AN EVALUATION OF THE KSIM CROSS-IMPACT MATRIX SIMULATION MODEL AS APPLIED TO MANAGEMENT DECISION MAKING

by

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ABSTRACT

KSIM is a simulation model which is designed to take into account the simultaneous effects of the relevant variables in a system as they interact over time and predicts their course.

The unusual characteristic of KSIM is that this model requires no mathematical or technological training of its users, but attempts to make use of their intuitive knowledge about the system.

This simulation model was applied to management forecasting as an aid to decision making. Its evaluation and application to business situations was performed by the scenario method. Direct predictions and then the use of KSIM as an alternate method were made. The two methods were compared to the actual outcome (truth) and the results tabulated. Predictions were made at both the individual and group level for additional comparisons.

The results showed that KSIM did not perform as well as a direct prediction in either uncommon and common situations. But, KSIM did have the propensity to perform better in uncommon situations. Also, those who did better in direct prediction also did better in using KSIM. This showed that KSIM did utilize the intuition of the user.

The results indicated that over time, with the use of KSIM, the accuracy did increase. This would suggest that performance increases with learning the use of KSIM.

INTRODUCTION

A procedure called KSIM devised by Kane (1972) has been used during the past few years as a forecasting tool in water resource management (Kane, Vertinsky and Thompson 1972), transportation planning (Nizlek and Wegmann 1974), and health care delivery planning (Kane, Thompson and Vertinsky 1972). Use without adequate or, in some cases, even rudimentary testing has characterized other attempts to harness intuitive knowledge, e.g., Delphi, cross-impact gaming, and certain Bayesian scoring schemes. This is bad because use without proper evaluation can lead to misinformation and costly mistakes in time, resources, and money.

Even though these simulations have been done, there has been no evaluation of KSIM's performance or measurement of its accuracy to date from the information available. It is the purpose of this thesis to evaluate KSIM and to determine its effectiveness as a forecasting tool as applied to management decision making.

This thesis reports an experimental test of a proposed method for providing decision makers with forecasts of the trajectories of relevant variables of complex dynamic systems. For reasons of cost, complexity, observability, etc., a validated quantitative model of a system may not be available, although there may be a substantial amount of intuitive knowledge about it gained from experience or by analogy with related systems. KSIM attempts to extract the essence of that intuitive knowledge from those who have it to generate quantitative or semi-quantitative forecasts. KSIM belongs to a class of approaches to assisting human performance of which a notable example is Edwards' (1963) PIP or Probabilistic Information Processor. The assumption is that people excel at recognizing which variables are relevant in a situation and the general nature and extent of their influence, but are not skillful at integrating or combining this information to reach conclusions, expecially when the number of variables is large. The approach is to rely on the person for inputs but to perform the aggregation by machine according to an algorithm. In the case of PIP, likelihood judgments are optimally aggregated by Bayes Rule. In KSIM, judgments of the influence of variables on each other are aggregated according to a plausible but otherwise ad hoc mathematical formula.

KSIM was tested by using the scenario approach. Harvard Business School case studies were used. These cases were divided into two categories, common and uncommon situations in business. The method of presenting the problem was to describe a particular situation along with critical variables for prediction from the case. The subjects would make their own predictions and then construct the KSIM impact matrix. The matrix and other data given by the subjects was keypunched and submitted as input into the KSIM computer program which was written for this evaluation. The resulting predictions were compared to the subjects' predictions and with the actual outcome (truth). Discrepancies between forecasts and the truth were tabulated and analyzed statistically.

GENERAL METHOD

KSIM may be described thus: the n important variables whose mutual interaction defines a system are identified by a person (or group) having intuitive knowledge of the system. He assigns to each an initial condition, X_{io}, on a 0-1 scale where zero represents the minimum value and one the maximum possible value of that variable. He then fills out an n x n cross-impact matrix with positive or negative numbers, a_{ij}, which represent the degree to which the magnitude of the column variable, X_j, influences that of the row variable, X_i. The forecast of the subsequent behavior of the system is obtained by iteratively computing incremental changes in the value of each variable by means of:

(1) $$X_i(t + \Delta t) = X_i(t)^{Q_i(t)}$$

where the exponent:

(2) $$Q_i(t) = \frac{1 + \frac{\Delta t}{2} \sum_{j=1}^{n} (|a_{ij}| - a_{ij}) X_j}{1 + \frac{\Delta t}{2} \sum_{j=1}^{n} (|a_{ij}| + a_{ij}) X_j}$$

The result is a trajectory for each variable on a 0-1 scale. Since no time information is contained in the impact matrix (the cross-impacts are assumed to be consistent with respect to time, though), the trajectory has no absolute time base and delta t is an arbitrary scale factor.

There are two principal problems in testing KSIM that stem from the ambiguity of its output and the corresponding difficulty of comparing it to the "true" outcome: (1) rescaling the variables from the given into the non-dimensional 0-1 scale, and (2) relating the output to real time.

Variable Scaling

The rescaling of variables was accomplished in part by the experimenter and in part by the subjects. The experimenter defined for the subjects the current value of each variable and also five intervals or outcome categories in units of that variable. The categories were named and designated as: 1 = substantial decrease, 2 = moderate decrease, 3 = practically no change, 4 = moderate increase, 5 = substantial increase.

The experimenter chose a point on the 0-1 scale to represent the current value, the initial condition. The subjects then specified on the 0-1 scale the points corresponding to the boundaries of the five outcome categories given to them in the units of the variables. They made their direct predictions by checking the outcome category they considered would be most likely at the end of the one year prediction interval.

Time Scaling

Relating the KSIM output to actual time, i.e., to the prediction interval of one year, was done by assuming a particular model for the way in which a decision maker would use KSIM output if it had no time scale. Ideally, the subjects should have been given the KSIM outputs and allowed to select the point on them they judged would correspond with the end of one year, but the computer output could not be obtained quickly enough to do that.

It was assumed that a person confronted with a set of trajectories of variables with no time scale, but having his own predictions for intervals within which the variables would lie at the end of a given period, would adjust the KSIM time scale so that the KSIM prediction would agree with the direct prediction for the variable about whose direct prediction he had the most confidence, assuming that were possible. Once the KSIM predictions were in the right interval, it was assumed that he would "fine tune" the time scale to maximize the number of agreements between KSIM and the direct prediction for the other variables.

If two or more variables had the highest confidence, it was assumed that the match would be made using the one that had the greatest net influence on the situation, i.e., the variable V_j with a maximum value of $\sum_{i=1}^{n} | a_{ij} |$. Having done this, a decision maker would really only be concerned with whether KSIM or his own direct predictions were better for the unmatched variables, the ones on which the KSIM prediction differed from his own.

To simplify the implementation of the matching procedure, a further assumption was made; that the prediction interval was sufficiently short relative to the time required for any major "turnarounds" in the variables' behavior that a linear extrapolation of the initial slope of the KSIM output would be a reasonable projection.

The matching was performed by a computer routine which read in the KSIM matrix and the prediction intervals along with confidence ratings of the variables to calculate a time value t_i such that, for the variable with the highest confidence rating, KSIM and the direct prediction agreed. The time values were then used with the calculated KSIM slopes and the initial conditions to generate KSIM values, K_i, for the other n-1 variables. The person's direct prediction was compared to the truth to determine a match by interval which was known as TP. KSIM values were also compared to the truth by interval to determine a match which was known as TK. A similar match was made between the direct prediction and KSIM also, which was known as PK.

The process of testing KSIM was performed by a management laboratory team composed of thirteen subjects who were volunteers with pay and bonus incentives. They were recruited from the College of Business and Public Administration at The University of Arizona. The prerequisites were that the subjects be pursuing or in possession of a master's degree or higher. Also, they had to have previous experience in using the case history approach to decision making. The pay scale was fifty dollars per subject with the stipulation that they attend the three-hour orientation session and make all five scenario testing sessions in order to be paid at all. This was designed to prevent people from dropping from the team prematurely and subsequently perturbing the results. Each scenario session lasted approximately two hours. Individual incentives were twenty-five, fifteen and ten dollars and group incentives were fifteen, twelve and nine dollars for the top three performers in each category. Incentive was given to those whose total of correct predictions, direct plus KSIM, were highest. The observed enthusiasm and high motivation to perform well are considered a direct result of the incentive bonuses.

Dr. Ernest Williams, Professor of Management at Columbia University, suggested the use of Harvard Business School case studies for testing KSIM. The case studies were condensed to include all the pertinent information needed to make predictions on the critical variables selected for the time period for prediction, one year in all cases. The subjects would make forecasts by both direct prediction and by using KSIM. The prediction of the two methods was later compared to the true outcome of each variable for one year later.

The responses the subjects could choose among to indicate confidence in their predictions were selected according to the results of an experiment on probability phrases (Lichtenstein and Newman 1967, p. 564). They were selected on the basis of the median estimates of the numerical probability subjects associated with the phrase. There were four confidence ratings. They were: (1) "very likely" which had an associated median probability of 0.90; (2) "rather likely," P = 0.70; (3) "fair chance," P = 0.50; (4) "just guessing," P = 0.30. These confidence ratings were picked as the probabilistic midpoints of intervals for which the lower and upper bounds would be 0.00 and 0.20, 0.20 and 0.40, 0.40 and 0.60, 0.60 and 0.80, 0.80 and 1.00. The midpoints of these intervals would be respectively 0.10, 0.30, 0.50, 0.70, and 0.90. It was felt that intervals one and two be combined and have the probability rating of 0.30 since a probability of 0.10 was practically guessing.

PROCEDURE

The subjects were instructed to read the scenario, make their predictions and fill in the KSIM matrix. Then they were formed into four groups of three members each to complete joint group predictions and KSIM matrices. The step by step procedure during a testing session is set forth below. But first some definitions are in order.

KSIM Notation

V_i = individual variables of the system, $i = 1, 2, \ldots, n$

P = subject's direct prediction

P_i = subject's direct prediction of the value of variable V_i at the end of the year; can take on integer values from 1 to 5, corresponding to specified amounts of change

X_i = value of variable V_i on a 0-1 scale

X_{io} = initial value of variable V_i on a 0-1 scale

K = subject's KSIM prediction

K_i = KSIM prediction of the value of variable V_i at the end of a year. It can take on values from 1 to 5

a_{ij} = individual impact of a column variable V_j on a row variable V_i

S_i = computed slope for variable V_i where

$$S_i = X_i \ln(X_i) \sum_{j}^{n} (a_{ij}) X_j$$

C_i = confidence ratings on P_i. C_i ranges from 1 to 4 where 1 = "just guessing," P = 0.30; 2 = "fair chance," P = 0.50; 3 = "rather likely," P = 0.70; 4 = "very likely," P = 0.90

t_i = actual value of V_i at end of one year. It can take on integer values from 1 to 5

R_i = ranges of change of a variable V_i. R refers to intervals from 1 to 5 where 1 = substantial decrease, 2 = moderate decrease, 3 = practically no change, 4 = moderate increase, 5 = substantial increase. These ranges were defined in units by the investigator for each variable and the subjects scaled the ranges onto the 0-1 continuum for KSIM

DRB_i = calculated midpoints of the five sub-intervals for the most confident rated V_i

KSIM Test Procedure for Evaluation

1. Instruct subjects on test format and procedure.
2. Present scenario.
3. Ask subjects if other variables are needed.
4. Ask for direct prediction, P_i, on each variable, V_i , $P_i \ni R$. Time period: one fiscal year. Boundaries of the categories of R were defined in units by the investigator.
5. Ask subjects to draw ranges of changes (boundary limits of each interval) corresponding to the R values on a 0-1 scale

for each variable for the KSIM output. Initial conditions for each variable were given to the subjects in units, and on the 0-1 scale.

6. Ask subjects to fill out the KSIM matrix interaction elements, a_{ij}.
7. Ask subjects to fill out the confidence rating for each direct prediction of a variable on a scale from 1 to 4.
8. "Run," KSIM, i.e., calculate S_i.
9. Match the most confident direct prediction with KSIM and get K_i for all n-1 other variables.
10. Determine t_i, the value of R that corresponds to the truth for each variable. This comes from the case study or if not given there, from Moody's and Standard and Poors business manuals.
11. T, K, and P are compared and errors are computed and tabulated for statistical analysis.
12. The process is repeated for group forecasting.
13. Comparisons are made between group and individual performances.

RESULTS AND DISCUSSION

Definitions

TK = KSIM matches the truth

TP = Direct prediction matches the truth

PK = Direct prediction matches KSIM

PN = Total possible outcomes minus PK

TKN = TK matches for PN

TPN = TP matches for PN

TK_s = TK matches by increase or decrease only

TP_s = TP matches by increase or decrease only

Discussion of Results

The results are listed in tables in the appendix.

The overall results of the experiment showed that KSIM did not predict the true category as often as direct prediction (i.e., less accurate). But, proportionately, KSIM was more accurate in uncommon cases than in common cases, though never exceeding the number of correct prediction matches, TP. However, KSIM, TK_s did exceed direct predictions, TP_s, by sign value, i.e., predictions of whether the variable would increase or decrease slightly.

The Table of Statistical Results shows the fraction of all possible TP matches as a function of the confidence ratings given the predicted variable. Also, the Pearson product-moment formula was used to calculate the correlation coefficient, r, between TK and TP for all five combined scenarios where r = .9789. This correlation coefficient was higher than any of the individual computed r values for each scenario.

There was the opportunity to consider the performance of groups vs. individuals and young, low-level, less-experienced subjects vs. older, higher-level, experienced subjects. In the experiment, group two was comprised of three professional people who all had the highest GPA (grade point average) of 3.3 (B+) out of 4.0, all had master's degrees in accounting, and an average age of 37.0 years. The rest of the other three groups were comprised of three members each who had some or little work experience, a GPA of 3.0 (B) for two groups, and 3.3 (B+) for the other group. They had ages averaging 21.3, 26.3 and 24.6 years. The older group, group two, had the poorest performance of any group as far as accurate forecasts were concerned.

In Figure 1 (see appendix), the graph of TK vs. TP for which the correlation coefficient was computed shows that individuals on the whole predicted better than KSIM, by interval. Also, those who performed better on TP had proportionately higher TK values. This would indicate that KSIM's performance is dependent upon the user's intuitive capabilities, i.e., that KSIM is not random in its outcome but reflects the skill of the user.

In Figure 2 (see appendix), the graph of TK/TP and TKN/TPN shows a steadily increasing performance until the last scenario given, which was scenario number four. The last three scenarios were given out of numerical order due to scheduling problems. Scenario number five was given in between scenarios two and three. This steady incline, though, means that learning may play a part in the improvement of KSIM performance. The sudden decrease in the last scenario can be explained by a change in the type of predictions given. All of the scenarios, except for that one, had a combination of objective and subjective answers, but scenario four was the only case that had all subjective answers.

An objective answer meant a quantitative prediction, a hard number, while a subjective answer meant a qualitative prediction. This was usually a verbal phrase to describe an outcome with some arbitrariness.

This arbitrary element was, quite possibly the cause for subjects to choose adjacent regions by mistake and subsequently perform much worse than the other scenarios. Another cause of the team's poor performance on scenario number four may well be attributed to the fact that most objective answers could be correctly estimated if one used an analytical approach of some sort, whereas subjective answers could not.

In Figure 2, if we compare the common and uncommon scenarios, the average proportionalities of TK/TP for the uncommon scenarios were 0.767 and for the common scenarios, 0.715. This would indicate, that, proportionately KSIM predicts better in uncommon situations than in common situations. If one could learn to use KSIM better than direct prediction, this would tend to confirm the hypothesis that KSIM is better in uncommon and/or complex situations. More importantly, the ratio of TKN/TPN, proportionately, confirms this same suspicion with ratios 0.589 vs. 0.412.

The table of TK vs. TP, in the appendix, shows the total TK and TP matches. If the percent correct is computed for TK to test hypothesis one, we find that KSIM had only 42.51 percent correct matches as compared to TP matches. But, if we focus attention on the table of TK_s and TP_s and compute the KSIM correct by sign, we find that KSIM was 53.7 percent correct as compared to direct prediction matches, TP_s. In the former case, KSIM is statistically a better predictor than chance; but in predicting the sign of change it is no better than chance. Similarly with direct prediction.

CONCLUSION

KSIM appears to have the propensity to perform better in uncommon situations than in common ones.

The KSIM results confirmed the findings of Webber (1973), related to age and performance between groups. Webber claimed that lower-level, young men were more effective in utilizing group decision making than older, higher-level managers.

In a study by Blau and Scott (1973), they maintained that groups are superior to individuals on certain types of problem solving because social interactions (1) provide an error-correcting mechanism; (2) furnish social support to group members; and (3) foster competition among peers for respect of their peers. The KSIM evaluation confirmed their results.

TK and TP scores were averaged by group and by individual. Group TK and TP scores were 9.8 and 12.6, respectively. Individual TK and TP scores were 7.47 and 10.29, respectively. And, group performance was superior to individual performance in <u>every</u> case.

Also, Argyle (1957) observed that group performance is better than most individual performance because group discussion improves individual prediction making and, secondly, the combined individual input is advantageous.

This study did not show an advantage for using KSIM as a forecasting tool over direct predictions. However, it failed to permit users to develop skill at using KSIM due to the limited time the subjects were exposed to it and lack of feedback results. Therefore, it is possible that KSIM could become a useful forecasting tool over time. The results indicate this propensity. But, we don't yet know if it will be. If it is, it should be utilized by people who are highly knowledgeable of the situation under consideration. They should also possess a high intuitive capacity for making direct predictions. Finally, they should have sufficient experience with KSIM before relying on its forecasts.
These three criteria are essential to KSIM's success, or failure to meet any of these criteria would lead to less than optimal utilization of KSIM.

Due to the high correlation between TK and TP, in Figure 2, an increase in TK accuracy should prevail over time and with proper familiarization with KSIM. In addition, when a large number of variables are used, direct prediction may be extremely difficult or impossible. This is where KSIM should excel as a forecasting tool.

Finally, the regular KSIM output graph of the variable trajectories should be used, as a pictorial overview, to display the total system behavior and users should themselves set the prediction interval unit. This added input would be an aid to the user's total intuitive capacity to make a more confident prediction.

In my opinion, KSIM should be utilized in an iterative way for optimization. The number of iterations/predictions should decrease over time as the user becomes accustomed to its use. Also, short-range predictions are far more accurate than long-range and so the user should plan his forecasting accordingly (Kast and Rosenzweig 1970). Hopefully, the user would become so proficient that only the first iteration would be necessary. However, whether people can learn to use it will remain to be seen.

APPENDIX

STATISTICAL DATA

Table 1. Table of Statistical Results

Statistics

Total Possible Outcomes = 646, (4 cases x 17S's x 8 Var) + (1 case x 17 S's x 6 Var) = 646

Distribution of TP_i by Confidence Rating

Confidence Rating — TP_i value: 1 = 4.6%, 2 = 22.3%, 3 = 47.8%, 4 = 25.3%

Correlation Coefficient for Combined Scenarios of TK vs. TP, r = 0.9789

PK=353	TK=176	TP=238	TK_S=391
PN=293	TKN=50	TPN=114	TP_S=336

$\frac{TK}{TP}$ ave=0.767 $\frac{TK}{646}$=0.272 $\frac{TP}{646}$=0.368 $\frac{TK_S}{646}$=0.605

$\frac{TK}{TP}$ ave=0.715 $\frac{TKN}{PN}$=0.171 $\frac{TPN}{PN}$=0.389 $\frac{TP_S}{646}$=0.520

$\frac{TK_S}{(TK_S+TP_S)}$=0.5378 $\frac{TKN}{646}$=0.142 $\frac{TPN}{646}$=0.323

$\frac{TK_S}{TP_S}$=1.164 $\frac{TKN}{TPN}$=0.439

Total Scenario Averages

Correct	TK	PK	TP	TKN	TPN
Objective Variables:	9.76	6.96	1.52	3.04	5.28
Subjective Variables:	8.38	4.92	0.923	2.92	4.17

Table 2. Table of Statistical Results by Scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
TKN/PK	.0255	.0283	.0255	.0198	.0425
TPN/PK	.0708	.0850	.0312	.0652	.0708
TK/646	.0341	.0774	.0372	.0341	.0898
TP/646	.0557	.1084	.0402	.0588	.1053
TKN/646	.0139	.0155	.0139	.0108	.0232
TPN/646	.0387	.0464	.0170	.0356	.0387
PN/646	.1053	.0991	.0820	.0805	.0867
PK/646	.1053	.1115	.1285	.0774	.1238
TK/TP	.6111	.7143	.9231	.5789	.8529
TKN/TPN	.3600	.3333	.8181	.3043	.6000
$\frac{TKN/TPN}{TK/TP}$	.5892	.4666	.8863	.5257	.7035

Table 3. Breakdown of TK and TP Values by Sign Match

	Scenario One Uncommon Case		Scenario Two Common Case		Scenario Three Uncommon Case		Scenario Four Common Case		Scenario Five Common Case		Total Sum for all Scenarios By Subject	
Item	TK	TP	TK	TP	TK	TP	TK	TP	TK	TP	TK	TP
Group 1	0	1	5	6	4	5	6	1	8	6	23	19
Group 2	7	4	6	3	3	3	3	0	8	5	27	15
Group 3	1	3	5	4	3	4	5	5	8	6	22	22
Group 4	6	4	8	7	5	4	3	2	7	5	29	22
Subject 1	1	2	5	5	4	4	5	2	8	4	23	17
Subject 2	0	2	5	4	3	3	4	2	8	7	20	18
Subject 3	1	3	5	2	4	4	6	4	7	7	23	20
Subject 4	2	0	5	4	4	3	6	4	8	5	25	16
Subject 5	6	5	4	4	4	4	0	0	6	7	20	20
Subject 6	2	1	6	6	4	4	4	3	7	7	23	21
Subject 7	3	5	4	6	2	4	6	2	7	6	22	23
Subject 8	7	5	6	6	4	4	6	4	8	5	31	24
Subject 9	2	3	4	2	4	4	4	6	7	6	21	21
Subject 10	1	2	1	5	2	3	4	2	8	7	16	19
Subject 11	6	7	4	4	3	1	2	0	5	5	20	17
Subject 12	1	4	6	5	4	3	5	6	7	3	23	21
Subject 13	2	2	5	6	3	4	5	2	8	7	23	21
											Grand Total	
Total Sum By Scenario	48	53	84	79	60	61	74	45	125	98	391	336

Group 1: Subjects #2, 3, and 4.
Group 2: Subjects #9, 10, and 11.
Group 3: Subjects #1, 12, and 13.
Group 4: Subjects #6, 7, and 8.
(Subject #5 did not participate in a group)

Table 4. Breakdown of PK and PN by Interval Match

Item	Scenario One Uncommon Case PK	Scenario One Uncommon Case PN	Scenario Two Common Case PK	Scenario Two Common Case PN	Scenario Three Uncommon Case PK	Scenario Three Uncommon Case PN	Scenario Four Common Case PK	Scenario Four Common Case PN	Scenario Five Common Case PK	Scenario Five Common Case PN	Total Sum for all Scenarios By Subject PK	Total Sum for all Scenarios By Subject PN
Group 1	7	1	4	4	2	6	1	5	4	4	18	20
Group 2	4	4	6	2	4	4	6	0	2	6	22	16
Group 3	3	5	1	7	5	3	6	0	4	4	19	19
Group 4	6	2	7	1	7	1	1	5	4	4	25	13
Subject 1	4	4	3	5	5	3	4	2	6	2	22	16
Subject 2	4	4	6	2	4	4	2	4	5	3	21	17
Subject 3	4	4	5	3	4	4	1	5	5	3	19	19
Subject 4	4	4	4	4	5	3	3	3	2	6	18	20
Subject 5	3	5	3	5	7	1	4	2	6	2	23	15
Subject 6	6	2	7	1	7	1	3	3	6	2	29	9
Subject 7	2	6	5	3	5	3	2	4	5	3	19	19
Subject 8	4	4	7	1	7	1	5	1	7	1	30	8
Subject 9	5	3	3	5	4	4	1	5	4	4	17	21
Subject 10	4	4	3	5	3	5	2	4	6	2	18	20
Subject 11	1	7	1	7	6	2	3	3	3	5	14	24
Subject 12	3	5	5	3	4	4	4	2	6	2	22	16
Subject 13	4	4	2	6	4	4	2	4	5	3	17	21
											Grand Total	
Total Sum By Scenario	68	68	72	64	83	53	50	52	80	56	353	293

Group 1: Subjects #2, 3, and 4.
Group 2: Subjects #9, 10, and 11.
Group 3: Subjects #1, 12, and 13.
Group 4: Subjects #6, 7, and 8.
(Subject #5 did not participate in a group)

Table 5. Breakdown of TK and TP Values by Interval Match

Item	Scenario One Uncommon Case TK	TP	Scenario Two Common Case TK	TP	Scenario Three Uncommon Case TK	TP	Scenario Four Common Case TK	TP	Scenario Five Common Case TK	TP	Total Sum for all Scenarios By Subject TK	TP
Group 1	0	0	4	6	3	2	2	1	6	5	15	14
Group 2	4	4	3	3	0	1	0	0	0	3	7	11
Group 3	3	3	2	4	0	2	5	5	4	6	14	20
Group 4	2	4	4	5	3	4	0	1	4	4	13	18
Subject 1	2	2	5	5	1	2	0	2	3	2	11	13
Subject 2	3	1	3	3	1	1	1	2	4	6	12	13
Subject 3	0	1	1	2	2	1	0	3	2	4	5	11
Subject 4	1	0	2	3	0	1	3	4	4	3	10	11
Subject 5	1	4	2	2	2	1	0	0	3	5	8	12
Subject 6	0	0	5	6	2	1	1	3	4	5	12	15
Subject 7	1	3	3	6	3	2	5	1	2	4	14	16
Subject 8	0	3	4	5	3	3	4	4	3	3	14	18
Subject 9	1	1	1	2	1	1	0	5	4	2	7	11
Subject 10	4	1	5	5	0	2	0	2	4	5	13	15
Subject 11	0	4	1	4	1	0	0	0	2	3	4	11
Subject 12	0	3	2	4	0	0	1	3	3	1	6	11
Subject 13	0	2	3	5	2	2	0	2	6	7	11	18
											Grand Total	
Total Sum By Scenario	22	36	50	70	24	26	22	38	58	68	176	238

Group 1: Subjects #2, 3, and 4.
Group 2: Subjects #9, 10, and 11.
Group 3: Subjects #1, 12, and 13.
Group 4: Subjects #6, 7, and 8.
(Subject #5 did not participate in a group)

Table 6. Breakdown of TKN and TPN Values by Interval Match

Item	Scenario One Uncommon Case		Scenario Two Common Case		Scenario Three Uncommon Case		Scenario Four Common Case		Scenario Five Common Case		Total Sum for all Scenarios By Subject	
	TKN	TPN	TKN	TPN	TKN	TPN	TKN	TPN	TKN	TKN	TKN	TPN
Group 1	0	0	0	2	2	1	1	0	2	1	5	4
Group 2	1	1	0	0	0	1	0	0	0	3	1	5
Group 3	2	2	1	3	0	2	0	0	1	3	4	10
Group 4	0	2	0	1	0	1	0	1	2	2	2	7
Subject 1	0	0	2	2	0	1	0	2	1	0	3	5
Subject 2	2	0	1	1	1	1	1	2	0	2	5	6
Subject 3	0	1	0	1	1	0	0	3	0	2	1	7
Subject 4	1	0	1	2	0	1	1	2	3	2	6	7
Subject 5	0	3	1	1	1	0	0	0	0	2	2	6
Subject 6	0	2	0	1	1	0	0	2	0	1	1	6
Subject 7	0	2	0	3	1	0	4	0	0	2	5	7
Subject 8	0	3	0	1	0	0	0	0	0	0	0	4
Subject 9	0	0	0	1	0	0	0	5	2	0	2	6
Subject 10	3	0	2	2	0	2	0	2	0	1	5	7
Subject 11	0	4	0	3	1	0	0	0	1	2	2	9
Subject 12	0	3	0	2	0	0	0	2	2	0	2	7
Subject 13	0	2	2	4	1	1	0	2	1	2	4	11
											Grand Total	
Total Sum By Scenario	0	25	10	30	9	11	7	23	15	25	50	114

Group 1: Subjects #2, 3, and 4.
Group 2: Subjects #9, 10, and 11.
Group 3: Subjects #1, 12, and 13.
Group 4: Subjects #6, 7, and 8.
(Subject #5 did not participate in a group)

Table 7. Summation of P, T and K By Interval

Scenario		Intervals 1	2	3	4	5
	P	11	40	39	39	7
1	T	34	68	0	17	17
	K	16	19	46	31	24
	P	4	30	51	48	3
2	T	0	17	34	68	17
	K	7	13	62	38	16
	P	0	11	37	77	11
3	T	34	17	17	17	51
	K	1	5	44	56	30
	P	3	26	30	36	7
4	T	0	0	0	102	0
	K	2	17	39	22	22
	P	1	3	34	73	25
5	T	0	0	0	68	68
	K	3	5	35	54	39
	P	19	110	191	273	53
Total	T	68	102	51	272	153
	K	29	59	226	201	131

Table 8. Contingency Table Test for Independence Prediction vs. Truth

PREDICTION

1		1 + 2	3	4	5	
6-2		15-13.6 0.14	28-15.1 11.02	22-115 75.21	3-12.6 7.31	68
7-3		38-20.4 15.18	32-15 19.27	36-43 1.14	3-8 3.13	102
0-1.5	⇒	16-10.2 3.30	28-15 11.27	6-21.6 11.27	0-4.2 4.20	51
3-8		45-54.3 1.59	61-80.4 4.68	145-115 7.83	14-22.3 3.09	272
1-4.5		10-30.6 13.87	38-45.2 1.15	63-64.7 0.05	34-12.6 36.35	153
19		129	191	273	53	N=646

Each Cell Contains

$$|0-E|$$

$$\frac{|0-E|^2}{E}$$

$$0-E = \sum_{i,j} \left[n_{ij} - \frac{n_i m_i}{N} \right]$$

Null Hypothesis: Cells are independent of each other.

$\sum \frac{|0-E|^2}{E} = 139.243$; Degrees of Freedom=(5-1)(4-1)=12

$P(X^2)=.005$ level, df=12; $X^2=28.30$

Therefore, the Null Hypothesis is Rejected.

(Columns 1 and 2 are combined to eliminate zero cells.)

Table 9. Contingency Table Test for Independence KSIM vs. Truth

		KSIM				
	1	1 + 2	3	4	5	
	17-3	28-9.3 37.63	16-23.8 2.56	13-21 3.05	9-13.8 1.67	68
	11-4.6	38-13.9 41.78	29-35.7 1.26	27-31.7 0.70	12-20.7 3.67	102
	0-2.3	9-6.9 0.64	29-17.8 7.05	11-15.9 1.51	1-10.3 8.40	51
	12-12.2	39-37 0.11	77-95 3.41	108-84.6 6.47	28-55 13.25	272
	3-6.9	18-20.8 0.38	42-53.5 2.47	48-47.6 0.003	41-31 3.23	153
	29	88	226	201	131	N=646

Each Cell Contains

$|O-E|$

$\frac{|O-E|^2}{E}$

$$O-E=\sum_{i,j}\left[n_{ij}-\frac{n_i m_i}{N}\right]$$

Null Hypothesis: Cells are independent of each other.

$\sum \frac{|O-E|^2}{E} =$ 230.60; Degrees of Freedom=(5-1)(4-1)=12

$P(X^2)=.005$ level, df=12; $X^2= 28.30$

Therefore, the Null Hypothesis is Rejected.

(Columns 1 and 2 are combined to eliminate zero cells.)

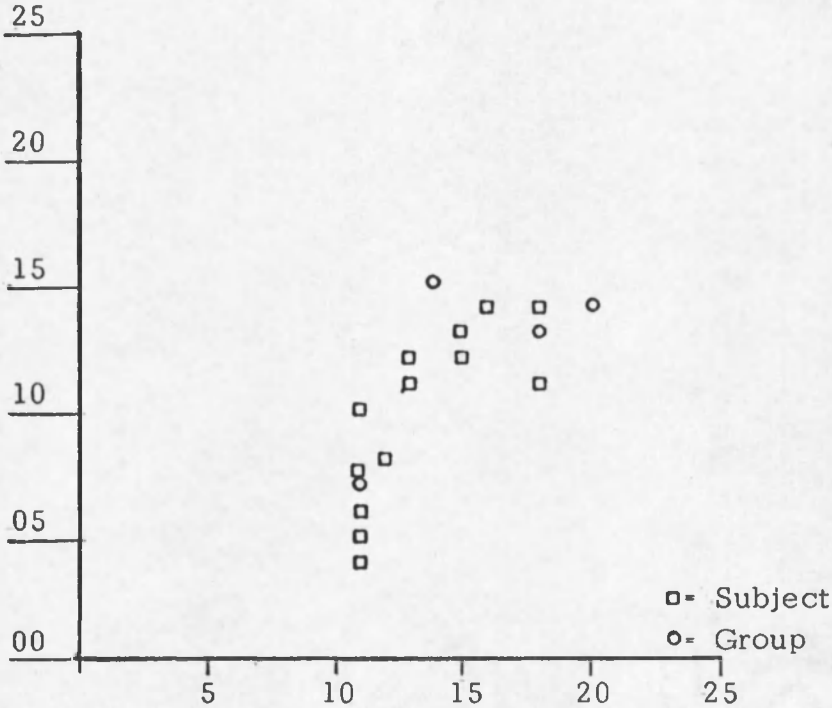

Fig. 1. Combined Scenario Plot of TK vs TP

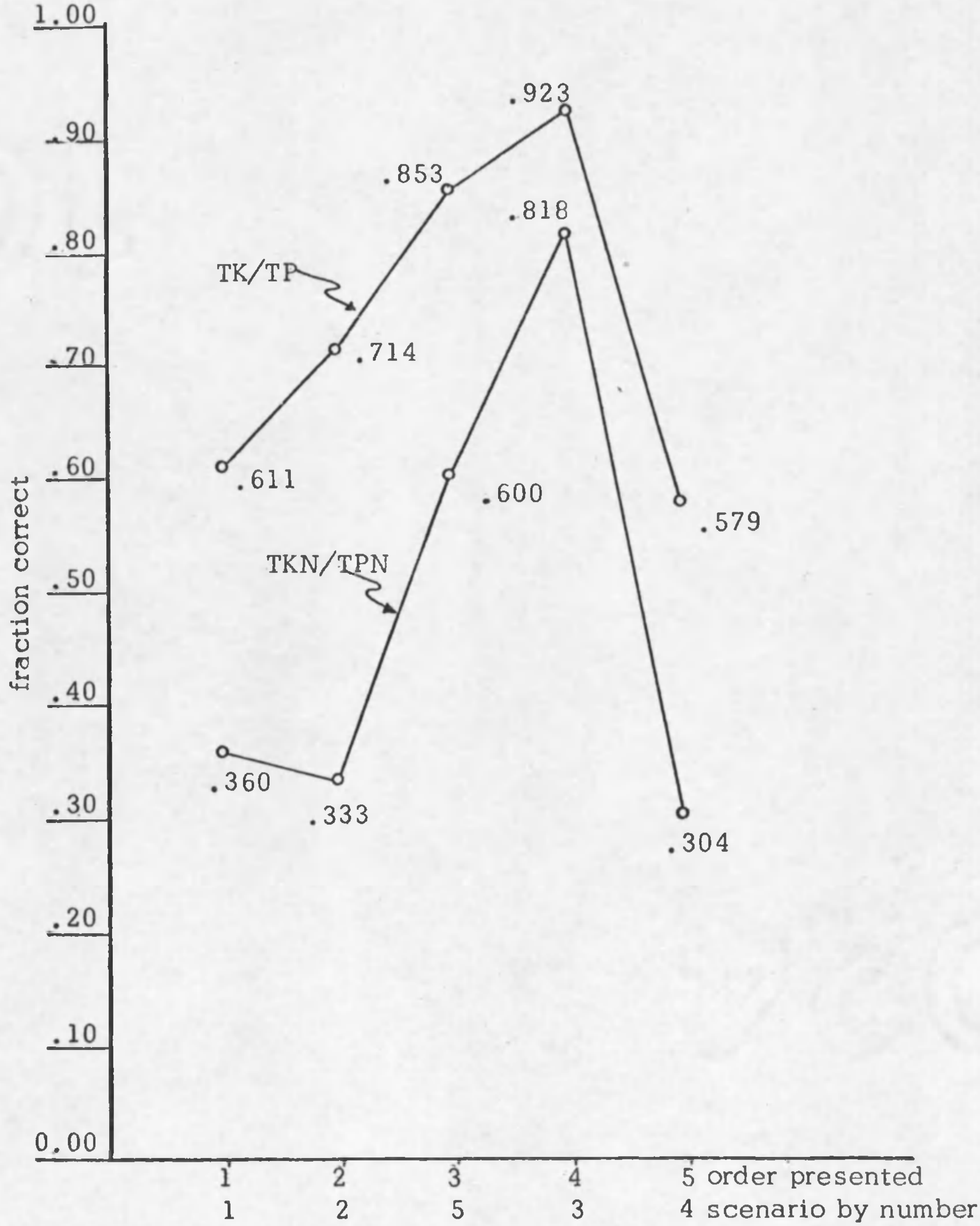

Fig. 2. Plot of TK/TP and TKN/TPN by Scenario

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