A Modified Life-Table Analysis System for Cohort Studies

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A person-years at risk life-table analysis system of computer programs has been developed by the National Institute for Occupational Safety and Health (NIOSH) and is available with detailed documentation. The system was specifically designed to analyze occupational cohort mortality data. These programs require more computer core space and processing time than other available life-table programs. However, the NIOSH programs are advantageous because they include the following: (1) input data editing and modification, (2) mortality rates for 89 cause-of-death categories, (3) assignment of cumulative doses to specific person-years based on either personal or area exposure data, and (4) simultaneous examination of observed and expected deaths by duration of employment (or dose), latency, age, and calendar time.

Over the last decade, the epidemiologic staff at the National Institute for Occupational Safety and Health (NIOSH) have developed, refined, and tested a modified Life-Table Analysis System (LTAS) of computer programs. This system was specifically designed to analyze occupational cohort mortality data, although it may also be modified to analyze other types of cohort data. The purpose of this article is to describe this system.

Conceptually, a modified life-table is a person-years at risk (PYAR) model in which each member of a cohort at risk is followed from his cohort entry date until his cohort withdrawal date. The dates, however, may be different for each person. This model was originally used to study prospectively the mortality of persons treated in sanatoria.[1,2] Its application to retrospective, also known as historical prospective, cohort studies was popularized by Wade Hampton Frost[3] in 1933 in a study of families of tuberculosis cases and further refined by Cutler and Ederer[4] in 1958. Occupational cohort applications of this model have been numerous since it was first used in 1954 by Case and Hosker,[5] who introduced the concept of observed and expected deaths.

Between cohort entry and withdrawal, each person contributes one PYAR for each year that he lives. These PYAR are summed over time and persons within five-year age and calendar period strata. The assumption is then made that within a given age and calendar period stratum a given number of PYAR would generate a constant number of expected deaths, independently of how many persons contributed to that given number of PYAR. Consequently, the total PYAR within a stratum can then be multiplied by an external comparison death rate to obtain an expected number of deaths in that stratum. These expected deaths are then summed over all strata and compared with the number observed during the follow-up period.

The PYAR and comparison mortality rates are stratified by potentially confounding variables (e.g., age, calendar time, race, sex), multiplied, and the resulting expected numbers of death are subsequently summed over the strata. Thus, the expected deaths are indirectly adjusted, and the measure of observed to expected deaths is the familiar standardized mortality ratio (SMR). This concept is also the basis for other modified life-table programs available publicly.[6-8]

Input Data

Input data for the LTAS consist of the following items for each cohort member: (1) name; (2) subject identification number; (3) date of birth; (4) date first employed (or alternative date on which a cohort entry date may be calculated); (5) date last employed; (6) vital status as of the date of the end of the follow-up period (alive, dead, lost-to-follow-up); (7) cause of death coded according to the International Classification of Diseases (ICD); (8) date of

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The computer programs and detailed documentation are available from the Epidemiologic Methods Activity, Industrywide Studies Branch, NIOSH, Robert A. Taft Laboratories, 4676 Columbia Pkwy., Cincinnati, OH 45226.

death or date last observed alive; (9) detailed work history consisting of department code, job title, date in, date out for each job held (optional); (10) begin PYAR date (optional); (11) race; and (12) sex.

In addition, if one desires to use the dose option in the LTAS, then exposure/dose data are needed in one of two forms. If the dose data are personnel oriented, each cohort member must have a file of his doses and the time periods over which the doses were accumulated. An example would be monthly or annual radiation film badge summaries.[9] Alternatively, if the exposure data are area oriented, then a matrix giving the exposure level in each plant-department/job title/time period combination must be supplied.[10] These area exposure data are linked to the individual detailed work histories in the LTAS. Thus, for any time period during the study, a cumulative dose can be determined for each worker.

Data Edits

Before the analysis, the LTAS edits the data for 14 different criteria, some of which are listed in Table 1. The program then either modifies the data temporarily according to certain assumptions, or deletes part or all of the worker's data. All modified or deleted data are listed in the analysis printout.

Analysis Parameters

For each analysis, the user may specify the following parameters:

1. Study begin date: (*a*) If a subject's date of last employment is before this date, he will be rejected; (*b*) If the "Begin PYAR date" is not specified, then calculation of PYAR will begin on the study begin date or the subject's first date of employment if the subject was not employed before the study begin date.

2. Study end date: PYAR stop on (for alive and lost-to-follow-up persons) or before (for deceased persons) this date. A person's vital status code reflects his vital status as of this date. No work history information beyond the study end date is analyzed.

3. Races to be included.

4. Sex to be included.

5. Minimum duration of employment in exposed areas for cohort inclusion: When invoked, a person does not begin his PYAR until the date he achieves this minimum. PYAR are calculated no earlier than the study begin date. Subjects who never reach this minimum duration of exposure are rejected.

6. Date last observed option: When invoked, all nondeceased persons will contribute PYAR until their date last observed alive rather than until the end of study date indicated above. (The date last observed for a person known to be alive would be the study end date.)

7. Overall begin PYAR date: If one desires to begin PYAR for the entire cohort on a date different from the begin study date, a begin PYAR date is entered.

8. Individual begin PYAR option: When invoked, PYAR begin on a date specified in each person's record.

PYAR

PYAR are calculated in terms of days. PYAR may be initiated on the first date employed, the first date worked in an exposed department/job, the date at which a minimum duration of employment, dose or latency criterion is

Table 1 – Selected Data Edits and Corresponding Corrective Actions Performed by the NIOSH LTAS

Criteria	Action
1. Invalid race code	Set race to white
2. Invalid sex code	Set sex to male
3. Invalid first employment date*	Reject subject
4. Invalid date of death*	Set date of death to study end date
5. Date of death after the end of study date	Consider worker alive
6. Invalid date of birth*	Set date of birth to 20 yrs before first date employed
7. Age first employed < 10 yr	Reject subject
8. All work histories before the study begin date	Reject subject
9. None of the subject's work histories meet the study criteria	Reject subject
10. Invalid work history†	Reject the invalid work history but accepts subject's other valid histories

* A date is considered invalid if: (*a*) it contains nonnumeric characters, (*b*) month > 12, (*c*) date > 31, (*d*) it is blank

† A work history is considered invalid if: (*a*) the beginning or ending date is invalid, (*b*) the beginning and ending dates are not chronologically ordered, (*c*) the ending date is after the date of death

met, an overall "begin PYAR date," or on a specific date for each subject by using the "begin PYAR" variable in each worker's record. An example of the latter option is a prospective cohort study that includes persons participating in a medical examination survey.[11] In such a case, the begin PYAR date would be the date of each person's examination.

PYAR will automatically be calculated until the date of death for deceased persons, and until the end-of-study date for persons alive or lost-to-follow-up, unless the date last observed option is invoked. PYAR are stratified by fixed five-year age (15 through 19, 20 through 24, . . . 85+) and calendar time (1940-1944, 1945-1949, . . . 1975-1979) intervals and may be additionally stratified by variable duration of exposure, latency, and dose categories (Table 2). To allocate PYAR to the various strata, the program uses a "critical date" concept. Critical dates are the dates at which each worker moves across strata. The program calculates critical dates for each worker than accumulates PYAR in the first stratum until the first critical date is reached. Subsequent PYAR are entered in each successive stratum as determined by the sequential critical dates.

Cause of Death Categories

The LTAS uses the World Health Organization ICD code for the underlying cause of death. Since the adoption by the National Center for Health Statistics (NCHS) of the fifth revision in 1940, there have been three revisions of the ICD (1949, 1959, 1968) through 1978. (For the period 1968-1977 when the eigth revision was in effect, the LTAS program uses the ICD, adapted for use in the United States [ICDA as opposed to ICD].) Each revision has its own rules for determination of the underlying cause of death and codes. The NCHS uses the appropriate revision to code annually all U.S. death certificates for compilation and publication of national and state mortality rates and death counts.

An example of the importance of changes in the rules between revisions can be illustrated with a death certificate listing death due to arteriosclerotic heart disease (ASHD) due to lung cancer. If such a death occurred during the fifth revision (1940-1948), lung cancer would be the underlying cause of death, whereas if it occurred during later revisions, ASHD would be the underlying cause.

Changes in the rules and codes among the various revisions (Table 3) must be taken into account. One method of maintaining comparability among the revisions involves coding all observed deaths to a standard revision, using the rules of that standard revision. Interrevision comparability ratios must be used then to adjust the U.S. death. This method was rejected because the comparability ratios were not age-specific or inclusive of all causes of interest in all revisions. Instead, observed study deaths are coded using the rules of the ICD revision in effect at the time of death. For instance, in the example in the previous paragraph, the death occurring during the fifth revision would be determined to be due to lung cancer, but if the same death had occurred in 1966, it would be determined to be due to ASHD.

Once the underlying cause of death is determined, the LTAS can then operate under either of two input modes. In the first mode, the ICD codes in effect at the time of death are used. In the second mode, the codes (not the rules) of a single revision are used. For both modes, the LTAS then classifies the observed death into one of 89 NIOSH cause categories which are based on the seventh revision disease definitions (Table 3). Comparability with national rates is maintained because U.S. deaths are also coded by the rules in effect at the time of death for the published *Vital Statistics.*[12] The national rates are allocated to the appropriate 89 cause categories in the same manner as the observed deaths in the study.

Comparison Death Rates

To compute expected deaths, the LTAS uses race- (white includes caucasians of Spanish/Mexican surname or origin

Table 2 – Example of Distribution Among Radiation Workers of Person-Years by Age and Calendar-Time Period Within a Dose and Latency Category

Dose = 0.001 to 0.030 roentgen equivalents man (rem) Latency = one day to one year

Age	1952-1954	1955-1959	1960-1964	1965-1969	1970-1974	1975-1977	Total
15-19	0.00	4.98	13.85	61.77	4.50	0.52	85.61
20-24	0.96	23.18	81.42	204.47	53.62	18.25	381.90
25-29	0.46	62.18	119.52	125.77	46.05	48.26	402.23
30-34	1.54	95.10	118.02	73.78	25.68	32.98	347.09
35-39	1.89	176.11	173.49	73.36	19.55	17.07	461.47
40-44	1.06	192.31	192.72	100.24	25.38	11.03	522.74
45-49	1.16	136.61	182.31	137.23	11.97	9.43	478.71
50-54	1.13	125.91	110.88	87.87	27.91	9.10	362.81
55-59	0.03	77.95	63.82	56.92	13.61	2.27	214.60
60-64	0.00	47.01	31.46	15.08	1.30	2.41	97.26
65-69	0.00	3.83	6.07	6.35	0.97	0.00	17.22
70-74	0.00	0.25	0.04	0.00	0.00	0.00	0.29
75-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85+	0.00	0.00	0.00	0.26	0.00	0.00	0.26
Total	**8.24**	**945.43**	**1,093.57**	**943.11**	**230.53**	**151.31**	**3,372.18**

Table 3 – ICD Elements of NIOSH Death Categories

NIOSH Code	Label	1940-1948, 5th Revision	1949, 6th Revision	1950-1967, 6th and 7th Revisions	1968-1978, 8th Revision
01*	**Tuberculosis**				
01†	Respiratory tuberculosis	13	001-008	001-008	010-012, 031
02	Other tuberculosis	14-22	010-019	010-019	013-019
02	**Malignant Neoplasm (MN) of Buccal Cavity and Pharynx**				
03	MN of lip	45A	140	140	140
04	MN of tongue	45B	141	141	141
05	MN of other parts of buccal cavity	45C, 45E	142-144	142-144	142-145
06	MN of pharynx	45F	145-148	145-148	146-149
03	**MN of Digestive Organs and Peritoneum**				
07	MN of esophagus	46A	150	150	150
08	MN of stomach	46B	151	151	151
09	MN of intestine except rectum	46C, 46E	152, 153	152, 153	152, 153
10	MN of rectum	46D	154	154	154
11+‡	MN of biliary passages and liver	46F	155, 156A	155	155, 156
12+‡	MN of liver not specified	No rates	No rates	156A	197.8
13	MN of pancreas	46G	157	157	157
14	MN of peritoneum and unspecified of digestive organs	46H, 46M	158, 159	158, 159	158, 159
04	**MN of Respiratory System**				
15	MN of larynx	47A	161	161	161
16	MN of trachea, bronchus and lung	47B-47F	162, 163	162, 163	162, 163.0
17+	MN of other parts of respiratory system	No rates	No rates	160, 164	160, 163.1, 163.9
05	**MN of Breast**				
18	MN of breast	50	170	170	174
06	**MN of Female Genital Organs**				
19+‡	MN of cervix uteri	No rates	No rates	171	180, 234.0
20+‡	MN of other parts of uterus	48	171, 172-174	172-174	181, 182.0, 182.9
21	MN of ovary, fallopian tube, and broad ligament	49A, 49B	175	175	183
22	MN of other female genital organs	49C-49E	176	176	184
07	**MN of Male Genital Organs**				
23	MN of prostate	51B	177	177	185
24	MN of other male genital organs	51A, 51C-51E	178-179	178, 179	172.5, 173.5, 186, 187
08	**MN of Urinary Organs**				
25	MN of kidney	52A	180	180	189.0, 189.1, 189.2
26	MN of bladder and other urinary organs	52B, 52C	181	181	188, 189.9

(Continued)

(Table 3 continued)

09	**MN of Other and Unspecified Sites**				
27	MN of skin	53	190, 191	190, 191	172.0-172.4, 172.6-172.9, 173.0-173.4, 173.6-173.9
28+	MN of eye	No rates	No rates	192	190
29	MN of brain and other parts of nervous system	54	193	193	191, 192
30+	MN of thyroid gland	No rates	No rates	194	193
31+	MN of bone	No rates	No rates	196	170
32+	MN of connective tissue	No rates	No rates	197	171
33	MN of other and unspecified sites (minor)	45D, 55	156B, 160, 164, 165, 192, 194-203, 205	156B, 165, 195, 198, 199	194, 195, 196, 197.0-197.7, 197.9, 198, 199
10	**Neoplasms of Lymphatic and Hematopoietic Tissue**				
34+	Lymphosarcoma and reticulosarcoma	No rates	No rates	200	200, 202.2
35+	Hodgkin's disease	No rates	No rates	201	201
36	Leukemia and aleukemia	74	204	204	204-207
37+	Other neoplasms of lymphatic and hematopoietic tissue	No rates	No rates	202, 203, 205	202.0, 202.1, 202.9, 203
11	**Benign and Unspecified Neoplasms of the Brain**				
38	Benign neoplasms of the brain	56D	223	223	224, 225, 743.4
39	Neoplasms of unspecified nature of brain	57D	237	237	238
12	**Diabetes Mellitus**				
40	Diabetes mellitus	61	260	260	250
13	**Diseases of the Blood and Blood-Forming Organs**				
41	Pernicious and hyperchromic anemias	73A	290	290	281.0, 281.9
42	Anemias of other and unspecified type	73B-73D	291-293	291-293	209, 280, 281.1-281.4, 282, 283.0, 284, 285
43	Purpura and other hemorrhagic conditions	72	296	296	286, 287
44	All other diseases of blood-forming organs	75, 76	294, 295, 297-299	294, 295, 297-299	208, 275, 283.9, 288, 289.0, 289.9
14	**Mental, Psychoneurotic and Personality Disorders**				
45	Alcoholism	77	322	322	303
46	Other mental disorders	79, 84	300-321, 323-326	300-321, 323-326	290-302, 304, 305, 306.0, 306.1, 306.5, 306.6, 306.7, 306.9, 307, 308, 310-315, 333.0, 759.3, 781.5
15	**Diseases of the Nervous System**				
47	Vascular lesions affecting CNS	83	330-334	330-334	430-438
48	Multiple sclerosis	87	345	345	340

(Continued)

(Table 3 continued)

16	**Diseases of the Circulatory System**				
49	Rheumatic fever	58	400-402	400-402	390-392
50	Chronic rheumatic heart disease	90A, 92B, 92C, 93C, 95B	410-416	410-416	393, 394, 395.0, 396-398
51+§	ASHD	94, 93D	420	420	410-413
52	Chronic endocarditis not specified as rheumatic	91C, 92A, 92D, 92E	421	421	395.9, 424
53§	Other myocardial degeneration	93B, 93E	422	422	428
54	Other diseases of the heart	90B, 91A, 91B, 93A, 95A, 95C	430-434	430-434	420-423, 425-427, 429
55+§	Hypertension with heart disease	131A	440-443	440-443	400.1, 400.9, 402, 404
56§	Hypertension without heart disease	102	444-447	444-447	400.0, 400.2, 400.3, 401, 403, 440.1
57	Diseases of the arteries and veins	96-101, 103	450-468	450-468	289.1-.3, 440.0, 440.2-.9, 441.0-444.1, 444.3-445.9, 446.0, 446.2-.9, 447-451, 453-458, 734.1
17	**Diseases of the Respiratory System**				
58	Acute upper respiratory	104, 105	470-475	470-475	460-465
59	Influenza	33	480-483	480-483	470-474
60	Pneumonia (except newborn)	107-109	490-493	490-493	480-486
61	Bronchitis	106	500-502	500-502	466, 490, 491
62	Other respiratory diseases	110, 111, 113, 114A-E, 115	510-527	510-527	492, 500-506, 508-519
18	**Diseases of Digestive System**				
63	Diseases of the stomach and duodenum	117, 118	540, 541, 543	540, 541, 543	531-533, 535
64	Hernia and intestinal obstruction	122	560, 561, 570	560, 561, 570	444.2, 550-553, 560
65	Cirrhosis of the liver	124	581	581	571
19	**Diseases of the Genitourinary System**				
66	Acute nephritis	130	590	590	580
67+‡	Nephritis with edema, including nephrosis	No rates	No rates	591	581, 593.1
68‡	Chronic and unspecified nephritis and other renal sclerosis	131B, 132	591-594	592-594	582-584, 593.0
69	Infection of kidney	133	600	600	590
70	Calculi of urinary system	134	602, 604	602, 604	592, 594
71	Hyperplasia of prostate	137	610	610	600
72	Other diseases of male genital organs	138	611-617	611-617	601-607
73+‡	Diseases of the breast	No rates	No rates	620, 621	610, 611
74+‡	Diseases of the female genital organs	139	620-637	622-637	612-616, 620-624, 625.0-.2, 625.9, 626-629, 131
75	Abortion	140-141	650-652	650-652	640-645
20	**Diseases of the Skin**				
76	Infections of the skin	151-152	690-698	690-698	079.0, 079.1, 680-684, 686

(Continued)

(Table 3 continued)

77	Other diseases of the skin	153	700-716	700-716	690-707, 709, 716.0, 734.0, 757.0, 757.2
21	**Disease of the Bone and Organs of Movement**				
78+‡	Arthritis and spondylitis	59	720-727	720-725	710-715
79+‡	Muscular rheumatism and rheumatism unspecified	No rates	No rates	726, 727	716.1, 717, 718
80	Osteomyelitis and periostitis	154	730	730	720
22	**Unknown Causes**				
81+	Unknown causes	162, 199, 200, blank	780-793, 795, blank	780-793, 795, blank	306.2-.4, 306.8, 780-793, 795, 796, blank
23	**Accidents**				
82	Transportation accidents	169-173	E800-866	E800-866	E800-845
83	Accidental poisoning	78, 178, 179	E870-895	E870-895	E850-877
84	Accidental falls	186A	E900-904	E900-904	E880-887
85	Other accidents	174-177, 180-185 186B-194 195C, D	E910-936 960-962	E910-936, 960-962	E890-929, 940-946
86	Medical complications and misadventure	195A, 195B	E940-959	E940-959	E930-936, E947-949
24	**Violence**				
87	Suicide	163, 164	E963, E970-979	E963, E970-979	E950-959
88	Homicide	165-168, 198	E964, E980-985	E964, E980-985	E960-978
25	**Other Causes**				
89	Other Causes	Residual	Residual	Residual	Residual

* Major NIOSH death category

† Minor NIOSH death category

‡ The following pairs of categories should be combined if there are person-years before 1950: 11 and 12, 19 and 20, 67 and 68, 73 and 74, 78 and 79

§ 51 and 53 should be combined if there are person-years after 1967; if there are person-years prior to 1950 the following four categories should be combined 51, 53, 55 and 56

11+, includes 1° and unspecified prior to 1950, 1° only after 1950.

12+, there is no category during fifth revision and sixth ICD's 156A is put into NIOSH 11 in 1949

17+, fifth ICD's 47F is put into NIOSH 16, fifth ICD's 55D is put into NIOSH 33, and sixth ICD's 160 and 164 are put in NIOSH 33 in the 1940s

19+, fifth ICD's 48A and sixth ICD's 171 are put into NIOSH 20 in the 1940s

20+, includes cervix and uterine cancer prior to 1950

28+, fifth ICD's 55E and sixth ICD's 192 are put into NIOSH 33 in the 1940s

30+, fifth ICD's 55C and sixth ICD's 194 are put into NIOSH 33 in the 1940s

31+, fifth ICD's 45D and 55B and sixth ICD's 196 are put into NIOSH 33 in the 1940s

32+, fifth ICD's 55E and sixth ICD's 197 are put into NIOSH 33 in the 1940s

34+, there is no category during fifth revision and sixth ICD's 200 is put into NIOSH 33 in 1949

35+, fifth ICD's 44B and sixth ICD's 201 are put in NIOSH 89 in the 1940s

37+, there is no category during fifth revision and sixth ICD's 202, 203, and 205 are put in NIOSH 33 in 1949

51+, includes other myocardial degeneration after 1967; includes part of myocardial degeneration and hypertension with heart disease prior to 1950

55+, there is some hypertension without heart disease prior to 1949 (part of 131A)

67+, there is no category in the fifth revision and sixth ICD's 591 is put into NIOSH 68 in 1949

73+, there is no category in the fifth revision and sixth ICD's 620 and 621 are put into NIOSH 74 in 1949

74+, contains breast disease prior to 1950

78+, includes rheumatism in the 1940s

79+, fifth revision ICD's 59C and sixth ICD's 726 and 727 are put into NIOSH 78 in the 1940s

81+, "Blank" indicates deaths without certificates

and caucasians not otherwise specified; nonwhite consists of blacks, American Indians, Chinese, Japanese, Hawaiians, and all other nonwhites[12]), sex-, and five-year age- and calendar-specific U.S. mortality rates for each of the 89 NIOSH cause of death categories. The numerator of the age-specific mortality rate is one fifth the number of deaths that occurred within the U.S. during the five-year calendar time interval. The denominator is the midpoint population of the United States for the five-year interval for that race-, sex-, and age-specific group.

Numerator – For each sex,race (white, nonwhite) group, the numbers of five-year age-specific (15 through 19, . . ., 85+) deaths occurring within the United States were abstracted from the annual *Vital Statistics of the United States* volumes from 1940-1965.[12] From 1966-1975, identical data were read from magnetic tapes supplied by the NCHS. As with U.S. rates, deaths occurring among U.S. citizens outside the country (regardless of war relatedness) were not included. These data were summed over five-year calendar intervals from 1940 through 1974. For the time period 1975-1979 only data for 1975 were available. (We intend to update rates for succeeding years, as the data become available from the NCHS.) The data were verified manually and by computer. The latter verification consisted of summing the age-, race-, sex-specific data over ages and again over race, sex groups, and of comparing these sums with the published totals.

Denominator – The denominators of the comparison death rates were the estimates of the age-, race- and sex-specific populations on July 1 of the midyear of the five-year calendar periods (1940-1944, etc.). They were based on the actual counts of the April 1 decennial censuses for 1940, 1950, 1960, and 1970.[13-18] Linear interpolations of the decennial censuses were made to determine the midpoint populations until 1970. July 1, 1972 and 1975 populations were based on the Bureau of Census estimates.[19]

Rate – For each race-, sex-, and age-specific strata, the total number of deaths over each five-year calendar period were divided by five to obtain an annual average. These averages were divided by the corresponding midpoint populations for the calendar period.

Deaths occurring in Alaska and Hawaii were not included in U.S. totals until 1960. Therefore, mortality rates for the 1950s were based on population estimates interpolated between the 1950 census and the 1960 census after subtracting Alaska and Hawaii.[18] However, mortality rates in the 1960s were based on population estimates interpolated from the 1960 census as recorded (i.e., including Alaska and Hawaii). The 1975 mortality rates were used for the entire five-year period 1975-1979.

In addition to U.S. mortality rates, other mortality/morbidity rates may be used with some modification of the program. Directly standardized risk ratios are not output from the LTAS; however, all data necessary for such calculations are available from a standard LTAS run.

Verification

Comparison of the U.S. mortality rates used for the NIOSH system and the rates calculated independently for a system developed at another institution[8] was performed as a second test of their accuracy. The comparison was age- and calendar time-specific. For the cause of death categories with the same ICD groupings, there were only minor differences, usually well under 5%. Some of the larger rate differences were attributable to differences in population estimates for the very young and very old.

Similarly, the distribution of PYAR and expected deaths over age, time, duration of employment, and time since first employment (latency) were verified. A test data check provided for users of the comparison system was run through both systems. There were minor differences between the systems in expected cause-specific deaths, but they were attributable to the previously discussed rate differences. The expected deaths for total mortality differed by only 0.5%. The total person-years were even closer; the difference was only 0.05%.

Output

A file of persons passing the study selection criteria and included in the analysis may be obtained. All persons rejected from the analysis or edited and the reason are also listed. The PYAR, observed deaths, and expected deaths are displayed by all the following: (1) any two of the following three variables: latency, duration of exposure, or dose (Tables 4 and 5); (2) age by calendar period for each strata of the matrix of item 1 above (Tables 2 and 6). In addition, PYAR are also displayed overall by age by calendar period.

Table 4 – Example of PYAR by Dose and Latency Period for Radiation Workers

	Dose, rem							
Latency	0.001-0.030	0.030-0.100	0.100-0.500	0.500-1.00	1.00-5.00	5.00-15.0	≥15.0	Total
1 day - 1 yr	3,372.18	1,514.23	1,447.97	462.95	486.39	1.74	0.00	7,285.48
1 - 3 yr	2,997.05	3,283.51	3,754.05	1,409.33	2,613.37	316.54	0.29	14,374.16
3 - 5 yr	2,148.68	2,569.49	3,641.29	1,446.21	3,006.27	905.25	24.55	13,741.78
5 - 10 yr	3,639.39	5,018.42	8,166.68	3,584.27	7,661.98	3,190.38	766.47	32,027.61
10 - 15 yr	1,802.12	2,582.80	5,183.03	2,562.32	5,589.56	2,642.48	1,268.13	21,630.48
15 - 20 yr	788.59	877.36	1,831.75	914.02	2,256.96	1,214.91	651.25	8,534.87
≥20 yr	62.00	114.50	112.78	39.16	154.04	79.01	67.47	628.98
Total	14,810.03	15,960.35	24,137.57	10,418.28	21,768.60	8,350.33	2,778.20	98,223.37

Table 5 – Example of Observed and Expected Deaths by Dose and Latency Period for Radiation Workers

Latency	All Cancers, Dose, rem 0.001-0.030	0.030-0.100	0.100-0.500	0.500-1.00	1.00-5.00	5.00-15.0	≥15.0	Total
1 day - 1 yr	...	...	...	...	...	...	...	**0**
	3.4587	1.4891	1.223	0.3268	0.3694	0.0017		6.8682
1 - 3 yr	3*	4	4	3	3	...	...	**17**
	3.8776†	4.1632	4.2989	1.3605	2.2550	0.3148	0.0003	16.2705
3 - 5 yr	5	3	...	1	2	3	...	**14**
	3.6459	4.2294	5.3191	1.8165	3.2809	1.0021	0.0234	19.3174
5 - 10 yr	10	12	19	4	10	5	...	**60**
	8.9632	11.8025	17.7714	6.9992	12.1354	5.0677	1.1529	63.8926
10 - 15 yr	6	11	18	11	20	5	3	**74**
	7.8686	9.8746	18.1438	8.4563	14.9293	6.7936	3.1793	69.2458
15 - 20 yr	5	2	5	7	9	4	3	**35**
	4.8279	4.7952	9.4143	4.3957	8.9013	4.4298	2.5053	39.2699
≥ 20	...	...	...	...	1	...	...	**1**
	0.5526	0.7328	0.6201	0.1670	0.8956	0.3534	0.3328	3.6546
Total	**29**	**32**	**46**	**26**	**45**	**17**	**6**	**201**
	33.1948	37.0870	56.7901	23.5223	42.7671	17.9634	7.1943	218.5194

* Observed deaths
† Expected deaths

Table 6 – Example of observed (OB) and Expected (EX) Deaths by age for Selected Causes of Death in Radiation Workers
Jan. 1, 1965 to Dec. 31, 1969 Dose = 0.001 to 0.030 rem Latency = 5 to 10 years

Age	Cause of Death* #04 MN of Respiratory System (160-164) OB	EX	#05 MN of Male Genital Organs (177-179) OB	EX	#06 MN of Urinary Organs (180-181) OB	EX	#07 MN of Other and Unspecified Sites (Major) (156B, 165 190-199) OB	EX
15-19	0	0.0000	0	0.0000	0	0.0000	0	0.0000
20-24	0	0.0000	0	0.0000	0	0.0000	0	0.0000
25-29	0	0.0002	0	0.0009	0	0.0001	0	0.0017
30-34	0	0.0012	0	0.0009	0	0.0002	0	0.0029
35-39	0	0.0080	0	0.0018	0	0.0011	0	0.0092
40-44	0	0.0317	0	0.0024	0	0.0041	0	0.0196
45-49	0	0.1029	0	0.0047	0	0.0135	0	0.0486
50-54	0	0.2138	0	0.0111	0	0.0281	0	0.0777
55-59	2	0.3024	0	0.0236	0	0.0407	0	0.0973
60-64	0	0.3285	0	0.0441	0	0.0475	0	0.0938
65-69	0	0.3659	0	0.0828	0	0.0630	2	0.0989
70-74	0	0.1465	0	0.0575	0	0.0329	0	0.0434
75-79	0	0.0062	0	0.0046	0	0.0019	1	0.0023
80-84	0	0.0000	0	0.0000	0	0.0000	0	0.0000
85+	0	0.0000	0	0.0000	0	0.0000	0	0.0000
Total	**2**	**1.5074**	**0**	**0.2344**	**0**	**0.2332**	**3**	**0.4953**

* Major NIOSH code

Any of the 89 causes or the major groupings listed in Table 3 may be requested, although a maximum of 29 of these causes can be listed per computer run. Results for all causes, all malignant neoplasms, and residual causes (those not specified to be listed in the computer run) are always printed.

Summary

A PYAR LTAS of computer programs has been developed, refined, and tested at NIOSH. Although the NIOSH LTAS uses more core space and central processing unit (CPU) time and is more difficult to install than other available modified life-table programs,[6-8] it has the following advantages:

1. Comprehensive data editing, and automatic deletion or modification of the data before analysis.
2. Option to use either ICD rules and codes in effect at the time of death, or rules in effect at the time of death but with codes from a single standard ICD revision.
3. Age-, calendar-time-, race-, and sex-specific mortality rates for the United States for 89 cause-of-death categories.
4. Automatic assignment of a cumulative dose to a specific person-year based on input of temporally specific exposure data, characterized by person or by work area.
5. Identification of any combination of specific departments and jobs as "exposure" areas, and a corresponding exposed subcohort analyzed.
6. Simultaneous examination of PYAR, observed deaths, and expected deaths over any two of the following three variables: latency (time since first exposure); duration of employment in exposed areas; and dose, measured as duration of exposure multiplied by an exposure rate. Results may be further examined by age and calendar time within each of these strata.

Technical Note

The NIOSH LTAS is a series of nine major system programs, supported by 11 auxiliary programs. All programs are written in PL/I language, thus they may be difficult to install on operating systems that are not IBM compatible. The main system programs are linked by job control language, with sorting between several programs accomplished by the user's system sort utility. The job control language described in the documentation is for IBM computers; if the system is to be used on another make of computer, the user will have to develop appropriate control statements.

A large computer (IBM 360 or its equivalent) is needed because a minimum of 320 K bytes of main storage is recommended. For run control, a card or interactive input device is required; and for data input and temporary storage between programs, tape drives and/or direct access devices (disk, mass storage) are required.

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