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THE COST OF MEDICAL COMPUTING

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Actual and reported implementation costs for four successful medical computing systems are presented. Actual costs were consistently 2½ times greater than reported costs. Although hardware/software costs accounted for a large part of reported costs, data definition/system analysis, and not hardware costs, accounted for 60-75% of actual costs. A method for projecting actual costs, at least for experimental, microcomputer-based, patient care information systems is presented.

Introduction. When reporting the successful implementation of a new medical computing system, it is customary to include estimates of the time and/or monetary costs involved. There is growing recognition that reported costs, even for similar-type projects, may be quite variable and may not necessarily serve as a good basis for projecting new-project costs. We have reported four, successful, computerized Newborn Intensive Care Unit (NICU), patient care information systems, including, to some extent at least, time and cost involved in their research, development and implementation (R&D).[1-4] We reexamined and compared detailed actual and reported (apparent) R&D costs for three experimental, prototype systems and a commercial, production system in an attempt to develop a method for projecting actual R&D costs for new patient care information systems.

Description of Systems. All four NICU patient care information systems examined shared similar databases and outputs. Approximately 400 items of demographic and medical information for each patient are captured onto respective computer systems through use of customized, site-specific forms and a project coordinator. One to two page, patient admission notes, discharge summaries, interim/off-service notes and/or letters to referring and follow-up physicians and agencies are automatically computer-produced from recorded patient data. Data are then accessable to clinicians and administrators for evaluation and research purposes using a highly-developed, generalized query program.

The systems differed mainly in hardware/software configuration. Three experimental systems included a keypunch, batch, IBM 370-based system written in COBOL[1] (Loma Linda University, Loma Linda, California), an online, time-shared IBM 370-based system written in COBOL, PL1 and MARK IV[2] (Loma Linda University, Loma Linda, California), and an online, dedicated, LSI-11-based, microcomputer system written in FORTRAN[3] (University of Utah, Salt Lake City, Utah). The commercial system used an online, dedicated, LSI-11/23-based microcomputer system and was written in FORTRAN IV[4] (Cetus Systems Corporation, Salt Lake City, Utah).

Materials and Method. Apparent times spent by contributors on each of the four systems were obtained from previous publications,[1-4] unpublished data used in preparing these publications and unpublished project status reports.

Apparent salary costs were calculated from apparent times. Apparent salaries generally did not include benefits. Office, secretarial, general and special services and supplies usually accompanying a salaried position were included, when indicated, in miscellaneous supplies. Generally speaking, salary costs were not reported if less than 20% of a contributor's average, daily time was spent on the project. Apparent equipment/supply costs were obtained in a manner similar to apparent times.

Actual times (work, in man-months) were obtained by detailed retrospective questioning of original contributors.

Actual salaries were calculated from actual times (work), and included benefits, office, secretarial, general and special services and supplies. Actual equipment/supply costs were obtained in a manner similar to actual times. Actual and apparent costs were then adjusted for 1982 for comparison purposes.

Results. Actual and apparent R&D time and costs for the experimental, microcomputer system are detailed in Table 1. Actual and apparent costs for the other systems are summariezed in Tables 2 and 3.

Total actual costs for experimental systems were consistently 2½ times greater than apparent costs.

For the experimental, microcomputer system, hardware costs accounted for less than 10% of total actual costs, but almost 30% of total apparent costs. Over 60% of total actual costs were attributable to data definition/system ananalysis. Hardware and software costs were not as easily separated for the other experimental systems due to the complex nature of their hardware/software configurations. However, data definition/system analysis costs represented 76% and 65% of total actual costs respectively.

The total actual cost of the commercial, microcomputer system was approximately 2 times greater than the total actual cost of the ex-

TABLE 1- Actual costs, actual time (work), apparent costs, and apparent time for research, development and implementation of an experimental, microcomputer-based, NICU patient care information system (University of Utah, 1982).

ITEM/CATEGORY	ACTUAL COST	ACTUAL WORK	APPARENT COST	APPARENT TIME
Hardware				
Equipment	$12,000	>0.1 man-months	$12,000	1.0 elapsed months
Technician ($60/hr)	5,200	0.5	5,200	0.5
Miscellaneous supplies	2,500	n/a	0	n/a
Subtotal	$19,700	0.5 man-months	$17,200	1.0 elapsed months
Software				
Analyst/programmer ($60/hr)	52,002	5.0	13,867	12.0
Medical consultant ($58/hr)	9,707	1.0	0	10.0
Project coordinator ($18/hr)	624	0.2	0	6.0
Documentation printing	500	>0.1	0	>0.1
Miscellaneous supplies	1,500	n/a	0	n/a
Subtotal	$64,333	6.2 man-months	$13,867	12.0 elapsed months
Data Definition/system analysis				
Analyst/programmer ($60/hr)	35,361	3.4	9,430	12.0
Medical consultant ($58/hr)	69,891	7.2	17,473	12.0
Project coordinator ($18/hr)	3,120	1.0	0	5.0
Site clinicians (4@ $58/hr)	6,795	0.7	0	4.0
Site nurses (2@ $19/hr)	659	0.2	0	4.0
Site administrators (2@ $30/hr)	1,560	0.3	0	2.0
Forms printing	2,500	>0.1	2,500	>0.1
Miscellaneous supplies	1,000	n/a	0	n/a
Subtotal	$120,886	12.8 man-months	$29,403	12.0 elapsed months
TOTALS	$204,919	19.5 man-months	$60,470	25.0 elapsed months

NOTE: Salaries/costs in dollars-US. Salaries indicated include benefits and office, secretarial, general and special services and supplies usually associated with service. Elapsed times are not necessarily additive.

perimental, microcomputer system. Total apparent costs for the commercial system were not available for comparison at the time of this publication.

Discussion. Our data suggest that for our teams and host-sites, a striking sidparity existed between apparent, reported and actual R&D costs. The amount of disparity compared to actual cost was remarkably similar for all three experimental systems, irregardless of host-site. This disparity probably corresponds to a host-site's ability to redistribute, or "bury" indirect and direct costs from within. Our host-sites, except for the commercial system, were all university-affiliated, and could easily

TABLE 2- Actual costs, by category, for research, development and implementation of three differently-configured, experimental and commercial, NICU patient care information systems (Loma Linda University, University of Utah, Cetus Systems Corporation, 1982).

CATEGORY	EXPERIMENTAL: KEYPUNCH, BATCH, IBM 370	EXPERIMENTAL: ONLINE, TIME-SHARED, IBM 370	EXPERIMENTAL: ONLINE, DEDICATED, MICROCOMPUTER	COMMERCIAL: ONLINE, DEDICATED, MICROCOMPUTER
Hardware	$24,575	$59,308	$19,700	$34,900
Software	77,006	110,574	64,333	142,047
Data definition/system analysis			120,886	183,393
TOTALS	$101,581	$169,882	$204,919	$360,340

NOTE: Costs in dollars-US. Commercial costs include prototype and conversion costs. Combined hardware/software costs include add-on hardware/software costs only. Keypunch, batch, IBM 370 system does not include generalized query function.

TABLE 3- Apparent costs, by category, for research, development and implementation of three differently-configured, experimental and commercial, NICU patient care information systems (Loma Linda University, University of Utah, Cetus Systems Corporation, 1982).

	EXPERIMENTAL			COMMERCIAL
CATEGORY	KEYPUNCH, BATCH, IBM 370	ONLINE, TIME-SHARED, IBM 370	ONLINE, DEDICATED, MICROCOMPUTER	ONLINE, DEDICATED, MICROCOMPUTER
Hardware	$5,492	$18,093	$17,200	not available
Software			13,867	not available
Data definition/system analysis	34,151	48,762	29,403	not available
TOTALS	$39,643	$66,855	$60,470	not available

NOTE: Costs in dollars-US. Commercial costs include prototype and conversion costs. Combined hardware/software costs include add-on hardware/software costs only. Keypunch, batch, IBM 370 system does not include generalized query function

have accomplished this between various departments and divisions participating in the project. Detailed apparent costs for the commercial system done by our team at a non-university-affiliated site were unfortunately not available for comparison at the time of this publication.

For the experimental, microcomputer system, combined hardware/software costs represented almost 50% of total apparent cost and consumed well over 50% of apparent time. If the entire cost of an IBM 370 facility is included in figures for the IBM 370-based systems, hardware/software time/costs would constitute well over 90% of total apparent time/cost. It is not surprising then, that hardware has been regarded by many as the single most important consideration in any medical computing project. Actual time/cost figures for our experimental and commercial microcomputer systems, however, do not support this viewpoint. Less than 10% of total actual cost and 3% of total actual time (work) were attributed to hardware. Conversely, almost 60% of total actual cost and 65% of total actual time (work) were attributed to data definition/system analysis. Data definition/system analysis is not only the first, but, time/cost-wise, also the single most important consideration in any medical computing effort. If add-on hardware/software costs rather than the cost of the entire IBM 370 facility are used, similar observations would also apply for our two experimental, IBM 370-based systems.

For our experimental, microcomputer system, actual and apparent hardware costs were remarkably similar. For this reason, it may be possible to project, to some extent at least, various actual R&D costs from apparent site or vendor hardware estimates. By multiplying apparent hardware estimates by 3, 6 and 10 one can obtain reasonable (conservative) projections for actual software, data definition/system analysis and total costs respectively. It should be noted that industrial-quality microcomputer systems were utilized for our projects. The wide variability of non-industrial-quality hardware and software would make projection of actual home, hobby or personal microcomputer system R&D costs quite difficult. Actual hardware costs for the IBM 370-based systems were inseparable from software costs, and taken together, actual and apparent hardware/software costs were quite dissimilar. For this reason, projections of actual costs for such systems, using the above formula, would again be difficult to apply.

Actual R&D costs for the commercial, microcomputer system were considerably higher than for the experimental, microcomputer system. Actual software costs were disproportionately high, representing change to table-driven programs and more easily supported and maintained software in general. If the costs of incorporation, marketing, sales and other activities commonly associated with commercial ventures were included, actual costs would probably triple.

While most medical computing projects reported in the literature involve implementation of an experimental or commercial system, a much more common type of medical computing project would involve re-implementing some version of a successful, reported, experimental system at another site. Actual and apparent costs for implementing a "copy" of one of our experimental systems at another site were not available at the time of this publication. However, our experience suggests that an even greater disparity may exist between actual and apparent costs, and that total actual cost may, in many instances, equal or exceed those of the parent system. When this happens, much of the disparity would probably be attributable to costs of "customizing" the parent database for application at the new site, and would therefore appear as data definition/system analysis rather then hardware cost.

A less common, but increasingly important type of medical computing project would involve re-implementing a copy of a successful, reported, commercial system at another site. When purchased and implemented as a "package" (turnkey), such as is done with our commercial system, total actual cost may be ¼ or less than an experimental system, and would result in far less risk of failure. This mode of disseminating medical computing technology is, despite initial cost, to be highly preferred.

Conclusion. We re-examined and compared actual and apparent implementation costs for four, differently-configured, computerized, NICU

patient care information systems. Three were experimental prototypes and one a commercial, production system. Actual costs were consistently 2½ times greater than apparent, reported costs. Although hardware/software costs figured prominently in total apparent cost, data definition/system analysis, and not hardware costs, accounted for the majority of actual, time/monetary cost. A method for estimating actual component and total costs, at least for an experimental, industry-standard, microcomputer system was presented. Although definitive data were not available at the time of this publication, it is the authors' opinion that the actual cost of implementing "copies" of experimental systems, in many instances, equals or exceeds those of their parent systems. Turnkey copies of commercial systems alone afford a consistent, easily-determined cost-savings to subsequent recipient sites. We are now examining, in detail, specific hardware, software and data definition/system analysis factors which are associated with successful copying of parent systems.

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