ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #36442

The SO-What Analytical Analysis for Virtual Decision Teams

Rashmi Mohansingh Solanki

Master's student at Arizona State University

Chad Kennedy (Graduate Chair of TEM Program)

Chad Kennedy’s experience spans entrepreneurship, engineering research, project management and advanced technology application in industry. His expertise stems from spending the last 25+ years working in the field of engineering. His early career began working in various engineering design, testing, and astronaut training capacities at NASA Johnson Space Center. After, Kennedy joined the start-up, VI Technology Inc., an automation and testing systems firm, and helped establish the Silicon Valley office and operations. VI Technology was later acquired by Aeroflex, Inc. Kennedy was the co-founder and CEO of the start-up company, Restorative Biosciences Inc., an early-stage company that focused on developing anti-fouling, anti-inflammatory coatings and therapeutics for ophthalmic applications. Kennedy is currently a Senior Lecturer and Graduate Chair in the technology entrepreneurship and management (TEM) program in the Polytechnic School, one of the Ira A. Fulton Schools of Engineering at Arizona State University. In addition, Dr. Kennedy is one of the founding faculty of the MS Innovation and Venture Development program, a joint partnership with FSE, WPC, and HIDA. Formerly, he was the national chair and Professor of biomedical engineering technology at DeVry University. Kennedy sat on the national Association for Medical Instrumentation (AAMI) educational committee and the American Institute for Medical and Biological Engineering (AIMBE) Academic Council. Kennedy holds a bachelor’s degree in mechanical engineering from the University of Texas at Austin in addition to master’s and doctorate degrees in Bioengineering from Arizona State University. Outside of academics, Kennedy mentors and consults with many technology start-up companies such as (Invoytech, Picmonics, OraVu LLC, Riviulet, Hat-tac, etc.).

Yash Shirke

I am interested in learning new technology and work on new projects. Passionate about electronics and automation also in SPC (statistical process control). Interested in WCM - World Class Manufacturing, Supply change management.

The SO-What Analytical Analysis for Virtual Decision Teams

Background

S.W.O.T. is a loosely structured planning method to evaluate strengths, weaknesses, opportunities, and threats involved in a project or business venture. It mainly consists of those four lists categorized as internal (strengths and weaknesses) and external (opportunities and threats). Typical SWOT analyses are carried out for making comparative decisions for product development, marketing, business strategy and operations location, new venture formation, engineering design evaluation, environmental considerations, economic development evaluation and a multitude of other applications. A comprehensive literature review was conducted by Helms and Nixon[4] in 2010 covering the extensive history and application of the SWOT so we refer the reader to that publication since that is not the goal of this study.

In its traditional form the SWOT is a discovery and decision-making tool; however, there is growing debate over its usefulness. There has been criticism of its effectiveness as a means of analysis or as part of a corporate strategy with nine categorical issues identified by Helms and Nixon[4].

1. *Vague and simplistic methodology*
2. *Lack of thoroughness of brainstorming and expertise within team*
3. *Issues with categorizing variables into SWOT quadrants SO, ST, WT, or WO.*
4. *Challenges in classifying items (i.e. is an item an opportunity or threat?)*
5. *No strategic result or direction emerges from analysis*
6. *Resource based SWOT alleviates some issues but varies greatly for external factors vs. internal factors and perceptions easily influenced by managerial role/position in the company*
7. *Need for quantification-lack of consistent weighing, ranking or prioritizing*
8. *Alternatives and improvements to SWOT needed*
9. *Need to combine with other strategy tools of analysis*

An earlier study pointed out one of the major issues with traditional SWOT is that any member participating in a SWOT analysis can provide any input they wish to without having to back it up with any kind of in-depth analysis[9]. Another criticism of SWOT analysis is that "*the success of SWOT analysis depends on the thoroughness of the internal and external analysis which is a function of time devoted to the task, the number of experts involved, and the level of consensus*"[4].

SWOT Team Group Effects

A SWOT can fall victim to bias. When performing evaluations in groups, people may fall victim to "groupthink". That is, there may be a tendency for individuals to accept the viewpoints or conclusions most represented in the group even if their own opinions contradict them[1]. In any group activity, the results of the activity can be heavily influenced by the makeup of the group. For example, when performing a SWOT analysis, a person's position, title, or professional background within the company could have an effect on the results. If the team member holds more power (real or perceived) within the company, his/her inputs are less likely to be met with opposition from other team members. If someone is more vocal in justifying their inputs because they possess an extrovert personality, they are more likely to have their inputs be taken seriously.

Someone who is more introverted about their inputs is likely to have them overshadowed or even undermined by the more outgoing members. The 'SO-WT' aims to reduce the impact that these biases may have on the analysis and allow full contribution by all participants in the group.

Current SWOT Methods

Currently, SWOT analysis is most often performed with groups in the same location. The most common and simple use of SWOT analysis requires simply listing strengths, weaknesses, opportunities, and threats, within a context under consideration, with no weighing the importance of the items listed[4]. Criticisms of this basic process range from subjective lists with group biases to no consistent methodology or procedure. Another major critique of traditional SWOT is the fact that it is a qualitative analysis rather than a quantitative one[2]. To address that criticism, analytical SWOT methods utilize a system in which the team assigns weights of importance to strengths, weaknesses, opportunities, and threats on a Likert like scale of importance. Although, weighted scales add a level of objectivity to the analysis, this approach still has issues since there is no standard for SWOT analysis weights and procedures yielding various results. The lack of standard practice for scoring leads to an inability to compare SWOT analysis against each other if the scoring mechanics differ resulting in a veritable "apples to oranges" comparison.

SWOT methods created to formalize some of these concerns are the Competitive Profile Matrix (CPM), External Factor Evaluation Matrix (EFEM), and the Internal Factor Evaluation Matrix (IFEM) presented previously in Strategic Management books[3] but still lack consistency or comparability in SWOT criterion selection and evaluation. Recognizing a need to have consistency in SWOT criterion evaluation, Kurttila et. al.[5] applied a hybrid Analytic Hierarchy Process (AHP) with the SWOT analysis to evaluate forest certification. Stewart et. Al.[7] applied a similar hybrid AHP method to construction cases.

The output of a weighted and scored SWOT analysis has long been established with a 2D plot showing the S-W (y-axis) vs. the O-T (x-axis). Chang and Huang plotted the O-T vs. S-W axis into a 2D graph to allow better visualization of the outcomes and offer suggestions based upon the quadrant outcomes[2]. They coined these developments as the Quantified SWOT and the Grand Strategy Matrix (GSM) which is a reversal of the S-W vs. O-T plot although there is no real value as to one plot version versus another. However, the real value added for teams using this method is the quadrant interpretation of the results. The (x, y) coordinate and resulting quadrant reveals suggested strategic directions and actions. Other researchers have advanced the idea of the Fuzzy Quantified SWOT and the Analytical Network Process (ANP) SWOT, with even more complex calculation, categorization, and quantification. These latter methods add complexity at the cost of useability for most decision teams.

SOWT Analysis Goals

We set out to develop a standardized quantitative approach to the SWOT analysis resulting in easy to use and interpret tool with normalized decision metrics that would be inclusive to all SWOT teams regardless of personality types, professional training or location. The major needs from previous work we aim to address are the following:

1. Quantitative tool
2. Actionable outcome metrics

3. Measure level of consensus within decision team
4. Mitigate 'Groupthink'
5. Minimize 'Authoritative Influencer Affect'
6. Quantitatively comparable with other SOWT analysis(es)
7. Process is practical for virtual, non-local, or local decision teams

The last component has become especially important due to the increase in virtual entrepreneurship, business, and engineering teams across industries. This is not surprising and correlates to increased globalization; thus, justifying the need for decision and analytical tools that can be applied in these environments. More recently the COVID-19 pandemic has greatly accelerated the use of virtual teams[8].

Although SWOT analytics are used for comparative and binary decision making, we chose to focus application of the SOWT analysis on simple "yes or no" decision making first to prove the model. Future work will be to include comparative decision making SOWT studies.

Methods

Our experimental SWOT analysis focused on the value of obtaining a Master of Business Administration (MBA). We performed this study in a project management class filled with multidisciplinary undergraduate students in their junior or senior year comprised of diverse majors that have technology, entrepreneurship, engineering, management, and business components. Consideration of obtaining an MBA was used since it did not require specialized knowledge or skill sets to understand the question; thus, minimizing various experience level effects[9]. Many of the students had already been considering the question as a possible career pathway. The actual question used was "Perform a SWOT analysis on whether or not it is worth getting an MBA". We are looking for a "yes or no" binary answer to a fuzzy input question. To that end, we developed a standard procedure and novel metric calculation and presentation to facilitate clarity and comparability of the results. To test the validity of the procedure and metrics we statistically compared results between three test groups, A Virtual Team SWOT (VTS), B Group Weighted SWOT (GWS) and C Traditional Unweighted SWOT (TUS). Each group was composed of 5 teams of 4-5 members each. The teams were randomly pre-assigned to a test group and all students were blind to the intent of the experiment and specific method they were using. All Groups were given explicit instructions on procedure based upon which group they fell into. Each team was given access to a google sheet designed for their specific procedure that accepted collaborative input from all team members and automatically calculated SOWT metrics.

Group A- Virtual Team SWOT (VTS) Procedure (Focus)

The SWOT procedural steps for the teams in Group A are outlined as follows. Items in bold italics were computed automatically in the spreadsheet.:

1. Use the spreadsheet to perform the following steps
2. Identify strengths, weaknesses, opportunities, and threats individually
3. As a group, remove duplicate or consolidate redundant items (requires a unanimous agreement on final item description)

4. Separate, and without discussing, individually weigh importance on a Likert scale of 0-3 (0 = not applicable 1 = low, 2 = medium 3 = high) of each item on each list
5. ***Calculate normalized team average scores for each item on each list*** (This is done automatically by the spreadsheet)
6. ***Calculate normalized group average for each category*** (e.g. S = strengths, W = weaknesses, O = opportunities and T = threats.)
7. ***Calculate 1D SO-WhaT Index: SOWT= (S+O) – (W+T)***
8. ***Calculate the X and Y components: X = O - T; Y = S – W***
9. ***Calculate the Consensus Vector Magnitude: $|C| = ((X)^2 + (Y)^2)^{1/2}$***
10. ***Plot Consensus Vector on the SOWT Graph***
11. Decide as a group.

Group B- Group Weighted SWOT (GWS) Procedure

The SWOT procedural steps for the teams in Group B are outlined as follows. Items in bold italics were computed automatically in the spreadsheet.:

1. Use the spreadsheet to perform the following steps
2. Identify strengths, weaknesses, opportunities, and threats as a group.
3. As a group weigh importance on a Likert scale of 0-3 (0 = not applicable 1 = low, 2 = medium 3 = high) of each item on each list
4. ***Calculate normalized team average scores for each item on each list*** (This is done automatically by the spreadsheet)
5. ***Calculate normalized group average for each category*** (e.g. S = strengths, W = weaknesses, O = opportunities and T = threats.)
6. ***Calculate 1D SO-WhaT Index: SOWT= (S+O) – (W+T)***
7. ***Calculate the X and Y components: X = O - T; Y = S – W***
8. ***Calculate the Consensus Vector Magnitude: $|C| = ((X)^2 + (Y)^2)^{1/2}$***
9. ***Plot Consensus Vector on the SOWT Graph***
10. Decide as a group.

Group C- Traditional Unweighted SWOT (TUS) Procedure

The SWOT procedural steps for the teams in Group B are outlined as follows. Items in bold italics were computed automatically in the spreadsheet.:

1. Use the spreadsheet to perform the following steps
2. Identify strengths, weaknesses, opportunities, and threats as a group.
3. Decide as a group. *
4. Count the total items in each list and find the maximum number
5. Divide 3 by the maximum number to get the normalization scale factor.
6. Multiply each of the total counts for each list by the normalization scale factor. These values represent the S, W, O, and T scores.
7. ***Calculate 1D SO-WhaT Index: SOWT= (S+O) – (W+T)***
8. ***Calculate the X and Y components: X = O - T; Y = S – W***
9. ***Calculate the Consensus Vector Magnitude: $|C| = ((X)^2 + (Y)^2)^{1/2}$***
10. ***Plot Consensus Vector on the SOWT Graph***

* This is the typical SWOT method decision point. We then had students help us normalize the data to a maximum value of 3 for any category so we could compare their relative control results with methods A and B.

Example google spreadsheets filled out by students for the various SWOT Methods, TUS GWS, and VTS are shown below in Figures 1, 2, and 3, respectively.

	Helpful To achieving objective	Importance Scale Scale (0-Not applicable,1-Low Importance, 2-Medium Importance, 3 High Importance)					Average of Weighted Rows	Harmful To achieving objective	Importance Scale Scale (0-Not applicable,1-Low Importance, 2-Medium Importance, 3 High Importance)					Average of Weighted Rows
Internal	Strengths: (Descriptions)	Member #						Weaknesses:	Member #					
		1	2	3	4	5			1	2	3	4	5	
Origin	You develop personal skills	3	3	2	3	3	2.75	Less sleep during studies.	1	3	2	3	2	2.25
Attributes of the Organization	Networking with others	3	3	3	3	3	3.00	Inflation of MBA degrees.	2	1	1	1	2	1.25
	Good paying job	2	2	3	3	2	2.50	May have to work less hours in order to keep up with school assignments, resulting in a lower paycheck	2	2	2	2	2	2.00
	A steady industry	3	1	2	2	1	2.00	managing tuition fees	1	2	3	3	1	2.25
	Better resume	1	1	1	2	1	1.25	large Time commitment	3	3	3	3	3	3.00
	Number of Strengths	5	5	5	5		Weighted Average of Strengths	Number of Weaknesses	5	5	5	5		Weighted Average of Weaknesses
	Sum of Strengths	12	10	11	13		2.30	Sum of Weaknesses	9	11	11	12		2.15
	Average Strengths Score	2.40	2.00	2.20	2.60		2.30	Average Weaknesses Score	1.80	2.20	2.20	2.40		2.15
External Origin	Opportunities:	Member #						Threats:	Member #					
		1	2	3	4	5	Average of Weighted Rows		1	2	3	4	5	Average of Weighted Rows
Attributes of the Environment	Opportunity to have a higher paying job.	2	3	3	2	3	2.50	Larger possible debt	3	3	3	3	3	3.00
	More plaques to fill your wall up.	0	0	1	1	1	0.50	May not be able to find a job after completion of MBA	2	1	2	3	3	2.00
	Can switch between industries for a career	2	1	2	2	3	1.75	Value decreases over time	3	0	1	2	0	1.50
	More credibility to your work and identity	3	2	3	3	3	2.75	may have to move for job	3	2	3	2	2	2.50
	Own a business	3	2	1	3	1	2.25	social problems from overworked schedule	0	2	1	1	0	1.00
	Number of Opportunities	5	5	5	5		Average of Opportunities	Number of Threats	5	5	5	5		Weighted Average of Threats
	Sum of Opportunities	10	8	10	11		1.95	Sum of Threats	11	8	10	11		2.00
	Average Opportunities Score	2.00	1.60	2.00	2.20		1.95	Average Threats Score	2.20	1.60	2.00	2.20		2.00

Figure 1: Traditional Unweighted SWOT (TUS Group C) Spreadsheet. Students communicated in person as a group throughout the entire process. Yes or No decision was determined before scoring process. Scores obtained by getting longest list count and dividing by 3 to normalize all numbers to 0-3 (0 – no importance, 1 – low, 2 – medium, and 3 - high importance) Likert scale

Helpful To achieving objective	Importance Scale Scale (0-Not applicable,1 Low Importance, 2-Medium Importance, 3 High Importance)	
Strengths: (Descriptions)	Group Scores	
Looks Good on Resume	2	
Broadening Intelligence	1	
Determination	1	
Provides Connections	3	
Prestige	2	
Shows dedication	1	
Number of Strengths	6	Weighted Average of Strengths
Sum of Strengths	10	1.67

Harmful To achieving objective	Importance Scale Scale (0-Not applicable,1 Low Importance, 2-Medium Importance, 3 High Importance)	
Weaknesses:	Group Scores	
Expensive	3	
Time Consuming	2	
Not Necessary	1	
Occupationally Specific	1	
Difficulty	3	
Number of Weaknesses	5	Average of Weaknesses
Sum of Weaknesses	10	2.00

Opportunities:	Group Scores	
More Jobs	3	
School Options	1	
Potentially Larger Salaries	2	
Potential Promotions	2	
Number of Opportunities	4	Average of Opportunities
Sum of Opportunities	8	2.00

Threats:	Group Scores	
Failure	3	
Better Alternatives	1	
Student Debt	2	
Degree Inflation	1	
Number of Threats	4	Weighted Average of Threats
Sum of Threats	7	1.75

Figure 2: Group Weighted SWOT (GWS Group B) Spreadsheet. Students communicated in person as a group throughout the entire process. Weighting was established as a team. All input scores are from a 0-3 (0 – no importance, 1 – low, 2 – medium, and 3 - high importance) Likert scale.

Strengths: (Descriptions) 4
intrinsic reward for achieving a MBA
More knowledge in respective field
More attrative to promotion for having an MBA already.
Greater networking through professors and fellow students

Weaknesses: (Descriptions) 1
Some fields an MBA does not gain and advantage in your field

Opportunities: (Descriptions) 3
Higher access to more lucrative occupations
More attractive to employers
You can teach at the CC level

Threats: (Descriptions) 3
More debt for a next level degree
Inflated masters degrees diminish your MBA to a degree (PUN INTENDED)

Figure 3: Virtual Team SWOT (VTS Group A) Spreadsheet. Students individually added items to each list and scored their weighting factor. The team was used to reconcile duplications only. After initial scores completed, then team worked on the analysis together virtually. All input scores are from a 0-3 (0 – no importance, 1 – low, 2 – medium, and 3 - high importance) Likert scale.

Note the effective equations to obtain the normalized **S**, **W**, **O**, and **T**. varies which each method. For the purposes of elaboration, we will look specifically at the strength's category, understanding that the same algorithms are used for all four factors.

For the **TUS method** (Group C) the equations were simply a normalization factor based on the maximum list count for all factors (eq. 1) followed by the strengths list multiplied by the normalization factor (eq. 2). The result is all factors get scaled with a 1 as a maximum:

$$Normalization\ Factor = \frac{1}{Maximum\ List\ Count} \qquad \text{eq. 1}$$

$$\boldsymbol{S} = (Strength\ List\ Count) * Normalization\ Factor \qquad \text{eq. 2}$$

The same normalization factor was used for W, O, and T so all lists were normalized to the longest list, thus making that factor the most important. Note if two lists had the same maximum value, they would both be scaled to a 3. A score a 0 for a category would signify 'no listed items' for that factor.

For the **GWS method** (Group B) the equations simply calculate a weighted sum (eq. 3) followed by scaling to a value of 1:3 (eq. 4).

$$S_{ave} = \left(\frac{\sum_{i=1}^{N} a_i}{N}\right) \qquad \text{eq. 3}$$

$$\boldsymbol{S} = S_{Norm} = \frac{S_{ave}}{3} = \frac{\sum_{i=1}^{N} a_i}{3N} \qquad \text{eq. 4}$$

For the **VTS method** (Group A) the equations modify eq. 3 above, since the number for ai is now substituted with an average for each listed item (See eq. 5 below). This represents each team member getting an individual importance score for each listed item without interference or influence.

$$a_i = \left(\frac{\sum_{j=1}^{n} a_j}{n}\right) \qquad \text{eq. 5}$$

Simplifying for S_{ave}:

$$S_{ave} = \frac{\left[\sum_{i=1}^{N}\sum_{j=1}^{n} a_{ij}\right]}{N*n} \qquad \text{eq. 6}$$

Therefore, for the normalized value, **S**, we get:

$$\boldsymbol{S} = \frac{\frac{\left[\sum_{i=1}^{N}\sum_{j=1}^{n} a_{ij}\right]}{N*n}}{3} = \frac{\left[\sum_{i=1}^{N}\sum_{j=1}^{n} a_{ij}\right]}{3Nn} \qquad \text{eq. 7}$$

Index Computations :

The importance of normalizing the data is critical to comparing groups to one another. The scale we choose was easy for the users to understand and use (e.g., none, low, medium, and high scores). For graphing and comparison purposes the S, O, W, T scores for each team are used to compute the normalized 1D SOWT Index (eq. 8) scaled to a hard maximum value of 6 (i.e. if S+O=6 and W+T=0).

$$SOWT\ Index = \frac{(S+O)-(W+T))}{6} \qquad \text{eq. 8}$$

The 2D X (Internal Axis) and Y (External Axis) coordinates are determined by eq. 9, 10, respectively:

$$X = \boldsymbol{S} - \boldsymbol{W} \qquad \text{eq. 9}$$

$$\boldsymbol{Y = O - T} \qquad \textbf{eq. 10}$$

Finally, the Consensus Vector Magnitude, |C|, is calculated and normalized to a maximum value of 1.00 in eq. 11, below:

$$|C| = \frac{\sqrt{(X)^2+(Y)^2}}{\sqrt{18}} \qquad \text{eq. 11}$$

The scaling denominator is the maximum value possible for X and Y, 3.00, plugged into the vector distance formula. This scales a vector with a coordinate of (3,3) to be equal to 1. Since the X and Y values represent a relative 'consensuses' of opinion on the **S**, **W**, **O**, and **T** values,

larger numbers, and thus longer vectors represent more consensus in the team vs. than do lower values. This gives the team some sense of relative confidence in their results.

HYPOTHESIS

1. Analysis of Variance (ANOVA) –

The analysis of variance for the captured data will give relation between the three procedures A, B & C. To apply the ANOVA test, we had three procedures A, B, C, and each of the procedures had six samples. Firstly, the SWOT score of all three procedures is taken into consideration to perform ANOVA analysis on it.

To calculate F value and F critical value we need to calculate these terms - Total Sum of Squares, Sum of Squares Within Group, Sum of Squares Between Groups. The relation in these three terms is shown in eq 12. Total Sum of Squares = Sum of Squares Within Group + Sum of Squares Between Groups eq. 12

First, calculation is - Sum of Squares Within Group that is 13.564. Then second calculation is - Total Sum of Squares that is 14.057. In the last third calculation is - Total Sum of Squares Between Groups that is 0.4928. Here, F critical value is 0.246. and with F table we get F value of F(2,15) as 3.682.

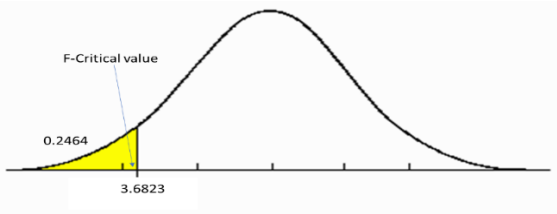

Figure 4: F-critical value and F-Calculated value

The Figure 4 shows the graphical representation of calculated F value. Here the calculate F-critical value and F-value for given data are found and it is not acceptable. Thus, the results of this test are not found to be significant.

As seen in Table 1, similar ANOVA testing was done for Strength, Weakness, Opportunity, and Threats data from three procedures A, B & C, with each procedures having six groups each.

Table 1: F-Critical value for SWOT

Data	F-Value	F-Critical Value	Test result
Strengths	1.772140275	3.6823	Fail
Weakness	0.120622779	3.6823	Fail
Opportunity	2.689320543	3.6823	Fail
Threats	0.041522581	3.6823	Fail

As results shows all tests failed which is due to the high range of group C, here, group C being an unscored method demonstrated highest variability in the results. In this group, the longest list count was considered and dividing 3 by maximum number to normalize the scores. The overall ANOVA testing was thus, significantly affected due to the high variability in group C. Hence, in order to find the relation between two such groups and justify the significance, t-test was performed for the captured data.

2. T-test for relation between A, B and C

In order, to determine if there was any difference between the results of the groups, T test was conducted on all possible combinations of groups A, B, and C. For each category, 3 group combinations were possible as shown in Table 2.

Table 2: Group combinations of T tests

Category	Group combinations		
S	A-B	A-C	C-B
W	A-B	A-C	C-B
O	A-B	A-C	C-B
T	A-B	A-C	C-B

Based on the t-test results of 12 combinations, the relation between A and B with regards to opportunities(O) was found to be significant as seen in Table 3. Here, assumed alpha was 0.05 to justify 95% significance. Similarly, the T tests and p-values were not found significant enough as seen in Table 3 and 4.

T Test: Two Independent Samples									
SUMMARY			Hyp Mean	0					
Groups	*Count*	*Mean*	*Variance*	*Cohen d*					
Group 1	6	2.018333	0.077657						
Group 2	6	2.473333	0.085707						
Pooled			0.081682	1.592022					
T TEST: Equal Variances				Alpha	0.05				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	0.165007	2.757463	10	0.010109	1.812461			yes	0.657217
Two Tail	0.165007	2.757463	10	0.020218	2.228139	-0.82266	-0.08734	yes	0.657217
T TEST: Unequal Variances				Alpha	0.05				
	std err	*t-stat*	*df*	*p-value*	*t-crit*	*lower*	*upper*	*sig*	*effect r*
One Tail	0.165007	2.757463	9.975777	0.01013	1.812461			yes	0.65767
Two Tail	0.165007	2.757463	9.975777	0.02026	2.228139	-0.82266	-0.08734	yes	0.65767

Figure 5: T-test: Two independent samples using MS Excel application

Table 3: Comparison of results for groups

T-test			
	A-B	A-C	B-C
S	Fail	Fail	Fail
W	Fail	Fail	Fail
O	Pass	Fail	Fail
T	Fail	Fail	Fail

Table 4: Comparison for p-value for groups

P-Value			
	A-B	A-C	B-C
S	Fail	Fail	Fail
W	Fail	Fail	Fail
O	Pass	Fail	Fail
T	Fail	Fail	Fail

INTERPRETATION

Interpretation of 1D SOWT Index. The interpretation of these indexes brings some level of objectivity to the normally subjective SWOT analysis. The simplest interpretation is that it represents a "Nominal" measurement according to Stanley Stevens taxonomy of measurements[6]. In other words, if we are asking a "Yes or No" question, the 1D SOWT Index simply states that if the SOWT index is greater than 0 then the answer is "Yes". If it is less than or equal to 0, then the answer is "No". If the TUS or GTS methods are used. This is arguably a fair assessment of the outcome. However, if the VTS method is used, there is more fidelity to the index with the advent of consensus and normalization as shown in Table 5.

Table 5: 1D SOWT Index Interpretation with consensus and normalization factored in. Consensus can only be applied if everyone on the SOWT analysis team has individual input as in the VTS method. GWS and TUS methods simply yield a Yes or No answer.

1D SOWT INDEX	**VTS INTERPRETATION**	**GWS**	**TUS**
0.66 < SOWT ≤ 1.00	Yes, with high consensus	Yes	Yes
0.33 < SOWT ≤ 0.66	Yes, with medium consensus	Yes	Yes
0 < SOWT ≤ 0.66	Yes, with low consensus	Yes	Yes
-0.33 < SOWT ≤ 0	No, with low consensus	No	No
-0.66 < SOWT ≤ 0.33	No, with medium consensus	No	No
-1.00 ≤ SOWT ≤ 0.66	No, with high consensus	No	No

Interpretation of 2D SOWT Index. The 2D SOWT Analysis yields more nuanced and in-depth feedback based upon not only the magnitude of the Consensus Vector, |C|, but also the quadrant or sub quadrant the vector is in (Refer to Figure 4 above). For a binary question, Quadrant I represent the "Yes" answer with relative consensus to qualify that "Yes". Quadrant III is the opposite yielding a "No" answer along with the relative consensus. With the graphical representation of 2D SWOT plot as seen in figure 7, it was observed that Group A results were similar to Group B results, with significant number of XY pairs with 'Yes' interpretation. Whereas, Group C results were more spread out, which does not help in decision making.

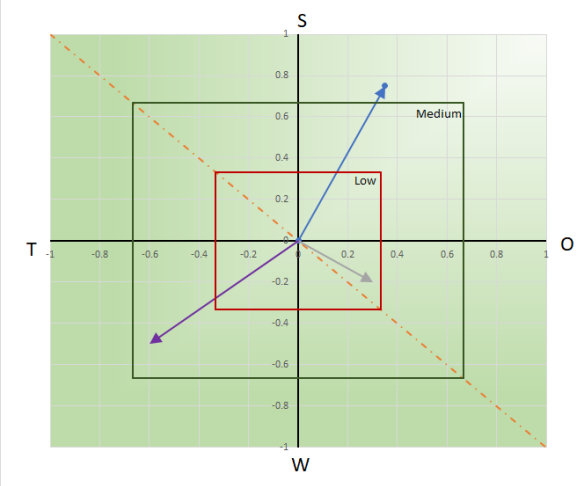

Figure 6: Figure 6: Example 2D Plot of three teams with independent SOWT analyses shown with each associated consensus vectors. The normalized maximum value for any of the factors (S, O, W, T) is 1; thus, the ranges of Low, Medium, and High Consensus are easily visible with the boarder squares at ±0.33 and ±0.66. The dashed line represents when the 1D SOWT index when (S+O) = (W+T).

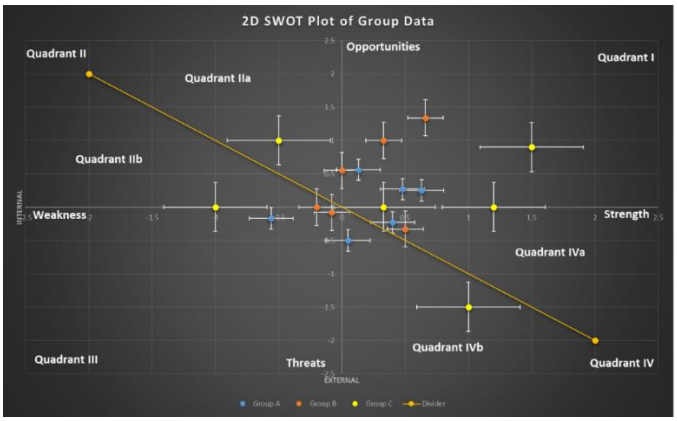

Figure 7: Example 2D plot with clustered points representing groups and the divider line showing decision-making quadrants.

DISCUSSION

Table 3 shows the distribution of the groups along the quadrants. Quadrant I represent the result as a strongly yes decision and for that, there is a total of three points from both groups A and B which again signifies that they have some relation also there is one point from group C. Next is quadrant II which is divided into two parts for better understanding (Refer to Figure 4 above). Where quadrant IIa which represents the result as a maybe yes decision, here the deciding factor is the fact to either add significant opportunities or overcome available weakness. Thus, it makes more sense to decide as maybe yes with certain assumptions. Also, quadrant IIa has only one point from group C. Next is quadrant IIb which represents the result as maybe no decision here the deciding factor is that is our opportunities are not high and we have more weaknesses. Thus, it is more towards no decision unless you have more opportunities, or you have a way to overcome your weakness which will be more difficult in the quadrant IIb. Quadrant IIb has one point of group B & C. Quadrant III has resulted as strongly no and it has points from both groups A & B. Quadrant VI is again divided into two parts quadrant IVa and IVb, here quadrant IVa represents the result as a maybe yes decision. The deciding factor here is if we can overcome our threats, we already have good score for strengths then we can convert this decision from maybe yes to strongly yes. Quadrant IVa has one point of group A and B and two-point of group C. Quadrant IVb represents the result as maybe no-decision. Here the deciding factor is that our threats are high, and we have good strengths. Thus, it is more towards no decision unless you have a way to overcome your threats. Quadrant IVb has one point of group A & C. Overall representation shows that group C does not demonstrate any strong decision due to its high variability whereas group A and B show some notable majority in decision making quadrants.

CONCLUSION

Initially, we used ANOVA analysis to analyze the relation between all three procedures. But the ANOVA analysis failed when we do it for the SWOT score for all three procedures. This happened due to high variability in group C results. Thus, in order to find the significant difference between the groups we tried to do t-test. Here, the t-test were used to check the significant difference in between procedure A, B, & C for its strength's, weakness, threats, and opportunities. After performing t-test we observed that the strength, weakness, and threats score given by all six teams while using procedure A are same with all six teams who used procedure B. Whereas found difference for the opportunity relation between procedure A & B. This means that the opportunity score given by all six teams while using procedure A is significantly different with all six teams who used procedure B to score the opportunities.

Thus, procedures A and B shows significant difference in relation for the opportunity score. Overall, we observed that in clusters group A and B tend to have similar clusters whereas C shows a different cluster. The C group had such a wide variability even between its own groups, that it would lead to radically different decisions depending upon the make-up of the teams. The A groups had a much tighter clustering, suggesting that regardless of the make-up of the team, similar binary decision outcomes are much more likely. Since this was basically a binary decision-making SWOT, based on the scores one can be definitive about the final decision. Thus, these procedures are more useful as compared to traditional SWOT method.

This Process also focuses on level of consensus measured in the team. In this method the level of consensus is analyzed in both the 1D scale and more dramatically with the 2D consensus vector. By normalizing the data within and across decision teams, team can now measure how aligned are the opinions of each member in a team. Also, in case of having multiple teams analyzing a binary decision, this method can compare consensus across teams as well.

With procedure A teams can come-up with more robust decisions which will help them to take the decision of "go" or "no-go". This procedure will help teams to take advantage of SWOT method and at the same time helps them to show more conclusive decision to higher management. This procedure will also encourage virtual team members to take active part in SWOT analysis. Thus, this will be a novel decision-making tool in virtual engineering management, project management, and product management teams. The future scope is to utilize this normalized SOWT analysis process to compare several product or project options as a complementary decision-making tool with typical financial and marketing analysis tools.

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