

# Chapter Ten

## Results and Analysis

The subject area concerned for this study is Fermi liquid. In all, 17945 keywords have been analyzed for this study. The keywords have been classified according to the proposed taxonomy. The nature of variation of the number of keywords belonging to some major classes with the age of the subject has been studied here. Some parameters related to the keywords have also been calculated and analyzed here to observe their variation pattern with the age of the subject. The numerical values as calculated on the basis of obtained data from the database are presented in tabular form. There are 66 tables in this chapter. A number is assigned to each table, which contains the chapter number first, and then the serial number of the table after the decimal point. The variations of the numerical values of different variables with the age of the subject are presented graphically with the aid of the software 'FindGraph', downloaded from Internet. If any numerical data shows considerable fluctuation from the set of other data, then that is not encountered for plotting the graph, but ignored. The graphical pattern followed by the majority of the points has been taken under consideration. There are 56 graphical presentations in this chapter. The equation followed by each graph is also given. The number of equations involved is 61. The graphs are plotted by the method of least squares. The numerical values of the constants involved in each equation have also been calculated by the software 'FindGraph'. Other than graphical presentations, 20 diagrams are also given, which include bar diagram and pie diagram.

### A. Growth of Literature and Keyword:

The growth of literature in the subject 'Fermi Liquid' is presented in Table 10.1 since 1985 to 2004. The age of the subject in the year 1985 has been assumed to be 'A', where  $0 \leq A \leq 100$  and A must be an integer. The upper

limit of the value of A is taken as 100, as our concerned subject is a subset under the major subject 'Condensed matter physics', which is not older than 100 years. For the present study the value of A has arbitrarily been assumed as 1.

Table 10.1: Growth of Literature and Keyword since 1985 to 2004

YEAR	AGE	AGE (ASSUMED) (L)	NUMBER of JOURNAL ARTICLES CONSULTED	NUMBER of DISTINCT KEYWORDS CONSULTED [Z(ALL)]	TOTAL FREQUENCY of OCCURRENCE of ALL DISTINCT KEYWORDS [Z(FREQ)]
1985	A	1	135	965	1832
1986	A+1	2	138	955	1761
1987	A+2	3	122	936	1683
1988	A+3	4	109	913	1568
1989	A+4	5	146	1038	2153
1990	A+5	6	207	1278	2951
1991	A+6	7	193	1190	2720
1992	A+7	8	185	1301	2889
1993	A+8	9	215	1322	3090
1994	A+9	10	334	1880	5245
1995	A+10	11	324	2027	5142
1996	A+11	12	339	1895	5218
1997	A+12	13	370	2139	5669
1998	A+13	14	388	2106	5844
1999	A+14	15	327	2696	7693
2000	A+15	16	667	3116	10423
2001	A+16	17	541	3072	8762
2002	A+17	18	620	3207	10383
2003	A+18	19	524	2783	8479
2004	A+19	20	487	3577	8866
ALL			6371	38396	102371

The number of journal articles consulted each year and the number of keywords culled out from those articles in the respective years are shown in the Table 10.1. The frequency of occurrence of all keywords in each year is

also shown here. In all, 38396 keywords have been culled out from 6371 journal articles. Of these keywords, only 17945 keywords are distinct, which means that on average each keyword has been taken at least twice in two different years (once in each year) during the said 20 years of time span. The frequency of occurrence of all these keywords is 102371, which means 17945 keywords occur in 6371 journal articles for 102371 times.

Table 10.2: Numerical Values of Some Parameters  
since 1985 to 2004

YEAR	AGE	AGE (ASSUMED) (L)	FREQUENCY PER DISTINCT KEYWORD (Z(FREQ)/Z(ALL))	DISTINCT KEYWORD PER JOURNAL ARTICLE (Z(ALL)/Z(JA))	FREQUENCY of OCCURRENCE PER JOURNAL ARTICLE (Z(FREQ)/Z(JA))
1985	A	1	2	7	14
1986	A+1	2	2	7	14
1987	A+2	3	2	8	16
1988	A+3	4	2	8	16
1989	A+4	5	2	7	14
1990	A+5	6	2	6	12
1991	A+6	7	2	6	12
1992	A+7	8	2	7	14
1993	A+8	9	2	6	12
1994	A+9	10	3	6	18
1995	A+10	11	3	6	18
1996	A+11	12	3	6	18
1997	A+12	13	3	6	18
1998	A+13	14	3	5	15
1999	A+14	15	3	8	24
2000	A+15	16	3	5	15
2001	A+16	17	3	6	18
2002	A+17	18	3	5	15
2003	A+18	19	3	5	15
2004	A+19	20	2	7	14
ALL			3	6	18

The patterns of growth of literature, keyword and total frequency are presented in the Graph-1, 2 & 3 below. It is to be noted that the numerical values of the parameters given in the fourth, fifth and sixth columns of the Table 10.2 encounter the total mass of keywords belonging to a particular year, while the parameters defined in the equations (5.4), (5.5) and (5.10) include a particular keyword or keyword cluster only. The lowest number of papers appeared in the year 1988 (109), whereas the highest number of papers appeared in the year 2000 (667). The lowest number of keywords appeared in the year 1988 (913), whereas the highest number of keywords appeared in the year 2004 (3577). The frequency of occurrence of all keywords was lowest in the year 1988 (1568), and the same was highest in the year 2000 (10423). The number of keywords per journal article remains more or less steady over the span of twenty years (fluctuates from 5 to 8), which is very little fluctuation. Hence, it is obvious that the ongoing trend of growth of keyword will be nearly alike in pattern with that of growth of literature. The frequency of occurrence per keyword remains almost steady over the span of twenty years, i.e. 2 and 3; that is to say, average number of journal articles responsible for creating a single keyword is 2 (for the years 1985-1993 and 2004) and 3 (for the year 1994-2003). The frequency of occurrence of all keywords per journal article fluctuates between 12 and 24 over the span of twenty years.

It is to be noted that in all graphs, the horizontal axis is taken as the axis for the independent variable, i.e. assumed age of the subject and denoted by  $L$ ; and the vertical axis is taken as the axis for the dependent variable, i.e. number of literature, or keyword etc. as the case may be, and denoted by  $Z$ . The particular group of keywords indicated for a particular graph, is always given within the argument of  $Z$ . For instance,  $Z(\text{JA})$  indicates total number of journal articles;  $Z(\text{KEI})$  indicates total number of clustered-ephemeral-mono-frequent keywords over the span of twenty years. The independent variable, i.e. the assumed age of the subject varies from 1 to 20 for the present study.

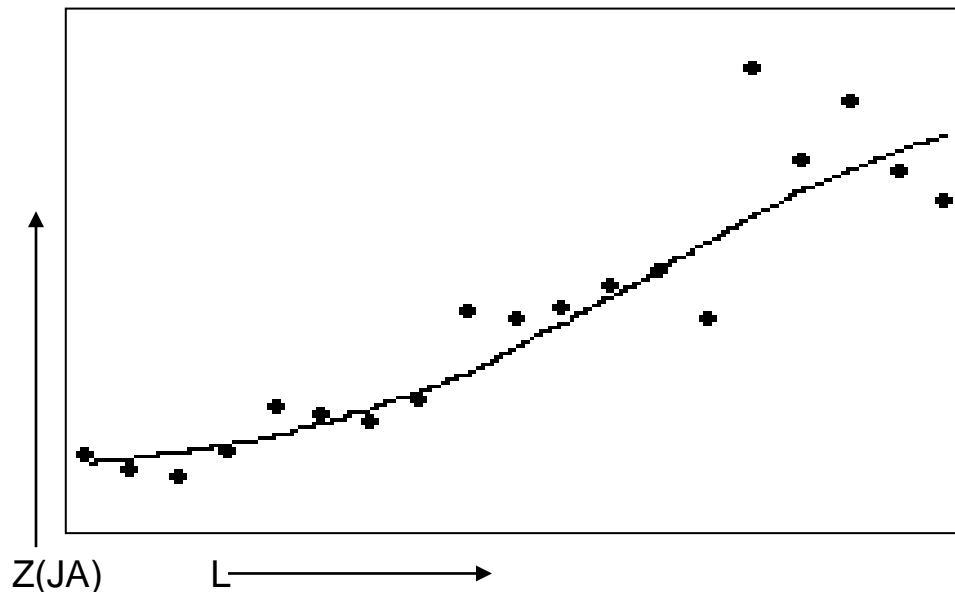
All graphs are plotted by the method of least square; and the values of the constants are shown approximated upto second decimal place. The mean graphs are shown and the experimentally obtained points are symmetrically scattered around the mean graph. The constants are indicated by the lowercase alphabets, and the keyword categories are indicated by the uppercase alphabets.

The growth pattern for research papers follows Logistic function:

$$Z(JA) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.1)$$

Where,  $a = 109$ ,  $b = 558$ ,  $c = 3.18$ ,  $d = -0.27$ ,  $Z(JA)$  = Number of research papers or journal articles consulted (Dependent variable),  $L$  = Assumed age of the subject concerned (Independent variable).

From eq.10.1, we get,  $Z(JA) \rightarrow a$ , i.e. constant as  $L \rightarrow \infty$  (very high value). The number of research papers will attain a constant value with the increase in the age of the subject. This means the ongoing research trend of this subject will get saturated in future.



Graph 1: Growth of Literature

Table 10.3: Data for Graph 1

L	1	2	3	4	5	6	7	8	9	10
Z(JA)	135	138	122	109	146	207	193	185	215	334
L	11	12	13	14	15	16	17	18	19	20
Z(JA)	324	339	370	388	327	667	541	620	524	487

The growth pattern for keywords follows Dose-Response Biphasic function:

$$Z(\text{ALL}) = a + b \cdot c / (1 + 10^{((L-d) \cdot g)}) + b \cdot (1-c) / (1 + 10^{((L-k) \cdot h)}) \dots \dots \dots (10.2)$$

Where, a = 910.86, b = 2669.11, c = 0.17, d = 5.28, g = -0.32, h = -0.17,  
i = 12.34,

Z(ALL) = Number of keywords consulted (Dependent variable), L = Assumed age of the subject concerned (Independent variable).

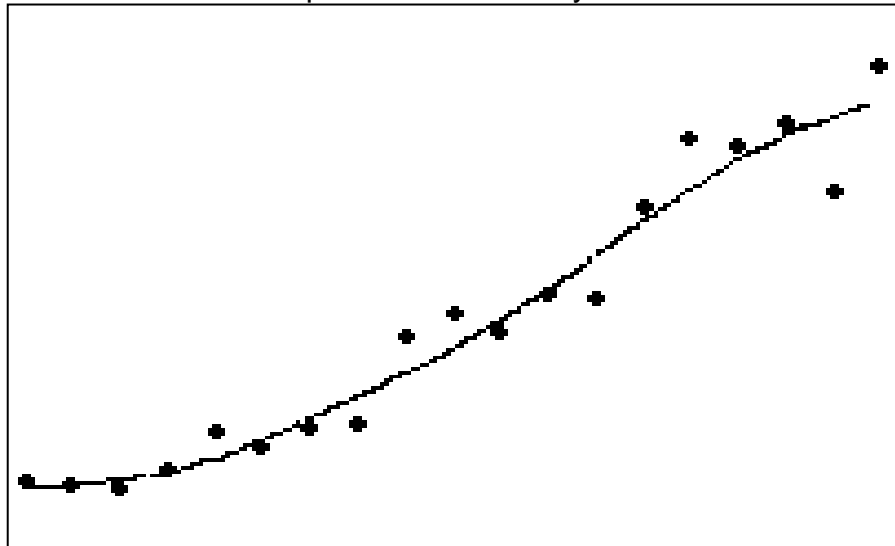
The number of keywords Z(ALL) will tend to attain a constant value with the increase in age (L) of the subject, as observed from eq.10.2.

Table 10.4: Data for Graph 2

L	1	2	3	4	5	6	7	8	9	10
Z(ALL)	965	955	936	913	1038	1278	1190	1301	1322	1880
L	11	12	13	14	15	16	17	18	19	20
Z(ALL)	2027	1895	2139	2106	2696	3116	3072	3207	2783	3577

The growth patterns of literature and keywords are not exactly alike; the two functions involved are different, though both of them will attain constant at very large value of L. Keywords are the indicators of the topics of research. The difference between two growth patterns indicates lack of consonance between them, or it can be said that their changing patterns are different.

Graph 2: Growth of Keyword

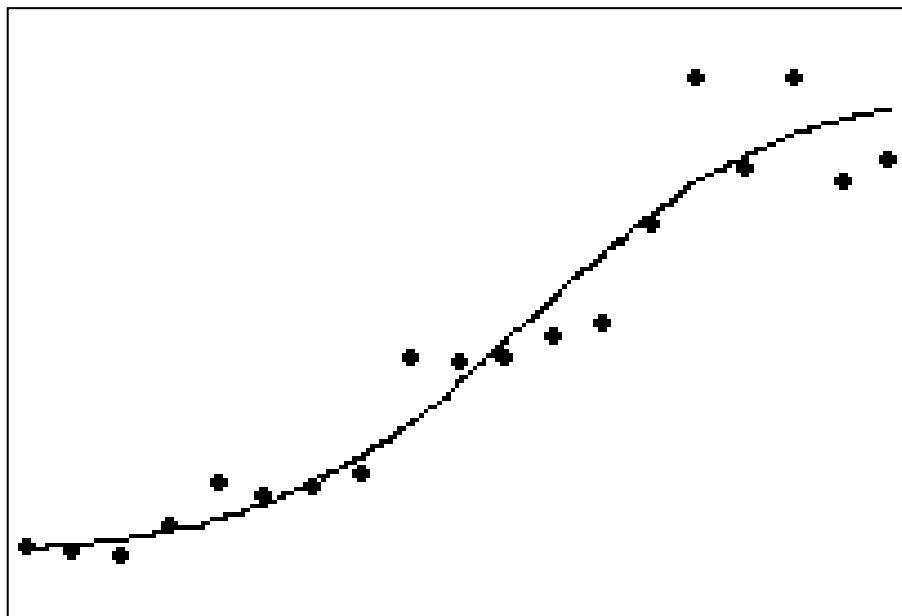


The growth pattern for total frequency of occurrence follows Logistic function:

$$Z(\text{FREQ}) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.3)$$

Where, a = 1568.00, b = 8855.00, c = 3.88, d = -0.37, Z(FREQ) = Total freq. of occurrence

Equation (10.3) [Graph 2] proves the first part of the hypothesis number (1) of chapter nine.



Graph 3: Growth of total Frequency of Occurrence

The growth patterns of total number of research papers and that of the total frequency of occurrence are exactly alike, only the values of the constants (a, b, c and d) are different. The growth pattern of keywords is different from that of the research papers or frequency of occurrence.

Table 10.5: Data for Graph 3

L	1	2	3	4	5	6	7
Z(FREQ)	1832	1761	1683	1568	2153	2951	2720
L	8	9	10	11	12	13	14
Z(FREQ)	2889	3090	5245	5142	5218	5669	5844
L	15	16	17	18	19	20	
Z(FREQ)	7693	10423	8762	10383	8479	8866	

### B. Keyword: Spatial Index

The spatial index of a keyword actually measures the number of research papers in which a single keyword occurs. In other words, the spatial index, denoted by V, provides an outline to get an idea about the probable area of locus of a keyword, which is the extent to which it is used in the scientific community. The spatial index thus measures the intellectual space of a keyword. Higher value of spatial index indicates presence of the keyword in more number of journal articles, i.e. the higher usage of the keyword, and vice versa.

Table 10.6: Spatial Index for Twenty Years

L	1	2	3	4	5	6	7	8	9	10
Z(JA)	135	138	122	109	146	207	193	185	215	334
Z(ALL)	965	955	936	913	1038	1278	1190	1301	1322	1880
V	0.14	0.14	0.13	0.12	0.14	0.16	0.16	0.14	0.16	0.18
L	11	12	13	14	15	16	17	18	19	20
Z(JA)	324	339	370	388	327	667	541	620	524	487
Z(ALL)	2027	1895	2139	2106	2696	3116	3072	3207	2783	3577
V	0.16	0.18	0.17	0.18	0.12	0.21	0.18	0.19	0.19	0.14



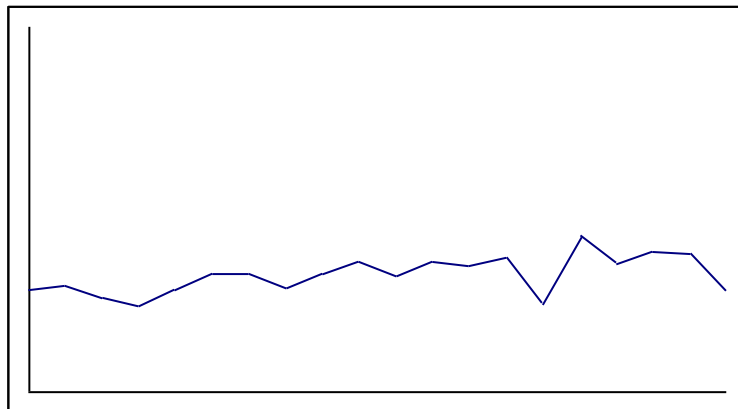
The data presented in Table 9 clearly shows that:

$Z(\text{JA})$  is directly proportional to  $Z(\text{ALL})$

Or,  $Z(\text{JA}) = V * Z(\text{ALL})$

Or,  $V = Z(\text{JA})/Z(\text{ALL}) \dots \dots \dots (10.4)$

Where,  $V$  = Spatial Index of the keyword, which is the proportionality constant and attains a constant value over the span of twenty years. The fluctuation is very small, which can be easily ignored. The spatial index may thus be recognized as a parametric property of keyword pertaining to a particular subject. This is constant for a particular subject and different for other subjects. The Graph 4 shows the constant pattern of the spatial index over the said time period. The constancy of spatial index indicates that total number of journal articles or research papers is directly proportional to total number of keywords. This phenomenon further indicates that the keyword-content per unit journal article remains steady over the full time span, and did not change with the growth of literature.



Graph 4: Constancy of Spatial Index

### C. Journal Article: Informative Index

The informative index of a journal article actually measures the number of keywords belonging to unit frequency of occurrence. The single frequency of occurrence of a keyword means the appearance of the keyword once in a journal-article. The informative index, denoted by  $Q$ , thus actually measures the

average number of keywords contained in a single research paper. As a research paper contains more keywords, it will provide more information. In other words, the informative index provides an outline to get an idea about the amount of information supplied by a single research paper. Higher value of informative index indicates the higher quantity of information generation from the research paper, and vice versa.

Table 10.7: Informative Index for Twenty Years

L	1	2	3	4	5	6	7	8	9	10
Z(ALL)	965	955	936	913	1038	1278	1190	1301	1322	1880
Z(FREQ)	1832	1761	1683	1568	2153	2951	2720	2889	3090	5245
Q	0.53	0.54	0.56	0.58	0.48	0.43	0.44	0.45	0.43	0.36
L	11	12	13	14	15	16	17	18	19	20
Z(ALL)	2027	1895	2139	2106	2696	3116	3072	3207	2783	3577
Z(FREQ)	5142	5218	5669	5844	7693	10423	8762	10383	8479	8866
Q	0.39	0.36	0.38	0.36	0.35	0.30	0.35	0.31	0.33	0.40

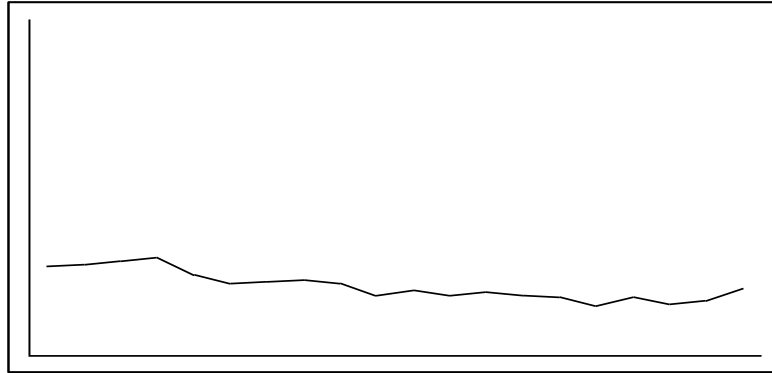
The data presented in Table 10.7 clearly shows that:

Z(ALL) is directly proportional to Z(FREQ)

Or,  $Z(\text{ALL}) = Q \cdot Z(\text{FREQ})$

Or,  $Q = Z(\text{ALL})/Z(\text{FREQ}) \dots \dots \dots (10.5)$

Where, Q = Informative Index of the journal article, which is the proportionality constant and is constant over the span of twenty years. The fluctuation is very small, which can be easily ignored. The informative index may thus be recognized as a parametric property of a research paper pertaining to a particular subject. This is constant for a particular subject and different for other subjects. The Graph-5 shows the constant pattern of the informative index over the said time period. The total number of keywords is thus directly proportional to total number of research-papers in which they occurred, or total frequency of occurrence of all the keywords.



Graph 5: Constancy of Informative Index

#### D. Classified Keyword Distribution

The keywords have been classified according to four criteria as stated in Table 3.3. The order of classification according to these criteria is: ASC---CAP---FOC---CAT. The classification at the first level is done on the basis of associativeness to the subject-content of the keyword in the subject (clustered, twin or single); the classification at the second level is done on the basis of mode of chronological appearance of the keyword during the entire time span concerned (once or more than once); the classification at the third level is done on the basis of frequency of occurrence of the keyword during the entire time span concerned; the classification at the fourth and final level is done on the basis of category of the keywords.

The number of keywords integrated over 20 years belonging to each of 36 classes is shown in the Table 10.8A and Table 10.8B. The keywords occurred during first ten years (1985-1994) are presented in Table 10.8A and the keywords occurred during second ten years (1995-2004) are presented in Table 10.8B. The keyword classes are shown in Tables 10.8A and 10.8B are in the decreasing order of number of class members, i.e. the number of keywords. The percentage contribution to the total number of keywords for each class is also shown in both tables under the Table-10.8. The highest

number of keywords occurs in the class KEI, i.e. Clustered-Ephemeral-(Mono-frequent) keywords are largest in number. The class containing lowest number of keywords is WEU, i.e. Twin-Ephemeral-(Multi-frequent) keywords. Of the total keywords, more than 50% is contained in only four classes, viz. KEI, KYI, KYU and SEI; and the remaining nearly 50% keywords are distributed over the remaining [(36-4) =] 32 classes. It is to be noted that some cells belonging to starting year (1985) and ending year (2004) are left vacant. The rows of the corresponding vacant cells contain number of new and obsolete keywords. Now, there is no question of obsolescence at the beginning year and also, there is no scope of occurring a new keyword at the ending year. The keywords occurring only at the starting or ending year have been categorized as ephemeral keywords. On the other hand, obsolescence at the last year (2004) and new arrival at the first year (1985) bears no significance, because at the starting and ending years all keywords may be said as new and obsolete keywords respectively.

Table 10.8A: Classified Keyword Year wise Distribution  
(Keyword Matrix: 1985-1994)

	85	86	87	88	89	90	91	92	93	94
KEI	180	171	179	160	133	191	163	185	144	261
KYI	232	82	102	141	112	160	186	250	237	265
KYU	107	98	82	86	102	165	151	152	188	251
SEI	114	133	138	105	86	115	92	109	110	146
KJI		146	122	94	205	183	183	170	140	186
KYD	84	42	61	58	68	76	76	83	98	154
SYI	124	28	22	30	26	54	46	62	68	107
KOI		14	21	32	10	14	18	31	19	35
SJI		64	52	52	94	82	75	74	86	100
SOI		13	12	20	4	4	8	7	6	25
WEI	22	30	20	25	17	26	18	23	19	29
SYD	25	4	15	13	13	13	15	17	32	33
SYU	6	4	3	6	6	21	13	13	16	41
WYI	26	4	14	14	16	14	28	28	43	42
WYU	10	6	6	3	6	15	12	11	20	23
KED	11	7	7	8	3	11	7	6	8	19
KJD		38	28	12	34	31	34	14	16	16
KOD		3	4	5	0	3	2	3	7	10
SED	9	8	3	7	3	3	1	6	6	14
WJI		11	14	9	33	38	28	20	23	16
WYD	7	1	4	9	3	9	11	12	13	24
WOI		3	4	6	0	1	2	1	2	6
SOD		4	4	4	1	0	1	0	0	4
KOU		3	1	0	0	1	0	0	2	6
SJD		13	3	3	20	14	5	7	10	13
KJU		8	11	3	25	15	8	8	3	35
KEU	2	0	1	0	1	5	0	1	0	4
SOU		0	0	1	0	0	0	0	0	2
WED	4	2	0	2	2	0	3	0	1	3
WJD		9	1	3	10	6	0	4	3	2
SEU	2	0	1	1	0	1	0	0	0	0
SJU		2	0	0	5	5	4	2	2	4
WOD		0	0	0	0	1	0	1	0	1
WOU		0	0	0	0	0	0	0	0	0
WJU		4	1	1	1	1	0	1	0	3
WEU	0	0	0	0	0	0	0	0	0	0

Table 10.8B: Classified Keyword Year wise Distribution  
(Keyword Matrix: 1995-2004)

	95	96	97	98	99	2k	01	02	03	04
KEI	290	256	314	310	440	501	547	566	487	941
KYI	326	342	361	351	408	361	344	267	138	469
KYU	275	281	285	299	376	455	392	429	297	357
SEI	207	152	206	168	269	353	352	392	319	764
KJI	172	121	142	136	119	108	71	55	14	
KYD	137	122	151	146	162	180	192	154	77	151
SYI	120	117	128	148	157	153	151	105	57	205
KOI	39	48	51	78	127	187	270	354	465	
SJI	107	77	83	77	74	63	41	26	16	
SOI	22	28	27	58	78	108	157	180	219	
WEI	27	40	46	37	48	78	81	72	58	138
SYD	49	41	48	55	67	73	70	66	25	73
SYU	40	56	53	48	68	92	73	68	42	70
WYI	48	47	55	62	45	65	48	38	13	62
WYU	24	30	28	30	41	54	54	48	32	36
KED	23	13	19	12	27	42	34	40	27	102
KJD	23	18	24	15	26	16	8	16	4	
KOD	3	6	9	12	18	36	42	64	127	
SED	10	14	21	7	17	36	22	33	25	84
WJI	26	22	18	8	16	16	7	9	3	
WYD	17	23	19	18	31	25	19	28	13	29
WOI	5	3	10	6	14	29	37	46	63	
SOD	2	4	4	6	14	29	20	53	57	
KOU	0	0	1	1	7	12	7	32	105	
SJD	10	15	13	2	17	9	2	4	1	
KJU	7	5	3	3	12	5	3	2	2	
KEU	2	0	3	1	3	4	5	3	10	37
SOU	0	0	2	1	1	5	5	24	36	
WED	0	7	1	2	2	5	1	10	4	18
WJD	5	2	5	4	2	4	4	1	1	
SEU	3	2	2	0	2	3	1	3	4	33
SJU	5	2	4	3	4	4	2	1	2	
WOD	1	1	2	2	2	3	5	13	17	
WOU	0	0	0	0	0	0	3	5	23	
WJU	2	0	1	0	1	1	1	0	0	
WEU	0	0	0	0	1	1	1	0	0	9

The clustered keywords indicate core areas of research, the twin and single keywords indicate peripheral supporting areas to the core subject domains. The ephemeral keywords are temporally most instable, occur only once during 20

years span. Ephemeral keywords indicate dynamic nature of a subject. More ephemeral keywords indicate continuous emergence and disappearance of the keywords. Appearance of a new keyword is associated with the evolution of a new concept, and any new concept is born only after some research works. Hence, it can be said that the birth of a new keyword is a direct consequence of the initiation of a new research work. In this study, more than two-third of the total volume of keyword is found to be ephemeral. The keywords belonging to the classes “New”, “Obsolete” and “Stable” occur more than once, i.e. at least twice and at most 20 times. The number of journal articles covered by a paper is indicated by frequency of occurrence of a keyword, i.e. whether it is mono-frequent, di-frequent or multi-frequent. The number of keywords contained by each class over twenty years time span is presented in the Table 10.9.

Table 10.9: Classified Keyword Integrated Distribution

Keyword Class	Total Number of Class Member	% of Class Member
KEI	6419	16.72
KYI	5134	13.37
KYU	4828	12.57
SEI	4330	11.28
KJI	2367	6.16
KYD	2272	5.92
SYI	1908	4.97
KOI	1813	4.72
SJI	1243	3.24
SOI	976	2.54
WEI	854	2.22
SYD	747	1.95
SYU	739	1.92
WYI	712	1.85
WYU	489	1.27
KED	426	1.11
KJD	373	0.97
KOD	354	0.92
SED	329	0.86
WJI	317	0.83
WYD	315	0.82
WOI	238	0.62
SOD	207	0.54

Table 10.9: Classified Keyword Integrated Distribution

(Continued from previous page)

Keyword Class	Total Number of Class Member	% of Class Member
KOU	178	0.46
SJD	161	0.42
KJU	158	0.41
KEU	82	0.21
SOU	77	0.20
WED	67	0.17
WJD	66	0.17
SEU	58	0.15
SJU	51	0.13
WOD	49	0.13
WOU	31	0.08
WJU	18	0.05
WEU	12	0.03

The top three classes belong to the “Clustered” group that constitutes 43% of the total keywords, as seen from Table 12. The fourth and fifth classes also belong to the ‘Clustered group’. The clustered keywords are thus dominating in this subject compared to twin and single keywords. As the clustered group of keywords indicates core research areas, it is clear that, in case of the subject “Fermi-Liquid”, the core research areas are in the forefront compared to the supporting areas of research. The core research areas are stronger than peripheral areas in the subject ‘Fermi liquid’. The core research areas constitute the essential parts of the subject, while the peripheral areas come due to interactions with other subjects. A subject, which interacts profusely with other subjects is said to be an inter-disciplinary or multi-disciplinary subject. The peripheral areas are stronger than core areas in case of inter-disciplinary or multi-disciplinary subject. The peripheral areas of a subject are indicated by the twin and single keywords. As the dominance of clustered keyword signals stronger core area of research, it can be said that the subject ‘Fermi liquid’ is more single-disciplinary but less multidisciplinary. The diagrammatic presentation of the Table 10.9 is given below in the Diagram 1, which is a bar diagram.



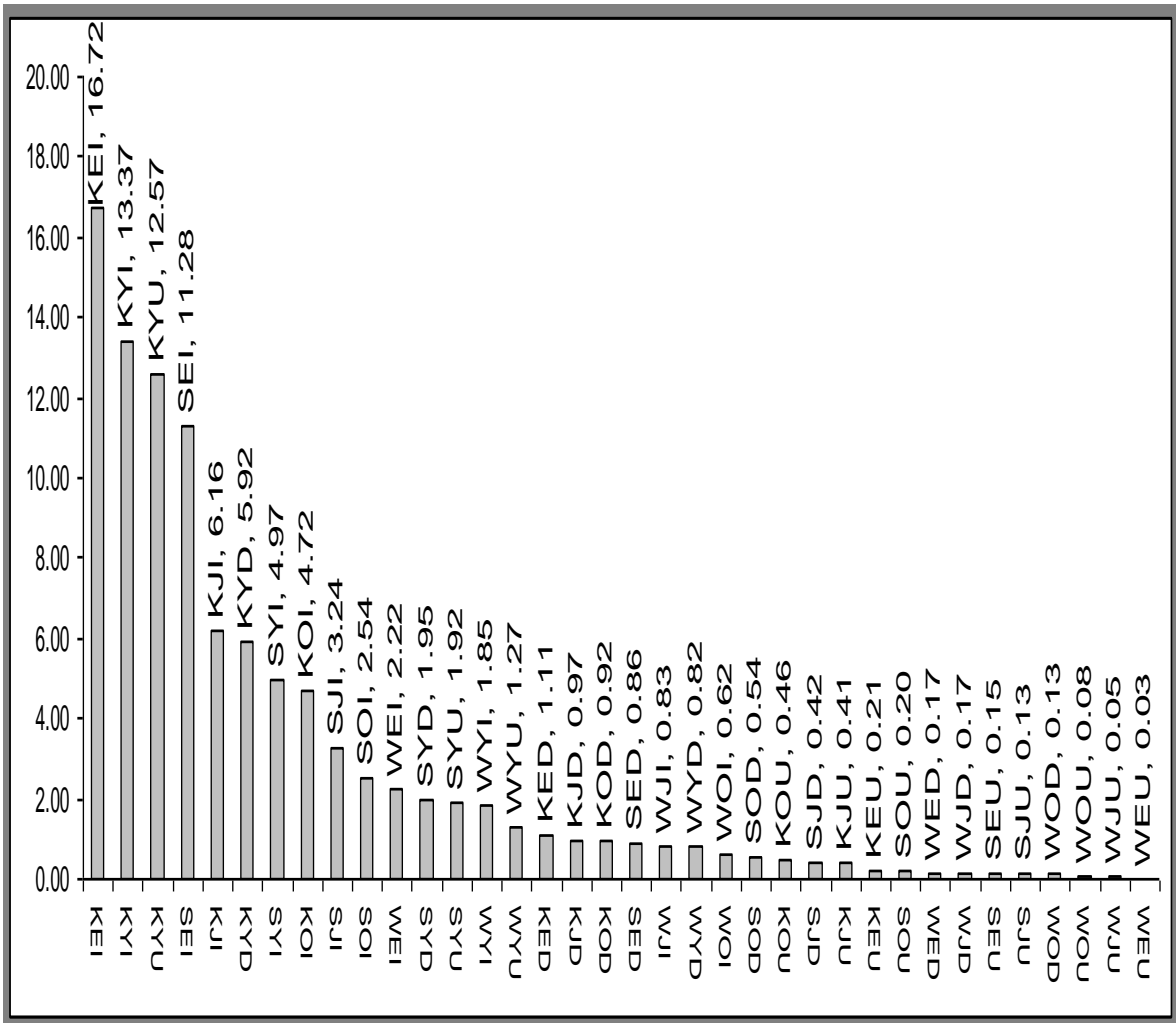


Diagram 1: Classified Keyword Integrated Distribution

The distribution of keywords among top nine classes is presented diagrammatically in the Diagram 1A below, which is a pie diagram. Of these nine classes, six classes belong to ‘Clustered’ category while the rest three belong to ‘Single’ category. This phenomenon reveals the dominance of clustered keywords. Out of top nine classes, there are seven classes that belong to ‘Mono-frequent’ category; and one class belongs to each of ‘Di-frequent’ and ‘Multi-frequent’ category. The mono-frequent keywords are thus dominating over other categories, viz. di-frequent and multi-frequent keywords. This phenomenon indicates that the keywords are hardly repeated in this subject area. The top four

classes belong to 'Ephemeral' and 'Steady' category, which reveals the dominance of these two classes over 'New' and 'Obsolete' keywords.

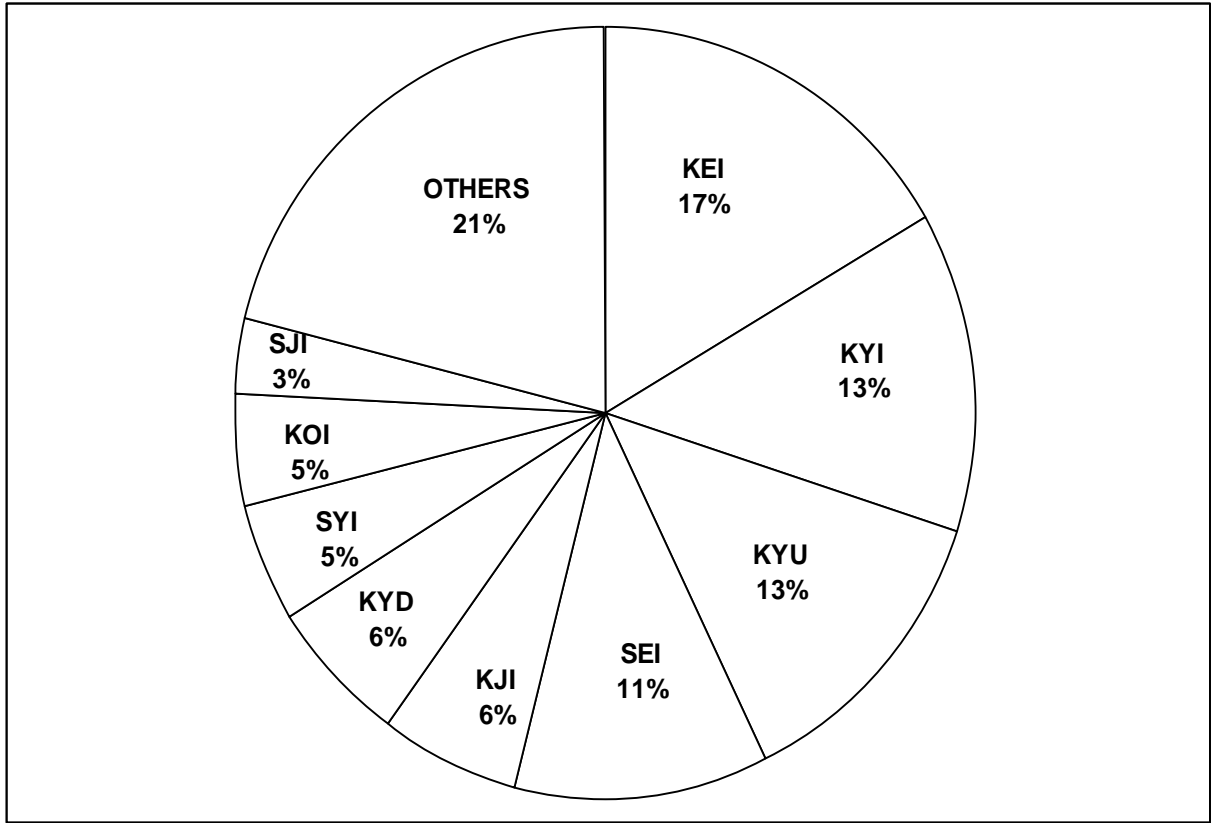


Diagram 1A: Classified Keyword Integrated Distribution

Only nine classes consist of 79% keywords, and the rest 21% keywords are scattered over the remaining 27 classes. Very few classes are highly populated, and majority of the classes are almost empty. The keywords are not homogeneously distributed among the classes, but this is a biased distribution.

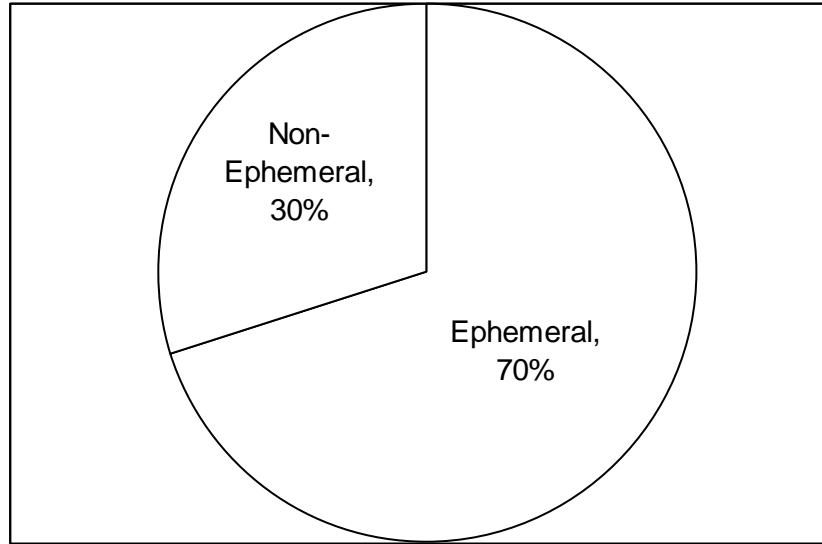


Diagram 2: Relative Proportion of Ephemeral and Non-Ephemeral Keyword over 20 years

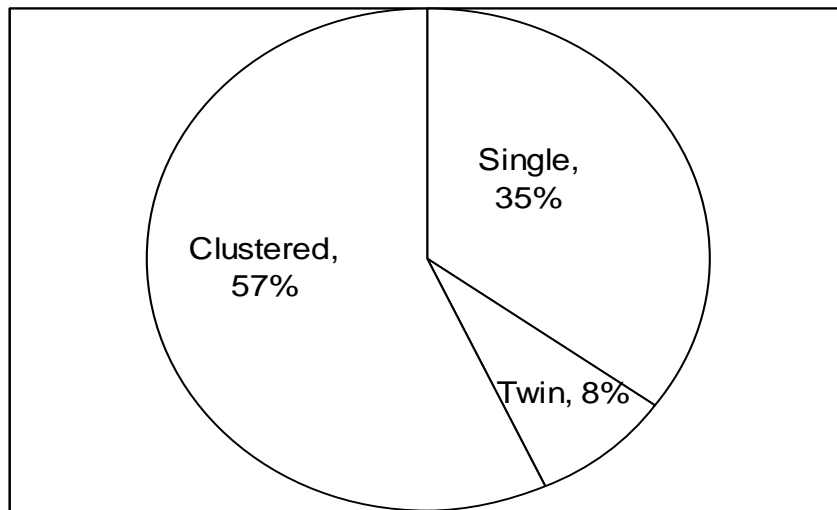


Diagram 3: Relative Proportion of Single, Twin and Clustered Keyword over 20 years

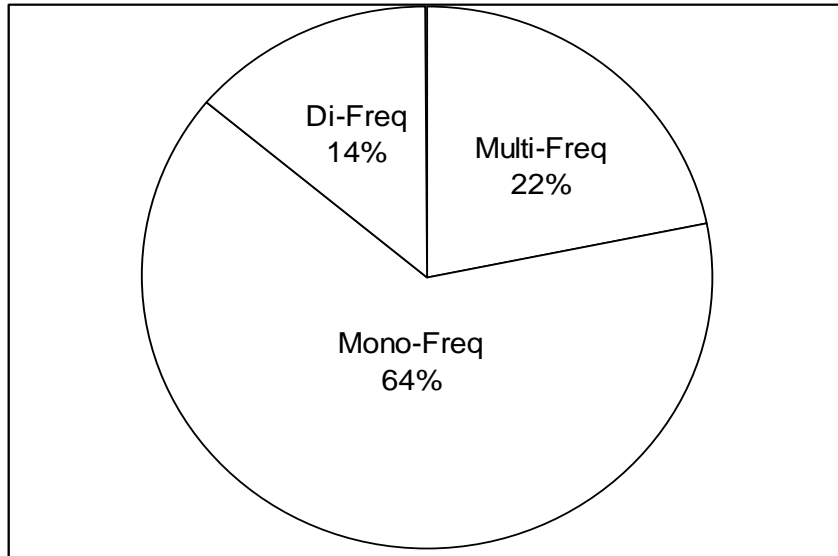


Diagram 4: Relative Proportion of Mono-, Di- and Multi-frequent Keywords over 20 years

A look at the diagrams (2), (3) and (4) immediately reveals the dominance of ephemeral, clustered and mono-frequent keywords. These are integrated distribution over 20 years. The ‘clusterity’ of the keyword group is an indicator of independence of the said subject with other peripheral subjects; the “Ephemeral” mode of occurrence of keywords indicates temporal instability of the terms and the “mono-frequent” keywords indicate uniqueness of a particular keyword that is not repeated. The hypothesis number (9) of the chapter nine has been proved by the Diagram 2. The ascendancy of clustered-ephemeral group of keyword indicates that this subject is more or less independently growing with trial and error research. The large number of ephemeral keywords indicate domination of trial and error research, and a continuous stream of ‘rejection of old’ and ‘acceptance of new’ propositions. The ongoing stream of continuous “rejection” and “acceptance” will eventually take some shape to cast the true reflection of the subject. In this way, a subject grows, changes and gets amended.

## E. Keyword Temporal distribution:

### Top Ten Classes from Keyword Matrix

The keyword matrix for 20 years is shown in Table 10.8A and Table 10.8B. The number of keywords in each class at each year is given therein. In all, 36 classes are shown there. Of the 36 classes, top ten classes contain 81% of total keywords, while the rest 19% keywords belong to the remaining 26 classes. The distribution of keywords in top ten classes is much more important, so far as the strength of keywords is concerned, compared to other 26 classes. The change in the number of keywords in these top ten classes from the year 1985 to 2004, are shown below, and the nature of variation of those numbers with time is also shown graphically. The relative percentage of keywords in a class compared to the total number of keywords is also shown along with their changing pattern from 1985 to 2004 in the bar diagrams. It has been noticed that the change in relative percentage is very small. The equations obeyed by each graph are given with the respective graph, and the values of the constants are also given. The constants are represented by the lower-case alphabets. The independent variable is represented by  $L$  (assumed age of the subject) and the dependent variable is represented by  $Z$  with some arguments within parenthesis to indicate the actual class, for instance, the notation 'KEI' stands for clustered-ephemeral-(mono-frequent) keyword, while  $Z(\text{KEI})$  stands for the number of clustered-ephemeral-(mono-frequent) keyword. The "New" keywords show decreasing tendency with time or age of the subject. The "Obsolete" and "Ephemeral" keywords show increasing tendency with the age of the subject. The "Stable" keywords show periodic variation with the age of the subject. The "Obsolete" and "New" keywords show just reverse changing pattern with the age of the subject, the former is increasing while the latter is decreasing. This phenomenon may be compared with the similar phenomenon occurring in the human body. With the aging of a human being, the number of new growing cells gradually decreases, while the number of dead cells gradually increases. If a subject is compared with the human body, then the growing cells are analogous to "New" keywords, while

the dead cells are analogous to “Obsolete” keywords. The obsolete keywords are indicators of fallow areas of research, and new keywords are indicators of fertile areas of research. The aging of a subject eventually leads to a saturation in the number of keywords.

Clustered-Ephemeral-(Mono-frequent) Keyword (KEI): Rank-1

The temporal evolution pattern of the keywords belonging to the class (KEI) follows sixth degree polynomial function:

$$Z(KEI) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots (10.6)$$

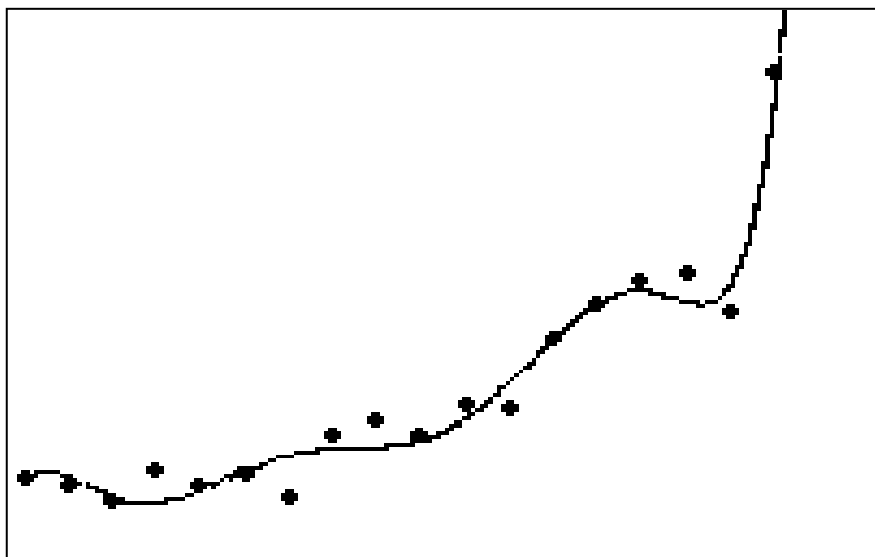
Where, a(0) = -153.96, a(1) = 618.38, a(2) = -393.84, a(3) = 113.57, a(4) = -16.87, a(5) = 1.34, a(6) = -0.05

Z(KEI) = Number of keywords belonging to the class (KEI)

L = Assumed age of the subject

Table 10.10: Data for Graph 6

L	1	2	3	4	5	6	7	8	9	10
Z(KEI)	180	171	179	160	133	191	163	185	144	261
L	11	12	13	14	15	16	17	18	19	20
Z(KEI)	290	256	314	310	440	501	547	566	487	941



Graph 6: Variation of Z(KEI) with L

The sum of positive co-efficients is greater than the sum of negative co-efficients in equation 10.6. This phenomenon can be presented symbolically as:

$$\Sigma(\text{Positive co-efficients}) > \Sigma(\text{Negative co-efficients})$$

This phenomenon indicates that the resultant equation shows an increasing trend with the variable L. Among the co-efficients, the numerical magnitudes of a(1) is highest followed by a(2) and a(3). Though this is a sixth degree polynomial functional variation, the significant functional contributions come from first, second and third degrees of L only. It is also to be noted that, as L tends to infinity (very large value), Z(KEI) will tend to larger value. Because, the cube of L will be much larger than the square of L, and also the square of L will be much larger than L, for very large values of L. The negative values of a(2), a(4) and a(6) will reduce the value of Z(KEI) to some extent. This phenomenon can be symbolically presented as follows:

$$\text{As } L \rightarrow \infty \text{ (Infinity), } Z(\text{KEI}) \rightarrow \infty \text{ (Larger value)}$$

Here, the term 'Infinity' indicates very large value.

$$\text{Because, as } L \rightarrow \infty, (L)^3 \gg (L)^2 \gg L$$

This phenomenon indicates that the number of clustered-ephemeral-(mono-frequent) keywords increases with the increase in the age of the subject 'Fermi liquid'. Now, clustered keywords portray core research area, ephemeral keywords represent temporally unstable terms and mono-frequent keywords embody non-repetitive terms. An enhance in the number of clustered-ephemeral-(mono-frequent) keywords thus indicates an increase in temporally unstable, non-repetitive keywords in the core area of this subject. Hence, it is also obvious from this trend that the aging of the subject 'Fermi liquid' brings hike in the number of temporally unstable, non-repetitive keywords residing in the core area. This fact is also recognizable from the Tables 10.8A and 10.8B respectively as highest number of keywords were observed in the year 2004, when L = 20, i.e. maximum in this range. It can thus also be said that the aging of this subject enhances the research works in the core area of study. The variation of relative

percentage of Z(KEI) over the total number of keywords is shown in the Diagram 5 below.

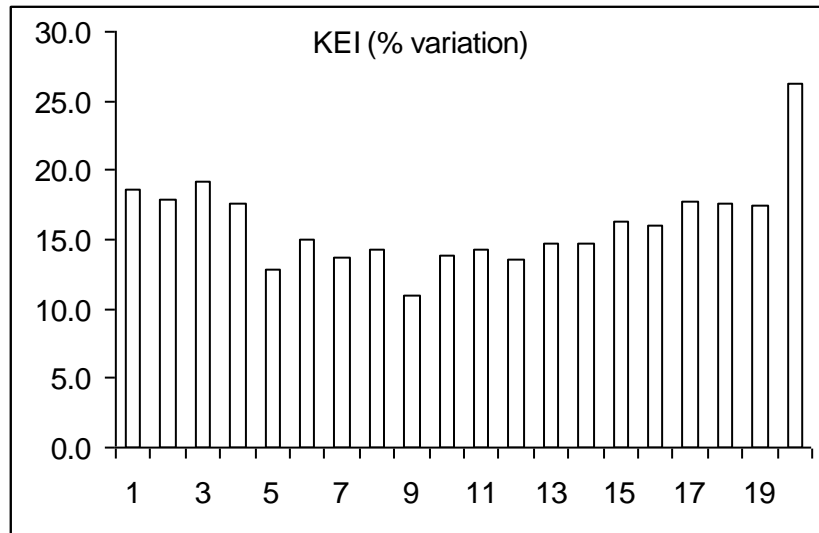


Diagram 5: Variation of Relative Percentage of Z(KEI) with L

It is clear from the Diagram 5 that the fractional contribution of keyword belonging to the class KEI was highest in the year 2004.

Clustered-Stable-Mono-frequent Keyword (KYI): Rank-2

The temporal evolution pattern of the keywords belonging to the class (KYI) follows sixth degree polynomial function:

$$Z(KYI) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.7)$$

Where, a(0) = -173.26, a(1) = 502.98, a(2) = -304.53, a(3) = 87.82, a(4) = -13.10  
a(5) = 1.05, a(6) = -0.04

Z(KYI) = Number of keywords belonging to the class (KYI)

L = Assumed age of the subject

In equation 10.7 also it is observed that,

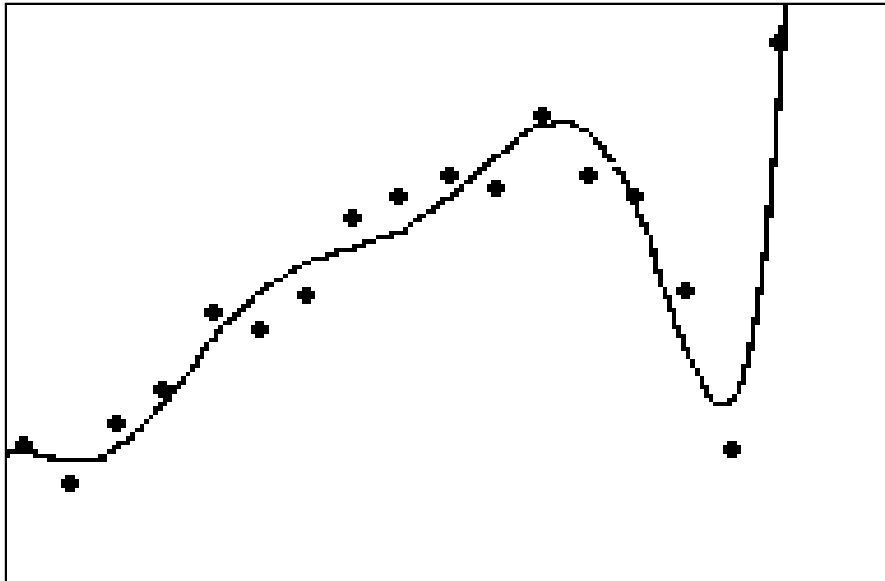
$$\Sigma(\text{Positive co-efficients}) > \Sigma(\text{Negative co-efficients}); \text{ and}$$

$$\text{As } L \rightarrow \infty \text{ (Infinity), } Z(KYI) \rightarrow \infty \text{ (Larger value)}$$



Table 10.11: Data for Graph 7

L	1	2	3	4	5	6	7	8	9	10
Z(KYI)	232	82	102	141	112	160	186	250	237	265
L	11	12	13	14	15	16	17	18	19	20
Z(KYI)	326	342	361	351	408	361	344	267	138	469



Graph 7: Variation of Z(KYI) with L

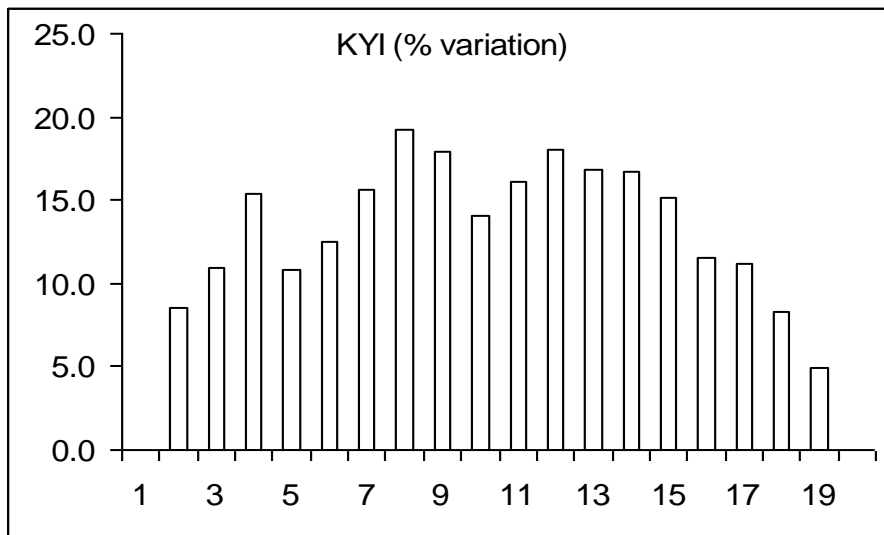


Diagram 6: Variation of Relative Percentage of Z(KYI) with L

The clustered-stable-(mono-frequent) keywords also show an increasing trend with the age of the subject 'Fermi liquid', though in the Graph 7 a depression has

been noticed from the year 2001 to 2003, followed by a steep hike in the year 2004. A look at the Diagram 6 also divulges that though the number of clustered-stable-(mono-frequent) keywords was highest in 2004, but that number constituted smallest relative percentage contribution than contributions come from other nineteen years. This is because the total number of keywords in the year 2004 was highest and that was remarkably higher than that for other years.

Clustered-Stable-(Multi-frequent) Keyword (KYU): Rank-3

The temporal evolution pattern of the keywords belonging to the class (KYU) follows sixth degree polynomial function:

$$Z(KYU) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.8)$$

Where, a(0) = -114.47, a(1) = 337.69, a(2) = -197.37, a(3) = 55.95, a(4) = -8.20  
a(5) = 0.64, a(6) = -0.03

Z(KYU) = Number of keywords belonging to the class (KYU)

L = Assumed age of the subject

In equation 10.8 also it is observed that,

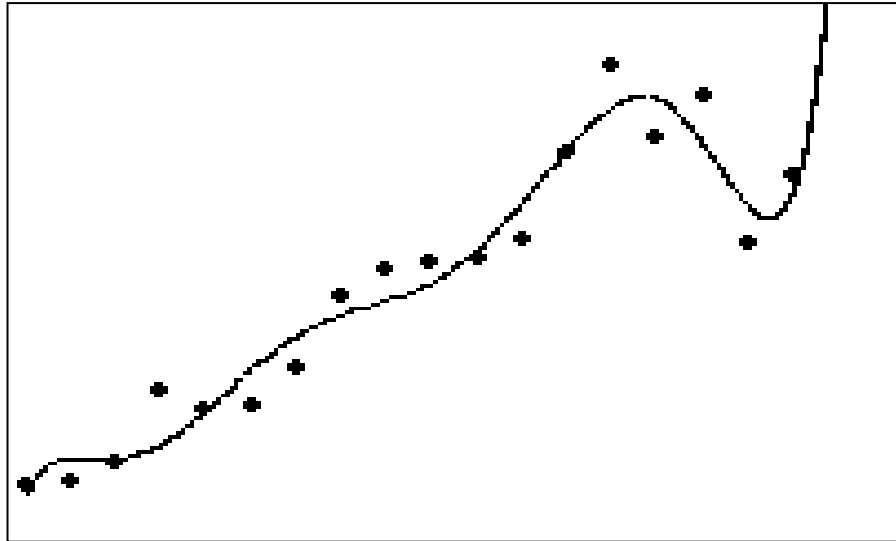
$$\sum(\text{Positive co-efficients}) > \sum(\text{Negative co-efficients}); \text{ and}$$

$$\text{As } L \rightarrow \infty \text{ (Infinity), } Z(KYU) \rightarrow \infty \text{ (Larger value)}$$

The variable Z(KYU) shows more or less steady increasing trend with L, except depressions in the last two years, i.e. 2003 and 2004 as evident from the Graph 8. The relative percentage variation in Z(KYU) was not very high as understood from the Diagram 7. The variables Z(KYI) and Z(KYU) show depression during the period 2001 to 2003 unlike Z(KEI), which shows increasing trend during the same period. The number of research papers and keywords were fairly high in the last three years. The decline in stable keywords and hike in ephemeral keywords in the last few years point toward an increase in number of new research projects as ephemeral keywords are born as a result of new research outcome.

Table 10.12: Data for Graph 8

L	1	2	3	4	5	6	7	8	9	10
Z(KYU)	107	98	82	86	102	165	151	152	188	251
L	11	12	13	14	15	16	17	18	19	20
Z(KYU)	275	281	285	299	376	455	392	429	297	357



Graph 8: Variation of Z(KYU) with L

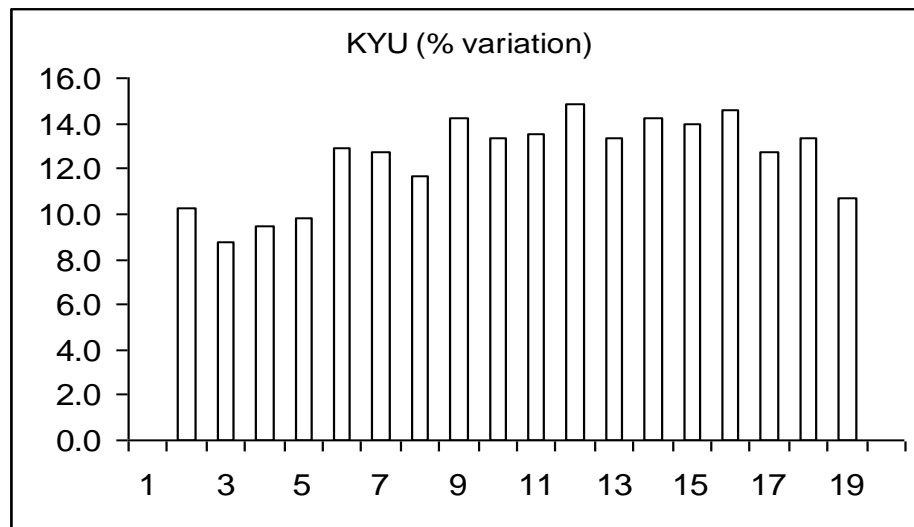


Diagram 7: Variation of Relative Percentage of Z(KYU) with L

Single-Ephemeral-Mono-frequent Keyword (SEI): Rank-4

The temporal evolution pattern of the keywords belonging to the class (SEI) follows sixth degree polynomial function:

$$Z(SEI) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.9)$$

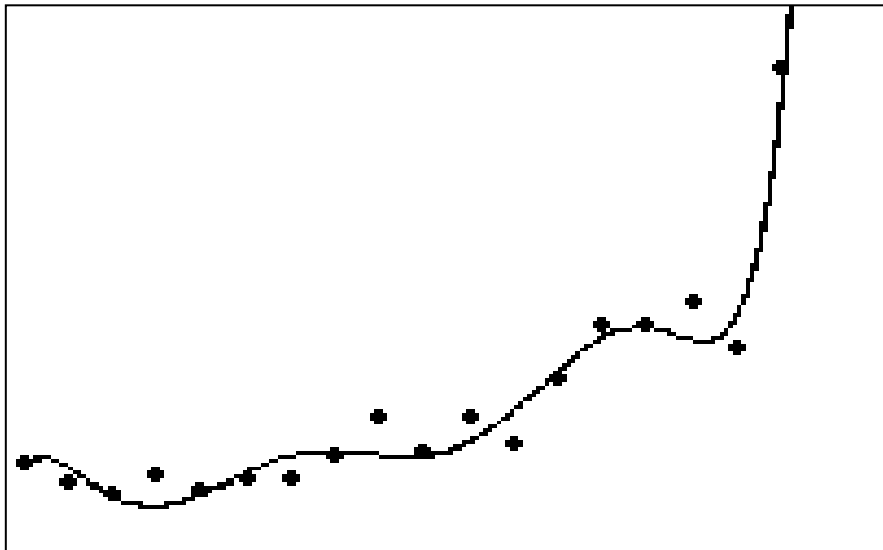
Where, a(0) = -180.90, a(1) = 601.50, a(2) = -390.51, a(3) = 112.78, a(4) = -16.69, a(5) = 1.32, a(6) = -0.05

Z(SEI) = Number of keywords belonging to the class (SEI)

L = Assumed age of the subject

Table 10.13: Data for Graph 9

L	1	2	3	4	5	6	7	8	9	10
Z(SEI)	114	133	138	105	86	115	92	109	110	146
L	11	12	13	14	15	16	17	18	19	20
Z(SEI)	207	152	206	168	269	353	352	392	319	764



Graph 9: Variation of Z(SEI) with L

In equation 10.9 also it is observed that,

$$\sum(\text{Positive co-efficients}) > \sum(\text{Negative co-efficients}); \text{ and}$$

As  $L \rightarrow \infty$  (Infinity),  $Z(SEI) \rightarrow \infty$  (Larger value)

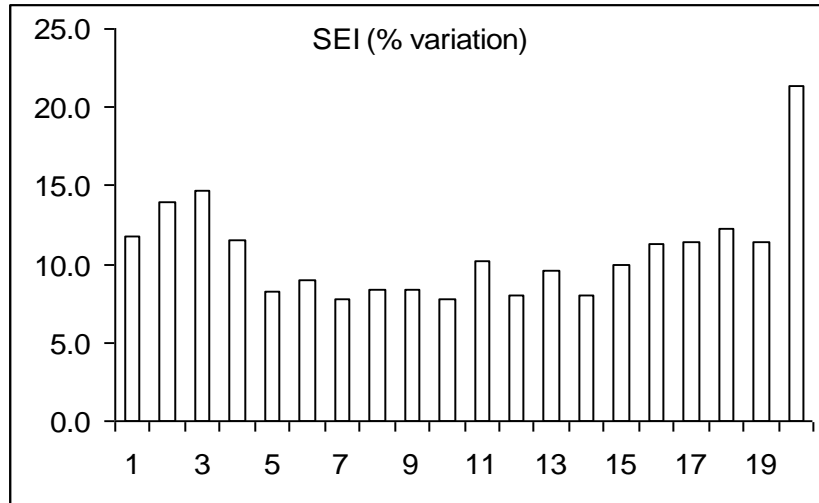


Diagram 8: Variation of Relative Percentage of Z(SEI) with L

The single-ephemeral-(mono-frequent) keyword shows an abrupt rise in the year 2004. The variable Z(KEI) also shows similar pattern. The ephemeral keywords whether belong to clustered or single group increases with L.

**Clustered-New-Mono-frequent Keyword (KJI): Rank-5**

The temporal evolution pattern of the keywords belonging to the class (KJI) follows Exponential Decay function:

$$Z(KJI) = a + b \cdot \exp(-L/c) + d \cdot \exp(-L/g) \dots \dots \dots (10.10)$$

Where, a = 7.13, b = 102.41, c = 13.14, d = 104.93, g = 12.67, Z(KJI) = Number of keywords belonging to the class (KJI), L = Assumed age of the subject

Table 10.14: Data for Graph 10

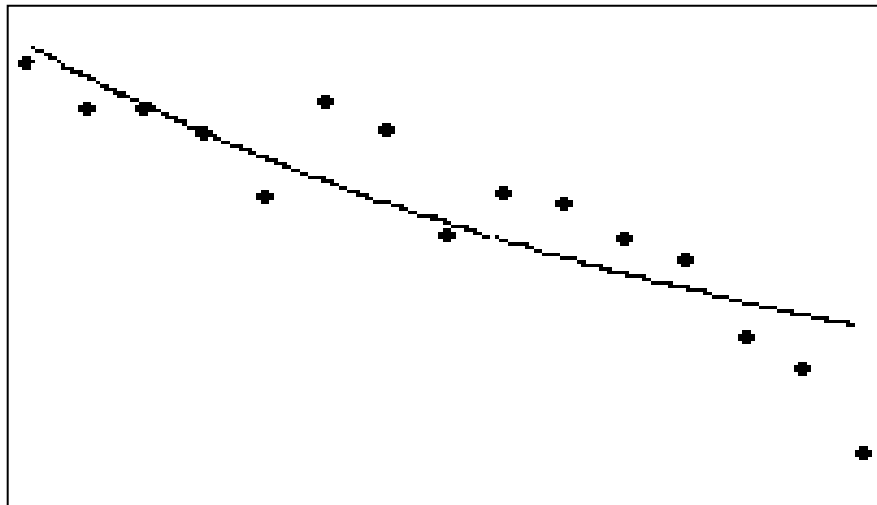
L	2	3	4	5	6	7	8	9	10
Z(KJI)	146	122	94	205	183	183	170	140	186
L	11	12	13	14	15	16	17	18	19
Z(KJI)	172	121	142	136	119	108	71	55	14

There are five constants involved in the equation 10.10 and all of them are positive. Now, from equation 10.10 it can be noticed that  $Z(KJI) \rightarrow a$  (7.13), as  $L \rightarrow \infty$  (Very large value). The variable Z(KJI) thus varies inversely as L, i.e. it decreases with the increase in L. The year in which the age of the subject 'Fermi

liquid' will be very high, the number of clustered-new-(mono-frequent) keywords will be equal to 7 only. The constant 'a' may thus be termed as the minimum possible number of keywords at the soaring age of the subject and may be denoted by the symbol  $Z(KJI)_{MIN}$ . The aging restrains incoming of new keywords. The equation 10.10 may thus be rewritten as follows:

$$Z(KJI) - Z(KJI)_{MIN} = b \cdot \exp(-L/c) + d \cdot \exp(-L/g) \dots \dots \dots (10.10A)$$

The number of keywords in any year is just the difference between the instantaneous and minimum number of keywords as seen from the equation 10.10A.



Graph 10: Variation of Z(KJI) with L

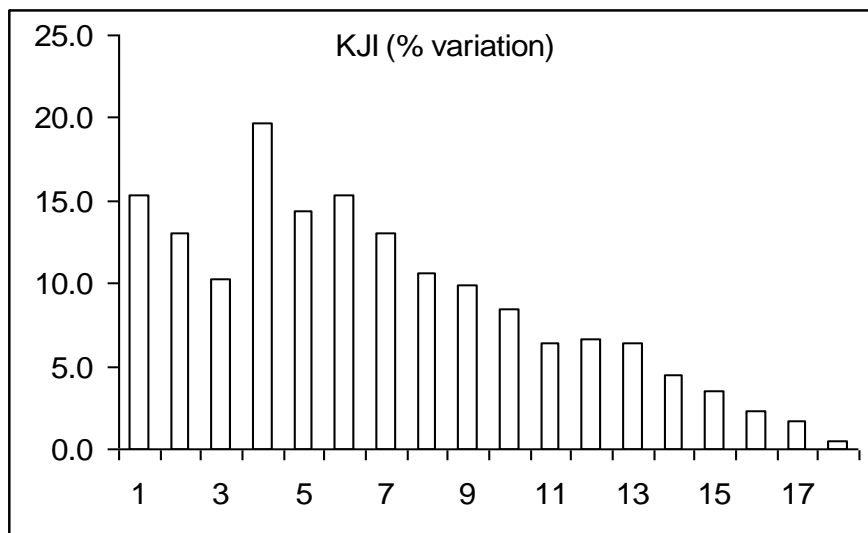


Diagram 9: Variation of Relative Percentage of Z(KJI) with L  
Clustered-Stable-Di-frequent Keyword (KYD): Rank-6

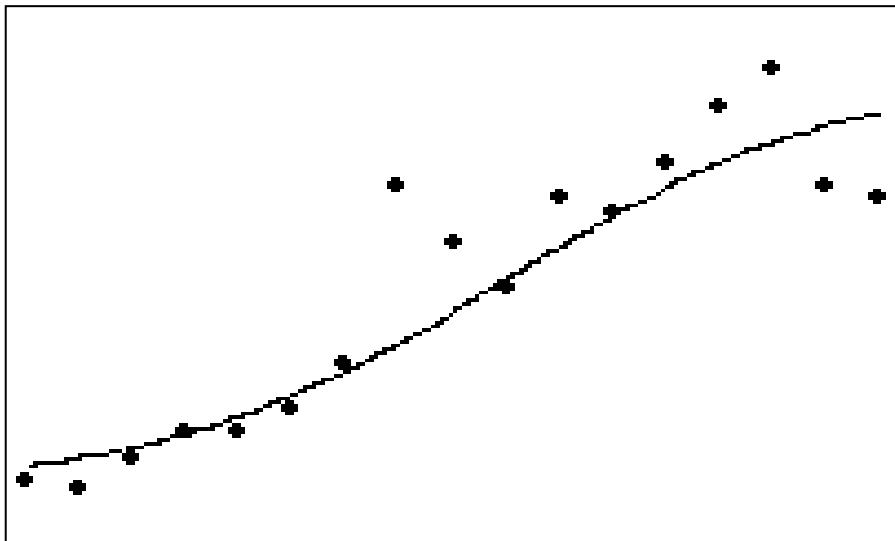
The temporal evolution pattern of the keywords belonging to the class (KYD) follows Logistic function:

$$Z(KYD) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.11)$$

Where, a = 58.00, b = 134.00, c = 2.81, d = -0.31, Z(KYD) = Number of keywords belonging to the class (KYD), L = Assumed age of the subject. There are four constants involved in the equation 10.11, out of which three constants are positive and one constant is negative. It is also noticed that  $Z(KYD) \rightarrow a$  (58), as  $L \rightarrow \infty$  (Very large value). The year in which the age of the subject 'Fermi liquid' will be very high, the number of clustered-stable-(di-frequent) keywords will be equal to 58 only. The constant a is therefore equal to Z(KYD) **MIN**. The aging restrains incoming of stable keywords also. Equation 10.11 may be rewritten as:  
 $[(b - Z(KYD)_{\text{MIN}})] / [Z(KYD) - Z(KYD)_{\text{MIN}}] = 1 + \exp(c+d*L) \dots \dots \dots (10.11A)$

Table 10.15: Data for Graph 11

L	1	2	3	4	5	6	7	8	9	10
Z(KYD)	84	42	61	58	68	76	76	83	98	154
L	11	12	13	14	15	16	17	18	19	20
Z(KYD)	137	122	151	146	162	180	192	154	77	151



Graph 11: Variation of Z(KYD) with L

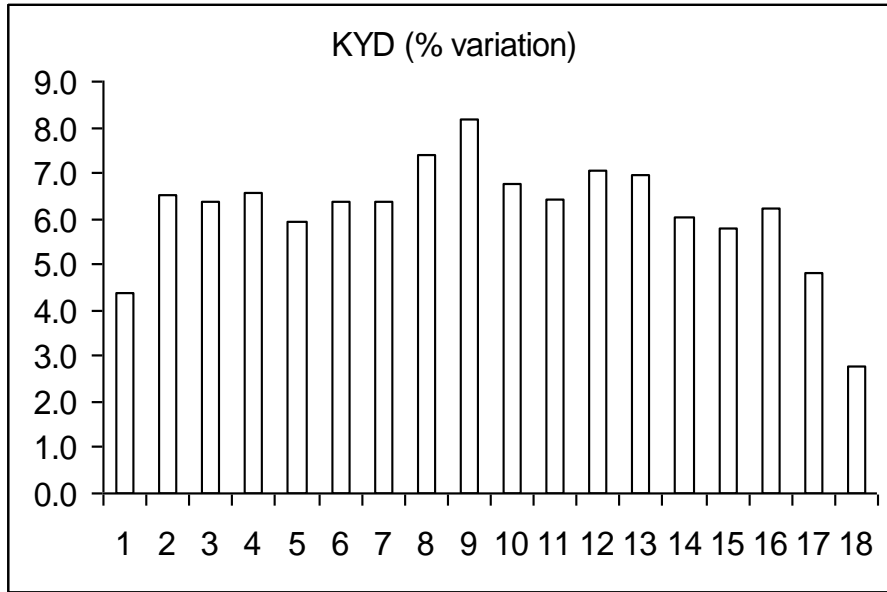


Diagram 10: Variation of Relative Percentage of Z(KYD) with L

The relative percentage of Z(KYD) is lowest in the year 2004 as evident from the Diagram 10.

Single-Stable-Mono-frequent Keyword (SYI): Rank-7

The temporal evolution pattern of the keywords belonging to the class (SYI) follows Logistic function:

$$Z(SYI) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.12)$$

Where, a = 22.00, b = 135.00, c = 2.34, d = -0.30, Z(SYI) = Number of keywords belonging to the class (SYI), L = Assumed age of the subject

Table 10.16: Data for Graph 12

L	1	2	3	4	5	6	7	8	9	10
Z(SYI)	124	28	22	30	26	54	46	62	68	107
L	11	12	13	14	15	16	17	18	19	20
Z(SYI)	120	117	128	148	157	153	151	105	57	205

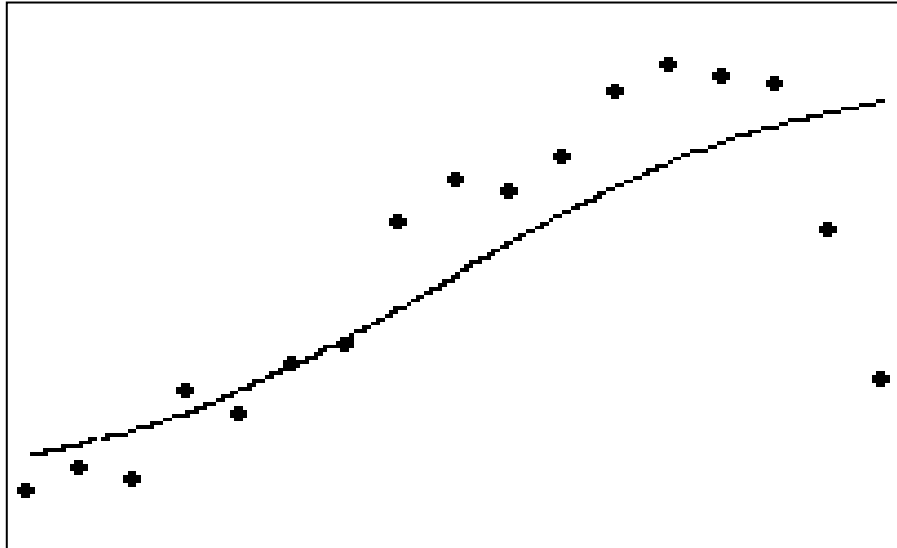
Four constants are involved in the equation 10.12, of which three constants are positive and one constant is negative. It is also noticed that Z(SYI) → a (22), as



$L \rightarrow \infty$  (Very large value). The year in which the age of the subject 'Fermi liquid' will be very high, the number of single-stable-(mono-frequent) keywords will be equal to 22 only. The aging restrains incoming of single-stable keywords also. Equation 10.12 may be rewritten as:

$$[(b - Z(\text{SYI})_{\text{MIN}})] / [Z(\text{SYI}) - Z(\text{SYI})_{\text{MIN}}] = 1 + \exp(c+d*L) \dots \dots \dots (10.12A)$$

Where,  $Z(\text{SYI})_{\text{MIN}} = a$ .



Graph 12: Variation of Z(SYI) with L

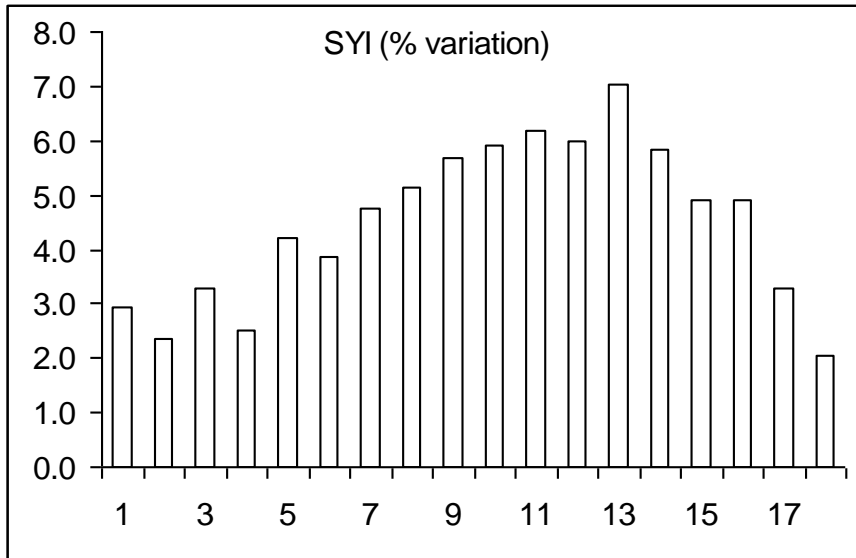


Diagram 11: Variation of Relative Percentage of Z(SYI) with L

The relative percentage contribution here is also lowest in the last year as clear from the Diagram 11.

Clustered-Obsolete-(Mono-frequent) Keyword (KOI): Rank-8

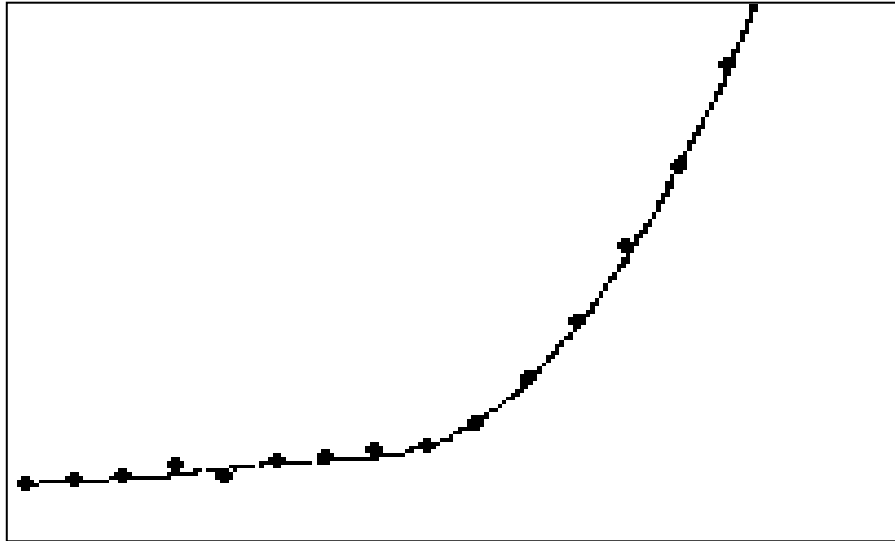
The temporal evolution pattern of the keywords belonging to the class (KOI) follows sixth degree polynomial function:

$$Z(KOI) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.13)$$

Where, a(0) = -211.46, a(1) = 279.87, a(2) = -137.61, a(3) = 34.65, a(4) = -4.78, a(5) = 0.36, a(6) = -0.01, Z(KOI) = Number of keywords belonging to the class (KOI), L = Assumed age of the subject. Here four constants are negative and three constants are positive. The variable Z(KOI) is less than zero, i.e. negative for lower values of L (L=1, 2); while it is greater than zero, i.e. positive for higher values of L (L>5). The clustered-obsolete-(mono-frequent) keywords thus increase directly with the increase in the age of the subject. The relative percentage of Z(KOI) is also highest in the last year as seen from the Diagram 12.

Table 10.17: Data for Graph 13

L	1	2	3	4	5	6	7	8	9	10
Z(KOI)		14	21	32	10	14	18	31	19	35
L	11	12	13	14	15	16	17	18	19	20
Z(KOI)	39	48	51	78	127	187	270	354	465	



Graph 13: Variation of Z(KOI) with L

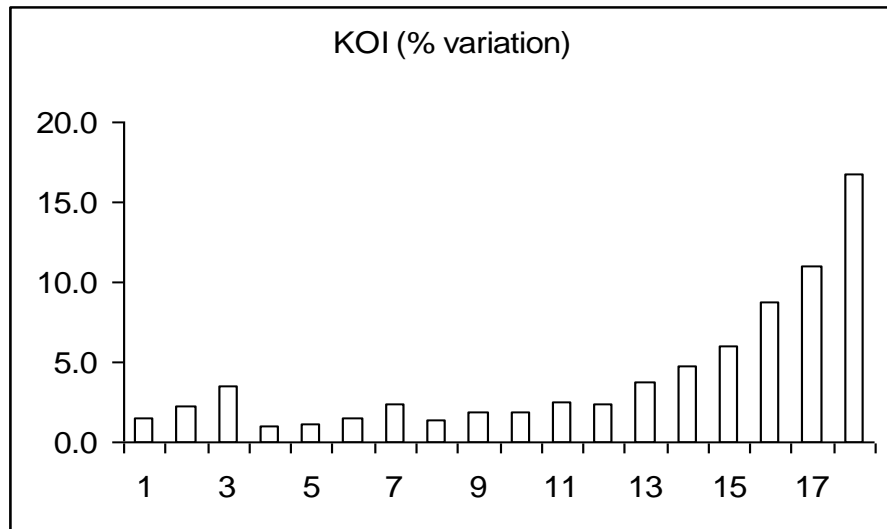


Diagram 12: Variation of Relative Percentage of Z(KOI) with L

Single-New-(Mono-frequent) Keyword (SJI): Rank-9

The temporal evolution pattern of the keywords belonging to the class (SJI) follows bell-shaped function:

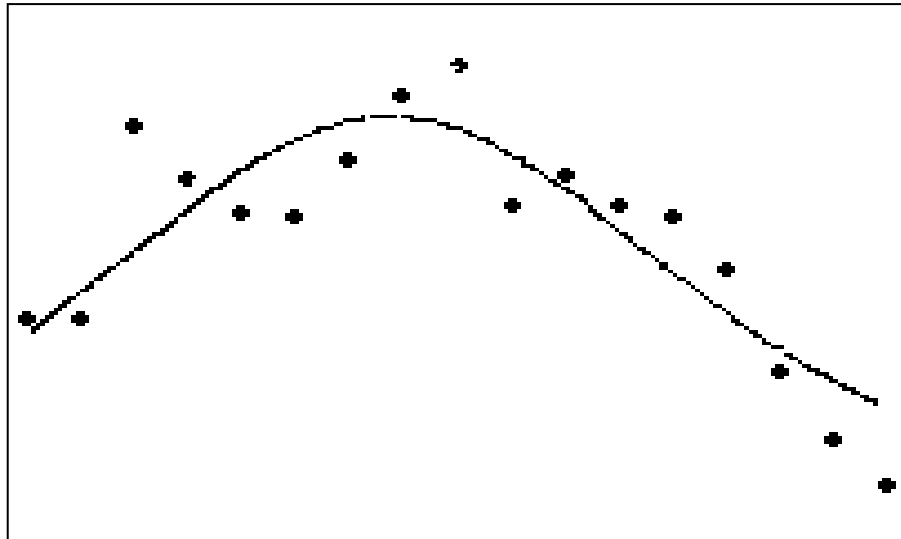
$$Z(SJI) = a + b/(1+((L-c)/d)^2)^g \dots \dots \dots (10.14)$$

Where, a = 10.13, b = 86.05, c = 6.71, d = 11.75, g = 2.72, Z(SJI) = Number of keywords belonging to the class (SJI), L = Assumed age of the subject.

Table 10.18: Data for Graph 14

L	2	3	4	5	6	7	8	9	10
Z(SJI)	64	52	52	94	82	75	74	86	100
L	11	12	13	14	15	16	17	18	19
Z(SJI)	107	77	83	77	74	63	41	26	16

Here all 5 constants are positive. The variable  $Z(SJI)$  tends to the constant value ( $a=10.13$ ) for very large values of  $L$ . The variable  $Z(SJI)$  shows an increasing trend first and then a decreasing trend as shown in the Graph 14. The relative percentage of  $Z(SJI)$  was also lowest in the last year as clear from the Diagram 13.



Graph 14: Variation of  $Z(SJI)$  with  $L$

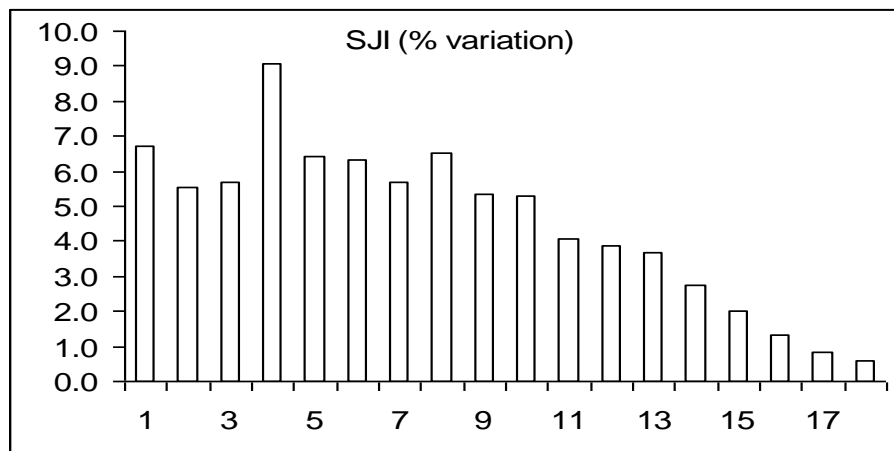


Diagram 13: Variation of Relative Percentage of  $Z(SJI)$  with  $L$

## Single-Obsolete-(Mono-frequent) Keyword (SOI): Rank-10

The temporal evolution pattern of the keywords belonging to the class (SOI) follows sixth degree polynomial function:

$$Z(\text{SOI}) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6$$

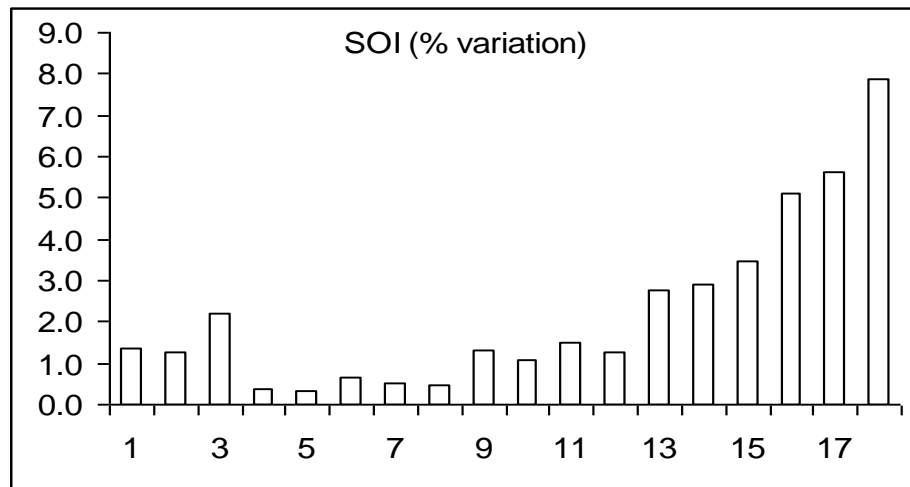
.....(10.15)

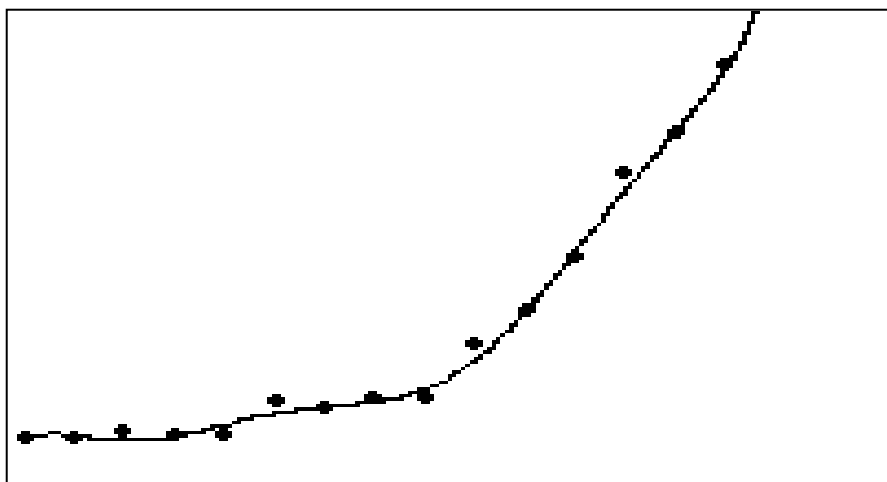
Where,  $a(0) = -250.87$ ,  $a(1) = 330.18$ ,  $a(2) = -164.52$ ,  $a(3) = 41.20$ ,  $a(4) = -5.64$ ,  $a(5) = 0.43$ ,  $a(6) = -0.02$ ,  $Z(\text{SOI})$  = Number of keywords belonging to the class (SOI),  $L$  = Assumed age of the subject. Here four constants are negative and three constants are positive. The variable  $Z(\text{SOI})$  is less than zero, i.e. negative for lower values of  $L$  ( $L=1, 2$ ); while it is greater than zero, i.e. positive for higher values of  $L$  ( $L>5$ ). The single-obsolete-(mono-frequent) keywords thus increase directly with the increase in the age of the subject. The relative percentage of  $Z(\text{SOI})$  is also highest in the last year as seen from the Diagram 14. Aging renders obsolescence, which is also evident by the behavioral pattern of the variable  $Z(\text{SOI})$ .

Table 10.19: Data for Graph 15

L	2	3	4	5	6	7	8	9	10
Z(SOI)	13	12	20	4	4	8	7	6	25
L	11	12	13	14	15	16	17	18	19
Z(SOI)	22	28	27	58	78	108	157	180	219

Diagram 14: Variation of Relative Percentage of Z(SOI) with L





Graph 15: Variation of Z(SOI) with L

Temporal evolution patterns of top ten keyword-classes: Summary

Table 10.20: Synopsis of the functional variation of the top ten keyword classes

Keyword class	Nature of graph	Changing trend as reflected from the graph	Number of constants involved	Corresponding equation
KEI	Sixth degree polynomial	Increasing	7	10.6
KYI	Sixth degree polynomial	Increasing	7	10.7
KYU	Sixth degree polynomial	Increasing	7	10.8
SEI	Sixth degree polynomial	Increasing	7	10.9
KJI	Exponential decay	Decreasing	5	10.10
KYD	Logistic function	Saturating	4	10.11
SYI	Logistic function	Saturating	4	10.12
KOI	Sixth degree polynomial	Increasing	7	10.13
SJI	Bell-shaped curve	Periodic	5	10.14
SOI	Sixth degree polynomial	Increasing	7	10.15

The summary of the top ten keyword-classes has been presented in the Table 10.20. Of the top ten keyword-classes, six classes show sixth degree polynomial graph. The clustered-stable-mono-frequent (KYI) and the clustered-stable-multi-frequent (KYU) classes show sixth degree polynomial graph, whereas clustered-stable-di-frequent (KYD) class show logistic function. This is an interesting

finding. The “Single-new-mono-frequent” keyword class (SJI) show periodic trend; the “Obsolete” classes (KOI & SOI) show increasing trend and the “Stable” classes (KYD & SYI) show saturating trend.

F. Keyword: Associativeness to the Subject Content (ASC)

The variation patterns of the keyword-classes revealed on the basis of the associativeness to the subject content is shown below. The variation patterns of single, twin and clustered keywords have been discussed. The single keyword class shows sixth degree polynomial function. The twin keyword class shows exponential growth function and the clustered keyword class shows logistic function. The relative percentage variation among these three classes is also shown in the Diagram 15, which shows constant pattern of twin and clustered keyword-classes, but a slight depression in single class on the midway.

Single Keyword:

The temporal evolution pattern of the single keywords follows sixth degree polynomial function:

$$Z(S) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.16)$$

Where, a(0) = -398.11, a(1) = 1151.89, a(2) = -684.28, a(3) = 187.66, a(4) = -26.69, a(5) = 2.04, a(6) = -0.08, Z(S) = Number of single keywords, L = Assumed age of the subject.

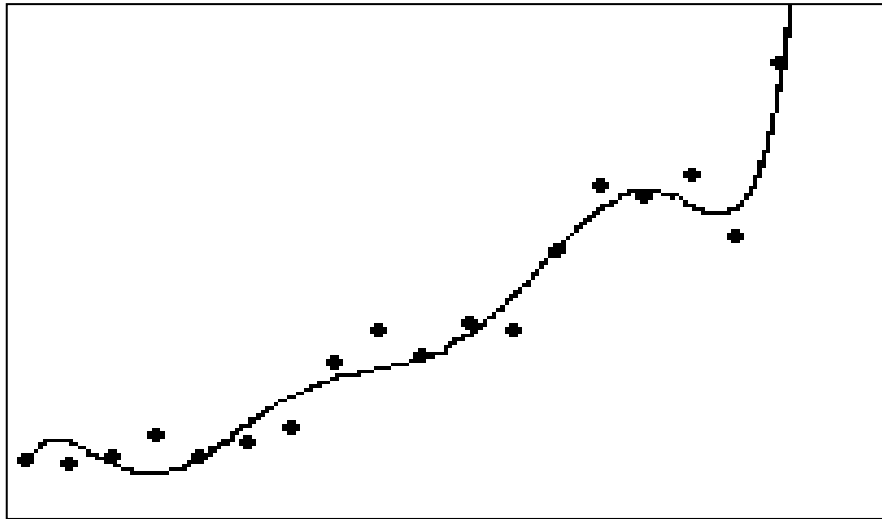
Table 10.21: Data for Graph 16

L	1	2	3	4	5	6	7	8	9	10
Z(S)	280	273	253	242	258	312	260	297	336	489
L	11	12	13	14	15	16	17	18	19	20
Z(S)	575	508	591	573	768	928	896	955	803	1229

In equation 10.16 it is observed that,

$$\Sigma(\text{Positive co-efficients}) > \Sigma(\text{Negative co-efficients}); \text{ and}$$

As  $L \rightarrow \infty$  (Infinity),  $Z(S) \rightarrow \infty$  (Larger value)



Graph 16: Variation of Z(S) with L

The number of single keywords is increasing with the increase in age of the subject, as also revealed from Table 10.21 and Graph 16.

Twin Keyword:

The temporal evolution pattern of the twin keywords follows exponential growth function:

$$Z(W) = a + b \cdot \exp(L/c) + d \cdot \exp(L/g) \dots \dots \dots (10.17)$$

Where,  $a = 57.07$ ,  $b = 19.55$ ,  $c = 7.43$ ,  $d = 17.46$ ,  $g = 29.67$ ,  $Z(S)$  = Number of single keywords,

$L$  = Assumed age of the subject.

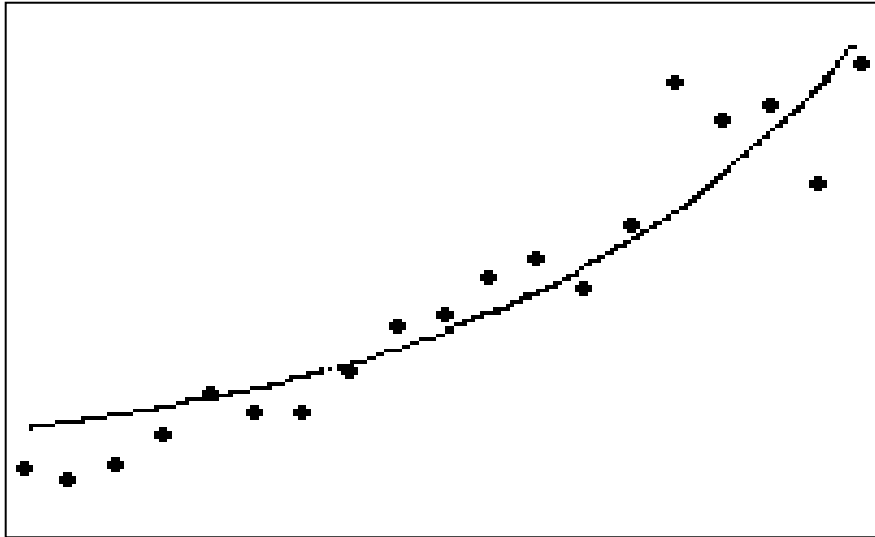
Table 10.22: Data for Graph 17

L	1	2	3	4	5	6	7	8	9	10
Z(W)	69	70	64	72	88	111	102	101	124	149
L	11	12	13	14	15	16	17	18	19	20
Z(W)	155	175	185	169	203	281	261	270	227	292

It is evident from equation (10.17) that as

$L \rightarrow \infty$  (Infinity),  $Z(W) \rightarrow \infty$  (Larger value)





Graph 17: Variation of Z(W) with L

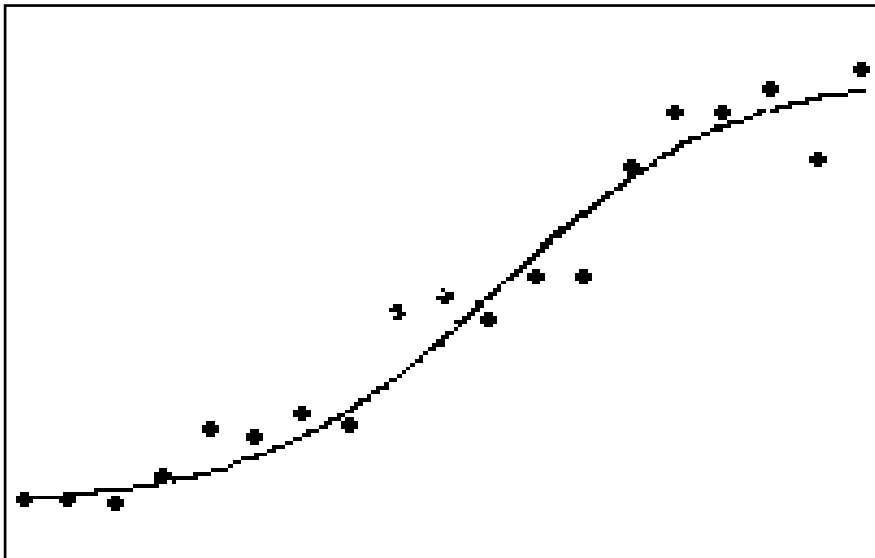
Clustered Keyword:

The temporal evolution pattern of the clustered keywords follows logistic function:

$$Z(K) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.18)$$

Where, a = 599.00, b = 1457.00, c = 4.00, d = -0.40, Z(K) = Number of clustered keywords,

L = Assumed age of the subject.



Graph 18: Variation of Z(K) with L

Table 10.23: Data for Graph 18

L	1	2	3	4	5	6	7	8	9	10
Z(K)	616	612	619	599	692	855	828	903	862	1242
L	11	12	13	14	15	16	17	18	19	20
Z(K)	1297	1212	1363	1364	1725	1907	1915	1982	1753	2056

It is evident from equation (10.18) that as

$$L \rightarrow \infty \text{ (Infinity)}, Z(K) \rightarrow a (=599)$$

The graphical analysis of single and twin keywords show increasing patterns while that for clustered keywords show saturating pattern. Single and twin keywords appear as a result of interactions with other subject, while clustered keywords belong to core and allied areas of the subject concerned. The aging of this subject enhances interactions with other subjects but the core area of study will eventually reach saturation point. An increase in interaction with other subject probably will accelerate proliferation of this subject with aging.

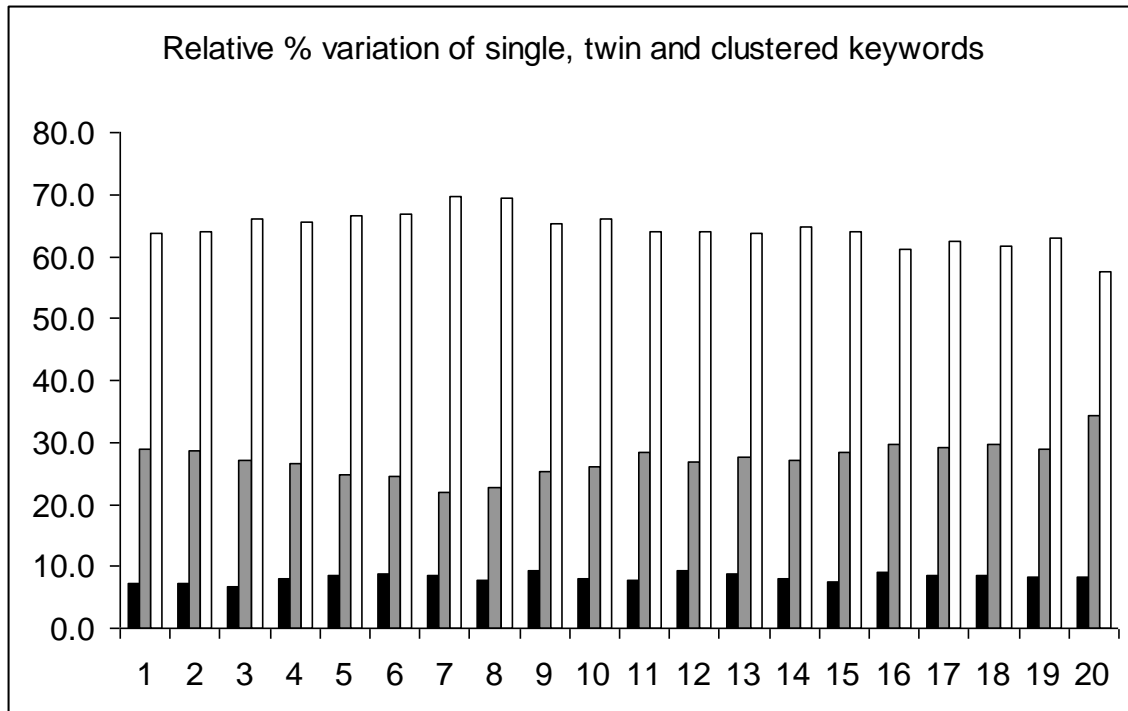


Diagram 15: Relative percentage variation of Z(S) [pale black-shaded bar], Z(W) [deep black-shaded bar] and Z(K) [white bar] over twenty years

G. Keyword: Chronological Appearance (CAP)

The variation patterns of the keyword-classes made on the basis of the chronological appearance is shown below. The variation patterns of ephemeral, new, obsolete and stable keywords are discussed. The ephemeral and stable keyword classes show sixth degree polynomial function. The new keyword class shows periodic bell-shaped function and the obsolete keyword class shows exponential growth function. The relative percentage variation among ephemeral and non-ephemeral classes are also shown in Figure 31, which shows little bulge in the pattern of non-ephemeral keyword class and slight depression in the pattern of ephemeral keyword-classes on the midway.

Ephemeral Keyword (Including Clustered, Twin and Single components):

The temporal evolution pattern of the ephemeral keywords follows sixth degree polynomial function:

$$Z(E) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.19)$$

Where, a(0) = -566.99, a(1) = 1691.67, a(2) = -1063.92, a(3) = 303.17, a(4) = -44.62, a(5) = 3.52, a(6) = -0.14, Z(E) = Number of ephemeral keywords, L = Assumed age of the subject.

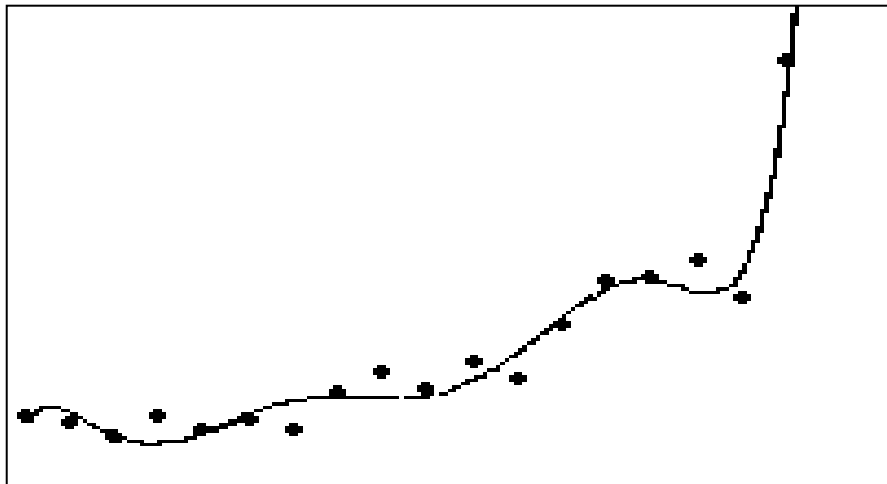
Table 10.24: Data for Graph 19

L	1	2	3	4	5	6	7	8	9	10
Z(E)	344	351	349	308	245	352	284	330	288	476
L	11	11	11	11	11	11	11	11	11	11
Z(E)	562	484	612	537	809	1023	1044	1119	934	2127

In equation 10.19 it is observed that,

$$\sum(\text{Positive co-efficients}) > \sum(\text{Negative co-efficients}); \text{ and}$$

As  $L \rightarrow \infty$  (Infinity),  $Z(E) \rightarrow \infty$  (Larger value)



Graph 19: Variation of Z(E) with L

The ephemeral keywords show an abrupt hike in the year 2004, as seen from Table 10.24 and Graph 19.

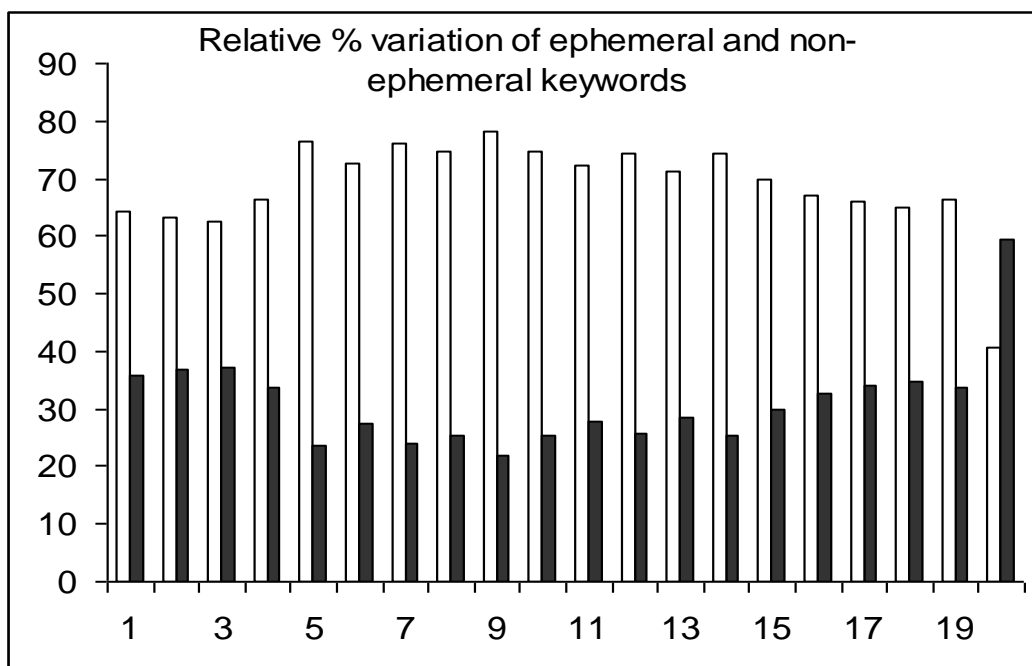


Diagram 16: Relative percentage variation of Z(E) [white bars] and Z(F) [black bars] over twenty years

In the Diagram 16, the non-ephemeral keywords overshadow the ephemeral keywords only in the year 2004, while the reverse phenomenon occurs in other years.

Single-Ephemeral keyword

The temporal evolution pattern of the single-ephemeral keywords follows sixth degree polynomial function:

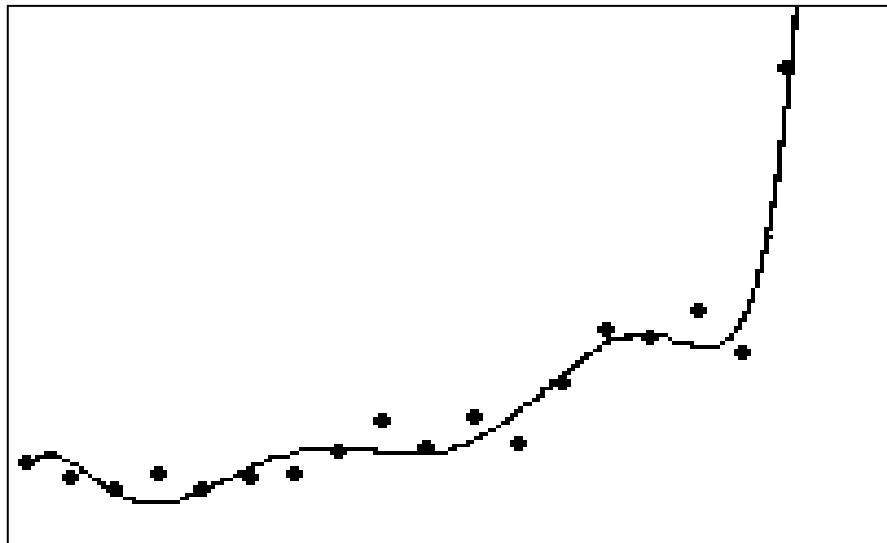
$$Z(SE) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6 \dots\dots\dots(10.20)$$

Where,  $a(0) = -254.20$ ,  $a(1) = 739.92$ ,  $a(2) = -472.10$ ,  $a(3) = 134.94$ ,  $a(4) = -19.84$ ,  $a(5) = 1.56$ ,  $a(6) = -0.06$ ,  $Z(SE)$  = Number of single-ephemeral keywords,  $L$  = Assumed age of the subject.

In equation 10.20 it is observed that,

$$\sum(\text{Positive co-efficients}) > \sum(\text{Negative co-efficients}); \text{ and}$$

As  $L \rightarrow \infty$  (Infinity),  $Z(SE) \rightarrow \infty$  (Larger value)



Graph 20: Variation of Z(SE) with L

Table 10.25: Data for Graph 20

L	1	2	3	4	5	6	7	8	9	10
Z(SE)	125	141	142	113	89	119	93	115	116	160
L	11	12	13	14	15	16	17	18	19	20
Z(SE)	220	168	229	175	288	392	375	428	348	881

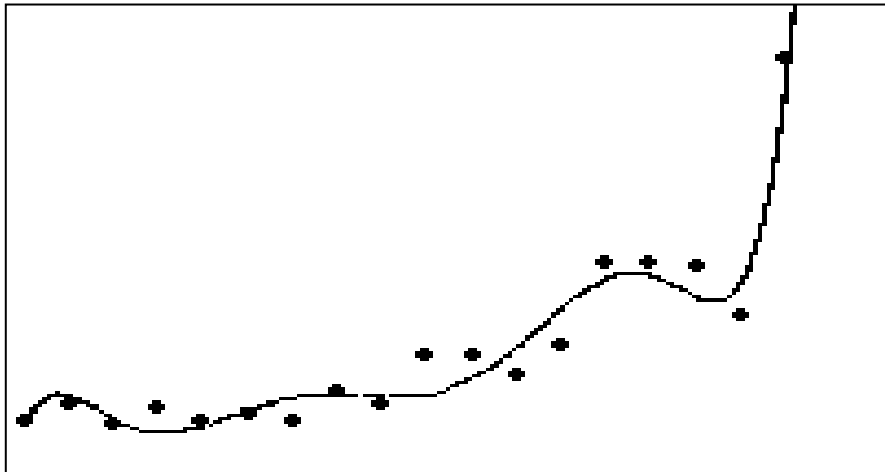
The number of single-ephemeral keywords shows an abrupt hike in the year 2004.

Twin-Ephemeral keyword

The temporal evolution pattern of the twin-ephemeral keywords follows sixth degree polynomial function:

$$Z(WE) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.21)$$

Where, a(0) = -86.24, a(1) = 188.26, a(2) = -109.90, a(3) = 29.93, a(4) = -4.29, a(5) = 0.33, a(6) = -0.01, Z(WE) = Number of twin-ephemeral keywords, L = Assumed age of the subject.



Graph 21: Variation of Z(WE) with L

Table 10.26: Data for Graph 21

L	1	2	3	4	5	6	7	8	9	10
Z(WE)	26	32	20	27	19	26	21	23	20	32
L	11	12	13	14	15	16	17	18	19	20
Z(WE)	27	47	47	39	51	84	83	82	62	165

Clustered-Ephemeral keyword

The temporal evolution pattern of the clustered-ephemeral keywords follows sixth degree polynomial function:

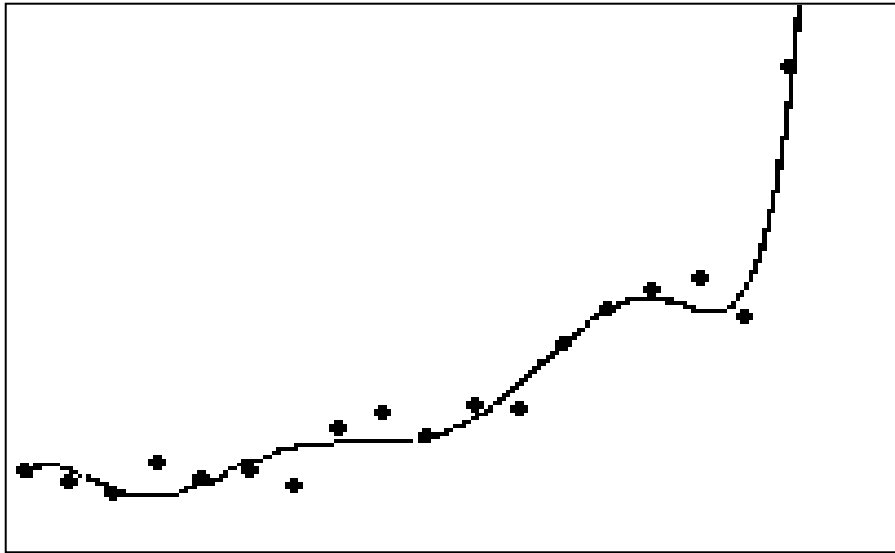
$$Z(KE) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.22)$$

Where, a(0) = -225.66, a(1) = 761.87, a(2) = -480.93, a(3) = 138..02,

$a(4) = -20.44$ ,  $a(5) = 1.62$ ,  $a(6) = -0.07$ ,  $Z(\text{KE}) =$  Number of clustered-ephemeral keywords,  $L =$  Assumed age of the subject.

Table 10.27: Data for Graph 22

L	1	2	3	4	5	6	7	8	9	10
Z(KE)	193	178	187	168	137	207	170	192	152	284
L	11	12	13	14	15	16	17	18	19	20
Z(KE)	315	269	336	323	470	547	586	609	524	1079



Graph 22: Variation of Z(KE) with L

The patterns followed by clustered-ephemeral keywords and twin-ephemeral keywords are alike with that for single-ephemeral keywords. The changing trends of ephemeral indices are discussed below, which show Gaussian functions of periodic nature. The changing trends of obsolescence index are also discussed later, which show exponential growth function.

### Ephemeral Index (R) [Integrated]

The temporal evolution pattern of Integrated Ephemeral Index (for single, twin and clustered components) follows the Gaussian function:

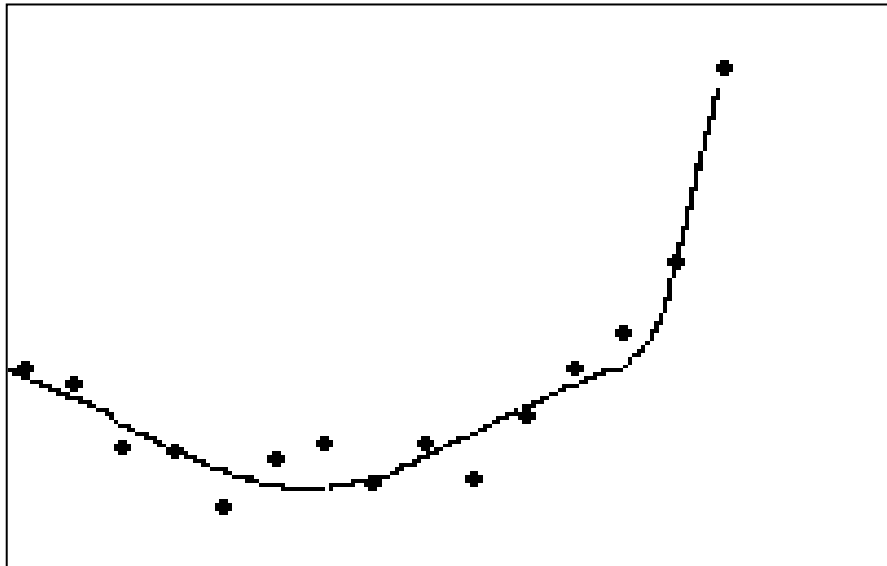
$$R = a + b \cdot \exp(-0.5 \cdot ((L-c)/d)^2) + g \cdot \exp(-0.5 \cdot (((L-h)/k)^2)) \dots \dots \dots (10.23)$$

Where,  $a = 0.76$ ,  $b = -0.31$ ,  $c = 7.65$ ,  $d = 3.39$ ,  $g = 0.59$ ,  $h = 16.04$ ,  $k = 0.71$ ,

$R =$  Integrated Ephemeral Index,  $L =$  Assumed age of the subject.

Table 10.28: Data for Graph 23

L	2	3	4	5	6	7	8	9	10
R	1.31	1.13	0.86	0.7	0.67	0.53	0.53	0.4	0.51
L	11	12	13	14	15	16	17	18	19
R	0.54	0.46	0.54	0.46	0.6	0.7	0.78	0.93	1.35



Graph 23: Variation of R with L

Ephemeral Index (R) [Single]

The temporal evolution pattern of Single Ephemeral Index (for single component only) follows the Gaussian function:

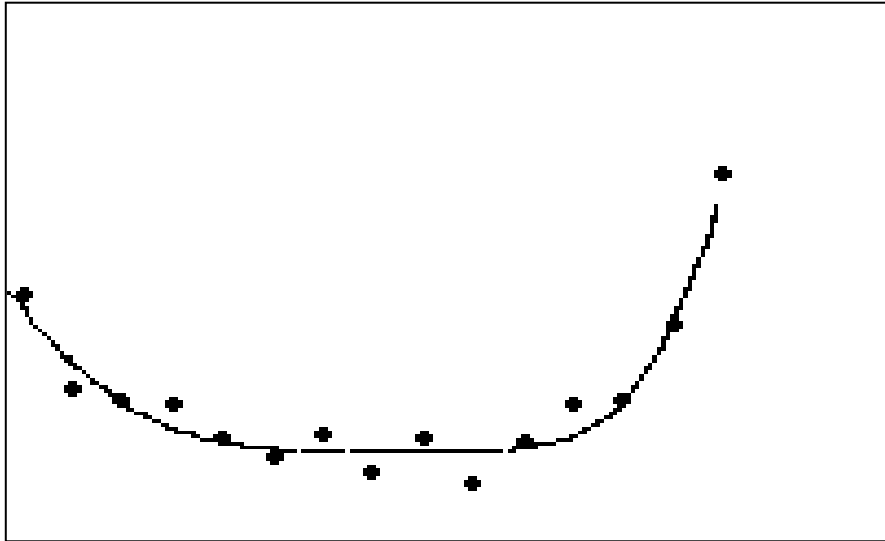
$$R(S) = a + b \cdot \exp(-0.5 \cdot ((L-c)/d)^2) + g \cdot \exp(-0.5 \cdot ((L-h)/k)^2) \dots \dots \dots (10.24)$$

Where, a = 0.93, b = 1.63, c = -0.86, d = 2.73, g = 3.91, h = 18.58, k = 2.11, R(S) = Single Ephemeral Index, L = Assumed age of the subject.

Table 10.29: Data for Graph 24

L	1	2	3	4	5	6	7	8	9	10
R(S)	0.81	3.92	3.55	2.31	1.98	1.35	1.26	1.25	1.00	0.88
L	11	12	13	14	15	16	17	18	19	20
R(S)	1.05	0.79	1.00	0.70	0.99	1.23	1.28	1.79	2.81	2.53





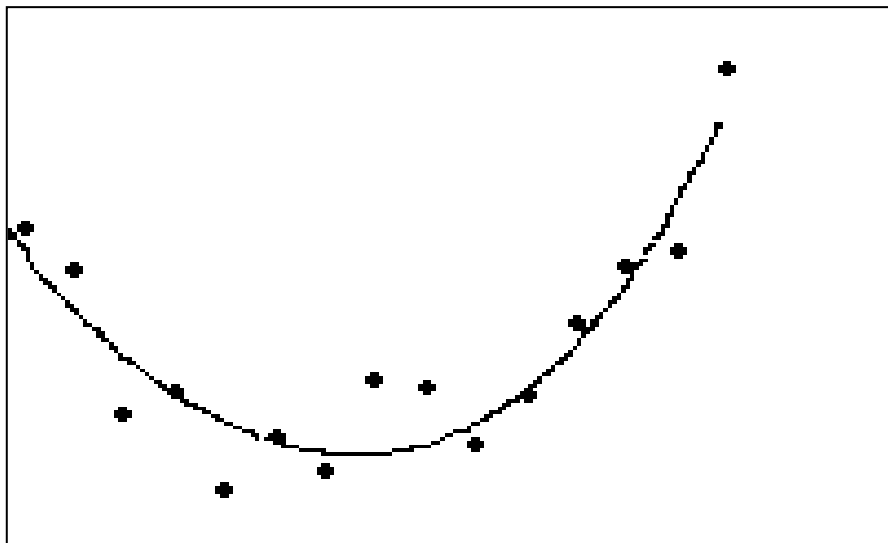
Graph 24: Variation of R(S) with L

Ephemeral Index (R) [Twin]

The temporal evolution pattern of Twin Ephemeral Index (for twin component only) follows the superposed Gaussian function and parabola:

$$R(W) = a + b \cdot \exp(-0.5 \cdot ((L-c)/d)^2) + g \cdot L + h \cdot L^2 \dots \dots \dots (10.25)$$

Where, a = -0.94, b = 2.14, c = 5.02, d = 10.58, g = -0.24, h = 0.02, R(W) = Twin Ephemeral Index, L = Assumed age of the subject.



Graph 25: Variation of R(W) with L

Table 10.30: Data for Graph 25

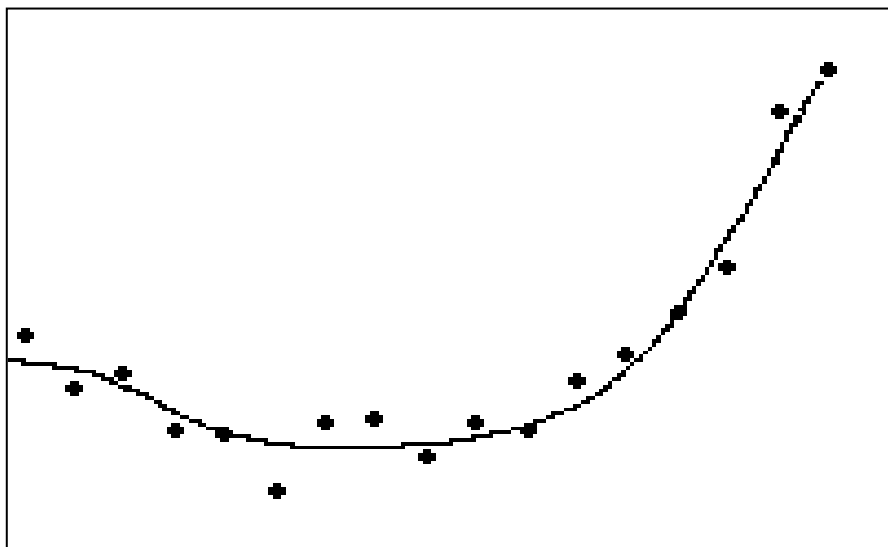
L	1	2	3	4	5	6	7	8	9	10
R(W)	0.60	2.91	0.83	1.04	0.76	0.68	0.41	0.45	0.26	0.36
L	11	12	13	14	15	16	17	18	19	20
R(W)	0.30	0.47	0.46	0.35	0.44	0.58	0.69	0.72	1.07	1.30

Ephemeral Index (R) [Clustered]

The temporal evolution pattern of Clustered Ephemeral Index (for clustered component only) follows the Dose-response biphasic function:

$$R(K) = a + b*c/(1+10^{((L-d)*g)}) + b*(1-c)/(1+10^{((L-k)*h)}) \dots \dots \dots (10.26)$$

Where, a = 0.37, b = 1.24, c = 0.14, d = 4.74, g = 0.50, h = -0.28, k = 16.67,  
 R(K) = Clustered Ephemeral Index, L = Assumed age of the subject.



Graph 26: Variation of R(K) with L

Table 10.31: Data for Graph 26

L	1	2	3	4	5	6	7	8	9	10
R(K)	0.46	0.80	0.76	0.59	0.49	0.52	0.41	0.40	0.29	0.42
L	11	12	13	14	15	16	17	18	19	20
R(K)	0.43	0.36	0.42	0.41	0.50	0.55	0.63	0.72	1.02	1.10

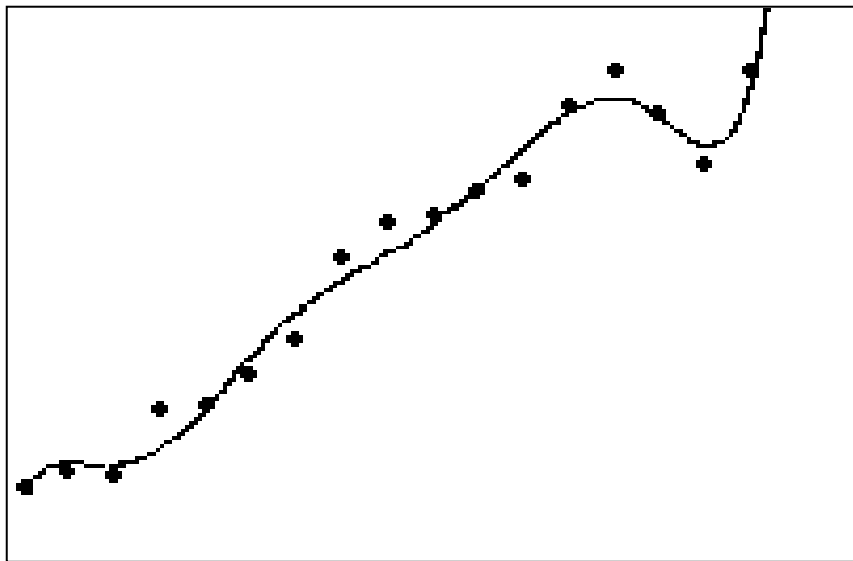
The variation patterns of four ephemeral indices with L (equation 10.23, 10.24, 10.25 and 10.26) as shown in the graphs (Graph 23, 24, 25 and 26) prove the hypothesis number (5) of chapter nine.

Stable Keyword (Including Clustered, Twin and Single components):

The temporal evolution pattern of the stable keywords follows sixth degree polynomial function, which is identical with the pattern followed by the ephemeral keywords:

$$Z(KE) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.27)$$

Where,  $a(0) = -297.80$ ,  $a(1) = 1089.30$ ,  $a(2) = -658.67$ ,  $a(3) = 191.14$ ,  
 $a(4) = -28.57$ ,  $a(5) = 2.30$ ,  $a(6) = -0.09$ ,  $Z(Y)$  = Number of stable keywords,  
 $L$  = Assumed age of the subject.



Graph 27: Variation of Z(Y) with L

Table 10.32: Data for Graph 27

L	1	2	3	4	5	6	7	8	9	10
Z(Y)	621	269	309	360	351	527	538	628	715	940
L	11	12	13	14	15	16	17	18	19	20
Z(Y)	1036	1059	1128	1157	1355	1458	1343	1203	694	1452

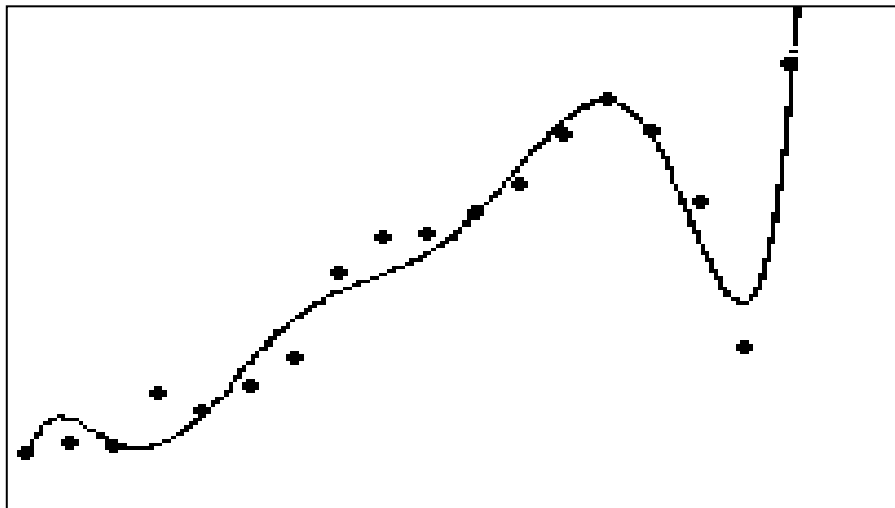
The three segments of the stable keyword (single, twin and clustered) also follow the same variation pattern, as shown below:

Single-Stable Keyword

The temporal evolution pattern of the single-stable keywords follows sixth degree polynomial function:

$$Z(SY) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.28)$$

Where, a(0) = -249.97, a(1) = 515.31, a(2) = -306.80, a(3) = 85.63, a(4) = -12.43, a(5) = 0.97, a(6) = -0.04, Z(SY) = Number of single-stable keywords, L = Assumed age of the subject.



Graph 28: Variation of Z(SY) with L

Table 10.33: Data for Graph 28

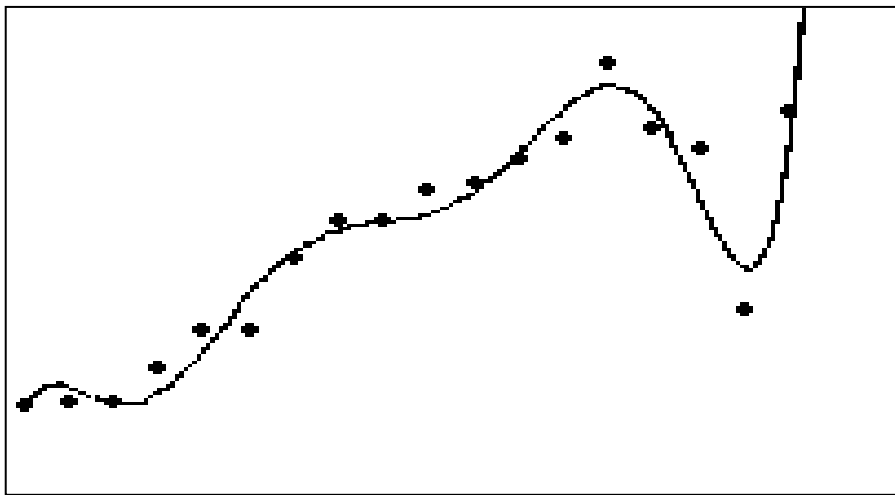
L	1	2	3	4	5	6	7	8	9	10
Z(SY)	155	36	40	49	45	88	74	92	116	181
L	11	12	13	14	15	16	17	18	19	20
Z(SY)	209	214	229	251	292	318	294	239	124	348

Twin-Stable Keyword

The temporal evolution pattern of the twin-stable keywords follows sixth degree polynomial function:

$$Z(WY) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.29)$$

Where,  $a(0) = -74.98$ ,  $a(1) = 182.51$ ,  $a(2) = -114.23$ ,  $a(3) = 33.21$ ,  $a(4) = -4.93$ ,  $a(5) = 0.39$ ,  $a(6) = -0.02$ ,  $Z(WY)$  = Number of single-stable keywords,  
 $L$  = Assumed age of the subject.



Graph 29: Variation of Z(WY) with L

Table 10.34: Data for Graph 29

L	1	2	3	4	5	6	7	8	9	10
Z(WY)	43	11	24	26	25	38	51	51	76	89
L	11	12	13	14	15	16	17	18	19	20
Z(WY)	89	100	102	110	117	144	121	114	58	127

Clustered-Stable Keyword

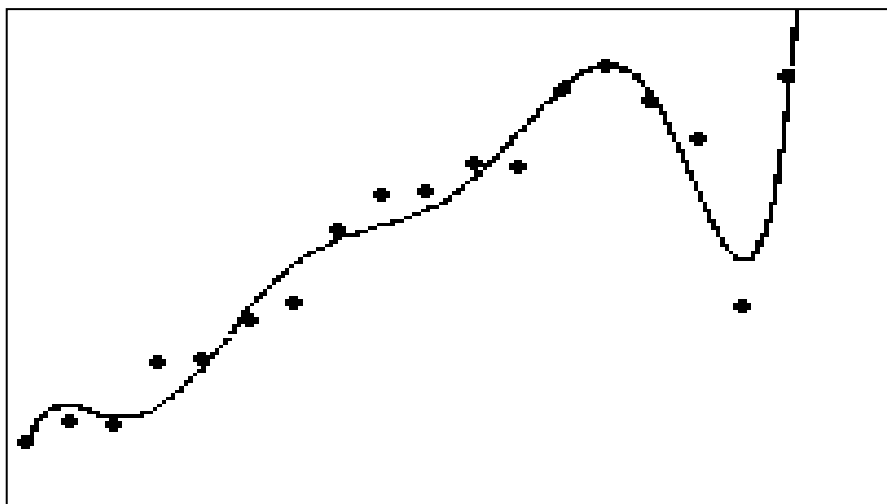
The temporal evolution pattern of the clustered-stable keywords follows sixth degree polynomial function:

$$Z(KY) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.30)$$

Where,  $a(0) = -411.61$ ,  $a(1) = 1171.01$ ,  $a(2) = -700.88$ ,  $a(3) = 199.20$ ,  
 $a(4) = -29.26$ ,  $a(5) = 2.31$ ,  $a(6) = -0.09$ ,  $Z(KY)$  = Number of clustered-stable  
 keywords,  $L$  = Assumed age of the subject.

Table 10.35: Data for Graph 30

L	1	2	3	4	5	6	7	8	9	10
Z(KY)	423	222	245	285	281	401	413	485	523	670
L	11	12	13	14	15	16	17	18	19	20
Z(KY)	738	745	797	796	946	996	928	850	512	977



Graph 30: Variation of  $Z(KY)$  with  $L$

The results revealed in the equations 10.27, 10.28, 10.29 and 10.30 (also the  
 Graphs 27, 28 29 and 30) prove hypothesis number (8) of chapter nine.

### New Keyword (Including Clustered, Twin and Single components)

The temporal evolution pattern of the new keywords follows sixth degree  
 decaying polynomial function:

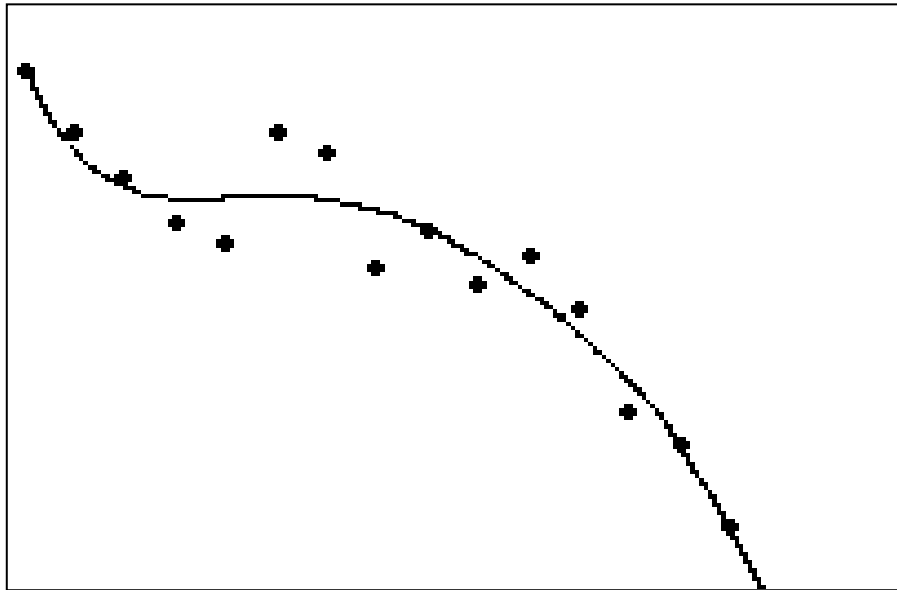
$$Z(J) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.31)$$

Where,  $a(0) = 808.60$ ,  $a(1) = -299.59$ ,  $a(2) = 69.71$ ,  $a(3) = -7.68$ ,  $a(4) = 0.41$ ,  
 $a(5) = -0.01$ ,  $Z(J)$  = Number of new keywords,  $L$  = Assumed age of the subject.

Table 10.36: Data for Graph 31

L	2	3	4	5	6	7	8	9	10
Z(J)	295	232	177	427	375	337	300	283	375
L	11	12	13	14	15	16	17	18	19
Z(J)	357	262	293	248	271	226	139	114	43

The number of new keywords is decaying with the age of the subject as evident from Table 10.36 and Graph 31.



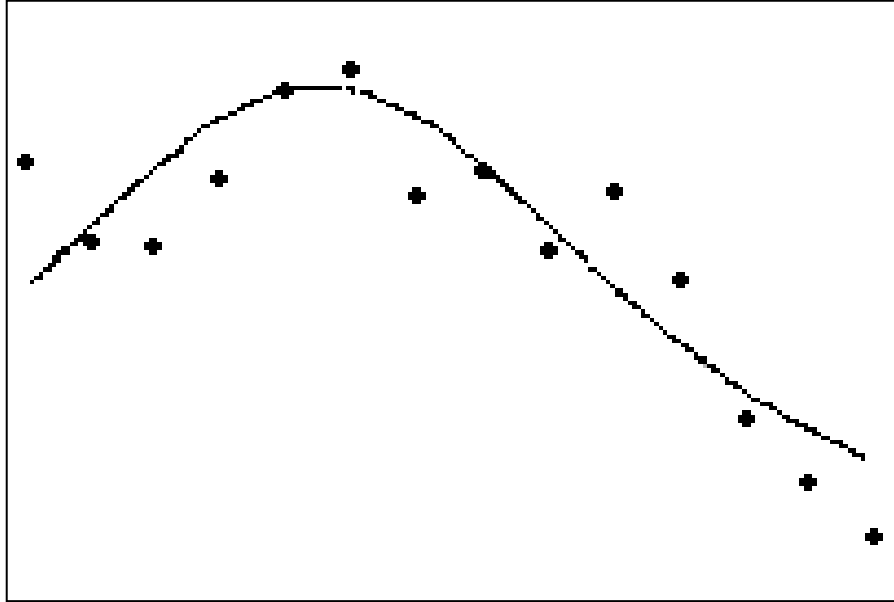
Graph 31: Variation of Z(J) with L

### Single-New Keyword

The temporal evolution pattern of the single-new keywords follows bell-shaped function:

$$Z(SJ) = a + b/(1+((L-c)/d)^2)^g \dots \dots \dots (10.32)$$

Where,  $a = 15.12$ ,  $b = 103.43$ ,  $c = 4.48$ ,  $d = 8.80$ ,  $g = 2.39$ ,  $Z(SJ)$  = Number of single-new keywords,  $L$  = Assumed age of the subject.



Graph 32: Variation of Z(SJ) with L

Table 10.37: Data for Graph 32

L	2	3	4	5	6	7	8	9	10
Z(SJ)	79	55	55	119	101	84	83	98	117
L	11	12	13	14	15	16	17	18	19
Z(SJ)	122	94	100	82	95	76	45	31	19

### Twin-New Keyword

The temporal evolution pattern of the twin-new keywords follows logistic function:

$$Z(WJ) = a + b \cdot \exp(-u) / ((1 + \exp(-u))^2), \quad u = (L - c) / d \dots \dots \dots (10.33)$$

Where,  $a = 12.83$ ,  $b = 51.66$ ,  $c = -0.59$ ,  $d = 4.04$ ,  $Z(WJ)$  = Number of twin-new keywords

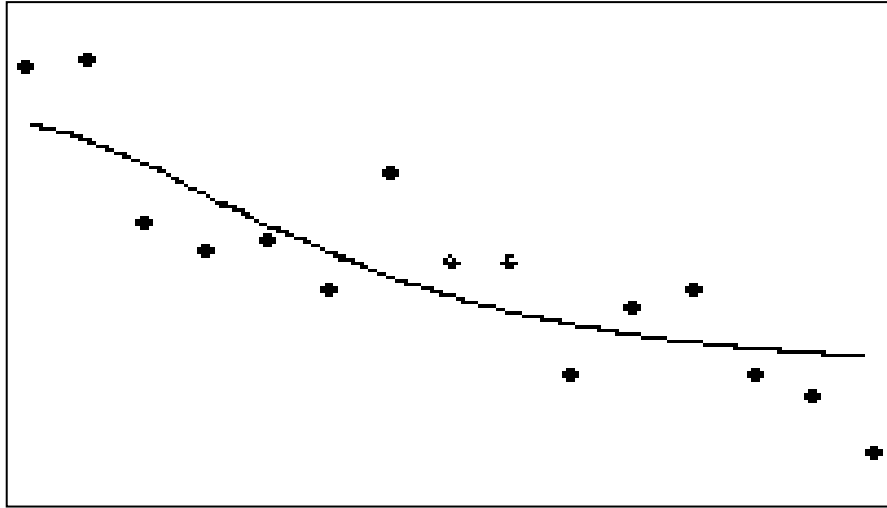
$L$  = Assumed age of the subject.

Table 10.38: Data for Graph 33

L	2	3	4	5	6	7	8	9	10
Z(WJ)	24	16	13	44	45	28	25	26	21
L	11	12	13	14	15	16	17	18	19
Z(WJ)	33	24	24	12	19	21	12	10	4



Graph 33: Variation of Z(WJ) with L



The single-new keywords show periodic decreasing trend, while twin-new keywords and clustered-new keywords show non-linear logistic decreasing trend. The points are fairly scattered around the mean graphs shown in the Graph 32, 33 and 34. The new keywords belonging to single, twin and clustered groups probably will show better statistics for a sample having larger size.

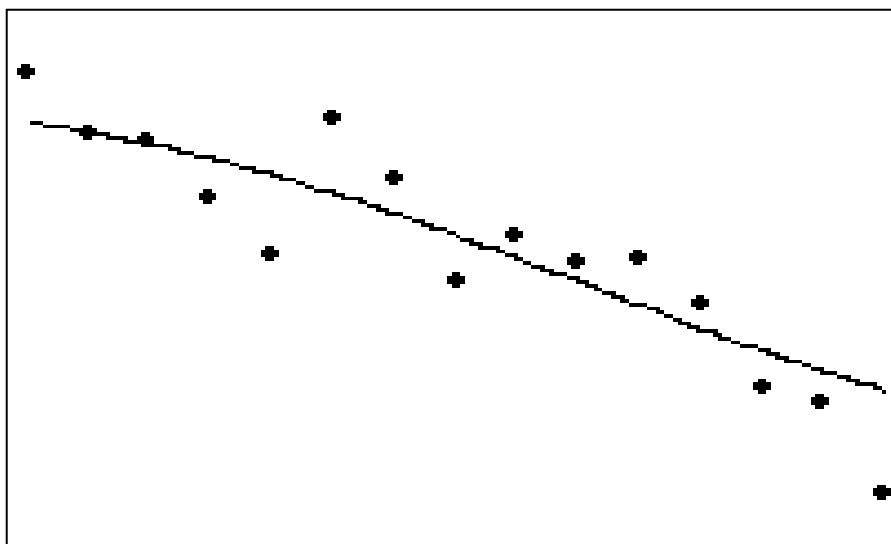
Clustered-New Keyword

The temporal evolution pattern of the clustered-new keywords follows logistic function:

$$Z(KJ) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.34)$$

Where, a = 20.00, b = 244.00, c = -2.04, d = 0.22, Z(KJ) = Number of clustered-new keywords, L = Assumed age of the subject.

It is to be noted that the results revealed in equations 10.31, 10.32, 10.33 and 10.34 (also the Graphs 31, 32, 33 and 34) proves the hypothesis number (6) of chapter nine.



Graph 34: Variation of Z(KJ) with L

Table 10.39: Data for Graph 34

L	2	3	4	5	6	7	8	9	10
Z(KJ)	192	161	109	264	229	225	192	159	237
L	11	12	13	14	15	16	17	18	19
Z(KJ)	202	144	169	154	157	129	82	73	20

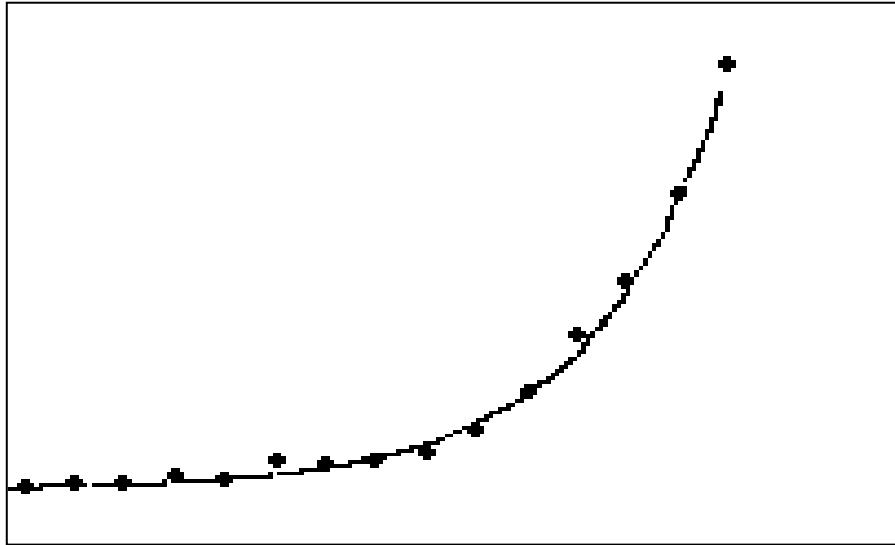
### Obsolete Keyword (Including Clustered, Twin and Single components)

The temporal evolution pattern of the obsolete keywords follows exponential growth function:  $Z(O) = a + b \cdot \exp((L-d)/c)$ .....(10.35)

Where,  $a = 14.95$ ,  $b = 408.70$ ,  $c = 2.70$ ,  $d = 13.32$ ,  $Z(O)$  = Number of obsolete keywords,  $L$  = Assumed age of the subject.

Table 10.40: Data for Graph 35

L	2	3	4	5	6	7	8	9	10
Z(O)	40	46	68	15	24	31	43	36	89
L	11	12	13	14	15	16	17	18	19
Z(O)	72	90	106	164	261	409	546	771	1112



Graph 35: Variation of Z(O) with L

There are four constants involved in the equation 10.35 and all are positive. Aging promotes obsolescence that is evident from equation 10.35 and Graph 35.

### Single-Obsolete Keyword

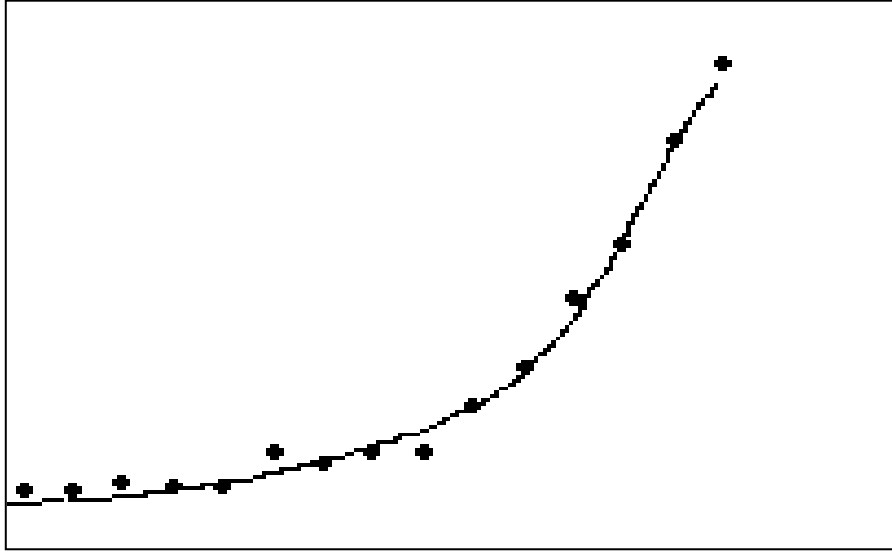
The temporal evolution pattern of the single-obsolete keywords follows the superposition of exponential growth function and second degree polynomial function:

$$Z(SO) = a + b \cdot \exp(-0.5 \cdot ((L-c)/d)^2) + g \cdot L + h \cdot L^2 \dots \dots \dots (10.36)$$

Where,  $a = -0.39$ ,  $b = 155.51$ ,  $c = 16.30$ ,  $d = 1.98$ ,  $g = -2.57$ ,  $h = 0.76$ ,  $Z(SO) =$  Number of single-obsolete keywords,  $L =$  Assumed age of the subject.

Table 10.41: Data for Graph 36

L	2	3	4	5	6	7	8	9	10
Z(SO)	17	16	25	5	4	9	7	6	31
L	11	12	13	14	15	16	17	18	19
Z(SO)	24	32	33	65	93	142	182	257	312



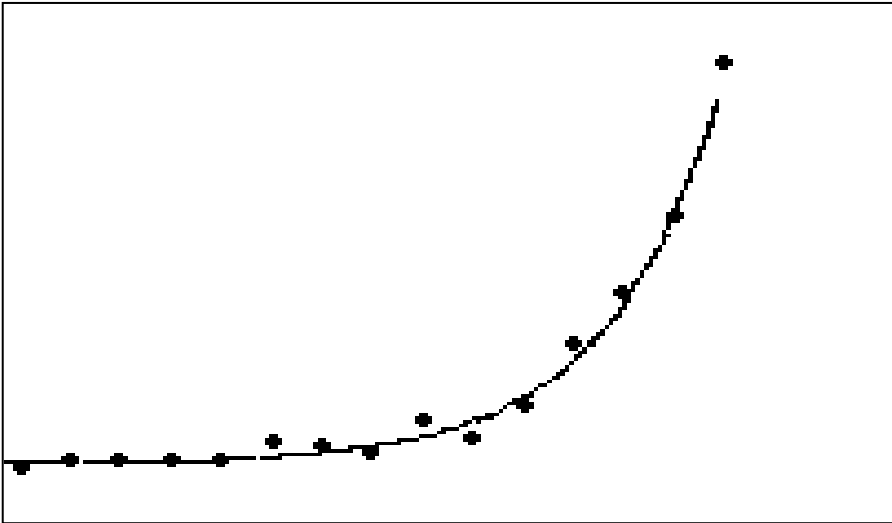
Graph 36: Variation of Z(SO) with L

Twin-Obsolete Keyword

The temporal evolution pattern of the twin-obsolete keywords follows the exponential growth function:

$$Z(WO) = a + b \cdot \exp((L-d)/c) \dots \dots \dots (10.37)$$

Where, a = 1.52, b = 39.42, c = 2.26, d = 13.87, Z(WO) = Number of twin-obsolete keywords, L = Assumed age of the subject.



Graph 37: Variation of Z(WO) with L

Table 10.42: Data for Graph 37

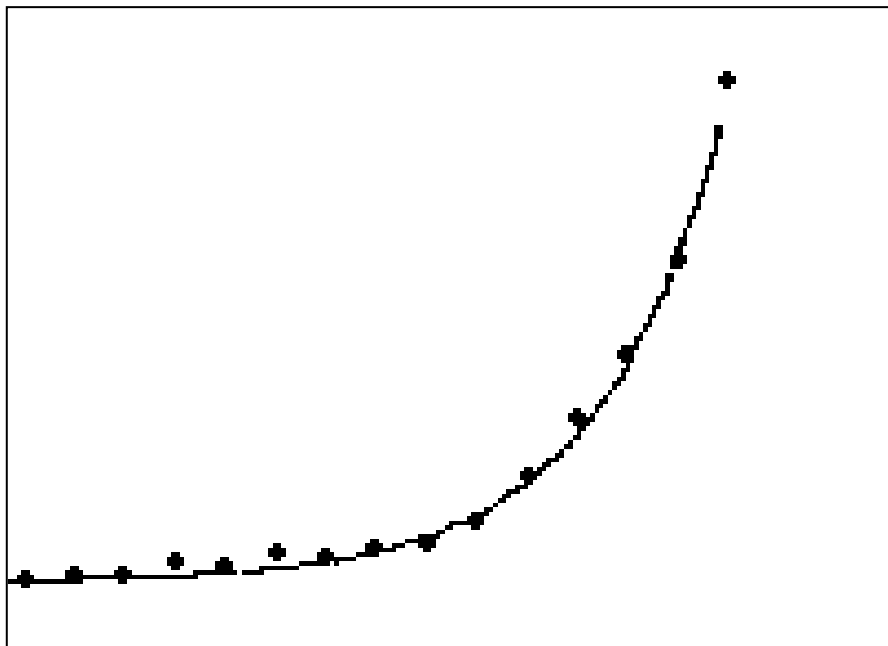
L	2	3	4	5	6	7	8	9	10
Z(WO)	3	4	6	0	2	2	2	2	7
L	11	12	13	14	15	16	17	18	19
Z(WO)	6	4	12	8	16	32	45	64	103

Clustered-Obsolete Keyword

The temporal evolution pattern of the clustered-obsolete keywords follows the exponential growth function:

$$Z(KO) = a + b \cdot \exp((L-d)/c) \dots \dots \dots (10.38)$$

Where, a = 10.19, b = 256.97, c = 2.53, d = 13.54, Z(KO) = Number of clustered-obsolete keywords, L = Assumed age of the subject.



Graph 38: Variation of Z(KO) with L

Table 10.43: Data for Graph 38

L	2	3	4	5	6	7	8	9	10
Z(KO)	20	26	37	10	18	20	34	28	51
L	11	12	13	14	15	16	17	18	19
Z(KO)	42	54	61	91	152	235	319	450	697

The obsolete keywords belonging to all groups follow nearly identical type of growth pattern. The four equations (equation 10.35, 10.36, 10.37 and 10.38) prove the second part of the hypothesis number (1) of chapter nine. The trends followed by new and obsolete keywords are just reverse. The new keywords decrease while the obsolete keywords increase with the aging of this subject. This phenomenon proves the hypothesis number (7) of the chapter nine.

Obsolescence Index (B) [Integrated]

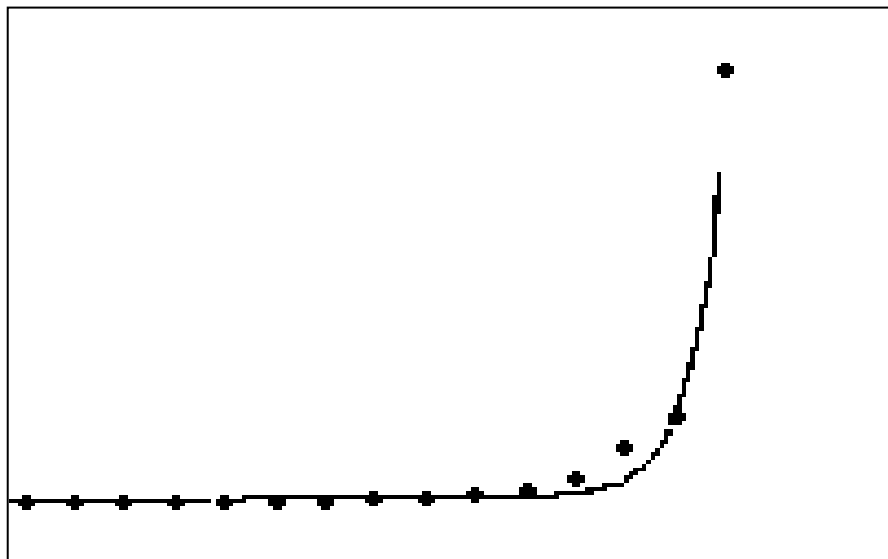
The temporal evolution pattern of Integrated Obsolescence Index (for single, twin and clustered components) follows the exponential growth function:

$$B = a \cdot \exp((L-d)/c) + b \cdot \exp((L-d)/g) \dots \dots \dots (10.39)$$

Where, a = 12.24, b = 0.54, c = 0.65, d = 15.61, g = 26.81, B = Integrated Obsolescence Index, L = Assumed age of the subject.

Table 10.44: Data for Graph 39

L	2	3	4	5	6	7	8	9	10
B	0.09	0.13	0.28	0.02	0.04	0.06	0.1	0.1	0.17
L	11	12	13	14	15	16	17	18	19
B	0.15	0.27	0.28	0.49	0.74	1.36	2.9	4.65	23.17



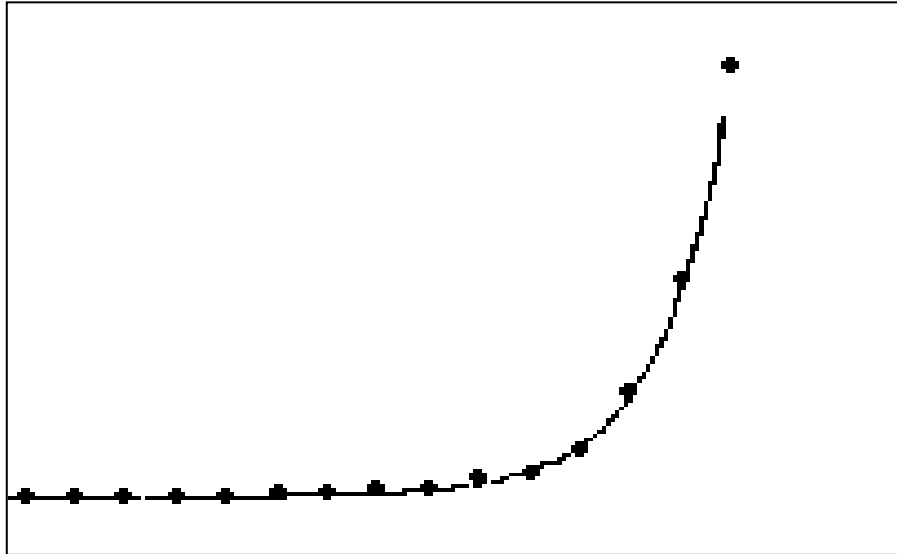
Graph 39: Variation of B with L

Obsolescence Index (B) [Single]

The temporal evolution pattern of Single Obsolescence Index (for single component only) follows the exponential growth function:

$$B(S) = a \cdot \exp((L-d)/c) + b \cdot \exp((L-d)/g) \dots \dots \dots (10.40)$$

Where, a = 8.22, b = 0.16, c = 1.40, d = 15.04, g = 27.12, B(S) = Single Obsolescence Index, L = Assumed age of the subject.



Graph 40: Variation of B(S) with L

Table 10.45: Data for Graph 40

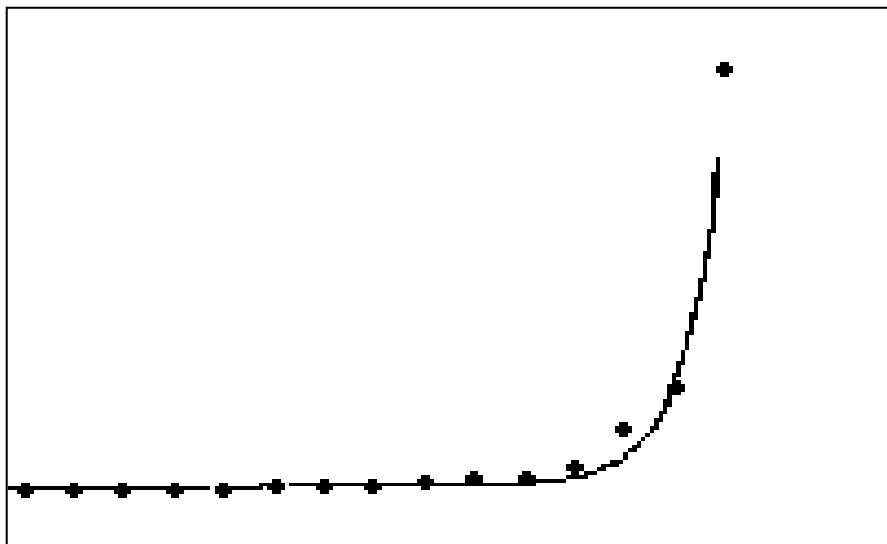
L	2	3	4	5	6	7	8	9	10
B(S)	0.22	0.29	0.45	0.04	0.04	0.11	0.08	0.06	0.26
L	11	12	13	14	15	16	17	18	19
B(S)	0.20	0.34	0.33	0.79	0.98	1.87	4.04	8.29	16.42

Obsolescence Index (B) [Twin]

The temporal evolution pattern of Twin Obsolescence Index (for twin component only) follows the exponential growth function:

$$B(W) = a \cdot \exp((L-d)/c) + b \cdot \exp((L-d)/g) \dots \dots \dots (10.41)$$

Where, a = 14.26, b = 0.56, c = 0.76, d = 15.57, g = 26.23, B(W) = Twin Obsolescence Index, L = Assumed age of the subject.



Graph 41: Variation of B(W) with L

Table 10.46: Data for Graph 41

L	2	3	4	5	6	7	8	9	10
B(W)	0.13	0.25	0.46	0.00	0.04	0.07	0.08	0.08	0.33
L	11	12	13	14	15	16	17	18	19
B(W)	0.18	0.17	0.50	0.67	0.84	1.52	3.75	6.40	25.75

### Obsolescence Index (B) [Clustered]

The temporal evolution pattern of Clustered Obsolescence Index (for clustered component only) follows the exponential growth function:

$$B(W) = a \cdot \exp((L-d)/c) + b \cdot \exp((L-d)/g) \dots \dots \dots (10.42)$$

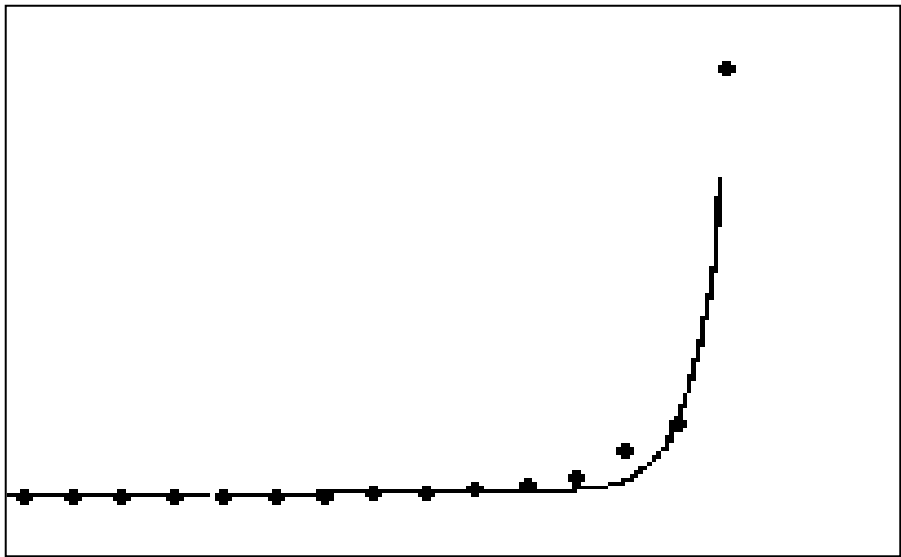
Where,  $a = 20.69$ ,  $b = 0.79$ ,  $c = 0.59$ ,  $d = 15.71$ ,  $g = 24.88$ ,  $B(K)$  = Clustered Obsolescence Index,  $L$  = Assumed age of the subject.

Table 10.47: Data for Graph 42

L	2	3	4	5	6	7	8	9	10
B(K)	0.1	0.16	0.34	0.04	0.08	0.09	0.18	0.18	0.22
L	11	12	13	14	15	16	17	18	19
B(K)	0.21	0.38	0.36	0.59	0.97	1.82	3.89	6.16	34.85

The above four equations (equation 10.39, 10.40, 10.41 and 10.42) proves the hypothesis number (4) of chapter nine.





Graph 42: Variation of B(W) with L

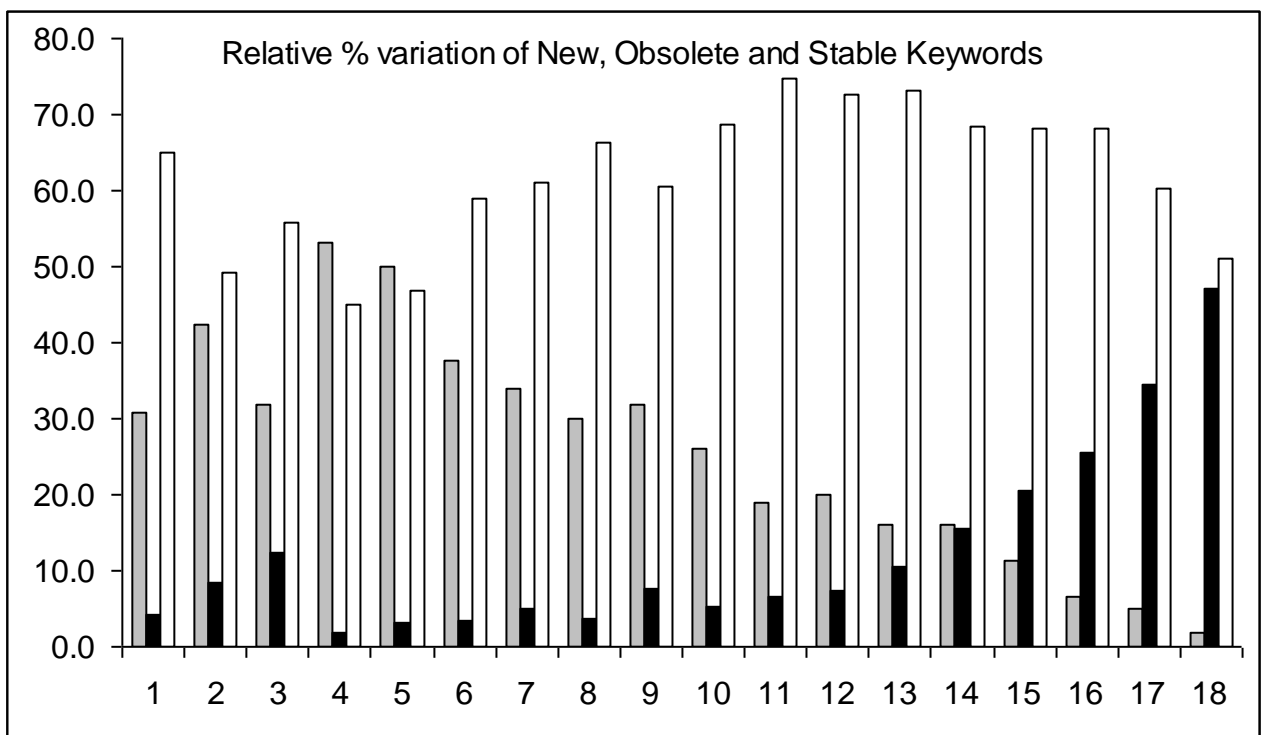


Diagram 17: Relative Variation of Z(J) [pale black-shaded bar], Z(O) [deep black-shaded bar] and Z(Y) [white bar] with L

It is clear from the above figure (Diagram 17) that the relative percentage of new keywords show decreasing trend and the obsolete keywords show increasing trend. The stable keywords show an initial depression and a bulge afterwards.

### H. Keyword: Frequency of Occurrence (FOC)

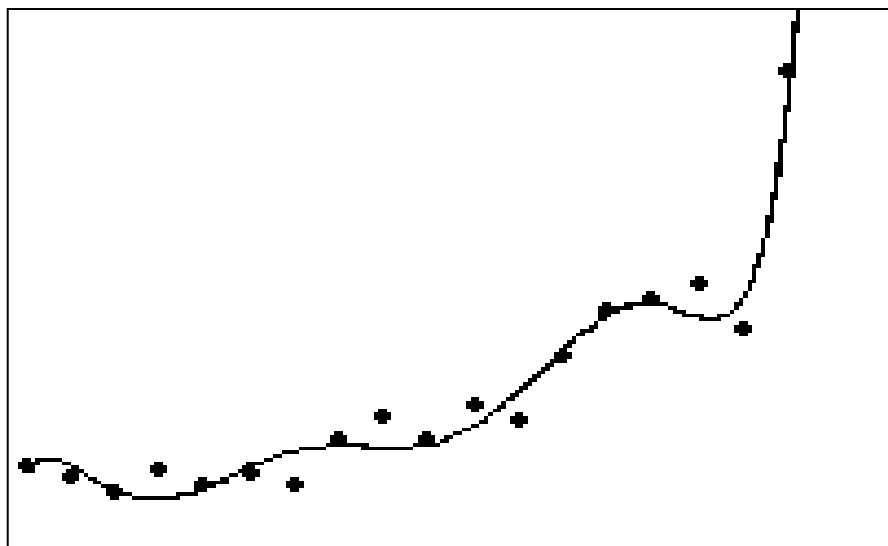
The functional variation patterns of mono-frequent, di-frequent and multi-frequent keywords are discussed below. The relative percentage variation among these keyword classes are shown in Diagram 18, which shows a constant pattern for multi-frequent keywords, slight depression for di-frequent keywords, and a bulge for mono-frequent keywords.

#### Mono-frequent Keyword

The temporal evolution pattern of the mono-frequent keywords follows sixth degree polynomial function:

$$Z(l) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.43)$$

Where,  $a(0) = -401.38$ ,  $a(1) = 1374.21$ ,  $a(2) = -875.41$ ,  $a(3) = 251.33$ ,  
 $a(4) = -37.16$ ,  $a(5) = 2.94$ ,  $a(6) = -0.12$ ,  $Z(l) =$  Number of mono-frequent keywords,  $L =$  Assumed age of the subject.



Graph 43: Variation of Z(l) with L

In equation 10.43 it is observed that,

$$\sum(\text{Positive co-efficients}) > \sum(\text{Negative co-efficients}); \text{ and}$$

As  $L \rightarrow \infty$  (Infinity),  $Z(l) \rightarrow \infty$  (Larger value)

The mono-frequent keywords are non-repetitive in nature and increases with the aging of this subject.

Table 10.48: Data for Graph 43

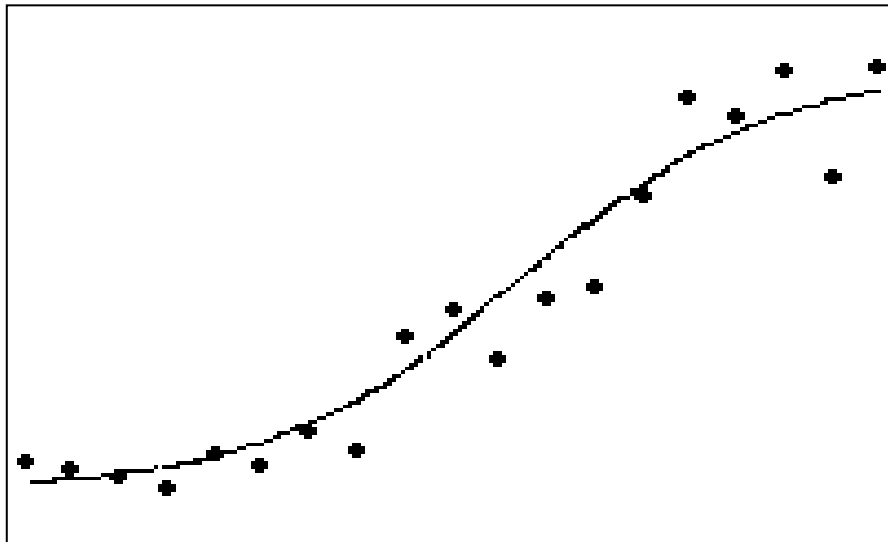
L	1	2	3	4	5	6	7	8	9	10
Z(l)	316	334	337	290	236	332	273	317	273	436
L	11	12	13	14	15	16	17	18	19	20
Z(l)	524	448	566	515	757	932	980	1030	864	1842

### Di-frequent Keyword

The temporal evolution pattern of the di-frequent keywords follows logistic function:

$$Z(D) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.44)$$

Where,  $a = 85.00$ ,  $b = 307.00$ ,  $c = 3.92$ ,  $d = -0.38$ ,  $Z(D)$  = Number of di-frequent keywords,  $L$  = Assumed age of the subject.



Graph 44: Variation of Z(D) with L

The di-frequent keywords show a saturating trend with the aging of this subject.

Table 10.49: Data for Graph 44

L	1	2	3	4	5	6	7	8	9	10
Z(D)	118	105	99	93	85	110	102	127	113	195
L	11	12	13	14	15	16	17	18	19	20
Z(D)	215	180	223	232	297	370	355	388	311	392

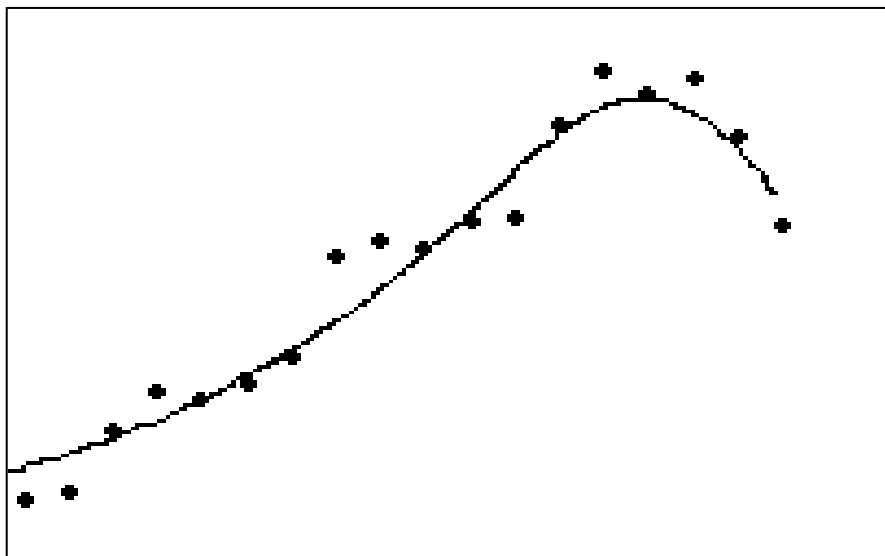
Multi-frequent Keyword

The temporal evolution pattern of the multi-frequent keywords follows the sum of two Gaussian functions:

$$Z(U) = a + b \cdot \exp(-0.5 \cdot ((L-c)/d)^2) + g \cdot \exp(-0.5 \cdot ((L-h)/k)^2) \dots \dots \dots (10.45)$$

Where, a = 497.09, b = 656.66, c = 12.19, d = 5.99, g = 656.38, h = 15.57,

k = 3.31, Z(U) = Number of multi-frequent keywords, L = Assumed age of the subject.



Graph 45: Variation of Z(U) with L

Table 10.50: Data for Graph 45

L	1	2	3	4	5	6	7	8	9	10
Z(U)	531	516	500	530	717	836	815	857	936	1249
L	11	12	13	14	15	16	17	18	19	20
Z(U)	1288	1267	1350	1359	1642	1814	1737	1789	1608	1343

The variation pattern followed by the multi-frequent keywords shows an increasing trend followed by a decreasing trend during the last three years.

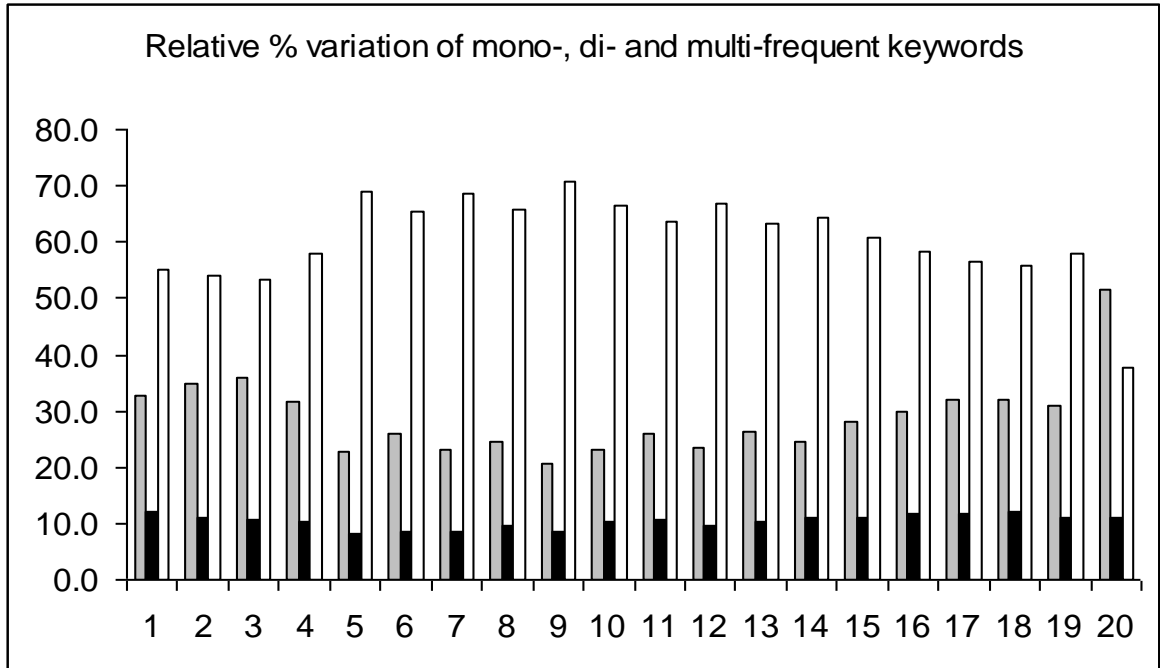


Diagram 18: Relative Variation of Z(I) [pale black-shaded bar]  
Z(D) [deep black-shaded bar] and Z(U) [white bar] with L

### I. Keyword: Category (CAT)

The functional variation pattern for six keyword categories is discussed below. The categories, property, theory and entity show logistic function; and the other three categories, viz. action, material and method show sixth degree polynomial function. The relative percentage variation among these six categories is also shown in the Diagram 19A and 19B respectively. The Diagram 19A shows variation among Property, Theory and Entity, while the Diagram 19B shows variation among Action, Method and Material. The fluctuations in the categories of Material and Action are most prominent compared to other categories. The category Method also shows some fluctuations.

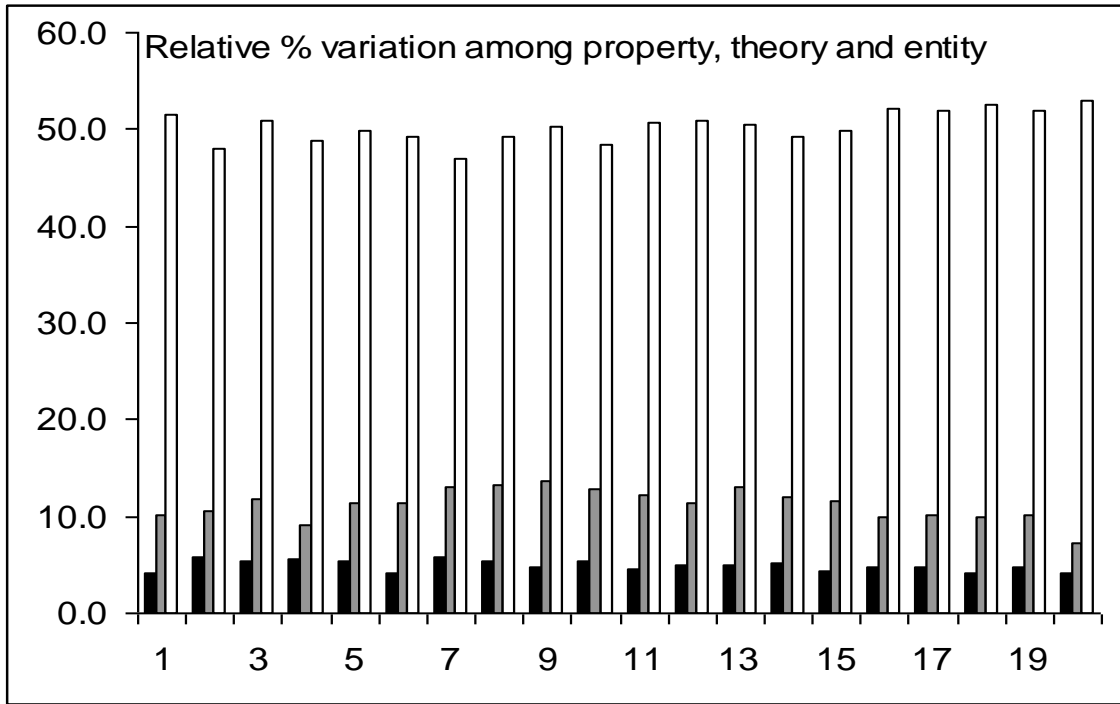


Diagram 19A (deep black-shaded bar indicates Property; pale black-shaded bar indicates Theory and white bar indicates Entity)

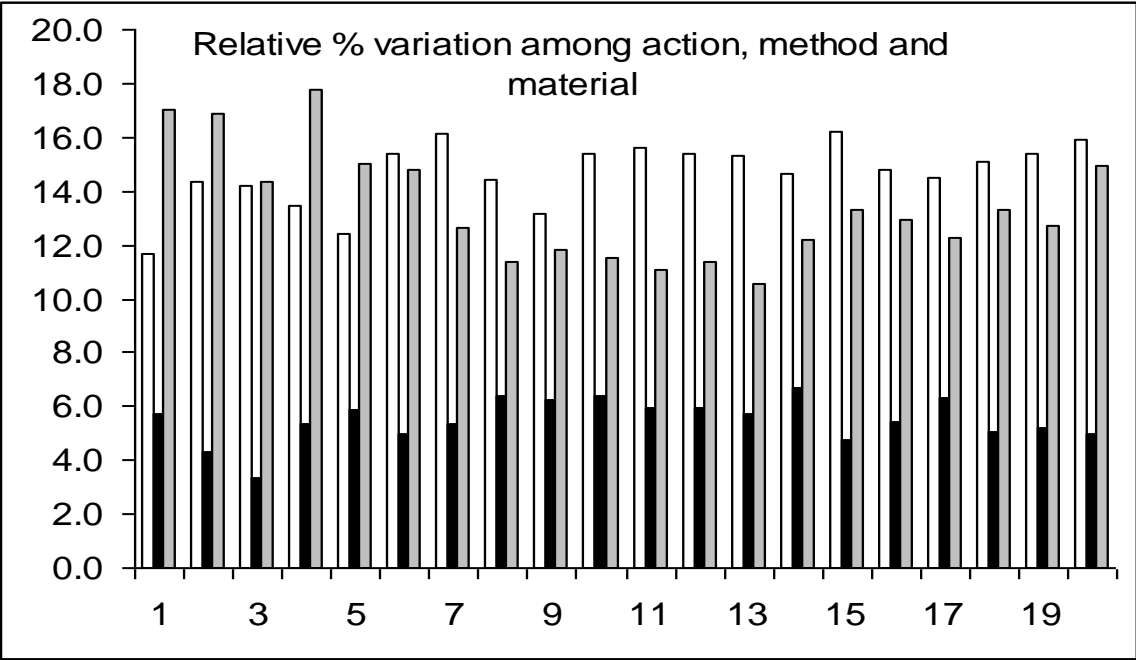


Diagram 19B (deep black-shaded bar indicates Method; pale black-shaded bar indicates Material and white bar indicates Action)

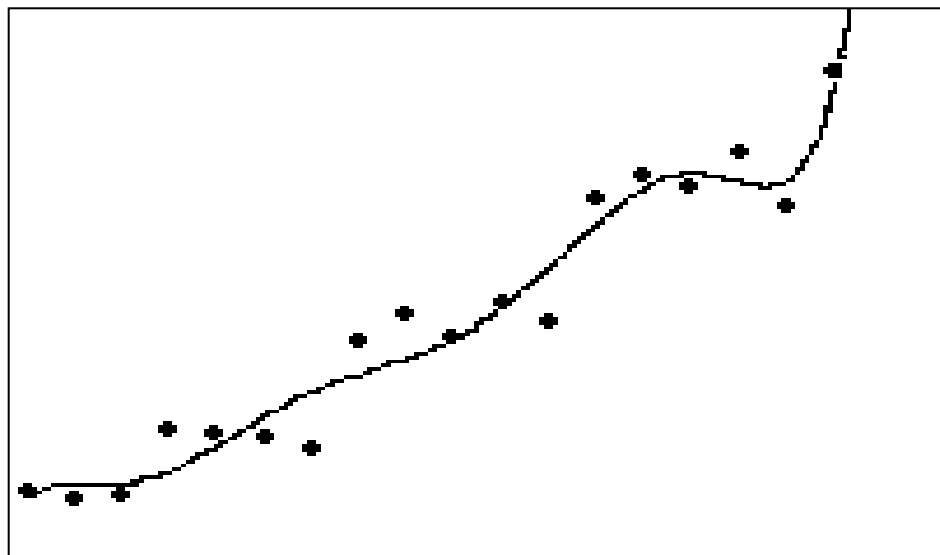
The variation in 'Entity' and 'Property' are nearly constant, but that in 'Theory' shows little fluctuation.

Action (G)

The temporal evolution pattern of the keywords belonging to the category "Action" follows sixth degree polynomial function:

$$Z(G) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.46)$$

Where, a(0) = 25.95, a(1) = 188.80, a(2) = -119.70, a(3) = 36.26, a(4) = -5.56, a(5) = 0.45, a(6) = -0.02, Z(G) = Number of keywords belonging to the category "Action", L = Assumed age of the subject.



Graph 46: Variation of Z(G) with L

Table 10.51: Data for Graph 46

L	1	2	3	4	5	6	7	8	9	10
Z(G)	113	137	133	123	129	197	192	188	174	289
L	11	12	13	14	15	16	17	18	19	20
Z(G)	316	291	327	309	437	461	446	483	428	568

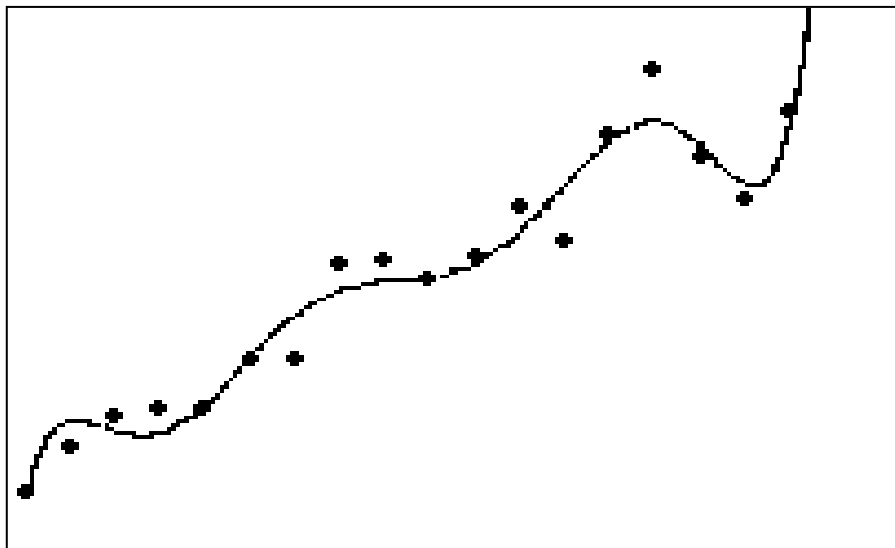
Method (H)

The temporal evolution pattern of the keywords belonging to the category “Method” follows sixth degree polynomial function:

$$Z(H) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.47)$$

Where, a(0) = -135.06, a(1) = 280.81, a(2) = -152.98, a(3) = 40.12, a(4) = -5.52, a(5) = 0.41, a(6) = -0.02, Z(H) = Number of keywords belonging to the category “Method”

L = Assumed age of the subject.



Graph 47: Variation of Z(H) with L

Table 10.52: Data for Graph 47

L	1	2	3	4	5	6	7	8	9	10
Z(H)	55	41	31	49	61	64	64	83	83	120
L	11	12	13	14	15	16	17	18	19	20
Z(H)	121	113	122	141	128	169	195	161	145	179

Material (M)

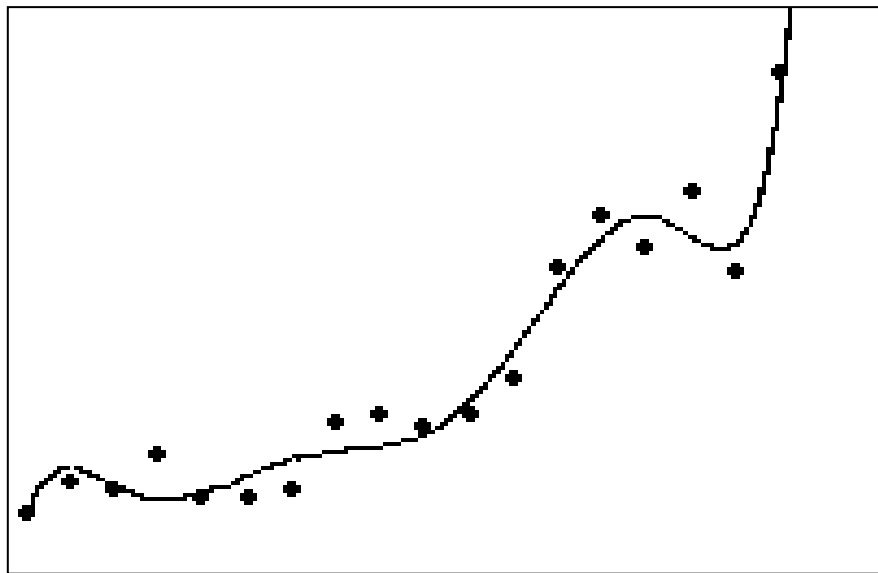
The temporal evolution pattern of the keywords belonging to the category “Material” follows sixth degree polynomial function:



$$Z(M) = a(0) + a(1)*L + a(2)*L^2 + a(3)*L^3 + a(4)*L^4 + a(5)*L^5 + a(6)*L^6, \dots\dots\dots(10.48)$$

Where,  $a(0) = -170.03$ ,  $a(1) = 521.03$ ,  $a(2) = -290.18$ ,  $a(3) = 77.07$ ,  $a(4) = -10.88$ ,  $a(5) = 0.84$ ,  $a(6) = -0.03$ ,  $Z(M)$  = Number of keywords belonging to the category “Material”

$L$  = Assumed age of the subject.



Graph 48: Variation of Z(M) with L

Table 10.53: Data for Graph 48

L	1	2	3	4	5	6	7	8	9	10
Z(M)	164	161	134	162	156	189	150	148	156	216
L	11	12	13	14	15	16	17	18	19	20
Z(M)	225	215	226	257	359	404	376	427	354	535

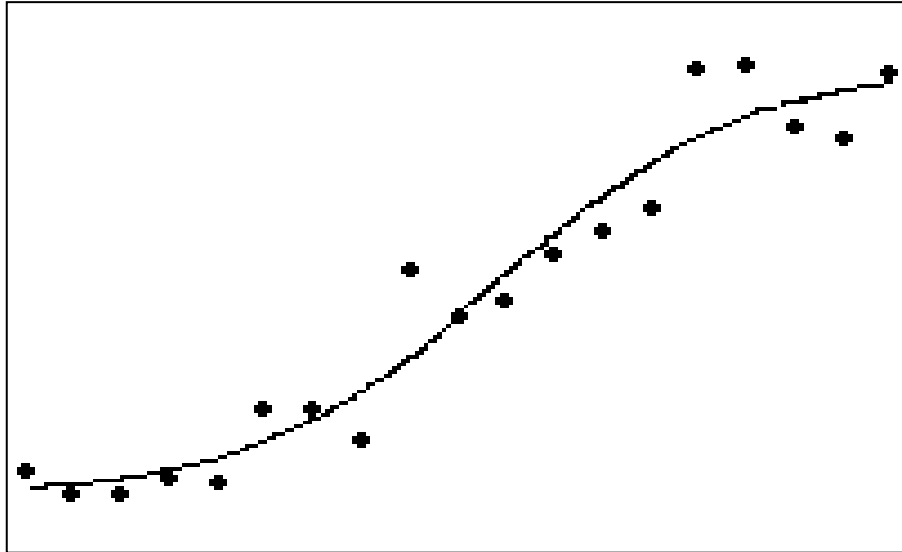
### Property (P)

The temporal evolution pattern of the keywords belonging to the category “Property” follows logistic function:

$$Z(P) = a + (b-a)/(1 + \exp(c+d*L))\dots\dots\dots(10.49)$$

Where,  $a = 51.00$ ,  $b = 97.00$ ,  $c = 3.86$ ,  $d = -0.39$ ,

Z(P) = Number of keywords belonging to the category “Property”, L = Assumed age of the subject.



Graph 49: Variation of Z(P) with L

Table 10.54: Data for Graph 49

L	1	2	3	4	5	6	7	8	9	10
Z(P)	39	56	51	51	55	54	70	70	63	102
L	11	12	13	14	15	16	17	18	19	20
Z(P)	91	95	105	110	116	147	148	134	131	146

### Theory (T)

The temporal evolution pattern of the keywords belonging to the category “Theory” follows logistic function:

$$Z(T) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.50)$$

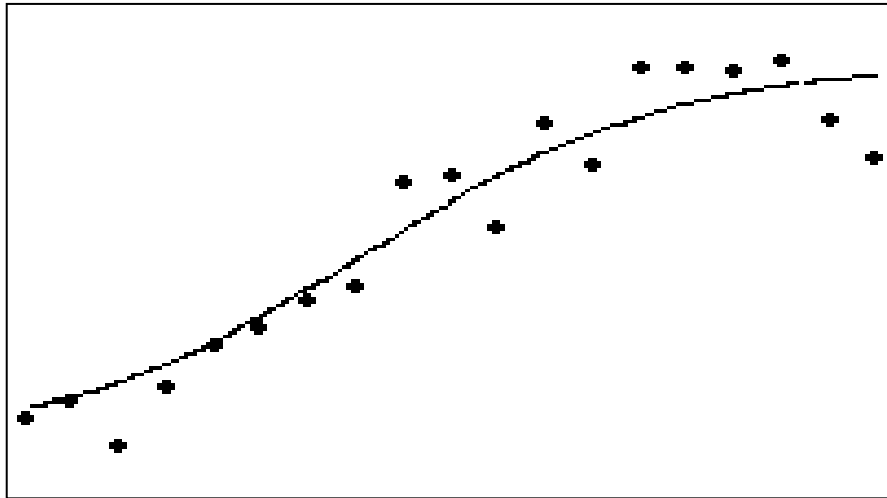
Where, a = 83.00, b = 233.00, c = 2.18, d = -0.31,

Z(T) = Number of keywords belonging to the category “Theory”, L = Assumed age of the subject.

Table 10.55: Data for Graph 50

L	1	2	3	4	5	6	7	8	9	10
Z(T)	97	101	111	83	119	145	155	171	180	242
L	11	12	13	14	15	16	17	18	19	20
Z(T)	246	216	278	252	311	312	309	316	281	256

Graph 50: Variation of Z(T) with L



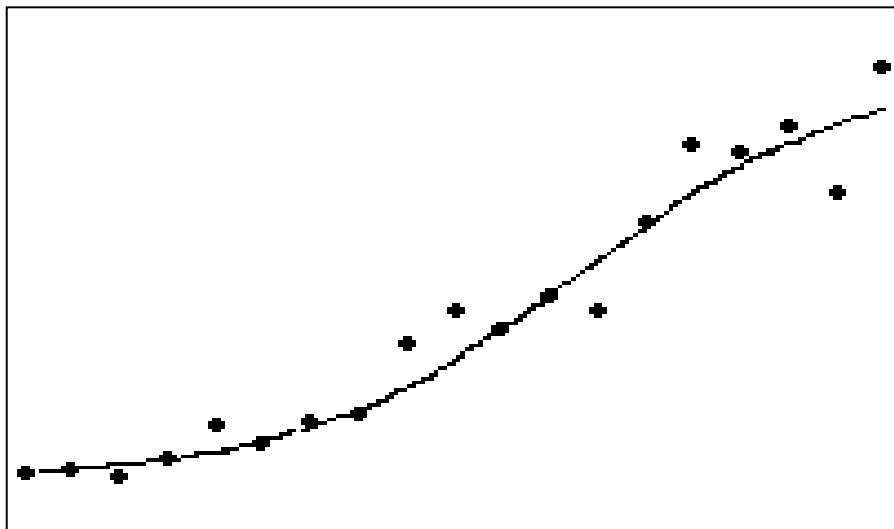
Entity (X)

The temporal evolution pattern of the keywords belonging to the category “Entity” follows logistic function:

$$Z(X) = a + (b-a)/(1 + \exp(c+d*L)) \dots \dots \dots (10.51)$$

Where, a = 445.00, b = 1449.00, c = 3.98, d = -0.34,

Z(X) = Number of keywords belonging to the category “Entity”, L = Assumed age of the subject.



Graph 51: Variation of Z(X) with L

Table 10.56: Data for Graph 51

L	1	2	3	4	5	6	7	8	9	10
Z(X)	497	459	476	445	519	629	559	641	666	911
L	11	12	13	14	15	16	17	18	19	20
Z(X)	1028	965	1081	1037	1345	1623	1598	1686	1444	1894

### J. Keyword: Potency Index and Clusterity Analysis

The total number of keywords analyzed for this study is 17945 over the time span of twenty years (1985-2004). The analysis of these keywords results in finding out 2562 keyword-clusters, 916 keyword-couples and 4329 single keywords in all. The keyword-couples consist of twin keywords and form no cluster. There is also no question of forming any cluster by the single keywords. The clustered keywords are forming keyword-clusters. All clusters are not identical in size. The number of keywords takes part in forming a cluster range from 3 to 665 in this study. Since the size of the clusters widely vary, therefore it is also obvious that different keywords possess different abilities to form a cluster. Let us say the ability of a clustered keyword to form a keyword-cluster as the 'Clusterity' of the same. Let us also introduce another parameter Potency Index (also defined in chapter five), denoted by 'p(i)' and is defined as:

$$p(i) = \ln(w) \dots \dots \dots (10.52)$$

Where,  $w = Z(\text{ALL}) * Z(\text{FREQ})$

Let us say the parameter 'w' as the keyword cluster weightage, as it encounters both the number of keywords and number of coverage of journal articles of a keyword-cluster. The potency index has been defined as the natural logarithm of the keyword cluster weightage. The potency index is an indicator of the size of a cluster. A largely sized cluster having high clusterity holds high value of potency index. The potency index for 2562 clusters have been calculated and found ranging from 1 to 15.18. The numerical values of potency index have been divided in five equal zones depending on this range

of values, which is given in the Table 10.57 below. The number of clusters in each zone along with the corresponding percentage values is also given.

Table 10.57: Five zones of potency index

Potency Index [p(i)]					
Range of value of p(i)	>11.3	8.8----11.3	6.2----8.7	3.6----6.1	1----3.5
Gradation of each range	Too large	Large	Medium	Small	Too small
Number of Keyword-clusters in each range	12	42	150	443	1915
Corresponding % in each range	0.47	1.64	5.85	17.29	74.75

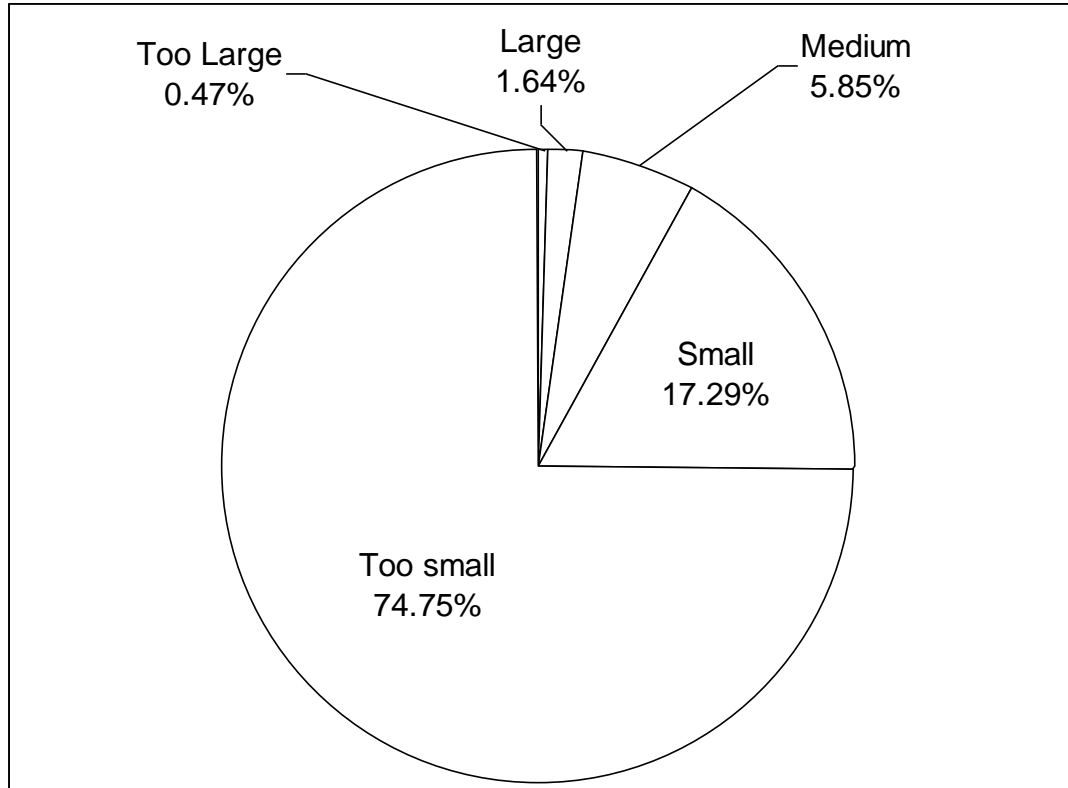
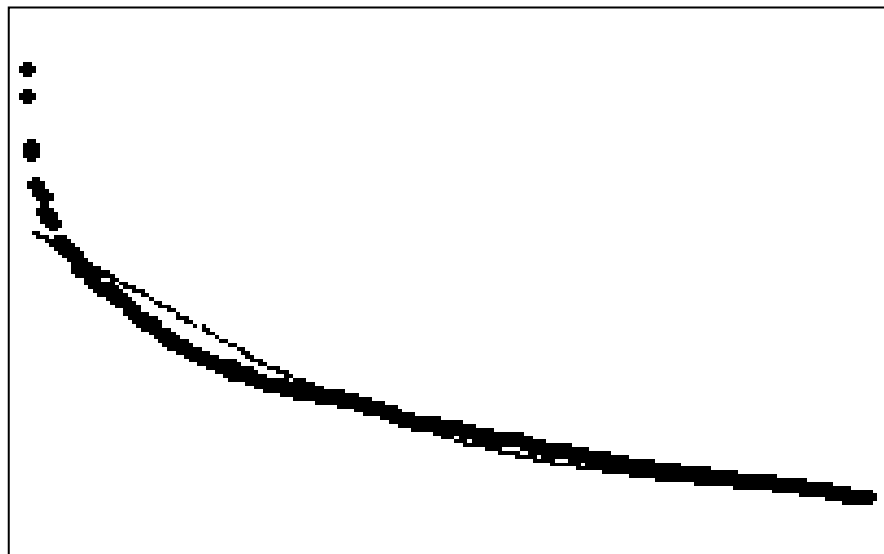


Diagram 20: Relative percentage distribution of keyword-clusters among five zones of potency indices

The potency index of only 12 clusters are greater than “11.3”. These clusters are too large clusters and represent the crux area of the subject ‘Fermi liquid’. The keyword clusters have been ranked according to the values of p (the

ranking is denoted by  $r(p(i))$ ; and the variation of  $p$  with the rank of keyword clusters  $r(p)$  is observed and presented in the following figures (Graph 52 and 53). The rank  $r(p(i))$  is independent variable and taken along horizontal (X) axis, and the  $p(i)$  is dependent variable and is taken along vertical (Y) axis. The keyword clusters having  $p(i)$  less than “6” indicate ‘Small’ and ‘Too small’ clusters [Table 10.57] and are less significant areas of research, which are not considered here. The relative dominance of different clusters is shown in Diagram 20. The weakest contribution comes from too large clusters that are only 12 in number (0.47%) followed by the number of large cluster, which are 42 (1.64%). The three-fourth of the total number of clusters is too small as evident from Diagram 20. The top 54 clusters (too large and large) are listed in Table 10.58. The variation of  $p$  with  $r(p)$  is observed in Graph 52 for too large, large and medium clusters only (12+42+150=204 clusters).



Graph 52: Variation of  $p$  with  $r(p)$

The variation pattern of  $p(i)$  with  $r(p(i))$  follows logistic function:

$$p(i) = a + (b-a)/(1 + \exp(c+d*r(p(i)))) \dots \dots \dots (10.53)$$

Where,  $a = 5.01$ ,  $b = 9.70$ ,  $c = -0.55$ ,  $d = 0.01$

$$\text{Or, } \ln[Z(\text{ALL}) * Z(\text{FREQ})] = a + (b-a)/(1 + \exp(c+d*r(p(i)))) \dots \dots \dots (10.54)$$

The above equation expresses the direct relationship among the number of keywords, total freq. of occurrence and rank of the keyword-clusters. The top 54 keyword clusters (too large and large only) ranked according to the  $p(i)$  are shown in the Table 10.58 below. These 54 keyword-clusters indicate significant thrust areas of research in the subject “Fermi-Liquid” since 1985-2004.

Table 10.58: Top 54 keyword-clusters ranked according to Potency Index  $p(i)$

Rank ( $r(p(i))$ )	Keyword Cluster	$p(i)$	Rank ( $r(p(i))$ )	Keyword Cluster	$p(i)$
1	Fermi liquid	15.18	27	Conductance	10.06
2	Electron	14.71	28	Boson	9.91
3	Spin	14.08	29	Hole	9.82
4	Alloy and compound	12.97	29	Charge carrier	9.82
5	Fermion	12.76	30	Low temperature	9.75
6	Susceptibility	12.11	31	Liquid	9.74
7	Superconductivity	11.91	32	Green's function	9.70
8	Quasiparticle	11.88	33	Perturbation	9.69
9	Fermi surface	11.83	34	Kondo effect	9.65
10	Impurity	11.48	35	Specific heat	9.62
11	Metal	11.38	36	Wave	9.53
12	Superconductor	11.32	36	Ground state	9.53
13	Temperature	11.22	37	Phase transition	9.48
14	Semiconductor	10.81	38	Phonon	9.43
15	Helium	10.78	39	Magnetoresistance	9.42
16	Magnetic field	10.74	40	Infrared	9.39
17	Energy	10.73	41	NMR	9.32
18	Electron system	10.72	42	Anderson model	9.25
19	Hubbard model	10.58	43	Fermion system	9.16
20	Luttinger liquid	10.57	44	Magnetism	9.11
21	Lattice	10.54	45	Plasma	9.04
22	Fermi liquid theory	10.46	46	Renormalization	9.00
23	Charge	10.38	47	Resistivity	8.97
24	Neutron	10.20	48	Density of state	8.95
24	Scattering	10.20	49	Particle	8.95
25	Crystal	10.18	50	Superfluid	8.91
26	Fermi level	10.13	51	Hall effect	8.84

The first 12 keyword-clusters of Table 10.58 have ‘Too large’ potency index. The cluster ‘Fermi liquid’ has largest potency index, which is quiet obvious, as the

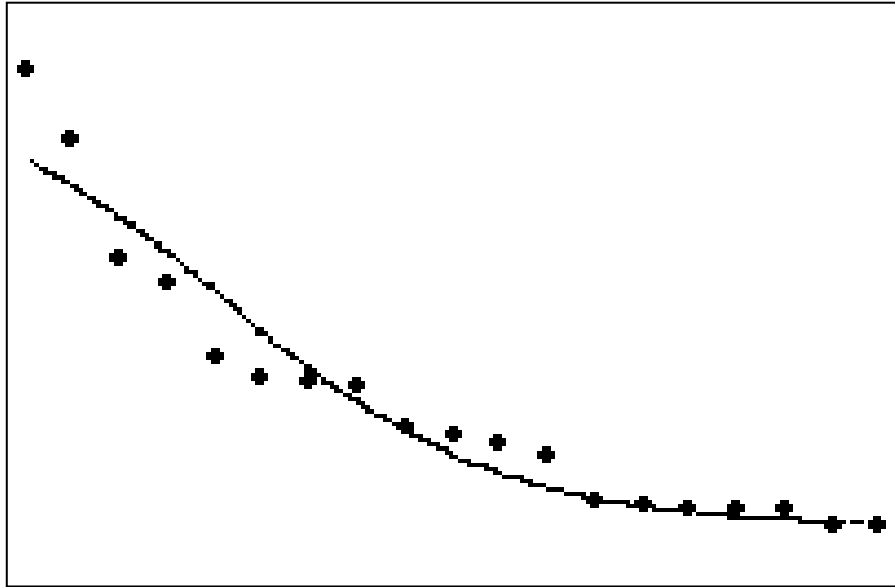
subject concerned is Fermi liquid. Other than 'Fermi liquid', the remaining 'Too large' clusters are: Electron, Spin, Alloy and compound, Fermion, Susceptibility, Superconductivity, Quasiparticle, Fermi surface, Impurity, Metal and Superconductor. The occurrence of both of the keywords 'Superconductor' and 'Superconductivity' in 'Too large' zone indicates that one of the focused areas of the subject Fermi liquid consists of low temperature phenomenon. Also the occurrence of the keywords like 'Electron', 'Spin', 'Fermion', 'Metal' and 'Alloy and compound' in this zone indicates that the thrust area of research of this subject also deal with different features of electron in metals along with the alloys and compounds formed by them. The keywords 'Susceptibility' and 'Impurity' also have 'Too large potency index'. These two keywords point out studies in magnetism and semiconductor respectively as two other thrust areas of research. The potency index thus helps in tracing thrust areas of research of a subject. It is also to be noted that the thrust area of research varies between different years, as the potency index of a keyword-cluster may or may not be identical in different years. The variations of potency index of keyword-clusters and thrust areas of research in different years are shown in Table 10.62 and Table 10.63.

The variation of  $p(i)$  with  $r(p(i))$  for top 20 keyword clusters is shown in the Graph 53 below. The variation pattern follows logistic function:

$$p = a + (b a)/(1 + \exp(c+d*r(p))) \dots \dots \dots (10.55)$$

Where,  $a = 10.57$ ,  $b = 4.14$ ,  $c = 1.42$ ,  $d = 0.34$





Graph 53: Variation of  $p(i)$  with  $r(p(i))$  (For top 20 keyword clusters)

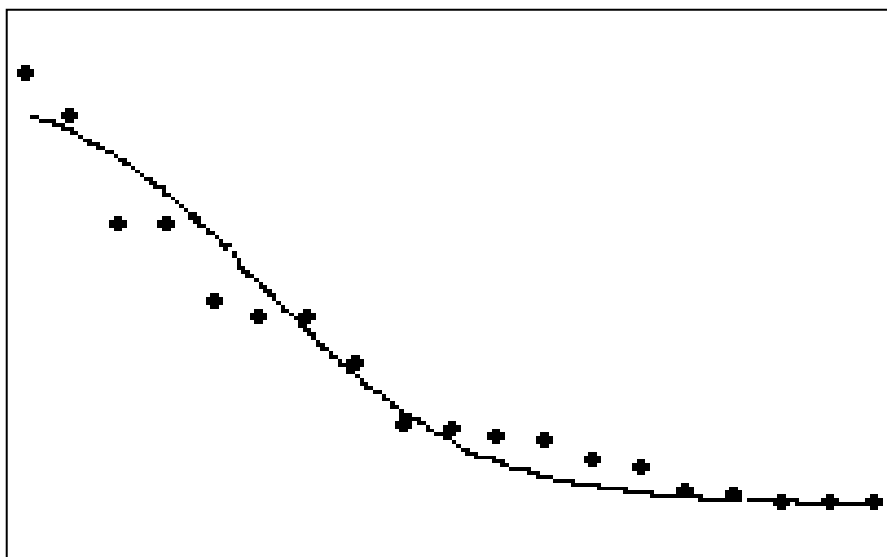
### K. Keyword: Momentary Visibility Index

The momentary visibility index (denoted by  $m(i)$ ) of a keyword cluster or keyphrase measures the number of journal articles touched by a single keyword or keyphrase in a single occurrence, i.e.

$$m(i) = (\text{Total freq. of a keyphrase}) / (\text{Occupancy of the keyphrase})$$

$$\text{Or, } m(i) = Z(\text{FREQ}) / Z(\text{OCC}) \dots \dots \dots (10.56)$$

The ranking or keyphrase done on the basis of  $m(i)$  is denoted by  $r(m(i))$ . The variation of  $m(i)$  with  $r(m(i))$  is shown in the graph below, which follows logistic function:



Graph 54: Variation of  $p(i)$  with  $r(p(i))$  (For top 20 keyword clusters)

$$m(i) = a + (b a)/(1 + \exp(c+d*r(m(i)))) \dots \dots \dots (10.57)$$

Where,  $a = 10.00$ ,  $b = 15.01$ ,  $c = 2.29$ ,  $d = 0.45$

The top 20 keyword clusters ranked according to the Momentary Visibility Index ( $m(i)$ ) are shown in Table 10.58 below. These 20 keyword clusters indicate significant supporting areas of research in the subject “Fermi Liquid” during 1985-2004, i.e. these highly instantly visible keyphrases behave as essential tools for research on Fermi Liquid. The keyword, which is most important and inseparable part of the subject, only will occur in maximum number of journal articles in a single instant and will have highest momentary visibility index.

Table 10.59: Top 20 keyword clusters ranked according to the Momentary Visibility Index  $m(i)$

Rank	Keyword cluster	Momentary Visibility Index
1	Mathematical model	26.64
2	Electric resistivity	25.00
3	Antiferromagnetic material	23.50
4	Quantum theory	19.72
5	Fermi level	19.66
6	Renormalisation	17.00
7	Thermal effect	16.53
8	Antiferromagnetism and antiferromagnet	16.42
9	Fermion system	14.85
10	Superconductivity	12.71
11	Phase diagram	12.52
12	Magnetic phase transition	12.35
13	Specific heat	12.21
14	Hamiltonian theory	11.50
15	Magnetism	11.20
16	Approximation theory	10.42
17	Fermi liquid theory	10.33
18	Kondo effect	10.06
19	Superconducting transition	10.00
19	Susceptibility	10.00

The keyword 'Mathematical model' possesses highest momentary visibility index as seen from Table 10.59, followed by the keywords 'Electric resistivity', 'Antiferromagnetic material' and 'Quantum theory' in the second, third and fourth positions respectively. The keyword 'Mathematical model' indicates a methodology and its highest momentary visibility index indicates that this methodology is an essential way to execute study on the subject 'Fermi liquid'. The mathematical modeling is done in both theoretical and experimental research and the subject 'Fermi liquid' thus encounters both types of research works. The keyword 'Electric resistivity' although belongs to physics, yet it is a common and well-known term. This keyword is closely associated with the major working areas of this subject. The momentary visibility index thus helps in tracing those concepts, which are closely associated with the thrust areas of research. A comparison between Table 10.58 and Table 10.59 reveals that the rankings of

same keywords are different in two tables. For instance, the keyword ‘Kondo effect’ holds 18<sup>th</sup> rank in Table 10.59, but 34<sup>th</sup> rank in Table 10.58. This phenomenon indicates that the keyword ‘Kondo effect’ is less significant as a potential research area in itself, rather than an associated tool supporting research works in the thrust areas. A subject embraces so many thrust areas of research at the time of inception, which normally decreases in course of time as the age of the subject increases. The squeeze in potential research areas gradually absolve the dynamism of the subject as an active topic of research, but it tends eventually to become a supporting tool for research in other areas belonging to other subjects. For instance, ‘Quantum theory’ was an active topic of research in modern physics at the time of its inception, i.e. during the first three decades of the last century. But today, it is a very significant supporting tool for research in almost all areas of physics and chemistry.

L. Keyword: Integrated Visibility Index

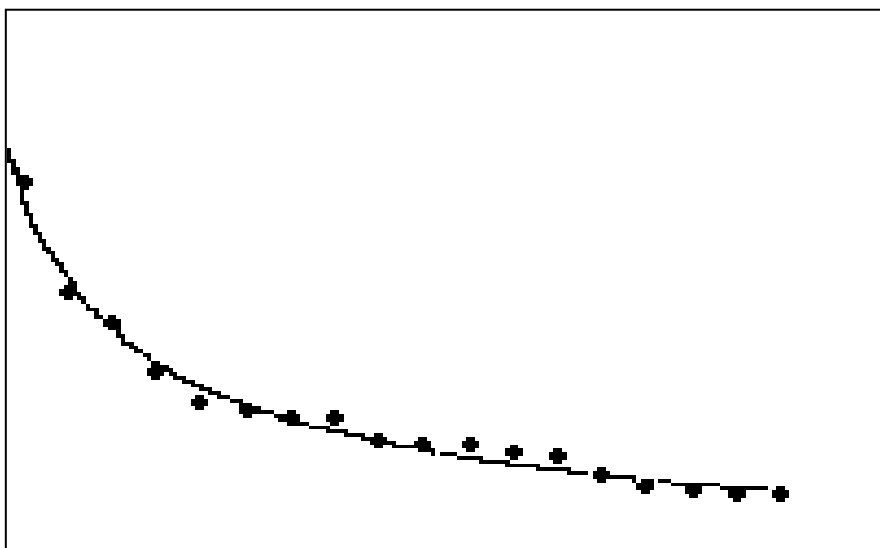
The integrated visibility index of a keyword cluster may be defined as the ratio of the total frequency of occurrence of all the keywords of the said cluster to the total number of keywords of that cluster. It is denoted by  $v(i)$ .

$$\text{Therefore, } v(i) = Z(\text{FREQ})/Z(\text{ALL})\dots\dots\dots(10.58)$$

The ranking of keyphrases done on the basis of  $v(i)$ , is denoted by  $r(v(i))$ . The variation of  $v(i)$  with  $r(v(i))$  is shown graphically below, which follows exponential decay function:

$$v(i) = a + b*\exp( r(v(i))/c) + d*\exp( r(v(i))/g)\dots\dots\dots(10.59)$$

Where,  $a = 61.06$ ,  $b = 127.94$ ,  $c = 1.62$ ,  $d = 120.70$ ,  $g = 8.39$



Graph 55: Variation of  $v(i)$  with  $r(v(i))$  (For top 20 keyword clusters)

The top 20 keyword clusters ranked according to the Integrated Visibility Index ( $v(i)$ ) are shown in Table 10.60 below. Integrated Visibility Index measures the number of journal articles touched by a single keyphrase. These 20 keyword clusters indicate highly intensive keyphrases in the subject “Fermi Liquid” during 1985 to 2004. The keyword ‘Quantum theory’ has highest visibility index followed by ‘Antiferromagnetism and antiferromagnet’, ‘Thermal effect’ and ‘Mathematical model’. The keyword ‘Quantum theory’ was present in highest number of journal articles during the span of 20 years. This phenomenon indicates that the keyword ‘Quantum theory’ had highest visibility during the span of 20 years, though the keyword ‘Mathematical model’ ranked top so far as visibility in a single occurrence has been concerned. Both of these keywords have high impact on the subject ‘Fermi liquid’.

Table 10.60: Top 20 keyword clusters ranked according to the Integrated Visibility Index  $v(i)$

Rank	Keyword cluster	Integrated Visibility Index
1	Quantum theory	355.00
2	Antiferromagnetism and antiferromagnet	312.00
3	Thermal effect	248.00
4	Mathematical model	186.50
5	Renormalisation	170.00
6	Antiferromagnetic material	141.00
7	Approximation theory	125.00
8	Electric resistivity	120.00
9	Numerical analysis	116.00
10	Helium 3-4	116.00
11	Alloy and compound	101.94
12	Normal state analysis	101.00
13	de Haas van Alphen effect	101.00
14	Superconducting transition	95.00
15	Tunneling effect	94.00
16	Pressure effect	82.00
17	Thermodynamic property	77.00
18	Spectroscopic analysis	74.00
19	Phase diagram	72.00
20	Helium 3	71.75

### M. Keyword: Stability Index

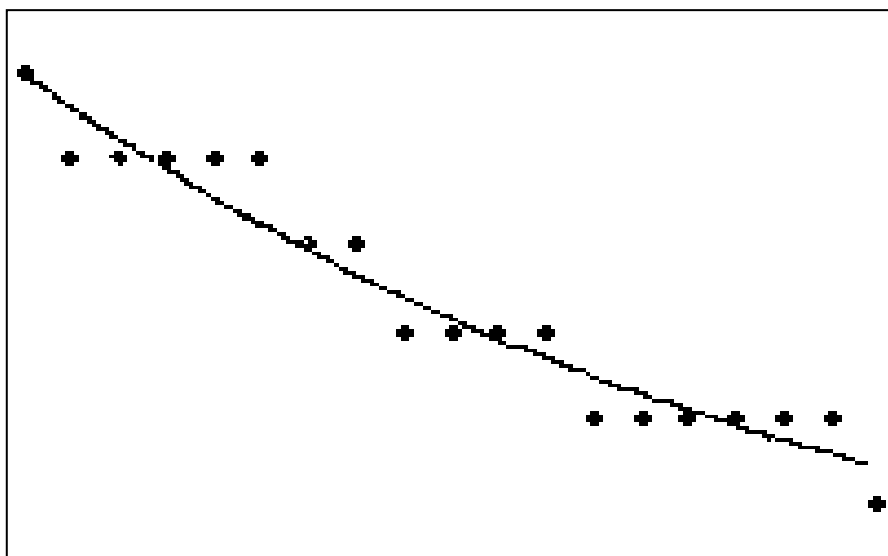
The stability index of a keyword cluster measures the number of appearances of the keywords belonging to a cluster during the entire span of twenty years. The stability index is denoted by  $s(i)$ . Now, according to the definition,  $s(i) = Z(\text{OCC}) * 100 / [Z(\text{OCC})]_{\text{max}}$ , where  $[Z(\text{OCC})]_{\text{max}} = 20 * Z(\text{ALL})$  (Where,  $Z(\text{ALL})$  indicates number of keywords within the said cluster).

$$\text{Therefore, } s(i) = Z(\text{OCC}) * 5 / Z(\text{ALL}) \dots \dots \dots (10.60)$$

The ranking of the keyphrases done on the basis of the stability index is denoted by  $r(s(i))$ .

Table 10.61: Top 20 keyword clusters ranked according to the Stability Index  $s(i)$

Rank	Keyword cluster	Stability Index
1	Helium 3-4	100.00
2	Antiferromagnetism and antiferromagnet	95.00
3	Quantum theory	90.00
3	de-Haas-van-Alphen effect	90.00
3	Anisotropy and anisotropy parameter	90.00
3	Scaling analysis	90.00
3	Superconducting thin film	90.00
4	Ginzburg-Landau theory	85.00
4	Alloy and alloying	85.00
5	Numerical analysis	80.00
5	Boltzmann distribution	80.00
5	Weak coupling theory	80.00
5	Momentum space	80.00
6	Thermal effect	75.00
6	Normal state analysis	75.00
6	Crystal and crystallography	75.00
6	Critical phenomena	75.00
6	Thomas-Fermi model	75.00
6	Elementary excitation	75.00
7	Phase separation	70.00



Graph 56: Variation of  $s(i)$  with  $r(s(i))$  (For top 20 keyword clusters)

The variation of  $s(i)$  with  $r(s(i))$  is shown above (Graph 56), which is an exponential decay function:

$$S(i) = a + b \cdot \exp(r(s(i))/c) + d \cdot \exp(r(s(i))/g) + h \cdot \exp(r(s(i))/k) \dots \dots \dots (10.61)$$

Where,  $a = 58.35$ ,  $b = 14.69$ ,  $c = 16.76$ ,  $d = 13.30$ ,  $g = 16.72$ ,  $h = 8.57$ ,  $l = 26.74$

The stability index indicates the sustainability of a keyword and/or keyword cluster over the span of 20 years. It may also be interpreted as the occupancy of a single keyword in a keyword cluster over the same span. The keyword Helium 3-4 has highest stability index. This keyword therefore possesses highest occupancy in 20 years. This is a single keyword, but not a keyword cluster. The diversity of terms is not present here, but its intensity is highest in terms of occupancy.

#### N. Thrust Area of Research

The thrust areas of research are identified from 1985 to 2000, and ranked in terms of the potency index ( $p(i)$ ). It has been observed that the thrust areas are not constant over the entire time span, but fluctuates. The notable feature is that high potential keyword clusters show no fluctuation in different years, but lower potential clusters show. The variation of potency index of the keyword clusters from 1985 to 1994 is presented in Table 10.62A, and the same for 1995 to 2004 is presented in Table 10.62B. The variation of rank of the same clusters made on the basis of potency indices from 1985 to 1994 is presented in Table 10.63A, and the same for 1995 to 2004 is presented in Table 10.63B. The oscillation of thrust areas of research among different clusters in different years is evident from Table 10.62 and Table 10.63. This phenomenon proves the hypothesis number 2 of chapter nine. The continuous shifting of thrust areas of research between different years indicates the dynamism of the research front of the subject 'Fermi liquid'.



Table 10.62A: Variation of Potency Index (p(i)) from 1985 to 1994

Keyword cluster	85	86	87	88	89	90	91	92	93	94
Electron	7.4	7.9	6.9	7.1	7.8	8.2	7.7	8.5	8.7	9.9
Spin	10.7	10.5	10.6	10.5	11.2	11.4	11.6	11.5	10.8	12.2
Fermi Liquid	8.5	8.3	8.4	8.1	8.9	9.4	9.3	9.2	9.4	10.1
Fermion	3.6	4.9	5.4	6.0	5.9	6.3	6.8	7.4	7.1	7.9
Impurity	3.2	3.2	1.4	3.8	2.8	2.9	4.4	6.0	6.1	6.5
Quasiparticle	4.4	5.3	6.0	5.4	5.5	6.0	5.7	6.4	6.8	6.9
Superconductor	4.1	3.2	5.2	4.7	5.3	6.4	6.1	5.5	5.2	5.4
Lattice	3.0	2.2	3.9	3.7	3.6	3.7	4.6	4.8	3.4	5.3
Fermi Surface	3.6	2.3	4.1	3.0	4.6	4.8	5.8	5.5	4.5	6.0
Scattering	4.1	2.2	3.4	1.4	2.8	4.4	3.9	4.8	4.5	4.8
Metal	4.9	5.3	3.7	5.6	4.9	5.5	5.2	4.9	5.8	6.1
Charge	1.4	1.8	3.6	1.4	3.7	4.3	4.4	3.2	4.1	5.9
Susceptibility	5.5	4.8	5.6	5.2	5.7	6.2	6.6	6.7	6.2	7.2
Temperature	5.2	4.1	3.4	3.6	4.1	5.2	5.4	4.5	5.3	6.3
Boson	0.7	0.0	3.6	1.8	3.4	3.3	3.3	3.6	4.6	5.9

Table 10.62B: Variation of Potency Index (p(i)) from 1995 to 2004

Keyword cluster	95	96	97	98	99	2k	1	2	3	4
Electron	9.5	9.9	9.6	9.6	10.3	10.6	10.4	10.9	10.7	10.5
Spin	12.1	11.8	11.9	12.0	12.2	12.7	12.3	12.5	12.6	12.1
Fermi Liquid	10.2	10.1	10.3	10.4	10.6	11.2	11.0	11.2	10.8	11.0
Fermion	7.9	7.7	8.4	7.9	7.8	7.8	8.4	8.4	8.3	8.6
Impurity	6.3	5.5	6.8	7.3	7.3	7.8	7.8	6.9	6.9	6.2
Quasiparticle	7.0	6.9	7.2	6.7	7.5	7.4	7.8	7.1	7.4	7.4
Superconductor	5.7	5.6	5.2	6.1	5.9	7.2	6.7	7.1	6.5	7.3
Lattice	5.3	3.2	5.0	5.4	5.3	5.9	6.1	7.0	6.1	6.7
Fermi Surface	7.0	7.1	6.5	6.9	7.3	7.9	7.2	7.2	7.8	7.6
Scattering	4.6	4.8	4.7	4.6	5.3	5.8	6.0	5.0	5.3	6.5
Metal	6.0	6.5	6.7	6.5	7.4	7.5	7.7	7.3	6.3	6.7
Charge	4.5	4.2	6.3	5.6	5.9	6.0	6.2	6.4	6.5	6.0
Susceptibility	7.0	7.1	7.2	6.7	7.8	8.3	7.4	7.8	7.3	6.9
Temperature	6.5	6.5	6.4	6.4	7.3	7.9	7.5	7.4	6.5	7.5
Boson	6.1	4.7	5.0	3.7	4.1	4.7	4.1	5.3	4.8	4.9

Table 10.63A: Variation of Rank of Keyword Clusters since 1985 to 1994

Keyword Cluster	85	86	87	88	89	90	91	92	93	94
Spin	1	1	1	1	1	1	1	1	1	1
Fermi Liquid	2	2	2	2	2	2	2	2	2	2
Electron	3	3	3	3	3	3	3	3	3	3
Fermion	9	5	6	4	4	5	4	4	4	4
Fermi Surface	9	9	8	12	9	10	7	8	12	10
Temperature	5	7	12	11	10	9	9	11	9	8
Quasiparticle	7	4	4	6	6	7	8	6	5	6
Superconductor	8	8	7	8	7	4	6	8	10	12
Susceptibility	4	6	5	7	5	6	5	5	6	5
Metal	6	4	10	5	8	8	10	9	8	9
Lattice	11	10	9	10	12	13	11	10	14	13
Scattering	8	10	12	14	14	11	13	10	12	14
Impurity	10	8	13	9	14	15	12	7	7	7
Charge	12	11	11	14	11	12	12	13	13	11
Boson	13	12	11	13	13	14	14	12	11	11

Table 10.63B: Variation of Rank of Keyword Clusters since 1995 to 2004

Keyword Cluster	95	96	97	98	99	2k	1	2	3	4
Spin	1	1	1	1	1	1	1	1	1	1
Fermi Liquid	2	2	2	2	2	2	2	2	2	2
Electron	3	3	3	3	3	3	3	3	3	3
Fermion	4	4	4	4	4	6	4	4	4	4
Fermi Surface	5	5	8	6	7	5	9	8	5	5
Temperature	6	7	9	9	7	5	7	6	9	6
Quasiparticle	5	6	5	7	5	8	5	9	6	7
Superconductor	10	8	11	10	8	9	10	9	9	8
Susceptibility	5	5	5	7	4	4	8	5	7	9
Metal	9	7	7	8	6	7	6	7	10	10
Lattice	11	13	12	12	9	11	12	10	11	10
Scattering	12	10	13	13	9	12	13	14	12	11
Impurity	7	9	6	5	7	6	5	11	8	12
Charge	13	12	10	11	8	10	11	12	9	13
Boson	8	11	12	14	10	13	14	13	13	14

Table 10.64: Fluctuation Index of top 15 keyword clusters

Keyword cluster	A	B	C
Spin	20	0	0.00
Fermi Liquid	20	0	0.00
Electron	20	0	0.00
Fermion	20	13	0.65
Fermi Surface	20	40	2.00
Temperature	20	33	1.65
Quasiparticle	20	32	1.60
Superconductor	20	28	1.40
Susceptibility	20	27	1.35
Metal	20	32	1.60
Lattice	20	27	1.35
Scattering	20	37	1.85
Impurity	20	48	2.40
Charge	20	31	1.55
Boson	19	27	1.42

[The explanation of second, third and fourth columns are as follows:

A – Number of occurrences of the keywords belonging to the clusters given in Table 10.63A and Table 10.63B

B – Number of Fluctuations of the keywords of the same clusters

C = B/A (Fluctuation Index)]

Number of fluctuations is calculated from the difference of ranks of the clusters between consecutive years as given in Table 63A and Table 10.63B. The magnitudes of the algebraic differences of the ranks between the consecutive years are added up to get the numerical values of the total number of fluctuations of the keyword clusters, as shown in the third column (B) of the Table 10.64. It is noticed from Table 10.64, that the first three clusters hold the constant position during 20 years, i.e. Spin (first), Fermi liquid (second) and Electron (third). These three clusters indicate core areas of research in the concerned subject. All other clusters show fluctuations in rank during 20 years. The fluctuation index is highest for the keyword cluster “Impurity” (2.4). The keyword ‘Impurity’ is related to semiconductor physics. It can be inferred that the impact of semiconductor physics on the subject ‘Fermi liquid’ was only temporarily prominent.

## O. Keyword: Stability Analysis

The number of appearances or occupancy measures the stability of a keyword over the entire time span. Higher the occupancy of a keyword, more it will be stable over the stipulated time span. The maximum possible occupancy of a keyword in the present study is 20, as here the published literature for 20 years have been concerned. A keyword with occupancy 20 has been categorized as perfectly stable keyword in this study. The other categories of stabilities for different occupancies are listed in Table 10.65 below.

Table 10.65: Stability analysis

Occupancy	Number of KW	Type of stability
1	12576	Ephemeral (Unstable)
2	2191	Semi Ephemeral (Almost unstable)
3	910	Weakly Stable
4	533	Weakly Stable
5	330	Weakly Stable
6	251	Weakly Stable
7	175	Weakly Stable
8	149	Weakly Stable
9	140	Weakly Stable
10	105	Moderately Stable
11	92	Moderately Stable
12	78	Moderately Stable
13	60	Moderately Stable
14	69	Moderately Stable
15	60	Moderately Stable
16	57	Highly Stable
17	34	Highly Stable
18	38	Highly Stable
19	30	Highly Stable
20	67	Perfectly Stable

The stability of a keyword depends on its occupancy or number of appearances. For the present case, the highest possible occupancy of a keyword is 20, while the lowest possible occupancy is one. The occupancy one means, the keyword is ephemeral. In Table 10.65 the stability of a keyword is graded with respect to its

occupancy. The ephemeral keyword has occupancy one, which is instable. The keywords with occupancy 2 are classed as semi ephemeral keyword, which is almost unstable in nature. The keywords with occupancy ranging from 3 to 9 are graded as weakly stable keywords. The keywords with occupancy ranging from 10 to 15 are classed in moderately stable keywords, and that from 15 to 19 are classed in highly stable keywords. The keywords with occupancy 20 are classed as perfectly stable keywords.

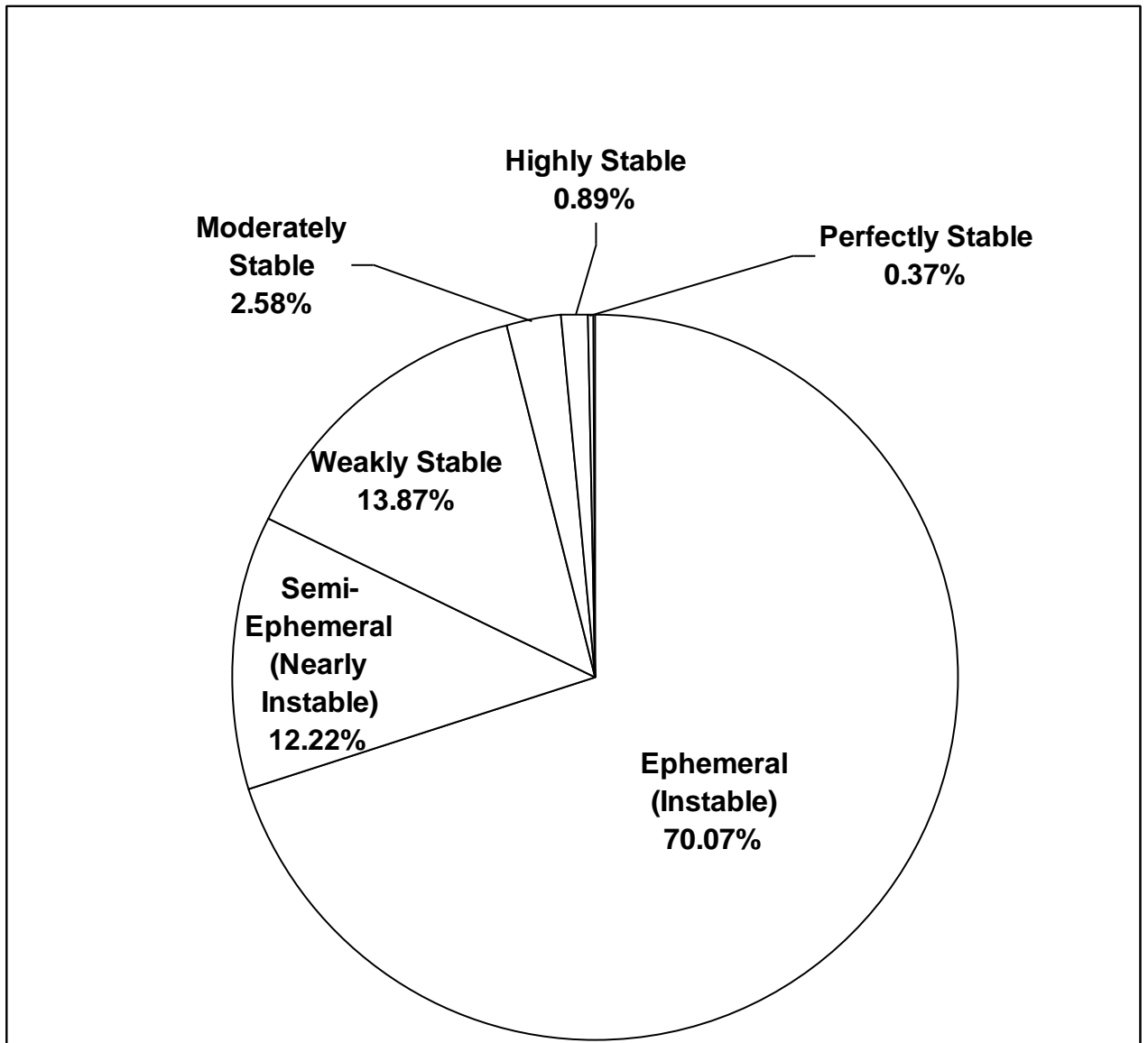


Diagram 21: Relative distribution of keywords with respect to different grades of stabilities over 20 years

A look at the above graph reveals that 70% of the total keywords are ephemeral, i.e. unstable, 12.2% keywords are nearly unstable, 13.9% keywords are weakly stable, and 2.6% keywords are moderately stable. The percentages of both highly stable and perfectly stable keywords are less than one. The percentage of perfectly stable keyword is almost negligible. The keywords almost never regularly appear and accumulate in the subject Fermi liquid. This is highly dynamic subject. The list of perfectly stable keyword is given below in Table 10.66, which may be considered as the core keyword of this subject.

Table 10.66: List of perfectly stable keywords

List of perfectly stable keywords with occupancy 20	
Alloy and Compound – Bismuth	Kondo Effect
Alloy and Compound – Cerium	Liquid Metal
Alloy and Compound – Copper	Liquid State Analysis
Alloy and Compound – Gallium	Low Temperature Physics
Alloy and Compound – Silicon	Magnetic Field
Alloy and Compound – Uranium	Magnetic Property
Anderson Model	Magnetism
Band Structure	Magnetoresistance
Bardeen-Cooper-Schrieffer Theory	Metal
Charge Transfer	Metal Insulator Phase Transition
Single Crystal	Monte Carlo Simulation
Density of State	Nuclear Magnetic Resonance
Dispersion Phenomenon	Nuclear Liquid Drop Model
Effective Mass Band Structure	Nuclear Matter
Electric Conductivity	Phase Diagram
Electron	Phase Transition
Electron Density of State	Phonon
Electron Gas	Quasiparticle
Electron Property	Random Phase Approximation
Energy Gap	Specific Heat
Fermi Energy	Specific Heat Solid

Table 10.66: List of perfectly stable keywords (Contd...)

List of perfectly stable keywords with occupancy 20	
Fermi Level	Spin Dynamics
Fermi Liquid	Spin Fluctuation
Fermi Liquid Model	Superconducting Material
Fermi Liquid Theory	Superconducting Transition Temperature
Fermi Liquid Theory Landau	Superconductivity
Fermion	Superfluidity
Fermi Surface	Magnetic Susceptibility
Ferromagnetism	Temperature Dependence
Ground State	Thermodynamic Property
Hall Effect	Thermoelectric Power
Helium	Mixed Valence Compound
Liquid Helium 3	Wave Function
Liquid Helium 3-4 Mixture	

### P. Keyphrase: Core, Allied and Alien

The total number of keywords analysed are 17945, which are distributed over 7807 keyphrases or keyword clusters. If this volume of keywords is divided in three equal zones, the number of keyphrases or keyword clusters containing keywords from each zone will be:

$$87:1746: 5974$$

$$\text{Or, } 87(1 : 20 : 69)$$

The keyword clusters or keyphrases in the first zone are core clusters, and indicate the central areas of research.

Table 10.67: List of core keyword clusters or keyphrases

Core keyword clusters	
Electron	Hamiltonian
Spin	Magnetoresistance
Fermi liquid	Low energy
Fermion	Resistivity
Impurity	Coulomb interaction
Quasiparticle	Singularity
Superconductor	Single particle
Lattice	Phase transition
Fermi surface	Anderson model

Table 10.67: List of core keyword clusters or keyphrases (Contd....)

Core keyword clusters	
Scattering	Density of state
Metal	Heat
Charge	Proton
Susceptibility	Relaxation
Temperature	Fermi system
Boson	Antiferromagnet
Conductance	Magnetization
Hole	Quark
Energy	Neutrino
Liquid	Fermi liquid theory
Magnetic field	X ray
Helium	Electron hole
Neutron	Sound
Semiconductor	Ground state
Plasma	Hydrogen
Wave	Electron-Electron interaction
Alloy compound	NMR
Particle	Nuclear matter
Charge carrier	Kondo lattice
Crystal	Density
Superconductivity	Interaction
Phonon	Electron state
Hubbard model	Kondo effect
Luttinger liquid	Kondo model
Electron system	d wave
Band	Light
Superfluid	Magnon
Infrared	Polaron
Low temperature	Quantum wire
Green's function	Nucleon
Symmetry	Fermi level
Fermi gas	Zero temperature
Renormalization	LASER
Ion	Spectroscopy
Perturbation	



Q. Keyword: Frequency of Occurrence and Occurrence Frequency

The frequency of occurrence of 17945 keywords over twenty years time span take 200 different numerical values ranging from 1 to 6371. These 200 values (Frequency of occurrence and denoted by Z(FREQ)) and frequency of each value (Occurrence frequency and denoted by Z(OF)) have been noticed and presented in Table 10.68. It has also been observed that the variables Z(FREQ) and Z(OF) obey the following equation:

$$Z(\text{FREQ}) = a/Z(\text{OF})^b \dots\dots(9.1)$$

Where, a = 6371 and b = 0.8942

The variable Z(FREQ)(Observed) indicates the numerical values as obtained from the keyword database and the variable Z(FREQ)(Theoretical) indicates values calculated on the basis of equation 9.1. Both values are displayed in Table 10.68. This phenomenon establishes the hypothesis number (3) of chapter nine. The form of equation (9) looks like Lotka's equation if Z(FREQ) and Z(OF) are replaced by number of authors and number of contributed papers respectively.

Table 10.68: Frequency of Occurrence and Occurrence Frequency (Cumulative) of 17945 keywords

Serial No.	Z(OF) (CUM.)	Z(FREQ) (Observed)	Z(FREQ) (Theoretical)	Serial No.	Z(OF) (CUM.)	Z(FREQ) (Observed)	Z(FREQ) (Theoretical)
1	1	6371	6371	101	131	108	81
2	2	1535	3428	102	132	106	81
3	3	1230	2385	103	133	105	80
4	4	1091	1844	104	134	104	80
5	5	1082	1511	105	136	102	79
6	6	1004	1283	106	139	101	77
7	7	988	1118	107	141	99	76
8	8	903	992	108	142	98	76
9	9	807	893	109	144	97	75
10	10	714	813	110	147	96	73
11	11	605	746	111	151	95	72
12	12	595	691	112	152	94	71
13	13	566	643	113	156	93	70

Table 10.68 (Contd.....)

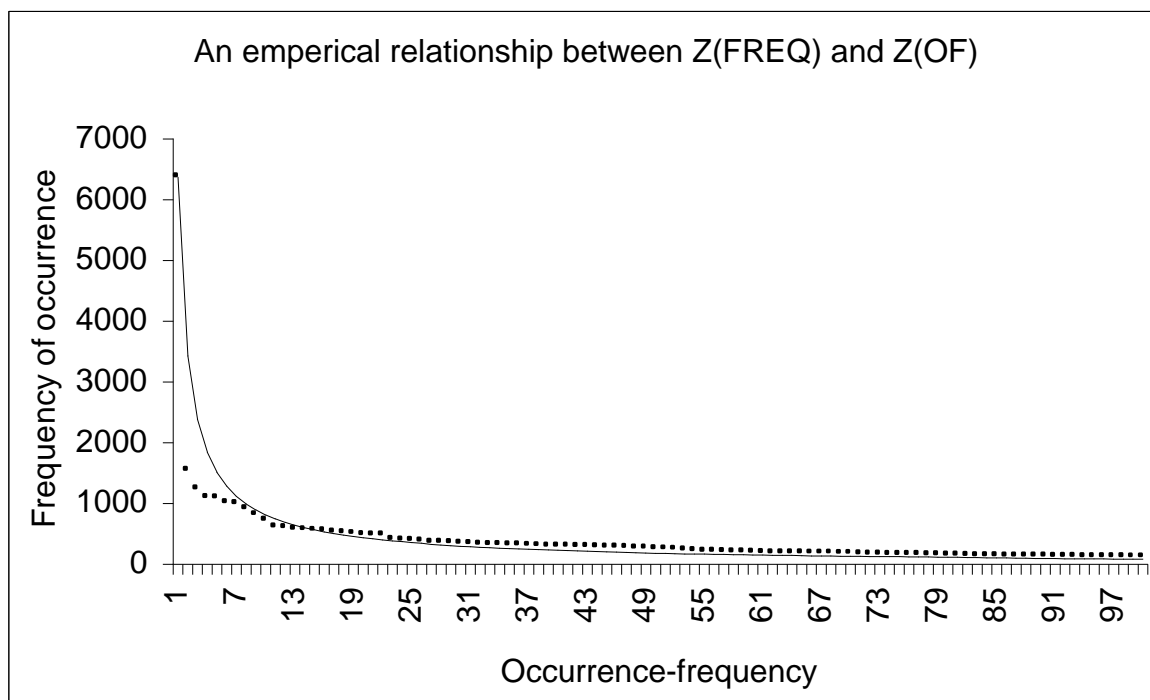
14	14	559	602	114	158	92	69
15	15	548	566	115	159	91	69
16	16	540	534	116	165	90	66
17	17	519	506	117	169	87	65
18	18	511	481	118	170	86	65
19	19	493	458	119	171	85	64
20	20	480	437	120	172	84	64
21	21	473	419	121	175	83	63
22	22	472	402	122	178	82	62
23	23	398	386	123	180	81	61
24	24	392	372	124	183	80	60
25	25	382	358	125	186	79	60
26	26	372	346	126	188	77	59
27	28	355	324	127	190	75	58
28	29	352	314	128	193	74	58
29	30	345	304	129	196	73	57
30	31	339	296	130	198	72	56
31	32	331	287	131	199	71	56
32	33	320	279	132	202	70	55
33	34	317	272	133	205	69	55
34	35	314	265	134	210	67	53
35	36	313	259	135	218	66	52
36	37	312	252	136	223	65	51
37	38	301	246	137	227	64	50
38	39	294	241	138	230	63	49
39	40	291	235	139	234	62	48
40	41	290	230	140	238	61	48
41	42	287	225	141	243	60	47
42	43	286	221	142	248	59	46
43	44	284	216	143	250	58	46
44	45	281	212	144	253	57	45
45	47	275	204	145	256	56	45
46	48	273	200	146	261	55	44
47	49	268	196	147	268	54	43
48	51	260	189	148	275	53	42
49	52	256	186	149	279	52	41
50	54	248	180	150	284	51	41
51	55	241	177	151	293	50	40
52	56	237	174	152	298	49	39
53	57	225	171	153	303	48	38
54	58	214	169	154	308	47	38
55	59	206	166	155	319	46	37
56	60	203	164	156	324	45	36

Table 10.68 (Contd.....)

57	61	201	161	157	330	44	36
58	62	196	159	158	338	43	35
59	63	193	157	159	347	42	34
60	64	190	155	160	351	41	34
61	65	182	152	161	357	40	33
62	67	181	148	162	368	39	32
63	68	180	146	163	379	38	32
64	69	179	145	164	391	37	31
65	71	178	141	165	396	36	30
66	72	176	139	166	409	35	29
67	73	173	137	167	421	34	29
68	74	172	136	168	435	33	28
69	75	167	134	169	445	32	27
70	77	166	131	170	456	31	27
71	78	161	130	171	463	30	26
72	79	159	128	172	475	29	26
73	80	157	127	173	494	28	25
74	81	155	125	174	512	27	24
75	82	154	124	175	528	26	23
76	84	153	121	176	546	25	23
77	85	151	120	177	563	24	22
78	86	149	119	178	591	23	21
79	87	147	117	179	612	22	21
80	88	143	116	180	639	21	20
81	89	140	115	181	661	20	19
82	92	136	112	182	695	19	18
83	94	133	110	183	734	18	17
84	99	131	105	184	762	17	17
85	100	129	104	185	793	16	16
86	101	128	103	186	841	15	15
87	103	127	101	187	901	14	15
88	105	126	99	188	970	13	14
89	108	125	97	189	1039	12	13
90	109	124	96	190	1126	11	12
91	112	122	94	191	1213	10	11
92	114	121	92	192	1327	9	10
93	115	120	92	193	1476	8	9
94	116	118	91	194	1676	7	8
95	118	117	89	195	1948	6	7
96	122	116	87	196	2308	5	6
97	123	115	86	197	2882	4	5
98	125	114	85	198	3883	3	4
99	128	112	83	199	6349	2	3

Table 10.68 (Contd.....)

100	130	109	82	200	17951	1	1
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Graph 57: Variation of Z(FREQ) with Z(OF)

The graphical analysis of equation 9.1 is presented in Graph 57 above. The continuous line indicates Z(FREQ)(Theoretical) and the points indicate Z(FREQ)(Observed). The observed points tally with the theoretical line as is evident from Graph 57. The graph is made for 100 points to distinguish them clearly.

### R. Keyword: Modulator, Qualifier and Keyterm

The total number of keywords analyzed here is 17945 and all keywords have been broken in three kernels, viz. keyphrase, modulator and qualifier, to get finally 7807 keyphrases, 1600 modulators and 2563 qualifiers. An analysis of 7807 keyphrases also results in 3342 keyterms. Some discussions on keyphrases have already been carried out. The modulators, qualifiers and keyterms have been ranked in accordance with their frequencies of occurrence. The top 30 modulators, qualifiers and keyterms are presented in Table 10.69,

Table 10.70 and Table 10.71 respectively. The lower limit of frequency of occurrence is always one, while the upper limits are 264, 233 & 965 for modulator, qualifier and keyterm respectively.

Table 10.69: Top 30 modulators

Rank	Modulator	Freq
1	Model	264
2	Interaction	201
3	Function	162
4	Density	154
5	Effect	134
6	Fluctuation	125
7	Energy	117
8	Transition	112
9	Phase	111
10	Scattering	108
11	Structure	106
12	Wave	101
13	Liquid	92
14	Excitation	89
15	Mode	82
16	Property	81
16	Rate	81
17	Coupling	79
18	Gas	71
19	Dynamics	69
20	Compound	66
20	Parameter	66
21	Potential	65
22	Correlation	64
23	Approximation	63
23	Relaxation	63
24	Spectra	59
25	Dependence	58
26	Temperature	56
27	Distribution	54

The top-ranked modulator is 'Model' followed by 'Interaction' and 'Function'. As noticed from Table 10.69 that all modulators are common terms and frequently used in all branches of science. The Keyphrases are subject-specific terms and

the modulators only modify and alter the scope and coverage of the concept expressed by keyphrase.

Table 10.70: Top 30 qualifiers

Rank	Qualifier	Freq
1	2d-point	233
2	2-component	129
2	Non	129
3	Heavy-mass	99
4	Interacting-electron-system	95
5	Effective	93
5	Spin	93
6	Strong	89
7	Liquid	81
8	2	78
9	Strongly	76
10	Finite-size	75
11	Correlation-induced	72
12	Antiferromagnetic	70
12	Crossing	70
12	Single	70
13	Anisotropic-surface-state	63
14	Dispersion	62
14	Magnetic	62
15	Quantum	60
16	Delocalized	57
17	Large	56
18	Low-temperature	55
19	Quasi	54
20	Transverse	52
20	Weakly	52
21	4f	50
21	Doppler-shifted	49
22	Covariance	46
23	Itinerant	45

The top-ranked qualifier is '2d-point' followed by '2-component' and 'Non'. The qualifiers are also mostly common terms except few. The qualifiers describe the actual state of the modified or amended concept articulated by the keyphrase with modulator. A qualifier may even be simply a digit or a letter, as seen in the above Table 10.70. The number '2' or '4f' describe a particular state of an

electron. The qualifier 'Non' describes the contrast of an entity, for instance 'Non-Fermi liquid' that indicates some other entity shows properties just contrast to that for the Fermi liquid.

Table 10.71: Top 30 keyterms

Rank	Key-term	Freq
1	Fermi	965
2	Electron	932
3	Liquid	808
4	Spin	695
5	State	430
6	Model	379
7	Magnetic	358
8	Quantum	333
9	System	320
10	Theory	300
11	Energy	289
12	Field	271
13	Phase	254
14	Surface	251
15	Band	245
16	Charge	238
17	Fermion	228
17	Temperature	228
18	Density	211
19	Particle	204
20	Metal	202
20	Wave	202
21	Kondo	196
22	Interaction	194
23	Impurity	193
24	Function	185
25	Lattice	183
26	Nuclear	172
27	Quasiparticle	167
28	Hole	157

A keyterm is the fundamental constituent of a keyphrase. The keyterms include three categories of terms, i.e. common term, subject-specific term and proper noun. The top-ranked keyterm is 'Fermi' followed by 'Electron' and 'Liquid'. The keyterms 'Spin', 'State', 'Model', 'Magnetic' and 'Quantum' are also very

important keyterms for this study. The keyterms 'Fermi' and 'Liquid' are toppers, which is obvious as the subject concerned here is 'Fermi liquid'. The proper noun combines with either common term or subject-specific term to form a keyphrase. This is one of the major ways of formation of keywords in this subject. For instance, 'Fermi' is a proper noun (last part of the name of a celebrated noble-laureate physicist Enrico Fermi), and liquid is a common term. But the combination of 'Fermi' and 'Liquid' creates another keyword 'Fermi liquid', which is a subject-specific term. Numerous examples of formation of subject-specific terms in this way can be cited here, to mention a few, 'Kondo effect', 'Luttinger liquid', 'Hofstadter model', 'Hubbard band', 'Pomeranchuk transition', 'Anderson model' and so on. Combining two, three or more common terms together also forms the keywords. Few examples are cited below: 'Anomalous oscillation', 'Charge excitation', 'Entropy balance', 'Low temperature relaxation' and so on. Combining two, three or more subject-specific terms either together or with some other common term(s) also forms the keywords. Some examples of the former case are, 'Antiferromagnetic spin fluctuation', 'Lattice potential', 'Dipole moment' etc. while some other examples of the latter case are, 'Electromagnetic screening', 'Magnetic quantum limit' etc. Since the keyterm(s) are the fundamental building block of a keyphrase and/or keyword, therefore an analytical study of keyterms also throw light on the features of keyphrase(s) and/or keyword(s).