Detailed Analysis of Team Movement and Communication Affecting Team Performance in the America's Army Game*

CASOS Technical Report

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Abstract

We conducted the second data analysis with a new game log record dataset and focused on what the optimal team structure is in terms of communication and movement. We utilized regression analyses and correspondence analyses to make the optimal network, and we identified several important features of optimal networks from those analyses. Furthermore we coded 'Network Fitter' and used it to make a computer program figure out the most effective team organization. From the fitting result, we could obtain five optimal movement networks and five optimal communication networks. Among them, we found out that a dense movement network with two sub graphs and a long-chain shaped communication network would make casualty lower without damaging the deadliness of a team. After identifying the optimal movement networks and communication networks, we applied the findings from the analyses to the real world and made three recommendations on training squad level unit, constructing effective TTP, and configuring an optimal squad unit.

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Keywords: Organization theory, computational organization theory, dynamic social network, computer simulation, computer game, America's Army

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1 Motivation

The online multi-player computer game America's Army, has more than three million registered players. Developed by the U.S. Army, the game was designed as a recruiting and training tool to paint a realistic portrait of combat in the U.S. Army. The game falls into a first person shooting (FPS) game genre, and all the game features are based on the real world. The game is the duel of two teams, usually an assault team and a defense team, and a team consists of one to fourteen players. The team can win the game by killing all of the opposing players, or accomplishing the goal for that mission, such as securing an oil pipeline, crossing a bridge, etc.

Though the original role of America's Army is about the recruitment of young adults, it is also possible that we can learn lessons from its game play because its features are based on the real world. It is already revealed that the top players and the top teams of America's Army act like trained soldiers from the previous research, so more extensive data mining and analyses on the log record of the games would be interesting. For the research, U.S. Army granted us an access to new log record dataset which had been gathered during a couple of weeks from over 130 game servers. The new dataset contains coordinate information for each log record, so the analyses will be more detailed than the previous one. From the addition analyses, we expect to find out typical/unconventional optimal team structure of America's Army and its application to squad level military unit in the real world.

2 Previous research

2.1 Previous research from the outside of CASOS

After the release of America's Army, there was a number of research papers published about the game. These papers can be divided into two categories: a tool for stimulating recruitment and a tool for training inexperienced soldiers. The research done by Belanich [1] et al is typical of research on America's Army's usefulness as a recruiting tool. Belanich surveys 21 experiment participants about the information presented during the game and motivational aspects of the game before and after playing America's Army. The assessment of motivational features suggest that PC-based training games should be designed with attention to challenge, realism, control, and opportunities for exploration, and America's Army should be improved in those perspectives. Also, the paper written by Nieborg [2] explores four aspects of America's Army: Advergame, the integration of advertising messages in online games; Propagame, a strategic communication tool; Edugame, a tool for introducing people to the goals and values of the Army; and Test bed & tool dimension, an experimental test bed and tool. Above two researches focused on the nature of America's Army as a tool for recruitment and political propaganda.

The most well known case study of America's Army as a combat training tool is the research done by Farrell et al [3]. Farrell used tailored America's Army as a land navigation simulator for training cadets taking "MS102-Ground Maneuver Warfare I." Therefore, this research would demonstrate the ability of America's Army as a land navigation simulator, but not as the training utilized other course materials.

2.2 The previous America's Army tech report

The first America's Army tech report [4] researched the log record dataset at player level, team level, and clan level. Particularly, many statistical methods are applied to discover traits of dynamic social networks, based on Report-In communication network, of winning teams in America's Army. From the research, several commonalities among the top teams were found, and some outlying teams were adopting unusual ways to win.

The player level analyses could reveal that there are several distinguishing characteristics of the top players. The characteristics are the variety of weapon selection, dodging bullets and being aggressive at the same time, and transmitting Report-In communication frequently.

The team level analyses have shown that there are some factors which distinguish winning teams from losing teams and which make teams more efficient and safer. The most favorable size of a team is 10 players because the 10-man team has the relatively higher survival ratio than the other sizes of teams have, in either winning or losing. It has been found that some parameters, frequent usage of the weapon, precision of the weapon use, and frequency of communication, can be the distinctions between winning teams and losing teams. Also, by using the Report-In communication, the team will have more chance to have unified situation awareness: where the team members are and how team members can support the other team members. The regression analyses, between ORA network level measures and team received/inflicted damage, suggest that observing Report-In who-talked-after-whom network can be a good way to collect explanatory variables which can predict the amount of team received/inflicted damage.

The clan level analyses strongly suggest that making a team with same clan members is the most effective way to win. Being in a same clan, players play together very often, and it results that each player becomes very familiar with the other clan members' play styles. When this is not an option, forming a team with players who are participating in clans is the alternative way to win. When someone is a clan member, it means that he played enough to get involved with a certain clan and he certainly has good knowledge about playing the game.

2.3 America's Army journal paper

The America's Army journal paper [5] analyzed the features of America's Army to investigate its potential value as a training tool for inexperienced soldiers. We looked at the realism of the game itself, in terms of how well it corresponds with the real world, and we looked at the behavior of high-performing players within the game, to see if the strategies they adopted corresponded to the behavior of real soldiers in combat. We analyzed the first and the second log record dataset at the same time, and we surveyed previous research about squad-level infantry units to determine how well the two correspond. The realism of America's Army is verified from three viewpoints: weapons, communications, and rules of engagement. The similarities between winning players and trained soldiers are investigated in terms of: weapon usage, communication usage, and team structure. Comparisons between America's Army and real world revealed a number of similarities and the actions of winning soldiers and trained soldiers are almost identical. Finally, we identify some improvements that would further increase the America's Army game's usefulness as a training tool.

3 Raw dataset and initial processing

The second log record data was recorded off of 138 America's Army game servers over the course of 23 days. Like previous dataset, each line of the log files represents one event recorded by the servers. However, unlike the previous dataset, every log records in the new dataset have three coordinates information representing a point on the 3D. These events describe the game statistics, where "game" is the unit for the data analysis. Each *game* contains two types of events: *logging events* and *collection events*. The logging events describe the teams and the players, the collection events represent actions performed by players. There are seven types of events used for the data analysis:

1. *Team is initialized*
2. *Player enters the team*
3. *Weapon is used*
4. *Damage caused by the weapon*
5. *Communication between the players*
6. *Player leaves the team, scores are reported*
7. *Team finishes, outcome is recorded*

There are always two teams per game playing against each other. A team can have up to 14 players. The logging event *team finishes, outcome is recorded* contains information of either the team wins or loses the game, as well as the initial and final number of players. The logging event *Player leaves the team, scores are reported* has multiple measures of the performance in the game, individual scores: leader score, wins score, objectives score, death score, kills score, ROE score, and total score. Aggregate scores can be calculated for the whole team if one aggregates the scores of the individual players playing in the team. Similarly, weapon usage and damage can be aggregated for the whole team.

Some portion of the data files ended abruptly without logical ending for the games, which caused some games to miss events of one or more types mentioned above. In cases where the event *Team finishes, outcome is recorded* is missing, the game was considered to be incomplete and excluded from analysis. In cases where the event *Player leaves the team, scores are reported* is missing for particular players, the information about those players is not recorded. In rare occasions, some games have teams which either both have won or both have lost. We discard games where both teams won as having no reasonable explanation. If both teams lost, it means neither team satisfied the conditions to win the game. In this case, such behavior is considered reasonable and the data was included for analysis. The newly added location information also caused parsing problems sporadically. There were cases that the location information is not recorded at the end of event log records or location information is recorded all zeros. These cases were discarded, too.

4 Data Analysis

We analyzed the America's Army game log records with two technical reports. While the first technical report focuses on the initial statistics of overall game plays and the detailed analysis of communication social network, the second technical report concentrates on the initial statistics about team/player movement information, the detailed analysis of movement/communication social network, and comparison between two social networks of one team. Therefore, the meta-matrix used in the previous technical report should include the new player-to-player social network, movement network. The other networks remain same.

As stated above, we approach the second dataset by calculating initial statistics of movement information. After the preliminary movement analysis, we extracted 'Report-in who-talked-after-whom network' and 'who-was-close-to-whom network' from each team's log records. Two networks represent Report-In network and movement network respectively. With the extracted two types of networks, we did regression analyses between the ORA measures of the networks [6] and the inflicted/received damage, k-means analyses to identify the clusters of the top 1000 teams, and correspondence analyses to know the attributes of each cluster among the top teams.

Table 1. The new meta-matrix for the second data analysis

	People (Players)	Knowledge (Character Ability)	Resources (Weapon)	Tasks (Mission Objectives)
People (Players)	Social Networks *Report-In Network, Movement Network*	Knowledge Network *Soldier, Medic*	Resource Network *Fire Trace Weapon : Normal Bullet* *Fire Projectile Weapon: RPG, AT4 Round, M203 Round* *Throw Weapon : Grenade, Smoke Grenade, Flashbang*	Assignment Network *Objectives for Mission Accomplishment*
Knowledge (Character Ability)		Not Used *There are only two kinds of knowledge.*	Not Used *Any player can use any weapons.*	Not Used *Objectives can be achieved by either medics or soldiers.*
Resources (Weapon)			Not Used *Weapons have their own unique attributes.*	Not Used *Objectives are not directly related to weapons.*
Tasks (Mission Objectives)				Not Used *There is no order for mission objectives.*

4.1 Comparison between the analysis result of previous dataset and that of new dataset

Before the detailed social network analysis starts, preliminary statistical analyses are done to verify whether the old dataset and new dataset shows similar tendencies in the perspective of basic statistics. Figure 1 represents the survival rate for each team size. As it shows, the overall tendency of survival rate still holds in the new dataset: the increment of the number of survived players of winning teams stop when the team size reaches 10 and the highest number of survived players of losing teams is gained when the team size is 10. Therefore, one of the conclusions in the previous tech report, the claim that 10-man team is the most recommendable team size from the viewpoint of survival rate, is also valid in the new dataset.

Figure 1. The number of survived players and the number of killed players across the size of teams (The left side figures are from the first dataset and the right side figures are from the second dataset).

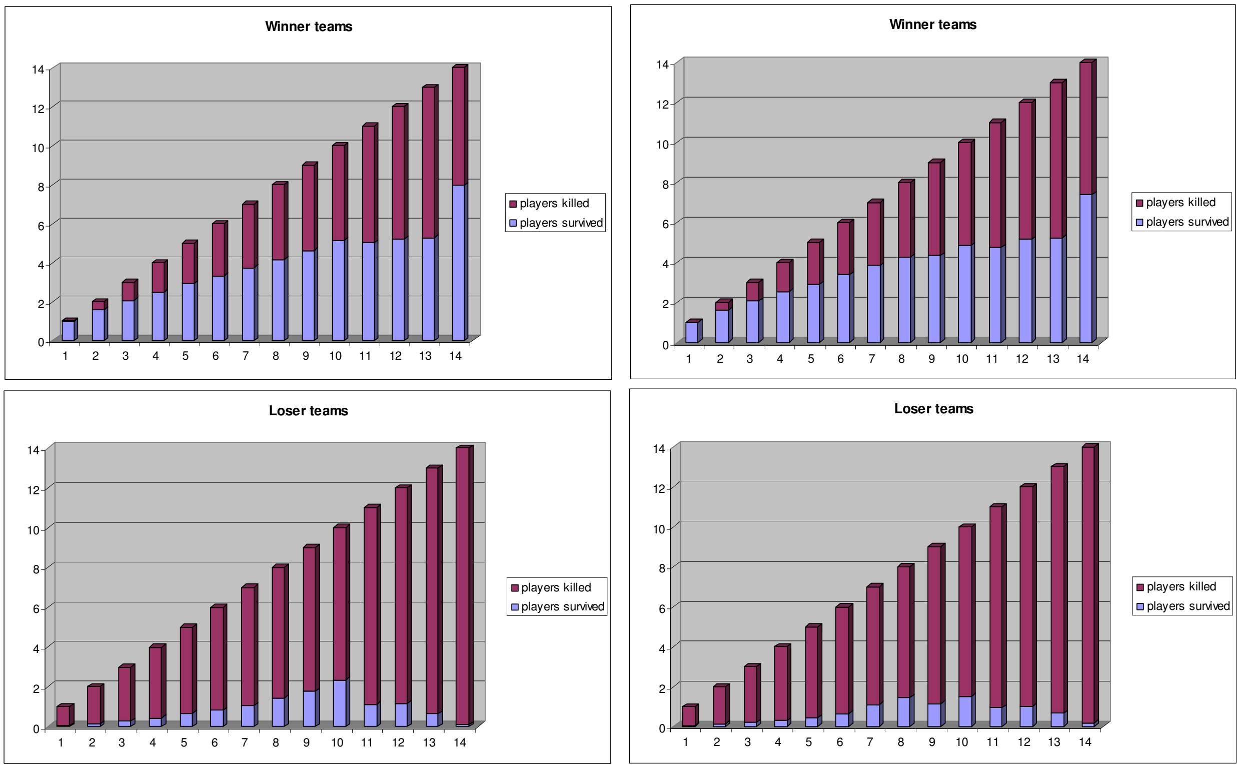
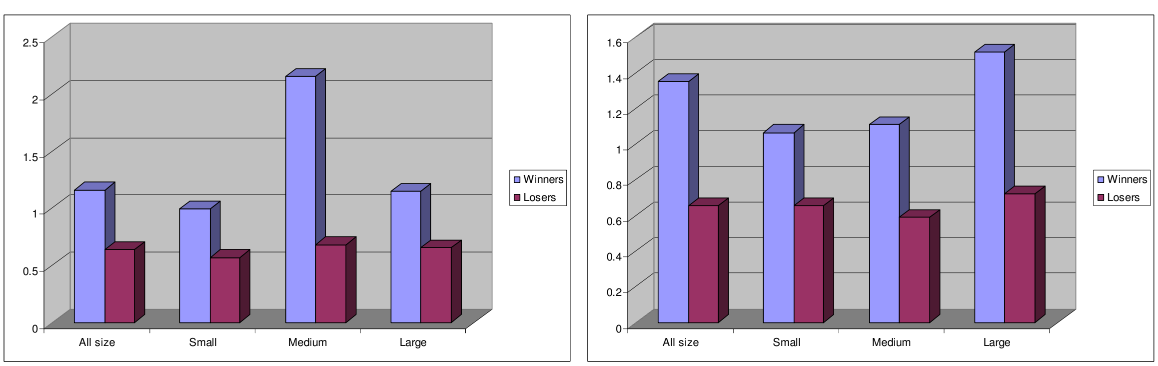


Figure 2 suggests that the importance of Report-In is still valid in the new dataset. The first tech report claimed that the number of Report-In communication of a team is one of the most obvious distinctions between winning teams and losing teams. Because the winning teams of the new dataset have the higher number of Report-In communication, we could identify that the new dataset also has the tendency: the importance of Report-In. Though the overall tendency is similar, the previous dataset showed the middle sized teams have the highest number of Report-In communication, but the current dataset suggests that the large sized teams have the highest frequency of Report-In communication.

Figure 2. The average numbers of Report-In per players of winners and losers (The left side figures are from the first dataset and the right side figures are from the second dataset)



4.2 Preliminary movement analysis

4.2.1 Four ways to determine the scatterness

There would be several different approaches for measuring how much team members are dispersed on the virtual game space. Among them, we had incorporated with the methods that can deal with the X, Y, Z coordinates and Euclidian distance between two points on 3D space. For the first analysis methodology, we just calculated the standard deviation of the log records coordinate of a team, and we start using Euclidian distance after that. The following four measures are the measurement for the scatterness of a team.

- Standard deviations of three coordinates
- Average movement distance
- Scatterness
- Average distance from K-means analysis

4.2.2 Standard deviation of three coordinates

Because the event locations are expressed with three coordinates, X, Y, and Z, the most basic approach would be calculating the standard deviation of each coordinates. Therefore, we calculated standard deviation for three coordinates for every winning team and losing team and average them. Also, we calculated the average of average standard deviations of three coordinates. Figure 3 represents the calculation results. We can observe that the three standard deviation of winning teams are lower than that of losing teams, and it suggests that the event of winning team are not dispersed like losing teams.

4.2.3 Average movement distance

Practically, there is no absolute ways to trace players' movements. However, we can trace the event locations the players invoked. Therefore, the best way to calculate the distance player traveled would be calculating distances between the pair of time sequenced event locations. For the calculation, we used Euclidian distance between two event location coordinates. Figure 4 displays the difference between winning teams and losing team in terms of movement distance. As it can be seen, losers traveled approximately 20% more than winners did, and it suggests ambushing the enemy is better strategy than rushing into the enemies. This result agrees with the standard deviation analysis because the winners' standard deviation suggested that the winning teams are less dispersed than the losing teams.

Figure 3 Standard deviations of three coordinates of the winning teams and the losing teams (X coordinate, Y coordinate, Z coordinate and average of three standard deviations of three coordinates)

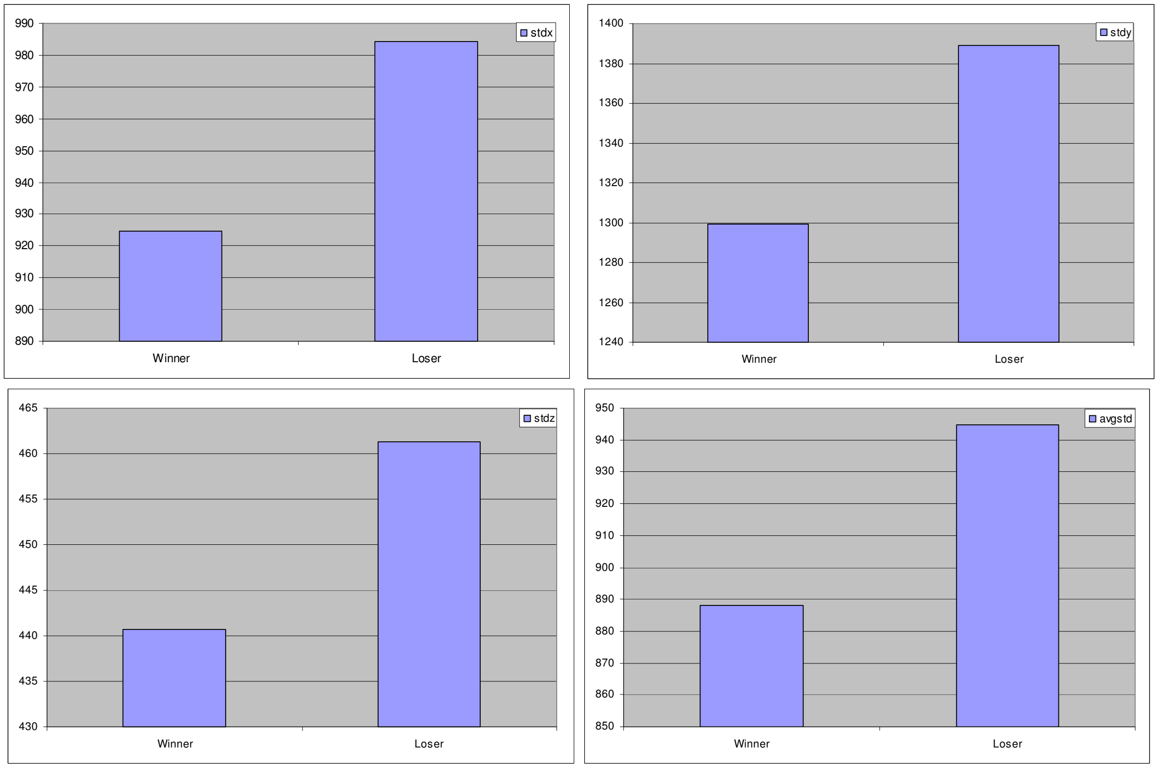
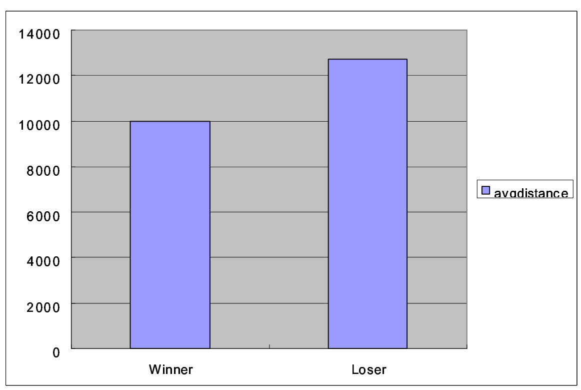


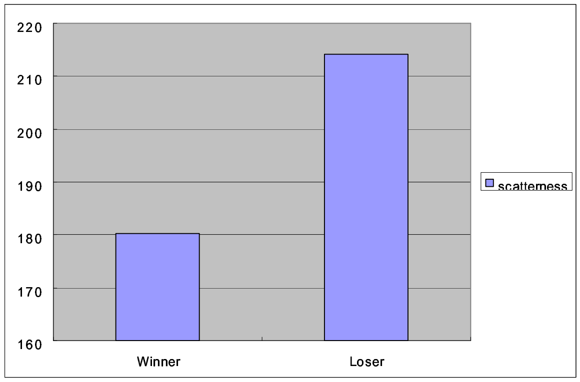
Figure 4 Average movement distance from the winning teams and the losing teams



4.2.4 Scatterness

As a matter of fact, the standard deviation or the movement distance might not be the best measure to observe how much a team member is dispersed across the virtual space. The standard deviation analysis approach might give some insights how much players are dispersed in terms of three coordinates, but it is only three averaged standard deviation which has no direct relation to scatterness. Also, we can conjecture that longer players traveled the more players dispersed, but the movement distance is not the direct measure of the degree of team scatterness. Therefore, we defined a measure: scatterness that directly measure how much team members are dispersed. According to Figure 5, the winners have lower scatterness calculated by the above formula, and it means the winners stayed closer together than the losers did.

Figure 5. Average scatterness of the winning teams and the losing teams



4.2.5 K-means analysis

Because the scatterness measure acts like 1-means analysis, the scatterness measure might miss some important tendencies. For example, if we consider two clusters densely centered, the scatterness might be misleading. In that case, the scatterness would be high, and it will be concluded that the team is very much dispersed though it is not true. Therefore, it would be better to find out the optimal K of the event locations of a team and do the K-means analysis with the determined K and the team event location data. To find the optimal K, we varied K from 1 to 10. If the one increment of K value doesn't improve the average distance from the center of the nearest cluster to the event location at least 90%, we stopped the increasing K and determined the value is optimal. Figure 6 shows the found optimal K values for winners and losers, and it presents that there is no difference in optimal K values between two groups because the optimal K values for both sides are 7. On the other hand, as shown in Figure 7, the average distance between the center of the nearest cluster and the event location was slightly different to each other: winners have slightly lower average distance than the losers do. It means that both winners and losers should cover the same number of spots, but the winners stick to the same team members who are at the spot.

Figure 6 Average optimal K for the winning teams and the losing teams (Optimal K means the K that cannot reduce the sum of distance from the cluster centers to every event point at least 90%)

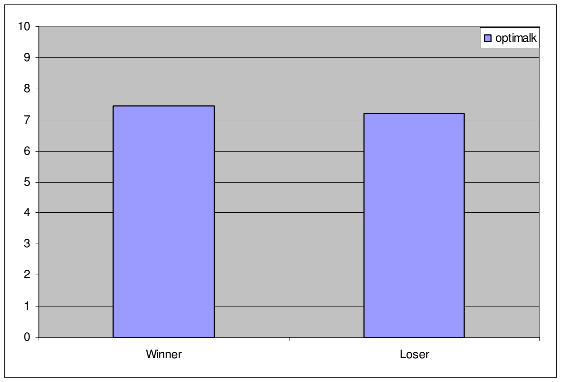
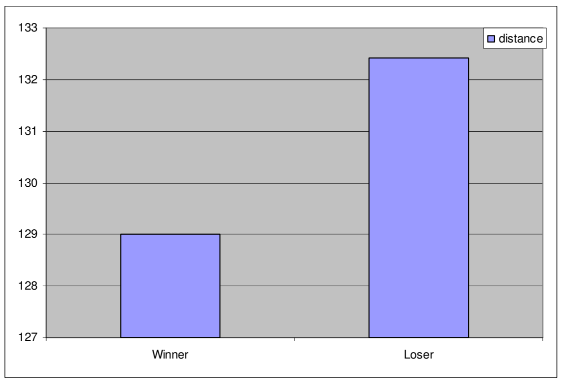


Figure 7 Average sum of distance from the cluster centers to every event point with given optimal K



4.3 Social network approach based on 'who-was-close-to-whom' network

4.3.1 How to construct 'who-was-close-to-whom' network

In the previous technical report, we defined 'who-talked-after-whom' network based on communication log record. This network could be the representative social network containing information, who talked to whom. The communication social network might be the salient feature of how to organize an America's Army team, and the communication social network approach would be one of the basic methods to analyze the organization dynamics. However, it would be also important to know the other network type, who was close to whom.

To extract the 'who-was-close-to-whom' network from log records, we need to define the meaning of 'close' more mathematically. Generally, to meet and to cooperate together, team members should be at the same place and at the same time. Therefore, the definition of 'close' should include timing condition and location condition.

- Timing Condition

1) Calculate the average game length of whole dataset

2) Assume that the one-tenth of the average game length would be good time frame to determine whether two players' event happened at the same time or not.
3) Player A's event time ≤ Player B's event time
Player B's event time < Player A's event time + 0.1 X (Average game length)
→ Player A and Player B acted at the same time.

- Location Condition

1) Calculate the average scatterness of whole dataset
2) Assume that the average scatterness would be a good standard distance to cooperate together.
3) Distance(Player A's event, Player B's event) < (average scatterness)
→ Player A and Player B acted at the same place.

By applying the above two conditions to every pair of log records, we could setup the directed edge of the location social network. Considering the players as nodes of the network, we can extract enough information to construct the location social network for every America's Army team in the new dataset.

4.3.2 Regression analysis between movement network ORA measures and inflicted/received damage amount

For the regression analyses, approximately 150,000 teams were sampled from the second dataset. Two regression analyses were done: one is between ORA measures and received damage amount and the other is between ORA measures and inflicted damage amount. When two regression analyses results are compared, it was noticeable that the inflicted damage was explained better than the received damage. This shows that the inflicted damage might be influenced by the movement of a team more. However, both R squares came from the movement network regression analyses were smaller than the R squares came from the communication network. Therefore, communication network might be the more appreciable social network to predict the received/inflicted damage amount.

According to the regression analyses between movement network ORA measures and inflicted/received damage amount, to reduce the received damage, high strong component count, high connectedness, and high span of control would be preferable. That means that the movement network should be strongly connected and nodes in the network itself should have many outgoing edges. On the other hand, to increase the inflicted damage, low clustering coefficient, high reciprocal edge count, and low span of control would be better. It means that the network would be more deadly if two players act closely and one by one, if a player in the network has an ego network with a low density. However, only reading the standardized coefficient of ORA measures will not suggest any firmly grounded concept of a network shape.

Table 2 Regression analysis model summary between movement network ORA measures and received damage amount

Model	R Square	Adjusted R Square	Std. Error of the Estimate

1	0.407	0.407	228.499

Table 3 Regression analysis model summary between movement network ORA measures and inflicted damage amount

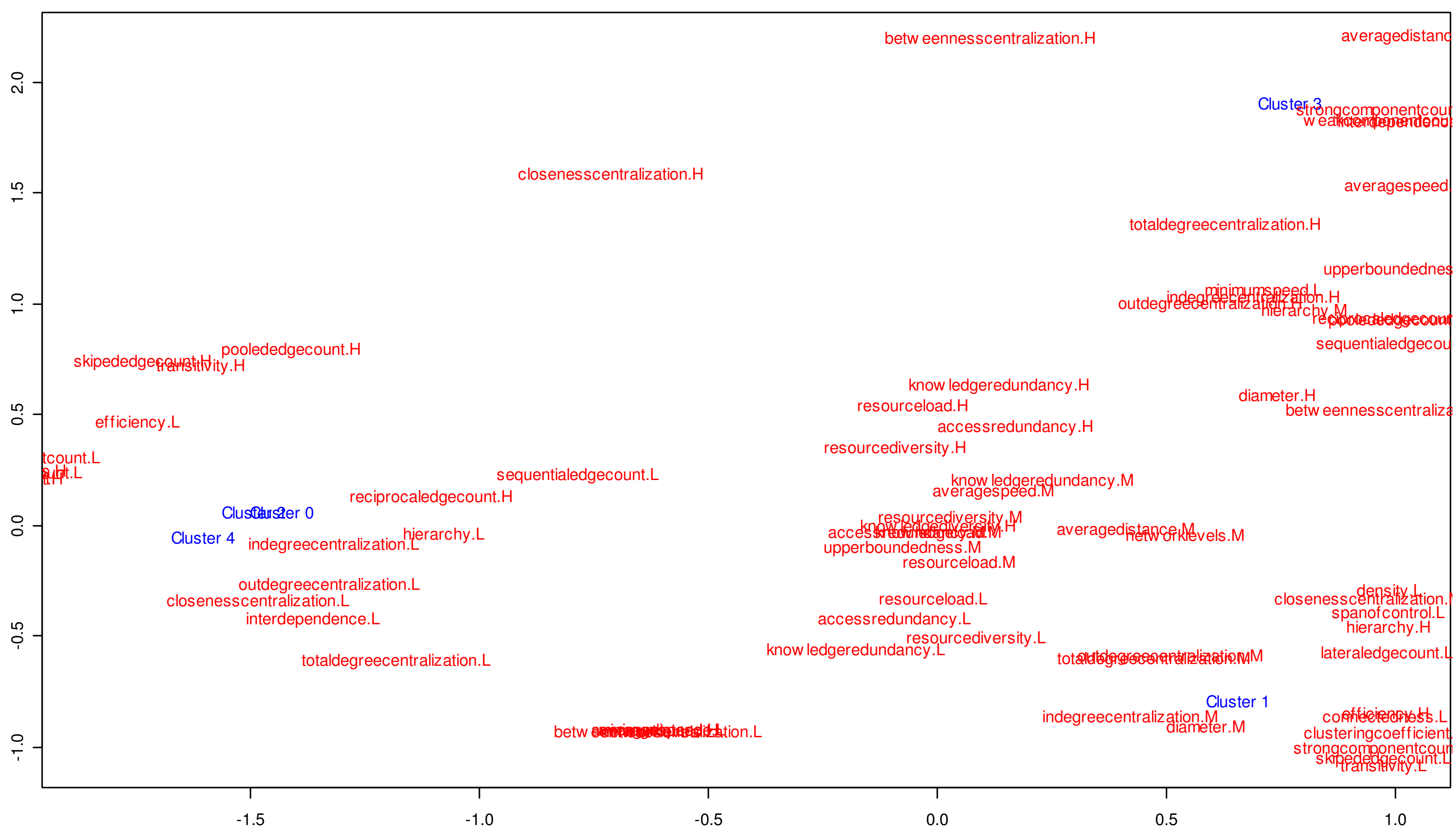
Model	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.453	0.453	222.731

4.3.3 Correspondence analysis with movement network ORA measures

In this section we conducted a correspondence analysis on the movement network ORA measures of the top 1000 teams. The top 1000 teams are selected with the respect of each team's new score introduced in the first technical report, and we consider the chosen top 1000 teams would be the most successful teams in the population. Before we did the correspondence analysis, we labeled the level of ORA measures with 'H', 'M', and 'L' representing 'High', 'Medium', and 'Low' respectively. The details about this labeling can be found in the first technical report. Also, the top 1000 teams are divided into 5 clusters, and these clusters are determined by K means analysis. After clustering and labeling, the number of instances for three levels of each ORA measures are counted for each cluster.

Figure 8 shows the result of the correspondence analysis mapping 32 ORA measures and 5 clusters. It is noticeable that three out of five clusters are closely located, and it means that there are three actual clusters though we tried to make five clusters. Cluster 0, Cluster 2, and Cluster 4 have low in-degree centralization, low hierarchy, and high reciprocal edge count, and it suggests that those three clusters might have movement networks that have less centralized nodes, less hierarchical attributes, and many incoming/outgoing edges between two agents. Cluster 1 is located far away from the above three clusters and has medium in-degree centralization, medium diameter, and low connectedness. With the analysis result, we can expect that the movement networks of Cluster 1 might have more centralized nodes than the above three clusters have. Cluster 3 has high betweenness centralization and high total-degree centralization, and it makes the movement networks of Cluster 3 have more centralized nodes than any other clusters. Therefore, we can see that the majority of the top teams have less centralized agents and less hierarchical attributes and there are some top teams adopting more centralized movement network structure.

Figure 8. Correspondence analysis graph with 32 movement network ORA measures and 5 clusters

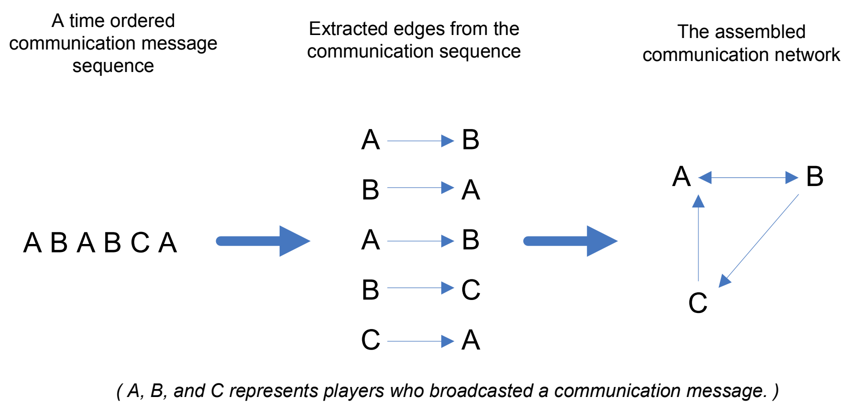


4.4 Social network approach based on 'who-talked-after-whom' network

4.4.1 How to construct 'who-talked-after-whom' network

'Who-talked-after-whom' social network has been analyzed since the first tech report of America's Army. Because every transmitted communication message is received by all the squad members, there was no way to extract the edges linking two players. Therefore, 'Who-talked-after-whom' heuristic is introduced. The basic idea of the heuristic is the person who talked after the other person is responding the previous message, so we can get edges based on this assumption. The more detailed information can be found in the previous tech report. Figure 9 describes the process of converting log records to the 'who-talked-after-whom' network.

Figure 9. How-to construct who-talked-after-whom network with the sequence of communication messages



4.4.2 Regression analysis between communication network ORA measures and inflicted/received damage amount

With about randomly selected 150,000 teams, two regression analyses were done between ORA measures and received/inflicted damage amount. Two regression analyses are almost same to the two regression analyses in the previous sub-chapter except we used ORA measures came from the communication network for this time. Compared to the previous pair of regression analyses with the movement network, the regression analyses with the communication network show higher R squares, and it means that the communication network might be the better input for predicting received/inflicted damage amount. Also, like the previous analyses, the inflicted damage amount is explained better than the received damage amount. Therefore, it seems that the social network of a team affects more on the inflicted damage amount rather than the received damage amount.

When we observe the standardized coefficients of the regression analyses between communication network ORA measures and inflicted/received damage amount, we can conclude that high average speed, low weak component count, and low reciprocal edge count will reduce the received damage amount. On the other hand, low average distance, low density, and high span of control would be better in increasing the inflicted damage amount. Also, this result suggests us to make sparse communication network instead of the dense communication network. However, it is true that there are other variables with strong standardized coefficients, so we cannot simply make the recommended shape of a communication network.

Table 4 Regression analysis model summary between communication network ORA measures and received damage amount

Model	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.411	0.411	227.675

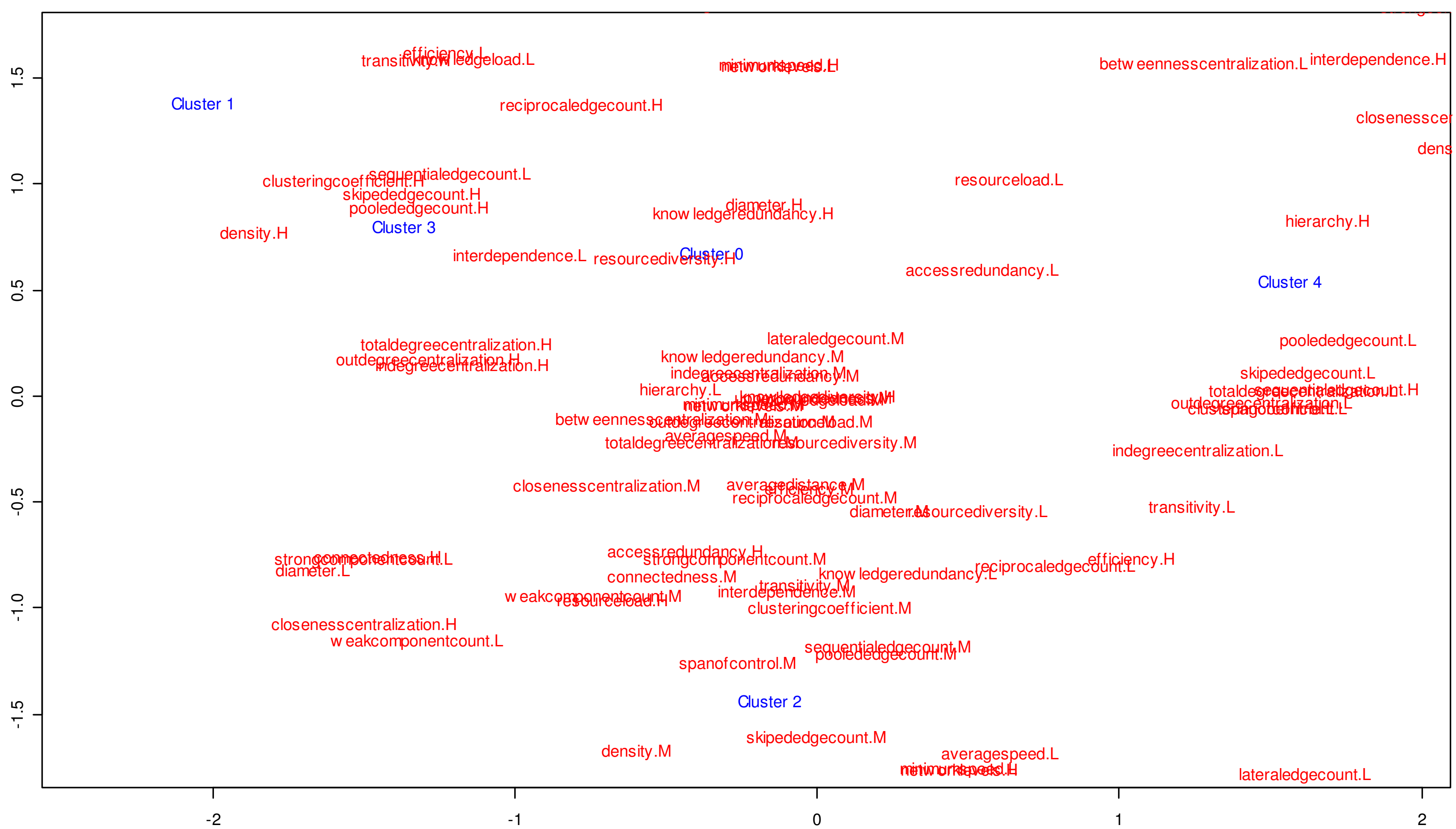
Table 5 Regression analysis model summary between communication network ORA measures and inflicted damage amount

Model	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.493	0.493	214.483

4.4.3 Correspondence analysis with communication network ORA measures

Figure 10 presents the result of the correspondence analysis mapping 32 communication network ORA measures and 5 clusters. There is no clear correlation between 5 clusters like the previous correspondence analysis on the movement network, and it means that all of the 5 clusters have their own structures. Cluster 0, Cluster 1, and Cluster 3 have relatively high density when they are compared to Cluster 2 and Cluster 4. Cluster 2 has medium level of sequential edge count unlike Cluster 1 and Cluster 3 having low sequential edge count. Cluster 4 has low skipped edge count compared to the rest of Clusters. However, it should be noted that we cannot make any hard recommendations based on the correspondence analysis because guessing the network structure with the levels of ORA measures is very difficult. Therefore we invented ‘Network Fitter’ to visualize the typical network structure for each cluster.

Figure 10. Correspondence analysis graph with 32 communication network ORA measures and 5 clusters



4.5 Statistical analysis with team variables

4.5.1 Regression analyses with team variables against performance measures

So far, regression analyses were done between ORA measures and the amount of the inflicted/received damage. Either movement social network or communication social network is used, not both networks at the same time. For this chapter, we will utilize the same regression analysis with more explanatory variables that came from general calculation like clanishness, the number of comm., etc. Moreover, we will use ORA measures obtained from the two social networks at the same time. We will use 150,000 team instances for this time. For the dependent variables of the regression analyses, we used four performance measures: inflicted damage amount, received damage amount, winning and new score.

First, we did a regression analysis with the whole explanatory variables against the inflicted amount of damage. Compared to the previous regression analysis that only used ORA measures calculated from one type of social network, R square is greatly improved, from 0.45~0.49 to 0.55. It is certain that the other factors except social network measures effects greatly on the performance measure. Movement network density (Beta coef.: 0.279), movement network span of control (-0.285), number of Report-In (0.172) have high beta coefficient values and can be considered significant factors affecting the amount of the inflicted damage. It is quite noticeable that adding more variables improves R square but still ORA measures have high standardized coefficient values. Thus, we may guess that organizing social networks would be important to increase the inflicted damage amount.

Table 6 Summary of the regression analysis: whole team level measures against the inflicted damage amount

Model	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.55	0.549	202.21238

Second, we conducted a regression analysis against the received damage amount. The R square of the regression against received damage is not as good as that of regression against inflicted damage. However, still the R square is reasonably good, 0.499. Surely, R square is improved compared to the previous analysis that used only ORA measures of individual social network (either movement or communication). Number of total communication (Beta coef.: 0.785), number of Report-In (-0.48), communication network knowledge redundancy (0.468) are the significant variables in terms of beta coefficient. Unlike the inflicted damage regression, communication related measures are highly regarded, and it tells us that communication is more important in reducing the amount of damage.

Table 7 Summary of the regression analysis: whole team level measures against the received damage amount

Model	R Square	Adjusted R Square	Std. Error of the Estimate

1	0.499	0.499	209.92397

Third, a regression analysis with the team level measures against winning is done. For the dependent variable value, we set the winning case is one and the losing case is zero. Though the R square is not good, but it is improved. However, we should consider that the winning variable is just a binary variable, so it will be hard to fit in the regression model. Though the R square is low, we can use the beta coefficient to get insights about factors affecting winning. Three communication measures, number of total communication (-0.543), number of Report-In (0.459), number of Commo. (A short message like 'move', 'roger', 0.271), are very highly ranked among the explanatory variables. The regression shows that the communication is very important in winning the game. Also, being deadly, being invulnerable, and being successful require different factors according to the regression analyses.

Table 8 Summary of the regression analysis: whole team level measures against the winning

Model	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.138	0.138	0.461

Finally, a regression against the new score is conducted. The new score is better in the fitting compared to the winning variable, but it has lower R square compared to the regression against the inflicted/received damage. It suggests that using the actual amount of damage might be good for analysis of regression, but still we need a regression analysis with a unified measure to get a general idea about team success. Levels of communication measures are very important, and it is true because the new score takes inputs from the original scores that are largely influenced by winning. Therefore, the measures having great influence on winning also affect greatly on the new score.

Table 9 Summary of the regression analysis: whole team level measures against the new score

Model	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.188	0.188	148.94017

When we review the four regression analyses that take inputs from the team measures and fit into the four performance variables, R square is improved when we compare it to the regression that used only one type of social network ORA measures. Predicting the inflicted/received damage amount is really well explained by the regressions (above 0.5 R square values). The inflicted amount of damage relies on the movement network measures (like movement network density or span of control), but the other performance measures are largely influenced by the level of communication. We could identify that the level of communication and the ORA measures are important factors in predicting a team performance. Appendix C contains the more detailed statistic analysis result such as beta coefficient, significance level, etc.

4.5.2 Factor analysis with team variables

With too many explanatory variables, it is difficult to identify how measures are related to each other and which measure differentiates teams greatly. Therefore, we did factor analysis on the variables of the top 1000 teams, and the detailed results (referred tables) can be found in Appendix D. According to table 27 "Total variance explained", above 90% of variance can be explained with 21 components. From the viewpoint of Communalities based on table 28, movement network clustering coefficient, movement network density, movement network strong component count have very high communality values, and experience, number of weapon fire, heavy weapon presence have quite low communality values. It means that most of the top 1000 teams had similar experience (high), weapon fire count (many), and heavy weapon presence (using heavy weapon). However, each team has different levels of movement clustering coefficient, movement network density, and movement network strong component count. Above result suggests that the top teams are using different strategies in organizing movement rather than fundamental team configuration. Also, it means that a team should satisfy the common features (with high experience, frequent weapon fire, heavy weapon usage) to be a top team.

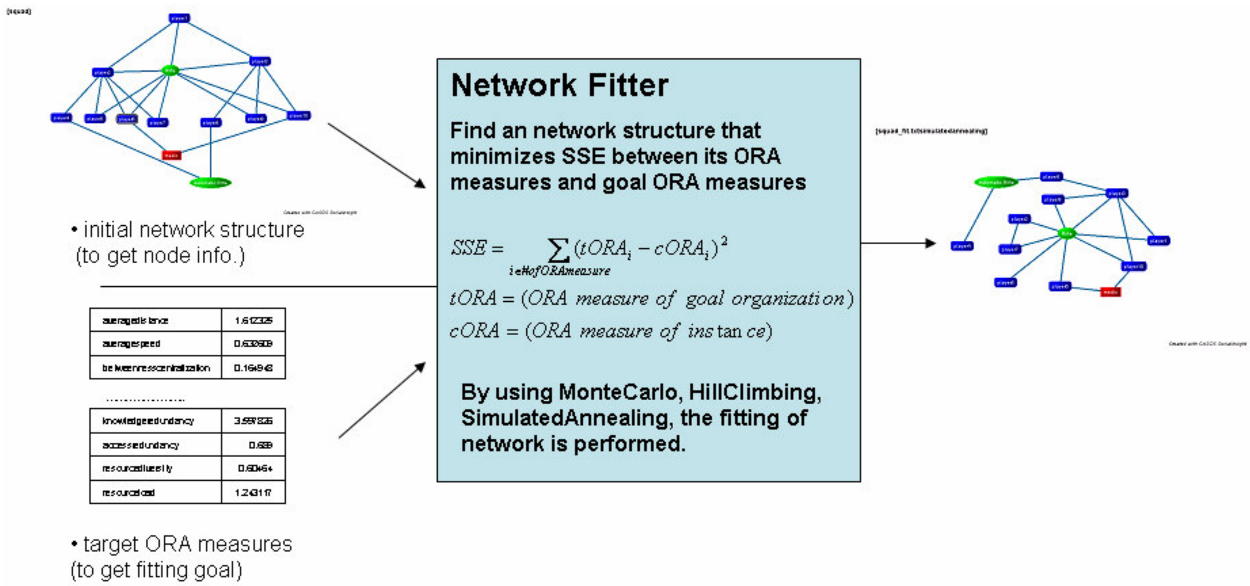
5 Optimal team structure to win the America's Army game

5.1 How to find an optimal structure from the statistical analysis

To find the optimal team structure, we utilized two statistical methodologies: regression analysis and correspondence analysis. However, the results came from the analyses don't suggest practical network shapes because these methodologies take inputs and make outputs by using ORA measures instead of original networks. Therefore, we interpreted the coefficients from the regression analysis and the correspondence analysis graph to obtain qualitative recommendations for practical applications.

Interpreting ORA measures with their regression analysis coefficients is very difficult because we have to reconstruct network shapes with considering the meaning of the ORA measures and without any computational help. Due to this difficulty, "Network Fitter" is coded and used for this tech report. Network Fitter is an optimization tool that accepts initial node information, target ORA measures and generates a reconstructed network having the identical node information and ORA measures similar to the target ORA measures. To determine the closeness between the target ORA measures and the ORA measures of each instance, the sum of squared error between two sets of measures is calculated, so the reconstructed network is the network having the lowest sum of squared error among the generated network instances.

Figure 11 How the network fitter works and what it can do



Because our goal of this chapter is generating the optimal shape of a social network, we coded the initial node information of a squad-level network that resembles to the 10-man team. After coding the node information, we applied Network Fitter to the node information with the averaged ORA measures of each cluster in the top 1000 teams. As a result, for each network type, we could obtain five suggested network shapes corresponding to the five clusters in the top 1000 teams.

5.2 Optimal team movement structure

As we conducted the correspondence analysis, we used the five clusters determined by the k-means analysis to make the five corresponding optimal team structures. After making the optimal team structures, we calculated some measures representing the characteristics of the teams in the clusters. The average measured values for each cluster are divided by the average values for the entire top 1000 teams, so we could compare the cluster specific measure value to the average of the top 1000 teams. Considering the five generated optimal movement network structure, we could identify there are three types of distinct network structures among the top 1000 teams. The three optimal structures are Dense Movement Network (Moving together), Sparse Movement Network (One fire-team and several isolated players), and Disconnected Movement Network (Keeping distance to each other). Table 10 illustrates how many top teams have a certain movement network type. It says that the disconnected movement network is the majority, but cluster1 that have a dense network is the majority when we considers only well connected networks. At the following sub chapters, we discuss the distinct characteristics for each movement network shape with two types of figures: one for a certain network shape and one for comparison between teams adopting the network shape and the entire top 1000 teams.

Table 10 Number of teams classified into each movement network clusters

	Moving together	One fire-team	Keeping distance to

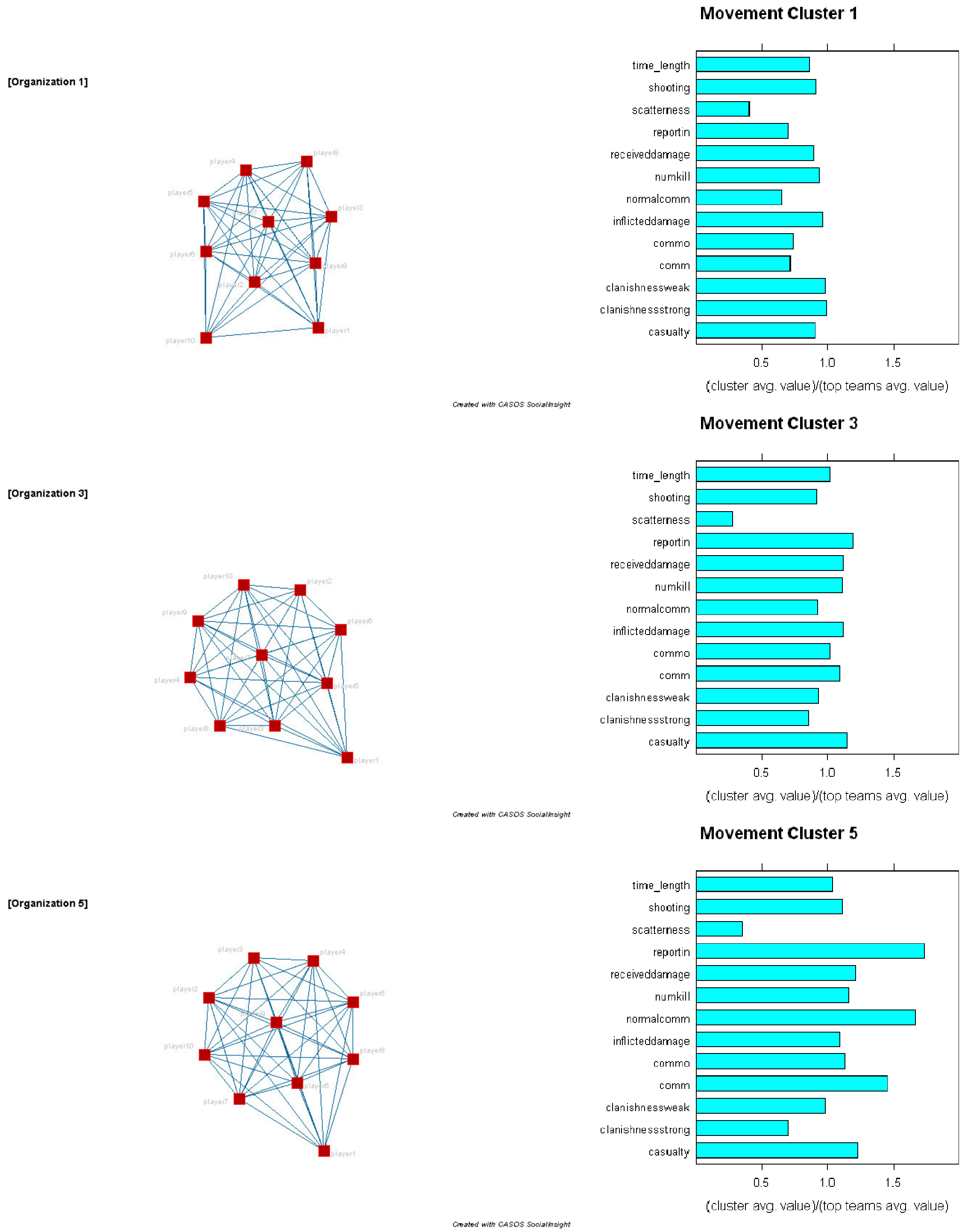
				and several isolated players	each other
	Cluster 1	Cluster 3	Cluster 5	Cluster 4	Cluster 2
Cluster Num.	252	65	17	198	508

5.2.1 Dense movement structures: Moving together

Cluster 1, 3, and 5 show somewhat similar movement network structures and the similarity is already identified by the correspondence analysis in the previous chapter. The overall movement network shapes of those clusters are very dense, so their scatterness is much lower than the average of the top 1000 teams. Particularly, the clannishness measures of cluster 3 and 5 are lower than the average, so it seems that the members of the teams move together very closely because the team members didn't know what the other members do.

Especially, cluster 1 should be noted due to its uniqueness of the structure and performance. Cluster 1 has low casualty and slightly low received damage, and it has somewhat low communication frequency which reduce team members' communication burden though they are communicating a lot than the ordinary teams. Moreover, cluster 1 movement network is good for reducing the number of normal communication messages because cluster 2 and cluster 4 have high frequency in the normal communication. Reducing the normal communication message allows players to concentrate on shooting, movement and achieving objectives. Cluster 1 also has lower number of shooting compared to the other top 1000 teams, and it is good because they are spending less ammos and still very good. Finally, cluster 1 has the lowest game length, and it means that the teams of cluster 1 won in very short time. Some of these good characteristics are so unique that even the other similar networks like cluster 3 or cluster 5 don't have such attributes. We conjecture the benefits of cluster 1 movement network came from its distinct movement network shape that is different to the other dense movement networks. Cluster 1's movement network structure has two distinct leaders and those leaders have connections to the rest of members, and this rational fits the two fire team structures. When we did the clique analysis of the network, we could see that two sub graphs exist in the network. On the other hand, the other two dense movement network did not show multiple sub graphs, but only one strongly connected network with the sub graph analysis.

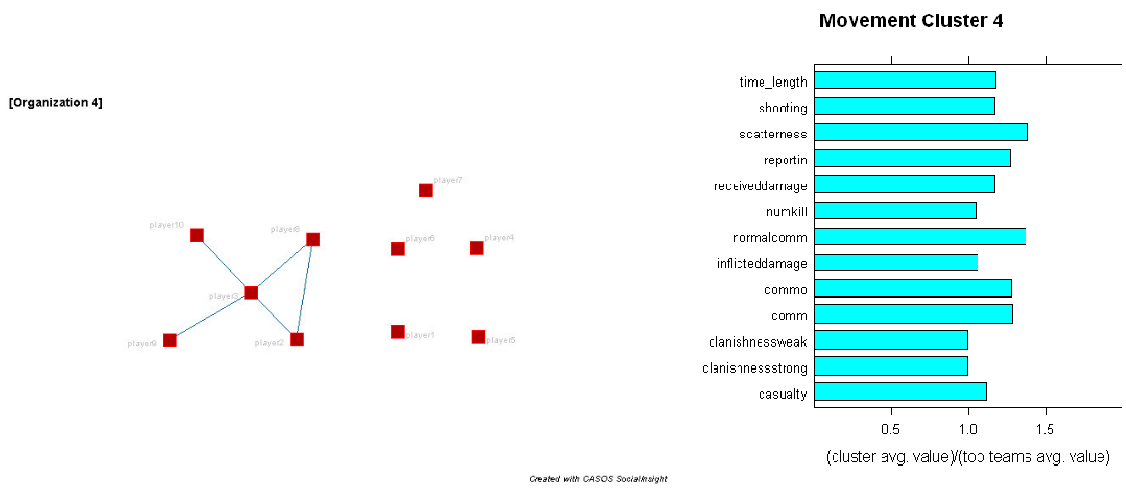
Figure 12 Dense optimal movement network structures (Left) and their descriptive measures (Right)



5.2.2 Sparse movement structures: One fire-team and several isolated players

Cluster 4 has medium density among the optimal movement networks. The optimal network for the cluster 4 shows one connected networks and five isolated nodes, and we think the connected network represents one fire team and the isolated nodes shows the individually moving players. This movement network is not typical because it has high scatterness and individually acting players. However, it has high clanishness measures compared to the clusters having dense movement network, so we guess that the isolated players are doing actions already coordinated. Because they are dispersed, the frequency of communication tends to increase, so the number of Report-In is high. The number of normal communication is also high, and it is unusual for a team having high clanishness. To wrap up, the teams of cluster 4 have high clanishness compared to the teams having dense movement network, high communication frequency in both Report-In and normal communication, and high scatterness. We think these teams already assigned detailed tasks to each player, some of highly skilled team members do their tasks individually, the other players form a fire team and fight against the enemy, and they communicate very frequently.

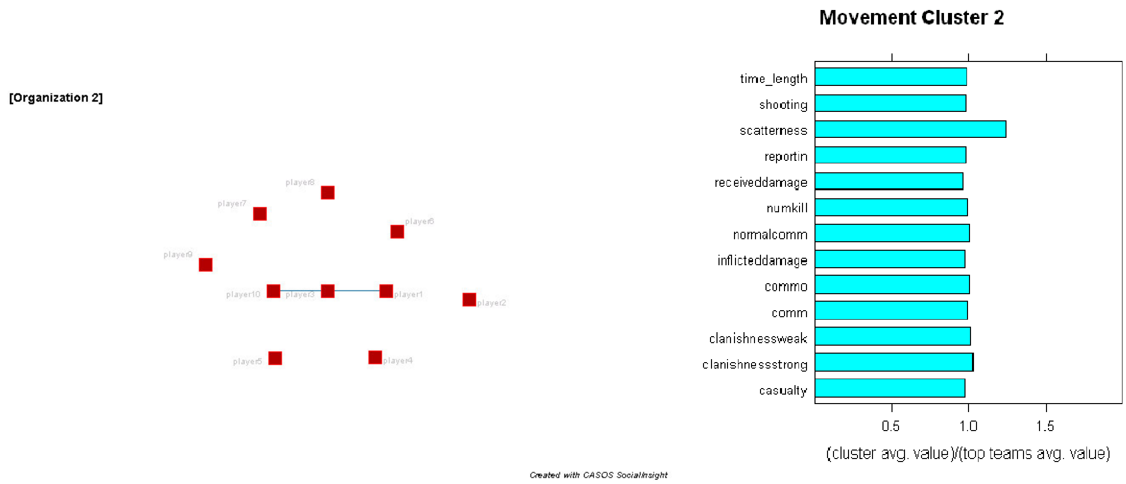
Figure 13 A sparse optimal movement network structure (Left) and its descriptive measures (Right)



5.2.3 No movement structures: Keeping distance to each other

Cluster 2 has an extremely sparse movement network, and it means the team members were scattered and did not stay close together in the virtual space. This is awkward according to the previous research that stated winning teams have lower scatterness. However, this sparse movement network is the majority among the top 1000 teams, so we conjecture that there are two types of teams among the top 1000 teams: well-organized teams and teams with excellent players. We guess that the well-organized teams usually adopt the previous movement networks, and the teams with excellent players organize the movement network with very low density in the network. This sparse movement network might not be a good recommendation because there is no guarantee that a squad will always have excellent and experienced soldiers.

Figure 14 An extremely sparse optimal movement network structure (Left) and its descriptive measures (Right)



5.3 Optimal team communication structure

We conducted the same analysis on five communication network clusters. These network clusters come from the top 1000 teams similar to the previous analysis. The five presented agent to agent networks are the optimal communication network structures corresponding to five clusters, and the bar graphs are the comparisons between the average measures of each cluster and those of the overall top teams.

With the five generated optimal communication network structure, we could capture two distinct communication network types: a long chain-shaped communication network and a star-shaped communication network. Among the top 1000 teams, there are slightly more teams adopting a long chain-shaped communication network, but the number of the top teams adopting the other communication network is also significant. Table 11 suggests the number of the top teams categorized into a certain cluster and the number of the top teams adopting a suggested optimal communication network. Unlike the previous optimal team structure analysis on the movement network, all the five suggested communication network have quite reasonably dense communication network, and it suggests that the top teams keep communicating each other even though they sometimes utilize quite unorganized movement network structures. Furthermore, the emphasis of the communication networks in terms of the network density reminds us the importance of communication.

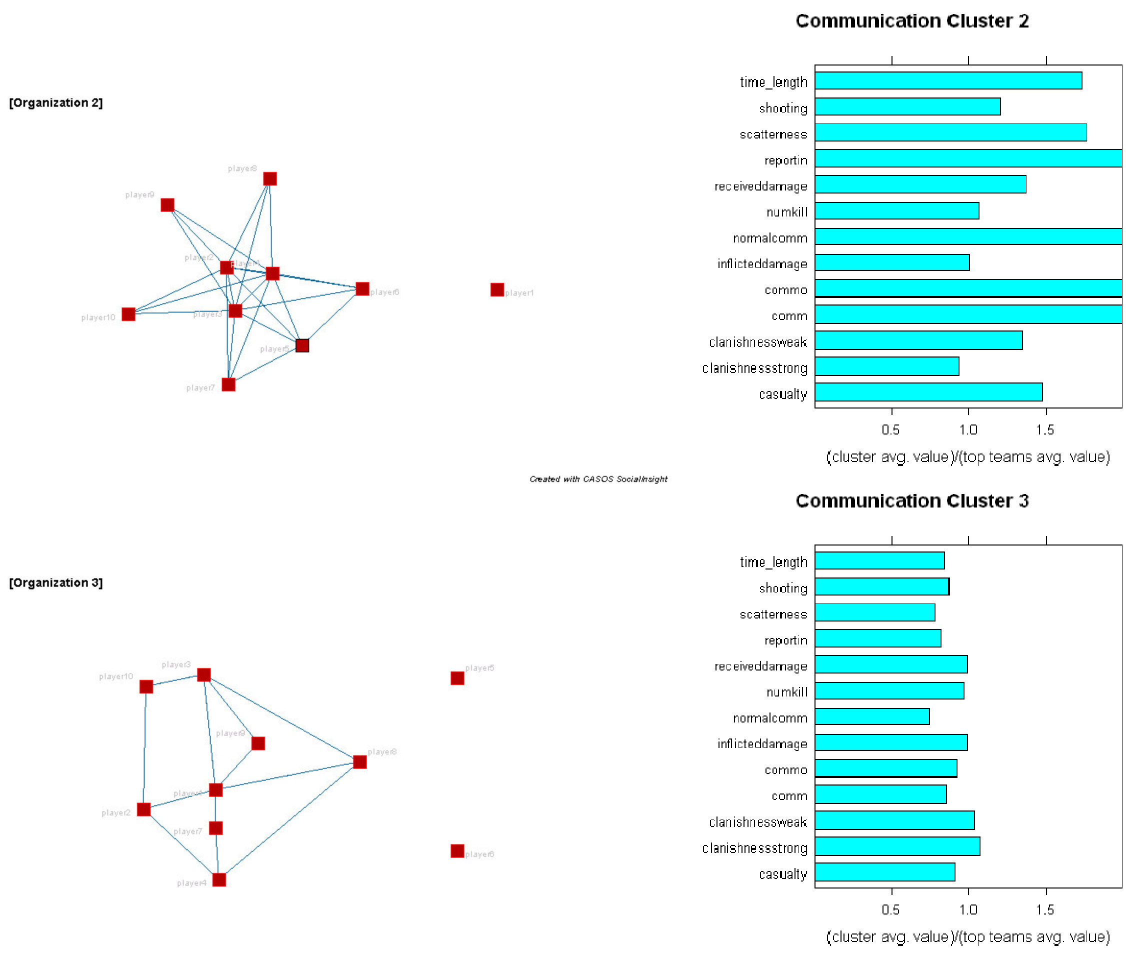
Table 11 Number of teams classified into each communication network clusters

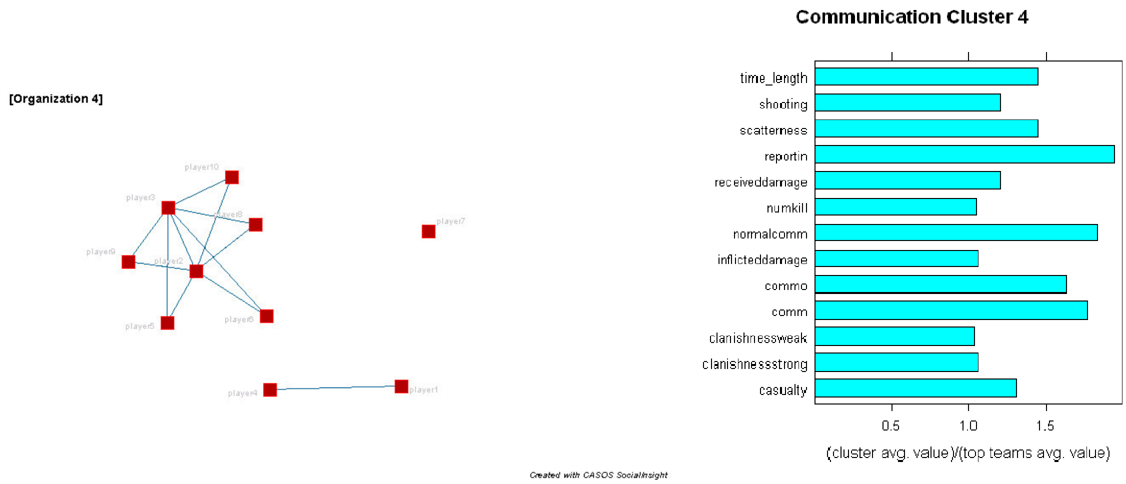
	Long chain-shaped Communication Network		Star-shaped Communication Network		
	Cluster 1	Cluster 5	Cluster 2	Cluster 3	Cluster 4
Cluster Num.	265	254	23	335	123

5.3.1 Dense communication structure: Star-shaped communication structure

Cluster 2, 3 and 4 have slightly denser communication networks than the other clusters have, but the casualties of those clusters are higher than the other networks. It means that they are quite vulnerable from the attack. At the same time, they have higher inflicted damage, so the teams adopting star-shaped communication networks seems to be more aggressive and more vulnerable. For example, it should be noted that the cluster 2 has very high casualty while it has higher communication frequencies across all types of communication. It means that only increasing number of communication would not improve the survival rate of a team. The communication network should be efficient, so it can exchange information well with fewer communication messages. Furthermore, cluster 2 and 4 have very high frequency in normal communication, and it is not that recommendable because it takes time to type in such a message. Cluster 3 is an eccentric cluster among the clusters using the star shaped communication network. It seems that cluster 3 has less dense communication network compared to the other star shaped communication network, so the slight difference in the topology or the number of communication links might changes the performance of teams of cluster 3.

Figure 15 Three optimal communication network structures (Left) and their descriptive measures (Right)

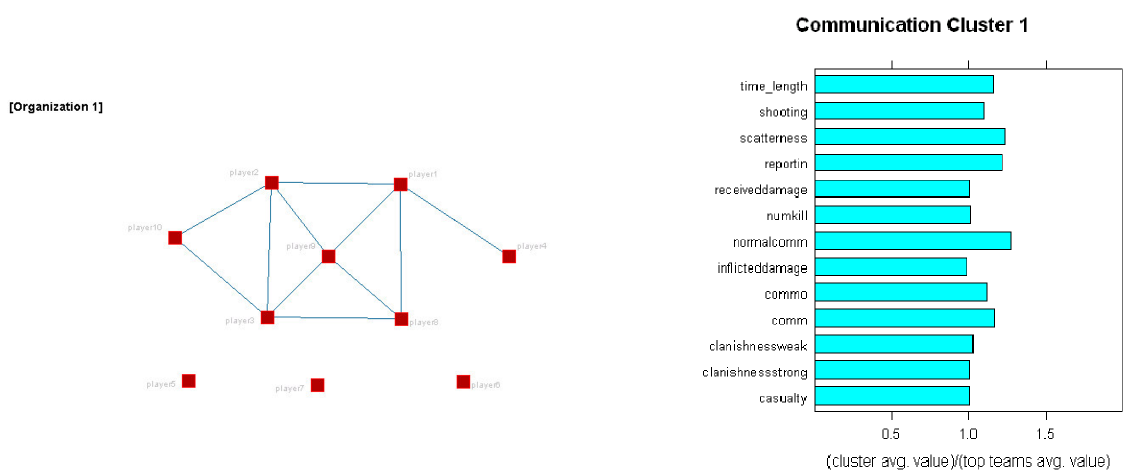


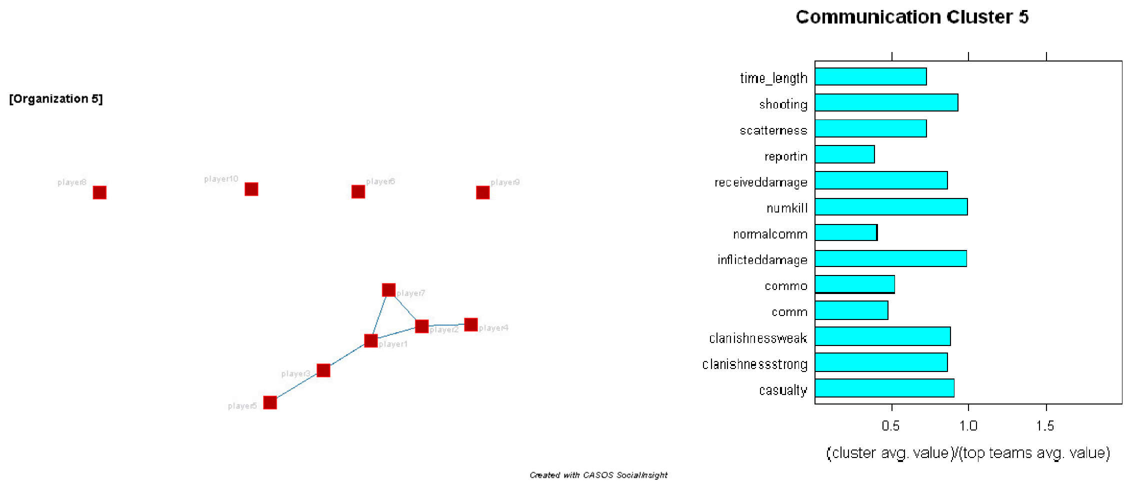


5.3.2 Sparse communication structure: Long chain-shaped communication structure

Cluster 5 has the typical long-chain shaped communication network, and cluster 1 has little similar structure compared to cluster 5. Because the long-chain communication network does not require many communication messages, the cluster has lower frequency of communication. However, the casualty and the received damage are low, and it means that the communication network was quite efficient in terms of survival rate. At the same time, the number of killed opponent players and the amount of inflicted damage are the average level of the top 1000 teams, so they are still deadly enough to be nominated among the top 1000 teams. This communication network shape may not be the best choice in a certain situation like maximizing the deadliness of a team because the clusters with star-shaped communication networks have slightly higher number of killed opponent, but the long-chain shaped communication network ensures the safety of a team by reducing the number of communication messages and by organizing the communication network efficiently. Particularly, we can observe that the communication network structure of cluster 5 has very small number of normal communication messages, and it helps team members to focus on the other tasks and team to win in short time length.

Figure 16 Two optimal communication network structures (Left) and their descriptive measures (Right)





6 Practical recommendations for training and configuring squad level military unit

6.1 Similarities and differences between America's Army and real world

6.1.1 Comparison between America's Army and real world research

To remind the comparison between America's Army and real world research, Table 12 is presented. After the statistical analyses of the first tech report, we could identify some similarities between them. The high performance team size, 10-men team size, was identical in both domains. Also, the importance of fire volume and Report-In was found in both domains. Because many recommendations and detailed statistical analyses were made based on the importance of them, the fact that fire volume and Report-In are important in both domains is very valuable in validating the recommendations and analyses.

Table 12.The summary of comparisons between America's Army and the squad-level real world research

	America's Army	Real world
Team configuration	High survival rate of 10-player teams	10-men infantry rifle squad of Reorganization Objective Army Division (ROAD) [7]
Weapon usage	Importance of Heavy weapon	Soldiers with heavy weapons are very effective [7]
Communication usage	Importance of Report-In communication	Importance of Provide (friendly) information communication [8]

6.1.2 Comparison between America's Army and Command and Control experiments

In previous tech report, Command and Control (C2) experiments [9] are compared to the America's Army game. For the brief recall of the comparison, Table 13 is made. First of all, it should be noted that C2 experiments are for higher layer military unit interaction, and America's Army is the simulation for the most bottom layer military unit. Therefore, the number and the attribute of interacting agents are very different to each other, and the experiment itself adopts different types of performance measure: received/inflicted damage for America's Army and shared situation awareness (SSA) for C2 experiments.

However, there are still similarities between two experiments. Because both simulations deal with the social network analysis, ORA measures can be applied to evaluate and extract the attribute of the social network for each experiment trial. Also, measurement for unity of unit and congruence of the knowledge might be good measurements for the social network. Not only the similarities in explanatory variables, but also their high performance in predicting the performance measure of both domains would be a good similarity. Furthermore, the high performance of explanatory variables drawn from the social network emphasizes the importance of the communication and social network in performance of the military units regardless of their sizes and positioning layers.

Table 13. The summary of comparisons between America's Army and C2 dataset research

	America's Army	Command and Control
Size/Level of Unit	Squad level soldiers	Brigade level staff officers
Performance measures	Received/Inflicted Damage, winning/losing	Shared Situation Awareness
Explanatory variables for the performance measures	ORA measures of social network among soldiers / Clannishness	Physical distance, social distance, and background similarities
Can performance measure be predicted by explanatory variables?	Yes with high R-square	Yes

The performance measure of C2 experiments is SSA, and SSA is calculated from three inputs: Agent to Agent, interaction/communication; Agent to Agent, physical proximity; and Agent to Agent, socio-demographic similarity. In America's Army, three measures that are similar to above three inputs were also calculated. According to SSA calculation formula, the increment of the three variables will increase the SSA. Also, it was commonly believed that higher SSA will result the positive outcomes of the organization. In America's Army, the higher frequency of Report-In is one of the most noticeable characteristics of winning team. Also, the lower scatterness (higher physical proximity in virtual space) is other characteristics of winning team. Finally, the higher clannishness can be seen in the winning teams. Therefore, when we consider the above similarities, we can speculate that the winning team in America's Army might have higher SSA. Thus, we would be able to conclude that SSA would be good performance measure not only for C2 brigade level experiments, but also for squad-level military unit training.

Table 14. The summary of comparisons between America's Army measures and C2 SSA calculation inputs

America's Army statistical result	SSA inputs

Number of communication (Number of Report-In)	interaction/communication
Scatterness	physical proximity
Clannishness	socio-demographic similarity

6.2 Guidelines to win America's Army game from the previous and the current tech report

By writing the first and the second tech report, we tried to identify winning strategies at player, team, and clan level. Of course it is very hard to say that certain aspects or methodologies are the strategies of winning team, so we assumes that the tendencies resulted from the statistical analyses of winners would be the winning strategies. Following subsections summarize the important findings with itemized phrases. More detailed implications can be found at Chapter 6.3, 6.4, and 6.5.

6.2.1 Strategies for players

- Handle various weapons: from M4, M16, AK47 rifles to M9 pistol and SPR,SVD sniper rifle
- Transmit Report-In communications as many times as possible
- Do seeking covers and firing weapons to enemy at the same time
- Keep selecting the medic role if you want to be a medic
- Ambushing enemy is better than rushing to enemy

6.2.2 Strategies for teams

- Be consisted of 10 players to maximize the survival rate
- Equip two or more fire team members with heavy weapons
- Overwhelm the enemy in the fire volume
- Report-In communication is the most important messages for team success.
- When a player transmits a Report-In, the other players should respond one by one, and this chain of Report-In should connect as many team members as possible.
- Even though the team is very experienced and play games together very often, it would be recommendable to keep transmitting a lot of Report-In during the play.
- Players should not be dispersed across the game play space.
- Both winning teams and losing teams should cover almost same number of spots on game field, but winning team members always stay close to the other team members who are at the same spot (fire team members).

6.2.3 Strategies for clans

- Making a team with same clan members is the most effective way to win.

- Play together very often to be familiar with the other clan members' play styles.
- Forming a team with players who are participating in clans is the alternative way to win because players who are in clans would have better knowledge and experience than the ordinary players have, but this is not as good as playing with same clan members because they don't know how to coordinate game play due to the lack of understanding each other's play.

6.3 Recommendation on training squad level military unit

6.3.1 Recommendation at soldier level

Top players in America's Army show some distinct traits in their game play. They tend to plan their role selection from the beginning, play with extreme caution, utilize the communication greatly, and know the characteristics of weapons. From the found traits, we made recommendations on training soldiers from the viewpoints of individual movement, equipment, communication, and carrier selection.

- Train soldiers to fire their weapons and to seek covers at the same time
  : Top players of America's Army don't get damage although they become more aggressive. They have an ability that makes them deadly and invulnerable at the same time. Therefore, the soldiers should be trained to move and shoot their weapons at the same time.

- Train soldiers to transmit Report-In frequently
  : It is obvious that transmitting Report-In many times is the key to win the combat. This can help the other team members aware where their friendly forces are. There might be incidents that friendly forces shot each other and some soldiers were isolated without notice. By training soldiers to transmit Report-In many times, these unwanted situations will be avoided.

- Train soldiers to handle heavy weapons
  : Heavy weapons are important and critical resources on America's Army battlefield. Sniper rifles, automatic rifles, and rockets can suppress the enemy and support the friendly forces. Also, in real world, many incidents were reported that numerous soldiers were suppressed by one sniper or one automatic rifle. Equipping more soldiers with heavy weapon might be the way to improve squad units.

- Train soldiers not to rush, but to ambush
  : Ambushing is the conspicuous tactic the top players adopt. It can be done in any place: room, air condition venue, roof, etc. Also, it is critical for soldiers not to rush into such places where enemy can easily ambush. This recommendation implies that the combat soldiers should be more patient and cautious.

- Train medics from the beginning of their training
  : Among the top players of America's Army, there are medic specialized top players, and they keep choosing medic role. By training them from the beginning, soldiers will know

what to do as a medic. In America's Army game, medic specialized top players transmit Report-In a lot, concentrate treating the other team members rather than fighting against enemies, and understand they should not be shot because it would be fatal.

6.3.2 Recommendation at squad level

Teamwork would be the most important feature in the success of a team, and we could identify some guidelines that can enhance the teamwork of America's Army team. Although a team consists of good players, they have to cooperate to each other to achieve the winning. Therefore, the guidelines to enhance the teamwork should be the guidelines to increase the chance of cooperation. We present several points that can maximize the cooperation.

- Train soldiers to move with their fire team members closely
  : Winning teams and losing teams of America's Army have almost same number of groups whose group members move together. However, the winning teams' small groups are more centered, and the winning players who belong to the small group stay closer to the other players who are in the same small group than the losing players do. Therefore, if we consider the small group as a fire team, soldiers should be trained to stay close to their fire team members.

- Train soldiers to make a chain of Report-In communication
  : The best communication network structure in America's Army game is the long chain shaped communication network. All squad members should remember the squad member who will Report-In next to them. When the squad leader starts Report-In, the squad members should respond by transmitting Report-In in the predefined order. If the next soldier who is supposed to Report-In has not responded, the soldier after that should report in. The squad leader should not have to remind him and distract the squad leader from his other duties.

- Train soldiers to transmit Report-In particularly frequently during the middle of combat
  : This can be done by training squad leaders to transmit Report-In a lot during the middle of combat because the other squad members should be trained to respond the squad leader's Report-In.

- Train soldiers to fire their weapon a lot
  : Each soldier might have small fire volume if the soldier has a sniper rifle. However, the overall squad should overwhelm the opponent by firing their weapons very frequently. Therefore, the soldier with Squad Automatic Weapon (SAW) and the soldier with the sniper rifle should cooperate closely with each other.

6.3.3 Recommendation at unit level

Clans in the America's Army community can be considered units that are higher level of squad units. During the analyses, we could identify the distinctive attribute of winning teams, and the attribute can be controlled at the clan level. Thus, it might be possible to upgrade the capability of a squad by training and configuring it with some unit level guidelines.

- Train soldiers to know their teammates' combat style
  : Being in the same unit lets soldiers be familiar with their teammates' combat style. This is very important because team members can reduce the verbal communication in real situations and concentrate on more valuable and meaningful communication like Report-In by knowing their teammates' combat style.

- Don't deploy soldiers trained in separate units as one squad
  : They are not familiar with the other squad members' combat style. In this case, their verbal communication increases and their time will be spent less efficiently in real world situations.

6.4 Recommendation on Tactics, Techniques, and Procedures at squad level

Tactics, Techniques, and Procedures (TTP) for Squad level radio communication was defined by Redden and Blackwell [10], 2001. It describes the procedures and rules for requesting and transmitting messages at squad level radio communication. So far, ARL research defined 5 TTPs, and they were utilized in the field experiments to evaluate its performance. The ARL defined TTPs emphasize the hierarchical command level, so the squad leader (SL) and two team leaders (TL) are the main contact node of the communication. The 5 TTPs can be seen in Table 15. According to the descriptions of TTPs and fundamental assumptions of ARL research, we can find some common aspects among TTPs.

- The SL can always transmit messages to anyone in his squad at any time.
- Everyone can always listen to squad radio transmissions.
- Everyone can use hand and arm signals at any time.
- If a TTP allows you to transmit, use the squad radio as your primary means of verbal communication
- If a TTP forbids you to transmit and you need to say something out loud, communicate the way you normally would without a squad radio

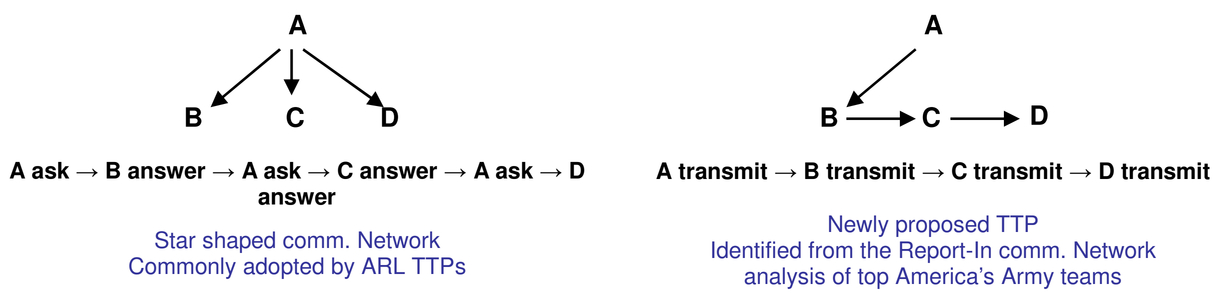
Table 15 5 TTPs defined by ARL research

TTP	Name	Description
TTP 1	Don't Talk	Team leaders and team members (TM) cannot transmit.
TTP 2	TL to SL Only	TLs can transmit at any time, but only to SL. The TMs cannot transmit.
TTP 3	When SL Asks	TLs and TMs cannot transmit, unless the SL asks them to transmit to him. TLs and TMs cannot transmit again until the SL asks them to transmit to him again.
TTP 4	Up and Down	TLs can transmit to their TMs and to the SL at any time. The TMs can transmit to their TL or to the SL at any time.
TTP 5	Free Talk	TLs and TMs can transmit to anyone in the squad at any time (including TL to TL and TMs to TMs in other teams).

However, in some perspectives, these TTPs are questionable. For example, what if an emergent situation happened, should squad members (SM) get permission to speak from their superior? According to the above tables and assumptions, SMs have no way but to wait SL asks questions, send information through TL, or shout the information loudly, and these solutions would not be very good idea in some situations. Also, we conjecture that the entire SMs should operate together even though there are two separate fire teams because the squad is a small military unit. However, the suggested TTPs are quite strict in terms of hierarchical structure between fire teams and squad leaders. There are not that obvious ways to communicate SMs who are in different fire teams. Of course, TTP5 grants unlimited communication privileges to SMs, but it lacks discipline that is crucial when number of soldiers communicate on one communication frequency.

To understand the ARL suggested TTPs and our recommended TTP, let's consider the following hypothetical case. If there are three squad members (B, C, and D) and one squad leader (A), the star shaped communication network might be the left network on Figure 17. Also, the long chain shaped communication network would be the right network.

Figure 17 Diagram describing how the star shaped communication network and the long chain shaped communication network work



Because ARL research is strict on the command hierarchy and tries to apply the command hierarchy to the communication TTP, the star shaped communication network might be the abstract version of communication network that can be generated by ARL recommended TTPs. On the other hand, the long chain shaped communication network is the network we discovered with the result of data-mining of the top 1000 teams communication network. Therefore, we first extracted desirable communication network from the America's Army top teams and rebuild an appropriate TTP that enables the long chain shaped communication network. Our TTP is "Sequential transmit": when the SL transmits the other SMs transmit, one by one, followed by previously defined order.

Star shaped communication network would be better if the leader can transmit many messages at the same time, but we are talking about single band squad radio communication. If a squad adopts the star shaped communication network, every time the SL asks, the SL will get only information from single SM. On the contrary, chain shaped communication network would be better if every member remembers their orders to send out communication message in squad radio communication. In that case, every time leader asks, the chain will be activated, and the information will flow through all the squad members.

If we understand the distinctive attributes of squad level radio communication, it will be easier to understand the pros and cons of each communication network topology. To know the attributes of the squad level radio communication, we compared brigade command and control (C2) level communication, upper layer military unit communication, to squad level communication, bottom layer military unit communication.

- At brigade level C2 communication
: There are multiple computers, communication devices, and communication frequencies. Each communication node consists of a number of officers, so each node can deal with multiple incoming/outgoing transmissions. They are not directly involved in combat as squad level soldiers are.

- At squad level radio communication
: One small radio is the only resource each soldier has for communication. Each soldier has to fire weapons, change positions, and communicate the other members at the same time. Extremely dynamic, so information should flow very automatically.

When we examine the above situation, we might conclude the chain shaped communication network would be better. The SL of a squad can gather information by making one report-in request. The Report-In information will flow through every single team members. Each team member only has to focus on their previous Report-In member. This way is very effective when there are many tasks that the SL should do with time and resource constraint. If the SL always has to ask where SMs are individually, it would be impossible to manage the whole squad. Also, if the communication is disconnected between two fire teams, there will be missing opportunity that two fire teams can cooperate together and be successful. This long chain shaped communication network and its corresponding TTP is very autonomous started by one request from the SL and covers all the SMs regardless of the fire team composition.

6.5 Recommendation on configuring the squad level military unit

Figure 18 shows the typical squad-level infantry unit composition. It specifies the size of a squad, the hierarchy of command, and the weapon equipment. This Reorganization Objective Army Division (ROAD) recommended squad structure was adopted in early 1960’s, but it was rejected soon due to the unbalanced sizes of two fire teams [7]. This diagram was introduced in this tech report because it resembles to our suggested squad structure. However, this ROAD recommended squad structure presents no information about how to move and how to communicate. It seems that this structure simply assumes every activity will be done with same fire team members.

Figure 18. The composition of squad-level infantry unit according to the ROAD recommendation

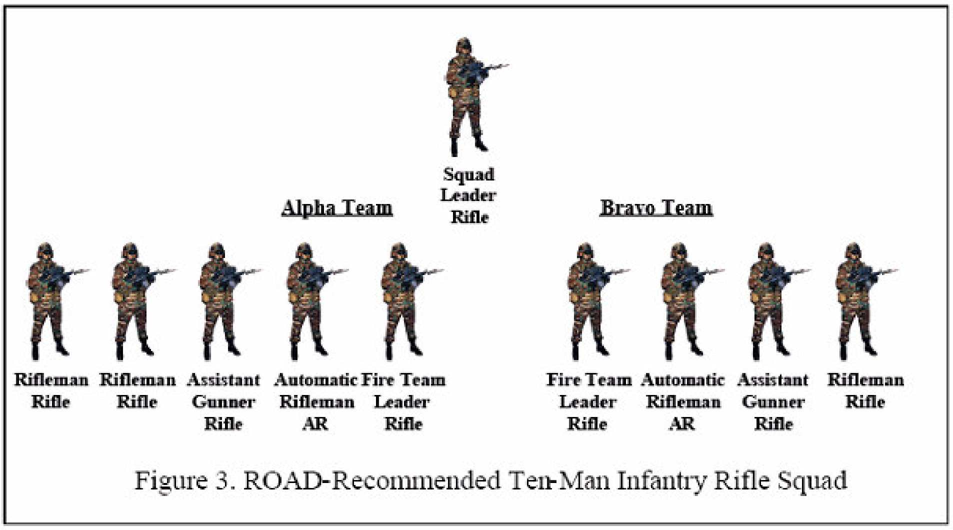
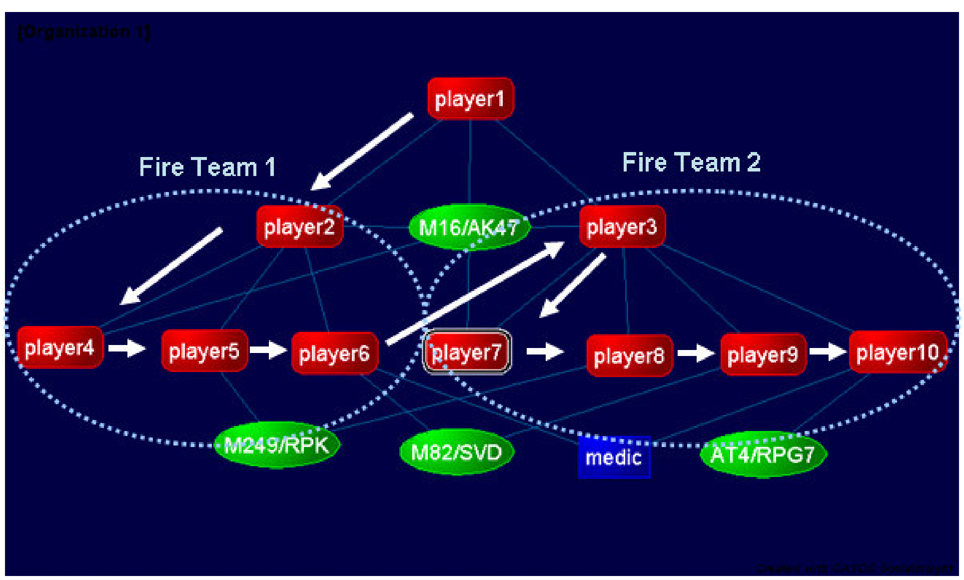


Figure 3. ROAD-Recommended Ten-Man Infantry Rifle Squad

After the data analyses of two datasets from the America's Army game, we could capture the important characteristics of winning teams and suggest the corresponding recommendations for configuring squad structure and training. We summarized some of those recommendations in one diagram showing the recommended squad-level structure. First of all, we specified the chain of communications with white arrows. Because we concluded the long chain shaped communication network structure would be good, the white arrows showing the communication network covers all of the squad members and shaped like a long chain. Also, we specified the two fire teams, and the members of a fire team should stay close to their same team members during the combat. Due to the importance of the heavy weapon, we added two soldiers with sniper rifles and one soldier with RPG instead of three soldiers with ordinary rifles.

Figure 19. The composition of the squad-level unit according to the result of the America's Army data analysis



7 Conclusion

We conducted the second data analysis with a new game log record dataset. Unlike the previous dataset, the new one includes the location information of each game event, so we could analyze the team organization and behavior from the viewpoint of movement of players or teams. Because we did numerous statistical analyses at player level and clan level in the first tech report, we focused on the team organization in terms of movement and communication at team level. To find more effective team organization, we utilized regression analyses and correspondence analyses. However, with only those statistical analyses, we was not able to make a recommendable team organization structure, so we coded 'Network Fitter' and used it to make a computer program figure out the most effective team organization. After identifying the optimal movement networks and the communication networks, we applied the findings from the analyses to the real world and made three recommendations on training squad level unit, constructing effective TTP, and configuring an optimal squad unit.

Before we did the major statistical analyses, we verified the second dataset shows the same tendencies found from the first tech report. With the simple calculation of communication frequency and survival ratio, we could confirm that the Report-In communication does important roles in teams' success and the 10-man team structure has relatively high survival rate. Because we confirmed the above two aspects, we used Report-In communication network to build the teams' communication network and made a recommended team structure having 10 players. Also, the location information had been analyzed with preliminary statistical analyses. We calculated the average standard deviation of three coordinates, the scatterness, the movement distance, and the average distance from the cluster centers determined by the k-means analysis on the game events. Those analyses agree that the team members should be located closely to the other team members and the physically scattered teams do worse in the games. Based on this result, we could identify that the relative location of team members affect to the team's success and determined to analyze the movement network furthermore.

From the regression analyses and correspondence analyses, we could capture a somewhat vague optimal network structure. The resulted network structure was not exact because we had to make a network structure based on the coefficients or graphs generated by those analyses. Furthermore, the R square value of the regressions was not quite impressive. From the correspondence analyses, we could capture how the 1000 teams can be categorized into five clusters and what the characteristics of each cluster are. However, due to the difficulty of the interpretation of ORA measures and the reconstruction of networks, we rather addressed the problem with the network fitter.

With K-means analysis, all of the top 1000 teams were categorized into five clusters in terms of movement and communications. After the clustering, we utilized the network fitter and obtained the five optimal team structures corresponding to the five clusters. This allowed us to capture the five optimal movement networks and the five communication networks. Among the five optimal movement networks, there were largely two types of networks: dense network and sparse network. The dense networks suggest that the team members stay together very closely. Among the dense networks, the network with two sub groups has fewer casualties and communications than others but a satisfying number of killed opponent. Hence, that team might be better off if it were to organize two fire teams and locate fire team members together. We used the same analysis technique on the communication networks, and found two dominant communication network types: star shaped communication network and long-chain shaped communication network. However, the long chain shaped communication network performed better than the other networks because the teams with the communication network has fewer casualties, less communication, and yet sufficient inflicted damage. Particularly, the lower communication frequency is important as it reduce team members' burden to communicate, but it should be emphasized that the reduced communication frequency of the long-chain shaped communication network teams is still higher than that of losing teams.

Based on the above analyses, we qualitatively analyzed the relation between the real world and America's Army and made recommendations to real world. We compared the features of America's Army and those of real world squad level research papers. Also, we compared America's Army data analysis to the C2 experiment analysis. By doing these qualitative comparisons, we could see there are number of similarities. Because we found some similarities between America's Army and the real world, we made three recommendations to the real world with the findings of America's Army data analyses. The first recommendation was about training squad level military unit. We pointed several important characteristics at squad level: Report-In, ambushing, handling heavy weapons, moving closely to the other fire team members. The second recommendation was suggesting new TTP that can be used in squad level radio communication. Because we saw the effectiveness of the long-chain shaped communication network, we interpreted the reason of its effectiveness. Unlike the upper layer military unit, the soldiers at squad level unit have only small radio as a communication device, face more vivid combat situation, and do multiple roles (firing weapons, treating wounds, and communicating other members) at the same time. Therefore, it would be better to train soldiers make a long chain of communication because one request of Report-In from the squad leader will start the sequence of Report-In of entire squad members. Finally, we integrated the findings into a squad team configuration. The previous squad configuration did not specify the movement behavior and the communication activity, and it is just assumed that every activity will be conducted at the level of fire team or squad. Our suggested new team configuration has 10 soldiers that ensures higher survival rate, more soldiers with heavy weapons, two fire teams as a group for movement, and a long chain of communication.

Appendix A. Unstandardized/Standardized Coefficients from the regression analyses

Table 16 Coefficients for regression analysis between movement network ORA measures and received damage amount

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Intercept)	591.460	65.972		8.965	0.000
Average distance	-40.749	24.458	-0.038	-1.666	0.096
Average speed	-13.725	45.735	-0.007	-0.300	0.764
Betweenness centralization	-23.270	25.056	-0.005	-0.929	0.353
Closeness centralization	53.662	13.918	0.016	3.856	0.000
Clustering coefficient	-8.901	18.953	-0.013	-0.470	0.639
Connectedness	-54.989	18.284	-0.072	-3.007	0.003
Density	103.120	25.056	0.137	4.116	0.000
Diameter	2.847	0.309	0.042	9.210	0.000
Efficiency	-5.351	7.829	-0.008	-0.683	0.494
Hierarchy	-11.897	6.821	-0.015	-1.744	0.081
Indegree centralization	59.277	17.639	0.018	3.360	0.001
Interdependence	20.859	14.560	0.010	1.433	0.152
Lateral edge count	0.621	0.138	0.074	4.513	0.000
Minimum speed	-2.081	13.156	-0.002	-0.158	0.874
Network levels	3.962	4.396	0.013	0.901	0.367
Outdegree centralization	14.632	17.366	0.004	0.843	0.399
Pooled edge count	-11.001	6.527	-0.015	-1.686	0.092
Reciprocal edge count	-8.974	10.742	-0.010	-0.835	0.404
Sequential edge count	4.742	10.137	0.005	0.468	0.640
Skip edge count	30.908	10.046	0.047	3.077	0.002
Span of control	-22.888	2.017	-0.271	-11.346	0.000
Strong component count	-10.083	1.777	-0.124	-5.673	0.000
Total degree centralization	34.315	24.356	0.011	1.409	0.159
Transitivity	1.702	10.085	0.003	0.169	0.866
Upper boundedness	8.622	6.781	0.004	1.272	0.204
Weak component count	-4.199	1.305	-0.043	-3.217	0.001
Knowledge diversity	NA	NA	NA	NA	NA
Knowledge load	-617.547	30.988	-0.048	-19.928	0.000
Knowledge redundancy	95.719	1.702	0.687	56.254	0.000
Access redundancy	82.844	12.062	0.045	6.868	0.000
Resource diversity	37.619	9.380	0.012	4.011	0.000
Resource load	6.141	4.196	0.008	1.464	0.143

Table 17 Coefficients for regression analysis between movement network ORA measures and inflicted damage amount

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Intercept)	642.393	64.306		9.990	0.000
averagedistance	44.276	23.840	0.041	1.857	0.063
averagespeed	-44.255	44.581	-0.023	-0.993	0.321
betweennesscentralization	-30.921	24.423	-0.006	-1.266	0.206
closenesscentralization	-15.603	13.567	-0.004	-1.150	0.250
clusteringcoefficient	-99.146	18.475	-0.140	-5.367	0.000
connectedness	-7.580	17.823	-0.010	-0.425	0.671
density	18.567	24.424	0.024	0.760	0.447
diameter	-3.518	0.301	-0.051	-11.675	0.000
efficiency	-17.560	7.632	-0.026	-2.301	0.021
hierarchy	15.174	6.649	0.019	2.282	0.022

indegreecentralization	-31.641	17.194	-0.010	-1.840	0.066
interdependence	-116.111	14.193	-0.054	-8.181	0.000
lateraledgecount	0.579	0.134	0.068	4.313	0.000
minimumspeed	-9.741	12.824	-0.010	-0.760	0.447
Network levels	-10.275	4.285	-0.033	-2.398	0.016
Outdegree centralization	38.139	16.928	0.011	2.253	0.024
Pooled edge count	26.653	6.362	0.037	4.190	0.000
Reciprocal edge count	67.516	10.471	0.073	6.448	0.000
Sequential edge count	-13.222	9.881	-0.013	-1.338	0.181
Skipped edge count	-8.033	9.793	-0.012	-0.820	0.412
Span of control	-16.832	1.966	-0.196	-8.560	0.000
Strong component count	-2.521	1.732	-0.030	-1.455	0.146
Total degree centralization	-0.401	23.741	0.000	-0.017	0.987
transitivity	-15.843	9.830	-0.024	-1.612	0.107
Upper boundedness	-30.047	6.609	-0.013	-4.546	0.000
Weak component count	-14.314	1.272	-0.146	-11.249	0.000
Knowledge diversity	NA	NA	NA	NA	NA
Knowledge load	-590.149	30.206	-0.045	-19.538	0.000
Knowledge redundancy	69.936	1.659	0.494	42.166	0.000
Access redundancy	418.865	11.758	0.223	35.625	0.000
Resource diversity	120.928	9.143	0.039	13.226	0.000
Resource load	68.153	4.090	0.087	16.664	0.000

Table 18 Coefficients for regression analysis between communication network ORA measures and received damage amount

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Intercept)	258.591	92.432		2.798	0.005
Average distance	-57.721	9.821	-0.079	-5.878	0.000
Average speed	-381.246	43.458	-0.153	-8.773	0.000
Betweenness centralization	-63.836	13.788	-0.026	-4.630	0.000
Closeness centralization	74.613	11.285	0.030	6.612	0.000
Clustering coefficient	62.118	9.481	0.037	6.552	0.000
Connectedness	23.798	15.600	0.019	1.526	0.127
Density	89.622	19.555	0.033	4.583	0.000
Diameter	1.790	0.389	0.019	4.605	0.000
Efficiency	1.573	8.338	0.001	0.189	0.850
Hierarchy	40.895	10.337	0.032	3.956	0.000
Indegree centralization	2.126	10.479	0.001	0.203	0.839
Interdependence	-180.729	28.333	-0.045	-6.379	0.000
Lateral edge count	0.342	0.112	0.008	3.043	0.002
Minimum speed	123.565	21.683	0.051	5.699	0.000
Network levels	10.164	2.207	0.039	4.604	0.000
Outdegree centralization	-82.580	11.430	-0.032	-7.225	0.000
Pooled edge count	36.040	10.532	0.028	3.422	0.001
Reciprocal edge count	136.199	7.086	0.105	19.220	0.000
Sequential edge count	23.680	11.920	0.016	1.987	0.047
Skipped edge count	-13.949	7.037	-0.015	-1.982	0.047
Span of control	-18.594	3.118	-0.049	-5.963	0.000
Strong component count	-3.572	2.245	-0.024	-1.591	0.112
Total degree centralization	56.757	17.214	0.023	3.297	0.001
Transitivity	6.070	9.850	0.004	0.616	0.538
Upperboundedness	199.811	78.118	0.005	2.558	0.011
Weak component count	24.605	2.874	0.142	8.560	0.000
Knowledge diversity	NA	NA	NA	NA	NA
Knowledge load	-394.317	28.866	-0.030	-13.660	0.000
Knowledge redundancy	73.021	1.359	0.524	53.715	0.000

Access redundancy	144.406	12.107	0.078	11.928	0.000
Resource diversity	41.082	9.376	0.014	4.382	0.000
Resource load	11.617	4.234	0.015	2.743	0.006

Table 19 Coefficients for regression analysis between communication network ORA measures and inflicted damage amount

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Intercept)	375.384	87.076		4.311	0.000
Average distance	-86.204	9.252	-0.117	-9.318	0.000
Average speed	-172.346	40.940	-0.068	-4.210	0.000
Betweenness centralization	21.059	12.989	0.008	1.621	0.105
Closeness centralization	-4.742	10.631	-0.002	-0.446	0.656
Clustering coefficient	-38.508	8.932	-0.022	-4.311	0.000
Connectedness	-73.361	14.696	-0.058	-4.992	0.000
Density	-59.469	18.422	-0.022	-3.228	0.001
Diameter	2.025	0.366	0.021	5.530	0.000
Efficiency	25.356	7.855	0.017	3.228	0.001
Hierarchy	-29.185	9.738	-0.023	-2.997	0.003
Indegree centralization	50.926	9.872	0.019	5.159	0.000
Interdependence	-107.805	26.691	-0.026	-4.039	0.000
Lateral edge count	0.131	0.106	0.003	1.240	0.215
Minimum speed	62.087	20.427	0.025	3.039	0.002
Network levels	10.041	2.080	0.038	4.829	0.000
Outdegree centralization	37.986	10.767	0.014	3.528	0.000
Pooled edge count	5.067	9.922	0.004	0.511	0.610
Reciprocal edge count	-12.668	6.676	-0.010	-1.898	0.058
Sequential edge count	-71.315	11.229	-0.046	-6.351	0.000
Skipped edge count	33.602	6.629	0.036	5.069	0.000
Span of control	20.755	2.938	0.053	7.065	0.000
Strong component count	-1.222	2.115	-0.008	-0.578	0.564
Total degree centralization	-22.914	16.217	-0.009	-1.413	0.158
Transitivity	81.109	9.279	0.055	8.741	0.000
Upperboundedness	271.790	73.591	0.007	3.693	0.000
Weak component count	-33.999	2.708	-0.193	-12.556	0.000
Knowledge diversity	NA	NA	NA	NA	NA
Knowledge load	-384.098	27.194	-0.029	-14.124	0.000
Knowledge redundancy	62.563	1.281	0.442	48.852	0.000
Access redundancy	432.589	11.405	0.229	37.929	0.000
Resource diversity	105.974	8.833	0.034	11.998	0.000
Resource load	28.025	3.989	0.035	7.025	0.000

Appendix B. 5 Cluster Centers of Movement/Communicatoin nework ORA measures

Table 20 K-means analysis on movement networks ORA measures, 5 cluster center coordinates

cluster	Cluster 0	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Average distance	1.02245	1.17418	1.01103	1.42564	1
Average speed	0.980454	0.878546	0.99021	0.730224	1
Betweenness centralization	0.023408	0.01365	0.012821	0.04004	0
Closeness centralization	0.064523	0.034264	0.031767	0.062182	0
Clustering coefficient	0.961017	0.017704	0.980572	0.111038	1
Connectedness	0.954967	0.079669	0.980276	0.204048	1
Density	0.927068	0.038103	0.965779	0.082673	1
Diameter	3	10.9291	2.12308	11.399	6.14E-39
Efficiency	0.033403	0.950661	0.015385	0.797531	0
Hierarchy	0.013695	0.558088	0.007298	0.483046	0
Indegree centralization	0.046851	0.12473	0.024113	0.173413	0
Interdependence	0.022748	0.193575	0.015324	0.144317	0.012821
Lateral edge count	71.9048	2.48425	109.846	8.05556	132
Minimum speed	0.918651	0.727002	0.953846	0.445539	1
Network levels	1.1627	1.64961	1.09231	2.63131	1
Outdegree centralization	0.050291	0.124035	0.024113	0.183243	0
Pooled edge count	0.998225	0.224961	0.999425	0.560934	1
Reciprocal edge count	0.997877	0.554598	0.99837	0.718686	1
Sequential edge count	0.000782	0.345136	0.000116	0.127231	0
Skipped edge count	0.997071	0.03965	0.99885	0.272044	1
Span of control	8.87212	1.18116	10.8853	1.6259	12
Strong component count	1.32143	9.63583	1.16923	8.37374	1
Total degree centralization	0.053225	0.118901	0.025525	0.179205	0
Transitivity	0.995913	0.055081	0.998737	0.298914	1
Upperboundedness	1	0.949906	1	0.945376	1
Weak component tcount	1.24206	8.27165	1.12308	6.37879	1
Knowledge diversity	0	0	0	0	0
Knowledge load	0.999278	0.999849	1	0.998278	1
Knowledge redundancy	9.34524	9.92717	11.1538	10.3788	12
Access redundancy	0.330794	0.354252	0.382154	0.40202	0.442353
Resource diversity	0.737606	0.722	0.75365	0.741415	0.769633
Resource load	1.42325	1.32291	1.3642	1.42259	1.39819

Table 21 K-means analysis on communication networks ORA measures, 5 cluster center coordinates

cluster	Cluster 0	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Average distance	1.93509	1.76378	2.3141	1.84651	2.0194
Average speed	0.528044	0.573694	0.445629	0.554058	0.520734
Betweenness centralization	0.178938	0.194823	0.262685	0.186761	0.101385
Closeness centralization	0.13506	0.182233	0.16436	0.17288	0.083703
Clustering coefficient	0.287042	0.443622	0.226791	0.390166	0.129559
Connectedness	0.524982	0.746067	0.668617	0.642256	0.294172
Density	0.171006	0.28959	0.161615	0.235464	0.081885
Diameter	10.8975	11.36	10.0554	10.3537	11.0615

Efficiency	0.688984	0.572915	0.778754	0.607201	0.774939
Hierarchy	0.114401	0	0.090442	0.03369	0.306057
Indegree centralization	0.291683	0.354286	0.266614	0.321853	0.203904
Interdependence	0.076024	0.044942	0.06618	0.058713	0.105471
Lateral edge count	8.9576	33.76	2.52478	16.8571	2.02308
Minimum speed	0.282105	0.309333	0.224604	0.291674	0.285963
Network levels	3.72792	3.4	4.70845	3.60544	3.9
Outdegree centralization	0.295192	0.359826	0.266251	0.3283	0.186348
Pooled edge count	0.788518	0.953289	0.724096	0.89122	0.538876
Reciprocal edge count	0.468093	0.587621	0.353484	0.541937	0.356563
Sequential edge count	0.161644	0.030846	0.229276	0.081066	0.367202
Skipped edge count	0.604941	0.905554	0.49604	0.796737	0.278977
Span of control	2.36433	3.54552	1.91498	3.03567	1.54062
Strong component count	4.46643	2.56	3.3207	3.42177	7.11154
Total degree centralization	0.315827	0.374404	0.285808	0.344388	0.207357
Transitivity	0.280229	0.416843	0.171022	0.393743	0.135983
Upperboundedness	1	1	0.999919	1	0.997564
Weak component tcount	4.04594	2.56	2.90671	3.27891	5.95769
Knowledge diversity	0	0	0	0	0
Knowledge load	0.999063	0.996364	0.999776	0.999433	0.999679
Knowledge redundancy	10.1908	10.8	9.71137	10.5034	10.0577
Access redundancy	0.33258	0.4048	0.397668	0.393742	0.313385
Resource diversity	0.743501	0.77992	0.724055	0.75599	0.721273
Resource load	1.28526	1.4533	1.49119	1.4413	1.19564

Appendix C. Unstandardized/Standardized Coefficients from the regression analyses done with whole team measures against four performance measures

Table 22 Coefficients for regression analysis between team measures and inflicted damage amount

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Constant)	567.531	98.596		5.756	0
move_averagedistance	60.408	21.72	0.056	2.781	0.005
move_averagespeed	42.821	40.616	0.022	1.054	0.292
move_betweennesscentralization	-54.776	23.386	-0.011	-2.342	0.019
move_closenesscentralization	43.453	12.642	0.013	3.437	0.001
move_clusteringcoefficient	-94.513	17.41	-0.134	-5.429	0
move_connectedness	-88.104	16.245	-0.113	-5.423	0
move_density	213.213	24.776	0.279	8.606	0
move_diameter	-1.552	0.279	-0.023	-5.557	0
move_efficiency	-10.006	6.931	-0.015	-1.444	0.149
move_hierarchy	15.872	6.038	0.02	2.629	0.009
move_indegreecentralization	0.873	15.659	0	0.056	0.956
move_interdependence	-74.664	13.096	-0.035	-5.701	0
move_lateraledgecount	0.927	0.133	0.108	6.979	0
move_minimumspeed	-17.6	11.65	-0.017	-1.511	0.131
move_networklevels	-5.36	3.893	-0.017	-1.377	0.169
move_outdegreecentralization	32.403	15.482	0.01	2.093	0.036
move_pooledegecount	9.77	5.822	0.013	1.678	0.093
move_reciprocaledgecount	46.302	9.583	0.05	4.832	0
move_sequentialedgecount	-5.287	9.022	-0.005	-0.586	0.558
move_skipededgecount	-26.915	8.98	-0.041	-2.997	0.003
move_spanofcontrol	-24.451	2.121	-0.285	-11.53	0
move_strongcomponentcount	-5.252	1.582	-0.063	-3.319	0.001
move_totaldegreecentralization	45.96	22.14	0.015	2.076	0.038
move_transitivity	7.346	8.947	0.011	0.821	0.412
move_upperboundedness	-28.191	6.009	-0.012	-4.691	0
move_weakcomponentcount	-7.841	1.159	-0.08	-6.763	0
move_accessredundancy	171.156	32.522	0.091	5.263	0
move_resourcediversity	-31.797	31.218	-0.01	-1.019	0.308
move_resourceload	12.981	8.346	0.017	1.555	0.12
comm_averagedistance	-36.501	8.774	-0.049	-4.16	0
comm_averagespeed	-63.753	38.667	-0.025	-1.649	0.099
comm_betweennesscentralization	34.431	12.286	0.014	2.803	0.005
comm_closenesscentralization	-6.002	10.119	-0.002	-0.593	0.553
comm_clusteringcoefficient	-38.987	8.529	-0.023	-4.571	0
comm_connectedness	-50.347	14.032	-0.039	-3.588	0
comm_density	-125.417	19.951	-0.046	-6.286	0
comm_diameter	1.814	0.35	0.019	5.188	0
comm_efficiency	29.002	7.423	0.02	3.907	0
comm_hierarchy	-42.746	9.186	-0.033	-4.653	0
comm_indegreecentralization	30.017	9.348	0.011	3.211	0.001
comm_interdependence	-183.842	25.461	-0.045	-7.221	0
comm_lateraledgecount	-0.049	0.1	-0.001	-0.494	0.621
comm_minimumspeed	21.311	19.299	0.009	1.104	0.269
comm_networklevels	5.302	1.965	0.02	2.699	0.007
comm_outdegreecentralization	20.44	10.172	0.008	2.009	0.044
comm_pooledegecount	22.847	9.38	0.017	2.436	0.015
comm_reciprocaledgecount	-23.38	6.31	-0.018	-3.705	0
comm_sequentialedgecount	-94.366	10.652	-0.061	-8.859	0

comm_skipededgecount	38.951	6.317	0.041	6.166	0
comm_spanofcontrol	-2.003	3.223	-0.005	-0.621	0.534
comm_strongcomponentcount	3.959	1.999	0.026	1.98	0.048
comm_totaldegreecentralization	-42.94	15.396	-0.017	-2.789	0.005
comm_transitivity	66.826	8.79	0.045	7.603	0
comm_upperboundedness	191.471	69.393	0.005	2.759	0.006
comm_weakcomponentcount	-28.124	2.565	-0.16	-10.966	0
comm_knowledgeload	-450.578	29.503	-0.034	-15.272	0
comm_knowledgeredundancy	58.416	1.826	0.413	31.993	0
comm_accessredundancy	129.263	32.394	0.069	3.99	0
comm_resourcediversity	-258.199	31.293	-0.084	-8.251	0
comm_resourceload	8.032	8.299	0.01	0.968	0.333
experience	0	0	0.039	22.395	0
scatterness	-0.004	0.001	-0.015	-6.771	0
communication	-0.573	0.088	-0.046	-6.525	0
reportin	4.047	0.09	0.172	44.824	0
commo	0.545	0.104	0.016	5.243	0
normalcommunication	-2.476	0.137	-0.048	-18.133	0
medic_presence	-56.839	2.901	-0.036	-19.592	0
heavy_weapon_presence	91.109	2.743	0.066	33.214	0
num_of_weapon_type	28.012	0.615	0.151	45.579	0
num_of_weapon_fire	0.276	0.004	0.146	71.333	0
clanishness_strong	-4.68	8.634	-0.001	-0.542	0.588
clanishness_weak	10.859	4.015	0.006	2.705	0.007

Table 23 Coefficients for regression analysis between team measures and received damage amount

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Constant)	150.674	102.356		1.472	0.141
move_averagedistance	-15.37	22.548	-0.014	-0.682	0.495
move_averagespeed	23.161	42.165	0.012	0.549	0.583
move_betweennesscentralization	-44.905	24.278	-0.009	-1.85	0.064
move_closenesscentralization	62.794	13.124	0.018	4.785	0
move_clusteringcoefficient	2.554	18.074	0.004	0.141	0.888
move_connectedness	-60.384	16.865	-0.079	-3.58	0
move_density	99.038	25.721	0.131	3.851	0
move_diameter	2.746	0.29	0.041	9.475	0
move_efficiency	-9.42	7.195	-0.014	-1.309	0.19
move_hierarchy	-10.156	6.268	-0.013	-1.62	0.105
move_indegreecentralization	71.308	16.256	0.022	4.386	0
move_interdependence	37.299	13.595	0.018	2.743	0.006
move_lateraledgecount	0.678	0.138	0.08	4.912	0
move_minimumspeed	-2.316	12.094	-0.002	-0.191	0.848
move_networklevels	3.666	4.041	0.012	0.907	0.364
move_outdegreecentralization	23.794	16.072	0.007	1.48	0.139
move_pooledEdgecount	-17.159	6.044	-0.024	-2.839	0.005
move_reciprocaledgecount	-10.855	9.948	-0.012	-1.091	0.275
move_sequentialedgecount	7.698	9.366	0.008	0.822	0.411
move_skipededgecount	48.065	9.322	0.074	5.156	0
move_spanofcontrol	-22.472	2.202	-0.266	-10.207	0
move_strongcomponentcount	-4.916	1.643	-0.06	-2.993	0.003
move_totaldegreecentralization	42.58	22.984	0.014	1.853	0.064
move_transitivity	-17.45	9.289	-0.027	-1.879	0.06
move_upperboundedness	1.485	6.238	0.001	0.238	0.812
move_weakcomponentcount	-8.702	1.204	-0.09	-7.229	0

move_accessredundancy	15.243	33.762	0.008	0.451	0.652
move_resourcediversity	-7.539	32.409	-0.002	-0.233	0.816
move_resourceload	-29.787	8.665	-0.038	-3.438	0.001
comm_averagedistance	-25.266	9.108	-0.035	-2.774	0.006
comm_averagespeed	-278.55	40.141	-0.112	-6.939	0
comm_betweennesscentralization	-33.961	12.754	-0.014	-2.663	0.008
comm_closenesscentralization	42.097	10.505	0.017	4.007	0
comm_clusteringcoefficient	67.795	8.855	0.04	7.656	0
comm_connectedness	70.074	14.568	0.056	4.81	0
comm_density	-26.426	20.712	-0.01	-1.276	0.202
comm_diameter	1.115	0.363	0.012	3.074	0.002
comm_efficiency	-8.583	7.706	-0.006	-1.114	0.265
comm_hierarchy	39.642	9.536	0.031	4.157	0
comm_indegreecentralization	-19.328	9.705	-0.007	-1.992	0.046
comm_interdependence	-318.632	26.432	-0.079	-12.055	0
comm_lateraledgecount	0.031	0.104	0.001	0.298	0.766
comm_minimumspeed	76.54	20.035	0.032	3.82	0
comm_networklevels	5.156	2.04	0.02	2.528	0.011
comm_outdegreecentralization	-50.613	10.56	-0.019	-4.793	0
comm_pooledEdgecount	25.88	9.738	0.02	2.658	0.008
comm_reciprocaledgecount	131.048	6.551	0.101	20.005	0
comm_sequentialedgecount	-33.725	11.058	-0.022	-3.05	0.002
comm_skipededgecount	27.178	6.557	0.029	4.145	0
comm_spanofcontrol	-73.167	3.346	-0.191	-21.867	0
comm_strongcomponentcount	1.133	2.075	0.008	0.546	0.585
comm_totaldegreecentralization	42.285	15.984	0.017	2.646	0.008
comm_transitivity	-29.911	9.125	-0.02	-3.278	0.001
comm_upperboundedness	209.874	72.039	0.005	2.913	0.004
comm_weakcomponentcount	29.85	2.662	0.172	11.211	0
comm_knowledgeload	-99.509	30.628	-0.008	-3.249	0.001
comm_knowledgeredundancy	65.195	1.896	0.468	34.394	0
comm_accessredundancy	285.709	33.629	0.154	8.496	0
comm_resourcediversity	-20.685	32.487	-0.007	-0.637	0.524
comm_resourceload	0.871	8.616	0.001	0.101	0.919
experience	0	0	-0.058	-31.451	0
scatterness	-0.007	0.001	-0.028	-11.736	0
communication	9.566	0.091	0.785	104.867	0
reportin	-11.114	0.094	-0.48	-118.584	0
commo	-12.262	0.108	-0.376	-113.726	0
normalcommunication	-0.957	0.142	-0.019	-6.754	0
medic_presence	-17.96	3.012	-0.012	-5.963	0
heavy_weapon_presence	-25.835	2.848	-0.019	-9.072	0
num_of_weapon_type	12.866	0.638	0.07	20.166	0
num_of_weapon_fire	0.02	0.004	0.011	4.953	0
clanishness_strong	59.04	8.963	0.016	6.587	0
clanishness_weak	-67.494	4.168	-0.038	-16.192	0

Table 24 Coefficients for regression analysis between team measures and winning

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Constant)	-0.123	0.225		-0.547	0.585
move_averagedistance	0.093	0.05	0.053	1.886	0.059
move_averagespeed	0.074	0.093	0.023	0.798	0.425
move_betweennesscentralization	-0.056	0.053	-0.007	-1.048	0.295
move_closenesscentralization	-0.029	0.029	-0.005	-1.008	0.313
move_clusteringcoefficient	-0.164	0.04	-0.14	-4.125	0

move_connectedness	-0.015	0.037	-0.012	-0.404	0.686
move_density	0.252	0.056	0.2	4.463	0
move_diameter	-0.004	0.001	-0.032	-5.613	0
move_efficiency	-0.009	0.016	-0.008	-0.539	0.59
move_hierarchy	0.015	0.014	0.011	1.06	0.289
move_indegreecentralization	-0.036	0.036	-0.007	-1.013	0.311
move_interdependence	-0.026	0.03	-0.007	-0.871	0.384
move_lateraledgecount	0	0	0.012	0.582	0.56
move_minimumspeed	-0.028	0.027	-0.017	-1.047	0.295
move_networklevels	-0.011	0.009	-0.022	-1.288	0.198
move_outdegreecentralization	0.051	0.035	0.009	1.448	0.148
move_pooledegecount	0.03	0.013	0.025	2.23	0.026
move_reciprocaledgecount	0.001	0.022	0.001	0.045	0.964
move_sequentialedgecount	-0.003	0.021	-0.002	-0.132	0.895
move_skipededgecount	-0.047	0.02	-0.043	-2.287	0.022
move_spanofcontrol	-0.002	0.005	-0.014	-0.419	0.675
move_strongcomponentcount	0.009	0.004	0.069	2.607	0.009
move_totaldegreecentralization	-0.031	0.05	-0.006	-0.615	0.538
move_transitivity	0.019	0.02	0.018	0.932	0.351
move_upperboundedness	0.002	0.014	0.001	0.16	0.873
move_weakcomponentcount	-0.002	0.003	-0.014	-0.845	0.398
move_accessredundancy	0.157	0.074	0.051	2.122	0.034
move_resourcediversity	-0.011	0.071	-0.002	-0.152	0.88
move_resourceload	0.055	0.019	0.042	2.874	0.004
comm_averagedistance	0.007	0.02	0.006	0.346	0.729
comm_averagespeed	0.078	0.088	0.019	0.889	0.374
comm_betweennesscentralization	0.037	0.028	0.009	1.328	0.184
comm_closenesscentralization	-0.053	0.023	-0.013	-2.319	0.02
comm_clusteringcoefficient	-0.119	0.019	-0.042	-6.122	0
comm_connectedness	-0.015	0.032	-0.007	-0.479	0.632
comm_density	0.08	0.045	0.018	1.751	0.08
comm_diameter	0.001	0.001	0.004	0.72	0.471
comm_efficiency	0.046	0.017	0.019	2.747	0.006
comm_hierarchy	-0.092	0.021	-0.043	-4.407	0
comm_indegreecentralization	0.042	0.021	0.01	1.982	0.047
comm_interdependence	0.117	0.058	0.017	2.019	0.043
comm_lateraledgecount	0	0	-0.004	-1.186	0.236
comm_minimumspeed	0.032	0.044	0.008	0.732	0.464
comm_networklevels	0.004	0.004	0.008	0.812	0.417
comm_outdegreecentralization	0.071	0.023	0.016	3.041	0.002
comm_pooledegecount	0.012	0.021	0.006	0.568	0.57
comm_reciprocaledgecount	-0.179	0.014	-0.083	-12.448	0
comm_sequentialedgecount	-0.09	0.024	-0.035	-3.692	0
comm_skipededgecount	0	0.014	0	-0.012	0.991
comm_spanofcontrol	0.066	0.007	0.104	9.048	0
comm_strongcomponentcount	0.009	0.005	0.035	1.897	0.058
comm_totaldegreecentralization	-0.023	0.035	-0.006	-0.667	0.505
comm_transitivity	0.151	0.02	0.062	7.555	0
comm_upperboundedness	-0.074	0.158	-0.001	-0.471	0.638
comm_weakcomponentcount	-0.033	0.006	-0.114	-5.662	0
comm_knowledgeload	0.585	0.067	0.027	8.701	0
comm_knowledgeredundancy	-0.018	0.004	-0.075	-4.206	0
comm_accessredundancy	-0.201	0.074	-0.065	-2.724	0.006
comm_resourcediversity	-0.367	0.071	-0.072	-5.141	0
comm_resourceload	0.007	0.019	0.005	0.375	0.708
experience	4.33E-07	0	0.07	29.045	0
scatterness	7.11E-06	0	0.018	5.813	0
communication	-0.011	0	-0.543	-55.245	0

reportin	0.018	0	0.459	86.482	0
commo	0.015	0	0.271	62.645	0
normalcommunication	-0.002	0	-0.028	-7.679	0
medic_presence	-0.086	0.007	-0.033	-13.075	0
heavy_weapon_presence	0.093	0.006	0.041	14.828	0
num_of_weapon_type	0.023	0.001	0.074	16.194	0
num_of_weapon_fire	0	0	0.081	28.773	0
clanishness_strong	0.011	0.02	0.002	0.573	0.567
clanishness_weak	0.053	0.009	0.018	5.748	0

Table 25 Coefficients for regression analysis between team measures and new score

	Unstandardized coef.		Standardized coef.	t value	Sig.
	B	Std. err	Beta		
(Constant)	0.767	72.621		0.011	0.992
move_averagedistance	32.264	15.998	0.055	2.017	0.044
move_averagespeed	15.168	29.916	0.014	0.507	0.612
move_betweennesscentralization	-27.432	17.225	-0.01	-1.593	0.111
move_closenesscentralization	-16.058	9.312	-0.008	-1.724	0.085
move_clusteringcoefficient	-57.798	12.824	-0.149	-4.507	0
move_connectedness	14.484	11.966	0.034	1.211	0.226
move_density	66.871	18.249	0.159	3.664	0
move_diameter	-1.471	0.206	-0.039	-7.152	0
move_efficiency	-1.165	5.105	-0.003	-0.228	0.82
move_hierarchy	5.546	4.447	0.013	1.247	0.212
move_indegreecentralization	-28.328	11.534	-0.016	-2.456	0.014
move_interdependence	-22.43	9.646	-0.019	-2.325	0.02
move_lateraledgecount	0.103	0.098	0.022	1.05	0.294
move_minimumspeed	-16.93	8.581	-0.03	-1.973	0.048
move_networklevels	-5.445	2.867	-0.032	-1.899	0.058
move_outdegreecentralization	14.435	11.403	0.008	1.266	0.206
move_pooledDuring edgecount	9.88	4.288	0.025	2.304	0.021
move_reciprocaledgecount	2.551	7.058	0.005	0.361	0.718
move_sequentialedgecount	-3.599	6.645	-0.007	-0.542	0.588
move_skipededgecount	-22.196	6.614	-0.061	-3.356	0.001
move_spanofcontrol	1.533	1.562	0.033	0.982	0.326
move_strongcomponentcount	3.971	1.165	0.087	3.407	0.001
move_totaldegreecentralization	-8.022	16.307	-0.005	-0.492	0.623
move_transitivity	10.879	6.59	0.03	1.651	0.099
move_upperboundedness	-6.744	4.426	-0.005	-1.524	0.128
move_weakcomponentcount	1.403	0.854	0.026	1.642	0.101
move_accessredundancy	42.403	23.954	0.041	1.77	0.077
move_resourcediversity	-2.746	22.994	-0.002	-0.119	0.905
move_resourceload	21.885	6.148	0.051	3.56	0
comm_averagedistance	1.517	6.462	0.004	0.235	0.814
comm_averagespeed	41.715	28.48	0.03	1.465	0.143
comm_betweennesscentralization	18.382	9.049	0.013	2.031	0.042
comm_closenesscentralization	-26.382	7.453	-0.019	-3.54	0
comm_clusteringcoefficient	-48.76	6.282	-0.052	-7.762	0
comm_connectedness	-20.812	10.336	-0.03	-2.014	0.044
comm_density	87.611	14.695	0.059	5.962	0
comm_diameter	0.096	0.257	0.002	0.373	0.709
comm_efficiency	10.682	5.467	0.013	1.954	0.051
comm_hierarchy	-39.917	6.766	-0.056	-5.9	0
comm_indegreecentralization	18.98	6.886	0.013	2.756	0.006
comm_interdependence	65.9	18.753	0.029	3.514	0
comm_lateraledgecount	-0.068	0.074	-0.003	-0.918	0.359

comm_minimumspeed	11.108	14.215	0.008	0.781	0.435
comm_networklevels	1.69	1.447	0.012	1.168	0.243
comm_outdegreecentralization	34.394	7.492	0.024	4.591	0
comm_poolededgecount	0.614	6.909	0.001	0.089	0.929
comm_reciprocaledgecount	-74.506	4.648	-0.103	-16.031	0
comm_sequentialedgecount	-33.765	7.846	-0.04	-4.304	0
comm_skipededgecount	2.649	4.652	0.005	0.569	0.569
comm_spanofcontrol	25.607	2.374	0.12	10.786	0
comm_strongcomponentcount	3.579	1.473	0.043	2.431	0.015
comm_totaldegreecentralization	-9.914	11.34	-0.007	-0.874	0.382
comm_transitivity	51.793	6.474	0.064	8	0
comm_upperboundedness	-38.314	51.112	-0.002	-0.75	0.453
comm_weakcomponentcount	-17.401	1.889	-0.18	-9.212	0
comm_knowledgeload	270.101	21.731	0.037	12.429	0
comm_knowledgeredundancy	-6.499	1.345	-0.084	-4.832	0
comm_accessredundancy	-63.683	23.86	-0.062	-2.669	0.008
comm_resourcediversity	-129.83	23.049	-0.077	-5.633	0
comm_resourceload	5.977	6.113	0.014	0.978	0.328
experience	0	0	0.089	38.038	0
scatterness	0.003	0	0.023	7.613	0
communication	-4.879	0.065	-0.719	-75.391	0
reportin	6.769	0.066	0.525	101.793	0
commo	6.49	0.077	0.357	84.833	0
normalcommunication	-0.731	0.101	-0.026	-7.274	0
medic_presence	-18.887	2.137	-0.022	-8.839	0
heavy_weapon_presence	51.072	2.02	0.068	25.278	0
num_of_weapon_type	4.395	0.453	0.043	9.709	0
num_of_weapon_fire	0.085	0.003	0.082	29.839	0
clanishness_strong	-5.019	6.359	-0.002	-0.789	0.43
clanishness_weak	31.395	2.957	0.032	10.616	0

Appendix D. The top 1000 teams factor analysis result tables

Table 26 Communalities

	Initial	Extraction
move_averagedistance	1	0.927
move_averagespeed	1	0.967
move_betweennesscentralization	1	0.758
move_closenesscentralization	1	0.734
move_clusteringcoefficient	1	0.991
move_connectedness	1	0.973
move_density	1	0.984
move_diameter	1	0.807
move_efficiency	1	0.916
move_hierarchy	1	0.915
move_indegreecentralization	1	0.859
move_interdependence	1	0.855
move_lateraledgecount	1	0.944
move_minimumspeed	1	0.909
move_networklevels	1	0.95
move_outdegreecentralization	1	0.818
move_pooledFor edgecount	1	0.905
move_reciprocaledgecount	1	0.955
move_sequentialedgecount	1	0.94
move_skipededgecount	1	0.947
move_spanofcontrol	1	0.973
move_strongcomponentcount	1	0.974
move_totaldegreecentralization	1	0.925
move_transitivity	1	0.918
move_upperboundedness	1	0.84
move_weakcomponentcount	1	0.951
move_knowledgeload	1	0.984
move_knowledgeredundancy	1	0.918
move_accessredundancy	1	0.954
move_resourcediversity	1	0.903
move_resourceload	1	0.925

comm_averagedistance	1	0.908
comm_averagespeed	1	0.957
comm_betweennesscentralization	1	0.884
comm_closenesscentralization	1	0.773
comm_clusteringcoefficient	1	0.833
comm_connectedness	1	0.934
comm_density	1	0.949
comm_diameter	1	0.668
comm_efficiency	1	0.871
comm_hierarchy	1	0.629
comm_indegreecentralization	1	0.743
comm_interdependence	1	0.806
comm_lateraledgecount	1	0.492
comm_minimumspeed	1	0.828
comm_networklevels	1	0.862
comm_outdegreecentralization	1	0.781
comm_pooledMedgecount	1	0.888
comm_reciprocaledgecount	1	0.69
comm_sequentialedgecount	1	0.835
comm_skipededgecount	1	0.902
comm_spanofcontrol	1	0.956
comm_strongcomponentcount	1	0.936
comm_totaldegreecentralization	1	0.944
comm_transitivity	1	0.82
comm_upperboundedness	1	0.652
comm_weakcomponentcount	1	0.93
comm_knowledgeload	1	0.984
comm_knowledgeredundancy	1	0.918
comm_accessredundancy	1	0.95
comm_resourcediversity	1	0.909
comm_resourceload	1	0.91
experience	1	0.306
scatterness	1	0.746
communication	1	0.901
reportin	1	0.661
commo	1	0.599

normalcommunication	1	0.611
heavy_weapon_presence	1	0.423
num_of_weapon_type	1	0.773
num_of_weapon_fire	1	0.333
clanishness_strong	1	0.756
clanishness_weak	1	0.775

Table 27 Total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.544	21.293	21.293	15.544	21.293	21.293
2	12.196	16.707	38	12.196	16.707	38
3	6.871	9.412	47.412	6.871	9.412	47.412
4	5.178	7.094	54.506	5.178	7.094	54.506
5	3.875	5.309	59.814	3.875	5.309	59.814
6	2.623	3.593	63.407	2.623	3.593	63.407
7	2.409	3.299	66.707	2.409	3.299	66.707
8	2.197	3.01	69.717	2.197	3.01	69.717
9	2.015	2.761	72.478	2.015	2.761	72.478
10	1.895	2.597	75.074	1.895	2.597	75.074
11	1.627	2.229	77.303	1.627	2.229	77.303
12	1.421	1.946	79.249	1.421	1.946	79.249
13	1.226	1.679	80.928	1.226	1.679	80.928
14	1.182	1.619	82.547	1.182	1.619	82.547
15	1.083	1.484	84.031	1.083	1.484	84.031
16	0.988	1.354	85.385			
17	0.907	1.243	86.628			
18	0.827	1.133	87.761			
19	0.801	1.097	88.858			
20	0.713	0.977	89.835			
21	0.678	0.928	90.763			
22	0.637	0.873	91.636			
23	0.587	0.804	92.44			
24	0.505	0.692	93.132			
25	0.453	0.621	93.753			
26	0.415	0.568	94.321			
27	0.386	0.528	94.849			
28	0.364	0.499	95.348			
29	0.332	0.455	95.803			
30	0.306	0.42	96.223			
31	0.266	0.364	96.587			
32	0.241	0.33	96.917			
33	0.21	0.288	97.206			
34	0.189	0.259	97.465			
35	0.182	0.249	97.714			
36	0.169	0.232	97.945			
37	0.165	0.226	98.171			
38	0.152	0.208	98.38			
39	0.129	0.176	98.556			
40	0.118	0.162	98.718			

41	0.11	0.15	98.869			
42	0.101	0.138	99.007			
43	0.082	0.112	99.12			
44	0.078	0.107	99.227			
45	0.063	0.086	99.313			
46	0.061	0.084	99.397			
47	0.055	0.075	99.472			
48	0.046	0.063	99.536			
49	0.04	0.055	99.591			
50	0.038	0.052	99.643			
51	0.034	0.046	99.689			
52	0.031	0.043	99.732			
53	0.027	0.037	99.769			
54	0.025	0.034	99.804			
55	0.023	0.032	99.835			
56	0.019	0.026	99.861			
57	0.016	0.022	99.884			
58	0.014	0.019	99.902			
59	0.013	0.018	99.921			
60	0.011	0.016	99.936			
61	0.009	0.012	99.948			
62	0.007	0.01	99.958			
63	0.007	0.009	99.967			
64	0.006	0.008	99.975			
65	0.006	0.008	99.983			
66	0.003	0.004	99.987			
67	0.003	0.004	99.991			
68	0.002	0.003	99.994			
69	0.002	0.003	99.997			
70	0.002	0.002	99.999			
71	0.001	0.001	100			
72	4.98E-16	6.82E-16	100			
73	-1.58E-16	-2.17E-16	100			

Table 28 Component Matrix

	Component							
	1	2	3	4	5	6	7	8
move_averagedistance	0.451	-0.24	0.403	0.576	0.007	-0.112	-0.141	-0.045
move_averagespeed	-0.481	0.278	-0.401	-0.593	-0.011	0.102	0.124	0.041
move_betweennesscentralization	0.129	0.021	0.31	0.756	-0.098	-0.055	-0.019	0.13
move_closenesscentralization	0.004	0.01	0.188	0.694	-0.136	-0.024	-0.04	0.171
move_clusteringcoefficient	-0.678	0.706	0.087	0.113	-0.021	-0.042	-0.057	0.037
move_connectedness	-0.646	0.677	0.154	0.199	-0.032	-0.052	-0.139	0.065
move_density	-0.695	0.691	0.079	0.062	-0.026	-0.026	-0.086	0.035
move_diameter	0.628	-0.555	-0.016	-0.005	0.154	-0.085	0.137	-0.072
move_efficiency	0.634	-0.677	-0.071	-0.082	0.008	0.06	-0.002	-0.005
move_hierarchy	0.447	-0.525	-0.042	-0.102	0.042	-0.101	-0.526	0.308

move_indegreecentralization	0.469	-0.324	0.171	0.57	-0.098	-0.022	0.133	0.012
move_interdependence	0.348	-0.387	-0.102	-0.068	-0.083	0.167	0.59	-0.337
move_lateraledgecount	-0.646	0.698	0.098	0	0.066	-0.131	-0.058	0.021
move_minimumspeed	-0.481	0.28	-0.385	-0.599	-0.044	0.1	0.089	0.013
move_networklevels	0.453	-0.234	0.416	0.59	0.042	-0.117	-0.143	-0.043
move_outdegreecentralization	0.485	-0.306	0.182	0.55	-0.116	0.016	0.041	0.049
move_pooledegecount	-0.437	0.605	0.244	0.424	-0.021	-0.113	-0.005	-0.039
move_reciprocaledgecount	-0.352	0.475	0.121	0.197	-0.031	0.093	0.58	-0.356
move_sequentialedgecount	0.255	-0.396	-0.203	-0.34	0.018	-0.036	-0.548	0.382
move_skipededgecount	-0.595	0.7	0.112	0.212	-0.022	-0.06	0.012	0.021
move_spanofcontrol	-0.671	0.704	0.092	0.047	0.013	-0.084	-0.066	0.031
move_strongcomponentcount	0.649	-0.673	-0.126	-0.234	0.124	-0.072	0	-0.019
move_totaldegreecentralization	0.481	-0.279	0.225	0.651	-0.112	0.006	0.237	-0.043
move_transitivity	-0.584	0.684	0.101	0.176	-0.01	-0.06	0.01	0.027
move_upperboundedness	-0.142	0.119	0.03	-0.022	-0.011	0.124	0.171	-0.03
move_weakcomponentcount	0.589	-0.629	-0.199	-0.314	0.096	-0.021	0.192	-0.102
move_knowledgeload	-0.058	-0.032	0.017	-0.068	-0.032	-0.116	0.188	0.465
move_knowledgeredundancy	0.175	0.137	0.203	-0.205	0.585	-0.604	0.082	-0.149
move_accessredundancy	0.151	0.032	0.637	-0.114	0.461	0.114	-0.259	-0.166
move_resourcediversity	0.17	0.375	0.083	-0.025	0.508	0.445	0.171	0.16
move_resourceload	0.111	0.193	0.555	-0.046	0.386	0.524	-0.207	-0.034
comm_averagedistance	-0.474	-0.411	0.646	-0.25	-0.018	-0.114	0.079	0.017
comm_averagespeed	0.457	0.432	-0.671	0.26	0.068	0.117	-0.063	0.032
comm_betweennesscentralization	0.16	0.017	0.495	-0.288	-0.429	0.11	-0.098	-0.344
comm_closenesscentralization	0.382	0.251	0.402	-0.255	-0.48	0.151	0.059	0.14
comm_clusteringcoefficient	0.701	0.565	-0.068	-0.035	-0.1	-0.007	-0.021	0.009
comm_connectedness	0.435	0.265	0.641	-0.335	-0.341	-0.033	0.038	0.086
comm_density	0.703	0.549	0.155	-0.124	-0.21	-0.01	0.039	0.185
comm_diameter	-0.142	-0.082	-0.137	0.085	0.502	-0.327	-0.049	-0.35
comm_efficiency	-0.515	-0.483	0.352	-0.133	-0.07	0.061	-0.111	-0.169
comm_hierarchy	-0.355	-0.302	-0.108	0.159	0.059	0.136	-0.039	0.165
comm_indegreecentralization	0.5	0.395	-0.101	-0.068	-0.125	0.099	-0.18	-0.349
comm_interdependence	-0.339	-0.23	-0.602	0.28	0.02	0.293	-0.183	-0.128
comm_lateraledgecount	0.511	0.327	-0.092	0.022	0.111	-0.133	0.003	0.091

comm_minimumspeed	0.359	0.374	-0.646	0.242	0.063	0.163	-0.066	0.03
comm_networklevels	-0.405	-0.392	0.655	-0.237	-0.009	-0.159	0.076	0.011
comm_outdegreecentralization	0.533	0.389	-0.042	-0.075	-0.267	0.084	-0.114	-0.284
comm_pooledegecount	0.661	0.497	-0.109	-0.024	-0.017	-0.111	-0.063	-0.076
comm_reciprocaledgecount	0.447	0.397	-0.384	0.071	0.038	0.083	-0.235	-0.227
comm_sequentialedgecount	-0.62	-0.472	0.222	-0.001	0.032	0.033	0.136	0.18
comm_skipededgecount	0.692	0.515	-0.09	-0.029	0.058	-0.157	-0.005	0.004
comm_spanofcontrol	0.724	0.599	-0.058	-0.06	0.064	-0.148	0.044	0.126
comm_strongcomponentcount	-0.491	-0.337	-0.531	0.304	0.39	-0.001	-0.033	-0.033
comm_totaldegreecentralization	0.55	0.419	-0.086	-0.053	-0.247	0.122	-0.178	-0.379
comm_transitivity	0.649	0.534	-0.274	0.072	0.085	-0.049	-0.062	0.055
comm_upperboundedness	0.034	0.072	0.105	0.001	-0.008	-0.052	0.133	-0.096
comm_weakcomponentcount	-0.41	-0.249	-0.623	0.305	0.426	-0.049	-0.024	-0.106
comm_knowledgeload	-0.058	-0.032	0.017	-0.068	-0.032	-0.116	0.188	0.465
comm_knowledgeredundancy	0.175	0.137	0.203	-0.205	0.585	-0.604	0.082	-0.149
comm_accessredundancy	0.178	-0.002	0.647	-0.105	0.453	0.11	-0.254	-0.173
comm_resourcediversity	0.23	0.3	0.07	-0.004	0.495	0.456	0.192	0.178
comm_resourceload	0.207	0.089	0.56	-0.022	0.368	0.545	-0.19	-0.03
experience	0.218	0.026	0.071	-0.051	-0.054	0.1	0.14	0.084
scatterness	0.619	-0.075	-0.096	0.062	0.04	0.027	0.341	0.14
communication	0.684	0.566	0.083	-0.108	0.061	-0.177	0.047	0.096
reportin	0.543	0.52	0.029	-0.146	0.024	-0.167	-0.007	0.047
commo	0.569	0.386	0.12	-0.057	0.085	-0.146	0.028	0.092
normalcommunication	0.482	0.392	0.036	-0.067	0.048	-0.051	0.172	0.136
heavy_weapon_presence	0.006	-0.026	0.048	0.001	0.249	0.122	0.192	0.227
num_of_weapon_type	0.288	0.362	0.217	-0.03	0.514	0.332	0.211	0.111
num_of_weapon_fire	0.3	0.151	0.052	0.041	0.223	0.042	0.069	0.219
clanishness_strong	0.112	-0.011	0.014	-0.047	-0.221	0.084	-0.038	0.024
clanishness_weak	0.123	0.052	-0.024	0.066	-0.198	0.035	0.015	-0.027
	9	10	11	12	13	14	15	
move_averagedistance	-0.003	0.019	-0.182	-0.245	0.189	0.062	0.064	
move_averagespeed	0.001	-0.015	0.164	0.224	-0.177	-0.072	-0.07	
move_betweennesscentralization	0.044	0.049	0.067	0.085	0.047	-0.157	0.005	
move_closenesscentralization	0.054	0.158	0.182	0.219	-0.076	-0.226	-0.03	
move_clusteringcoefficient	0.005	0.027	0.05	0.03	-0.023	-0.002	0.004	
move_connectedness	-0.004	0.035	-0.011	-0.053	0.02	0.013	0.035	
move_density	-0.01	0.014	-0.001	-0.03	0.032	0.012	0.037	
move_diameter	0.012	0.048	0.109	0.142	-0.094	-0.031	-0.069	

move_efficiency	-0.022	-0.026	-0.101	-0.107	0.118	0.006	0.059	
move_hierarchy	-0.028	0.141	0.028	-0.064	-0.123	0.043	0.031	
move_indegreecentralization	0.013	0.009	0.114	0.102	-0.314	0.079	-0.155	
move_interdependence	-0.006	-0.136	-0.144	-0.067	-0.078	0.115	-0.101	
move_lateraledgecount	-0.011	0.035	0.006	-0.029	0.044	0.004	0.017	
move_minimumspeed	-0.006	-0.026	0.11	0.151	-0.162	-0.064	-0.081	
move_networklevels	0.001	0.038	-0.166	-0.234	0.192	0.071	0.075	
move_outdegreecentralization	0.08	0.116	0.149	0.233	-0.113	-0.157	-0.05	
move_pooledNedgecount	-0.021	-0.001	0.042	-0.078	-0.209	0.178	-0.1	
move_reciprocaledgecount	0.025	-0.157	-0.094	0.025	0.209	-0.005	0.006	
move_sequentialedgecount	0.009	0.165	0.142	0.107	0.052	-0.205	0.099	
move_skipededgecount	0.031	0.033	0.116	0.109	-0.1	-0.013	-0.046	
move_spanofcontrol	-0.004	0.038	0.023	-0.006	0.02	-0.006	0.02	
move_strongcomponentcount	0.011	0.037	0.031	0.03	-0.06	0.001	-0.038	
move_totaldegreecentralization	0.043	-0.008	0.102	0.189	-0.111	-0.07	-0.071	
move_transitivity	0.037	0.051	0.134	0.128	-0.143	0.005	-0.062	
move_upperboundedness	0.108	-0.02	-0.003	0.304	0.611	-0.496	0.186	
move_weakcomponentcount	0.019	0	0.052	0.083	-0.004	-0.05	-0.045	
move_knowledgeload	0.786	-0.281	-0.068	-0.078	-0.005	0.027	0.015	
move_knowledgeredundancy	0.118	0.097	0.094	-0.005	0.113	0.017	-0.061	
move_accessredundancy	0.09	-0.38	0.011	0.179	-0.04	0.066	-0.017	
move_resourcediversity	0.013	0.375	-0.003	-0.246	-0.018	-0.112	-0.035	
move_resourceload	0.039	-0.285	-0.018	0.094	-0.075	-0.001	0.022	
comm_averagedistance	-0.058	0.078	0.037	-0.045	-0.03	-0.021	0.018	
comm_averagespeed	0.012	-0.09	-0.055	0.063	0.036	0.06	0.004	
comm_betweennesscentralization	0.328	0.285	0.111	-0.025	-0.016	0.03	0.049	
comm_closenesscentralization	0.008	0.124	-0.069	0.053	0.145	0.123	-0.05	
comm_clusteringcoefficient	0.025	0.002	-0.036	0.018	-0.036	0.006	0.042	
comm_connectedness	-0.05	0.038	-0.049	0.059	0.027	-0.009	-0.123	
comm_density	-0.142	-0.072	-0.065	0.062	0.01	0.019	-0.037	
comm_diameter	0.167	0.066	0.206	0.008	-0.158	-0.168	0.058	
comm_efficiency	0.188	0.236	0.181	0.046	0.155	0.139	-0.108	
comm_hierarchy	-0.012	0.105	0.116	0.288	0.286	0.291	-0.227	
comm_indegreecentralization	0.287	0.181	0.104	0.017	-0.008	0.111	0.059	
comm_interdependence	0.154	-0.062	0.015	-0.04	0.09	0.054	-0.142	

comm_lateraledgecount	-0.206	0.015	0.094	0.119	0.065	0.069	0.04	
comm_minimumspeed	0.058	-0.085	-0.097	0.056	0.009	0.135	0.077	
comm_networklevels	-0.09	0.064	0.067	-0.038	-0.001	-0.081	-0.051	
comm_outdegreecentralization	0.298	0.248	0.081	0.024	-0.028	0.029	0.082	
comm_pooledとしedgecount	0.008	-0.159	-0.099	-0.078	-0.067	-0.282	-0.207	
comm_reciprocaledgecount	0.176	0.046	0.096	-0.017	0.117	0.076	-0.053	
comm_sequentialedgecount	-0.092	0.111	0.06	0.061	0.003	0.205	0.236	
comm_skipededgecount	-0.064	-0.162	-0.112	-0.07	-0.09	-0.239	-0.09	
comm_spanofcontrol	-0.117	-0.066	-0.028	0.051	0.024	0.022	-0.02	
comm_strongcomponentcount	0.035	0.016	0.086	0.075	0.122	0.152	0.006	
comm_totaldegreecentralization	0.342	0.245	0.123	0.019	-0.007	0.052	0.092	
comm_transitivity	-0.056	-0.099	-0.043	-0.025	-0.007	-0.037	0.003	
comm_upperboundedness	-0.004	0.014	-0.091	-0.09	-0.31	-0.099	0.694	
comm_weakcomponentcount	0.052	-0.03	0.045	-0.052	0.012	0.039	0.117	
comm_knowledgeload	0.786	-0.281	-0.068	-0.078	-0.005	0.027	0.015	
comm_knowledgeredundancy	0.118	0.097	0.094	-0.005	0.113	0.017	-0.061	
comm_accessredundancy	0.075	-0.361	0.016	0.187	-0.038	0.065	-0.022	
comm_resourcediversity	0.001	0.399	0.009	-0.248	-0.012	-0.122	-0.065	
comm_resourceload	0.006	-0.248	-0.012	0.095	-0.067	-0.011	0.002	
experience	-0.07	-0.131	0.244	-0.029	0.029	0.255	0.249	
scatterness	-0.016	0.056	0.343	0.263	-0.039	0.013	0.121	
communication	-0.075	0.053	0.03	0.033	0.09	0.172	-0.016	
reportin	-0.041	0.148	-0.096	0.038	0.05	0.029	-0.076	
commo	-0.061	-0.046	0.065	-0.016	0.092	0.228	-0.006	
normalcommunication	-0.108	-0.025	0.241	0.057	0.092	0.251	0.143	
heavy_weapon_presence	0.174	0.315	0.021	-0.257	-0.122	0.056	-0.2	
num_of_weapon_type	-0.018	0.235	0.079	-0.092	0.058	-0.069	0.035	
num_of_weapon_fire	-0.006	0.069	0.133	0.184	0.026	0.126	0.195	
clanishness_strong	-0.075	-0.323	0.64	-0.361	0.14	-0.112	-0.042	
clanishness_weak	-0.11	-0.323	0.625	-0.439	0.062	-0.08	-0.028	

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