industry	✓			1. Macro level risks 2. Demand management risks 3. Supply management risks 4. Product/service management risks	ISM modelling	Identified and ranked the various risks affected to food supply chain, and determined the interactions among identified risks. Based on the categorisation risk mitigation strategies are adopted
Rao and Goldsby (2009)	SCRM review			✓	1. Environmental factors 2. Industry factors 3. Organisational factors 4. Problem-specific factors and 5. Decision-maker related factors	Review paper	Proposed a typology of risk which allows identification of vulnerabilities within the supply chain

Author(s)	Problem settings	Approach F/T	S	R	Risks covered	Techniques used	Description
Tang (2006)	Perspectives in supply chain risk management			✓	1. Operational risk Uncertain cost 2. Disruption risk Natural and man-made disasters Economic crises	Review paper	Quantitative models were evaluated for managing the risk in supply chain. The author also compared the several SCRM strategies present in the literature with the actual practices
Wu *et al.* (2006)	Model for inbound supply risk	✓			1. Internal risk Quality, cost, engineering capability, production flexibility, continuity of supply 2. external risk Demand, economical stability, market characteristics, natural or man-made disaster, security	AHP	Proposed an integrated approach which helps to categorise, assess, and manage the inbound supply risks
Chopra and Sodhi (2004)	Managing risk to avoid supply chain breakdown	✓			1. Supply risk 2. Strategic risk 3. Regulatory risk 4. Customer risk 5. Operations risk 6. Impairment asset risk 7. Competitive risk 8. Financial risk 9. Reputation risk	Supply chain risk tool	Addressed the review of various classifications of risks and highlighted the risk assessment and management perspective
Juttner *et al.* (2003)	Supply chain risk management: outlining an agenda for future research	✓	✓		1. Environmental risk sources Accident, socio-political actions, acts of God 2. Network risk sources lack of ownership, chaos and inertia 3. Organisational risk sources production uncertainties, labour strikes	Empirical study	Classified an outline for future research and highlighted the concept of SCRM
Yeung and Morris (2001)	Consumer perception of food risk in chicken meat			✓	1. Microbiological risk 2. Chemical risk 3. Technological risk	Pilot study	Investigated the food risks in the chicken meat product and developed a risk-reducing strategy

Table I.

Notes: F/T, framework/theory; S, survey; R, review

Rathore, Thakkar, and Jha (2017: 1275-1276)