

CALL CENTERS (CENTRES)

Research Bibliography with Abstracts

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Chronologically Ordered within Research Fields

Note to the Reader: The present list is undoubtedly biased in favour of my own research interests. I would therefore appreciate, and thank in advance, any feedback that points to missing sources or references. In particular, authors of qualified papers are encouraged to send their pre- or re-prints to Jody Bar-On (the reference librarian in charge), either electronically (jodyb@tx.technion.ac.il) or as hard copies (Library of Industrial Engineering and Management, Technion, Haifa 32000, Israel.)

Efforts will be made to maintain the document complete and updated. We shall perhaps also create alternative versions (for example, alphabetical list), expand the scope (e.g. accommodate contact centers, when enough research accumulates) or simply improve usefulness (e.g. add commentary). Indeed, readers may wish to help with the creation of such alternative versions. In this case, a latex-source of the document can be obtained from the author, under a single condition—that the outcome is *publicly available* (both source and postscript/pdf/...).

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Introduction [†]

Call center is the common term for a telephone-based human-service operation. A call center provides *tele-services*, namely services in which the customers and the service agents are remote from each other. The agents, who sit in cubicles, constitute the physical embodiment of the call center. With numbers varying from very few to many hundreds, they serve customers over the phone, while facing a computer terminal that outputs and inputs customer data. The customers, possibly up to thousands at a given instant, are only virtually present: they are either being served or they are delayed in, what we call, *tele-queues*. Those waiting to be served share a phantom queue, invisible to each other and the agents serving them, waiting and accumulating impatience until one of two things happens – an agent is allocated to serve them (through a supporting software), or they abandon the tele-queue, plausibly due to impatience that has built up to exceed their anticipated worth of the service.

Contact centers are the contemporary successors of call centers. In addition to phone services, they interface with customers via the internet, email, chat and fax. Call or contact centers are the preferred and prevalent way for many companies to communicate with their customers. (Fortune-500 companies are estimated to operate, on average, 30 call centers each.) The call center industry is thus vast, and rapidly expanding in terms of both workforce and economic scope. For example, it is estimated that 70% of all customer-business interactions occur in call centers and that \$700 billion in goods and services were sold through call centers in 1997. These figures have been expanding 20% annually. Three percent of the U.S. working population is currently employed in call centers. This amounts to 1.55 million agents, and some estimates actually go up to 6 million.

The modern call center is a complex socio-technical system. Some view call centers as the *business frontiers* but others as the *sweat-shops* of the 21st century. Either way, within our service-driven economy, telephone services are now unparalleled in scope, service quality and operational efficiency. Indeed, in a large best-practice call center, hundreds of agents can cater to thousands of phone callers per hour; agent utilization levels can average between 90% to 95%; no customer encounters a busy signal and, in fact, about half of the customers are answered immediately; the waiting time of those delayed is measured in seconds, and very few abandon while waiting.

The design of the modern call center, and the management of its performance, surely must be based on sound scientific principles. This is manifested by a growing body of academic multi-disciplinary research, devoted to call centers, and ranging from Mathematics and Statistics, to Operations Research, Industrial Engineering, Information Technology and Human Resource Management, all the way to Psychology and Sociology. My goal here is to “describe” this research through a list of abstracts, as complete and updated a list as possible. The abstracts originate in papers that are either directly related to or have been judged potentially helpful for *academic research* on call centers.

[†]The text is adapted from “Empirical Analysis of a Call Center”, by A. Mandelbaum, A. Sakov, S. Zeltyn, Technion Technical Report, 2001; and from “Introduction to Mathematical Models of Call Centers”, preprint by G. Koole and A. Mandelbaum, 2001.

I Operations Research, Operations Management

1. Erlang, A.K., On the rational determination of the number of circuits. In *The Life and Works of A.K. Erlang*, E. Brockmeyer, H.L. Halstrom and A. Jensen (eds.). Copenhagen: The Copenhagen Telephone Company, 1948.
2. Edie, Leslie C. Traffic delays at toll booths, *Journal of the Operations Research Society of America*, 2 (2), 1954, 107–138.

Abstract. The collection of vehicular tolls at Port Authority tunnels and bridges is one of the most important operations conducted by the police personnel. More than 250 traffic officers are utilized, and the payroll costs exceed a million dollars annually. In staffing its toll plazas, the Port Authority attempts to handle traffic with a minimum number of toll collectors consistent with uniformly good service to the public and properly spaced relief periods for the toll collectors. This requires finding the level of traffic delays that gives the best compromise between the conflicting objectives of economy and service. In the past, the number of toll collectors provided for operating a toll plaza was determined by judgment based on experience and a rule-of-thumb work standard which had not been related to service. Judgment was likewise used to allocate manpower and control the number of toll booths opened at any time. This method resulted in patron delays observed to vary from 2 to 50 sec. The tools of probability theory provide methods for dealing with the problem in quantitative terms. They enable determination of the relations between traffic volumes, number of toll booths, and grade of service. With this knowledge, the optimum grade of service can be established in a logical manner and the number of toll booths required at any time of day can be specified in advance. Use of this method permitted savings in toll collection expenses and better service.

(Appears also in Section II.)

3. Edie, Leslie C. Review of Port of New York Authority study. Case Histories Five Years After—A Symposium, 1959, 263–277.
4. Larson, Richard C. Improving the effectiveness of New York City's 911, in *Analysis of Public Systems*, Alvin W. Drake, Ralph L. Keeney and Philip M. Morse (Eds.), Cambridge, M.I.T. Press, 1972, Chapter 9: 151–180.

Abstract. This chapter summarizes the results of a one-month operational study of police emergency telephone operations in the central communications room of the New York City Police Department. The study serves as an example of elementary quantitative modeling to improve an ongoing operation.

5. Larson, Richard C. A hypercube queuing model for facility location and redistricting in urban emergency services, *Computing & Operations Research*, 1, 1974, 67–95.

Abstract. This paper develops computationally efficient algorithms for studying the analytical behavior of a multi-server queuing system with distinguishable servers. The model is intended

for analyzing problems of vehicle location and response district design in urban emergency services, includes interdistrict as well as intradistrict responses, and allows computation of several point-specific as well as area-specific performance measures.

6. Segal, M. The operator-scheduling problem: A network-flow approach, *Operations Research*, 22 (4), 1974, 808–823.

Abstract. The number of telephone operators required on duty at switchboards fluctuates widely during the day. Work periods of operators are defined by start and end times of tours and by the timing of break and relief periods within tours. This paper proposes a method for determining the number of operators assigned to tours and their corresponding timing of breaks and reliefs; it relies on various network flow formulations. An example application of the method is presented.

Keywords: Network analysis, Personnel, Scheduling, Telephone operators, Network flow formulations, Operator scheduling

7. Buffa, E.S., M.J. Cosgrove and B.J. Luce. An integrated work shift scheduling system, *Decision Sciences*, 7, 1976, 620–630.

Abstract. An integrated work shift scheduling system is developed and applied in the scheduling of 2600 telephone operators in 43 locations of the General Telephone Company of California. The system involves the forecasting of calls on a half-hourly basis, the conversion to operator requirements, the scheduling of tours by a heuristic algorithm, the assignment of operators to tours, and the operation of the system.

8. Henderson, W.B. and W.L. Berry. Heuristic methods for telephone operator shift scheduling: an experimental analysis, *Management Science*, 22 (12), 1976, 1372–1380.

Abstract. Heuristic methods are presented for scheduling telephone traffic exchange operators to meet demand that varies over a 24-hour operating period. Two types of heuristics are described: (1) for determining the work shift types to be considered in preparing an operator shift schedule and (2) for constructing an operator shift schedule from a given set of work shift types. These heuristics are evaluated both in terms of solution quality and computational efficiency, using actual operating data.

Keywords: Telephone operator shift scheduling, Computational efficiency, Heuristic methods, Linear programming

9. Segal, M. and D.B. Weinberger. Turfing, *Operations Research*, 25 (3), 1977, 367–386.

Abstract. We discuss both the analytical methods and some implementation considerations involved in enriching the job of telephone repairpersons/installers by letting each take full responsibility for all jobs within his own territory, or “turf”. For the problem of carving the region into turfs, which bears a great similarity to the political districting problem, we use a highly interactive software system at the heart of which is a heuristic algorithm combining shortest

path, minimum cost flow, and enumerative techniques. We also discuss a stochastic model of the work backlog in a turf, based on the variability of the demand for service. Preliminary experience seems to indicate that this mode of operation is both workable and desirable. It should therefore be noted that, while the discussion takes place in the context of telephone repairpersons/installers, it is of considerably wider applicability.

10. Gaballa, Adel and Wayne Pearce. Telephone sales manpower planning at Qantas, *Interfaces*, 9 (3), 1979, 1–9.

Abstract. When the traditional procedure for planning annual manpower requirements for the telephone sales reservation offices of Qantas Airways was replaced by a model utilizing queueing and integer linear programming techniques, savings in excess of US\$235,000 were realized in staff reductions over a two-year period, and investigation into applications in several other Qantas service areas continues. Relationships of staff size to waiting time and service time are also evaluated.

11. Halfin, Shlomo and Ward Whitt. Heavy-traffic limits for queues with many exponential servers, *Operations Research*, 29 (3), 1981, 567–587.

Abstract. Two different kinds of heavy-traffic limit theorems have been proved for s -server queues. The first kind involves a sequence of queueing systems having a fixed number of servers with an associated sequence of traffic intensities that converges to the critical value of one from below. The second kind, which is often not thought of as heavy traffic, involves a sequence of queueing systems in which the associated sequences of arrival rates and numbers of servers go to infinity while the service time distributions and the traffic intensities remain fixed, with the traffic intensities being less than the critical value of one. In each case, the sequence of random variables depicting the steady-state number of customers waiting or being served diverges to infinity but converges to a nondegenerate limit after appropriate normalization. However, in an important respect neither procedure adequately represents a typical queueing system in practice because in the (heavy-traffic) limit an arriving customer is either almost certain to be delayed (first procedure) or almost certain not to be delayed (second procedure). Hence, we consider a sequence of $(GI/M/s)$ systems in which the traffic intensities converge to one from below, the arrival rates and the numbers of servers go to infinity, but the steady-state probabilities that all servers are busy are held fixed. The limits in this case are hybrids of the limits in the other two cases. Numerical comparisons indicate that the resulting approximation is better than the earlier ones for many-server systems operating at typically encountered loads.

12. Smith, D.R. and W. Whitt. Resource sharing for efficiency in traffic systems, *Bell System Technical Journal*, 60 (1), 1981, 39–55.

Abstract. Experience has shown that efficiency usually increases when separate traffic systems are combined into a single system. For example, if Group A contains 10 trunks and Group B 8 trunks, there should be fewer blocked calls if A and B are combined into a single group of 18 trunks. It is intuitively clear that the separate systems are less efficient because a call can be blocked in one when trunks are idle in the other. Teletraffic engineers and queueing theorists

widely accept such efficiency principles and often assume that their mathematical proofs are either trivial or already in the literature. This is not the case for two fundamental problems that concern combining blocking systems (as in the example above) and combining delay systems. For the simplest models, each problem reduces to the proof of an inequality involving the corresponding classical Erlang function. Here the two inequalities are proved in two different ways by exploiting general stochastic comparison concepts: first, by monotone likelihood-ratio methods and, second, by sample-path or ‘coupling’ methods. These methods not only yield the desired inequalities and stronger comparisons for the simplest models, but also apply to general arrival processes and general service-time distributions. However, it is assumed that the service-time distributions are the same in the systems being combined. This common-distribution condition is crucial since it may be disadvantageous to combine systems with different service-time distributions. For instance, the adverse effect of infrequent long calls in one system on frequent short calls in the other system can outweigh the benefits of making the two groups of servers mutually accessible.

Keywords: Queueing theory, Telephone traffic efficiency, Traffic systems, Queueing, Blocking systems, Delay systems, Classical Erlang function, Stochastic comparison, Monotone likelihood ratio, Sample path, Coupling, Arrival processes, Service-time distributions, Telephone traffic

13. Sze, David Y. A queuing model for telephone operator staffing, *Operations Research*, 32 (2), 1984, 229–249.

Abstract. In the Bell Telephone System, service criteria for telephone operator staffing are based on target delays. The goal is to ensure that customers receive good levels of service during normal load times and to protect against very poor service during peak load periods. The system’s staffing problem cannot be solved using standard queuing models because of: 1. the large number of servers involved, 2. bimodal service time distributions, 3. nonstationarity of customer arrivals, 4. customer abandonment and reattempts for service, and 5. nonpreemptive priority rules for service. Therefore, a new queuing model was developed to generate staffing tables for each operating system and range of service times per customer. The tables specify the number of servers required to meet given load levels under average delay criteria, based on load forecasts derived from historical data, usage trends, and traffic growth patterns. The staffing tables are then used to arrange individual operators’ schedules to meet service requirements per half hour.

Keywords: 683 nonstationary inputs, abandonments, and reattempts, 693 $M/G/c$ queues with large (100–300) server teams, 698 nonabsolute priorities for nonhomogeneous traffic

14. Whitt, W. Heavy-traffic approximations for service systems with blocking, *AT&T Bell Laboratories Technical Journal*, 63 (5), 1984, 689–708.

Abstract. Develops approximations for the blocking probability and related congestion measures in service systems with s servers, r extra waiting spaces, blocked customers lost, and independent and identically distributed service times that are independent of a general stationary arrival process (the $G/GI/s/r$ model). The approximations are expressed in terms of the normal distribution and the peakedness of the arrival process. They are obtained by applying previous heavy-traffic limit theorems and a conditioning heuristic. There are interesting connec-

tions to Hayward's approximation, generalized peakedness, asymptotic expansions for the Erlang loss function, the normal-distribution method, and bounds for the blocking probability. For the case of no extra waiting space, a renewal arrival process and an exponential service-time distribution (the GI/M/s/O model), a heavy-traffic local limit theorem by A.A. Borovkov implies that the blocking depends on the arrival process only through the first two moments of the renewal interval as the offered load increases. Moreover, in this situation, Hayward's approximation is asymptotically correct.

Keywords: Probability, Queueing theory, Telecommunication traffic, Service systems, Blocking, Blocking probability, Congestion measures, Servers, Waiting spaces, G/GI/s/r model, Heavy traffic limit theorems, Conditioning heuristic, Hayward's approximation, Peakedness, Asymptotic expansions, Erlang loss function, Normal distribution method, Exponential service time distribution, GI/M/s/O model, Arrival process

15. Mabert, V.A. Short interval forecasting of emergency phone call (911) work loads, *Journal of Operations Management*, 5 (3), 1985, 259–271.

Abstract. There has been a growing emphasis over the last 5–10 years on improving productivity in the service sector of the US economy. Effective scheduling of the workforce in these organizations requires good estimates of demand, which may show substantial variations between days for certain times of the year. An examination is made of the use of 6 different forecasting methods for predicting daily emergency call workloads for the Indianapolis Police Department's communications area: 1. one-year lag, 2. zero/one regression, 3. multiplicative/additive, 4. zero/one with adjustment, 5. multiplicative/additive with adjustment, and 6. autoregressive, integrated moving average intervention. The research suggests that there are clearly significant differences in performance for the 6 models analyzed. Simple modeling approaches can perform well in the complex environments found in many service organizations. Special tailoring of the forecasting model is required for many service firms. Historical data patterns for these organizations tend to be more involved than just trend and seasonal elements.

Keywords: Studies, Police, Mathematical models, Implementations, Forecasting techniques, Emergencies, Departments, Communications, Case studies
(Appears also in Section II.)

16. Hoffman, K.L. and C.M. Harris. Estimation of a caller retrial rate for a telephone information system, *European Journal of Operational Research*, 27 (2), 1986, 207–214.

Abstract. As part of a continuing study of the usage of its Taxpayer Service Telephone Network, the US Internal Revenue Service wished to determine more accurate methods for demand measurement. It has long been recognized that the total number of calls coming into such a busy telephone system overestimates the actual number of distinct callers. The service had previously estimated its real demand by adding ($\frac{1}{3}$) of both the number of blocked or overflow calls and the number of abandonments to the total actually answered. The thrust of this current study then was to develop an accurate statistical method for providing a more objective formula for this true demand, which turns out to be equivalent to estimating the probability of retrial by blocked and abandoned callers.

The major result which has come from this effort is that the average daily retrial percentage taken across location and time of year seems to be moderately stable about a mean value of 69%, somewhat dependent on both location and (particularly) time of year. The value is consistently higher during periods close to important filing milestones and lower otherwise. We show this to mean that, whenever a rate of 69% is used, the actual demand would be estimated by augmenting completed loads by 31% of the number of blocked and abandoned calls for the period of concern.

Keywords: Communications, Queues, Stochastic processes, Operations research, Statistics, Telephone systems, Caller retrial rate, Taxpayer service telephone network, US Internal Revenue Service, Statistical method

17. Harris, C.M., K.L. Hoffman and P.B. Saunders. Modeling the IRS telephone taxpayer information system, *Operations-Research*, 35 (4), 1987, 504–523.

Abstract. The Internal Revenue Service (IRS) toll-free, nationwide telephone system provides prompt tax-information assistance. In 1986, the IRS processed 37.8 million calls from taxpayers at 32 answering sites. This paper documents a critical review of the IRS approach to allocating its staff and equipment. The authors built a simulation-based model to test various allocation policies for deploying IRS resources. The simulation study included detailed sensitivity analysis of key network variables, and showed the feasibility of modeling a typical IRS location as a multiserver loss/delay queue with retrial and reneging. The second phase of this effort therefore centered around developing a prototype probabilistic model for determining the most effective way of providing service at reasonable levels and at minimum cost. The resulting model allows the IRS to determine from tables the best configuration of people and telephone lines for any expected levels of incoming traffic. In addition, the authors provided flow balance analyses of the underlying feedback queues that permit the IRS to separate their caller streams into fresh and repeat callers, and thus to estimate actual demand for service.

Keywords: Queueing theory, Telephone traffic, Telephone taxpayer information system, Internal Revenue Service, Simulation-based model, Allocation policies, Probabilistic model, Flow balance analyses, Feedback queues, Caller streams

18. Kuhn, Patricia and Thomas P. Hoey. Improving police 911 operations in Washington, D.C. *National Productivity Review*, New York, 6 (2), 1987, 125–134.

Abstract. The 911 operation in Washington, DC, has generated an increasing number of complaints from city officials and residents in recent years. Call handling performance was not satisfactory, with 33% of the calls in 1985 kept waiting and 17% abandoned for lack of response. In 1986, two initiatives were begun to improve 911 operations. New technology, Enhanced 911, was introduced to replace antiquated telephone and call distribution equipment. The 2 foremost features of Enhanced 911 are automatic number identification and automatic location identification. An operations improvement project also was initiated, emphasizing: 1. matching staff deployment with call demand, 2. improving call-handling performance, and 3. improving civilian pay equity. Call-handling performance gains were brought about by: 1. modifying call distributor software to increase call processing efficiency, 2. starting revised employee and supervisor work schedules, and 3. beginning a workstation coverage policy to guarantee constant manning

throughout a shift.

Keywords: Telephone service, Studies, Productivity, Problems, Police, Operations research, Improvements

19. Mok, S.K. and J.G. Shanthikumar. A transient queueing model for business office with standby servers, *European Journal of Operational Research*, 28 (2), 1987, 158–174.

Abstract. Customers call business offices of a telephone company for services and billing information. Mok (“A queueing model for an SL-1 ACD equipped Business Office”, Bell Canada Management Sciences Report no. 1158441 and 1158442, Canada, 1985) considered a business office in which customers are usually serviced by scheduled servers. These scheduled servers are backed up by some standby servers who will answer a call only when the number of calls waiting to be answered is big. Impatient customers may renege. A transient solution to a queueing model is presented that can be used to help a business office manager efficiently determine the optimal numbers of scheduled and standby servers for achieving the designated service objective cost effectively. It is estimated that our model would save each of the 108 Business Office managers of Bell Canada 20 minutes per day. Our tests of the model, using real data from randomly selected days, reveal that the model is about 93% accurate.

Keywords: Queues, Standby servers, Scheduled servers, Reneging customers, Optimisation, Transient queueing model, Business office, Bell Canada

20. Kwan, Stephen K., Mark M. Davis and Allen G. Greenwood. A simulation model for determining variable worker requirements in a service operation with time-dependent customer demand, *Queueing Systems*, 3, 1988, 265–276.

Abstract. In a service operation where worker requirements have to be determined for short scheduling time periods with nonstationary customer demand, the assumptions necessary for applying steady-state solutions to elementary queueing models are usually violated. This paper describes a simulation study of the behavior of such a service operation. The results are compared with the steady-state solutions to a queueing model where individual scheduling time periods are assumed to be independent. It is found that if the system utilization is below a derived maximum value (based on a service level criterion), then the steady-state solutions are robust enough to explain the behavior of the system and can be used to schedule worker requirements.

Keywords: Simulation, Service operations, Worker requirements, Queueing models
(Appears also in Section IX.)

21. Larson, Richard C. Operations research and the services industries. In *Managing Innovation: Cases from the Services Industries*, B.R. Guile and J.B. Quinn (eds.). National Academic Press, 1988, 115–143.
22. Andrews, Bruce H. and Henry L. Parsons. L.L. Bean chooses a telephone agent scheduling system, *Interfaces*, 19 (6), 1989, 1–9.

Abstract. Concerns the development for mail order company L.L. Bean of a computerized procedure for selecting complex large-scale telephone-operator scheduling systems. To assess capability in forecasting work load, setting requisite capacity levels, and generating satisfactory work-shift schedules, cost/benefit analysis was used and the expected penalty costs of lost orders due to understaffing and loaded-wage costs of overstaffing were considered. Queuing theory was used to model customer-call behavior for every hour over 24-hour days, seven days per week, and the results of linear regression, which correlated customer-service level with expected customer abandonment rate, were implemented to estimate the impact on order revenues of telephone-service level.

Keywords: Work load forecasting, Queueing theory, Telephone agent scheduling system, Mail-order company, L.L. Bean, Computerized procedure, Complex large-scale telephone operator scheduling systems, Capacity levels, Work shift schedules, Cost-benefit analysis, Expected penalty costs, Understaffing, Loaded wage costs, Overstaffing, Linear regression
(Appears also in Section VIII.)

23. Green, L. and P. Kolesar. Testing the validity of a queueing model of police patrol, *Management Science*, 35 (2), 1989, 127–148.

Abstract. This paper describes efforts to validate a multiple car dispatch queueing (MCD) model of police patrol operations using New York City data. The MCD model was designed for use in a computer system that has been disseminated to many police departments in the U.S. to help planners allocate patrol cars among precincts. It has also been used to evaluate specific changes in patrol policy in New York. We define validation as a series of hierarchical procedures ranging from tests of mathematical correctness to evaluations of model robustness. We discuss the difficulties and limitations of assessing the validity of a model of a loosely managed system in which human behavior is central and in which controlled experiments cannot be performed. Focusing on specific uses, we conclude that the MCD model is a good although imperfect description of patrol operations in New York and is a potentially useful planning tool for many other urban police departments.

Keywords: Queueing, Validation, Police patrol, Multiple car dispatch queueing model, New York City, Hierarchical procedures, Mathematical correctness, Model robustness, Urban police departments

24. Blake, R.H., S.C. Graves and P.C. Santos. A model for the configuration of incoming WATS lines, *QUESTA*, 7, 1990, 3–21.

Abstract. WearGuard is a direct marketer and retailer of uniforms and work clothes, which relies primarily on phone orders for sales. For this purpose it maintains a series of toll-free “800-number” lines, known as WATS lines, to receive its incoming calls. These lines are of several types, where each type serves a different portion of the country and has a different usage fee. In this paper, we determine how many of each type of WATS lines should be employed. After defining the problem more completely, we develop a queueing model to describe the system and a dynamic program to solve the configuration problem to optimality. The model has been applied to the problem by WearGuard since 1984. We present an example and examine the sensitivity of the solution to variations in various parameters. We validate the model by comparing the

results of this model to other approximate models.

Keywords: Overflow, Telephone traffic, WATS lines, Queueing model, Dynamic program, Sensitivity

25. Feinberg, M.A. Performance characteristics of automated call distribution systems. GLOBE-COM '90: IEEE Global Telecommunications Conference and Exhibition. 'Communications: Connecting the Future'. IEEE, New York, NY, USA, 1990, 415–419.

Abstract. It is shown that choosing appropriate performance characteristics is crucial to the correct sizing of an automated call distribution (ACD) system. The fraction of rejected calls, which is widely considered as the major performance characteristic, should be replaced by the fraction of served clients. The opportunity to measure the fraction of served clients will arise with the introduction of ISDN and SS7. It is argued that the number of access circuits and ACD systems needs to exceed the number of agents by only approximately 10%. Increasing this percentage further leads to tremendous growth in the waiting time without any further significant increase in the fraction of served clients. It is shown that the performance characteristics of the ACD system are very sensitive to parameters that are mostly defined by the nature of the user's business, and are not very sensitive to parameters that are defined by human nature.

Keywords: Telephone system, Automated call distribution, Rejected calls, Performance characteristic, Served clients, Access circuits, Waiting time, ACD system, Human nature

26. Agnihothri, Saligrama R. and Patricia F. Taylor. Staffing a centralized appointment scheduling department in Lourdes Hospital, *Interfaces*, 21 (5), 1991, 1–11.

Abstract. Lourdes Hospital in Binghamton, New York, uses a centralized system to schedule appointments by telephone for outpatients, inpatients, and other ambulatory services. Customer surveys and an increase in customer complaints revealed lengthy delays in answering telephone calls. Using queueing theory to plan optimal staffing levels to meet estimated demand has been successful. Based on the results of a study, staffing patterns were adjusted to more adequately match demand peaks with capacity. It was found that the existing staff and the number of hours they were working was adequate to meet the demand. Supervision was increased to monitor telephone response levels for specific time periods, and non-telephone tasks were assigned and scheduled so as to supplement the required telephone coverage. It was also discovered that low server utilization, in terms of telephone answering, is quite essential to providing a high level of service.

Keywords: USA, Centralized appointment scheduling department, Lourdes Hospital, Binghamton, New York, Queueing model, Optimal staffing levels, MMC approximation

27. Feinberg, M.A. Analytical model of automated call distribution system, Queueing, Performance and Control in ATM. ITC-13 Workshops. *Proceedings of the Thirteenth International Teletraffic Congress*. North-Holland, Amsterdam, The Netherlands, 1991, 193–197.

Abstract. An analytical model of the automated call distribution (ACD) system was developed which allows one to obtain results for systems with possible retries after a busy signal, with an

impatient hang up, and with limitations on the number of access circuits and waiting time. A special iteration algorithm is applied to this model. As the comparison with simulation results shows, this approach allows one to obtain good results.

Keywords: Automated call distribution system, Analytical model, ACD, Busy signal, Access circuits, Waiting time, Iteration algorithm, Simulation results

28. Milito, Rodolfo A., Yonatan Levy and Yair Arian. Dynamic algorithms for distributed queues with abandonments. *Teletraffic and Datatraffic in a Period of Change. ITC-13. Proceedings of the Thirteenth International Teletraffic Congress*. North-Holland, Amsterdam, The Netherlands, 1991, 329–334.

Abstract. In this paper we consider the problem of distributing traffic to multiple parallel queues based on incomplete and possibly inaccurate state information. This problem arises in the context of intelligent networks where large customers rely on the network for traffic distribution to multiple locations. The main contributions of the paper are: (i) classification of approaches to the problem; (ii) a revenue-driven, Markovian decision model which captures the crucial elements of the problem; profit maximization, multiple job classes, blocking, and abandonments; and (iii) demonstration of the superior performance of implementable dynamic policies.

29. Nowikow, P. and K. Wajda. Agent scheduling for ACD switches. *Telecommunication Services for Developing Economies. Proceedings of the ITC Specialist Seminar*, Elsevier, Amsterdam, The Netherlands, 1991, 655–660.

Abstract. The authors describe a system for staff scheduling in automatic call distribution PBX exchanges based on gathered statistical data. General traffic engineering aspects for ACD exchanges employing the Erlang C formula are presented. An algorithm for choosing the number of active operators implementing an idea of ‘daily call profile’ is also included. Trials carried out for a ROLM 9000 ACD exchange proved that system is technologically feasible and economically attractive.

Keywords: ACD switches, Staff scheduling, Automatic call distribution PBX exchanges, Traffic engineering aspects, ACD exchanges, Erlang-C formula, Daily call profile, ROLM-9000 ACD exchange

30. Quinn, P., B. Andrews and H. Parsons. Allocating telecommunications resources at L.L. Bean, Inc., *Interfaces*, 21, 1991, 75–91.

Abstract. We developed and implemented a model for optimizing the deployment of telemarketing resources at L.L. Bean, a large telemarketer and mail-order catalog house. The deployment levels obtained with economic optimization were significantly different from those formerly determined by service-level criteria, and the resultant cost savings were estimated as \$9 to \$10 million per year. To develop the economic-optimization approach, we used queueing theory, devised an expected total-cost objective function, and accounted for retrial behavior and potential caller abandonments through a regression model that related the abandonment rates

to customer service levels. Management at L.L. Bean has fully accepted this approach, which now explicitly sets optimal levels for the number of telephone trunks (lines) carrying incoming traffic, the number of agents scheduled, and the maximum number of queue positions allowed for customers waiting for a telephone agent.

Keywords: Telecommunications resources, L.L. Bean Inc., Telemarketing resources, Mail-order catalog house, Queuing theory, Expected total cost objective function

31. Sparrow, L.B. Manning the telephone enquiry bureau at British Gas West Midlands. In *Operations Research in Management*, S.C. Littlechild, editor. New York: Prentice Hall, 1991, 167–173.

Abstract. All telephone enquiries to British Gas West Midlands are dealt with by a team of specialist clerks in two centralized enquiry bureaux. Customers anywhere in the region can contact a bureau at local call costs. At all times it is essential to maintain a high standard of answering service, not only because this is expected by the customer for any type of enquiry but also to ensure that emergency calls relating, perhaps, to gas leaks are accepted and dealt with.

In about 1970, the enquiry bureaux were finding it difficult to maintain the servicing of customers' calls at peak periods with the existing monitoring equipment. It was decided to set up a queueing theory model of the telephone answering system. The aim was to derive the relationships between traffic level, grade of service, waiting time and manning levels within the bureaux. The model would be used as a planning tool, both for indicating peak manning requirements and for optimizing number of staff at off-peak times. This chapter describes the model which was developed and the results which were obtained.

(Appears also in Section II.)

32. Sumita, S. and T. Ozawa. Performance analysis and design for distributed switching systems. Teletraffic and Datatraffic in a Period of Change. ITC-13. *Proceedings of the Thirteenth International Teletraffic Congress*. North-Holland, Amsterdam, The Netherlands; 1991, 761–766.

Abstract. The authors address performance analysis and design issues for distributed switching systems. Four major issues are discussed from the viewpoint of switching system performance: allocation of call-control functions to individual processors; distribution of call-processing load to individual processors; interprocessor communications; and access contention for shared resources. Several functional distribution architectures are introduced and are compared in terms of call connection delay, interprocessor communications traffic, and total cost. Several key principles for allocating call-processing functions are drawn from this comparison. Finally, a balanced design approach is presented as a promising method for dealing with a wide range of traffic conditions that will be typical in the broadband ISDN era.

Keywords: Call control function allocation, Call processing load distribution, Interprocessor traffic, Performance analysis, Design issues; Distributed switching systems, Interprocessor communications, Access contention, Shared resources, Functional distribution architectures, Call connection delay, Total cost, Broadband-ISDN

33. Khalil, Z., G. Falin and T. Yang. Some analytical results for congestion in subscriber line modules, *QUESTA*, 10 (4), 1992, 381–402.

Abstract. In modern telephone exchanges, subscriber lines are usually connected to the so-called subscriber line modules. These modules serve both incoming and outgoing traffic. An important difference between these two types of calls lies in the fact that in the case of blocking due to all channels busy in the module, outgoing calls can be queued whereas incoming calls get busy signal and must be re-initiated in order to establish the required connection. The authors study the corresponding queueing model which takes into account subscriber retrials and investigate some of its properties such as existence of stationary regime, derive explicit formulas for the system characteristics, limit theorems for systems under high repetition intensity of blocked calls and limit theorems for systems under heavy traffic.

Keywords: Telephone traffic, Queueing model, Retrial queue, Queueing theory, Congestion, Subscriber line modules, Telephone exchanges, Limit theorems

34. Perry, M. and A. Nilsson. Performance modeling of automatic call distributors: assignable grade of service staffing. International Switching Symposium 1992. 'Diversification and Integration of Networks and Switching Technologies towards the 21st Century' Proceedings. Inst. Electron. Inf. Commun. Eng, Tokyo, Japan, 1992, 294–298.

Abstract. A new generation of automatic call distributors (ACDs) has been developed that can handle multiple cell queues and associate priorities with these queues. The priority of a call is determined through an aging factor, which is a real number used to age the time a call has been queued. For example, if the oldest call in call queue 1 has waited 10 seconds, and the oldest call in call queue 2 has waited 7 seconds, and the aging factors for queue 1 and queue 2 are 3 and 5, then the second call would have a higher priority, since the calculated priority factors are $(10 \cdot 3)$ and $(7 \cdot 5)$. The paper gives an analytical model for computing the expected waiting time for call types that have different aging factors. The results can be used to determine both the number of agents and the aging values needed to yield specified expected waiting times. Numerical examples focus on the ACD application operator services, in which both directory assistance and toll/assist calls are served from the same positions.

Keywords: Performance modeling, Automatic call distributors, Operator services staffing, Heterogeneous positions, Telephony industry, Multi-purpose operator positions, Automatic call distributor, ACD, Toll and assist calls, Directory-assistance calls, Classical Erlang-type queueing models, Expected waiting-time, Average operator occupancy, Average occupancies, Simulation results

35. Whitt, W. Understanding the efficiency of multi-server service systems, *Management Science*, 38 (5), 1992, 708–723.

Abstract. In the design and operation of service systems, it is important to determine an appropriate level of server utilization (the proportion of time each server should be working). In a multiserver queue with unlimited waiting space, the appropriate server utilization typically increases as the number of servers (and the arrival rate) increases. They explain this economy of scale and give a rough quantitative characterization. The authors also show how increased variability in the arrival and service processes tends to reduce server utilization with a given grade of service. As part of this analysis, the author develops simple approximations for the mean steady-state waiting time and the fully steady-state waiting-time distribution. These approxi-

mations exploit an infinite-server approximation for the probability of delay and a single-server approximation for the conditional waiting-time distribution given that waiting occurs. The emphasis is on simple formulas that directly convey understanding.

Keywords: Operations research, Probability, Queueing theory, Multi-server service systems, Server utilization, Unlimited waiting space, Service processes, Mean steady-state waiting time, Fully steady-state waiting-time distribution, Infinite-server approximation, Delay

36. Andrews, Bruce and Henry Parsons. Establishing telephone-agent staffing levels through economic optimization, *Interfaces*, 23 (2), 1993, 14–20.

Abstract. We developed and implemented an economic-optimization model for telephone-agent staffing at L.L. Bean, a large tele-marketer and mail-order catalog house for quality outdoor sporting goods and apparel. The staffing levels we obtained with economic optimization were very different from those used by the company in the past, when staff size was determined by service-level criteria. For L.L. Bean, the resultant savings were estimated to amount to more than \$500,000 per year. In the model, we used queueing theory, devised an expected total-cost objective function, and accounted for retrials and potential caller abandonments through a regression model that related the abandonment rates to the telephone-service factor (percentage of calls answered within a predetermined time interval).

Keywords: Telephone agent staffing levels, Economic optimization, L.L. Bean, Telemarketer, Mail-order catalog house, Outdoor sporting goods, Apparel, Queueing theory, Expected total cost objective function, Retrials, Potential caller abandonments, Regression model
(Appears also in Section VIII.)

37. Sacks, Stephen R., Richard C. Larson and Christian Schaack. Minimizing the cost of dispatch delays by holding patrol cars in reserve, *Journal of Quantitative Criminology*, 9 (2), 1993, 203–224.

Abstract. At many police departments high-priority callers sometimes incur undue delays that could be avoided by the use of a differential response strategy that takes full account of the different “costs” of delay for different priority calls. In this article, we examine such a strategy, in which lower-priority callers may not be served immediately, even though some response units are available. Arriving priority i callers are queued whenever the number of busy patrol units equals or exceeds the cutoff number for that priority. Our purpose is (1) to find a practical way of choosing the set of cutoff numbers that will minimize the expected total cost of delays for the entire system and (2) to use that method to investigate how the optimal set of cutoffs changes in response to changes in several important variables, including the relative costs of delay for different priorities, the overall workload, and the relative frequencies of different priority calls.

Keywords: Differential response, Police deployment, Police dispatching, 911

38. Whitt, W. Approximations for the GI/G/m queue, *Production and Operations Management*, 2 (2), 1993, 114–161.

Abstract. Approximations for a basic queueing model are developed and evaluated. The model

is the GI/G/m queue, which has m identical servers in parallel, unlimited waiting room, and the first-come first-served queue discipline, with service and interarrival times coming from independent sequences of independent and identically distributed random variables with general distributions. The approximations depend on the general interarrival-time and service-time distributions only through their first two moments. The main focus is on the expected waiting time and the probability of having to wait before beginning service, but approximations are also developed for other congestion measures, including the entire distributions of waiting time, queue-length and number in system. These approximations are especially useful for incorporating GI/G/m in larger models, such as queueing networks, wherein the approximations can be components of rapid modeling tools.

Keywords: Approximation theory, Probability, Queueing theory, GI/G/m queue, First-come first served queue discipline, Interarrival times, Service times, Approximations, Service-time distributions, Queue length

39. Berman, O. and R.C. Larson. Determining optimal pool size of a temporary Call-In work force, *European Journal of Operations Research*, 73, 1994, 55–64.

Abstract. This paper is one in a series that introduces concepts of JUST-IN-TIME PERSONNEL. Management of worker job time and assignment are in many ways analogous to inventory management. Idle workers represent unutilized ‘inventoried’ personnel, imposing potentially large costs on management. But a lack of workers when needed may force the use of otherwise unnecessary overtime or other emergency procedures, creating excessive costs analogous to costs of stockout in traditional inventory systems. A system having JUST-IN-TIME PERSONNEL attempts to meet all demands for personnel at minimum cost by sharply reducing both excess worker inventory with its concomitant ‘paid lost time’ and underage of worker inventory with its associated costs of stockout. The model in this paper focuses on one important component of a JUST-IN-TIME or ‘JIT’ PERSONNEL system: response to day-to-day fluctuations in workload, worker outages due to sick leave, personal constraints or other unscheduled events. To maximize utilization of the JIT concept, we assume there exists a pool of call-in personnel who can be called on the day that they are needed. Each such call-in ‘temp’ is guaranteed a minimum number of offered days per month. A temp is paid each month for the days actually worked plus the differential, if any, between the number of days offered and the number of days guaranteed. Temps, like regular workers, may be unavailable on any given day due to illness, etc. The analysis leads to an exact probabilistic model that can be solved to find the optimal pool size of temps. Numerical results are included.

Keywords: Work force management, Optimal pool size, Temporary work force

40. Gordon, J.J. and M.S. Fowler. Accurate force and answer consistency algorithms for operator services. Proceedings of the 14th International Teletraffic Congress, ITC-14, Elsevier, Amsterdam, The Netherlands, 1994, 339–348.

Abstract. Operator services are big business. In the United States operator salaries per annum amount to approximately one billion dollars. Service providers constantly strive to cut costs while maintaining customer satisfaction. Queueing theory provides two tools to help them do this: force algorithms for accurately provisioning their teams, and answer consistency algorithms

for evaluating the consistency of the service provided to customers.

We analyze force and answer consistency algorithms based on three models: Erlang C, M/G/c, and M/G/c with abandonments. Using two weeks of directory assistance (DA) field data, we investigate how well these algorithms model the behavior of a real DA operator team. Although the M/G/c model performs best, our analysis suggests that certain modifications to the simple M/G/c model could significantly enhance its practical value.

41. Levy, Y., Johri S. Durinovic and R.A. Milito. Dynamic network call distribution with periodic updates. Fundamental Role of Teletraffic in the Evolution of Telecommunications Networks. Proceedings of the 14th International Teletraffic Congress, ITC-14, Elsevier, Amsterdam, The Netherlands, 1994, 85–94.

Abstract. The ability to effectively distribute calls in the network to multiple customer sites has become one of the major challenges for the intelligent network. The general goal is to make effective use of available information to improve the load balancing across the sites and the overall service level customers provide to their own clients. This paper introduces a new approach consisting of two coupled algorithms: a traffic allocation algorithm and a call distribution algorithm. The traffic allocation algorithm dynamically generates the proportion of global traffic to be sent to each site in response to periodic updates of system state. The call distribution algorithm converts this time varying allocation into a sequence of routing decisions. The paper demonstrates that this easy-to-implement approach achieves superior performance even when only a fraction of the offered traffic is controllable, provided that the update interval is not excessively long.

Keywords: Dynamic network call distribution, Periodic updates, Multiple customer sites, Intelligent network, Load balancing, Overall service level, Coupled algorithms, Traffic allocation algorithm, Call distribution algorithm, Global traffic, System state, Time-varying allocation, Routing decisions, Update interval, Traffic management

42. Perry, M. and A. Nilsson. Performance modeling of automatic call distributors: Operator services staffing with heterogeneous positions. Fundamental Role of Teletraffic in the Evolution of Telecommunications Networks. Proceeding of the 14th International Teletraffic Congress, ITC-14. Elsevier, Amsterdam, The Netherlands, 1994, 1023–1032.

Abstract. The telephony industry has introduced a new generation of multi-purpose operator positions, that with their associated automatic call distributor (ACD) allow operators to serve both toll and assist (TA) and directory assistance (DA) calls from the same position. When all operators can serve both TA and DA calls and all of the positions are multi-purpose, classical Erlang-type queueing models can be used to calculate two important measures: the expected waiting time for calls and the average operator occupancy. However when all of the positions are not multi-purpose (i.e. the operators are a heterogeneous group: some can do both TA and DA, some can do just TA and some can do just DA) the calculation of these two measures is a new and challenging problem. In this paper, approximations for expected waiting times and average occupancies are presented, and are shown, by comparison to simulation results, to be quite accurate.

Keywords: Performance modeling, Automatic call distributors, Operator services staffing, Heterogeneous positions, Telephony industry, Multi-purpose operator positions, Automatic call distributor, ACD, Toll and assist calls, Directory-assistance calls, Classical Erlang-type queueing models, Expected waiting time, Average operator occupancy, Average occupancies, Simulation results

(Appears also in Section IX.)

43. Andrews, Bruce H. and Shawn M. Cunningham. L.L. Bean improves call-center forecasting, *Interfaces*, 25 (6), 1995, 1–13.

Abstract. Two forecasting models are developed and implemented for use at L.L. Bean Inc., a widely known retailer of high-quality outdoor goods and apparel. The models forecast calls incoming to L.L. Bean’s call center so that efficient staffing schedules for telephone agents can be produced two weeks in advance. The ARIMA/transfer function methodology is used to model these time series data since they exhibit seasonal patterns but are strongly influenced by independent variables, including holiday and advertising interventions. The improved precision of the models is estimated to save \$300,000 annually through enhanced scheduling efficiency.

Keywords: Call center forecasting, L.L. Bean, Forecasting models, Retailer, Telephone agents, Staffing schedules, ARIMA transfer function methodology, Time series data, Seasonal patterns, Holiday, Advertising interventions

(Appears also in Section II.)

44. Borst, S.C. Optimal probabilistic allocation of customer types to servers. Proceedings of the Joint International Conference on Measurement and Modeling of Computer Systems (SIGMET-RICS95). Ottawa, ON, Canada, 1995, 116–125.

Abstract. The model under consideration consists of n customer types attended by m parallel non-identical servers. Customers are allocated to the servers in a probabilistic manner; upon arrival customers are sent to one of the servers according to an $m * n$ matrix of routing probabilities. We consider the problem of finding an allocation that minimizes a weighted sum of the mean waiting times. We expose the structure of an optimal allocation and describe for some special cases in detail how the structure may be exploited in actually determining an optimal allocation.

Keywords: Probabilistic allocation, Customer types, Servers, Non-identical servers, Routing probabilities, Parallel servers, Distributed computer systems, Communication networks, Global scheduling

45. Thompson, G.M. Improved implicit optimal modeling of the labor shift scheduling problem, *Management Science*, 41 (4), 1995, 595–607.

Abstract. This paper presents an integer programming model for developing optimal shift schedules while allowing extensive flexibility in terms of alternate shift starting times, shift lengths, and break placement. The model combines the work of Moondra (1976) and Bechtold and Jacobs (1990) by implicitly matching meal breaks to implicitly represented shifts. Moreover,

the new model extends the work of these authors to enable the scheduling of overtime and the scheduling of rest breaks. We compare the new model to Bechtold and Jacobs' model over a diverse set of 588 test problems. The new model generates optimal solutions more rapidly, solves problems with more shift alternatives, and does not generate schedules violating the operative restrictions on break timing.

Keywords: Labor scheduling, Integer programming, Implicit modeling

46. Jennings, O.B., A. Mandelbaum, W.A. Massey and W. Whitt. Server staffing to meet time-varying demand, *Management Science*, 42 (10), 1996, 1383–1394.

Abstract. We consider a multiserver service system with general nonstationary arrival and service-time processes in which $s(t)$, the number of servers as a function of time, needs to be selected to meet projected loads. We try to choose $s(t)$ so that the probability of a delay (before beginning service) hits or falls just below a target probability at all times. We develop an approximate procedure based on a time-dependent normal distribution, where the mean and variance are determined by infinite-server approximations. We demonstrate that this approximation is effective by making comparisons with the exact numerical solution of the Markovian $M_t/M/s_t$ model.

Keywords: Operator staffing, Queues, Nonstationary queues, Queues with time-dependent arrival rates, Multiserver queues, Infinite-server queues, Capacity planning

47. Alanyali, M. and B. Hajek. Analysis of simple algorithms for dynamic load balancing, *MOR*, 22 (4), 1997, 840–871.

Abstract. The principle of load balancing is examined for dynamic resource allocation subject to certain constraints. The emphasis is on the performance of simple allocation strategies which can be implemented on-line. Either finite capacity constraints on resources or migration of load can be incorporated into the setup. The load balancing problem is formulated as a stochastic optimal control problem. Variants of a “Least Load Routing” policy are shown to lead to a fluid type limit and to be asymptotically optimal.

Keywords: Dynamic load balancing, Dynamic resource allocation, Constraints, Finite capacity constraints, Load migration, Stochastic optimal control problem, Least load routing policy

48. Berman, Oded, Richard C. Larson and Edieal Pinker. Scheduling workforce and workflow in a high volume factory, *Management Science*, 43 (2), 1997, 158–172.

Abstract. We define a high volume factory to be a connected network of workstations, at which assigned workers process work-in-progress that flows at high rates through the workstations. A high rate usually implies that each worker processes many pieces per hour, enough so that work can be described as a deterministic hourly flow rate rather than, say, a stochastic number of discrete entities. Examples include mail processing and sorting; check processing, telephoned order processing, and inspecting and packaging of certain foods. Exogenous work may enter the factory at any workstation according to any time-of-day profile. Work-in-progress flows through the factory in discrete time according to Markovian routings. Workers, who in general

are cross-trained, may work part time or full time shifts, may start work only at designated shift starting times, and may change job assignments at mid-shift. In order to smooth the flow of work-in-progress through the service factory, work-in-progress may be temporarily inventoried (in buffers) at workstations. The objective is to schedule the workers (and correspondingly, the workflow) in a manner that minimizes labor costs subject to a variety of service-level, contractual and physical constraints. Motivated in part by analysis techniques of discrete time linear time-invariant (LTI) systems, an object-oriented linear programming (OOLP) model is developed. Using exogenous input work profiles typical of large U.S. mail processing facilities, illustrative computational results are included.

Keywords: Linear programming, Scheduling, Manufacturing, Object-oriented, Queueing, Queueing networks, Markov chains

49. Brandt, A., M. Brandt, G. Spahl and D. Weber. Modelling and optimization of call distribution systems. *Teletraffic Contributions for the Information Age. Proceedings of the 15th International Teletraffic Congress, ITC-15, Elsevier, Amsterdam, The Netherlands, 1997, 133–144.*

Abstract. This paper deals with the problem of finding optimal parameters for automatic call distribution (ACD) systems. A very general ACD model is considered, based on a multi-server combined loss/waiting system with impatient customers allowing an announcement before entering the service. For constant announcement time, approximations for all performance characteristics are provided. The accuracy of the results is compared with simulations. Within a flexible ACD cost model the modelling is used to find cost optimal ACD system parameters under pre-defined service quality constraints. Realistic examples are used to demonstrate the optimizing procedure.

Keywords: Call distribution systems, Optimal parameters, ACD systems, ACD model, Loss waiting system, Impatient customers, Flexible ACD cost model, Predefined service quality constraints, Optimizing procedure, Open queueing network

50. Coffman, E.G. Jr., E.N. Gilbert and Y.A. Kogan. Optimal redialing policies. *Proceedings of the 15th International Teletraffic Congress, ITC-15, Elsevier, Amsterdam, The Netherlands, 1997, 943–952.*

Abstract. Since callers encountering busy signals often want to redial, modern communication networks have been designed to provide redialing automatically. Redialing services commonly have two parameters: a maximum number n of retries and a total duration τ over which retries are to be made. Typically, retries are made at evenly-spaced time intervals of length τ/n until either the call succeeds or n retries have failed. We analyze this redialing policy in detail for several models of called-number availability; we describe situations where it maximizes the probability of call completion, and situations where it does not.

51. Duffield, N.G. and W. Whitt. Control and recovery from rare congestion events in a large multi-server system, *Queueing Systems*, 26, 1997, 69–104.

Abstract. We develop deterministic fluid approximations to describe the recovery from rare

congestion events in a large multi-server system in which customer holding times have a general distribution. There are two cases, depending on whether or not we exploit the age distribution (the distribution of elapsed holding times of customers in service). If we do not exploit the age distribution, then the rare congestion event is a large number of customers present. If we do exploit the age distribution, then the rare event is an unusual age distribution, possibly accompanied by a large number of customers present. As an approximation, we represent the large multi-server system as an $M/G/\infty$ model. We prove that, under regularity conditions, the fluid approximations are asymptotically correct as the arrival rate increases. The fluid approximations show the impact upon the recovery time of the holding-time distribution beyond its mean. The recovery time may or may not be affected by the holding-time distribution having a long tail, depending on the precise definition of recovery. The fluid approximations can be used to analyze various overload control schemes, such as reducing the arrival rate or interrupting services in progress. We also establish large deviations principles to show that the two kinds of rare events have the same exponentially small order. We give numerical examples showing the effect of the holding-time distribution and the age distribution, focusing especially on the consequences of long-tail distributions.

Keywords: Multi-server systems, High congestion, Recovery from congestion, Overload control, Long-tail distributions, Transient behavior, Fluid limits, Fluid approximations, Large deviations, Sanov's theorem, Residual lifetimes, Age distributions

52. Durinovic, Johri S. and Y. Levy. Advanced routing solutions for toll-free customers: algorithm design and performance. *Teletraffic Contributions for the Information Age. Proceedings of the 15th International Teletraffic Congress, ITC-15, Elsevier, Amsterdam, The Netherlands, 1997, 157–167.*

Abstract. This paper describes algorithms that are at the core of recent offerings in the AT&T intelligent network for dynamic, real-time network call distribution. These algorithms: (1) provide call by call routing to multiple customers sites based on periodic site-state updates; (2) address diverse goals such as geographic preferences and constraints, least cost routing, performance thresholds, and service objectives; and (3) allow user control within a structured algorithmic framework. We provide examples of simulation predictions of performance and efficiency improvements as well as results of field experience by customers.

Keywords: Advanced routing solutions, Toll-free customers, Algorithm design, Algorithm performance, AT&T, Intelligent network, Dynamic real-time network call distribution, Call-by-call routing, Periodic site state updates, Least cost routing, Performance thresholds, Service objectives, Simulation predictions, Automatic call distribution

53. Kogan, Y., Y. Levy and R.A. Milito. Call routing to distributed queues: Is FIFO really better than MED? *Telecommunication Systems—Modeling, Analysis, Design and Management*, 7 (1–3), 1997, 299–312.

Abstract. New services providing automatic call distribution in the network have been one of the most hotly contested areas in the USA telecommunications arena in recent years. This has been fuelled by increasing demand from large corporations for intelligent network routing that will keep their geographically distributed telemarketing/service centers operating with maximum

efficiency. This paper compares two basic strategies for a network call distributor: a centralized FIFO queue and a distributed queueing strategy called minimum-expected-delay (MED). According to MED, a central controller routes each arrival to the node that minimizes its expected delay (waiting time). Our main result qualifies the conventional wisdom that perceives FIFO as optimal. We show that the waiting time under FIFO is not stochastically smaller than that under MED. Furthermore, we prove that the waiting time distribution functions intersect at a single point. Numerical experiments suggest that, for certain performance criteria and over a range of parameters of interest, MED can actually outperform FIFO.

Keywords: MED, Automatic call distribution, USA, Intelligent network routing, Telemarketing, Service centers, Centralized FIFO queue, Distributed queueing strategy, Minimum expected delay strategy, Central controller, Delay minimization, Distribution functions, Performance criteria

54. Shanthikumar, J.G. and S.H. Xu. Asymptotically optimal routing and service rate allocation in a multiserver queueing system, *Operations Research*, 45 (3), 1997, 464–469.

Abstract. We consider a single stage queueing system with c heterogeneous servers. Customers arrive at this system according to a renewal process with mean $1/\lambda$ and squared coefficient of variation (scv) C_a^2 . An incoming customer is routed to server i with probability θ_i , $\sum_{i=1}^c \theta_i = 1$. The service times at server i are i.i.d random variables with mean $1/\mu_i$ and scv $C_{S_i}^2$. The holding cost rate of queue i is h_i per customer, $i = 1, 2, \dots, c$. The problems of interest are twofold: (a) for a fixed service rate allocation μ_i , $\sum_{i=1}^c \mu_i = \mu$, find the routing probabilities, θ_i^* , $\sum_{i=1}^c \theta_i^* = 1$, that minimize the average total holding cost; and (b) for fixed routing probabilities θ_i , $\sum_{i=1}^c \theta_i$, and total service rate μ , find the service rate allocation $\mu_i^* = \mu \delta_i^*$, $\sum_{i=1}^c \delta_i^* = 1$, that minimizes the average total holding cost of the system. For each problem, we characterize the optimal policy under heavy traffic conditions. We also derive the routing probabilities, $\hat{\theta}_i$ (proportions $\hat{\delta}_i$), $i = 1, \dots, c$, that are strongly asymptotically optimal. That is, the difference between the average total holding costs under $\hat{\theta}_i$, $i = 1, \dots, c$, and θ_i^* , $i = 1, \dots, c$, and $\hat{\delta}_i$, $i = 1, \dots, c$, and δ_i^* , $i = 1, \dots, c$ is bounded by a fixed constant independent of the routing probabilities (proportions) and the arrival rate. In addition, we discuss the necessity and sufficiency of the accurate knowledge of the means and scvs of the interarrival and service times in obtaining asymptotically optimal policies.

Keywords: Queues: approximations, limit theorems, optimization; Probability: stochastic model, applications; Optimal routing; Service rate allocation; Multiserver queueing system; Single-stage queueing system; Renewal process; Holding cost; Optimal policy

55. Thompson, G.M. Assigning telephone operators to shifts at New Brunswick Telephone Company, *Interfaces*, 27 (4), 1997, 1–11.

Abstract. The author developed a procedure for assigning telephone operators to shifts at New Brunswick Telephone Company (NBTEL). Although the problem has received scant attention in the literature, its solution greatly affects employees' satisfaction with their work schedules. NBTEL requires that all shifts be assigned to employees, and it is obligated contractually to satisfy preferences for shifts in order of employee seniority. The specialized shift assignment heuristic (SSAH) developed runs on a personal computer, generating approximately three solutions per second. Employee and shift databases are maintained in a spreadsheet, and macros are used to integrate the heuristic into the spreadsheet. Both management and employees see SSAH as an

improvement over the previous manual procedure.

Keywords: Operator shift assignment, New Brunswick Telephone Company, Specialized shift assignment heuristic, Spreadsheet, Management, Employees, Optimisation

56. Fischer, M.J., D.A. Garbin and A. Gharakhanian. Performance modeling of distributed automatic call distribution systems, *Telecommunication Systems—Modeling, Analysis, Design and Management*, 9 (2), 1998, 133–152.

Abstract. The number of businesses using automatic call distribution (ACD) systems has grown significantly in the last five years. The industry shows all the signs of continued or greater growth in the foreseeable future. While ACD systems have proliferated they have also evolved from fundamentally local to distributed systems. An ACD manager can no longer optimize his traffic by using inputs from a simple set of queueing tables. The most common system is now a distributed network where subsystems interact with each other and cannot be analyzed in isolation. This paper examines the strengths and weaknesses of queueing models that have been used historically with ACD systems and develops modifications to these models (including agent wrap-up times) that are combined with queueing network theories to construct an original ACD network performance algorithm to work with distributed systems.

Keywords: Automatic call distribution systems, Businesses, ACD, Distributed network, Agent wrap-up times, Queueing network theories, Network performance algorithm, Traffic optimization

57. Kolesar, Peter J. and Linda V. Green. Insights on service system design from a normal approximation to Erlang’s delay formula, *Production and Operations Management*, 7 (3), 1998, 282–293.

Abstract. We show how a simple normal approximation to Erlang’s delay formula can be used to analyze capacity and staffing problems in service systems that can be modeled as M/M/s queues. The numbers of servers, s , needed in an M/M/s queueing system to assure a probability of delay of, at most, p can be well approximated by $s \approx \rho + z_{1-p}\sqrt{\rho}$, where z_{1-p} is the $(1 - p)$ th percentile of the standard normal distribution and ρ , the presented load on the system, is the ratio of λ , the customer arrival rate, to μ , the service rate. We examine the accuracy of this approximation over a set of parameters typical of service operations ranging from police patrol, through telemarketing to automatic teller machines, and we demonstrate that it tends to slightly underestimate the number of servers actually needed to hit the delay probability target—adding one server to the number suggested by the above formula typically gives the exact result. More importantly, the structure of the approximation promotes operational insight by explicitly linking the number of servers with server utilization and the customer service level. Using a scenario based on an actual teleservicing operation, we show how operations managers and designers can quickly obtain insights about the trade-offs between system size, system utilization and customer service. We argue that this little-used approach deserves a prominent role in the operations analyst’s and operations manager’s tool bags.

Keywords: Erlang’s delay formula, M/M/s queue, Service system design, Normal approximation, Staffing levels

58. Mandelbaum, A. and S. Zeltyn. Estimating characteristics of queueing networks using transac-

tional data, *Queueing Systems*, 29, 1998, 75–127.

Abstract. We are motivated by queueing networks in which queues are difficult to observe but services are easy to record. Our goal is to estimate the queues from service data. More specifically, we consider an open queueing network with Poisson external arrivals, multi-server stations, general service times and Markovian switches of customers between stations. Customers' transitions between stations may be either immediate or of exponentially distributed durations. Each customer is supplied with an Identification Number (ID) upon entering the network. Operational data is collected which includes transaction times (starts and terminations of services) and ID's of served customers. Our objective is to estimate the evolution of the queues in the network, given the collected data. We cover estimation at both end of busy periods and in real time. The applicability of the theory is demonstrated by analyzing a service operation.

Keywords: Queues, Queueing networks, Nonparametric inference, Data analysis, Hidden Markov models, Performance evaluation, Queueing inference engine

59. Mandelbaum, A., W.A. Massey and M.I. Reiman. Strong approximations for Markovian service networks, *Queueing Systems*, 30, 1998, 149–201.

Abstract. Inspired by service systems such as telephone call centers, we develop limit theorems for a large class of stochastic service network models. They are a special family of nonstationary Markov processes where parameters like arrival and service rates, routing topologies for the network, and the number of servers at a given node are all functions of time as well as the current state of the system. Included in our modeling framework are networks of $M_t/M_t/n_t$ queues with abandonment and retrials. The asymptotic limiting regime that we explore for these networks has a natural interpretation of scaling up the number of servers in response to a similar scaling up of the arrival rate for the customers. The individual service rates, however, are not scaled. We employ the theory of strong approximations to obtain functional strong laws of large numbers and functional central limit theorems for these networks. This gives us a tractable set of network fluid and diffusion approximations. A common theme for service network models with features like many servers, priorities, or abandonment is “non-smooth” state dependence that has not been covered systematically by previous work. We prove our central limit theorems in the presence of this non-smoothness by using a new notion of derivative.

Keywords: Strong approximations, Fluid approximations, Diffusion approximations, Multi-server queues, Queues with abandonment, Queues with retrials, Priority queues, Queueing networks, Jackson networks, Nonstationary queues

60. Mandelbaum, A. and G. Pats. State-dependent stochastic networks. Part I: Approximations and applications with continuous diffusion limits, *The Annals of Applied Probability*, 8 (2), 1998, 569–646.

Abstract. In a state-dependent queueing network arrival and service rates, as well as routing probabilities, depend on the vector of queue lengths. For properly normalized such networks, we derive functional laws of large numbers (FLLNs) and functional central limit theorems (FCLTs). The former support fluid approximations and the latter support diffusion refinements.

The fluid limit in FLLN is the unique solution to a multidimensional autonomous ordinary

differential equation with state-dependent reflection. The diffusion limit in FCLT is the unique strong solution to a stochastic differential equation with time-dependent reflection.

Examples are provided that demonstrate how such approximations facilitate the design, analysis and optimization of various manufacturing service, communication and other systems.

Keywords and phrases: Birth and death process, State-dependent networks, Fluid and diffusion approximations, Weak convergence, State- and time-dependent oblique reflection, Congestion-dependent routing, Learning systems, Multiserver systems, Large finite buffers, Transient analysis

61. Mandelbaum, A. and M.I. Reiman. On pooling in queueing networks, *Management Science*, 44 (7), 1998, 971–981.

Abstract. We view each station in a Jackson network as a queue of tasks, of a particular type, which are to be processed by the associated *specialized* server. A complete pooling of queues, into a single queue, and servers, into a single server, gives rise to an M/PH/1 queue, where the server is *flexible* in the sense that it processes all tasks. We assess the value of complete pooling by comparing the steady-state mean sojourn times of these two systems. The main insight from our analysis is that care must be used in pooling. Sometimes pooling helps, sometimes it hurts, and its effect (good or bad) can be unbounded. Also discussed briefly are alternative pooling scenarios, for example complete pooling of only queues which results in an M/PH/S system, or partial pooling which can be devastating enough to turn a stable Jackson network into an unstable Bramson network. We conclude with some possible future research directions.

Keywords: Service facility design, Specialized server, Service operations, Efficiency, Stability, Economics of scale

62. Marbach, P., O. Mihatsch and J.N. Tsitsiklis. Call admission control and routing in integrated services networks using reinforcement learning. Proceedings of the 37th IEEE Conference on Decision and Control, IEEE, Piscataway, NJ, USA, 1998, 563–568.

Abstract. In integrated services communication networks, an important problem is to exercise call admission control and routing so as to optimally use the network resources. This problem is naturally formulated as a dynamic programming problem, which, however, is too complex to be solved exactly. We use methods of reinforcement learning, together with a decomposition approach, to find call admission control and routing policies. We compare the performance of our policies with a commonly used heuristic policy.

Keywords: Dynamic call admission control, Call routing, Integrated services networks, Neurodynamic programming, Resource requirements, Call classes, Dynamic programming problem, Revenue maximization, Admitted calls per unit time maximization, Reinforcement learning, Decomposition approach, State-dependent call admission control, State-dependent link costs, Simulation-based learning method, Experiments, Performance, Heuristic

63. Mason, A.J., D.M. Ryan and D.M. Panton. Integrated simulation, heuristic and optimisation approaches to staff scheduling, *Operations Research*, 46 (2), 1998, 161–175.

Abstract. This paper details a new simulation and optimisation based system for personnel scheduling (rostering) of Customs staff at the Auckland International Airport, New Zealand. An integrated approach using simulation, heuristic descent and integer programming techniques has been developed to determine near-optimal staffing levels. The system begins by using a new simulation system embedded within a heuristic search to determine minimum staffing levels for arrival and departure work areas. These staffing requirements are then used as the input to an integer programming model which optimally allocates full and part-time staff to each period of the working day. These shifts are then assigned to daily work schedules having a six-day-on, three-day-off structure. The application of these techniques has resulted in significantly lower staffing levels, while at the same time creating both high quality rosters and ensuring that all passenger processing targets are met. This paper charts the development of this system, outlines failures.

Keywords: Simulation, Heuristic, Optimisation, Staff scheduling, Personnel scheduling, Rostering, Customs staff, Auckland International Airport, New Zealand, Heuristic descent, Integer programming, Near optimal staffing levels, Minimum staffing levels, Integer programming model, Full-time staff, Part-time staff
(Appears also in Section IX.)

64. Servi, L.D. and S. Humair. Optimizing Bernoulli routing policies for balancing loads on call centers and minimizing transmission costs. Proceedings of the 37th IEEE Conference on Decision and Control, IEEE, Piscataway, NJ, USA, 1998, 1653–1655.

Abstract. We address the problem of assigning probabilities at discrete time instants for routing toll-free calls to a given set of call centers in order to minimize a weighted sum of transmission costs and load variability at the call centers during the next time interval. We model the problem as a tripartite graph and decompose finding the optimal probability assignment in the graph into an estimation problem and a convex quadratic program problem. Using a heuristic that uses gradient information around a given probability assignment we further address a practical variant in which the number of probability assignments that can be changed at each time instant is constrained.

Keywords: Bernoulli routing policy optimization, Call center load balancing, Transmission cost minimization, Toll-free call routing, Load variability, Tripartite graph, Optimal probability assignment decomposition, Estimation problem, Convex quadratic program problem, Heuristic, Gradient information

65. Van Dijk, N.M. On hybrid combination of queueing and simulation. Simulation: Past, Present and Future. 12th European Simulation Multiconference 1998. ESM'98. As Part of the 50th Anniversary Celebrations of the University of Manchester - the Home of Computing. SCS, San Diego, CA, USA, 1998, 731–735.

Abstract. This paper illustrates how simulation and queueing theory can and should go hand in hand for a variety of practical problems, both in daily-life and industry, which are still open for fundamental research. To this end, it highlights real-life cases taken from: daily-life situations (postal office or bank); administrative logistics (reengineering); tele-servicing (call-centres); and transportation (railways).

Keywords: Simulation, Queueing theory, Postal office, Bank, Administrative logistics, Tele-servicing, Call centres, Transportation, Railways
(Appears also in Section IX.)

66. Bakshi, Y. and R.A. Skoog. Call distribution in a non-homogeneous distributed switching system. *Teletraffic Engineering in a Competitive World. Proceedings of the International Teletraffic Congress, ITC-16. Vol. 3a. Elsevier Science, Amsterdam, The Netherlands, 1999, 303–312.*

Abstract. A new adaptive call distribution algorithm is developed for a nonhomogeneous multiprocessor switch. The algorithm does not require the knowledge of call handling capacities of individual call processing nodes and, hence, does not require tuning for different system configurations or during system upgrades. As shown by the simulation experiments, the algorithm performs well in nonhomogeneous environments during both normal operation and when dynamic changes in capacities of system nodes take place.

Keywords: Distributed switching system, Adaptive call distribution algorithm, Nonhomogeneous multiprocessor switch, Simulation, System node capacities

67. Borst, Sem and Pierre Seri. Robust algorithms for sharing agents with multiple skills. Working paper, Bell Laboratories, Lucent Technologies, Murray Hill, NJ, USA, 1999.

Abstract. We consider a queueing model for a call center which is offered calls from several skill classes. The agents may have heterogeneous skill sets, determining which classes of call they can serve. We assume that there are traffic estimates specified for the various call classes in the form of the expected arrival rate and mean service time. There are also service level objectives defined for each class, including the target mean waiting time and the probability of the waiting time exceeding a certain threshold.

We obtain conditions characterizing the range of feasible agent configurations. In addition, we propose two simple credit schemes for sharing the agents among the various call classes in a disciplined fashion. The credit schemes help ensure that each class receives a service level that is similar to or better than it would have experienced when served in isolation. Numerical experiments demonstrate the robustness properties of the credit schemes in case of inaccurate traffic forecasts.

68. Brandt, Andreas and Manfred Brandt. On a two-queue priority system with impatience and its application to a call center, *Methodol. Comput. Appl. Probab.*, 1 (2), 1999, 191–210.

Abstract. We consider an s -server priority system with a protected and an unprotected queue. The arrival rates at the queues and the service rate may depend on the number n of customers being in service or in the protected queue, but the service rate is assumed to be constant for $n > s$. As soon as any server is idle, a customer from the protected queue will be served according to the FCFS discipline. However, the customers in the protected queue are impatient. If the offered waiting time exceeds a random maximal waiting time I , then the customer leaves the protected queue after time I . If I is less than a given deterministic time, then he leaves the system, else he will be transferred by the system to the unprotected queue. The service of a

customer from the unprotected queue will be started if the protected queue is empty and more than a given number of servers become idle. The model is a generalization of the many-server queue with impatient customers. The global balance conditions seem to have no explicit solution. However, the balance conditions for the density of the stationary state process for the subsystem of customers being in service or in the protected queue can be solved. This yields the stability conditions and the probabilities that precisely n customers are in service or in the protected queue. For obtaining performance measures for the unprotected queue, a system approximation based on fitting impatience intensities is constructed. The results are applied to the performance analysis of a call center with an integrated voice-mail server.

Keywords: Two-queue priority system, Call center, s -server priority system, Arrival rates, Service rate, Random maximal waiting time, Many-server queue, Global balance conditions, Stability conditions, Performance analysis, Integrated voice-mail server

69. Coffman, S. and M.L. Saxton. Staffing the reference desk in the largely-digital library, *Reference Librarian*, 66, 1999, 141–161.

Abstract. The article examines how a centralized, networked reference service might improve efficiency and reduce costs by addressing two long-standing and seemingly intractable problems associated with the reference process: that librarians spend only a small portion of their time at the reference desk actually answering questions, and that many of the questions they do answer could be handled by paraprofessionals. The authors explore the feasibility of a live, centralized, networked reference service in a library setting by comparing traditional reference services at the County of Los Angeles Public Library with a commercial inbound call center designed to handle the same volume of questions. Applying Erlang C, the standard algorithm used to calculate staffing requirements for commercial call centers, the authors find that a networked reference service based on a call center model could reduce the reference staff requirements at the County of Los Angeles Public Library by 42% or more. These results are very preliminary, and the article cautions against jumping to conclusions until we have much better data on the questions we are answering and the reference process as a whole, but the evidence we do have suggests that networked reference services have the potential to truly revolutionize the way we have been doing reference for the past 100 years.

Keywords: Reference desk staff, Largely digital library, Networked reference service, Intractable problems, Reference process, Librarians, Paraprofessionals, Library setting, Traditional reference services, County of Los Angeles Public Library, Commercial inbound call center, Erlang-C, Standard algorithm, Staffing requirements, Call center model, Reference staff requirements (Appears also in Sections IV and VII.)

70. Gans, Noah and Yong-Pin Zhou. Managing learning and turnover in employee staffing. Working Paper, The Wharton School, The University of Pennsylvania, July 1999 (Revised November 2000).

Abstract. We study the employee staffing problem in a service organization that uses employee service capacities to meet random, nonstationary service requirements. The employees experience learning and turnover on the job, and we develop a Markov Decision Process (MDP) model that explicitly represents the stochastic nature of these effects. Theoretical results are developed

that show the optimal hiring policy is of a state-dependent “hire-up-to” type, similar to the inventory “order-up-to” policy. This holds for discounted-costs MDP’s under both finite and infinite planning horizons.

We also develop structural properties of the optimal policy to facilitate computation of the optimal hiring numbers. For two important special cases of the general model, we prove the optimality of a myopic policy under both stationary and stochastically increasing service requirements. Moreover, we show that in these two cases, when service requirements are k -periodic, it is sufficient to solve a k -period MDP problem with appropriate end-of-horizon cost function. When general, non-stationary service requirements are present, we prove the existence of a one-sided “smoothing effect” of the optimal hire-up-to-levels.

Numerical results show that the use of state-dependent hire-up-to policies may offer significant cost savings over simpler hiring policies. In particular, our results show that when employee capacity increase due to learning is substantial and flexible incremental capacity (overtime) is tight, a fully state-dependent policy out-performs a policy that hires only on the basis of the total number of employees in the system.

Our problem formulation and results suggest natural connections to the classic results in inventory literature. We also discuss many of the connections and distinctions in the paper.

71. Garnet, O. and A. Mandelbaum. An introduction to skills-based routing and its operational complexities. Teaching note sponsored by the Fraunhofer IAO Institute, Stuttgart, Germany, June 1999. Available at <http://ie.technion.ac.il/serveng>.
72. Harris, Foster R. and S. De Reyts. Re-inventing the call centre with predictive and adaptive execution, *British Telecommunications Engineering*, 18 (2), 1999, 180–184.

Abstract. Call centres have evolved from simple single-function centres to offer access, convenience, choice and courtesy to callers. Forecasting and staffing tools support planning, enterprise databases permit the business to craft specific caller treatments, and cross trained agents using desktop applications can respond to a wider range of caller needs and business opportunities on a single call. One key element of the call centre, however has changed only superficially-the question of ‘What should each agent do next?’ The ‘oldest waiting call’ rule has answered that question for the last 20 years. Signs that this methodology is obsolete are seen in call centres where designs become more complex and results more difficult to achieve; where manual intervention moves agents from skill to skill chasing problems; where the most talented agents are overworked. This paper describes predictive and adaptive techniques that answer the question, ‘What should an agent do next?’. These techniques re-invent the call centre, creating a robust operation where performance is aligned with business intentions, without the manual, corrective intervention common in conventional centres.

Keywords: Call centre, Specific caller treatments, Cross-trained agents, Oldest waiting call rule, Predictive techniques, Adaptive techniques, Customer service

73. Mandelbaum, A., W.A. Massey, M.I. Reiman and B. Rider. Time varying multiserver queues with abandonment and retries. *Teletraffic Engineering in a Competitive World*. Proceedings of

the International Teletraffic Congress, ITC-16., Elsevier Science, Amsterdam, The Netherlands, 1999, 355–364.

Abstract. In this paper we consider a multiserver queueing model where waiting customers may abandon and subsequently retry. This model is of particular interest for analyzing performance and setting staffing levels in call centers. All of the parameters (arrival rate, service rate, etc.) are allowed to be time-dependent. We propose a simple fluid approximation for the queue length process arising in this model. The fluid approximation, which is obtained as the solution of an intuitively appealing ordinary differential equation, is in fact asymptotically exact as the size of the system (arrival rate and number of servers) grows large. The fluid approximation is compared with simulations for several sets of parameters and performs extremely well.

Keywords: Time varying queues, Abandonment, Retrials, Multiserver queueing model, Performance, Staffing levels, Call centers, Arrival rate, Service-rate, Fluid approximation, Queue length, Ordinary differential equation, Simulations

74. Mandelbaum, A., W.A. Massey, M.I. Reiman and A. Stolyar. Waiting time asymptotics for time varying multiserver queues with abandonment and retrials. Allerton Conference Proceedings, 1999.

Abstract. The queue length results for the abandonment/retrial model in Theorem 5.1 (A. Mandelbaum, W.A. Massey, R.I. Reiman, “Strong approximations for Markovian service networks”, *Queueing Systems* (1998), Section 5) are extended to include the fluid and diffusion limits for the waiting time in nonstationary, many server Jackson networks with abandonment.

Keywords: Strong approximations, Fluid approximations, Diffusion approximations, Multiserver queues, Queues with abandonment, Queues with retrials, Priority queues, Queueing networks, Jackson networks, Nonstationary queues.

75. Samuelson, Douglas A. Predictive dialing for outbound telephone call centers, *Interfaces*, 29 (5), 1999, 66–81.

Abstract. In the late 1980s, I used queueing and simulation to invent predictive dialing, a method to determine when computer-directed outbound telephone dialing systems should dial. I included a real-time estimation updating feature that was highly robust against sudden changes in the system’s operation environment; thorough validation to ensure that the models tracked all important features of the real systems; and a modular software design that allowed “plug-in” replacement of the control software, eliminating debugging of field upgrades. The improved systems kept operators busier and drastically reduced the number of calls the systems abandoned because no operator was available to talk to the answering party. This invention was critical to the success, in the late 1980s, of International Telesystems Corporation (ITC), a small company founded in 1984, which a competitor, EIS International, bought in 1993 for approximately \$12 million.

Keywords: Predictive dialing, Outbound telephone call centers, Real-time estimation updating feature, Modular software design

76. Whitt, Ward. Using different response-time requirements to smooth time-varying demand for service, *Operations Research Letters*, 24, 1999, 1–10.

Abstract. Many service systems have demand that varies significantly by time of day, making it costly to provide sufficient capacity to be able to respond very quickly to each service request. Fortunately, however, different service requests often have very different response-time requirements. Some service requests may need immediate response, while others can tolerate substantial delays. Thus it is often possible to smooth demand by partitioning the service requests into separate priority classes according to their response-time requirements. Classes with more stringent performance requirements are given higher priority for service. Lower capacity may be required if lower-priority-class demand can be met during off-peak periods. We show how the priority classes can be defined and the resulting required fixed capacity can be determined, directly accounting for the time-dependent behavior. For this purpose, we exploit relatively simple analytical models, in particular, $M_t/G/\infty$ and deterministic offered-load models. The analysis also provides an estimate of the capacity savings that can be obtained from partitioning time-varying demand into priority classes.

Keywords: Time-varying demand, Smoothing time-varying demand, Priority queues, Nonstationary queues, Deterministic fluid models, Infinite-server queues, Offered-load models

77. Whitt, Ward. Dynamic staffing in a telephone call center aiming to immediately answer all calls, *Operations Research Letters*, 24 (5), 1999, 205–212.

Abstract. This paper proposes practical modeling and analysis methods to facilitate dynamic staffing in a telephone call center with the objective of immediately answering all calls. Infinite-server queueing models are considered. These models are very useful because they are so tractable. A key to the dynamic staffing is exploiting detailed knowledge of system state in order to obtain good estimates of the mean and variance of the demand in the near future. The near-term staffing needs can often be predicted by exploiting information about recent demand and current calls in progress, as well as historical data. The remaining holding times of calls in progress can be predicted by classifying and keeping track of call types, by measuring holding-time distributions and by taking account of the elapsed holding times of calls in progress. The number of new calls in service can be predicted by exploiting information about both historical and recent demand.

Keywords: Staffing, Telephone call center, Infinite server queueing models, Holding-time distributions, Queueing theory, Forecasting, Nonstationary queues, Management

78. Whitt, Ward. Improving service by informing customers about anticipated delays, *Management Science*, 45 (2), 1999, 192–207.

Abstract. The effect upon performance in a service system, such as a telephone call center, of giving waiting customers state information is investigated. In particular, two $M/M/s/r$ queueing models with balking and reneging are studied. For simplicity, it is assumed that each customer is willing to wait a fixed time before beginning service. However, customers differ, so the delay tolerances for successive customers are random. In model 2, all reneging is replaced by balking. The number of customers in the system for model 1 is shown to be larger than that for model 2 in

the likelihood-ratio stochastic ordering. Thus, customers are more likely to be blocked in model 1 and are more likely to be served without waiting in model 2. Algorithms are also developed for computing important performance measures in these, and more general, birth-and-death models.

Keywords: Telephone service, Anticipated delays, Customer service, Queueing models, Delay tolerance, Probability, Exponential distribution, Service time, Telephone call centre, Reneging, Balking, Birth-and-death process
(Appears also in Section III.)

79. Whitt, Ward. Predicting queueing delays, *Management Science*, 45 (6), 1999, 870–888.

Abstract. The possibility of predicting each customer’s waiting time in queue before starting service in a multiserver service system with the first-come first-served service discipline, such as a telephone call center, is investigated. A predicted waiting-time distribution or an appropriate summary statistic such as the mean or the 90th percentile may be communicated to the customer upon arrival and possibly thereafter in order to improve customer satisfaction. The predicted waiting-time distribution may also be used by the service provider to better manage the service system, e.g., to help decide when to add additional service agents. The possibility of making reliable predictions is enhanced by exploiting information about system state, including the number of customers in the system ahead of the current customer.

Keywords: Queueing delays, Delay prediction, Multiserver service system, Telephone call center, Waiting-time distribution, Response time

80. Whitt, Ward. Partitioning customers into service groups, *Management Science*, 45 (11), 1999, 1579–1592.

Abstract. We explore the issues of when and how to partition arriving customers into service groups that will be served separately, in a first-come first-served manner, by multiserver service systems having a provision for waiting, and how to assign an appropriate number of servers to each group. We assume that customers can be classified upon arrival, so that different service groups can have different service-time distributions. We provide methodology for quantifying the tradeoff between economies of scale associated with larger systems and the benefit of having customers with shorter service times separated from other customers with longer service times, as is done in service systems with express lines. To properly quantify the tradeoff, it is important to characterize service-time distributions between their means. In particular, it is important to also determine the variance of the service-time distribution of each service group. Assuming Poisson arrival processes, we then can model the congestion experienced by each server group as an $M/G/s$ queue with unlimited waiting room. We use previously developed approximations for $M/G/s$ performance measures to quickly evaluate partitions.

Keywords: Queues, Multiserver queues, Service systems, Service-system design, Resource sharing, Service systems with express lines

81. Whitt, Ward. Decomposition approximations for time-dependent Markovian queueing networks, *Oper. Res. Lett.*, 24 (3), 1999, 97–103.

Abstract. Motivated by the development of complex telephone call center networks, we present a general framework for decompositions to approximately solve Markovian queueing networks with time-dependent and state-dependent transition rates. The decompositions are based on assuming either full or partial product form for the time-dependent probability vectors at each time. These decompositions reduce the number of time-dependent ordinary differential equations that must be solved. We show how special structure in the transition rates can be exploited to speed up computation. There is extra theoretical support for the decomposition approximation when the steady-state distribution of the time-homogeneous version of the model has product form.

Keywords: Time-dependent queues, Time-dependent Markovian queueing networks, Time-dependent Markov chains, Markovian queueing networks, Decomposition approximations, Systems of ordinary differential equations, Product-form queueing networks, Product-form approximations, Telephone call centers, Air traffic management, Decompositions, Transition rates, Probability vectors, Differential equations

82. Zhou, Yong-Pin and Noah Gans. A single-server queue with Markov modulated service times. Working Paper, The Wharton School, The University of Pennsylvania, October 1999.

Abstract. We study an M/MMPP/1 queueing system, where the arrival process is Poisson and service requirements are Markov modulated. When the Markov Chain modulating service times has two states, we show that the distribution of the number-in-system is a superposition of two matrix-geometric series and provide a simple algorithm for computing the rate and coefficient matrices. These results hold for both finite and infinite waiting space systems and extend results obtained in Neuts [5] and Naoumov [4].

Numerical comparisons between the performance of the M/MMPP/1 system and its M/G/1 analogue lead us to make the conjecture that the M/MMPP/1 system performs better if and only if the total switching probabilities between the two states satisfy a simple condition. We give an intuitive argument to support this conjecture.

83. Weidong Xu. Long range planning for call centers at FedEx, *The Journal of Business Forecasting Methods & Systems*, 18 (4), Winter 1999/2000, 7–11.

Abstract. FedEx is the world's largest express transportation company, generating \$14 billion in annual revenue. To support the global transportation network, FedEx has established 51 worldwide customer service call centers. The customer service at FedEx in the US handles about 500,000 calls per day. There are three major networks: 1. Domestic, 2. International, and 3. Freight. For each network, the company has developed four different types of forecasts based on different forecasting horizons: 1. Strategic Plan, 2. Business Plan, 3. Tactical Forecast, and 4. Operational Forecast. Different methodologies are adopted for different levels of forecasts. An overview of these methodologies is presented.

Keywords: Postal & delivery services, Forecasting techniques, Customer services, Case studies (Appears also in Sections VIII and II.)

84. Aksin, O.Z. and P.T. Harker. Computing performance measures in a multi-class multi-resource

processor-shared loss system, *European Journal of Operational Research*, 123 (1), 2000, 61–72.

Abstract. This paper develops methods to compute performance measures in a specific type of loss system with multiple classes of customers sharing the same processor. Such systems arise in the modeling of a call center, where the performance measures of interest are the blocking probability of a call and the reneging probability of customers that are put on hold. Expressions for these performance measures have been derived in previous work by the authors. Given the difficulty of computing these performance measures for realistic systems, this paper proposes two different approaches to simplify this computation. The first method introduces the idea of multi-dimensional convolutions, and uses this approach to compute exact blocking and reneging probabilities. The second method establishes an adaptation of the Monte Carlo Summation technique in order to obtain good estimates of blocking and reneging probabilities in large systems along with their associated confidence intervals.

Keywords: Performance measures, Multi-class multi-resource processor-shared loss system, Call center, Blocking probability, Reneging probability, Multi-dimensional convolutions, Monte-Carlo summation technique, Confidence intervals

85. Bhulai, Sandjai and Ger Koole. Scheduling time-constrained jobs in the presence of background traffic. Proceedings of the 39th IEEE Conference on Decision and Control, Sydney, Australia, December 2000.

Abstract. In this paper we study the scheduling of jobs with a constraint on the average waiting time in the presence of background jobs. The objective is to schedule to s servers such that the throughput of the background traffic is maximized while satisfying the response time constraint on the foreground traffic.

The arrivals are determined by a Poisson process and the service times of the jobs are independent exponentially distributed. We consider both the situation where service requirements by both types of jobs are equal and unequal. The first situation is solved to optimality; for the second situation we find the best policy within a certain class of policies. Optimal schedules always keep part of the service capacity free for arriving foreground jobs. Applications of this model can be found in computer systems, communication networks and call centers.

Keywords: Call centers, Communication networks, Markov decision processes, Parallel systems and queueing

86. Brandt, Andreas and Manfred Brandt. Asymptotic results and a Markovian approximation for the $M(n)/M(n)/s + GI$ system. Working paper, Wirtschaftswissenschaftliche Fakultät, Humboldt-Universität zu Berlin, Berlin, Germany, 2000.

Abstract. In this paper for the $M(n)/M(n)/s + GI$ system, i.e., for a s -server queueing system where the calls in the queue may leave the system due to impatience, we present new asymptotic results for the intensities of calls leaving the system due to impatience and a Markovian system approximation where these results are applied. Furthermore, we present a new proof for the formulae of the conditional density of the virtual waiting time distributions, recently given by Movaghar for the less general $M(n)/M/s + GI$ system. Also, we obtain new explicit expressions for refined virtual waiting time characteristics as a by-product.

Keywords: $M(n)/M(n)/s + GI$ system, Limited waiting times, Finite buffer, Virtual waiting times, Blocking-, Abandon probability, Impatience rates, Asymptotic results, $M(n)/M(n)/s$ system with waiting place dependent impatient rates, Markovian approximation

87. Brusco, Michael J. and Larry W. Jacobs. Optimal models for meal-break and start-time flexibility in continuous tour scheduling, *Management Science*, 46 (12), 2000, 1630–1641.

Abstract. A compact integer-programming model is presented for large-scale continuous tour scheduling problems that incorporate meal-break window, start-time band, and start-time interval policies. For practical scheduling environments, generalized set-covering formulations (GSCF) of such problems often contain hundreds of millions of integer decision variables, usually precluding identification of optimal solutions. As an alternative, an implicit integer-programming model has been presented that frequently has fewer than 1,500 variables and can be formulated and solved using PC-based hardware and software platforms. An empirical study using labor-requirement distributions for customer service representatives at a Motorola Inc. call center was used to demonstrate the importance of having a model that can evaluate tradeoffs among the various scheduling policies.

Keywords: Continuous tour scheduling, Integer programming, Meal-break window, Start-time band, Generalized set-covering, Customer service, Workforce scheduling, Production control

88. Easton, Fred F. Labor requirements for multi-server multi-class finite queues. Working paper, Robert H. Brethen Operations Management Institute, School of Management, Syracuse University, Syracuse, NY, USA, June 2000.

Abstract. Most of North American's 70,000 call centers use Erlang queueing models to determine appropriate staffing levels for each period their systems operate. These standard queueing models ($M/M/C$ or $M/M/C/N$) assume a one-stage single-queue service, FCFS priority, multiple identical servers, and exponential inter-arrival times and service times. If a call center provides two or more types of service, each with distinct mean service times, its workforce management system typically averages the interarrival and service times over all calls. These parameters are then automatically passed to a $M/M/C/\infty$ or a $M/M/C/N$ model to determine the minimum staff needed to assure a prescribed level of service.

In this research we consider a multi-server finite Poisson queueing system that provides two types of service, classified $H_2/H_2/C/N$. We decompose the two arrival streams and show that the system is reversible, allowing efficient computation of its two-dimensional state probabilities. The model enables us to better understand the magnitude of the staffing errors that result when standard Erlang models are applied to multi-class queueing systems. For example, we find that when an equal number of callers arrive for each of two classes of service, but the mean service rate for one class is nine times faster than the other, $M/M/C/N$ can recommend a staffing level that is less than one-half the minimum number of employees actually needed to provide the desired level of service.

89. Jongbloed, Geurt and Ger Koole. Managing uncertainty in call centers using Poisson mixtures. Working paper, Vrije Universiteit, Division of Mathematics and Computer Science, Amsterdam,

The Netherlands, November 2000.

Abstract. We model a call center as a queueing model with Poisson arrivals having an unknown varying arrival rate. We show how to compute prediction intervals for the arrival rate, and use the Erlang formula for the waiting time to compute the consequences for the occupancy level of the call center. We compare it to the current practice of using a point estimate of the arrival rate (assumed constant) as forecast.

(Appears also in Section II.)

90. Larson, Richard C. and E.J. Pinker. Staffing challenges in financial services, in *Creating Value in Financial Services: Strategies, Operations, and Technologies*, Edward L. Melnick, Praveen R. Nayyar, Michael L. Pinedo, Sridhar Seshadri (Eds.). Boston: Kluwer Academic Publishers, 2000, Chapter 17: 327–356.

Abstract. Financial services institutions are providing a rapidly expanding variety of products and services; technology is making customers more mobile, and delay is unacceptable in financial transactions. These attributes of the financial services sector mean that firms must provide effective, efficient and reliable service or quickly lose customers to competitors. To avoid huge labor costs, financial services firms must develop innovative approaches to managing their workforces and their service delivery process. We outline and provide examples of effective techniques for managing part-time and flexible personnel in back room operations, bank teller scheduling and management, improving customer queueing experiences, and the design and operation of call centers to take into account cross-training, learning and cross selling.

Acknowledgement: The abstract was taken from the introduction of the book.

(Appears also in Section VIII.)

91. Mandelbaum, A. and N. Shimkin. A model for rational abandonments from invisible queues, *QUESTA*, 36 (1–3), 2000, 141–173.

Abstract. We propose a model for abandonments from a queue, due to excessive wait, assuming that waiting customers act rationally but without being able to observe the queue length. Customers are allowed to be heterogeneous in their preferences and consequent behavior. Our goal is to characterize customers' patience via more basic primitives, specifically waiting costs and service benefits: these two are optimally balanced by waiting customers, based on their individual cost parameters and anticipated waiting time. The waiting time distribution and patience profile then emerge as an equilibrium point of the system. The problem formulation is motivated by teleservices, prevalently telephone- and Internet-based. In such services, customers and servers are remote and queues are typically associated with the servers, hence queues are invisible to waiting customers. Our base model is the M/M/m queue, where it is shown that a unique equilibrium exists, in which rational abandonments can occur only upon arrival (zero or infinite patience for each customer). As such a behavior fails to capture the essence of abandonments, the base model is modified to account for unusual congestion or failure conditions. This indeed facilitates abandonments in finite time, leading to a nontrivial, customer dependent patience profile. Our analysis shows, quite surprisingly, that the equilibrium is unique in this case as well, and amenable to explicit calculation.

Keywords: Multiserver exponential queues, Abandonments, Nash equilibrium, Call centers (Appears also in Section III.)

92. Mockus, Jonas. “Call centers” in *A Set of Examples of Global and Discrete Optimization: Applications*, Jonas Mockus (Editor). Dordrecht: Kluwer Academic, 2000, part 3, ch. 15.
93. Pinedo, Michael L., Sridhar Seshadri and J. George Shanthikumar. Call centers in financial services: Strategies, technologies and operations, in *Creating Value in Financial Services: Strategies, Operations, and Technologies*, Edward L. Melnick, Praveen R. Nayyar, Michael L. Pinedo, Sridhar Seshadri (Eds.). Boston: Kluwer Academic Publishers, 2000, Chapter 18: 357–388.

Abstract. Call centers are becoming more important in financial services. They are of importance to retail banking operations, credit card operations and mutual fund organizations. A significant part of the dynamics of call centers in financial services is similar to call centers in other industries. Analyzing both static and dynamic aspects of managing call centers, we discuss necessary service, security and database requirements for call centers in financial services firms. We also analyze the differences between call centers in financial services and call centers in other industries such as airlines. These differences center around the more extensive database requirements necessary to handle each call, as well as the fact that customers of financial institutions tend to be more captive than customers of airlines.

Acknowledgement: The abstract was taken from the introduction of the book.

94. Pinker, E. and R. Shumsky. The efficiency-quality tradeoff of cross-trained workers, *Manufacturing and Service Operations Management*, 2 (1), Winter 2000, 32–48.

Abstract. Does cross-training workers allow a firm to achieve economies of scale when there is variability in the content of work, or does it create a work force that performs many tasks with consistent mediocrity? To address this question we integrate a model of a stochastic service system with models for tenure- and experience-based service quality. When examined in isolation, the service system model confirms a well-known “rule of thumb” from the queueing literature: Flexible or cross-trained servers provide more throughput with fewer workers than specialized servers. However, in the integrated model these economies of scale are tempered by a loss in quality. Given multiple tasks, flexible workers may not gain sufficient experience to provide high-quality service to any one customer, and what is gained in efficiency is lost in quality.

Through a series of numerical experiments we find that low utilization in an all-specialist system can also reduce quality, and therefore, the optimal staff mix combines flexible and specialized workers. We also investigate when the performance of the system is sensitive to the staffing configuration choice. For small systems with high learning rates, the optimal staff mix provides significant benefits over either extreme case (a completely specialized or completely flexible work force). If the system is small and the rate of learning is slow, flexible servers are preferred. For large systems with high learning rates, the model leans toward specialized servers. In a final set of experiments, the model analyzes the design options for an actual call center.

Keywords: Queues: Approximations, Service quality, Learning curves, Cross-training, Worker turnover; Personnel

95. Puhalskii, A.A. and M.I. Reiman. The multiclass GI/PH/N queue in the Halfin-Whitt regime, *Advances in Applied Probability*, 32 (2), 2000, 564–595.

Abstract. A consideration is made of a multiserver queue in the heavy-traffic regime introduced and studied by Halfin and Whitt (1981) who investigated the case of the single customer class with exponentially distributed server times. The purpose is to extend their analysis to a system with multiple customer classes, priorities and phase-type service distributions. A weak convergence limit theorem is proven showing that a properly defined and normalized queue length process converges to a particular K -dimensional diffusion process, where K is the number of phases in the service time distribution. It is also shown that a properly normalized waiting time process converges to a simple functional of the limit diffusion for the queue length.

Keywords: Call Centers, Multiserver queues, Priority queues, Heavy traffic, Diffusion approximation, Weak convergence

96. Reiman, Martin I. Diffusion limits for multiskill call centers with many agents. Applied Probability Society at INFORMS 2000, San Antonio, Nov. 5–8, 2000.

Abstract. We consider a queueing model of a call center providing service to several customer types (skills), where each server (agent) can handle some subset of the skills. We examine this model in the Halfin-Whitt regime, which involves the number of servers growing large while the traffic intensity approaches unity.

97. Ridley, A. Performance optimization of a telecommunication call center. Proceedings of the Applied Telecommunication Symposium (ATS'00). SCS, San Diego, CA, USA, 2000, 163–167.

Abstract. Telecommunication call centers have become the primary channel of customer interaction service for many businesses. The level of professionalism and efficiency that call center agents deliver to customers provides a significant advantage over traditional customer service practices. The growth of call centers has been substantial over the last two decades. This growth is driven by a company's desire to lower operating costs and to increase revenues (Kim 1997). The author investigates analytical and simulation-based models for the design and management of a call center. Given three classes of traffic (voice, E-mail, and facsimile) with different target waiting-times in queue and target service levels, the goal is to optimize the call center performance. The system performance can be measured with quantities such as the expected waiting-time in queue, the expected time in system, the percentage of calls answered within a given time, and the expected waiting-time probability distribution. The system performance of the call center is measured using analytical and simulation-based queueing models. For analytical models, the traffic classes will have exponential inter-arrival and service time distributions where the arrival and service rates will differ among classes. Also, each customer call will be assigned a queue priority based on its traffic class. The call agents will be able to handle calls from any class. For the simulation-based models, the inter-arrival and service time distributions will not be exponential, the agents will have different skill-levels, and the queue length will be finite.

Keywords: Performance optimization, Telecommunication call center, Simulation-based models,

Management, Voice traffic, E-mail, Facsimile, Service levels, Expected waiting time, Probability distribution, Queuing models, Exponential inter-arrival distributions, Service-time distributions (Appears also in Section IX.)

98. Aksin, O.Z. and P.T. Harker. Modeling a phone center: analysis of a multichannel, multiresource processor shared loss system, *Management-Science*, 47 (2), 2001, 324–336.

Abstract. Presents a model for the study of operations at an inbound call center. The call center is modeled as a multiclass processor shared loss system, where the interacting effects of human, telecommunication, and information technology resources are explicitly incorporated. Product form solutions and approximations for this type of system are provided along with expressions for performance measures like blocking and reneging. Some structural properties of system throughput are analyzed in an effort to pave the way for future optimization studies dealing with the design and management of phone centers.

Keywords: Phone center, Multichannel multiresource processor-shared loss system, Inbound call center, Information technology resources, Human resources, Telecommunication resources, Blocking, Reneging

99. Bae, Jongho, Sunggon Kim and Eui Yong Lee. The virtual waiting time of the $M/G/1$ queue with impatient customers, *Queueing Syst. Theory Appl.*, 38 (4), 2001, 485–494.

Abstract. The paper deals with the limiting distribution of the virtual waiting time of the $M/G/1$ queueing systems with impatient customers having constant patience. This model has been dealt with in the past by many authors (some in the reference list and some missing), and the approach the authors take to this problem is not new. Further, the “explicit” solution is given by an infinite series of convolutions, which, except in some simple cases, is not computable. This work deals with a problem that has been receiving a lot of attention recently because of its use in the analysis of call centers, but the form in which the final result appears makes its contribution rather limited.

100. Benjaafar, Saifallah. Modeling and analysis of flexible queueing systems, *Naval Research Logistics*, 2001 (Under review).

Abstract. We consider queueing systems with multiple classes of arrivals and heterogeneous servers where customers have the flexibility of being routed to more than one server and servers possess the capability of processing more than one customer class. We provide a unified framework for the modeling and analysis of these systems under arbitrary routing and server flexibility and for a rich set of control policies that includes customer/server-specific priority schemes for routing and queue selection. We use our models to generate several insights into the effect of system configuration. In particular, we examine the relationship between flexibility and throughput under varying assumptions for system parameters.

101. Brusco, Michael J. and Larry W. Jacobs. Starting-time decisions in labor tour scheduling: An experimental analysis and case study, *European Journal of Operational Research*, 131 (3), 2001,

Abstract. Many service organizations limit the number of daily planning periods in which employees may begin their shifts to a fixed number, S . Even for relatively small values of S , which are quite common in practice, there may be hundreds, thousands or millions of possible subsets of starting times. This paper presents the results of a large experimental study that revealed that, in many instances, only a very small portion of starting-time subsets was capable of providing the minimum workforce size.

Keywords: Starting-time decisions, Labor-tour scheduling, Starting-time subsets, Minimum workforce size, Effective starting-time selection, Spreadsheet-based program

102. Cezik, Tolga, Oktay Gunluk and Hanan Luss. An integer programming model for the weekly tour scheduling problem, *Naval Research Logistics*, 48 (7), 2001, 607–624.

Abstract. We study a workforce planning and scheduling problem in which weekly tours of agents must be designed. Our motivation for this study comes from a call center application where agents serve customers in response to incoming phone calls. Similar to many other applications in the services industry, the demand for service in call centers varies significantly within a day and among days of the week. In our model, a weekly tour of an agent consists of five daily shifts and two days off, where daily shifts within a tour may be different from each other. The starting times of any two consecutive shifts, however, may not differ by more than a specified bound. Furthermore, a tour must also satisfy constraints regarding the days off. For example, it may be required that one of the days off is on a weekend day. The objective is to determine a collection of weekly tours that satisfy the demand for agents’ services, while minimizing the total labor cost of the workforce. We describe an integer programming model where a weekly tour is obtained by combining seven daily shift scheduling model and days-off constraints in a network flow framework. The model is flexible and can accommodate different daily models with varying levels of details. It readily handles different days-off rules and constraints regarding start time differentials in consecutive days. Computational results are also presented.

103. Duder, J.C. and M.B. Rosenwein. Towards “zero abandonments” in call center performance, *European Journal of Operational Research*, 135 (1), 2001, 50–56.

Abstract. The call center industry is a big business in today’s global economy. Staffing costs account for over half of a call center’s total operational costs. Some large call centers, in practice, operate at very close to maximum capacity, believing that such an operations policy is efficient. However, by operating at levels close to 100% utilization, a call center is “living dangerously”. If, for example, call volumes even slightly exceed forecasts, customer calls will queue. As queue lengths and durations increase, customers will tend to abandon their calls. We provide some “rule-of-thumb” formulas that evaluate the cost of abandonments. These formulas may be used to justify an investment in additional agents required to improve the quality of service and reduce abandonments. Standard Erlang-C queueing formulas imply that abandonments can be significantly reduced with a small investment in additional agents. Thus, by improving customer service and hiring additional staff, a call center can improve profitability. We illustrate our analysis with realistic data, based on our work with large-scale customer service centers.

104. Feng, W. and R.T. Hurley. Birth-death models for a class of service systems. Proceedings of the IASTED International Conference Applied Informatics. International Symposium on Parallel and Distributed Computing and Networks. ACTA Press, Anaheim, CA, USA, 2001, 320–325.

Abstract. In this paper, we discussed three birth-death models for service systems, such as telephone call centers of Internet access points. The first model assumes that customers have no information about the system and so they may balk or renege upon arrival. The other two models assume that customers receive the state information as they arrive and thus, the balking probability is state-dependent. Model 2 uses the assumption that the balking probabilities depend on a waiting time threshold while model 3 assumes that the balking probabilities depend directly on the number of customers in the waiting queue. Both analysis and simulation are used to investigate the performance of the systems based on the three models. We compare the server utilization and mean response time. Our results indicate that model 2 tends to have a lower response time than model 1 and the performance of a system based on model 3 greatly depends on the sequence of balking probabilities. We show the results for two such scenarios.

105. Green, Linda V., Peter J. Kolesar and Joao Soares. Improving the SIPP approach for staffing service systems that have cyclic demands, *Operations Research*, 49 (4), 2001, 549–564.

Abstract. This paper evaluates the practice of determining staffing requirements in service systems with random cyclic demands by using a series of stationary queueing models. We consider Markovian models with sinusoidal arrival rates and use numerical methods to show that the commonly used “stationary independent period by period” (SIPP) approach to setting staffing requirements is inaccurate for parameter values corresponding to many real situations. Specifically, using the SIPP approach can result in staffing levels that do not meet specified period by period probability of delay targets during a significant fraction of the cycle. We determine the manner in which the various system parameters affect SIPP reliability and identify domains for which SIPP will be accurate. After exploring several alternatives, we propose two simple modifications of SIPP that will produce reliable staffing levels in models whose parameters span a broad range of practical situations. Our conclusions from the sinusoidal model are tested against some empirical data.

Keywords: Service systems, Staffing: Use of queueing models, Queueing systems, Cyclic: Accuracy of stationary models, Call centers

106. Green, Linda V., Peter J. Kolesar and Joao Soares. An improved heuristic for staffing telephone call centers with limited operating hours. Report, Centre for Mathematics, University of Coimbra (CMUC), Portugal, 2001.

107. Grossman, Thomas A., Douglas A. Samuelson, Sherry L. Oh and Thomas R. Rohleder. Call centers. In *Encyclopedia of Operations Research and Management Science*, Centennial edition, Saul I. Gass and Carl M. Harris (Eds.). Norwell: Kluwer Academic Publishers, 2001.

108. Masi, Denise M. Bevilacqua, Martin Fisher and Carl M. Harris. Computation of steady-state probabilities for resource sharing call center queueing systems, *Stochastic Models* [online], 17 (2), 2001 [viewed July 24, 2001].

Abstract. Two routing rules for a queueing system of two stations are considered as alternative models for modeling a call-center network. These routing rules allow customers to switch queues under certain server and other resource availability conditions, either external to the system upon arrival to the network, or internal to the system after arrival to a primary call center. Under the assumption of Poisson arrivals and exponentially distributed service times, these systems are analyzed using matrix-geometric techniques, yielding a non-trivial set of ergodicity conditions and the steady-state joint probability distribution for the number of customers at each station. An extensive numerical analysis is conducted, yielding some physical insight into these systems and related generalizations.

109. Shumsky, R. and E. Pinker. Gatekeepers and referrals in services. Working paper OP01-02, Simon School, University of Rochester, 2001.

Abstract. We examine services in which customers encounter a gatekeeper who makes an initial diagnosis of the customer's problem and then may refer the customer to a specialist. The gatekeeper may also attempt to solve the problem, but the probability of treatment success decreases as the problem's complexity increases. Given the costs of treatment by the gatekeeper and the specialist, we find the firm's optimal referral rate from a particular gatekeeper to the specialists. We then consider the principal-agent problem that arises when the gatekeeper, but not the firm, observes the gatekeeper's treatment ability as well as the complexity of each customer's problem. We examine the relative benefits of compensation systems designed to overcome the effects of this information asymmetry and identify when bonuses based solely on referral rates do not ensure first-best system performance. We also consider the value of such output-based contracts when gatekeepers are heterogeneous in ability, so that two gatekeepers face different probabilities of treatment success when given the same problem. Finally, we compare environments in which the gatekeeper is, and is not, faced with risk in the form of significant variance in compensation.

110. Atlason, Julius, Marina A. Epelman and Shane G. Henderson. Combining simulation and cutting plane methods in service systems. Proceedings of the 2002 National Science Foundation Design, Service and Manufacturing Grantees Conference, 2002.

Abstract. In this paper we describe a method that combines simulation and cutting plane methods to solve resource allocation and scheduling problems. We solve a relaxed linear (integer) program iteratively and pass the solution of each iteration to a simulation. The results of the simulation are used to generate constraints in the linear (integer) program. We provide conditions under which the solutions of the linear (integer) program converges to an optimal solution of the unrelaxed problem. The concavity of the underlying service level function is critical for the method and we present a linear programming method to numerically check the concavity of a function.

111. Chen, Bert P.K. and Shane G. Henderson. Two issues in setting call centre staffing levels, *Annals*

of *Operations Research*, 108, 2002, 175–192.

Abstract. Motivated by a problem facing the Police Communication Centre in Auckland, New Zealand, we consider the setting of staffing levels in a call centre with priority customers. The choice of staffing level over any particular time period (e.g., Monday from 8am–9am) relies on accurate arrival rate information. The usual method for identifying the arrival rate based on historical data can, in some cases, lead to considerable errors in performance estimates for a given staffing level. We explain why, identify three potential causes of the difficulty, and describe a method for detecting and addressing such a problem.

112. Garnet, O., A. Mandelbaum and M. Reiman. Designing a call center with impatient customers, *Manufacturing & Service Operations Management*, 4 (3), 2002, 208–227. Available at <http://ie.technion.ac.il/serveng>.

Abstract. The most common model to support work force management of telephone call centers is the M/M/N/B model, in particular its special cases M/M/N (Erlang C, which models out busy-signals) and M/M/N/N (Erlang B, disallowing waiting). All of these models lack a central prevalent feature, namely that impatient customers might decide to leave (abandon) before their service begins.

In this paper we analyze the simplest abandonment model, in which customers' patience is exponentially distributed and the system's waiting capacity is unlimited (M/M/N + M). Such a model is both rich and analyzable enough to provide information that is practically important for call center managers. We first outline a method for exact analysis of the M/M/N + M model, that while numerically tractable is not very insightful. We then proceed with an asymptotic analysis of the M/M/N + M model, in a regime that is appropriate for large call centers (many agents, high efficiency, high service level). Guided by the asymptotic behavior, we derive approximations for performance measures and propose "rules-of-thumb" for the design of large call centers. We thus add support to the growing acknowledgment that insights from diffusion approximations are directly applicable to management practice.

113. Koole, Ger and A. Mandelbaum. Queueing models of call centers: An introduction, *Annals of Operations Research*, 113, 2002, 41–59. Special volume dedicated to a selection of papers presented at the "First Madrid Conference on Queueing Theory" (MCQT '02), July 2–5, 2002.

Abstract. This is a survey of some academic research on telephone call centers. The surveyed research has its origin in, or is related to, queueing theory. Indeed, the "queueing-view" of call centers is both natural and useful. Accordingly, queueing models have served as prevalent standard support tools for call center management. However, the modern call center is a complex socio-technical system. It thus enjoys central features that challenge existing queueing theory to its limits, and beyond.

114. Mandelbaum, A., W.A. Massey, M.I. Reiman and B. Rider. Queue lengths and waiting times for multiserver queues with abandonment and retrials, *Telecommunication Systems*, 21 (2–4), 2002, 149–171.

Abstract. We consider a Markovian multiserver queueing model with time dependent parameters where waiting customers may abandon and subsequently retry. We provide simple fluid and diffusion approximations to estimate the mean, variance, and density for both the queue length and virtual waiting time processes arising in this model. These approximations, which are generated by numerically integrating only 7 ordinary differential equations, are justified by limit theorems where the arrival rate and number of servers grow large. We compare our approximations to simulations, and they perform extremely well.

Keywords: Fluid approximations, Diffusion approximations, Multiserver queues, Queues with abandonment, Virtual waiting time, Queues with retrials, Nonstationary queues, Call centers

115. Massey, W.A. The analysis of queues with time-varying rates for telecommunication models, *Telecommunication Systems Modeling, Analysis, Design and Management*, 21 (2–4), 2002, 173–204.

Abstract. Time-dependent behavior has an impact on the performance of telecommunication models. Examples include: staffing a call center, pricing the inventory of private line services for profit maximization, and measuring the time lag between the peak arrivals and peak load for a system. These problems and more motivate the development of a queueing theory with time-varying rates. Queueing theory is presented and organized from a communications perspective. Canonical queueing models with time-varying rates are given and the necessary mathematical tools are developed to analyze them. Finally, the use of these models are illustrated through various communication applications.

Keywords: Time-varying rate queues, Telecommunication models, Time-dependent behavior, Time lag, Peak arrivals, Peak load, Queueing theory, Communication networks, Call center staffing, Private line services, Profit maximization

116. Zohar, E., A. Mandelbaum and N. Shimkin. Adaptive behavior of impatient customers in tele-queues: Theory and empirical support, *Management Science*, 48 (4), 2002, 566–583.

Abstract. We address the modeling and analysis of abandonment from a queue which is invisible to its occupants. Such queues arise in remote service systems, notably the Internet and telephone call centers, hence, we refer to them as *tele-queues*. A basic premise of this paper is that customers adapt their patience (modeled by an abandonment-time distribution) to their service expectations, in particular to their anticipated waiting time. We first present empirical support for that hypothesis, and propose an M/M/m-based model which incorporates adaptive customer behavior. In our model, customer patience (and possibly the arrival rate) depend on the *mean* waiting time in the queue. We then characterize the system equilibrium and establish its existence and uniqueness when the growth rate of customer patience is bounded by that of the mean waiting time. The feasibility of multiple system equilibria is illustrated when this condition is violated. We also discuss a decision-theoretic model for customer abandonment, and relate it to our basic model. Finally, a dynamic learning model is proposed where customer expectations regarding their waiting time are formed through accumulated experience. We address certain issues related to censored-sampling that arise in this framework and demonstrate, via simulation, convergence to the theoretically anticipated equilibrium.

Keywords: Exponential (Markovian) queues, Abandonments, Equilibrium analysis, Invisible queues, Performance-dependent behavior, Tele-services, Tele-queues, Call centers
(Appears also in Section III.)

117. Aksin, O. Zeynep and Patrick T. Harker. Capacity sizing in the presence of a common shared resource: Dimensioning an inbound call center, *European Journal of Operational Research*, 147 (3), 2003, 464–483.

Abstract. This paper studies a capacity sizing problem for service systems where capacity is determined by multiple types of resources that are required simultaneously in order to provide service. In addition to the simultaneous use of resources, the systems are characterized by the presence of a common resource that is shared across multiple types of customers. The paper focuses on inbound call centers as an important example of such systems. The capacity sizing problem in this context is one where the optimal number of servers that need to be allocated to different call types is determined. Optimality is defined as the number of servers that maximize revenues net of staffing costs. For the case where customers do not wait, it is shown that a greedy allocation procedure yields the optimal server allocation. Heuristics are proposed for the case with waiting customers that can exhibit impatience. The numerical analysis illustrates that for systems experiencing heavy loads and serving a diverse set of customers, the proposed heuristics outperform current methods that ignore the role of a shared resource in these types of dimensioning problems.

Keywords: Queueing, Staff dimensioning, Resource sharing, Call center design

118. Bhulai, S. and G. Koole. A queueing model for call blending in call centers, *IEEE Transactions on Automatic Control*, 48 (8), 2003, 1434–1438.

Abstract. Call centers that apply call blending obtain high productivity and high service levels by dynamically mixing inbound and outbound traffic. We show that agents should be assigned to outbound calls if the number of available agents exceeds a certain threshold. This control policy is optimal for equal service time distributions and a very good approximation otherwise.

Keywords: Call centres, Decision theory, Dynamic programming, Markov processes, Queueing theory, Stochastic processes

119. Chevalier, P. and N. Tabordon. Overflow analysis and cross-trained servers, *International Journal of Production Economics*, 85 (1), 2003, 47–60.

Abstract. In this paper, we evaluate the performance of a call center composed of specialized and cross-trained operators (i.e., operators trained to answer different classes of calls). The paper focuses on the approximation of the loss probability of a call center where the different classes of calls arrive according to a Poisson distribution and service time distribution is exponential. We make the simplifying assumption that calls not immediately answered are lost. Our closed form approximation is based on an approximation for hierarchical overflow systems in telecommunication developed by Hayward and later extended by Fredericks (1980).

Keywords: Statistical decision theory, Operations research, Personnel management, Executive

120. Gans, N., G. Koole and A. Mandelbaum. Telephone call centers: Tutorial, review, and research prospects. Invited review paper by *Manufacturing and Service Operations Management (M&SOM)*, **5** (2), 2003, 79–141. Available at: <<http://ie.technion.ac.il/serveng>>

Abstract. Telephone call centers are an integral part of many businesses, and their economic role is significant and growing. They are also fascinating socio-technical systems in which the behavior of customers and employees is closely intertwined with physical performance measures. In these environments, traditional operational models are of great value—and at the same time fundamentally limited—in their ability to characterize system performance.

We review the state of research on telephone call centers. We begin with a tutorial on how call centers function and proceed to survey academic research devoted to the management of their operations. We then outline important problems that have not been addressed and identify promising directions for future research.

Keywords: Telephone call center, Contact center, Tele-services, Tele-queues, Capacity management, Staffing, Hiring, Workforce management systems, ACD reports, Queueing, Erlang C, Erlang B, Erlang A, QED regime, Time-varying queues, Call routing, Skills-based routing, Forecasting, Data mining

121. Gans, Noah and Yong-Pin Zhou. A call-routing problem with service-level constraints, *Operations Research*, **51** (2), 2003, 255–271.

Abstract. This paper considers a queueing system, commonly found in inbound telephone call centers, that processes two types of work. Type H jobs arrive at rate λ_H , are processed at rate μ_H , and are served on a first-come first-served basis within class. A service level constraint of the form $E[\text{delay}]$ less than or equal to α or $P\{\text{delay less than or equal to } \beta\}$ greater than or equal to α limits the delay in queue that these jobs may face. An infinite backlog of type L jobs awaits processing at rate μ_L , and there is no service level constraint on this type of work. A pool of c identical servers processes all jobs, and a system controller must maximize the rate at which type L jobs are processed, subject to the service-level constraint placed on the type H work. The problem is formulated as a constrained, average-cost Markov decision process and the structure of effective routing policies is determined. When the expected service times of the two classes are the same, these policies are globally optimal, and the computation time required to find the optimal policy is about that required to calculate the normalizing constant for a simple M/M/c system. When the expected service times of the two classes differ, the policies are optimal within the class of priority policies, and the determination of optimal policy parameters can be determined through the solution of a linear program with $O(c^3)$ variables and $O(c^2)$ constraints.

Keywords: Studies, Operations research, Dynamic programming, Markov analysis, Queueing, Call centers, Routing, Optimization

122. Jagerman, David L. and Benjamin Melamed. Models and approximations for call center design, *Methodology and Computing in Applied Probability*, **5** (2), 2003, 159.

Abstract. A call center is a facility for delivering telephone service, both incoming and outgoing. This paper addresses optimal staffing of call centers, modeled as M/G/n queues whose offered traffic consists of multiple customer streams, each with an individual priority, arrival rate, service distribution and grade of service (GoS) stated in terms of equilibrium tail waiting time probabilities or mean waiting times. The paper proposes a methodology for deriving the approximate minimal number of servers that suffices to guarantee the prescribed GoS of all customer streams. The methodology is based on an analytic approximation, called the Scaling-Erlang (SE) approximation, which maps the M/G/n queue to an approximating, suitably scaled M/G/1 queue, for which waiting time statistics are available via the Pollaczek-Khintchine formula in terms of Laplace transforms. The SE approximation is then generalized to M/G/n queues with multiple types of customers and non-preemptive priorities, yielding the Priority Scaling-Erlang (PSE) approximation. A simple goal-seeking search, utilizing SE/PSE approximations, is presented for the optimal staffing level, subject to GoS constraints. The efficacy of the methodology is demonstrated by comparing the number of servers estimated via the PSE approximation to their counterparts obtained by simulation. A number of case studies confirms that the SE/PSE approximations yield optimal staffing results in excellent agreement with simulation, but at a fraction of simulation time and space.

Keywords: Studies, Call centers, Queueing, Methods, Mathematical models

123. Koole, Ger. Redefining the service level in call centers. Technical report, Department of Stochastics, Vrije Universiteit Amsterdam, 2003.

Abstract. We propose a new waiting time metric for call centers that circumvents some of the problems that the standard way of defining service level has.

124. Qiang, Yang, Wang Yong, Zhang Zhong. SANet: A service-agent network for all center scheduling, *IEEE Transactions on Systems, Man & Cybernetics, Part A: Systems & Humans*, 33 (3), 2003, 396–406.

Abstract. We consider a network of service-providing agents, where different agents have different capabilities, availability, and cost to solve problems. These characteristics are particularly important in practice for semi-automated call centers which provide quality customer service in real time. We have developed SANet, a service agent network for call center automation, to serve as an experimental test-bed for our research. SANet can select appropriate agents to provide better solutions for customer problems according to the changing capabilities and availability of service agents in the network. It can also add or delete appropriate agents to balance problem-solving quality, efficiency, and cost according to the number and types of incoming customer problems. On this network, each service agent can be a human service agent, an automated software service agent, or a combination of the two. This paper describes the architecture, a problem scheduling algorithm and an agent assignment algorithm on the SANet. We highlight an application in which we apply SANet to a call-center scheduling problem for a cable TV company. Finally, we show the efficiency and adaptability of our system via experimental results and discuss related works.

Keywords: Cable television, Call centres, Multi-agent systems, Problem-solving, Real-time systems

(Appears also in Section VI.)

125. Stolletz, Raik. Performance analysis of M -designed inbound call centers, *Operations Research Proceedings*, 2003, 9–16.

Abstract. Many call centers provide service for customers of different classes. We analyze a queueing model of an inbound call center with two customer classes, three agent groups, and skills-based routing. In our model we assume that a waiting customer may hang up before his service begins. We describe the states and the state space of this Markov queueing system and develop the steady-state equations. The behavior of this system is analyzed in numerical experiments and optimal economical allocations of the agents are discussed.

126. Whitt, Ward. How multiserver queues scale with growing congestion-dependent demand, *Operations Research*, 51 (4), July–August 2003, 531–542. Available at: <http://www.ieor.columbia.edu/~wow/>.

Abstract. We investigate how performance scales in the standard $M/M/n$ queue in the presence of growing congestion-dependent customer demand. We scale the queue by increasing the number of servers. We let the arrival rate depend on the steady-state congestion, considering several alternative congestion measures. We assume that the arrival rate is equal to the maximum possible output rate (the individual service rate times the number of servers) multiplied by a decreasing function of the congestion measure. Under minor regularity conditions, there is a unique equilibrium arrival rate for each n and, as n increases, the queue is brought into heavy traffic. The three different heavy-traffic regimes for multiserver queues identified by Halfin and Whitt (1981) each can arise depending on the congestion measure used. In considerable generality, there is asymptotic service efficiency—the server utilization approaches one—even if there is significant uncertainty about the arrival rate.

Keywords: Queues, State-dependent queues, Multiserver queues, Heavy traffic, Equilibrium, Congestion-dependent demand, Asymptotic service efficiency, Uncertainty about demand in queues, Economics of queues

127. Aguir, Salah, Fikri Karaesmen, O. Zeynep Aksin and Fabrice Chauvet. *OR Spectrum*, 26 (3), 2004, 353–376.

Abstract. This paper models a call center as a Markovian queue with multiple servers, where customer balking, impatience, and retrials are modeled explicitly. The resulting queue is analyzed both in a stationary and nonstationary setting. For the stationary setting a fluid approximation is proposed, which overcomes the computational burden of the continuous time Markov chain analysis, and which is shown to provide an accurate representation of the system for large call centers with high system load. An insensitivity property of the retrial rate to key system parameters is established. The fluid approximation is shown to work equally well for the nonstationary setting with time-varying arrival rates. Using the fluid approximation, the paper explores the retrial phenomenon for a real call center. The model is used to estimate the real arrival rates based on demand data, where retrials cannot be distinguished from first time calls. This is a common problem encountered in call centers. Through numerical examples, it is

shown that disregarding the retrial phenomenon in call centers can lead to huge distortions in subsequent forecasting and staffing analysis.

Keywords: Performance evaluation, Servers, Markov analysis, Call centers, Queueing, Studies, Models

128. Aksin, O. Zeynep, Francis de Vericourt and Fikri Karaesmen. Call center outsourcing contract design and choice. Working paper, October, 2004.
Available at <http://faculty.fuqua.duke.edu/fdv1/bio/OUT31_10.04.pdf>.

Abstract. This paper considers a call center outsourcing contract design and choice problem, faced by an outsourcing vendor and a service provider. The service provider receives an uncertain call volume over multiple periods, and is considering outsourcing all or part of these calls to an outsourcing vendor. Each call brings in a fixed revenue to the service provider. Answering calls requires having service capacity, thus implicit in the outsourcing decision is a capacity decision. Insufficient capacity implies that calls cannot be answered, which in turn means there will be a revenue loss. Faced with a choice between a volume-based and a capacity-based contract offered by an outsourcing vendor who has pricing power, the service provider determines optimal capacity levels. The optimal price and capacity of the outsourcing vendor together with the optimal capacity of the service provider determine optimal profits of each party under the two contracts being considered. Each party will prefer the contract that leads to higher profits. The paper characterizes optimal capacity levels, and partially characterizes optimal pricing decisions under each contract. The impact of demand variability and economic parameters on contract choice are explored through numerical examples. It is shown that no contract type is universally preferred, and that operating environments as well as cost-revenue structures have an important effect in outsourcing contract design and choice.

Keywords: Call center, Outsourcing, Contract design, Contract choice, Capacity investment, Exogenous and endogenous price

129. Armony, Mor and Constantinos Maglaras. On customer contact centers with a call-back option: Customer decisions, routing rules, and system design, *Operations Research*, 52 (2), 2004, 271–292.

Abstract. Organizations worldwide use contact centers as an important channel of communication and transaction with their customers. This paper describes a contact center with two channels, one for real-time telephone service, and another for a postponed call-back service offered with a guarantee on the maximum delay until a reply is received. Customers are sensitive to both real-time and call-back delay and their behavior is captured through a probabilistic choice model. The dynamics of the system are modeled as an M/M/N multiclass system. We rigorously justify that as the number of agents increases, the system's load approaches the maximum processing capacity. Based on this observation, we perform an asymptotic analysis in the many-server, heavy traffic regime to find an asymptotically optimal routing rule, characterize the unique equilibrium regime of the system, approximate the system performance, and finally, propose a staffing rule that picks the minimum number of agents that satisfies a set of operational constraints on the performance of the system.

Keywords: Operations research, Call centers, Service level agreements, Equilibrium, Mathematical models, Routing, Optimization, Real time

130. Atar, R., A. Mandelbaum and M.I. Reiman. Scheduling a multi-class queue with many exponential servers: Asymptotic optimality in heavy-traffic, *Annals of Appl. Prob.*, 14 (3), 2004, 1084–1134. Downloadable from: <http://ie.technion.ac.il/serveng>.

Abstract. We consider the problem of scheduling a queueing system in which many i.i.d. servers cater to several classes of impatient customers. Service times and impatience clocks are exponential while arrival processes are renewal. Our cost is an expected cumulative discounted function, linear or nonlinear, of appropriately normalized performance measures. As a special case, the cost per unit time can be a function of the number of customers waiting to be served in each class; the number actually being served, the abandonment rate, the delay experienced by customers, the number of idling servers, as well as certain combinations thereof. We study the system in an asymptotic heavy-traffic regime where the number of servers n and the offered load R are simultaneously scaled up and carefully balanced: $n \approx R + \beta\sqrt{R}$, for some scalar β . This yields an operation that enjoys the benefits of both heavy traffic (high server utilization) and light traffic (high service levels.)

We first consider a formal weak limit, through which our queueing scheduling problem gives rise to a diffusion control problem. We show that the latter has an optimal Markov control policy, and that the corresponding Hamilton-Jacobi-Bellman (HJB) equation has a unique classical solution. The Markov control policy and the HJB equation are then used to define scheduling control policies which we prove are asymptotically optimal for our original queueing system. The analysis yields both qualitative and quantitative insights, in particular on staffing levels, the roles of non-preemption and work-conservation, and the tradeoff between service quality and servers' efficiency.

131. Atar, R., A. Mandelbaum and M.I. Reiman. A Brownian control problem for a simple queueing system in the Halfin-Whitt regime, *Systems and Control Letters*, 51 (3–4), 2004, 269–275.

Abstract. We consider a formal diffusion limit for a control problem of a multi-type multi-server queueing system, in the regime proposed by Halfin and Whitt, in the form of a control problem where the dynamics are driven by a Brownian motion. In one dimension, a pathwise minimum is obtained and is characterized as the solution to a SDE. The pathwise solution to a special multi-dimensional problem (corresponding to a multi-type system) follows.

Keywords: Queueing networks, Stochastic control, Heavy traffic asymptotics

132. Atlason, Julius, Marina A. Epelman and Shane G. Henderson. Call center staffing with simulation and cutting plane methods, *Annals of Operations Research*, 127 (1–4), March 2004, 333–358. Available at: <http://critical.orie.cornell.edu/~shane/pubs.html>.

Abstract. We present an iterative cutting plane method for minimizing staffing costs in a service system subject to satisfying acceptable service level requirements over multiple time periods. We assume that the service level cannot be easily computed, and instead, is evaluated

using simulation. The simulation uses the method of common random numbers, so that the same sequence of random phenomena is observed when evaluating different staffing plans. In other words, we solve a sample average approximation problem. We establish convergence of the cutting plane method on a given sample average approximation. We also establish both convergence, and the rate of convergence, of the solutions to the sample average approximation to solutions of the original problem as the sample size increases. The cutting plane method relies on the service level functions being concave in the number of servers. We show how to verify this requirement as our algorithm proceeds. A numerical example showcases the properties of our method, and sheds light on when the concavity requirement can be expected to hold.

Keywords: Simulation optimization, Call centers, Cutting planes, Sample average approximation

133. Borst, S., A. Mandelbaum and M.I. Reiman. Dimensioning large call centers, *Operations Research*, 52 (1), 2004, 17–34. Downloadable from: <<http://ie.technion.ac.il/serveng>>.

Abstract. We develop a framework for asymptotic optimization of a queueing system. The motivation is the staffing problem of call centers with 100s of agents (or more). Such a call center is modeled as an M/M/N queue, where the number of agents N is large. Within our framework, we determine the asymptotically optimal staffing level N^* that trades off agents' costs with service quality: the higher the latter, the more expensive is the former. As an alternative to this optimization, we also develop a constraint satisfaction approach where one chooses the least N^* that adheres to a given constraint on waiting cost. Either way, the analysis gives rise to three regimes of operation: quality-driven, where the focus is on service quality; efficiency-driven, which emphasizes agents' costs; and a rationalized regime that balances, and in fact unifies, the other two. Numerical experiments reveal remarkable accuracy of our asymptotic approximations: over a wide range of parameters, from the very small to the extremely large, N^* is *exactly* optimal, or it is accurate to within a single agent. We demonstrate the utility of our approach by revisiting the square-root safety staffing principle, which is a long-existing rule-of-thumb for staffing the M/M/N queue. In its simplest form, our rule is as follows: if c is the hourly cost of an agent, and a is the hourly cost of customers' delay, then $N^* = R + y\left(\frac{a}{c}\right)\sqrt{R}$, where R is the offered load, and $y^*(\cdot)$ is a function that is easily computable.

134. de Vericourt, Francis and Yong-Pin Zhou. A routing problem for call centers with customer callbacks after service failure. Working paper, University of Washington, March 2004.

Abstract. Traditional research on queue routing models usually ignore service quality-related factors. In this paper, we analyze the routing problem in a system where customers call back when the service customer representatives (CSR) do not satisfy them. We introduce the concept of call resolution probability, and we argue that this constitutes a good proxy for call quality. This call resolution probability (p) but also the average service time is CSR dependent. The objective is then to minimize the average total time of call resolution including callbacks. We use an MDP formulation to study the optimal routing policy. We obtain analytical results and insights regarding how to account for both the service time and the call resolution probability. In particular, we provide conditions for which routing to the available CSR with the highest call resolution rate is optimal. We also develop heuristics that can be easily implemented in practice.

135. Gans, Noah and Yong-Pin Zhou. Overflow routing for call-center outsourcing. Working paper, Wharton School of Business Administration, May 2004.

Abstract. Companies may choose to outsource parts, but not all, of their call-center operations. In some cases, they classify customers as high or low-value, serving the former with their “in house” operations and routing the latter to an outsourcer. Typically, they impose service-level constraints on the time each type of customer waits on hold. We consider this outsourcing problem from both the client company’s and the outsourcer’s points of view. We pose the client’s problem as that of maximizing the throughput of low-value calls, subject to a high-value customer service-level constraint, and the outsourcer’s as one of finding the minimal staffing level able to fulfill the low-value customers service-level constraint. The paper’s analytical results characterize effective routing policies at the client, as well as the overflow process of low-value calls to the outsourcer. Its numerical results help to show how the percentage of low-value calls that overflows from the client affects the burstiness of the overflow process and, in turn, the effectiveness of various staffing heuristics at the outsourcer.

136. Jelenković, A., A. Mandelbaum and P. Momčilović. Heavy traffic limits for queues with many deterministic servers, *QUESTA*, 47, 2004, 53–69. Available at: <<http://ie.technion.ac.il/serveng>>.

Abstract. Consider a sequence of stationary GI/D/N queues indexed by $N \uparrow \infty$, with servers’ utilization $1 - \beta/\sqrt{N}$, $\beta > 0$. For such queues we show that the scaled waiting times $\sqrt{N}W_N$ converge to the (finite) supremum of a Gaussian random walk with drift $-\beta$. This further implies a corresponding limit for the number of customers in the system, an easily computable nondegenerate limiting delay probability in terms of Spitzer’s random-walk identities, and $\sqrt{N}$ rate of convergence. Our asymptotic regime is important for rational dimensioning of large-scale service systems, for example telephone- or internet-based, since it achieves, simultaneously, arbitrarily high service-quality and utilization-efficiency.

Keywords: Multi-server queue, GI/D/N, Deterministic service time, Heavy-traffic, Quality-and-efficiency-driven (QED) or Halfin-Whitt regime, Telephone call or contact centers, Economies of scale, Gaussian random walk, Spitzer’s identities

137. Jiménez, Tania and Ger Koole. Scaling and comparison of fluid limits of queues applied to call centers with time-varying parameters, *OR Spectrum*, 26, 2004, 413–422. **Abstract.** Transient overload situations in queues can be approximated by fluid queues. We strengthen earlier results on the comparison of multi-server tandem systems with their fluid limits. At the same time, we give conditions under which economies-of-scale hold. We apply the results to call centers.

Keywords: Call centers, Fluid limits, Economies-of-scale, Inhomogeneous Poisson processes

138. Mandelbaum, A. and A.L. Stolyar. Scheduling flexible servers with convex delay costs: Heavy-traffic optimality of the generalized $c\mu$ -rule, *Operations Research*, 52 (6), 2004, 836–855. Available at: <<http://ie.technion.ac.il/serveng>>

Abstract. We consider a queueing system with multi-type customers and flexible (multi-skilled) servers that work in parallel. Let μ_{ij} denote the service rate of type i customers by server j (the

reciprocal of an average service time); $\mu_{ij} = 0$ indicates that server j cannot serve type i . We analyze the system in heavy traffic, seeking to minimize either queueing or waiting costs. To this end, assume that the queue of type i incurs a queueing cost at rate $C_i(Q_i)$, which is an increasing convex function $C_i(\cdot)$ of the queue length Q_i . Then, we show that a simple generalized $c\mu$ -rule minimizes queueing costs, asymptotically, over essentially all scheduling disciplines, preemptive or non-preemptive. Specifically, when becoming idle at time t , server j chooses for service the longest-waiting type i customers where

$$i \in \arg \max_i C'_i(Q_i(t))\mu_{ij} .$$

(C'_i is the derivative of C_i .) Alternatively, each type i customer could incur a waiting cost $C_i(W_i)$, where W_i is its sojourn time. Then, waiting costs are asymptotically minimized by serving type i such that

$$i \in \arg \max_i C'_i(W_i(t))\mu_{ij} ,$$

where $W_i(t)$ is the head-of-the-line waiting time in queue i at time t .

139. Mandelbaum, A. and Zeltyn, S. The impact of customers' patience on delay and abandonment: Some empirically-driven experiments with the M/M/n+G queue, *OR Spectrum*, 26 (3), 2004, 377–411. Downloadable from: <<http://ie.technion.ac.il/serveng>>.

Abstract. Our research is motivated by a phenomenon that has been observed in telephone call center data: A clear linear relation between the probability to abandon and average waiting time. Such a relation is theoretically justifiable when customers' patience is memoryless, but it lacks an explanation in general. We thus analyze its robustness within the framework of the M/M/n+G queue, which gives rise to further and empirically-driven experiments. In the theoretical part of the paper, we establish order relations for performance measures of the M/M/n+G queues, and some light-traffic results. In particular, we prove that, with λ, μ, n and *average patience time fixed*, deterministic patience minimizes the probability to abandon and maximizes the average wait in queue. In the experimental part, we describe the behavior of M/M/n+G performance measures for different patience distributions. The findings are then related to our theoretical results and some observed real-data phenomena. In particular, clear nonlinear relations (convex, concave and mixed) emerge between the probability to abandon and average wait. However, when restricted over low to moderate abandonment rates, approximate linearity prevails, as observed in practice.

Keywords: Abandonment, Call centers, Erlang-A, Queues and queueing

140. Shimkin, N. and A. Mandelbaum. Rational abandonment from tele-queues: Nonlinear waiting costs with heterogeneous preferences, *QUESTA*, 47 (1–2), May-June, 2004, 117–146. Available at: <<http://ie.technion.ac.il/serveng>>

Abstract. We consider the modeling of abandonment from a queueing system by impatient customers. Within the proposed model, customers act rationally to maximize a utility function that weights service utility against expected waiting cost. Customers are heterogeneous, in the sense that their utility function parameters may vary across the customer population. The queue is assumed invisible to waiting customers, who do not obtain any information regarding their

standing in the queue during their waiting period. Such circumstances apply, for example, in telephone centers or other remote service facilities, to which we refer as *tele-queues*. We analyze this decision model within a multi-server queue with impatient customers, and seek to characterize the Nash equilibria of this system. These equilibria may be viewed as stable operating points of the system, and determine the customer abandonment profile along with other system-wide performance measures. We provide conditions for the existence and uniqueness of the equilibrium, and suggest procedures for its computation. We also suggest a notion of an equilibrium based on sub-optimal decisions, the *myopic* equilibrium, which enjoys favorable analytical properties. Some concrete examples are provided to illustrate the modeling approach and analysis. The present paper supplements previous ones which were restricted to linear waiting costs or heterogeneous customer population.

Keywords: Tele-queues or invisible queues, Abandonment, Impatient customers, Nash equilibrium, Telephone call centers, Contact centers, Multi-server queues

141. Shumsky, Robert A. Approximation and analysis of a call center with flexible and specialized servers, *OR Spectrum*, 26 (3), 2004, 307–330.

Abstract. This paper describes a decomposition algorithm to estimate the performance of a call center with two types of customers and two server categories. In this system, specialized servers can process only one customer type, while flexible servers handle both types. The algorithm divides the systems state space into regions, and simple approximate models find the conditional system performance within each region. While the procedure described here is tailored for a system with a priority queue discipline and two customer classes, it can be adapted for systems with FCFS queue disciplines and for systems with more than two customer types. Performance measures generated by the procedure are sufficiently accurate for many service system design decisions, such as setting telephone call center staffing levels and long-term capacity planning. The procedure is also extremely fast, and its computational requirements do not grow with system congestion. Numerical tests demonstrate that its running time is significantly lower than traditional numerical methods for generating approximations. As an example of its use, we employ the procedure to demonstrate the benefits of server flexibility in a particular telephone call center.

Keywords: Servers, Call centers, Studies, Algorithms, Queueing

142. Sisselman, Michael E. and Ward Whitt. Empowering customer-contact agents via preference-based routing. SeatLink Working paper, 2004. Available at: <http://www.columbia.edu/~ww.2040/recent/html>.

Abstract. SeatLink improves the overall performance of a contact center, by allowing agents to influence the routing of inbound interactions based on their personal preferences.

143. Steckley, Samuel G., Shane G. Henderson and Vijay Mehrotra. Service system planning in the presence of a random arrival rate. Working paper, School of Operations Research and Industrial Engineering, Cornell University, November 1, 2004.

Abstract. A fundamental workforce management challenge for inbound call center managers is to determine the number of agents to be scheduled to answer calls during each time period. These decisions are typically based on the desire to minimize cost while achieving some pre-determined service objectives. These service objectives are typically functionals of the customer queue time distributions, which in turn are highly dependent on the distribution of customer arrivals. The traditional call center modelling approach is to divide a given planning horizon into a series of time periods, and to assume a deterministic fixed-rate Poisson arrival process for each period. These arrival processes then determine the performance measures that drive the selection of staffing levels. The arrival rate is very often not known with certainty, as we show in this paper through the analysis of historical data from several call centers. This type of uncertainty arises either because the arrival rate varies randomly over time or because the rate is simply unknown due to lack of information. In either case, the uncertainty in the arrival rate has major implications for the validity of traditional performance measures and consequently on the quality of staffing decisions. In this paper, we consider two potential forms of uncertainty in the arrival rates, and in each case address the question of what performance measures to use in order to support staffing decisions. We also explore ways to compute appropriate estimates for these performance measures. We clarify when the analytical approximations can be expected to be accurate and describe when and how simulation should be used to provide better estimates.

144. Whitt, Ward. A diffusion approximation for the $G/GI/n/m$ queue, *Operations Research*, **52** (6), 2004, 922–941. Available at: <http://www.ieor.columbia.edu/~wow/>.

Abstract. We develop a heuristic diffusion approximation for the queue-length stochastic processes representing the number in system at arrival epochs and at arbitrary times in the $G/GI/n/m$ queueing model, which has a general (stationary or asymptotically stationary) arrival process, independent and identically distributed service times with a general distribution, n servers and m extra waiting spaces. We use the steady-state distribution of that diffusion process to obtain approximations for steady-state performance measures, focusing especially upon the steady-state delay probability.

We primarily base our diffusion approximation on heavy-traffic limits in which n tends to infinity as the traffic intensity increases. For the $GI/M/n/\infty$ special case, Halfin and Whitt (1981) showed that scaled versions of these queue-length processes converge to a piecewise-linear diffusion process when the traffic intensity ρ_n approaches 1 with $(1 - \rho_n)\sqrt{n} \rightarrow \beta$ for $0 < \beta < \infty$. A companion paper, Whitt (2002b), extends that limit to a special class of $G/GI/n/m$ models in which the service-time distribution is a mixture of an exponential distribution with probability p and a unit point mass at 0 with probability $1 - p$. Finite waiting rooms are treated by incorporating the additional limit $m_n/\sqrt{n} \rightarrow \kappa$ for $0 < \kappa \leq \infty$. The heuristic one-dimensional diffusion-process approximation for the more general $G/GI/n/m$ model developed here is consistent with those heavy-traffic limits. Heavy-traffic limits for the $GI/PH/n/\infty$ model with phase-type service-time distributions established by Puhalskii and Reiman (2000) imply that this one-dimensional diffusion process is not asymptotically correct for non-exponential phase-type service-time distributions, but nevertheless the heuristic diffusion approximation developed here yields useful approximations for key performance measures, such as the delay probability. The accuracy is confirmed by simulation.

Keywords: Queues, Multiserver queues, Delay probability, Blocking probability, Heavy-traffic,

145. Armory, M., N. Shimkin and W. Whitt. The impact of delay announcements in many-server queues with abandonment. Working paper + supplementary material, 2005. Available at: <http://www.columbia.edu/~ww.2040/recent/html>.

Abstract. This paper develops methods to study the impact upon aggregate system performance of state-dependent delay announcements to arriving customers in a many-server queue with customer abandonment. We assume that the queue is not visible to waiting customers, as in most customer contact centers, when contact is made by telephone, email or instant messaging. As a function of the announced delay, customers may balk or have new abandonment behavior. To perform a rough-cut analysis, prior to detailed simulation, we use a fluid model, which provides an approximate and highly simplified description of large systems in an overloaded regime. In the fluid model, all customers are faced with the same delay and consequently can be given the same delay announcement. At the same time, the time-to-abandon distribution plays a critical role. We show that the resulting approximate description of aggregate performance is effective by comparing to (1) a numerical algorithm approximating the steady-state performance of an $M/GI/s + GI$ queueing model with a constant delay announcement and (2) simulations with state-dependent announcements. Specifically, customers who cannot enter service immediately are told the delay of the last customer to enter service. Within the fluid-model framework, we find conditions under which there exists a unique equilibrium delay, where the actual delay coincides with the announced delay, and for a natural iteration to converge to that equilibrium delay. We further consider the effect of providing biased delay information, and show how the fluid model can be applied to do further studies.

Keywords: Delay announcements, Informing customers about anticipated delays, Customer abandonment, Call centers, Contact centers, Deterministic fluid models, Multi-server queues

146. Atar, Rami, A. Mandelbaum and G. Shaikhet. Queueing systems with many servers: Null controllability in heavy traffic. Submitted to the *Annals of Appl. Prob.*, June 2005. Available at: http://iew3.technion.ac.il/serveng2006W/References/null_controllability.pdf.

Abstract. A queueing model has $J \geq 2$ heterogeneous service stations, each consisting of many independent servers with identical capabilities. Customers of $I \geq 2$ classes can be served at these stations at different rates, that depend on both the class and the station. A system administrator dynamically controls scheduling and routing. We study this model in the Central Limit Theorem (or heavy traffic) regime proposed by Halfin and Whitt. We derive a diffusion model on $\mathbb{R}^I$ with a singular control term, that describes the scaling limit of the queueing model. The singular term may be used to constrain the diffusion to lie in certain subsets of $\mathbb{R}^I$ at all times $t > 0$. We say that the diffusion is *null-controllable* if it can be constrained to X_- , the minimal closed subset of $\mathbb{R}^I$ containing all states of the prelimit queueing model for which all queues are empty. We give sufficient conditions for null controllability of the diffusion. Under these conditions, we also show that an analogous, asymptotic result holds for the queueing model, by constructing control policies under which, for any given $0 < \epsilon < T < \infty$, all queues in the system are kept empty on the time interval $[\epsilon, T]$, with probability approaching one. This introduces a new, unusual heavy traffic ‘behavior’: On the one hand, the system is critically loaded, in

the sense that an increase in any of the external arrival rates at the ‘fluid level’ results with an overloaded system. On the other hand, as far as queue lengths are concerned, the system behaves as if it is underloaded.

Keywords: Multiclass queueing systems, heavy traffic, scheduling and routing, singular control of diffusions, null controllability

147. Brown, L., N. Gans, A. Mandelbaum, A. Sakov, H. Shen, S. Zeltyn and L. Zhao. Statistical analysis of a telephone call center: A queueing-science perspective, *JASA*, 100 (469), 2005, 36–50. Available at: <<http://ie.technion.ac.il/serveng>>

Abstract. A call center is a service network in which agents provide telephone-based services. Customers that seek these services are delayed in tele-queues.

This paper summarizes an analysis of a unique record of call center operations. The data comprise a complete operational history of a small banking call center, call by call, over a full year. Taking the perspective of queueing theory, we decompose the service process into three fundamental components: arrivals, customer abandonment behavior and service durations. Each component involves different basic mathematical structures and requires a different style of statistical analysis. Some of the key empirical results are sketched, along with descriptions of the varied techniques required.

Several statistical techniques are developed for analysis of the basic components. One of these is a test that a point process is a Poisson process. Another involves estimation of the mean function in a nonparametric regression with lognormal errors. A new graphical technique is introduced for nonparametric hazard rate estimation with censored data. Models are developed and implemented for forecasting of Poisson arrival rates.

We then survey how the characteristics deduced from the statistical analyses form the building blocks for theoretically interesting and practically useful mathematical models for call center operations.

Keywords: Call centers, Queueing theory, Lognormal distribution, Inhomogeneous Poisson process, Censored data, Human patience, Prediction of Poisson rates, Khintchine-Pollaczek formula, Service times, Arrival rate, Abandonment rate, Multiserver queues
(Appears also in Section II.)

148. Feldman, Z. A. Mandelbaum, W.A. Massey and W. Whitt. Staffing of time-varying queues to achieve time-stable performance. Working paper, May 2005. Available at <<http://iew3.technion.ac.il/serveng2006W/References/JournalVersion0515.pdf>>

Abstract. Continuing research by Jennings, Mandelbaum, Massey and Whitt (1996), we investigate methods to perform time-dependent staffing for many-server queues. Our aim is to achieve time-stable performance in the face of general time-varying arrival rates. As before, we target a stable probability of delay. Motivated by telephone call centers, we focus on many-server models with customer abandonment, especially the Markovian $M_t/M/s_t + M$ model, having an exponential time-to-abandon distribution (the $+M$), an exponential service-time distribution and a nonhomogeneous Poisson arrival process. We develop three different methods for staffing, with decreasing generality and decreasing complexity: (i) a simulation-based iterative-staffing

algorithm (ISA), (ii) the square-root-staffing rule with service grade determined by the modified-offered-load approximation, and (iii) simply staffing at the offered load itself.

Keywords: Contact centers, Call centers, Staffing, Non-stationary queues, Queues with time-dependent arrival rates, Capacity planning, Queues with abandonment, Time-varying Erlang models

149. Feldman, Z. A. Mandelbaum, W.A. Massey and W. Whitt. Staffing of time-varying queues to achieve time-stable performance—Unabridged version: Internet supplement to the above-named paper. Available at <<http://iew3.technion.ac.il/serveng2006W/References/Supplement0515.pdf>>.

150. Harrison, J.M. and Assaf Zeevi. A method for staffing large call centers based on stochastic fluid models, *Manufacturing & Service Operations Management*, 7(1), Winter 2005, 20–36.

Abstract. We consider a call center model with m input flows and r pools of agents; the m -vector lambda of instantaneous arrival rates is allowed to be time dependent and to vary stochastically. Seeking to optimize the trade-off between personnel costs and abandonment penalties, we develop and illustrate a practical method for sizing the r agent pools. Using stochastic fluid models, this method reduces the staffing problem to a multidimensional news-vendor problem, which can be solved numerically by a combination of linear programming and Monte Carlo simulation. Numerical examples are presented, and in all cases the pool sizes derived by means of the proposed method are very close to optimal.

Keywords: Call center staffing, Stochastic fluid models, Call center model, Input flows, Personnel costs, Abandonment penalties, Multidimensional news-vendor problem, Linear programming, Monte-Carlo simulation, Capacity sizing, Fluid analysis, Queueing process, Random environment, Stochastic programming

151. Milner, Joseph M. and Tava Lennon Olsen. Service level agreements in call centers: Perils and prescriptions. Working paper, John M. Olin School of Business, September, 2004; Revised: July, 2005. Available at <<http://www.olin.wustl.edu/workingpapers/pdf/2004-11-004.pdf>>.

Abstract. A call center with both contract and non-contract customers was giving priority to the contract customers only in off-peak hours, precisely when having priority was least important. In this paper we investigate whether this is rational behavior on the part of the call center and what the implications are for customers. In particular, we show that under contracts on the percentile of delay, which are commonly used in the call-center industry, this is rational behavior, at least under the asymptotic regime considered in the paper. We then suggest other contracts that do not result in this type of undesirable behavior from a contract customer's perspective. We compare the performance of the different contracts in terms of mean, variance, and outer percentiles of delay for both customer types using both numerical and asymptotic heavy-traffic analyses. We argue that including terms reflecting the second moment of delay in a contract would be beneficial to contract customers and, in a sense, fairer.

152. Ormeci, E. Lerzan and O. Zeynep Aksin. Revenue management through dynamic cross-selling in call centers. Working paper, Koc University, August 2004; revised October 2005. Available

at <<http://home.ku.edu.tr/lormeci/OA-MS-05.pdf>>.

Abstract. This paper models the cross-selling problem of a call center as a dynamic service rate control problem. The key tradeoff between revenue generation and congestion in a call center is addressed in a dynamic framework. The question of when and to whom to cross-sell is explored using this model. The analysis shows that unlike current marketing practice which targets cross-sell attempts to entire customer segments, optimal dynamic policies may target selected customers from different segments. Structural properties of optimal policies are explored. Sufficient conditions are established for the existence of preferred calls and classes; i.e., calls that will always generate a cross-sell attempt. Numerical examples, that are motivated by a real call center, identify call center characteristics that increase the significance of considering dynamic policies rather than simple static cross-selling rules as currently observed. The value of these dynamic policies and static rules are compared. The numerical analysis further establish the value of different types of automation available for cross-selling. Finally, the structural properties lead to a heuristic that generates sophisticated static rules leading to near optimal performance both for a loss system and a queueing system.

Keywords: Call center, Cross-selling, Revenue management, Customer relationship management, Dynamic control, Loss system

153. Sisselman, Michael E. and Ward Whitt. Value-based routing and preference-based routing in customer contact centers. Working paper, 2005. Also: A preference-based-routing example solved by linear programming with excel solver. Supporting material, 2005. Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. Telephone call centers and their generalizations—customer contact centers—usually handle several types of customer service requests (calls). Since customer service representatives (agents) have different call-handling abilities, contact centers exploit skill-based routing (SBR) to assign calls to appropriate agents, aiming to respond properly as well as promptly. Established agent-staffing and call-routing algorithms ensure that agents have the required call-handling skills and that constraints are met for standard congestion measures, such as the percentage of calls of each type that abandon before starting service and the percentage of answered calls of each type that are delayed more than a specified number of seconds. We propose going beyond these traditional performance measures to focus on the expected value accrued from having the agent handle the call. Expected value might represent expected revenue or the likelihood of first-call resolution. Value might also reflect agent call-handling preferences. We show how value-based routing (VBR) and preference-based routing (PBR) can be introduced in the context of an existing SBR framework, where the existing SBR is based on static-priority routing using a highly-structured priority matrix. Since VBR and PBR use the same SBR framework, they can be implemented with the existing SBR algorithm in the automatic call distributor (ACD); it is not necessary to replace the ACD. We use mathematical programming to find an effective priority matrix. We select the priority matrix to use during a specified time interval (e.g., 30-minute period) by maximizing the total expected value over that time interval, subject to constraints that ensure that standard performance constraints are met.

Keywords: Customer contact centers, Telephone call centers, Skill-based routing, Value-based routing, Preference-based routing, Indirect value-based routing, Priorities, Mathematical pro-

gramming, Assignment problem, Turnover, Churn

154. Wallace, Rodney B. and Ward Whitt. A staffing algorithm for call centers with skill-based routing, *Manufacturing & Service Operations Management*, 7 (4), 2005, 276–294. Available at: <http://www.columbia.edu/~ww.2040/recent/html>. Supplementary material on this paper is also available at this website.

Abstract. Call centers usually handle several types of calls, but it is usually not possible or cost effective to have every agent be able to handle every type of call. Thus, the agents tend to have different skills, in different combinations. In such an environment, it is challenging to route calls effectively and determine the staff requirements. This paper addresses both of these routing and staffing problems by exploiting limited cross-training. Consistent with the literature on flexible manufacturing, we find that minimal flexibility can provide great benefits: Simulation experiments show that when (1) the service-time distribution does not depend on the call type or the agent and (2) each agent has only two skills, in appropriate combinations, the performance is almost as good as when each agent has all skills. We apply this flexibility property to develop an algorithm for both routing and staffing, aiming to minimize the total staff subject to per-class performance constraints. With appropriate flexibility, it suffices to use a suboptimal routing algorithm. Simulation experiments show that the overall procedure can be remarkably effective: The required staff with limited cross-training can be nearly the same as if all agents had all skills. Hence, the overall algorithm is nearly optimal for that scenario.

Keywords: Call centers, Flexibility, Workforce planning, Scheduling algorithms, Skills, Simulation, Studies

155. Whitt, Ward. Heavy-traffic limits for the $G/H_2^*/n/m$ queue, *Mathematics of Operations Research*, 30 (1), 2005, 1–27. Available at: <http://www.ieor.columbia.edu/~wow/>.

Abstract. We establish heavy-traffic stochastic-process limits for queue-length and waiting-time stochastic processes in a class of $G/GI/n/m$ queueing models with n servers and m extra waiting spaces. We let the arrival process be general, only requiring that it satisfy a functional central limit theorem. We consider a special class of service-time distributions, denoted by H_2^* , which are mixtures of an exponential distribution with probability p and a unit point mass at 0 with probability $1 - p$. As in Halfin and Whitt (1981), Mandelbaum, Massey and Reiman (1998), Puhalskii and Reiman (2000) and Garnett, Mandelbaum and Reiman (2000), we consider a sequence of queueing models indexed by the number of servers, n , and let n tend to infinity along with the traffic intensities ρ_n so that $\sqrt{n}(1 - \rho_n) \rightarrow \beta$ for $-\infty < \beta < \infty$. To treat finite waiting rooms, we let $m_n/\sqrt{n} \rightarrow \kappa$ for $0 < \kappa \leq \infty$. We also consider the case of exponential customer abandonments. With the special H_2^* service-time distribution, the limit processes are piecewise-linear one-dimensional diffusion processes with an infinitesimal variance that has a discontinuity at the origin when $p < 1$.

Keywords: Queues, Multiserver queues, Stochastic-process limits, Heavy-traffic, Diffusion approximations, Abandonments, Reneging, Customer impatience

156. Whitt, Ward. Engineering solution of a basic call-center model, *Management Science*, 51 (2),

2005, 221–235. Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>. Supplementary material on this paper is also available at this website.

Abstract. An algorithm is developed to rapidly compute approximations for all the standard steady-state performance measures in the basic call-center queuing model $M/GI/s/r+GI$, which has a Poisson arrival process, independent and identically distributed (IID) service times with a general distribution, s Servers, r extra waiting spaces and IID customer abandonment times with a general distribution. Empirical studies of call centers indicate that the service time and abandon-time distributions often are not nearly exponential, so that it is important to go beyond the Markovian $M/M/s/r+M$ special case, but the general service-time and abandon-time distributions make the realistic model very difficult to analyze directly. The proposed algorithm is based on an approximation by an appropriate Markovian $M/M/s/r+M(n)$ queueing, where $M(n)$ denotes state-dependent abandonment rates.

Keywords: Algorithms, Call centers, Queuing theory, Markov analysis, Performance evaluation, Statistical analysis, Workforce planning

157. Whitt, Ward. Two fluid approximations for multi-server queues with abandonments, *Operations Research Letters*, 33, 2005, 363–372.

Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. Insight is provided into a previously developed $M/M/s/r+M(n)$ approximation for the $M/GI/s/r+GI$ queueing model by establishing fluid and diffusion limits for the approximating model. Fluid approximations for the two models are compared in the many-server efficiency-driven (overloaded) regime. The two fluid approximations do not coincide, but they are close.

Keywords: Multi-server queues with abandonment, Queues with state-dependent rates, Heavy-traffic limits, Fluid limits, Diffusion approximations, Call centers

158. Abate, J. and W. Whitt. A unified framework for numerically inverting Laplace transforms, *INFORMS Journal of Computing*, 2006. To appear. Available at:

<<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. We introduce and investigate a framework for constructing algorithms to numerically invert Laplace transforms. Given a Laplace transform $\hat{f}$ of a complex-valued function of a nonnegative real-variable, f , the function f is approximated by a finite linear combination of the transform values; i.e., we use the inversion formula

$$f(t) \approx f_n(t) \equiv \frac{1}{t} \sum_{k=0}^n \omega_k \hat{f}\left(\frac{\alpha_k}{t}\right), \quad 0 < t < \infty,$$

where the weights ω_k and nodes α_k are complex numbers, which depend on n , but do not depend on the transform $\hat{f}$ or the time argument t . Many different algorithms can be put into this framework, because it remains to specify the weights and nodes. We examine three one-dimensional inversion routines in this framework: the Gaver-Stehfest algorithm, a version of the Fourier-series method with Euler summation, and a version of the Talbot algorithm, which is

based on deforming the contour in the Bromwich inversion integral. We show that these three building blocks can be combined to produce different algorithms for numerically inverting two-dimensional Laplace transforms, again all depending on the single parameter n . We show that it can be advantageous to use different one-dimensional algorithms in the inner and outer loops.

Keywords: Laplace transforms, Numerical transform inversion, Fourier-series method, Talbot's method, Gaver-Stehfest algorithm, Multi-precision computing, Multidimensional Laplace transforms, Multidimensional transform inversion

159. Armony, M., I. Gurvich and A. Mandelbaum. Service level differentiation in call centers with fully flexible servers. Working paper, Technion—Israel Institute of Technology, Haifa, Israel, 2006. Available at <<http://iew3.technion.ac.il/serveng2006W/References/MS-01040-2004R1.pdf>>.

Abstract. We study large-scale service systems with multiple customer classes and many statistically identical servers. The following question is addressed: How many servers are required (staffing) and how does one match them with customers (control) in order to minimize staffing cost, subject to class level quality of service constraints? We tackle this question by characterizing scheduling and staffing schemes that are asymptotically optimal in the limit, as system load grows to infinity. The asymptotic regimes considered are consistent with the Efficiency Driven (ED), Quality Driven (QD) and Quality and Efficiency Driven (QED) regimes, first introduced in the context of a single class service system.

Our main findings are: a) *Decoupling* of staffing and control, namely (i) Staffing disregards the multi-class nature of the system and is analogous to the staffing of a single class system with the same aggregate demand and a single *global* quality of service constraint, and (ii) Class level service differentiation is obtained by using a simple *Idle server based Threshold-Priority* (ITP) control (with state-independent thresholds), b) *Robustness* of the staffing and control rules: Our proposed Single-Class Staffing (SCS) rule and ITP control are approximately optimal under various problem formulations and model assumptions. Particularly, although our solution is shown to be asymptotically optimal for large systems, we numerically demonstrate that it performs well also for relatively small systems.

160. Armony, M., I. Gurvich and A. Mandelbaum. Service level differentiation in call centers with fully flexible servers: Technical appendix. Working paper, Technion—Israel Institute of Technology, Haifa, Israel, 2006. Available at <http://iew3.technion.ac.il/serveng2006W/References/MS-01040-2004R1_Appendix.pdf>.

Abstract. In this technical appendix, we provide proofs for the various results stated in the manuscript entitled: “Service level differentiation in call centers with fully flexible servers”.

161. Green, Linda V., Peter J. Kolesar and Ward Whitt. Coping with time-varying demand when setting staffing requirements for a service system, *Production and Operations Management (POMS)*, 2006 (forthcoming). Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. We review queueing-theory methods for setting staffing requirements in service systems where customer demand varies in a predictable pattern over the day. Analyzing these

systems is not straightforward, because standard queueing theory focuses on the long-run steady-state behavior of stationary models. We show how to adapt stationary queueing models for use in nonstationary environments so that time-dependent performance is captured and staffing requirements can be set. Relatively little modification of straightforward stationary analysis applies in systems where service times are short and the targeted quality of service is high. When service times are moderate and the targeted quality of service is still high, time-lag refinements can improve traditional stationary independent period-by-period and peak-hour approximations. Time-varying infinite-server models help develop refinements, because closed-form expressions exist for their time-dependent behavior. More difficult cases with very long service times and other complicated features, such as end-of-day effects, can often be treated by a modified-offered-load approximation, which is based on an associated infinite-server model. Numerical algorithms and deterministic fluid models are useful when the system is overloaded for an extensive period of time. Our discussion focuses on telephone call centers, but applications to police patrol, banking and hospital emergency rooms are also mentioned.

Keywords: Staffing, Call centers, Time-varying demand, Queues with time-varying arrival rate, Nonstationary queueing models, Police patrol, Banking, Hospital emergency rooms

162. Khudyakov, Polina. Designing a call center with an IVR (Interactive Voice Response). M.Sc. thesis, Technion—Israel Institute of Technology, Haifa, Israel, 2006.

Abstract. A call center is a popular term for a service operation that handles telephone calls of customers. A call center typically consists of agents that handle incoming calls, telephone trunk lines, an Interactive Voice Response (IVR) unit, and a switch that routes calls to agents.

The subject of this thesis is a Markovian model for a call center with an IVR. We calculate operational performance measures, such as the probability for a busy signal and average wait for an agent. The calculations of these measures are cumbersome and they lack insight. We thus approximate the measures in an asymptotic regime known as QED (Quality Efficiency Regime), which is suitable for moderate to large call centers. The approximations are both insightful and easy to calculate (for up to 1000's of agents). They yield, as special cases, known approximations for the Erlang-B, Erlang-C and M/M/S/N queue.

Finally, we develop an algorithm for optimal staffing and trunk level. The algorithm is then used to analyze ways for reducing the operational costs of a call center, to understand the effect of a call center's size on its service level, and to investigate the effect of changes in system parameters on performance—for example, increasing IVR functionality (which would reasonably imply fewer but longer agent calls).

163. Mandelbaum, A. and S. Zeltyn. Staffing many-server queues with impatient customers: Constraint satisfaction in call centers. Working paper, Technion—Israel Institute of Technology, Haifa, Israel, 2006. Available at http://iew3.technion.ac.il/serveng2006W/References/MMNG_constraint.pdf.

Abstract. Motivated by call center practice, we study asymptotically optimal staffing of many-server queues with abandonment. A call center is modelled as an M/M/n+G queue, which is characterized by Poisson arrivals, exponential service times, n servers and Generally distributed

patience times of customers. Our asymptotic analysis is performed as the arrival rate, and hence the number of servers n , increase indefinitely.

We consider a constraint satisfaction problem, where one chooses the minimal staffing level n that adheres to a given cost constraint. The cost can incorporate the fraction abandoning, average wait and tail probabilities of wait. Depending on the cost, several operational regimes arise as asymptotically optimal: Efficiency-Driven (ED), Quality and Efficiency Driven (QED) and also a new ED+QED operational regime that enables QED tuning of the ED regime. Numerical experiments demonstrate that, over a wide range of system parameters, our approximations provide useful insight as well as excellent fit to exact optimal solutions. It turns out that the QED regime is preferable either for small-to-moderate call centers or for large call centers with relatively strict performance constraints. The other two regimes are more appropriate for large call centers with loose constraints.

We consider two versions of the constraint satisfaction problem. The main one is constraint satisfaction on a single time-interval, say one hour, which is common in practice. Of special interest is a constraint on the tail probability, in which case our new ED+QED staffing turns out asymptotically optimal. We also address a global constraint problem, say over a full day. Here several time intervals, say 24 hours, are considered, with interval-dependent staffing levels allowed; one seeks to minimize staffing levels, or more generally costs, given overall performance constraint. In this case, there is the added flexibility of trading service levels among time intervals, but we demonstrate that only little gain is associated with this flexibility.

164. Mandelbaum, A. and S. Zeltyn. Service engineering in action: The Palm/Erlang-A queue, with applications to call centers. Working paper, Technion—Israel Institute of Technology, Haifa, Israel, 2006. Available at <http://iew3.technion.ac.il/serveng2006W/References/MMNM_IAO.pdf>.

Abstract. Our note is dedicated to the Palm/Erlang-A Queue. This is the simplest practice-worthy queueing model, that accounts for customers impatience while waiting. The model is gaining importance in support of the staffing of call centers, which is a central step in their Service-Engineering. We discuss computations of performance measures, both theoretical and software-based (via the 4CallCenter software). Then several examples of Palm/Erlang-A applications are presented, mostly motivated by and based on real call center data.

165. Whitt, Ward. Fluid models for multiserver queues with abandonments, *Operations Research*, 54 (1), 2006, 37–54. Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. Deterministic fluid models are developed to provide simple first-order performance descriptions for multiserver queues with abandonment under heavy loads. Motivated by telephone call centers, the focus is on multiserver queues with a large number of servers and non-exponential service-time and time-to-abandon distributions. The first fluid model serves as an approximation for the $G/GI/s + GI$ queueing model, which has a general stationary arrival process with arrival rate λ , independent and identically distributed (IID) service times with a general distribution, s servers and IID abandon times with a general distribution. The fluid model is useful in the overloaded regime, where $\lambda > s$, which is often realistic because only a small amount of abandonment can keep the system stable. Numerical experiments, using simulation for $M/GI/s + GI$ models and exact numerical algorithms for $M/M/s + M$ models,

show that the fluid model provides useful approximations for steady-state performance measures when the system is heavily loaded. The fluid model accurately shows that steady-state performance depends strongly upon the time-to-abandon distribution beyond its mean, but not upon the service-time distribution beyond its mean. The second fluid model is a discrete-time fluid model, which serves as an approximation for the $G_t(n)/GI/s + GI$ queueing model, having a state-dependent and time-dependent arrival process. The discrete-time framework is exploited to prove that properly scaled queueing processes in the queueing model converge to fluid functions as $s \rightarrow \infty$. The discrete-time framework is also convenient for calculating the time-dependent fluid performance descriptions.

Keywords: Queues, Approximations

166. Whitt, Ward. A multi-class fluid model for a contact center with skill-based routing, *International Journal of Electronics and Communications* (AEU), 60 (2), 2006, 95–102. Available at: <http://www.columbia.edu/~ww.2040/recent/html>.

Abstract. A multi-class deterministic fluid model is proposed to describe and improve the performance of a customer contact center with skill-based routing. The fluid model can be regarded as an approximation for a stochastic queueing system with multiple customer classes and multiple server groups, with customer abandonment and non-exponential service-time and time-to-abandon distributions. The fluid model is attractive to provide a rough analysis of large systems, with high arrival rate and many servers. Even though the fluid model evolves deterministically, the service-time distributions and time-to-abandon distributions beyond their means play a critical role. The fluid model can be used for staffing, routing and system design, because it is possible to formulate tractable optimization problems.

Keywords: Deterministic fluid models, Multi-server queues with abandonment, Contact centers, Call centers, Skill-based routing

167. Whitt, Ward. Sensitivity of performance in the Erlang A model to changes in the model parameters, *Operations Research*, 54 (2), 2006, 247–260. Available at: <http://www.columbia.edu/~ww.2040/recent/html>.

Abstract. This paper studies the $M/M/s + M$ queue, i.e., the $M/M/s$ queue with customer abandonment, also called the Erlang-A model, having independent and identically distributed customer abandon times with an exponential distribution (the $+M$), focusing on the case in which the arrival rate and the number of servers are large. The goal is to better understand the sensitivity of performance to changes in the model parameters: the arrival rate, the service rate, the number of servers, and the abandonment rate. Elasticities are used to show the percentage change of a performance measure caused by a small percentage change in a parameter. Elasticities are calculated using an exact numerical algorithm and simple finite-difference approximations. Insight is gained by applying fluid and diffusion approximations. The analysis shows that performance is quite sensitive to small percentage changes in the arrival rate or the service rate, but relatively insensitive to small percentage changes in the abandonment rate.

Keywords: Queues, Multichannel, Sensitivity analysis, Balking and reneging

168. Whitt, Ward. Analysis for the design of simulation experiments. To appear as Chapter 13 in *Simulations* in the Elsevier series of *Handbooks in Operations Research and Management Science*, edited by Shane Henderson and Barry Nelson. Available at: <<http://www.columbia.edu/~ww.2040/recent/>>

Abstract. This paper will be Chapter 13 in *Simulations* in the Elsevier series of *Handbooks in Operations Research and Management Science*, edited by Shane Henderson and Barry Nelson. Herein we discuss analysis for the design of simulation experiments. By that we mean, not the traditional (important) methods to design statistical experiments, but rather techniques that can be used, before a simulation is conducted, to estimate the computational effort required to obtain desired statistical precision for contemplated simulation estimators. In doing so, we represent computational effort by simulation time, and that in turn by either the number of replications or the run length within a single simulation run. We assume that the quantities of interest will be estimated by sample means. In great generality, the required length of a single simulation run can be determined by computing the asymptotic variance and the asymptotic bias of the sample means. Existing theory supports this step for a sample mean of a function of a Markov process. We would prefer to do the calculations directly for the intended simulation model, but that usually is prevented by model complexity. Thus, as a first step, we usually approximate the original model by a related Markovian model that is easier to analyze. For example, relatively simple diffusion-process approximations to estimate required simulation run lengths for queueing models can often be obtained by heavy-traffic stochastic-process limits.

169. Whitt, Ward. Staffing a call center with uncertain arrival rate and absenteeism, *Production and Operations Management*, forthcoming. Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. This paper proposes simple methods for staffing a single-class call center with uncertain arrival rate and uncertain staffing due to employee absenteeism. The arrival rate and the proportion of servers present are treated as random variables. The basic model is a multi-server queue with customer abandonment, allowing non-exponential service-time and time-to-abandon distributions. The goal is to maximize the expected net return, given throughput benefit and server, customer-abandonment and customer-waiting costs, but attention is also given to the standard deviation of the return. The approach is to approximate the performance and the net return, conditional on the random model-parameter vector, and then uncondition to get the desired results. Two recently-developed approximations are used for the conditional performance measures: First, a deterministic fluid approximation and, second, a numerical algorithm based on a purely Markovian birth-and-death model, having state-dependent death rates.

Keywords: Model-parameter uncertainty, Contact centers, Employee absenteeism, Customer abandonment, Fluid models

170. Whitt, Ward. The impact of increased employee retention upon performance in a customer contact center, *Manufacturing and Service Operations Management (M&SOM)*, forthcoming. Available at: <<http://www.columbia.edu/~ww.2040/recent/html>>.

Abstract. A mathematical model is developed to help analyze the benefit in contact-center performance obtained from increasing employee (agent) retention, by increasing agent job sat-

isfaction. The contact-center “performance” may be restricted to a traditional productivity measure such as the number of calls answered per hour or it may include a broader measure of the quality of service, e.g., revenue earned per hour or the number of problems successfully resolved per hour. The analysis is based on an idealized model of a contact center, in which the number of employed agents is constant over time, assuming that a new agent is immediately hired to replace each departing agent. The agent employment periods are assumed to be independent and identically distributed random variables with a general *agent-retention probability distribution*, which depends upon management policy and actions. The *steady-state staff-experience distribution* is obtained from the agent-retention distribution by applying renewal theory. An increasing real-valued function specifies the average performance as a function of agent experience. Convenient closed-form expressions for the overall performance as a function of model elements are derived when either the agent-retention distribution or the performance function has exponential structure. Management actions may cause the agent-retention distribution to change. The model describes the consequences of such changes upon the long-run average staff experience and the long-run average performance.

Keywords: Contact centers, Call centers, Retention, Employee turnover, Churn, Agent job satisfaction, Compensation, Autonomy, Stress, Stochastic models, Renewal theory, Stochastic comparisons

II Statistics, Forecasting

1. Edie, Leslie C. Traffic delays at toll booths, *Journal of the Operations Research Society of America*, 2 (2), 1954, 107–138.

Abstract. The collection of vehicular tolls at Port Authority tunnels and bridges is one of the most important operations conducted by the police personnel. More than 250 traffic officers are utilized, and the payroll costs exceed a million dollars annually. In staffing its toll plazas, the Port Authority attempts to handle traffic with a minimum number of toll collectors consistent with uniformly good service to the public and properly spaced relief periods for the toll collectors. This requires finding the level of traffic delays that gives the best compromise between the conflicting objectives of economy and service. In the past, the number of toll collectors provided for operating a toll plaza was determined by judgment based on experience and a rule-of-thumb work standard which had not been related to service. Judgment was likewise used to allocate manpower and control the number of toll booths opened at any time. This method resulted in patron delays observed to vary from 2 to 50 sec. The tools of probability theory provide methods for dealing with the problem in quantitative terms. They enable determination of the relations between traffic volumes, number of toll booths, and grade of service. With this knowledge, the optimum grade of service can be established in a logical manner and the number of toll booths required at any time of day can be specified in advance. Use of this method permitted savings in toll collection expenses and better service.

(Appears also in Section I.)

author. They must go together!

2. Edie, Leslie C. Review of Port of New York Authority study. Case Histories Five Years After—A Symposium, 1959, 263–277.
3. Roberts, J.W. Recent observations of subscriber behavior. 9th International Tele-traffic Conference (ITC-9), Torremolinos, 1979.

Abstract. This paper presents an analysis of experimental observations of subscriber repeated attempts and subscriber patience in relation to the post-dialing delay. The analysis includes, in particular, an investigation of the influence of the interval between successive attempts and we derive estimates of the probability distributions of the subscribers' patience. The results concern local, trunk and international calls made by certain subscribers on a Paris exchange.

(Appears also in Section III.)

4. Kort, Barry W. Models and methods for evaluating customer acceptance of telephone connections, *IEEE*, 1983, 706–714.

Abstract. This paper describes models and methods developed at Bell Laboratories to evaluate customer acceptance of telephone connections in the Bell System Public Switched Telephone Network. We present three related customer opinion models (Call Setup Rating, Transmission Rating, and Call Completion Rating), two customer behavior models (Abandonment/Retrial

Behavior and Complaint Rate models), several network Performance Characterization models (for call setup and transmission performance parameters) and a Monte-Carlo Simulation model which combines all the above models to estimate the grade of service, abandonment and retrial behavior, the complaint rate, and the ineffective attempt rate of the Public Network.

These models and the method of analysis are presented as a prototype to support current efforts of the IEEE Subcommittee on Telecommunications System Performance Characteristics. That Subcommittee has been chartered to develop industry-wide standards for expressing telephone network performance characteristics. The goal of the IEEE work is to provide a uniform method for vendors of voice-grade telecommunications services to describe the performance of their service offerings.

(Appears also in Section III.)

5. Mabert, V.A. Short interval forecasting of emergency phone call (911) work loads, *Journal of Operations Management*, 5 (3), 1985, 259–271.

Abstract. There has been a growing emphasis over the last 5–10 years on improving productivity in the service sector of the US economy. Effective scheduling of the workforce in these organizations requires good estimates of demand, which may show substantial variations between days for certain times of the year. An examination is made of the use of 6 different forecasting methods for predicting daily emergency call workloads for the Indianapolis Police Department’s communications area: 1. one-year lag, 2. zero/one regression, 3. multiplicative/additive, 4. zero/one with adjustment, 5. multiplicative/additive with adjustment, and 6. autoregressive, integrated moving average intervention. The research suggests that there are clearly significant differences in performance for the 6 models analyzed. Simple modeling approaches can perform well in the complex environments found in many service organizations. Special tailoring of the forecasting model is required for many service firms. Historical data patterns for these organizations tend to be more involved than just trend and seasonal elements.

Keywords: Studies, Police, Mathematical models, Implementations, Forecasting techniques, Emergencies, Departments, Communications, Case studies

(Appears also in Section I.)

6. Sparrow, L.B. Manning the telephone enquiry bureau at British Gas West Midlands. In *Operations Research in Management*, S.C. Littlechild (Editor). New York: Prentice Hall, 1991, 167–173.

Abstract. All telephone enquiries to British Gas West Midlands are dealt with by a team of specialist clerks in two centralized enquiry bureaux. Customers anywhere in the region can contact a bureau at local call costs. At all times it is essential to maintain a high standard of answering service, not only because this is expected by the customer for any type of enquiry but also to ensure that emergency calls relating, perhaps, to gas leaks are accepted and dealt with.

In about 1970, the enquiry bureaux were finding it difficult to maintain the servicing of customers’ calls at peak periods with the existing monitoring equipment. It was decided to set up a queueing theory model of the telephone answering system. The aim was to derive the relationships between traffic level, grade of service, waiting time and manning levels within the bureaux.

The model would be used as a planning tool, both for indicating peak manning requirements and for optimizing number of staff at off-peak times. This chapter describes the model which was developed and the results which were obtained.

(Appears also in Section I.)

7. Bianchi, Lisa, Jeffrey Jarrett and R. Choudary Hanumara. Forecasting incoming calls to telemarketing centers, *The Journal of Business Forecasting Methods & Systems*, 12 (2), 1993, 3–12.

Abstract. For forecasting incoming calls to telemarketing centers, AT&T Bell Laboratories uses an adaptation of Holt-Winters' forecasting model with its telemarketing scheduling system, called NAMES. A study evaluates the current use of the Holt-Winters' model for forecasting as done by the NAMES system and indicates whether improvement is possible through the use of ARIMA time series modeling. The data consisted of daily call volumes from March 1, 1991 to June 26, 1991. Initial plots of the data revealed weekly seasonality, the presence of outliers, and no apparent trend over time. Intervention analysis is the way in which ARIMA models can be utilized to account for outliers. The current methodology contained in the NAMES software may perform well. Problems usually arise when outliers appear in the time series data. The ARIMA modeling with an outlier detection feature could improve forecasts of a series containing outliers which was the case with incoming calls at different telemarketing centers. The ARIMA modeling method was significantly better than either Holt-Winters' model in more than 1/2 of the time series studies.

Keywords: Time series, Telemarketing, Studies, Models, Forecasting techniques

8. Andrews, Bruce H. and Shawn M. Cunningham. L.L. Bean improves call-center forecasting, *Interfaces*, 25 (6), 1995, 1–13.

Abstract. Two forecasting models are developed and implemented for use at L.L. Bean Inc., a widely known retailer of high-quality outdoor goods and apparel. The models forecast calls incoming to L.L. Bean's call center so that efficient staffing schedules for telephone agents can be produced two weeks in advance. The ARIMA/transfer function methodology is used to model these time series data since they exhibit seasonal patterns but are strongly influenced by independent variables, including holiday and advertising interventions. The improved precision of the models is estimated to save \$300,000 annually through enhanced scheduling efficiency.

Keywords: Call center forecasting, L.L. Bean, Forecasting models, Retailer, Telephone agents, Staffing schedules, ARIMA transfer function methodology, Time series data, Seasonal patterns, Holiday, Advertising interventions

(Appears also in Section I.)

9. Massey, W.A., G.A. Parker and W. Whitt. Estimating the parameters of a nonhomogeneous Poisson process with linear rate, *Telecommunications Systems—Modeling, Analysis, Design and Management*, 5 (4), 1996, 361–688.

Abstract. We want to be able to determine if a Poisson process traffic model is appropriate and, when it is, we want to be able to estimate its parameters from measurements, with linear rate

over a finite interval, based on the number of counts in measurement subintervals. Such a linear arrival-rate function can serve as a component of a piecewise-linear approximation to a general arrival-rate function. We consider ordinary least squares (OLS), iterative weighted least squares (IWLS) and maximum likelihood (ML), all constrained to yield a nonnegative rate function. We prove that ML coincides with IWLS. As a reference point, we also consider the theoretically optimal weighted least squares (TWLS), which is least squares with weights inversely proportional to the variances (which would not be known with data). Overall, ML performs almost as well as TWLS. We describe computer simulations conducted to evaluate these estimation procedures. None of the procedures differ greatly when the rate function is not near 0 at either end, but when the rate function is near 0 at one end, TWLS and ML are significantly more effective than OLS. The number of measurement subintervals (with fixed total interval) makes surprisingly little difference when the rate function is not near 0 at either end. The variances are higher with only two or three subintervals, but there usually is little benefit from going above ten. In contrast, more measurement intervals help TWLS and ML when the rate function is near 0 at one end. We derive explicit formulas for the OLS variances and the asymptotic TWLS variances (as the number of measurement intervals increases), assuming the nonnegativity constraints are not violated. These formulas reveal the statistical precision of the estimators and the influence of the parameters and the method. Knowing how the variance depends on the interval length can help determine how to approximate general arrival-rate functions by piecewise-linear ones. We also develop statistical tests to determine whether the linear Poisson model is appropriate.

Keywords: Digital simulation, Iterative methods, Least-squares approximations, Maximum likelihood estimation, Parameter estimation, Piecewise linear techniques, Queueing theory, Stochastic processes, Telecommunication traffic, Nonhomogeneous Poisson process, Piecewise linear approximation, Linear arrival-rate function, Ordinary least squares, Iterative weighted least squares, Computer simulations, Statistical precision, Traffic model
(Appears also in Section IX.)

10. Chlebus, E. Empirical validation of call holding time distribution in cellular communications systems. *Teletraffic Contributions for the Information Age. Proceedings of the 15th International Teletraffic Congress, ITC-15.* Elsevier, Amsterdam, The Netherlands, 1997, 1179–1188.

Abstract. Various probability distributions are fitted to empirical call holding time data collected in cellular communications systems. Their parameters are determined through maximum likelihood estimation. A visual plots examination of empirical and fitted cumulative distribution functions enables qualitative comparison. Goodness-of-fit techniques based on supremum and quadratic empirical distribution function statistics, namely the Kolmogorov-Smirnov and Anderson-Darling tests, respectively are implemented to compare quantitatively the produced fits.

Keywords: Empirical validation, Call holding time distribution, Cellular communications systems, Probability distributions, Empirical call holding time data, Maximum likelihood estimation, Cumulative distribution functions, Goodness-of-fit techniques, Supremum empirical distribution function statistics, Quadratic empirical distribution function statistics, Kolmogorov-Smirnov test, Anderson-Darling test, Exponential distribution, Gamma distribution, Lognormal distribution

11. Klungle, Roger and Jim Maluchnik. Call center forecasting at AAA Michigan, *The Journal of Business Forecasting Methods & Systems*, 16 (4), 1997/1998, 8–13.

Abstract. The number of incoming calls for Emergency Road Service at AAA Michigan at different times of a day differ significantly during winter and spring seasons. A regression model is the bet, though weather, which is used as one of the independent variables, is difficult to forecast more than a few days in advance. One the first day of a cold spell, call volumes are usually very high which later on return to normal even though the temperatures are still very low.

Keywords: Case studies, Associations, Forecasting techniques, Automobiles, Call centers, Customer relations, Member services

12. Bianchi, Lisa, Jeffrey Jarrett and R. Choudary Hanumara. Improving forecasting for telemarketing centers by ARIMA modeling with intervention, *International Journal of Forecasting*, 14 (4), 1998, 497–504.

Abstract. This study analyzes existing and improved methods for forecasting calls to telemarketing centers for the purposes of planning and budgeting. The use of additive and multiplicative versions of Holt-Winters exponentially weighted moving average models is analyzed and compared to Box-Jenkins (ARIMA) modeling with intervention analysis. The forecasting accuracy of HW and ARIMA models for samples of telemarketing data is determined.

Although there is much evidence in recent literature that simple models such as Holt-Winters perform as well as or better than more complex models, it is found that ARIMA models with intervention analysis perform better for the time series studied.

Keywords: Holt-Winters models, Intervention analysis, Box-Jenkins (ARIMA) modeling, Time series

13. Faerber, J., S. Bodamer and J. Charzinski. Statistical evaluation and modeling of Internet dial-up traffic. Proceedings of the SPIE—The International Society for Optical Engineering, 3841, 1999, 112–121.

Abstract. In times of Internet access being a popular consumer application even for “normal” residential users, some telephone exchanges are congested by customers using modem or ISDN dial-up connections to their Internet service providers. In order to estimate the number of additional lines and switching capacity required in an exchange or a trunk group, Internet access traffic must be characterized in terms of holding time and call interarrival time distributions. We analyze log files tracing the usage of the central ISDN access line pool at the University of Stuttgart for a period of six months. Mathematical distributions are fitted to the measured data and the fit quality is evaluated with respect to the blocking probability caused by the synthetic traffic in a multiple server loss system. We show how the synthetic traffic model scales with the number of subscribers and how the model could be applied to compute economy of scale results for Internet access trunks or access servers.

Keywords: Statistical evaluation, Internet dial-up traffic, Traffic modeling, Holding-time distribution, Consumer applications, Residential users, Telephone exchanges, Modem dial-up connec-

tions, ISDN dial-up connections, Internet service providers, Switching capacity, Trunk group, Internet access traffic, Call interarrival time distribution, Log files, Central ISDN access line pool, University of Stuttgart, Mathematical distributions, Measured data, Blocking probability, Synthetic traffic, Multiple server loss system, Synthetic traffic model, Economy-of-scale results, Internet access trunks, Internet access servers, WWW-based services

14. Weidong Xu. Long range planning for call centers at FedEx, *The Journal of Business Forecasting Methods & Systems*, 18 (4), Winter 1999/2000, 7–11.

Abstract. FedEx is the world’s largest express transportation company, generating \$14 billion in annual revenue. To support the global transportation network, FedEx has established 51 worldwide customer service call centers. The customer service at FedEx in the US handles about 500,000 calls per day. There are three major networks: 1. Domestic, 2. International, and 3. Freight. For each network, the company has developed four different types of forecasts based on different forecasting horizons: 1. Strategic Plan, 2. Business Plan, 3. Tactical Forecast, and 4. Operational Forecast. Different methodologies are adopted for different levels of forecasts. An overview of these methodologies is presented.

Keywords: Postal & delivery services, Forecasting techniques, Customer services, Case studies (Appears also in Sections I and VIII.)

15. Betts, Alan, Maureen Meadows and Paul Walley. Call centre capacity management, *International Journal of Service Industry Management*, 11 (2), 2000, 185–196.

Abstract. Call centres often experience large fluctuations in demand over relatively short periods of time. However, most centres also need to maintain short response times to the demand. This places great emphasis upon capacity management practices within call centre operations. A total of 12 UK-based call centres from one retail bank were studied to investigate how they managed forecasting, capacity management and scheduling tasks. Provides evidence of the difficulties associated with capacity management in call centres. Regression modelling is used to link forecasting and capacity planning practices to performance. Shows that random variation is a very important factor when assessing call centre performance. The results suggest that call centre managers can have only a small influence upon short-term performance. Existing mathematical models, such as the Erlang queuing system methodologies, have only limited value as the assumptions concerning demand patterns made in their derivation contradict observations made within the 12 sites. Spiked demand patterns present special capacity management problems, including a direct trade-off between high service levels and operator boredom. Conventional methods of flexing capacity cannot respond sufficiently well to some of the short-term fluctuations in demand.

Keywords: Capacity management, Service operations, Banking, Call centres (Appears also in Section VIII.)

16. Jongbloed, Geurt and Ger Koole. Managing uncertainty in call centers using Poisson mixtures. Working paper, Vrije Universiteit, Division of Mathematics and Computer Science, Amsterdam, The Netherlands, November 2000.

Abstract. We model a call center as a queueing model with Poisson arrivals having an unknown varying arrival rate. We show how to compute prediction intervals for the arrival rate, and use the Erlang formula for the waiting time to compute the consequences for the occupancy level of the call center. We compare it to the current practice of using a point estimate of the arrival rate (assumed constant) as forecast.
(Appears also in Section I.)

17. Mandelbaum, A., A. Sakov and S. Zeltyn. Empirical analysis of a call center. Technical report, Faculty of Industrial Engineering and Management, Technion—Israel Institute of Technology, Haifa, Israel, 2001.
18. Antipov, A. and N. Meade. Forecasting call frequency at a financial services call centre, *The Journal of the Operational Research Society*, 53 (9), 2002, 953–960.

Abstract. A forecasting model is developed for the number of daily applications for loans at a financial services telephone call center. The purpose of the forecasts and the associated prediction intervals is to provide effective staffing policies within the call center. The model building process is constrained by the availability of only 2 years and 7 months of data. The distinctive feature of the data is that demand is driven in the main by advertising. The analysis given focuses on applications stimulated by press advertising. Unlike previous analyses of broadly similar data, where ARIMA models were used, a model with a dynamic level, multiplicative calendar effects and a multiplicative advertising response is developed and shown to be effective.

Keywords: Studies, Forecasting techniques, Call centers, Financial services, Mathematical models, Workforce planning, Advertising

19. Bayerl, S., T. Bollinger and C. Schommer. Applying models with scoring, *Third International Conference on Data Mining*, WIT Press, Southampton, UK, 2002, 757–766.

Abstract. “Scoring”, in general, is defined as the usage of mining models—based on historical data—for classification or segmentation of new items. For example, if the historical data consist of classified customers, then we can use the model for the prediction of the behaviour of a new customer. Scoring offers novel ways to exploit the power of data mining models in everyday business activities, and proliferate mining applications to users who are not educated in mining. In this paper, we present a) the generic scoring process, b) its technical implementation, and c) an example of how scoring can be integrated in a real application. The generic process consists of three steps: The mining models are learned first, then they are transferred into the application database, and finally, the models are applied to the data loaded in that database. Arguments for the necessity of such a mining improvement are collected. IBM DB2 Intelligent Miner Scoring (IM Scoring) is the first technical implementation of scoring. It is based on the emerging open standard for mining models (Predictive Model Markup Language—PMML), and the mining extensions for SQL. Implementation issues are discussed, as well as problems that come along with its integration into operational applications. The article closes with the description of a sample application, the integration of scoring into a call center environment. A discussion of the scoring method concludes this article.

Keywords: Call centres, Classification, Customer relationship management, Data mining, Hypermedia markup languages, Marketing data processing, SQL, Very large databases

20. Foss, Bryan, Iain Henderson, Peter Johnson, Don Murray and Merlin Stone. Managing the quality and completeness of customer data, *The Journal of Database Marketing*, 10 (2), 2002, 139–158.

Abstract. Although companies have been collecting customer-related data for years, this was normally for administration rather than customer management. While larger companies have more recently collected customer data for database marketing—to recruit new customers, sell more to existing customers, support customer service operations, and retain customers—returns are usually limited because most data are still held and used departmentally. The growth of contact centers, e-commerce, and more complex value chains has raised additional issues of enterprise data management and exploitation, while demonstrating beyond doubt that available data are insufficient to support new customer management processes. The article considers these issues and proposed tried and tested approaches for addressing these customer data management issues in a practical and achievable manner.

Keywords: Database marketing, Marketing management, Data integrity, Customer relationship management
(Appears also in Section VIII.)

21. Hur, D. A comparative evaluation of forecast monitoring systems in service organizations, *33rd Annual Meeting of the Decision Sciences Institute*, Decision Sciences Institute, San Diego, CA, USA, 2002, 5 pp.

Abstract. Demand forecasts are major inputs to workforce scheduling and material planning in many service organizations, and the effectiveness of such planning activities hinges upon the accuracy of the forecasts. Since forecasts are rarely precise in reality, managers need to monitor forecast errors when they implement the labor and material plans. The paper aims to identify and evaluate an automatic detector of forecast bias to help managers. The paper identified and evaluated five error detection techniques using both actual data from a call center, and simulated data. All five techniques detected a considerable demand shift in a timely manner, and appeared very robust across diverse demand environments. In particular, the threshold curve and wine-glass chart turned out to be the quickest and most powerful of the five methods. In addition, the patterns of within day demand arrival and their stability throughout the day significantly influenced the performance of the detection techniques.

Keywords: Call centres, Forecasting theory, Human resource management, Manufacturing resources planning, Scheduling, Service industries, Statistics

22. Avramidis, Athanassios, Alexandre Deslauriers and Pierre L'Ecuyer. Modeling daily arrivals to a telephone call center, *Management Science*, 50 (7), 2004, 896–908.

Abstract. We develop stochastic models of time-dependent arrivals, with focus on the application to call centers. Our models reproduce essential features of call center arrivals observed in

recent empirical studies, namely, a time-varying arrival intensity over the course of a day, and nonzero correlation between the arrival counts in different time periods within the same day. For each of the new models, we characterize the joint distribution of the vector of arrival counts with particular focus on characterizing how the new models are more flexible than standard or previously proposed models. We report empirical results from a study on arrival data from a real-life call center, including the essential features of the arrival process, the goodness-of-fit of the estimated models, and the sensitivity of various simulated performance measures of the call center to the choice of arrival process model.

Keywords: Studies, Management science, Call centers, Process engineering

23. Brown, L., N. Gans, A. Mandelbaum, A. Sakov, H. Shen, S. Zeltyn and L. Zhao. Statistical analysis of a telephone call center: A queueing-science perspective, *JASA*, 100 (469), 2005, 36–50.

Abstract. A call center is a service network in which agents provide telephone-based services. Customers that seek these services are delayed in tele-queues.

This paper summarizes an analysis of a unique record of call center operations. The data comprise a complete operational history of a small banking call center, call by call, over a full year. Taking the perspective of queueing theory, we decompose the service process into three fundamental components: arrivals, customer abandonment behavior and service durations. Each component involves different basic mathematical structures and requires a different style of statistical analysis. Some of the key empirical results are sketched, along with descriptions of the varied techniques required.

Several statistical techniques are developed for analysis of the basic components. One of these is a test that a point process is a Poisson process. Another involves estimation of the mean function in a nonparametric regression with lognormal errors. A new graphical technique is introduced for nonparametric hazard rate estimation with censored data. Models are developed and implemented for forecasting of Poisson arrival rates.

We then survey how the characteristics deduced from the statistical analyses form the building blocks for theoretically interesting and practically useful mathematical models for call center operations.

Keywords: Call centers, Queueing theory, Lognormal distribution, Inhomogeneous Poisson process, Censored data, Human patience, Prediction of Poisson rates, Khintchine-Pollaczek formula, Service times, Arrival rate, Abandonment rate, Multiserver queues
(Appears also in Section I.)

III Consumer and Agent Psychology

1. Cavanaugh, J.R., R.W. Hatch and J.L. Sullivan. Models for the subjective effects of loss, noise and talker echo on telephone connections, *Bell System Technical Journal*, 55, 1976, 1319–1371.

Abstract. Tests have been conducted at Bell Laboratories within the last 10 years to obtain subjective evaluations of the effects of loss, noise, and talker echo on telephone transmission quality. We use these subjective test results to formulate graphical and analytical models of subjective opinion that can be used in network planning studies to evaluate transmission performance of the network and to study the effects of network changes on performance. These models are based on the concept of a generalized transmission-rating scale. Separate opinion curves for each test take into account differences caused by factors such as subject group, type of test, and range of conditions. We also describe the methods of data analysis used in the formulation of the transmission-rating scale and opinion models, provide a comparison of the test results with the models, and discuss the models in sufficient detail to permit their application in transmission planning studies.

2. Cohen, H.S. and B.W. Kort. Psychological evaluation of telephone switching and transmission performance. Proceedings of the Human Factors Society, 21st Annual Meeting, San Francisco, 1977, 505–507.

Abstract. In order to set standards for the performance of the telephone network, it is necessary to understand the subjective effects of the telephone service impairments we wish to control. In a laboratory environment, we asked subjects to play a computer-controlled game which required the frequent use of the telephone as a natural part of the game. Impairments to telephone switching service, such as dial-tone delay, post-dialing delay, and blocked call attempts, and impairments to telephone transmission quality, such as loss and noise were introduced into the telephone service which the subjects experienced. After each use of the telephone, the subjects rendered their opinion, on a five-point rating scale, as to the quality of telephone service just provided.

The data produced by the experiment were used to construct a mathematical model of customer opinion as a function of the objective measures of telephone network performance. This model will enable us to analyze the present performance of the telephone system. More importantly, the model will enable us to estimate customer opinion for future telephone systems, were we to implement new or revised standards for the control of switching and transmission impairments.

3. Duffy, F.P. and R.A. Mercer. A study of network performance and customer behavior during direct-distance-dialing call attempts in the U.S.A., *Bell System Technical Journal*, 57 (1), 1978, 1–33.

Abstract. A survey was conducted throughout the Bell System in October 1974 to gather detailed information about Direct-Distance-Dialing call attempts. The dispositions, setup times, and customer abandonment times associated with DDD attempts are discussed in detail in this article to provide network performance and customer behavior characteristics to network planners and administrators and to designers of equipment and systems which use, and interact

with, the telephone network. It is shown that both network performance and customer behavior affect the call dispositions and the total call setup time; however, customer-dependent failures to complete account for 85 percent of all failures, and customer-determined components of the call setup time make up 71 percent of the total setup time. It is found that traffic composition in terms of the relative mix of business and residential originations exerts a strong influence on call dispositions. Network performance affects the probability of equipment blockages and failures and the interval from end of dialing to receipt of a network response. These are both found to depend on calling distance, while the latter is also affected by the types of originating and terminating local switching.

4. Roberts, J.W. Recent observations of subscriber behavior. 9th International Tele-traffic Conference (ITC-9), Torremolinos, 1979.

Abstract. This paper presents an analysis of experimental observations of subscriber repeated attempts and subscriber patience in relation to the post-dialing delay. The analysis includes, in particular, an investigation of the influence of the interval between successive attempts and we derive estimates of the probability distributions of the subscribers' patience. The results concern local, trunk and international calls made by certain subscribers on a Paris exchange. (Appears also in Section II.)

5. Cohen, H.S. Measuring and modeling user satisfaction with telephone switching and transmission performance. Proceedings of the 9th International Symposium on Human Factors in Telecommunications, Red Bank, NJ, 1980, 237-242.
6. Isobe, S., S. Sato and M. Hoshi. Opinion test on dial tone delay and post-dialing delay by PABX customers. Proceedings of the 9th International Symposium on Human Factors in Telecommunications, Red Bank, NJ, 1980, 243-250.
7. Liu, K.S. Direct distance dialing: Call completion and customer retrieval behavior, *Bell System Technical Journal*, 59 (3), 1980, 295-311.

Abstract. Most customers placing a direct-distance-dialing (DDD) call in the United States are able to complete the call on the first attempt. However, it is reasonable to expect that the probability of an initial completion will be less than 1. When an initial attempt fails to complete, a customer may decide to abandon his desired telephone connection or to make one or more retrials. In general, a sequence of one or more attempts may be initiated by a customer in an effort to establish the desired connection. A study of DDD call completion and retrials is important to provide an overall characterization of network performance and customer behavior in setting up customers' desired telephone connections. A survey adopting a two-stage stratified sampling plan was undertaken to obtain DDD retrieval statistics. Data associated with sampled DDD calls that were originated from one of 890 switching entities in the Bell System network were collected for a period of one week. The basic DDD retrieval results reported here are initial attempt disposition probabilities, retrieval probabilities, number of additional attempts, ultimate success probabilities, and distribution functions for retrieval intervals following different types of

incomplete initial attempts. Results of subclass analyses of retrial statistics by originating and terminating classes of service (residence and business) are also presented. Results obtained in this study are useful in many network planning applications. An application of significant importance is provision of a tool to evaluate the revenue and cost impact of call completion improvement programs. A technique to analyze the revenue and cost impact is outlined in the paper.

8. Cavanaugh, J.R., R.W. Hatch and J.L. Sullivan. Transmission rating model for use in planning telephone networks, *IEEE*, 1983, 683–688.

Abstract. Customer opinions are an important element in transmission planning for the telephone network. Since the invention of the telephone, considerable effort has been expended in estimating customer assessment of transmission quality. Subjective test results have been used to formulate models. These models, in the form of smooth functions which permit interpolation to allow examination of specific impairment values of interest, have been used to provide transmission performance estimates for guiding evolution of the telephone network.

This paper first considers a previous model which covered the subjective effects of loss, circuit noise and talker echo (reported at NTC76) updated to reflect an IEEE loudness loss method (rather than the loudness loss method for the original model). This is followed by discussion of model extensions to cover listener echo, quantization noise, band width/attenuation distortion, room noise, side tone and echo control devices. Then the paper outlines several studies in which the expanded model has been extensively used to study transmission quality of telephone connections as a function of the various impairments. The paper concludes with some illustrative examples demonstrating use of the model including comments on possible interpretation of results.

(Appears also in Section VI.)

9. Kort, Barry W. Models and methods for evaluating customer acceptance of telephone connections, *IEEE*, 1983, 706–714.

Abstract. This paper describes models and methods developed at Bell Laboratories to evaluate customer acceptance of telephone connections in the Bell System Public Switched Telephone Network. We present three related customer opinion models (Call Setup Rating, Transmission Rating, and Call Completion Rating), two customer behavior models (Abandonment/Retrial Behavior and Complaint Rate models), several network Performance Characterization models (for call setup and transmission performance parameters) and a Monte-Carlo Simulation model which combines all the above models to estimate the grade of service, abandonment and retrial behavior, the complaint rate, and the ineffective attempt rate of the Public Network.

These models and the method of analysis are presented as a prototype to support current efforts of the IEEE Subcommittee on Telecommunications System Performance Characteristics. That Subcommittee has been chartered to develop industry-wide standards for expressing telephone network performance characteristics. The goal of the IEEE work is to provide a uniform method for vendors of voice-grade telecommunications services to describe the performance of their service offerings.

(Appears also in Section II.)

item Maister, David H. The psychology of waiting lines. Report #9-684-064, Harvard Business School, Boston, MA, 1984. Also appears in *The Service Encounter*, J. Czepiel, M. Solomon and C. Suprenant (Eds.). Lexington, MA: Lexington Books, 1985, 113–123.

10. Larson, Richard C. Perspectives on queues: Social justice and the psychology of queueing, *Operations Research*, 35 (6), 1987, 895–905.

Abstract. Queues involve waiting, to be sure, but one’s attitudes toward queues may be influenced more strongly by other factors. For instance, customers may become infuriated if they experience *social injustice*, defined as violation of first in, first out. *Queueing environment* and *feedback regarding the likely magnitude of the delay* can also influence customer attitudes and ultimately, in many instances, a firm’s market share. Even if we focus on the wait itself, the “outcome” of the queueing experience may vary nonlinearly with the delay, thus reducing the importance of average time in queue, the traditional measure of queueing performance. This speculative paper uses personal experiences, published and unpublished cases, and occasionally, “the literature” to begin to organize our thoughts on the important attributes of queueing. To flesh out more of these issues, the author asks for your cards and letters.

11. Larson, Richard C. There’s more to a line than its WAIT, *Technology Review*, 1988, 59–68.
12. Cotton, B. and K. Lam. Caller acceptability of network interactions for advanced intelligent network services. ICC 91. International Conference on Communications Conference Record. IEEE, New York, NY, USA, 1991, 1582–1585.

Abstract. The goal of this study is to characterize the relationship between customer satisfaction and the number and duration of NIs (network interactions). A laboratory experiment was conducted with subjects who placed a series of simulated N-ACD type calls. Each call differed by the number and duration of the interactions. After each call, the subject rated the overall call setup performance on a five-point scale. The ratings were used to develop a preliminary service completion time (SCT) opinion model. This model shows that opinion varies as an exponential function of total SCT and the presence or absence of network interactions.

Keywords: Network automatic call distribution, Grade-of-service, Network interactions, Advanced intelligent network services, Customer satisfaction, N-ACD, Overall call setup performance, Service completion time

13. Davis, Mark M. How long should a customer wait for service? *Decision Sciences*, 22, 1991, 421–433.

Abstract. A major concern for service managers is the determination of how long a customer should wait to be served. Services, due to the customer’s direct interaction with the process, must face a trade-off between minimizing the cost of having a customer wait and the cost of providing good service. A total cost model is presented for determining how long a customer

should wait when these two conflicting cost components are considered. An integral part of this model includes a measure of customer satisfaction with waiting time which is used to develop a waiting cost function. The model is then applied to a major fast food chain, using data collected at several locations. Analysis of the data reveals that the “ideal” waiting time for this firm is significantly less than the current corporate waiting time policy. Thus, as indicated by the model, a corporate policy change is recommended to provide much faster service. The adoption of such a policy would result in increased labor costs, and would simultaneously increase the firm’s overall profits. Although appearing contradictory, increases in current labor costs and long-term profits are both possible when management takes the long-range perspective suggested in this paper.

Keywords: Consumer behavior, Service operations management

14. Katz, Karen L., Blaire M. Larson and Richard C. Larson. Prescription for the waiting-in-line blues: Entertain, enlighten, and engage, *Sloan Management Review*, 1991, 44–53.

Abstract. As consumers experience a greater squeeze on their time, even short waits seem longer than ever before. If firms can improve customers’ perceptions of the time they spend waiting to be served, then customers will experience less frustration and may feel more satisfied with the service encounter. This paper examines customer perceptions of waiting in line and investigates methods for making waiting more tolerable.

15. Green, Linda V., Donald R. Lehmann and Bernd H. Schmitt. Time perceptions in service systems: An overview of the TPM framework, *Advances in Services Marketing and Management*, 5, 1996, 85–107.

Abstract. We present Time Perception Management (TPM)—a conceptual framework for organizing research and managerial issues regarding time perceptions in service systems. The TPM framework proposes that customers’ perceptions of time in service systems are affected by factors that operate both before and after, as well as during, the actual service encounter. Moreover, whereas some of these factors are related to the specific service system, others are the result of the generic service type and personal/sociocultural characteristics. The framework has important implications for managing and measuring time perceptions and for the relationship between time perceptions and customer satisfaction.

16. Hui, Michael K. and David K. Tse. What to tell consumers in waits of different lengths: An integrative model of service evaluation, *Journal of Marketing*, 60, 1996, 81–90.

Abstract. We conduct an experimental study to examine the impact of two types of waiting information—waiting-duration information and queueing information—on consumers’ reactions to waits of different lengths. We test a model that includes three different constructs—perceived waiting duration, acceptability of the wait, and effective response to the wait—as mediators between waiting information and service evaluation. Results show that though acceptability of the wait and affective response to the wait have a significant mediating effect on the relationship between waiting information and service evaluation, perceived waiting duration does not. Moreover, neither type of information has significant impact in the short-wait condition, whereas waiting-duration information has greater impact than queueing information in the intermediate-

wait condition and a smaller impact in the long-wait condition. We conclude with a discussion of research and managerial implications.

17. Tom, Gail, Michal Burns and Yvette Zeng. Your life on hold: The effect of telephone waiting time on customer perception, *Journal of Direct Marketing*, 11 (3), 1997, 25–31.

Abstract. Customer phone contact with companies is a service encounter that can turn out to be a liability if customers perceive their time on hold as too long or unenjoyable. This paper reports on two studies that demonstrated that different waiting conditions (silence, music, or choice of listening alternatives) affected customer-perceived waiting time and customer perception/satisfaction with the company.

18. Whitt, Ward. Improving service by informing customers about anticipated delays, *Management Science*, 45 (2), 1999, 192–207.

Abstract. The effect upon performance in a service system, such as a telephone call center, of giving waiting customers state information is investigated. In particular, two M/M/s/r queueing models with balking and reneging are studied. For simplicity, it is assumed that each customer is willing to wait a fixed time before beginning service. However, customers differ, so the delay tolerances for successive customers are random. In model 2, all reneging is replaced by balking. The number of customers in the system for model 1 is shown to be larger than that for model 2 in the likelihood-ratio stochastic ordering. Thus, customers are more likely to be blocked in model 1 and are more likely to be served without waiting in model 2. Algorithms are also developed for computing important performance measures in these, and more general, birth-and-death models.

Keywords: Telephone service, Anticipated delays, Customer service, Queueing models, Delay tolerance, Probability, Exponential distribution, Service time, Telephone call centre, Reneging, Balking, Birth-and-death process
(Appears also in Section I.)

19. Bennington, Lynne, James Cummane and Paul Conn. Customer satisfaction and call centers: an Australian study, *International Journal of Service Industry Management*, 11 (2), 2000, 162–173.

Abstract. Call centers are growing at unprecedented rates, yet relatively little is known about customer satisfaction with this method of service delivery. Therefore, a review of the advantages and disadvantages of call centers is provided before reporting on a study carried out with users of a very large human services call center network. The results indicate that customers have slightly higher satisfaction levels with in-person services than with call center services. Although it was predicted that older customers might be more dissatisfied with call centers than younger customers, this was not borne out by the data. Attributes of a best-in-the-world call center operation are provided to guide those who design and manage call center services.

Keywords: Call Centres, Customer satisfaction, Australia
(Appears also in Section VIII.)

20. Feinberg, Richard A., Ik-Suk Kim, Leigh Hokama, Ko de Ruyter and Cherie Keen. Operational determinants of caller satisfaction in the call center, *International Journal of Service Industry Management*, 11 (2), 2000, 131–141.

Abstract. There has been, and will be, a spectacular growth in the number of call centers on both sides of the Atlantic. So far, however, empirical evidence is lacking as to the operational determinants of caller satisfaction in call centers, despite the multitude of call performance metrics registered in many call centers. Undertakes an empirical assessment of the relationship between caller satisfaction and a number of critical variables. The results are astonishing. Of all the critical operational determinants only “percentage of calls closed on first contact” and “average abandonment” have a significant, albeit weak, influence on caller satisfaction. Concludes, therefore, with a call for more research into reliable and valid predictors of caller satisfaction.

Keywords: Performance measures, Customer service, Customer satisfaction, Call centres
(Appears also in Section VIII.)

21. Mandelbaum, A. and N. Shimkin. A model for rational abandonments from invisible queues, *QUESTA*, 36 (1–3), 2000, 141–173.

Abstract. We propose a model for abandonments from a queue, due to excessive wait, assuming that waiting customers act rationally but without being able to observe the queue length. Customers are allowed to be heterogeneous in their preferences and consequent behavior. Our goal is to characterize customers’ patience via more basic primitives, specifically waiting costs and service benefits: these two are optimally balanced by waiting customers, based on their individual cost parameters and anticipated waiting time. The waiting time distribution and patience profile then emerge as an equilibrium point of the system. The problem formulation is motivated by teleservices, prevalently telephone- and Internet-based. In such services, customers and servers are remote and queues are typically associated with the servers, hence queues are invisible to waiting customers. Our base model is the M/M/m queue, where it is shown that a unique equilibrium exists, in which rational abandonments can occur only upon arrival (zero or infinite patience for each customer). As such a behavior fails to capture the essence of abandonments, the base model is modified to account for unusual congestion or failure conditions. This indeed facilitates abandonments in finite time, leading to a nontrivial, customer dependent patience profile. Our analysis shows, quite surprisingly, that the equilibrium is unique in this case as well, and amenable to explicit calculation.

Keywords: Multiserver exponential queues, Abandonments, Nash equilibrium, Call centers
(Appears also in Sections I.)

22. Gibson, F.P. Is it better to forget? Stimulus-response, prediction, and the weight of past experience in a fast-paced bargaining task, *Computational & Mathematical Organization Theory*, 8 (1), 2002, 31–47.

Abstract. Decision makers in dynamic environments, such as air traffic control, fire-fighting, and call center operations, adapt in real-time using outcome feedback. Understanding this adaptation is important for influencing and improving the decisions made. Recently, stimulus-response (S-R) learning models have been proposed as explanations for decision makers’ adap-

tation. S-R models hypothesize that decision makers choose an action option based on their anticipation of its success. Decision makers learn by accumulating evidence over action options and combining that evidence with prior expectations. This study examines a standard S-R model and a simple variation of this model, in which past experience may receive an extremely low weight, as explanations for decision makers' adaptation in an evolving Internet-based bargaining environment. In Experiment 1, decision makers are taught to predict behavior in a bargaining task that follows rules that may be the opposite of congruent to, or unrelated to a second task in which they must choose the deal terms they will offer. Both models provide a good account of the prediction task. However, only the second model, in which decision makers heavily discount all but the most recent past experience, provides a good account of subsequent behavior in the second task. To test whether Experiment 1 artificially related choice behavior and prediction, a second experiment examines both models' predictions concerning the effects of bargaining experience on subsequent prediction. In this study, decision models where long-term experience plays a dominating role do not appear to provide adequate explanations of decision makers' adaptation to their opponent's changing response behavior.

23. Holman, David, Clair Chissick and Peter Totterdell. The effects of performance monitoring on emotional labor and well-being in call centers, *Motivation and Emotion*, 26 (1), 2002, 57–81.

Abstract. Investigated the relationship between performance monitoring and well-being. The study also examined a mechanism (emotional labor) that might mediate the relationship between them, assessed the effect of the work context on the relationship between performance monitoring and well-being, and examined the relative effects of performance monitoring and work context on well-being. Three aspects of performance monitoring were covered, namely, its performance-related context, its beneficial-purpose, and its perceived intensity. Subjects were 347 customer service agents (70.6% female and 29.4% male, aged 19–57 yrs). Regression analyses revealed that the performance-related content and the beneficial-purpose of monitoring were positively related to well-being, while perceived intensity had a strong negative association with well-being. Emotional labor did not mediate the relationship between monitoring and well-being. Work context did not mediate the relationship between monitoring and well-being, but job control and supervisory support did moderate the relationship between perceived intensity and well-being. Perceived intensity showed stronger associations with emotional exhaustion, while job control and supervisory support showed stronger associations with depression and job satisfaction

24. Torre, I. Users modeling for adaptive call centers, *Proceedings of the Second International Conference, AH, Adaptive Hypermedia and Adaptive Web-Based Systems*, Lecture Notes in Computer Science, Vol. 2347, Springer-Verlag, Germany, 2002, 603–607.

Abstract. The project described in this paper applies the principles of adaptivity to a “traditional” call center in order to support the operator in the interaction with the customer. The system uses the models of both the customer and the operator and builds up the stepwise answer through an adaptive workflow.

25. Whalen, Jack, Marilyn Whale and Kathryn Henderson. Improvisational choreography in tele-service work, *The British Journal of Sociology*, 53 (2), 2002, 239–258.

Abstract. This naturalistic study of the ordinary work practice of sale representatives employed by the call centre of a large office-equipment company focuses on the actions of those sales reps during their calls with customers. We show how this work performance is organized through an improvisational choreography of action involving not only the turn-by-turn interchange with customers on the telephone, but also the concurrent utilization of a variety of tools and artifacts. While ‘improvise’ and ‘choreograph’ may appear to be conceptually incongruent, our analysis demonstrates that even though these teleservice workers recurrently fabricate their actions out of materials and means that are conveniently on hand, the convenience is often carefully arranged to afford such extemporaneous composition. Finally, we conclude from this analysis that the traditional topics of ‘work routines’ and ‘routinization’ need to be respecified in order to take into account how any ‘routine’ is a contingently produced result (and in this centre, a craft-like performance).

Keywords: Studies, Ethnology, Call centers, Customer services, Social sciences

26. Zohar, E., A. Mandelbaum and N. Shimkin. Adaptive behavior of impatient customers in tele-queues: Theory and empirical support, *Management Science*, 48 (4), 2002, 566–583.

Abstract. We address the modeling and analysis of abandonment from a queue which is invisible to its occupants. Such queues arise in remote service systems, notably the Internet and telephone call centers, hence, we refer to them as *tele-queues*. A basic premise of this paper is that customers adapt their patience (modeled by an abandonment-time distribution) to their service expectations, in particular to their anticipated waiting time. We first present empirical support for that hypothesis, and propose an M/M/m-based model which incorporates adaptive customer behavior. In our model, customer patience (and possibly the arrival rate) depend on the *mean* waiting time in the queue. We then characterize the system equilibrium and establish its existence and uniqueness when the growth rate of customer patience is bounded by that of the mean waiting time. The feasibility of multiple system equilibria is illustrated when this condition is violated. We also discuss a decision-theoretic model for customer abandonment, and relate it to our basic model. Finally, a dynamic learning model is proposed where customer expectations regarding their waiting time are formed through accumulated experience. We address certain issues related to censored-sampling that arise in this framework and demonstrate, via simulation, convergence to the theoretically anticipated equilibrium.

Keywords: Exponential (Markovian) queues, Abandonments, Equilibrium analysis, Invisible queues, Performance-dependent behavior, Tele-services, Tele-queues, Call centers (Appears also in Section I.)

27. Hyman, J., C. Baldry, D. Scholarios and D. Bunzel. Work-life imbalance in call centres and software development, *British Journal of Industrial Relations*, 41 (2), 2003, 215.

Abstract. The paper evaluates the centrality of work to employees in two growing employment sectors, call centres and software development. It then examines evidence for extensions of work into household and family life in these two sectors. Extensions are identified as tangible, such as unpaid overtime, or intangible, represented by incursions imported from work, such as exhaustion and stress. The study finds that organizational pressure, combined with lack of work centrality, result in work intruding into non-work areas of employee lives, though intrusions

manifest themselves in different ways according to type of work, levels of worker autonomy and organizational support.

Keywords: Studies, Call centers, Software industry, Work life programs, Working conditions, Statistical analysis
(Appears also in Section VIII.)

28. Korczynski, Marek. Communities of coping: Collective emotional labour in service work, *Organization*, 10 (1), 2003, 55-79.

Abstract. This article argues that communities of coping among front-line service workers are an important part of what Hochschild has called “collective emotional labor” in service work. The analysis is framed in a sociological understanding of the customer as the key source of both pleasure and pain for service workers. Irrate and abusive customers, who are systematically part of the social relations of the service workplace, may occasion real pain in service workers. The structure of workers’ social situation means that they are likely to turn to each other to cope with this pain, forming informal communities of coping. Drawing an extensive research in four call centers in Australia and the US, this article highlights this important process in action. The communities of coping were an important social process in these workplaces, creating informal, dense cultures among the workforce. These cultures had important implications for how far the social relations of the workplace were open to management control.

Keywords: Corporate culture, Organizational behavior, Studies, Call centers, Service industries, Customer relations, Emotions
(Appears also in Section IV.)

29. Lewig, K.A. and M.F. Dollard. Emotional dissonance, emotional exhaustion and job satisfaction in call centre workers, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 366–392.

Abstract. The rapid rise of the service sector, and in particular, the call centre industry, has made the study of emotional labour increasingly important within the area of occupational stress research. Given high levels of turnover and absenteeism in the industry, this article examines the emotional demands (emotional labour) of call centre work and their relationship to job satisfaction and emotional exhaustion in a sample of South Australian call centre workers (NV=v98) within the theoretical frameworks of the job demand v-v control model, the effort v-v reward imbalance model, and the job demands v-v resources model. Qualitatively, the research confirmed the central role of emotional labour variables in the experience of emotional exhaustion and satisfaction at work. Specifically, the research confirmed the pre-eminence of emotional dissonance compared to a range of emotional demand variables in its potency to account for variance in emotional exhaustion and job satisfaction. Specifically, emotional dissonance mediated the effect of emotional labour (positive emotions) on emotional exhaustion. Furthermore, emotional dissonance was found to be equal in its capacity to explain variance in the outcomes compared to the most frequently researched demand measure in the work stress literature (psychosocial demands). Finally, emotional dissonance was found to exacerbate the level of emotional exhaustion at high levels of psychosocial demands, indicating jobs combining high levels of both kinds of demands are much more risky. Future theorizing about work stress needs to account for

emotional demands, dissonance in particular. Potential ways to alleviate emotional exhaustion due to emotional dissonance is to reduce other psychosocial demands, increase rewards, support and control as conceptualized in the JDR model. Ways to boost job satisfaction are to increase control, support, and rewards.
(Appears also in Section IV.)

30. Sheeder, Tony and Jennifer Balogh. Say it like you mean it: Priming for structure in caller responses to a spoken dialog system, *International Journal of Speech Technology*, 6 (2), 2003, 103–111.

Abstract. In this paper, we report results of a study undertaken to evaluate the initial prompts of ‘open prompt’ style call-routing applications. Specifically, we examined how placement and phrasing of examples in the initial query affected caller responses and routing success. We looked at the comparative effectiveness of placing examples before and after the initial query and of phrasing these examples such that they promoted either a succinct structure in the form of a keyword or phrase, or a more complex but natural structure in the form of a question or statement. Findings indicate that examples encouraging a more natural structure, when presented prior to the initial query, result in significantly improved routing performance. We discuss this result in the context of using initial prompts to prime for desired structure in caller responses.

Keywords: Call routing, Call Steering, Natural language, Prompting, Dialog strategy
(Appears also in Section VII.)

31. Zapf, Dieter, Amela Isic, Myriam Bechtoldt and Patricia Blau. What is typical for call centre jobs? Job characteristics, and service interactions in different call centres, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 311–340.

Abstract. Call centres have been one of the few booming branches in recent years. The main task of call centre operators is to interact with customers by telephone, usually supported by computer systems. It has been argued that call centre work is a modern form of “Taylorism”, because it is characterized by routine tasks, and low level of control for the employees. Moreover, it has been suggested that there is a high level of stress at work, both with regard to the work tasks and to the interactions with customers. In the present study, a sample of 375 call centre employees from eight different call centres was compared with a sample of noncall centre workers ($N=405$) in terms of job characteristics, job stressors, and emotional labour (emotion work). The results showed that call centre workers had worse job characteristics, but were better off with regard to most job stressors compared to representative comparison groups of no-service workers, service workers, and workers in human services, respectively. Moreover, compared to the other groups, customer service representatives (CSRs) had to express less negative emotions, but were most frequently exposed to states of emotional dissonance. A comparison of the working conditions of the eight call centres revealed that in most call centres, the working conditions could be substantially improved. In addition, various call centre parameters, such as inbound vs. outbound, or inhouse vs. external service centres were examined. The strongest effects were found for the percentage of time spent on the telephone. With some exceptions, the results support the view that the majority of call centres have been established to organize mass service for customers, that the work in the call centres is characterized by routine work and low task

control, and that call centre employees are required to suggest a “friendly smile” when they are on the phone.

(Appears also in Section IV.)

32. Higgs, Malcolm. A study of the relationship between emotional intelligence and performance in UK call centres, *Journal of Managerial Psychology*, 19 (4), 2004, 442–454.

Abstract. Within business, the organisational concept of call centres has developed rapidly. Within the UK, the use and development of these centres has grown at a significant rate over the last decade. The economic benefits of this organisational concept have been threatened by the nature of the work and operating environment leading to high levels of attrition with associated recruitment, training and loss of productivity costs. As a result, much effort has been focused on recruitment criteria and selection processes. In reviewing the criteria, it is clear that many overlap with elements from within the concept of emotional intelligence (EI). This research note reports a study designed to explore the relationship between the EI of call centre agents (using the EIQ measure developed by Dulewicz and Higgs, and ratings of their performance. A sample of 289 agents from three organisations was studied. Results included a strong relationship between overall EI and individual performance, as well as between several EI elements from the model and performance. Furthermore, a relationship between age and performance was established along with a number of gender differences. The practical implications of these findings are discussed along with the study limitations. Further areas for research are identified including differences between agents in reaction and proactive roles and relationships to more direct measures of agent attrition.

Keywords: Occupational psychology, Call centers, Studies, Skills, Personality traits, Performance evaluation, Correlation analysis

33. Witt, L.A., Martha C. Andrews, Dawn S. Carlson. When conscientiousness isn’t enough: Emotional exhaustion and performance among call center customer service representatives, *Journal of Management*, 30 (1), 2004, 149–160.

Abstract. The authors examined the relationship of the interaction between emotional exhaustion and conscientiousness with objectively-measured call volume performance and subjectively-measured service quality ratings among 92 call center customer service representatives (CSR) of a financial services institution. Results supported the interactive effects on call volume but not service quality. Specifically, the relationship between emotional exhaustion and call volume was stronger among high- than low-conscientiousness CSR’s. Among CSR’s reporting low levels of emotional exhaustion, those high in conscientiousness achieved higher call volumes than those low in conscientiousness. In contrast, among CSR’s reporting high levels of emotional exhaustion, those high in conscientiousness achieved lower call volumes than those low in conscientiousness. Implications for both the personality and stress literature are discussed. Practical implications for human resource managers are also offered.

Keywords: Studies, Emotions, Fatigue, Call centers, Customer services, Volume, Quality of service, Management theory

34. Castilla, Emilio J. Social networks and employee performance in a call center, *American Journal of Sociology (AJS)*, 110 (5), 2005, 1243–1283.

Abstract. Much research in sociology and labor economics studies proxies for productivity; consequently, little is known about the relationship between personal contacts and worker performance. This study addresses, for the first time, the role of referral contacts on workers performance. Using employees hiring and performance data in a call center, the author examines the performance implications over time of hiring new workers via employee referrals. When assessing whether referrals are more productive than nonreferrals, the author also considers the relationship between employee productivity and turnover. This study finds that referrals are initially more productive than nonreferrals, but longitudinal analyses emphasize post-hire social processes among socially connected employees. This article demonstrates that the effect of referral ties continues beyond the hiring process, having long-term effects on employee attachment to the firm and on performance.

Keywords: Call centers, Employees, Productivity, Performance appraisal, Labor economics, References, Recruitment
(Appears also in Section IV.)

35. Wilk, Steffanie L. and Lisa M. Moynihan. Display rule “regulators”: The relationship between supervisors and worker emotional exhaustion, *Journal of Applied Psychology*, 90 (5), September 2005, 917–927.

Abstract. This field study examined the effect of supervisory regulation of display rules—the rules about what kind of emotion to express on the job (R. Ekman, 1992; A. Rafaeli & R.I. Sutton, 1987)—on the emotional exhaustion of subordinates. On the basis of a sample of 940 call center employees, the authors found that worker emotional exhaustion varied across supervisors within jobs, suggesting that emotion work is influenced at the supervisory, rather than job, level. Moreover, the authors found that the importance supervisors place on interpersonal job demands of their workers was positively related to worker emotional exhaustion. Worker career identity moderated the interpersonal-job-demands–emotional-exhaustion relationship, but self-efficacy did not. Study conclusions and suggestions for future research are provided.

Keywords: Studies, Emotions, Management styles, Behavioral sciences, Call centers, Professional relationships, Fatigue

IV Human Resource Management

1. Karlin, J.E. The changing and expanding role of human factors in telecommunications engineering at Bell Laboratories. Proceedings of the Eighth International Symposium on Human Factors in Telecommunications. Standard Telecommunication Labs, Harlow, UK, 1977, 329–333.

Abstract. In recent years it has become clear that the continued growth and profitability of common carrier telecommunications will depend much more on people considerations than was the case in the past. In part this derives from the need to automate work force job design to offset sharply rising labor costs; in part from the need to increase revenues by expanding the range of customer services. The former raises questions regarding the impact on the customer of dealing more with machines and less with telephone operators and other employees as well as impact on employee satisfaction with the change in the job. The latter raises questions regarding new and future customer communication needs as well as efficient and economical ways of satisfying them. At Bell Laboratories, the total human factors effort is being reorganized to enhance its effectiveness.

Keywords: Human factors, Telecommunications engineering, Common carrier telecommunications

2. Klenke, M. ACDs get skills-based routing, *Business Communications Review*, 25 (7), 1995, 48–51.

Abstract. The goal of automated call distributor (ACD) technology has always been to spread incoming calls among call center agents so that each agent handled an equitable share of the load and the caller had the best chance of being served quickly. Now, a new kind of thinking skills-based routing has entered the call center arena. It takes ACDs one step further and ensures that an incoming call is routed to the available agent whose skills are best matched to the caller's needs. Skills-based routing software works by linking call center agents with predefined skills groups. The author discusses the identification of customer needs, defining agent skills, and setting up a routing scheme which allows callers and agents to come together efficiently.

Keywords: ACD, Skills-based routing, Automated call distributor technology, Incoming calls, Call center agents, Routing software, Skills groups, Customer needs, Agent skills
(Appears also in Section VI.)

3. Hoekstra, Edward J., Joseph Hurrell, Naomi G. Swanson and Allison Tepper. Ergonomic job task, and psychosocial risk factors for work-related musculoskeletal disorders among teleservice center representatives, *International Journal of Human Computer Interaction*, 8 (4), 1996, 421–431.

Abstract. Evaluated the association between work-related musculoskeletal disorders (WRMDs) and work conditions, perceived exhaustion, job dissatisfaction, and job-stress issues at two tele-service centers (TSCs). One facility had upgraded workstation furniture while the other did not have such ergonomic upgrades. A questionnaire survey among 114 teleservice representatives and an ergonomic evaluation were conducted to determine WRMDs and their risk factors. A

high prevalence of symptoms was found at both TSCs. Suboptimal ergonomic conditions were associated with neck, shoulder, elbow, and back WRMDs, as well as with increased job dissatisfaction. Perceived increased workload variability and lack of job control were associated with the occurrence of neck and back WRMDs, respectively. WRMDs were more frequently reported by Ss at the center with older furniture and suboptimal ergonomic conditions. Authors suggest that WRMDs may be prevented by improving ergonomic conditions at workstations and addressing work-organization elements.
(Appears also in Section VII.)

4. Hook, K. and L. Matta. Organisational variables in call centres: Mediator relationships. In *Contemporary Ergonomics 1997*, S.A. Robertson (ed.), Taylor & Francis, London, 1997, 295–300.

Abstract. This study explored the role of perceived satisfaction of the environment as a mediator variable in the relationship between seven objective organisational variables and individual affective outcomes (stress and job satisfaction). Eleven organisations were involved in the study ($n = 566$) focusing specifically on telephone call centres. Using analysis of covariance, mediated, partially mediated and direct effects were observed. Practical implications are discussed. Theoretically, the results highlight the validity of developing a more complex conceptual link between the environment and its impact upon individuals.

5. Frenkel, Stephen, May Tam, Marek Korczynski, Karen Shire. Beyond bureaucracy? Work organization in call centres, *The International Journal of Human Resource Management*, 9 (6), 1998, 957–979.

Abstract. Call centres are a rapidly growing, IT-based channel for service and sales delivery, particularly in the financial services and telecom industries. Although little research has been undertaken on the human resource aspects of call centres, two contrasting images are emerging. The first emphasizes the bureaucratic, constraining nature of these work settings, while the second image points towards worker empowerment characteristic of knowledge-intensive settings. Which of these two images more faithfully portrays the nature of work organization in call centres is the subject of our paper. Drawing on qualitative research undertaken in six call centres and a survey of front-line workers, we show that elements of both models coexist and that a hybrid model predominates. The theoretical basis for this contention, and its institutionalization as mass customized bureaucracy, lies in management's on-going attempts to reconcile two conflicting principles: standardization of processes and customization of products. The paper also explores, as key consequences of mass customized bureaucracy, front-line workers' satisfaction with various facets of their job and their overall job satisfaction, in addition to discretionary work effort. Only in relation to job security and co-worker relations could front-line workers be considered satisfied. Overall, these employees were ambivalent in their responses. They were however more likely to give more discretionary work effort than indicated by their extent of satisfaction. We conclude that, although the existing pattern of work organization may be superior to more bureaucratic forms, it is by no means ideal from the standpoint of either front-line workers or management.

Keywords: Organization, Customer, Service, Representatives, Bureaucracy, Information, Tech-

nology, Satisfaction, Discretionary, Effort

6. Henderson, S.G., A.J. Mason, R. Thomson, T. Seabrook and D. Burgess. Heuristics in rostering for call centres. 33rd ORSNZ Conference, 1998, Auckland, New Zealand.

Abstract. An important new feature on the business scene is the development of call centres, whereby a pool of staff is used to answer incoming calls from customers. This project develops a model that enables staffing levels to be determined to meet specified quality targets on customer wait times.

7. Sarel, D. and H. Marmorstein. Managing the delayed service encounter: the role of employee action and customer prior experience, *Journal of Services Marketing*, 12 (3), 1998, 195–208.

Abstract. Despite the increased attention being paid to service delivery, lengthy waits for service are still common. This paper provides a conceptual and empirical examination of the effects of perceived employee action and customer prior experience, on reactions to service delays. The results of a field study of customers experiencing actual delays in a major retail bank are then discussed. The findings indicate that events and actions taking place prior to, during, and after the delay, affect consumer response. First, customers' prior experience with that service provider is critical. Contrary to much of the literature on expectations, customers who had frequently experienced delays in the past were even more angered by the current service failure. Second, perceived employee effort during the delay had a tremendous impact on customers' reactions. Irrespective of the length of the delay, when employees are perceived as not making a real effort, customer anger is high. Third, the impact of an apology is more complex. An apology is not a substitute for genuine employee effort. An insincere apology may even backfire, especially when customers experience frequent delays and believe employees are not making a concerted effort to help. Managerial implications for addressing this problem, before, during and after the delay, are discussed.

Keywords: Banking, Customer satisfaction, Employee attitudes, Services marketing, Service Quality

8. Van Emster, Gregory, R. and Albert A. Harrison. Role ambiguity, spheres of control, burnout, and work-related attitudes of teleservice professionals, *Journal of Social Behavior and Personality*, 13 (2), 1998, 375–385.

Abstract. Forty-six customer service representatives from financial services and high-tech firms completed a modified version of J. Singh and G.K. Rhoads' (1991) MULTIRAM measure of role ambiguity; D.L. Paulhus' (1983) Spheres of Control (SOC) scale; components of J. Singh, J.R. Goolsby and G.K. Rhoads' (1994) adaptation of the Maslach Burnout Inventory; and an exploratory Attitudes Toward Telephone Work Survey. High overall role ambiguity was associated with low overall SOC scores, and all of the role ambiguity measures correlated negatively with interpersonal control scores. Role ambiguity correlated positively with depersonalization and emotional exhaustion, but not with reduced personal accomplishment. High role ambiguity was associated with relatively unfavorable assessments of one's personal performance on the telephone, and both depersonalization and emotional exhaustion were accompanied by unfavorable

attitudes toward telephone work.

9. Batt, Rosemary. Work organization, technology, and performance in customer service and sales, *Industrial and Labor Relations Review*, 52 (4), 1999, 539–564.

Abstract. The strengths and weaknesses of Total Quality Management and Self-Managed Teams, as compared to mass production approaches to service delivery, among customer service and sales workers in a large unionized regional Bell operating company, are analyzed. Participation in self-managed teams was associated with a statistically significant improvement in self-reported service quality and a 9.3% increase in sales per employee. When combined with new technology, teams boosted sales an additional 17.4%. These effects persisted over time. Total Quality Management, by contrast, did not affect performance. This study represents a strong test of the efficacy of teams because theory predicts weak outcomes for self-managed teams among service and sales employees in establishments where technology and organizational structure limit opportunities for self-regulation, the nature of work and technology do not require interdependence, and downsizing creates pervasive job insecurity—conditions found at the company studied.

10. Chen, E.T. Reengineering a call center using a performance measurement system. Proceedings of the Fifth Americas Conference on Information Systems (AMCIS 1999). Assoc. Inf. Syst., Atlanta, GA, USA, 1999, 668–670.

Abstract. Enhancing customer loyalty and eventually increasing profitability can be facilitated by the services of a call center, which takes charge of customer service calls and acts as a repository of marketing information. The most expensive and important resource a call center has is its people. Support of the call center staff is critical to maintaining quality of service. This paper describes the determination of installing a performance measurement system for a call center in a beauty-supply corporation. This PMS is essential to improve organizational productivity as one of several information system priorities. Many practical implications have been derived in this case study.

Keywords: Call centre reengineering, Performance measurement system, Customer loyalty, Profitability, Marketing information, Staff, Quality of service, Beauty supply corporation, Organizational productivity, Information system, Case study, Wholesale distribution
(Appears also in Section VIII.)

11. Coffman, S. and M.L. Saxton. Staffing the reference desk in the largely-digital library, *Reference Librarian*, 66, 1999, 141–161.

Abstract. The article examines how a centralized, networked reference service might improve efficiency and reduce costs by addressing two long-standing and seemingly intractable problems associated with the reference process: that librarians spend only a small portion of their time at the reference desk actually answering questions, and that many of the questions they do answer could be handled by paraprofessionals. The authors explore the feasibility of a live, centralized, networked reference service in a library setting by comparing traditional reference services at the County of Los Angeles Public Library with a commercial inbound call center designed to handle

the same volume of questions. Applying Erlang C, the standard algorithm used to calculate staffing requirements for commercial call centers, the authors find that a networked reference service based on a call center model could reduce the reference staff requirements at the County of Los Angeles Public Library by 42% or more. These results are very preliminary, and the article cautions against jumping to conclusions until we have much better data on the questions we are answering and the reference process as a whole, but the evidence we do have suggests that networked reference services have the potential to truly revolutionize the way we have been doing reference for the past 100 years.

Keywords: Reference desk staff, Largely digital library, Networked reference service, Intractable problems, Reference process, Librarians, Paraprofessionals, Library setting, Traditional reference services, County of Los Angeles Public Library, Commercial inbound call center, Erlang-C, Standard algorithm, Staffing requirements, Call center model, Reference staff requirements (Appears also in Sections I and VII.)

12. Fenety, A., C. Putnam and C. Loppie. Self-reported health determinants in female call centre tele-operators: A qualitative analysis. In *Advances in Occupational Ergonomics and Safety*, G.C.H. Lee (Editor). IOS Press, Amsterdam, 1999, 219–224.

Abstract. In Atlantic Canada, telephone call centres are a new, and rapidly expanding industry that employs predominantly women. Little is known about the psychosocial and work organization stressors present in the call centre industry, nor the impact of these stressors on the health of female call centre tele-operators (CCTs). Using a qualitative research technique (in-depth interviews), the authors asked a diverse group of CCTs ($n = 25$) to identify job stressors, job supports, home-work interactions and health concerns that they experienced in call centre work. They present interview results for three stressors (shiftwork, perceived control, and work support) and the impact of call centre work on their personal life and well-being.

13. Hampe, J.F. Call centre: technical and organisational challenges. *Human-Computer Interaction: Ergonomics and User Interfaces*. Proceedings of HCI International '99 (8th International Conference on Human-Computer Interaction). Lawrence Erlbaum Associates, Mahwah, NJ, USA, 1999, 1316–1320.

Abstract. Following a period of significant growth in the conventional call centre market in Europe, a new phase in technological development is emerging, bringing with it complex challenges for call centre architects. The call centres are being upgraded to communication centres by integrating additional media channels. First we must mention the standard Internet messaging communication streams, these are mainly standard based email but increasingly all types of web forms or inbound fax files. At the same time the first web enabled call centres are being set up and operating, allowing for voice over IP connections and conferencing. This leads us to the notion of customer coaching, sometimes also referred to, by other authors, as ‘one to one marketing’, although the latter might be regarded as a much more general approach. Effectively this technical set up offers simultaneous phone conversation and joint web browsing between customer and agent. Beside this technical evolution it seems most relevant to study the necessary redesign of the communication centre agent software, especially customer management software etc. Therefore, the primary goal is integration into carefully redesigned workflows and user in-

interfaces, resulting in a transparent, time synchronised customer interaction database, allowing us to improve future customer service. Simultaneously we are observing various difficulties for an adequate personnel recruiting process for communication centre agents as the traditional qualification patterns of call centre agents are no longer sufficient. The much broader palette of tasks to be handled by the new type of agents must also result in a reconsideration of personnel planning schemes and underlying assumptions on the work process.

Keywords: Call centre, Organisational challenges, Technical challenges, Technological development, Communication centres, Internet messaging communication streams, Inbound fax files, Conferencing, Web-browsing, Workflows, User interfaces
(Appears also in Section VII.)

14. Ristimäki, T., T. Leino and P. Huuhtanen. Implementation of information technology in call centers. In *Human-Computer Interaction: Ergonomics and User Interfaces*, H.J. Bullinger and J. Ziegler (eds.). Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 6–10.

Abstract. In this paper the implementation of information technology is analyzed in two call centres of a bank, which provide a variety of banking services by telephone to customers. It is important to emphasize that call centre work is extremely intensive, using the latest information and telecommunication technologies. In addition, the number of call centres is continuously rising. This study aims to analyze some of the organizational and social factors during the implementation process of a new information system (IS) in call centre work.
(Appears also in Section VI.)

15. Bagnara, S., F. Gabrielli and P. Marti. Human work in call centres. *Ergonomics for the New Millennium. Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society*, San Diego, California, USA, Vol. 1, 2000, 553–556.

Abstract. Many people are currently working in call centres and many more are expected to work in them in the near future. Call centres are in a sense ‘modern factories’ where services are delivered through information and communication technologies. This paper describes the technological evolution and discusses some aspects of human and work organisation in call centres. The final part of the paper focuses on a crucial issue commonly faced in call centres: the building up of organisational memories.
(Appears also in Section VII.)

16. Bain, Peter and Phil Taylor. Entrapped by the ‘electronic panopticon’? Worker resistance in the call centre, *New Technology, Work, and Employment*, 15 (1), 2000, 2–18.

Abstract. This paper presents a thoroughgoing critique of Fernie and Metcalf’s (1998) perspective, that the call center is characterized by the operation of an “electronic panopticon” in which supervisory power has been rendered perfect. Drawing on evidence from a telecommunications call center, this paper analyzes the significance of emerging forms of employee resistance.

Keywords: Electronic panopticon, Electronic surveillance, Telecommunications call centre, Employee resistance

17. Batt, Rosemary. Strategic segmentation in front-line services: Matching customers, employees and human resource systems, *Int. J. of Human Resource Management*, 11 (3), 2000, 540–561.

Abstract. This paper examines variation in the use of high involvement work practices in service and sales operations. It is argued that the relationship between the customer and the front-line service provider is a central feature that distinguishes production-level service activities from manufacturing. In particular, through strategic segmentation, firms are able to segment customers by their demand characteristics and to match the complexity and potential revenue stream of the customer to the skills of employees and the human resource system that shapes the customer-employee interface. Unlike manufacturing, where high involvement systems have emerged in a wide variety of product markets, therefore, service organizations are likely to use high involvement systems only to serve higher value-added customers because of the high costs of these systems and the labour intensive nature of services. Data from a nationally random sample of 354 call centres in US telecommunications documents this pattern: from classic mass production approaches for back office workers and increasingly for front office residential service agents, to greater involvement for small business service providers and high involvement practices for middle-market service agents.

Keywords: High performance work systems, Strategic human resource management, Service management, Telecommunications, Call centres

18. Belt, V., R. Richardson and J. Webster. Women's work in the information economy: The case of telephone call centres, *Information, Communication & Society*, 3 (3), 2000, 366–385.

Abstract. This paper is concerned with the work experiences and career opportunities of women employed in technology-intensive offices known as telephone 'call centres'. Call centres have grown rapidly across Europe in recent years, creating a significant number of new jobs and receiving considerable attention within the media, business and academic communities. However, despite the fact that the majority of call centre jobs have been taken by women, researchers have so far paid little attention to their position in this new 'industry'. The article addresses this research gap. In particular, it is concerned with the question of whether call centre work is offering women new opportunities for skill development and career progression, or whether a more familiar trend is taking place in which women are being drawn into a highly routinized, 'de-skilled' and de-valued area of work. The paper also uses the specific example of call centre work in order to reflect on broader issues about the changing nature of women's work and employment in the so-called 'information economy'.

19. Boddy, D. Implementing interorganizational IT systems: lessons from a call centre project, *Journal of Information Technology*, 15 (1), 2000, 29–37.

Abstract. The growing power of computer-telephony integration (CTI) systems is encouraging many companies to create call centres. These deal with a growing range of business processes and, in doing so, can be used to challenge established organizational arrangements. The range of human and management issues that need to be dealt with has yet to become clear. Some insights into these are offered from a study of one call centre over 2 years, from shortly before its

physical introduction to the present day. These empirical observations are set within the wider literature on organizational change and information technology (IT), particularly the processing and integrationist perspectives. The paper uses the evidence of the case to elaborate the integrationist model so that it reflects the areas of human action more fully. It concludes by outlining the implications of this perspective for managers seeking to build effective call centres or other forms of interorganizational IT system.

Keywords: Interorganizational IT systems, Call centre project, Computer telephony integration, CTI systems, Business processes, Organizational arrangements, Management issues, Human issues, Organizational change, Information technology, Integrationist perspective, Human action (Appears also in Section VI.)

20. Dugdale, J., B. Pavard and J.L. Soubie. A pragmatic development of a computer simulation of an emergency call centre. *Designing Cooperative Systems. Use of Theories and Models. Proceedings of the 5th International Conference on the Design of Cooperative Systems (COOP'2000)*. IOS Press, Amsterdam, The Netherlands, 2000, 241–256.

Abstract. In cases where it is infeasible to experiment in a real life setting, computer simulation is a valuable tool in the design and understanding of cooperative systems. This paper describes the development of a computer based simulation of an emergency call centre. The centre, which is a perfect example of a complex cooperative system, is currently undergoing a physical reorganisation. The aim of the simulator is to help in the redesign process by allowing the user to test the effects of new physical organisations. Whilst grounded in a solid theoretical framework, the simulator was developed using a bottom-up approach. We are particularly interested in modelling and analysing how environmental factors, such as the level of noise, affect mutual awareness, overhearing, interruption, cooperation and communication. A methodology is employed which is strongly participative and which, we believe, is well suited for the development of a computer based simulation of complex real world settings. We explain our methodology and show how the environmental and cognitive factors have been analysed, translated into a design and subsequently implemented using an object-oriented approach. Finally, we demonstrate the computer based simulator by running an experiment using data obtained from our observations of the real world setting.

Keywords: Computer simulation, Emergency call centre, Cooperative systems, Bottom-up approach, Environmental factors, Noise, Cognitive factors, Object-oriented approach, Experiment, Ergonomics, Multi-agent systems (Appears also in Section IX.)

21. Houlihan, Maeve. Eyes wide shut? Querying the depth of call centre learning, *Journal of European Industrial Training*, 24, 2000, 228–240.

Abstract. Call centres are high-pressure work environments characterised by routinization, scripting, computer-based monitoring and intensive performance targets. This promises a series of business advantages, but also risks counterproductive outcomes. Drawing on evidence from ethnographic field data, it is suggested that both desired and risked outcomes are mediated by personal modes of coping and organizational sustaining mechanisms. A central concern is to explore the underlying assumptions of call centre design and management, and to establish

whether or to what extent information systems have been constructed as learning sites or behavioural control sites. When behavioural control is a primary goal, this introduces a climate of resistance, further inflated by the culture of measurement and enforcement that is likely to ensue. In this environment, agent, manager and organization become defensive and the main outcome is a destructive crisis of trust that creates important and difficult implications for the capacity to learn.

Keywords: Learning, Control, Measurement, Corporate culture
(Appears also in Section VIII.)

22. Hutchinson, Sue, John Purcell and Nick Kinnie. Evolving high commitment management and the experience of the RAC call centre, *Human Resource Management Journal*, 10 (1), 2000, 63–78.

Abstract. This study of the RAC Customer Services Centre in Bristol is designed to show how a bundle of high commitment management (HCM) practices evolved at a time of significant competitive challenge to the business, and how the HRM choices were woven in, both in process and content terms, with changes to other functional strategies inside and outside the organization.

Keywords: Management styles, Changes, Call centers, Studies, Human resource management

23. Mascia, F.L., R. Marx and G. Arbix. Old paradigms for new jobs in call centers. Ergonomics for the New Millennium. Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, California, USA, Vol. 2, 2000, 543–546.

Abstract. Organizational structure, working process and task conception based on Tayloristic paradigms have become common in call centres in Brazil. Considering work as a simple repetition of procedures has consequences in terms of productivity, quality and workers' health. Actually the task is complex and cannot be strictly formalized.

24. Sczesny, Sabine and Dagmar Stahlberg. Sexual harassment over the telephone: Occupational risk at call centres, *Work and Stress*, 14 (2), 2000, 121–136.

Abstract. Examined call center employees' experiences of telephone sexual harassment (SH). 93 telephone company employees (aged 20–59 yrs) completed questionnaires concerning past experiences of telephone SH, including prevalence, characteristics, stress, behavioral reactions, coping strategies, consequences, and anticipated consequences. Results show that female Ss experienced more workplace telephone SH than did males. 94% of SH involved males harassing females, with 10+% involving sexual violence threats. Most calls were ended by recipients' hanging up. Coping strategies included self-instruction, verbal exchanges, and expressions of feelings. Telephone SH was stressful, left Ss feeling disgusted or disrespected, and negatively affected job satisfaction and performance. Findings suggest that female employees in call centers and other work environments with intensive employee telephone use experience frequent occurrences of telephone SH. SH experiences are a risk factor in telephone-related jobs.

25. Spini, M. Guidelines for a human resources development model in call centre, *International Journal of Psychology*, 35 (3–4), 2000, 363–363.
26. Sturdy, A. Training in service—importing and imparting customer service culture as an interactive process, *International Journal of Human Resource Management*, 11 (6), 2000, 1082–1103.

Abstract. Customer service culture initiatives have received renewed academic attention. Recent surveys of employee responses have highlighted the importance of training. However, its precise nature and how messages and various responses are mediated through an interactive and dynamic process have been largely neglected. In addition, employees’ experience of customer service as consumers and of its contradictions has yet to be fully explored in accounting for employee responses. In an effort to develop existing knowledge and models of customer service culture, these issues are addressed by drawing on observational research. Four training programmes are examined in varied contexts, including a UK call centre and a Malaysian bank. They reveal a dynamic whereby trainers’ anticipation of employee attitudes such as cynicism and the immediate reactions and dialogue of trainees help shape both the service message and subsequent responses.

Keywords: Customer service, Employee orientations, Knowledge diffusion, Participant observation, Training

27. Sznelwar, L.I., M. Zilbovicius and R.F.R. Soares. The structure of tasks at ‘call centers’: Control and learning difficulties. *Ergonomics for the New Millennium. Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society, San Diego, California, USA, Vol. 2, 2000, 547–550.*

Abstract. The organizational structures of call centres are based on standardized and rigorously controlled tasks. This paper, based on studies in companies located in Sao Paulo, Brazil, during the 1990s, discusses the difficulties of learning and work-related anxieties present in these types of organization.

(Appears also in Section VII.)

28. Wallace, Catriona M., Geoff Eagleson and Robert Waldersee. The sacrificial HR strategy in call centers, *International Journal of Service Industry Management*, 11 (2), 2000, 174–184.

Abstract. Balancing the competing objectives of efficiency and service typically requires management compromises to be made. However, some call centers have found that a compromise is not necessary. By using a “sacrificial HR strategy”, they achieve both efficiency and high levels of service at the same time. This is possible because part of the sacrificial HR strategy is the deliberate, frequent replacement of employees in order to provide enthusiastic, motivated customer service at low cost to the organization. Describes a multiple-case analysis of four call centers and the sacrificial HR strategy they used. The contingencies leading to the appearance of this strategy are discussed.

Keywords: Call centres, Service, Efficiency, HR strategy

29. de Ruyter, Ko, Martin Wetzels and Richard Feinberg. Role stress in call centers: Its effects on employee performance and satisfaction, *Journal of Interactive Marketing*, 15 (2), 2001, 23–35.

Abstract. Call centers have become an important customer access channel as well as an important source of customer-related information. Frequently, call center employees experience role stress as a result of the conflicting demands of the company, supervisors, and customers. In a study, antecedents and consequences of role stress in a call center setting are examined. Specifically, which forms of empowerment and leadership styles decrease role stress and how this subsequently effects job satisfaction, organizational commitment, performance, and turnover intentions, are investigated. It was found that particularly the autonomy dimension of empowerment has a role-stress-reducing effect. Interesting substantive direct positive effects of empowerment competence and leadership consideration on job satisfaction were found.

Keywords: Call centers, Studies, Roles, Stress, Employee problems

30. Dilevko, J. An ideological analysis of digital reference service models, *Library Trends*, 50 (2), 2001, 218–244.

Abstract. Using the theories of Pierre Boudieu about occupational fields of struggle and species of capital, this article examines the ideological implications of the digital reference call-center model. This model has the potential to lead to deprofessionalization of reference work because of increased automation and the replication of employment conditions prevailing in private sector call centers. Call-center work typically involves unskilled women earning low wages in jobs that present little opportunity for career building. Library directors who advocate digital reference call centers as models of the future have neglected the negative aspects of call centers in their rush to cut costs and provide efficient services. One answer to the deskilling dilemma is the simple act of reading: the more a librarian reads, the more he or she becomes an irreplaceable contributor in the reference transaction.

(Appears also in Section VIII.)

31. Gilmore, Audrey. Call centre management: Is service quality a priority? *Managing Service Quality*, 11 (3), 2001, 153–159.

Abstract. In recent years the call centre industry has grown rapidly in size and popularity. In so doing, the industry has been perceived to suffer from some of the problems associated with industrial mass production. The nature of the requirement to answer a high number of calls in these centres had led to the use of a traditional “production-line” management approach. Recently, as a result of both customers’ and employees’ expectations rising in relation to service delivery, the trend is for call centre operations to become more focused on staff empowerment, moving away from the traditional production-line approach. For many companies, this has become a difficult management problem. This paper reports on one such company. Following a number of years’ reliance on carrying out surveys of customer perceptions, and a history of subsequent lack of service improvement, this research used an in-depth case study approach incorporating observation studies, interviews with different levels of managers, and focus-group discussions with

front-line service delivery staff (agents). The findings identified the service quality issues to be addressed in order to reconcile customers' and agents' needs, and the implications for managers.

Keywords: Service quality, United Kingdom, Production, Empowerment
(Appears also in Section VIII.)

32. Houlihan, Maeve. Managing to manage? Stories from the call centre floor, *Journal of European Industrial Training*, 25, 2001, 208–220.

Abstract. Call centres are centralized operations where trained agents communicate with customers via phone and using purpose-built information and communication technologies. The normative model of call centre organization is that tasks are tightly prescribed, routinized, scripted and monitored. What are the implications for managers and management? Drawing on ethnographic fieldwork, this article focuses on middle management in call centres: how they work, how they talk about their work and what alternatives they see. It describes an emerging understanding of a manager who is as constrained as a worker under this mass customized bureaucracy. Lack of strategic support and development, a powerfully normative focus on micro-management and deeply embedded goal conflicts combine to undermine these managers' scope to truly manage. Like the agents they supervise, call centre managers are engaged in a coping project. In this context, they perform their identity with ambivalence: sometimes role embracing, sometimes resisting.

Keywords: Telemarketing, Customer service management
(Appears also in Section VIII.)

33. Knights, D. and D. McCabe. A different world: Shifting masculinities in the transition to call centres, *Organization*, 8 (4), 2001, 619–645.

Abstract. This article explores how business process reengineering (BPR) is informed by a masculine discourse that emphasizes competition, control and conquest while simultaneously appealing to care, trust, nurturing, creativity and teamwork. We explore how this contradiction is reflected in the language and practice of management. We demonstrate some of the ways in which this contradiction infuses with, subverts and may ultimately undermine BPR. We locate the debate within a contextual consideration of how reengineering is displacing an earlier form of masculinity within financial services which we understand and describe as paternalism. It is apparent that the preeminence of masculinity was never questioned. Indeed, both paternalism and reengineering simply fought over which masculinity would predominate.

Keywords: Business reengineering, Empowerment, Gender, Identity, Power, Strategy

34. Taylor, P. and P. Bain. Trade unions, workers' rights and the frontier of control in UK call centres, *Economic and Industrial Democracy*, 22 (1), 2001, 39–66.

Abstract. In developing a model of call centre diversity, spanning the dimensions of quantity and quality, the article develops a critique of aspects of Frenkel et al.'s recent study of 'front line' work. Drawing upon employee survey and interview data from six UK financial sector call centres, patterns of resistance and the contrasting responses of trade unions to the experience

of intensive working conditions are examined. It is argued, in conclusion, that the newly established managerial 'frontiers of control' require to be combated by new union bargaining agendas which seek to address employees' concerns at the point of production.

Keywords: Labor unions, Call centers, Control, Workers, Financial services, Studies

35. Thompson, Paul and George Callaghan. Edwards revisited: Technical control and call centres, *Economic and Industrial Democracy*, 22 (1), 2001, 13–37.

Abstract. Call centers represent a new strategy by capital to rescue unit labor costs. This article argues that management has developed a new form of structural control. Theoretically this draws heavily on Edwards' concept of technical control, but not only is this shown to be extended and modified, it is also combined with bureaucratic control which influences the social structure of the workplace. Contrary to Edwards, such systems are not distinct; rather, they are blended together in the process of institutionalizing control. Part of the rationale for this is to camouflage control, to contain conflict by making control a product of the system rather than involving direct confrontation between management and workers. Despite such attempts, the struggle for transforming labor power into profitable labor remains, and the article ends by exploring confrontation between workers and managers and worker agency more generally.

Keywords: Call centers, Control, Work environment, Studies
(Appears also in Section VIII.)

36. Adria, Marco and Shamsud D. Chowdhury. Making room for the call center, *Information Systems Management*, 19 (1), 2002, 71–80.

Abstract. A call center can dramatically improve an organization's ability to serve its customers. Skills for employees in call centers can and should be upgraded. The article suggests ways of ensuring that the ideal configuration of decentralized decision making and centralized control takes hold in the organization after the call center is established. Practical advice is offered for enhancing an organization's culture even as employees begin to spend less time in face-to-face interactions.

Keywords: Studies, Call centers, Customer services, Corporate culture
(Appears also in Section VIII.)

37. Armistead, Colin, Julia Kiely, Linda Hole and Jean Prescott. An exploration of managerial issues in call centres, *Managing Service Quality*, 12 (4), 2002, 246–256.

Abstract. This paper explores managerial issues in call centres through two intensive case studies in UK organisations, supplemented by interviews with five operations managers in other call centres. The research explores key issues from the perspective of managers, team leaders, and customer-service agents. Our findings show a growing professionalism among those working in call centres—in keeping with the prominent role played by call centres in the market value chains of many organisations. Managers are under pressure to meet the potentially conflicting goals of customer service and efficiency in variable circumstances which cause the work load on call centres to alter significantly. In this environment, decisions on the use of technology, and

on the roles, skills, and competencies of customer agents, are critical. So too are the ways in which human resource practices are employed in this relatively new and fast-growing form of organisation.

Keywords: Communications industries, Information technology, Professionalism, Motivation

38. Bagnara, S., R. Bugatti, F. Gabrielli and A. Morawetz. Customer contact centers: Perspectives in work organisation. WWDU 2002—World Wide Work. Proceedings of the 6th International Scientific Conference on Work with Display Units, H. Luczak, A.E. Cakir and G. Cakir (Eds.). Ergonomic Institut für Arbeits- und Sozialforschung, Forschungsgesellschaft mbH, Berlin, 2002, 79–81.

Abstract. Many people are currently employed in call centres and many more are expected to work in them in the near future. As shown by an overview of work in call centres carried out during a European project (Euro-Telework), operators coordinate and take care of the relationship with customers. They fully represent the company. Their work in practice is based on a processing of distributed knowledge that is dynamic and continuously evolving. Nevertheless, they have to face a sort of ‘tayloristic’ organization that hampers knowledge sharing and reduces the quality of work. Additionally, there is scarce attention to training, retention and career development of agents. The paper reports a case study where a team-based perspective has been set out for building and empowering new professional roles in order to make the contact centres evolve from customer care to customer relationship management structures.

Keywords: Training, Team work

39. Bain, Peter and Phil Taylor. Ringing the changes? Union recognition and organisation in call centres in the UK finance sector, *Industrial Relations Journal*, 33 (3), 2002, 246–261.

Abstract. The massive rise in UK call center employment in recent years has been closely related to developments in the finance sector. This paper analyzes these developments in order to contextualize the organizational experiences of unions in the sector. Recruitment activity in both hostile and compliant employer environments, and findings from the first national survey of call center employees’ attitudes towards trade unionization, are discussed, as the prospects for union recruitment and organization are assessed. On the basis of the findings reported here, and on what is known about sectoral developments, it is not possible to make a definitive calculation of the extent of union membership or density in finance sector call sectors. However, despite uneven development in relation to individual unions and companies, the research indicates some growth in both union membership and employer recognition.

Keywords: Studies, Labor unions, Labor relations, Call centers, Recruitment, Memberships

40. Batt, Rosemary. Managing customer services: Human resource practices, quit rates, and sales growth, *Academy of Management Journal*, 45 (3), 2002, 587–597.

Abstract. This study examines the relationship between human resource practices, employee quit rates, and organizational performance in the service sector. Drawing on a unique nationally representative sample of call centers, multivariate analyses show that quit rates are lower and

sales growth is higher in establishments that emphasize high skills, employee participation in decision-making and in teams, and HR incentives such as high relative pay and employment security. Quit rates partially mediate the relationship between human resource practices and sales growth. These relationships also are moderated by the customer segment served.

41. Batt, Rosemary, Alexander Colvin and Jeffrey Keefe. Employee voice, human resource practices, and quit rates: Evidence from the telecommunications industry, *Industrial Labor Relations Review*, 55 (4), 2002, 573–594.

Abstract. In this paper, we examine the predictors of aggregate quit rates at the establishment level. We draw on strategic human resource and industrial relations theory to identify the sets of employee voice mechanisms and human resource practices that are likely to predict quit rates. With respect to alternative voice mechanisms, we find that union representation significantly predicts lower quit rates after controlling for compensation and a wide range of other human resource practices that may be affected by collective bargaining. Direct participation via offline problem-solving groups and self-directed teams is significantly negatively related to quit rates, but non-union dispute resolution procedures are not. In addition, higher relative wages and internal promotion policies significantly predict lower quit rates, while contingent staffing, electronic monitoring, and variable pay predict significantly higher rates.

42. Batt, Rosemary and Lisa Moynihan. The viability of alternative call centre production models, *Human Resource Management Journal*, 12 (4), 2002, 14–34.

Abstract. This article outlines three alternative production models and discusses their applicability to call centre management. These include the classic mass production model, the professional service model and the mass customisation model. It then develops a theoretical framework that identifies potential causal links between management practices, workers, affective and cognitive reactions, and performance outcomes. It uses this framework to review literature on service workplaces in organizational behavior and HR studies and to assess the empirical evidence regarding these causal explanations. Finally, the paper presents two recent quantitative studies of call centre performance—one that examines affective explanations and one that explores cognitive explanations for the HR–performance link. It concludes with directions for future research.

Keywords: Call centers, Human resource management, Models, Correlation analysis, Organizational behavior, Studies

43. Belt, Vicki, Randal Richardson and Juliet Webster. Women, social skill and interactive service work in telephone call centers, *New Technology, Work, and Employment*, 17 (1), 2002, 20–34.

Abstract. This paper contributes to current debates about gender, work and skill in the service economy, focusing specifically on the case of women’s employment in telephone call centers. The paper asks whether call centre employers are capitalizing on women’s feminine social skills, and examines the degree to which these skills are being developed, acknowledged and recognized.

Keywords: Human resource management, Call centers, Women, Statistical data

44. Callaghan, George and Paul Thompson. 'We recruit attitude': The selection and shaping of routine call centre labour, *The Journal of Management Studies*, 39 (2), 2002, 233–254.

Abstract. Call centers are growing rapidly and are receiving attention from politicians, policy makers and academics. While most of the latter focus on work relations, notably patterns of control and surveillance, this paper explores the role of recruitment, selection and training in the shaping call center labor. The paper uses data from a case study of a call center to argue that the increased significance of social competencies within interactive service work gives these procedures greater salience and that they are used by management to address the indeterminacy of labor, in part, outside the labor process. Primary data from management and customer service representatives is used to examine and contrast their respective perceptions of recruitment, selection and training.

Keywords: Studies, Call centers, Recruitment, Employee attitude, Training

45. Couture, Jon Nicholas. The impact of role ambiguity, locus of control and job satisfaction on call center agent productivity. *Dissertation - Abstracts - International Section A: Humanities and Social Sciences*, 63 (5-A), 1678, 2002.

Abstract: As the global economy continues to migrate from a product and manufacturing orientation to a services orientation, the need for high performance call centers is increasing at a rapid pace. An obvious part of building a high performance call center is ensuring the employees, or Call Center Agents (CCA), are as productive as possible so businesses can provide high quality call center services as effectively and efficiently as possible. This study focused on the impact of role ambiguity, locus of control and job satisfaction as it relates to CCA productivity. It was conducted in a large, international IT Services firm that provides a wide range of IT services (e.g., consulting, help desk support, etc.) to Fortune 1000 companies. Sixty-one CCAs participated in this study. The hypotheses suggested that certain correlations would exist between the independent and dependent variables. The results of the study did not reveal a significant predictor of call CCA performance. Although there were some interesting correlations between one pair of the variables (e.g., role ambiguity and job satisfaction were highly correlated), based on the results of this study, it does not appear as though the degree of role ambiguity, locus of control or the level of job satisfaction of CCAs can predict productivity. It's important to note that questions were raised around the productivity measures used in terms of their reliability due to an aggregating process used to normalize how call center managers view the performance of their CCAs. Further implications associated with the results of this study, and directions for future research were discussed.

46. Dean, Alison M. Service quality in call centres: Implications for customer loyalty, *Managing Service Quality*, 12 (6), 2002, 414–423.

Abstract. Studies on call centres suggest that there is a focus on efficiency at the expense of effectiveness, where effectiveness is indicated by characteristics such as customer orientation, service priorities and quality. It therefore appears that customers will expect and experience low levels of service quality from call centres, with possible implications for their loyalty to the

providing organisation. These issues are the focus of this study. A mail survey was conducted of recent clients of two call centres in Australia. The respondents were individual consumers in an insurance company ($n = 248$, 14 percent) or business customers of a bank ($n = 325$, 16 percent). Key findings are similar for the two samples. Both perceptions of quality and customer orientation of the call centre were related to loyalty to the providing organisation, and perceptions of quality partially mediated the customer orientation to loyalty relationship. The discussion includes managerial implications and potential future research.

Keywords: Service quality, Customer orientation, Call centres, Customer loyalty

47. Deery, Stephen, Roderick Iverso and Janet Walsh. Work relationships in telephone call centres: Understanding emotional exhaustion and employee withdrawal, *The Journal of Management Studies*, 39 (4), 2002, 471–496.

Abstract. This paper examines the nature of employment and the conditions of work in five telephone call centers in the telecommunications industry in Australia. The paper draws upon survey data from 480 telephone service operators to identify the factors that are associated with emotional exhaustion and the frequency of absence amongst the employees. A modeling of the data using LISREL VIII revealed that a number of job and work-setting variables affected the level of emotional exhaustion of employees. These included interactions with the customer, a high workload and a lack of variety of work tasks. Moreover, higher rates of absence were associated with emotional exhaustion.

Keywords: Studies, Call centers, Stress, Work environment, Emotions

48. Easton, Fred F. and John C. Goodale. Labor scheduling with employee turnover and absenteeism. Working paper, Syracuse University, March 15, 2002.

Abstract. Most labor staffing and scheduling models presume that all employees scheduled for duty reliably report for work at the beginning of their shift. For industries with even moderate turnover or absenteeism, this assumption may be quite costly. We present a profit-oriented labor scheduling model that accounts for the day-to-day flux of employees and capacity induced by voluntary resignations, new hires, experience curves, and absenteeism. The proposed model also anticipates revenue losses due to renegeing by customers whose patience decays exponentially with queue time. Our computational studies suggest that firms with comparatively high transaction volumes, long transaction times, and/or relatively tight profit margins may experience significant benefit from this approach. Compared with conventional labor scheduling models, the proposed method boosts average expected profits by more than 10 percent in certain operating environments.

49. Matthews, G. and S. Falconer. Personality, coping and task-induced stress in customer service personnel, *Proceedings of the Human Factors and Ergonomics Society, 46th Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, USA, 2002, 963–967.

Abstract. This study investigated predictors of stress responses in customer service personnel working for a major telecommunications company. Ninety-one participants performed a simu-

lation of their work task. They were presented with telephone inquiries, and tested for their knowledge of the correct response. Several findings of a previous study (Matthews and Falconer, 2000) were replicated. Performing the task appeared to be intrinsically stressful, as evidenced by a large magnitude increase in subjective distress. Individual differences in stress state were related to strategy for coping with task demands. The ‘big five’ personality traits were compared with measures of dispositional coping style as predictors of subjective stress state. Coping measures added significantly to the variance in stress state explained by the big five. Emotion-focused strategies such as self-criticism appeared to be especially damaging in the customer service context. Coping measures might be used by organizations to select operators likely to be resistant to task-induced stress.

Keywords: Behavioral sciences computing, Call centres, Human factors, Marketing, Personnel, Psychology

(Appears also in Section VII.)

50. Moshavi, Dan and James R. Terborg. The job satisfaction and performance of contingent and regular customer service representatives: A human capital perspective, *International Journal of Service Industry Management*, 13 (4), 2002, 333–347.

Abstract. Although research on customer service representatives (CSRs) in call centers has increased in recent years, little attention has been paid to the growing use of contingent (temporary) CSRs in this setting. This study investigated the role that human capital plays in explaining the job satisfaction and performance of contingent and regular CSRs. Consistent with our expectations, contingent CSRs had less human capital but higher job satisfaction than regular workers. In addition, we found that human capital mediated the relationship between work status and job satisfaction. Contrary to expectations, no performance differences were found between contingent and regular CSRs. Implications for research and practice are discussed.

Keywords: Work, Customer service, Job satisfaction

51. Mulholland, Kate. Gender, emotional labour and teamworking in a call centre, *Personnel Review*, 31 (3), 2002, 283–303.

Abstract. This article examines teamworking in a call centre and how this is shaped for the employees by an increase in technical control, the dynamics of emotional labour and gender politics. The research is based on a case study of call centre work organization in different sectors, and this paper draws specifically on ethnographic research on two teams and their managers in broadcasting. Drawing on theoretical insights, it suggests that teamworking results in a fundamental contradiction involving a “soft” discourse versus a regime of increasing managerial control. Participation is measured against Thompson and Wallace’s three-dimensional notion of participation, showing that employees have little discretion over the way work is organized. The normative aspect of team organization accommodates managerial coping strategies in conditions of staff shortage via numerical flexibility. However, management’s efforts to disguise control are resisted by employees who transform workplace discourses into oppositional politics, shattering the illusion of unity promoted by the pundits of team organization.

Keywords: Teamwork, Management control, Gender, Participation, Resistance

52. Richardson, H. and K. Richardson. Customer relationship management systems (CRM) and information ethics in call centres—‘You are the weakest link. Goodbye!’, *Australian Journal of Information Systems*, 9 (2), 2002, 166–171.

Abstract. This paper catalogues the rise of call centres in the North West of England, UK and their use of CRM systems. CRM systems often imply new technologies and new ways of working. However, in this account, we explore the historical development of the telegraph and work in early telephone exchanges and find the same old story. Our consideration of the ethics of CRM system use and some inherent contradictions are in terms of privacy, communication richness, management methods and computer ethics in an organizational context. Call centres today are viewed by some as offering satisfying employment of intrinsic value; for others, they are the ‘new sweatshops of the 21st century’ (Belt et al., 2000). Our interpretative field study makes a contribution to this debate.

(Appears also in Section VIII.)

53. Smith, W.L. Customer service call centers: Managing rapid personnel changes, *Human Systems Management*, 20 (2), 2002, 123–129.

Abstract. This paper examines academic and practitioner literature relative to service quality and the changing personnel requirements for customer service call centers (CSCC). From this review, propositions are developed which (1) may be useful to call center managers in meeting this critical need, and (2) may be used to direct future academic research in this growth area. This review is organized around eight key human resource management practices consisting of: 1. recruiting, 2. selection, 3. retention, 4. teamwork, 5. training and development, 6. appraisal, 7. rewarding quality, and 8. employee involvement. Propositions based on the literature review are developed for each key practice. Conclusions are drawn and implications for managerial and academic implications are discussed.

54. Swanson, N., P. Grubb, C. Beam, R. Dunkin, L. Schleifer and S. Sauter. The influence of job stressors on the taking of rest breaks among call center operators. WWDE 2002—World Wide Work. Proceedings of the 6th International Scientific Conference on Work and Display Units, H. Luczak, A.E. Cakir and G. Cakir (Eds.). Ergonomic Institut fur Arbeits- und Sozialforschung, Forschungsgesellschaft mbH, Berlin, 2002, 674–675.

Abstract. Nearly 5000 customer service operators in a large government agency were surveyed about working conditions at their agency. The survey included questions about rest break behaviours and job stressors. The results indicated that job demands were predictive of rest break behaviours. Employees who reported low levels of job control, supervisory support, and decision-making ability, along with greater time pressures, work backlogs, and contact with upset customers also reported taking fewer rest breaks during the workday.

Keywords: Rest pauses and work duration, Etiology, Job characteristics

55. van den Broek, Diane. Monitoring and surveillance in call centres: Some responses from Australian workers, *Labour & Industry*, 12 (3), 2002, 43–58.

Abstract. Australian call centres currently number around 4,000, in industries such as banking, public utilities, airlines, information technology, and telecommunications. Of the 200,000 employees in the call centre industry, the Australian Council of Trade Unions (ACTU) estimates that around 15 to 20 percent are unionised. Unionised call centres are generally located in the public or ex-public sector such as the airlines, while employees in other industries including telecommunications and banking are considerably less unionised. The contract call centres have proven to be the most difficult to organise. (Interview ACTU Organiser, 2001). (Appears also in Section VIII.)

56. Anonymous. Shift-pattern switch improves staff turnover and recruitment at Seeboard, *Human Resource Management International Digest*, 11 (1), 2003, 12.

Abstract. Switching from 3-week rolling shifts to fixed shift patterns at Seeboard Energy's customer-contact center was seen as a high-risk strategy by some managers, but has dramatically reduced staff turnover and improved recruitment. Seeboard Energy Ltd is a utility company with around 1.8 million customers, mainly in south-east England. Its customer-contact center operates from 8 a.m.–10 p.m. (Saturday 8 a.m.–6 p.m.). Staff answer around 3 million calls a year and respond to around 800,000 letters or e-mails from customers. The company piloted the approach in an area of the organization that had the highest number of vacancies (150). Throughout the project, from identification of the problem to implementation of a solution, the company placed great emphasis on communication. This project demonstrated that the switch to a fixed shift pattern at Seeboard Energy halved staff turnover, to 10%, in a 9-month period, and cut the proportion of women leaving by almost a third. In addition, response to recruitment advertisements improved markedly.

Keywords: Retention, Working hours, Personnel policies, Electric utilities, Corporate profiles

57. Bakker, Arnold B., Evangelia Demerouti and Wilmar B. Schaufeli. Dual processes at work in a call centre: An application of the job demands v-v resources model, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 393–417.

Abstract. This study among 477 employees working in the call centre of a Dutch telecom company (response 88%) examined the predictive validity of the job demands v-v resources (JDv-vR) model for self-reported absenteeism and turnover intentions. The central hypothesis was that job demands would be the most important predictors of absenteeism, through their relationship with health problems (i.e., exhaustion, and Repetitive Strain Injury—RSI), whereas job resources would be the most important predictors of turnover intentions, through their relationship with involvement (i.e., organizational commitment and dedication). Results of a series of SEM analyses largely supported these dual processes. In the first *energy-driven* process, job demands (i.e., work pressure, computer problems, emotional demands, and changes in tasks) were the most important predictors of health problems, which, in turn, were related to sickness absence (duration and long-term absence). In the second *motivation-driven* process, job resources (i.e., social support, supervisory coaching, performance feedback and time con-

trol) were the only predictors of involvement, which, in turn, was related to turnover intentions. Additionally, job resources had a weak negative relationship with health problems, and health problems positively influenced turnover intentions. The application of the JDv-vR model as a human resource management tool in call centres as well as in other organizations is discussed.

58. Cartwright, Susan. New forms of work organization: Issues and challenges, *Leadership and Organization Development Journal*, 24 (3), 2003, 121–122.

Abstract. The changing nature of work and the emergence of new forms of work organization present particular challenges to leadership and management. This special issue examines some of the challenges and issues in the relationship between technology, stress and satisfaction within call centre environments, the problems of remote leadership and the rise in contingent workforce.

Keywords: Work organization, Work teams, Call centres, Workforce, Leadership, Temporary workers

(Appears also in Section VIII.)

59. Holdsworth, Lynn and Susan Cartwright. Empowerment, stress and satisfaction: An exploratory study of a call centre, *Leadership and Organization Development Journal*, 24 (3), 2003, 131–140.

Abstract. The aim of this study was to explore the relationship between stress, satisfaction and the four dimensions of psychological empowerment (meaning, impact, self-determination and competence) within a call centre. The occupational stress indicator and Spreitzer's empowerment measure were used to collect data from a northwest (UK) call centre ($n = 49$). The study found the call centre agents were more stressed, less satisfied and reported poorer mental and physical health than the general working population. In addition, the sample perceived themselves as less empowered than other workers in a traditional office environment. The empowerment dimensions of meaning, impact and particularly self-determination, seem to directly influence job satisfaction, but not health.

Keywords: Stress, Empowerment, Call centres, Job satisfaction

60. Holman, David. Phoning in sick: An overview of employee stress in call centres, *Leadership and Organization Development Journal*, 24 (3), 2003, 123–130.

Abstract. This paper reviews three studies that examine the main causes of employee stress and well-being in call centres. All three studies were conducted by the author and his colleagues and reveal that employee well-being in call centres is associated with: effective job design; performance monitoring that is not perceived to be intense and which aims to develop employees; supportive management; and, supportive human resource practices. Furthermore, levels of well-being in call centres are shown to compare favourably to other forms of work. The studies challenge the image of call centres as “electronic sweatshops” and question the idea that call centre work is inevitably stressful. It is argued that managers have a choice in how to organise call centre work and can take steps to actively design employee stress out of call centre work. Practical recommendations on how to reduce employee stress in call centres are discussed.

Keywords: Call centres, Stress, Job design, Performance monitoring, Human resource management

61. Konradt, U., G. Hertel and K. Joder. Web-based assessment of call center agents: Development and validation of a computerized instrument, *International Journal of Selection and Assessment*, 11 (2-3), 2003, 184–193.

Abstract. This study describes the development and validation of the Call Center Aptitude Test (C-A-T), an Internet-based multi-method measure for the pre-selection of call centre agents. The C-A-T includes a short biographical form, a cognitive speed test, a personality inventory, and a multimedia situational judgement test. A total of 327 call centre agents completed the C-A-T and were concurrently assessed by their superiors. In a pilot study ($N = 151$), a prototype was tested and subsequently optimized. In the main study ($N = 176$), the revised and extended version of the C-A-T was reliable ($\alpha = 0.85$) and showed good convergent and discriminant validity. The concurrent validity ($r = 0.33$) can be considered to be satisfactory for a computerized pre-selection instrument. Evidence was also found for high face validity and acceptance in both studies.

62. Korczynski, Marek. Communities of coping: Collective emotional labour in service work, *Organization*, 10 (1), 2003, 55-79.

Abstract. This article argues that communities of coping among front-line service workers are an important part of what Hochschild has called “collective emotional labor” in service work. The analysis is framed in a sociological understanding of the customer as the key source of both pleasure and pain for service workers. Irrate and abusive customers, who are systematically part of the social relations of the service workplace, may occasion real pain in service workers. The structure of workers’ social situation means that they are likely to turn to each other to cope with this pain, forming informal communities of coping. Drawing on extensive research in four call centers in Australia and the US, this article highlights this important process in action. The communities of coping were an important social process in these workplaces, creating informal, dense cultures among the workforce. These cultures had important implications for how far the social relations of the workplace were open to management control.

Keywords: Corporate culture, Organizational behavior, Studies, Call centers, Service industries, Customer relations, Emotions
(Appears also in Section III.)

63. Lewig, K.A. and M.F. Dollard. Emotional dissonance, emotional exhaustion and job satisfaction in call centre workers, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 366–392.

Abstract. The rapid rise of the service sector, and in particular, the call centre industry, has made the study of emotional labour increasingly important within the area of occupational stress research. Given high levels of turnover and absenteeism in the industry, this article examines the emotional demands (emotional labour) of call centre work and their relationship to job satisfaction and emotional exhaustion in a sample of South Australian call centre workers (NV=v98)

within the theoretical frameworks of the job demand v-v control model, the effort v-v reward imbalance model, and the job demands v-v resources model. Qualitatively, the research confirmed the central role of emotional labour variables in the experience of emotional exhaustion and satisfaction at work. Specifically, the research confirmed the pre-eminence of emotional dissonance compared to a range of emotional demand variables in its potency to account for variance in emotional exhaustion and job satisfaction. Specifically, emotional dissonance mediated the effect of emotional labour (positive emotions) on emotional exhaustion. Furthermore, emotional dissonance was found to be equal in its capacity to explain variance in the outcomes compared to the most frequently researched demand measure in the work stress literature (psychosocial demands). Finally, emotional dissonance was found to exacerbate the level of emotional exhaustion at high levels of psychosocial demands, indicating jobs combining high levels of both kinds of demands are much more risky. Future theorizing about work stress needs to account for emotional demands, dissonance in particular. Potential ways to alleviate emotional exhaustion due to emotional dissonance is to reduce other psychosocial demands, increase rewards, support and control as conceptualized in the JDR model. Ways to boost job satisfaction are to increase control, support, and rewards.
(Appears also in Section III.)

64. Shah, Vishal and Rajenda K. Bandi. Capability development in knowledge intensive IT enabled services, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 418–427.

Abstract. Most of the call centre literature discusses cases where the customer support task is routine and low in complexity. Call centres are considered to be modern equivalents of factory sweatshops in this literature. Technical support, however, is an example of a knowledge intensive support service. The article presents a case study of a call centre providing remote technical support and illustrates the nature of capabilities required for consistent service performance. The practices adopted at this technical support call centre do not confirm to the sweatshop stereotype mentioned in the literature.

65. Workman, Michael. Results from organizational development interventions in a technology call center, *Human Resource Development Quarterly*, 14 (2), 2003, 215–230.

Abstract. Technology support call centers are becoming an increasingly important part of the American economy. However, there are many scholarly reports of problems associated among these endeavors. Research into mitigating these problems has tended to focus on structural alignment, or forms of team participation, leading to conflicting outcomes. HRD researchers are left with an unclear picture of the outcomes, and HRD practitioners have been left with the question of which of these interventions to implement. This study concurrently investigated the effects on job satisfaction from structural-alignment, high-involvement, autonomous-team interventions compared to a control group. The analysis indicated job satisfaction improvements in the alignment and high-involvement groups, with the high-involvement groups suggesting the most significant improvements. As a result, recommendations are made for HRD practitioners and future HRD research.

Keywords: Personnel economics, Labor management (team formation, worker empowerment, job design, tasks and authority, job satisfaction)

66. Zapf, Dieter, Amela Isic, Myriam Bechtoldt and Patricia Blau. What is typical for call centre jobs? Job characteristics, and service interactions in different call centres, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 311–340.

Abstract. Call centres have been one of the few booming branches in recent years. The main task of call centre operators is to interact with customers by telephone, usually supported by computer systems. It has been argued that call centre work is a modern form of “Taylorism”, because it is characterized by routine tasks, and low level of control for the employees. Moreover, it has been suggested that there is a high level of stress at work, both with regard to the work tasks and to the interactions with customers. In the present study, a sample of 375 call centre employees from eight different call centres was compared with a sample of noncall centre workers (Nv=v405) in terms of job characteristics, job stressors, and emotional labour (emotion work). The results showed that call centre workers had worse job characteristics, but were better off with regard to most job stressors compared to representative comparison groups of no-service workers, service workers, and workers in human services, respectively. Moreover, compared to the other groups, customer service representatives (CSRs) had to express less negative emotions, but were most frequently exposed to states of emotional dissonance. A comparison of the working conditions of the eight call centres revealed that in most call centres, the working conditions could be substantially improved. In addition, various call centre parameters, such as inbound vs. outbound, or inhouse vs. external service centres were examined. The strongest effects were found for the percentage of time spent on the telephone. With some exceptions, the results support the view that the majority of call centres have been established to organize mass service for customers, that the work in the call centres is characterized by routine work and low task control, and that call centre employees are required to suggest a “friendly smile” when they are on the phone.

(Appears also in Section III.)

67. Anonymous. Call centres losing millions of working days to absence, *Occupational Health*, 56 (1), 2004, p. 4.

Abstract. A survey by technology organization Dimension Data found absenteeism is a problem for the contact center industry, which accounts for almost 3% of the UK’s work force. The study of more than 200 call centers around the world also reported very high staff turnover rates, at 19% globally, but up to 25% in Europe and the UK.

Keywords: Call centers, Absenteeism, Employee turnover

68. Bordoloi, Sanjeev K. Agent recruitment planning in knowledge-intensive call centers, *Journal of Service Research (JSR)*, 6 (4), May 2004, 309–323.

Abstract. The key ingredient in a call center’s operational efficiency is labor. Agent turnover remains a major concern for call centers. The top three reasons for turnover are low salary, lack of career path, and burnout. On average, it costs about \$10 to a call center for each call, and the cost to bring on a new agent is more than \$6,000. The author treats call centers as knowledge-intensive operations that are characterized by extensive knowledge required for each

agent, combines control theory and chance-constrained programming in a model for workforce planning that allows for agent learning, and derives steady state workforce levels for different knowledge groups within the call center to minimize total labor-related costs. The objective is to meet stochastic demands with a desired service level. The author applies his model to an actual call center situation in the high-tech industry with adjusted data and discusses the managerial implications.

69. Chaudhry, Abdus Sattar and Chua Jeanne. Call centres for enhanced reference services: A comparison of selected library call centres and the Reference Point at the National Library of Singapore, *Library Review*, 53 (1), 2004, 37–49.

Abstract. The concept of a call center is defined and the technologies employed in call center applications are examined. The principles and practices relevant in the context of telephone services offered by libraries are highlighted. Features of call centers in selected libraries are described and compared with the Reference Point at the National Library of Singapore and recommendations on call center practices with regard to the provision of LIS are presented.

Keywords: Comparative analysis, Call centers, Libraries, Communication systems, Customer services, Reference services

70. Fisher, Michael. The crisis of civil service trade unionism: A case study of call centre development in a civil service agency, *Work, Employment & Society*, 18 (1), 2004, 157–177.

Abstract. This article examines why and how management in a British civil service agency has sought to respond to the Modernising Government agenda of the present Labour government by seeking to apply Taylorist principles of work organisation to a complex form of administrative case work. This has led to the establishment of a call centre within the agency for the first time. The article discusses the response to this of the main trade union within the agency, the positive and cooperative nature of which is argued to be founded in the historic character of management-union relations within the agency, and in the ‘high-quality’ form that call centre working has to far assumed. The reasons for this are identified as having their origins primarily in a number of potentially temporary technical limits to the further realization of a Taylorist decomposition of call handling tasks. The persistence of these limits is argued to have compelled management to preserve complex working and employment terms that they may otherwise have sought to challenge and change. The article concludes by arguing that trade unionism in the agency is in crisis: A crisis consisting of a too uncritical understanding of the potential that the further development of call centre working has to enhance the degradation and devaluation of staff labour.

Keywords: Civil service, Call centers, Labor relations

71. Forsyth, Anne Marie. Lloyds TSB banks on call-center quality, *Human Resource Management International Digest*, 12 (1), 2004, 14–16.

Abstract. More than 10 million Britons currently use telephone banking and an estimated 11.5 million online active bank accounts are in use—more than in any other European country.

These figures demonstrate that Internet and telephone banking are firmly embedded in everyday lives and are here to stay. Lloyds TSB has been working not only to ensure that its call centers provide the best possible service to customers, but also that it provides the staff with the best possible place to work. A dedicated project team at Lloyds TSB, consisting of people from HR and quality management from the 3 call-center sites, was set up to work towards CCA accreditation. One of the main challenges the bank faced in this was how to reconcile the geographical disparity and reasons for departmental differences of its call centers.

Keywords: Call centers, Electronic banking, Working conditions, Training, Career development planning

72. Pollitt, David. Nationwide dials up training over the telephone for call-center staff, *Human Resource Management International Digest*, 12 (1), 2004, 12–13.

Abstract. The Nationwide's regional call centers are designed to supplement the services of the society's two main call centers, in Swindon and Nottingham. These two centers employ hundreds of staff, trained face-to-face by instructors working in classrooms. In order to meet the needs of the new regional centers, the Nationwide had to find an efficient way of introducing new staff and managers across the country to basic call-center skills and to the Nationwide customer culture while maintaining an acceptable level of service. The society also needed a training approach that involved managers to a greater extent in transferring learning into the workplace. Audio-conferencing was the obvious solution. Course tests and quizzes showed that the Nationwide delegates achieved higher scores with remote training than they had in traditional classroom settings.

Keywords: Building societies, Training, Call centers, Telephones

73. Tuten, Tracy L. and Presha E. Neidermeyer. Performance, satisfaction and turnover in call centers: The effects of stress and optimism, *Journal of Business Research*, 57 (1), 2004, 26–34.

Abstract. This paper reports the results of a study, which measured the role of optimism and its effect on stress in call centers. Service providers at inbound call centers answered questionnaires designed to measure their personal orientation towards optimism, perceptions of job stress, work/nonwork conflict, performance, absenteeism and intent to turnover. We found that optimists did perceive lower levels of job stress and lower work/nonwork conflict. However, pessimists reported higher levels of performance and satisfaction and lower turnover intent. Implications for future research are discussed.

Keywords: Studies, Stress, Call centers, Personality traits, Job satisfaction, Employee turnover

74. Wickham, James and Grainne Collins. The call centre: A nursery for new forms of work organisation? *The Service Industrial Journal*, 24 (1), 2004, 1–18.

Abstract. Within the existing literature, call centre work is defined as a combination of Taylorism, emotional labour and surveillance. Yet call centres also involve new forms of customer relationship. Call centre work is abstracted from any geographical location; it can involve many people separate in time and space and the customer can often monitor it directly. We term

such work ‘virtual’, ‘poly-authored’ and ‘market supervised’. These new forms of work are now spreading beyond conventional call centres, partly because of the new expectations of customers, partly because of the migration of call centre employees into other areas of the enterprise.

Keywords: Studies, Call centres, Customer relations, Organisational structure

75. Ayios, Angela and Lisa Harris. Customer relationships in the e-economy: Mutual friends or just a veneering? *Qualitative Market Research*, 8 (4), 2005, 454–469.

Abstract. This paper investigates whether technological developments can be used in call center environments to build trust and hence lasting customer relationships beyond the usual focus on efficiency gains through automation. It draws upon depth interviews with management and staff in three very different types of call center to critically examine the ways in which caring attitudes and competent behavior of call center staff can contribute to building durable bases for customer trust. While one of the case studies exemplifies a purely economic rationale for call center operations, the other two demonstrate that a truly optimal application of technology creates a shared system of which customers and employees form an integrated part. Employees’ knowledge of the system and the product it underpins are applied in a positive way to create relationships and trust with the customers with whom they transact.

Keywords: Call centers, Customer relations, Loyalty, Competitive advantage, Models, Electronic commerce, Studies

76. Baumgartner, Marc and Ivars Udris. Call center ist nicht gleich call center: Personalselektion und -entwicklung in einer dynamischen branche (auch in der Schweiz), *Arbeit*, 14 (1), 2005, 3–17.

Abstract. Investigations in 14 Swiss call centers identified four types, which differ according to work and communication direction: 1. consulting and complaint-management, 2. information management, 3. ordering management, and 4. customer- and campaign management. This also has effects on the personnel structure, personnel selection and personnel development in the call center. Further research is made on the different work skills that are demanded in those call center types and how the personnel selection and personnel development strategies, like initial training, further training and coaching, differ among those types. Perspectives for the future of call center work are also discussed.

Keywords: Call centers, Studies, Statistical analysis, Organizational behavior, Personnel selection, Skills

77. Bolton, Sharon C. and Maeve Houlihan. The (mis)representation of customer service, *Work, Employment & Society*, 19 (4), 2005, 685–703.

Abstract. The growth of service work has introduced the customer as a third party to the employment relationship. Yet dominant images of customer relations portray docile service workers offering de-personalized care to sometimes aggressive but otherwise not much more agential customers. This paper seeks to bring humanity back into an analysis of customer service, and to reinterpret customer service interaction as a human relationship. Using labour process analysis and data from call-centre workers and their customers, we rerepresent customers as many-faceted,

complex and sophisticated social actors and introduce a new conceptual framework of the roles customers play: as mythical sovereigns, functional transactants and moral agents, thereby offering a more accurate representation of customer service and the role of the actors involved in it.

Keywords: Customer services, Call centers, Customer relations, Studies

78. Castilla, Emilio J. Social networks and employee performance in a call center, *American Journal of Sociology (AJS)*, 110 (5), 2005, 1243–1283.

Abstract. Much research in sociology and labor economics studies proxies for productivity; consequently, little is known about the relationship between personal contacts and worker performance. This study addresses, for the first time, the role of referral contacts on workers performance. Using employees hiring and performance data in a call center, the author examines the performance implications over time of hiring new workers via employee referrals. When assessing whether referrals are more productive than nonreferrals, the author also considers the relationship between employee productivity and turnover. This study finds that referrals are initially more productive than nonreferrals, but longitudinal analyses emphasize posthire social processes among socially connected employees. This article demonstrates that the effect of referral ties continues beyond the hiring process, having long-term effects on employee attachment to the firm and on performance.

Keywords: Call centers, Employees, Productivity, Performance appraisal, Labor economics, References, Recruitment
(Appears also in Section III.)

79. Cordray, Kevin. High retention rates bring customer benefits at SITEL Direct, *Human Resource Management International Digest*, 13 (4), 2005, 23–25.

Abstract. This paper explains SITEL Direct's approach to staff retention and how successful strategies to empower, encourage and promote employees provide business benefits to its clients and their customers. It highlights the main benefits available to agents working in SITEL's bureau and fulfillment programs: varied work, flexible hours, good training and personal development opportunities, and the chance to work in one of England's prettiest towns. The paper emphasizes the importance of having a settled team. It shows that SITEL has established a monthly retention target of 95% for its bureau agents, but in 2004, there was an average monthly retention rate of 97.2% in quarter one, 95.9% in quarter two and 94.3% in quarter three. Fulfillment has achieved even higher retention rates. With a similar target of 95% monthly retention, the program in 2004 achieved an average monthly retention rate of 100% in quarter one, 97.2% in quarter two and 97.8% in quarter three. High staff turnover need not, in all cases, characterize the call-centre industry. The agents working in SITEL's bureau and fulfillment programs are critical to the success of a client's campaign, as they are the first people that consumers interact with either directly or indirectly.

Keywords: Case studies, Human resource management, Employee turnover, Call centers, Customer relations, Telecommunications industry
(Appears also in Section X.)

80. Gwinner, Kevin P., Mary Jo Bitner, Stephen W. Brown and Ajith Kumar. Service customization through employee adaptiveness, *Journal of Service Research (JSR)*, 8 (2), 2005, 131–148.

Abstract. Customization strategies aimed at providing customers with individually-tailored products and services are growing in popularity. In a service context, the responsibility for customization frequently falls on the shoulders of frontline customer contact employees. Few marketing scholars, however, have considered what it means to be adaptive in these roles and how customization behaviors can be encouraged. Drawing on marketing, organizational behavior, and psychology literatures, the authors define and empirically test antecedents of two distinct dimensions of employee adaptive behavior: interpersonal adaptive behavior and service-offering adaptive behavior. Results indicate that an employee's level of customer knowledge, certain personality predispositions, and intrinsic motivation positively influence the propensity to adapt both their interpersonal style and the actual service offering. Implications for market segmentation, employee selection, training, and motivation are offered.

Keywords: Customization, Organizational behavior, Employee attitude, Adaptability, Customer services, Call centers, Motivation, Studies
(Appears also in Section V.)

81. Hyman, Jeff, Dora Scholarios and Chris Baldry. Getting on or getting by?: Employee flexibility and coping strategies for home and work, *Work, Employment & Society*, 19 (4), 2005, 705–725.

Abstract. Recent speculation about the impact on family life of contemporary patterns of work has prompted considerable and concerted social research activity in which the workplace and household have figured prominently. This article extends these studies to examine employment in prototypical new sectors of the economy, namely call centres and software, which at the time of the study were enjoying spectacular growth. Employees in both sectors reported spillover from work to home, though the extent, nature and intensity of spillover varied significantly between the sectors. The study identified the different and hitherto unexplored ways in which employees in these different sectors attempt to cope with complex articulations between home and work, and the varying resources which they bring to bear in doing so. Contemporary work settings indicate little change from more established sectors in that gender, status and labour market strength are important factors in offering work boundary discretion.

Keywords: Call centers, Software industry, Families & family life, Social research, Studies, Work life balance, Work environment

82. Kantsperger, Roland and Werner H. Kunz. Managing overall service quality in customer care centers: Empirical findings of a multi-perspective approach, *International Journal of Service Industry Management*, 16 (2), 2005, 135–151.

Abstract. This paper aims to clarify the interdependencies among three main stakeholder groups and to show how to manage overall service quality in customer care centers. A framework of the relations among the target groups of a customer care center was developed. A survey methodology with a 360 degree approach that encompasses top management, employees and final customers as three main target groups was conducted. The sample incorporates 58 customer care centers and seven industries in Germany and Austria. Besides the management

interviews, 1,580 completed questionnaires by employees, and 2,010 completed questionnaires by customers were received. Multiple regression analysis was applied on multi-item measurement scales of the three different levels. Findings show that employee satisfaction is the main factor for driving customer orientation. Further management efforts resulting in employee orientation will facilitate the job of employees and increase employee loyalty.

Keywords: Studies, Quality of service, Customer satisfaction, Job satisfaction, Call centers, Loyalty, Customer relationship management

83. Rose, Ed and Gillian Wright. Satisfaction and dimensions of control among call centre customer service representatives, *The International Journal of Human Resource Management*, 16 (1), 2005, 136–160.

Abstract. The impact of the call centre workplace upon employee satisfaction or well-being is beginning to attract the attention of researchers. The aim of this paper is to explore the factors related to control and other work-based characteristics that impact upon employee well-being in call centres. Based on a survey ($n = 173$), data are presented to highlight antecedents of employee well-being or job satisfaction in a call centre. Using factor analysis and regression modelling, we have isolated eight factors that are significantly associated with job satisfaction (see Figure 1). Emotional pressure emerges as a significant dimension of control underpinning factors impacting upon job satisfaction. In addition, work-based characteristics including computer-facilitated and supervisory control associated with the role of the customer service representative (CSR) are shown to be direct antecedents of satisfaction. Another element of control, that of targets, emerged as a distinct factor, contributing indirectly to job satisfaction via its influence on work-based job characteristics. Much current research infers relatively low levels of satisfaction with both work and management on the part of customer service representatives (CSRs). The significance of our analysis resides partly in the qualification of the view that CSRs are subjected to, and perceive themselves as being victims at the ‘sharp end’ of, extreme technological control of the ‘electronic panopticon’ variety, itself based on a ‘mass production of services’ model. Moreover, much call centre work is considered relatively low-skilled, and much sociological research indicates that low-skilled work generally is not intrinsically satisfying and, indeed, employees look to extrinsic factors such as pay and job security as compensatory mechanisms. Following on from this, and even more significant for our purposes, is the argument that those call centre workers who generally regard themselves as playing a positive role within the wider organization, are regularly informed and valued by team leaders, and recognize the benefits of certain HRM practices, will have their view of the work situation ameliorated by those compensatory mechanisms. Given the validity of this argument, call centre work in certain circumstances may therefore accord more with the characteristics of ‘mass customization’ models. This is not to deny, however, the undoubted pressures of call centre work, which were commented upon by respondents and which still may represent the ‘unacceptable face’ of call centre culture.

Keywords: Studies, Call centers, Job satisfaction, Impact analysis, Skills, Control, Customer services

V Marketing

1. Grig, Rufus. Outbound calling—discredited or misunderstood? *Journal of Targeting, Measurement and Analysis for Marketing*, 13 (4), August 2005, 295–298.

Abstract. Telemarketing is an industry that has grown up so quickly—and some might say irresponsibly—that it could now be facing an early demise. In order to survive, the industry needs to up its game and behave more responsibly. Most of the problems associated with telemarketing and other cold calls stems from the technology used to make them. This paper reviews the technology in use, places it in some historical context, examines the regulatory environment and finally makes recommendations as to the responsible future use of outbound calling systems. Business to consumer outbound calling is a laborious process to carry out manually. In order to improve agent productivity, three technologies have been developed to automate parts of the process. Achieving an acceptable balance of agent productivity to nuisance call rate is generally left to the call center manager—although the quality of the predictive pacing algorithm obviously plays a key part in the performance.

Keywords: Telemarketing, Call centers, Productivity, Salespeople, Automatic call distribution, Innovations

(Appears also in Section VI.)

2. Gwinner, Kevin P., Mary Jo Bitner, Stephen W. Brown and Ajith Kumar. Service customization through employee adaptiveness, *Journal of Service Research (JSR)*, 8 (2), 2005, 131–148.

Abstract. Customization strategies aimed at providing customers with individually-tailored products and services are growing in popularity. In a service context, the responsibility for customization frequently falls on the shoulders of frontline customer contact employees. Few marketing scholars, however, have considered what it means to be adaptive in these roles and how customization behaviors can be encouraged. Drawing on marketing, organizational behavior, and psychology literatures, the authors define and empirically test antecedents of two distinct dimensions of employee adaptive behavior: interpersonal adaptive behavior and service-offering adaptive behavior. Results indicate that an employee's level of customer knowledge, certain personality predispositions, and intrinsic motivation positively influence the propensity to adapt both their interpersonal style and the actual service offering. Implications for market segmentation, employee selection, training, and motivation are offered.

Keywords: Customization, Organizational behavior, Employee attitude, Adaptability, Customer services, Call centers, Motivation, Studies

(Appears also in Section IV.)

3. Sun, Baohong and Shibo Li. Improving effectiveness of customer service in a cost-efficient way—with an empirical application to the service allocation decisions with out-sourced centers. Working paper, Tepper School of Business, Carnegie Mellon University, 2005. Available at <http://business.tepper.cmu.edu/display_paper.aspx?id=26033>

Abstract. Ever since the 1990s, the function of call centers has been transformed from dealing

with inquiries to being a preferred and prevalent channel for interacting with customers. The operation of call centers and the resulting customer retention have become crucial elements of a firm's customer and revenue growth strategy. However, the management of call centers has always remained the research topic of operation management, which focuses on minimizing operating cost and often ignores the marketing consequences of customer reactions. In this paper, we treat service duration as a measurement of operation efficiency, as well as a determinant of customer retention or marketing effectiveness. We formulate call allocation decisions as a CRM problem in which the firm learns the heterogeneity of customer preference and comparative advantages of centers and makes optimal allocation decisions that best match customers preference. The proposed framework allows the firm to take into account the long-term marketing consequences of cost-saving operating effort. Applying our framework to customer data provided by a telecom services provider that operates off-shore service centers, we analyze the relationship among call allocation, service duration, customer retention and profit as well as that between short-term cost benefit and long-term marketing consequences. Based on the estimation results, we conduct simulations to derive the optimal service allocation strategies of the proposed framework. We demonstrate how the operating decisions are driven by marketing consequences, as well as the dynamic, customized, and state-dependent nature of the derived allocations strategies. We also demonstrate that the proposed solution allows the firm to reduce costs, increase customer retention, and improve profit. We demonstrate that by taking into account long-term marketing consequences, the optimal allocation decisions derived from our framework (1) improve customer retention; (2) reduce service costs; and (3) enhance profit by growing relationships. In other words, the effectiveness can be improved in an efficient way. Our findings shed new light on the understanding of marketing consequences of service allocations. The estimation and simulation results provide descriptive and analytical guidance for call-center managers to adjust their service allocation decision to accommodate customer reactions to operating decisions. The proposed solution is different from conventional ways of increasing customer retention by improving service quality, which incurs cost.

Keywords: Call center, Call allocation, Service outsourcing, Adaptive learning, Service duration, Customer retention, Customer profitability, Customer relationship management, Dynamic intervention, Dynamic structural model

VI Information and Telecommunication Technology, Artificial Intelligence, Multi-agent Systems

1. Hirvela, R.J. The application of computer controlled PCM switching to automatic call distribution. Communications Systems and Technology Conference. IEEE, New York, NY, USA, 1974, 66–74.

Abstract. This paper describes a new computer controlled Automatic Call Distribution (ACD) System which represents the first application of these technologies to call distribution. The ACD switching function is provided by a time division PCM switching matrix which has a capacity of up to 1536 digital voice channels. The call processing is performed by a computer control system which also provides system management information as an integral part of the system.

Keywords: Automatic telephone systems, Communications applications of computers, Pulse code modulation, Switching systems, Telephone-exchanges, Computer-controlled PCM switching, Automatic call distribution

2. Cavanaugh, J.R., R.W. Hatch and J.L. Sullivan. Transmission rating model for use in planning telephone networks, *IEEE*, 1983, 683–688.

Abstract. Customer opinions are an important element in transmission planning for the telephone network. Since the invention of the telephone, considerable effort has been expended in estimating customer assessment of transmission quality. Subjective test results have been used to formulate models. These models, in the form of smooth functions which permit interpolation to allow examination of specific impairment values of interest, have been used to provide transmission performance estimates for guiding evolution of the telephone network.

This paper first considers a previous model which covered the subjective effects of loss, circuit noise and talker echo (reported at NTC76) updated to reflect an IEEE loudness loss method (rather than the loudness loss method for the original model). This is followed by discussion of model extensions to cover listener echo, quantization noise, band width/attenuation distortion, room noise, side-tone and echo control devices. Then the paper outlines several studies in which the expanded model has been extensively used to study transmission quality of telephone connections as a function of the various impairments. The paper concludes with some illustrative examples demonstrating use of the model including comments on possible interpretation of results.

(Appears also in Section III.)

3. Basso, Richard J., Hugh J. Beuscher, Iris, S. Dowden, Richard J. Plereth and Samuel M. Salchenberger. OSPS system architecture, *AT&T Technical Journal*, 1989, 9–24.

Abstract. Operator services position system (OSPS) architecture builds on the 5ESS switch Integrated Services Digital Network (ISDN) base to provide modern, flexible operator services. This article details some major operator system innovations provided by the OSPS system architecture.

4. Basso, Richard J., John C. Lund, Jr. and James H. Tendick. OSPS operator services applications, *AT&T Technical Journal*, 1989, 25–37.

Abstract. Toll and assistance and listing services are two important applications of the operator services position system (OSPS). These applications are built on the distributed architecture of the 5ESS switch and use the building blocks provided by the OSPS software architecture to incorporate new features easily. This article focuses on two toll and assistance features, interflow and more efficient call handling (MECH), as well as the listing services application and a combination of the two applications through the combined services feature to demonstrate the power of the OSPS software architecture.

5. Bornhoft, M., B. Day and P. Curnow. Computer-switch telephony applications. Third IEE Conference on Telecommunications. IEE, London, UK, 1991, 62–66.

Abstract. Describes the integration of computing systems with public and private telecommunication switching networks and the configuration options that affect application performance and need to be carefully considered to ensure successful deployment. Automatic call distribution (ACD) is examined in detail. Joint peer-peer applications in the distributed environment are examined with regard to standards. The benefits of standards in this area are discussed and the progress of standardisation of switch computer interfaces in ECMA (European Computer Manufacturers' Association) with computer supported telecommunications applications (CSTA) is reviewed. The authors draw conclusions on the future of interworking of computing and switching systems as the scope of applications for joint applications expands.

Keywords: Public telecommunication switching networks, ACD, Automatic call distribution, Telephony, Integration, Computing systems, Private telecommunication switching networks, Standardisation, Switch computer interfaces

6. Bose, R. and W.A. Davidson. Automatic call distribution using the ISDN basic rate interface. ICC 91. International Conference on Communications Conference Record. IEEE, New York, NY, USA, 1991, 969–971.

Abstract. An ISDN application that combines Q.931 messages on the basic rate interface (BRI) with features of the 5ESS switch to provide automatic call distribution capabilities for small telemarketing centers is described. A personal computer equipped with a BRI card and custom software acts as an intelligent ISDN terminal. By sharing call appearances with ISDN and analog agent sets connected to subscriber loops on the same switch, the PC provides call distribution features and management information systems reports via intelligent interaction with Centrex features of the 5ESS switch. The architecture allows for enhancements based on calling number information and for integration with other telemarketing computers and voice mail systems.

Keywords: Automatic call distribution, Small telemarketing centers, Personal computer, BRI card, Custom software, Intelligent ISDN terminal, Analog agent sets, Subscriber loops, Management information systems reports, Intelligent interaction, Centrex, Calling number information

7. Hassler, K.W., C.C. Jones, J.E. Kohler and R.D. Nalbone. Revolutionizing DEFINITY(R) call centers in the 1990s, *AT&T Technical Journal*, 1995, 64–73.

Abstract. The award-winning AT&T DEFINITY(R) G3 Expert Agent Selection (EAS) feature has fundamentally changed the way in which call centers provide services for a variety of business applications. The skills-matching concept of EAS simplifies the problem of meeting incoming caller needs with trained call center agents. The Logical Agent part of EAS provides call center agents with an incentive for advancement while also providing newfound flexibility in how they perform their jobs. Both these EAS innovations are patented, with the skills-matching patent winning the 1995 AT&T Patent Recognition Award. This paper describes how EAS improves the efficiency of call centers, and discusses the implementation approach used to realize this important new call center feature.

Keywords: DEFINITY call centers, AT&T, G3 expert agent selection, Business applications, Logical agent, Skills-matching patent, PBX, Automatic call distribution
(Appears also in Section VIII.)

8. Klenke, M. ACDs get skills-based routing, *Business Communications Review*, 25 (7), 1995, 48–51.

Abstract. The goal of automated call distributor (ACD) technology has always been to spread incoming calls among call center agents so that each agent handled an equitable share of the load and the caller had the best chance of being served quickly. Now, a new kind of thinking skills-based routing has entered the call center arena. It takes ACDs one step further and ensures that an incoming call is routed to the available agent whose skills are best matched to the caller's needs. Skills-based routing software works by linking call center agents with predefined skills groups. The author discusses the identification of customer needs, defining agent skills, and setting up a routing scheme which allows callers and agents to come together efficiently.

Keywords: ACD, Skills-based routing, Automated call distributor technology, Incoming calls, Call center agents, Routing software, Skills groups, Customer needs, Agent skills
(Appears also in Section IV.)

9. Anupindi, R. and B.T. Smythe., Call centers and rapid technological change. Teaching note. Operations Management, Managerial Economics and Decision Sciences, J.L. Kellogg Graduate School of Management, Northwestern University, July 1, 1997.

Abstract. Call centers are an increasingly important link in the value chain for many firms. From the earliest call centers of the Bell Telephone Company, the centers have evolved into technically specialized points of contact with the customer. New types of technology now enable firms to decrease costs, improve customer service and improve call center agents' job satisfaction. Although the results have been convincing, these benefits have not come without costs and complications. The three key steps to minimizing these have proven to be choice among technologies, implementation and measurement of success. By utilizing these steps, such firms as the Frost National Bank have excelled in call center management. The future remains uncertain, however, as new technologies continue to emerge and competition becomes ever fiercer. Call centers are nevertheless an aspect of many firms that managers must not overlook as they seek competitive

advantage and enhanced profits.
(Appears also in Section VIII.)

10. Bakshi, Y., A.H. Diaz, K. Meier Hellstern, R.A. Mito and R. Skoog. Overload control in a distributed system. *Teletraffic Contributions for the Information Age. Proceedings of the 15th International Teletraffic Congress, ITC-15.* Elsevier, Amsterdam, The Netherlands, 1997, 571–582.

Abstract. A new algorithm for the joint call distribution and overload control in a distributed environment is proposed and evaluated. The algorithm, which falls into the category of direct adaptive control methods, integrates three mechanisms: (i) adaptive throttling; (ii) adaptive call allocation; (iii) call routing. The throttling mechanism adjusts the arrival rejection rate to meet performance requirements, the call allocation mechanism adaptively determines the fractions of calls to be assigned to different nodes, and the call routing ensures the regularity of the routing sequence that meets the allocated fractions (including the fraction of rejections).

Keywords: Overload control, Distributed system, Joint call distribution, Direct adaptive control methods, Adaptive throttling, Adaptive call allocation, Call routing, Arrival rejection rate, Routing sequence, Distributed overload control

11. Gordon, J.J., K. Murti and A. Rayes. Overview of Internet traffic issues on the PSTN. *Teletraffic Contributions for the Information Age. Proceedings of the 15th International Teletraffic Congress, ITC-15.* Elsevier, Amsterdam, The Netherlands, 1997, 643–652.

Abstract. Recent evidence indicates that Internet traffic is saturating the public switched telephone network (PSTN). Methods must be developed to traffic-engineer and administer the network so that an extensive range of data and voice services can be provided at reasonable cost. Traffic engineering methods must determine the sufficient capacity to meet the anticipated demand while meeting different grade-of-service (GoS) objectives, and ensure that the capacity is not so excessive as to render network services uneconomical. In order to engineer and administer the network effectively traffic engineers must recognize and deal with a variety of new traffic characteristics and be able to evaluate their effects and the factors that affect them. This paper addresses the impacts of Internet traffic on the PSTN. It includes an overview of the behavior of the combined voice and data traffic such as long holding time distribution, call arrival patterns, call retrials, peakedness and traffic variation, and engineering periods.

Keywords: Internet traffic, PSTN, Public switched telephone network, Data services, Voice services, Traffic engineering, Capacity, Grade-of-service, Network services, Holding time distribution, Call arrival patterns, Call retrials, Peakedness, Traffic variation

12. Xia, P. Knowledge discovery in integrated call centers: a framework for effective customer-driven marketing. *Proceedings of the Third International Conference on Knowledge Discovery and Data Mining.* AAAI Press, Menlo Park, CA, USA, 1997, 279–282.

Abstract. As call centers become more pervasive, the customers seek individualized service and greater attention. The call centers are becoming the contact centers-a one-stop, single interface

for all interactions—from pre-sales to post-sales, and continuing relationship. The paper presents some results in utilizing data mining in managing customer profile toward a greater business advantage. One solution is to build a predictive customer profile based on the customer's Lifetime Value (LTV). Many different types of data mining techniques can be combined to meet this challenge. The paper explores the solution to using knowledge discovery methods in integrated inbound/outbound call center environments. Significant performance gain is reported on a customized knowledge acquisition system over a conventional approach.

Keywords: Knowledge discovery, Integrated call centers, Customer-driven marketing, Individualized service, Contact centers, Continuing relationship, Data mining, Customer profile, Business advantage, Predictive customer profile, Lifetime Value, Data mining techniques, Knowledge discovery methods, Integrated inbound/outbound call center environments, Performance gain, Customized knowledge acquisition system

13. Bauer, B. and C. Klein. A multi-agent solution for advanced call centers. Multiple Approaches to Intelligent Systems, Proceedings. *Lecture Notes in Artificial Intelligence*, 1611, 1999, 450–459.

Abstract. In the past few years, call centers have been introduced with great success by many service-oriented enterprises such as banks and insurance companies. It is expected that this growth will continue in the future and that call centers will be improved by adding new functionality and by embedding call centers better into the workflow of a company. In this paper we show how agent technology can help to realize goals. Agent-based approaches are becoming more and more mature for applications distributed over networks, supporting (dynamic) workflow and integrating systems and services of different vendors. We show by a typical example of a call center, the call center of a car rental agency, what the deficiencies of current call centers are and how agents can help to improve this situation.

Keywords: Multi-agent systems, Advanced call centers, Service-oriented enterprises, Banks, Insurance companies, Agent technology, Distributed applications, Workflow, Car rental agency

14. Brazier, F.M.T., C.M. Jonker, F.J. Jungen and J. Treur. Distributed scheduling to support a call center: a cooperative multiagent approach, *Applied Artificial Intelligence*, 13 (1–2), 1999, 65–90.

Abstract. This article describes a multi-agent system architecture to increase the value of 24-hour-a-day call center service. This system supports call centers in making appointments with clients on the basis of knowledge of employees and their schedules. Relevant activities are scheduled for employees in preparation of such appointments. The multi-agent system architecture is based on principled design, using the compositional development method for DESIRE multi-agent systems. To schedule procedures in which more than one employee is involved, each employee is represented by its own personal assistant agent, and a work manager agent coordinates the schedules of the personal assistant agents and clients through the call center. The multi-agent system architecture has been applied to the banking domain, in cooperation with and partially funded by the Rabobank.

Keywords: Distributed scheduling, 24-hour-a-day call center support, Cooperative multi-agent approach, Client appointment-making, Employee knowledge, Employee schedule knowledge,

Principled design, Compositional development method, DESIRE, Personal assistant agent, Work manager agent, Rabobank

15. Duxbury, D., R. Backhouse, M. Head, G. Lloyd and J. Pilkington. Call centres in BT UK customer service, *British Telecommunications Engineering*, 18, 1999, 165–173.

Abstract. Call centres are a growing industry. In a recent Ovum Report it was estimated that by 2000 5% of the working population in Europe would be employed in call centres. It is also predicted that call-centre revenues globally will be \$6 billion. Call centres have become the core of the service economy in the UK. Counting part-timers, UK call centres currently employ 1.7% of the working population, or nearly 400,000 people. And the numbers are growing. Datamonitor predicts that call-centre positions will double by 2002 before beginning to level off. Since 1994, customer calls to large organizations have roughly doubled, with call centres being largely responsible.

BT UK is a leader in call-centre technology and expertise. It operates its own call centres and manages them for other organizations. BT's own call-centre operations fall into the two broad categories of *outbound* and *inbound*. Outbound operations involve companies' staff calling out to customers, usually to offer new services, while inbound call centres handle enquiries from customers. This article looks at how the inbound call centres are presently used in the following environments, which between them are responsible for handling approximately 1 billion calls per year:

- answering Operator Assistance enquiries (100, 155 and 999 emergency services),
- giving accurate number information (192 and 153 services),
- receiving sales and billing enquiries and taking orders (150), and
- taking fault reports from residential and business customers (151 and 154).

It does not consider some of the more specialist centres (for example, Welsh language, Directory Enquiries for the blind and disabled) or inbound services and business after-sales units, although these all form an important part of the BT Customer Service call-centre management operation.

The article explores 'where we are now' and in particular focuses on systems, switching and queueing capabilities. Finally, it looks at the future of call centres and gives some indication of the way things will change.

Keywords: Customer service, Call centres
(Appears also in Section VIII.)

16. Hampe, J.F. Call centre: Technical and organisational challenges. In *Human-Computer Interaction: Communication, Cooperation, and Application Design*, H.J. Bullinger and J. Ziegler (Eds.). Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 1316–1320.
17. Ristimäki, T., T. Leino and P. Huuhtanen. Implementation of information technology in call centers. In *Human-Computer Interaction: Ergonomics and User Interfaces*, H.J. Bullinger and J. Ziegler (Eds.). Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 6–10.

Abstract. In this paper the implementation of information technology is analyzed in two call centres of a bank, which provide a variety of banking services by telephone to customers. It is important to emphasize that call centre work is extremely intensive, using the latest information and telecommunication technologies. In addition, the number of call centres is continuously rising. This study aims to analyze some of the organizational and social factors during the implementation process of a new information system (IS) in call centre work.

(Appears also in Section IV.)

18. Yannakopoulos, D., M. Ferretti and M. Schultz. Object lessons learned from an intelligent agents framework for telephony-based applications. *Proceedings of Technology of Object-Oriented Languages and Systems - TOOLS 30*. IEEE Comput. Soc, Los Alamitos, CA, USA, 1999, 222–236.

Abstract. Contact Center-related activities, at the business level, are common regardless of parent organizations or industries. The implementation of such activities is unlikely to change throughout the lifetime of the Contact Center and therefore, it could be the basis (“framework”) upon which customized solutions can be built. Specifying such a framework is mainly a business rather than a technical problem. Programmers create “what” a system does while business analysts determine “when” the system takes certain actions. Factors influencing the framework architecture are the requirements for small, mobile, intelligent components, the ability for run-time modifications, and a reasonable foreknowledge of the technology that will minimize risks. We present a distributed, object-oriented, telephony framework based on Intelligent Agents and coupled with a rules engine. The goals are reuse, platform independence, support for a distributed environment, system scalability, and adherence to standards. The framework’s core is an influence engine that accepts external stimuli and based on business rules, determines the resulting actions. This engine is an intelligent agent that can be attached to any object for which intelligence is needed and thus, it is able to create an integrated, customizable solution. We discuss our architectural decisions, limitations, design choices, and experiences in development, customization, and operation of the framework. Tools and procedures used during implementation of specific solutions are also reported.

Keywords: Object lessons, Intelligent agent framework, Telephony-based applications, Contact Center-related activities, Parent organizations, Customized solutions, Business analysts, Framework architecture, Small mobile intelligent components, Run-time modifications, Distributed object-oriented telephony framework, Rules engine, Platform independence, Distributed environment, System scalability, Influence engine, External stimuli, Business rules, Integrated customizable solution, Architectural decisions, Design choices

19. Boddy, D. Implementing interorganizational IT systems: lessons from a call centre project, *Journal of Information Technology*, 15 (1), 2000, 29–37.

Abstract. The growing power of computer-telephony integration (CTI) systems is encouraging many companies to create call centres. These deal with a growing range of business processes and, in doing so, can be used to challenge established organizational arrangements. The range of human and management issues that need to be dealt with has yet to become clear. Some insights into these are offered from a study of one call centre over 2 years, from shortly before its physical introduction to the present day. These empirical observations are set within the wider

literature on organizational change and information technology (IT), particularly the processing and integrationist perspectives. The paper uses the evidence of the case to elaborate the integrationist model so that it reflects the areas of human action more fully. It concludes by outlining the implications of this perspective for managers seeking to build effective call centres or other forms of interorganizational IT system.

Keywords: Interorganizational IT systems, Call centre project, Computer telephony integration, CTI systems, Business processes, Organizational arrangements, Management issues, Human issues, Organizational change, Information technology, Integrationist perspective, Human action (Appears also in Section IV.)

20. Bong, Ki Moon, Kyu Lee Jae and Jun Lee Kyoung. A next generation multimedia call center for Internet commerce: IMC, *Journal of Organizational Computing and Electronic Commerce*, 10 (4), 2000, 227–240.

Abstract. Human assistance, as well as automated service, is necessary for providing more convenient services to customers in Internet-based commerce systems. Call centers have typically been human-based service systems. However, the services of existing public switched telephone network-based call centers are not enough to meet the needs of customers on the Internet. Most of them have been designed without considering the interactions involved in shopping on the Internet. In our research, we designed a call center named IMC (Internet-based Multimedia Call-center) that can be integrated with an Internet shopping mall. It contains two parts: an Internet multimedia dialogue system and a human-agent assisting system. The dialogue system is an Internet and multimedia version of the interactive voice response service of computer-telephony integration-based call centers, because it provides access to multimedia Web pages along with a recorded voice explanation via the Internet. The human-agent assisting system aims to select the most appropriate human agents in the call center and to support them in providing high-quality individualized information for each customer. IMC is a real-time, human-embedded system that can provide high-quality services cost-effectively for Internet commerce.

Keywords: Internet commerce, IMC, Human assistance, Automated service, Online shopping interactions, Internet-based Multimedia Call-center, Internet shopping mall, Internet multimedia dialogue system, Human-agent assisting system, Interactive voice response service, Computer-telephony integration, Multimedia Web pages, Recorded voice explanation, Human-agent selection, High-quality individualized customer information, Real-time human-embedded system, High-quality services, Cost-effectiveness, Electronic commerce (Appears also in Section VIII.)

21. Burgess, Michelle. Ensuring call center quality: A case study. In *Data Management Handbook*, Sanjiv Purba (Editor). Boca Raton, FL: Auerbach, 2000, p. 223.
22. Chan, C.W., L.L. Chen and L.Q. Geng. Knowledge engineering for an intelligent case-based system for help desk operations, *Expert Systems with Applications*, 18 (2), 2000, 125–132.

Abstract. Help desks are computer-aided environments in customer support centers that provide frontline support to external and internal customers. The paper reports on an automated

help desk system developed at an information technology company. With the proliferation of diverse software and hardware, the center provides support to a large variety of client systems. The number of calls increases while the turnover rate of employees is high, which means the cost of training escalates. The objective of this project is to develop an automated case-based help desk system to support both call center personnel and customers. The system would contribute to shortening the response time on incoming calls and reduce training time for new employees. The focus of the paper is on the knowledge engineering process of the system. We discuss in detail the knowledge acquisition, knowledge representation, system implementation and verification processes, and we emphasize the structured and automated development methods adopted.

Keywords: Knowledge engineering, Intelligent case-based system, Help desk operations, Computer-aided environments, Customer support centers, Frontline support, External customers, Internal customers, Automated help desk system, Information technology company, Client systems, Employee turnover rate, Automated case-based help desk system, Call center personnel, Response time, Incoming calls, Training time, Knowledge engineering process, Knowledge acquisition, Knowledge representation, System implementation, Verification processes, Automated development methods

23. Cramp, D.G. and E.R. Carson. A model-based framework for public health: a vehicle for maximising the value of telecare? Proceedings 2000 IEEE EMBS International Conference on Information Technology Applications in Biomedicine. ITAB-ITIS 2000. Joint Meeting Third IEEE EMBS International Conference on Information Technology Applications in Biomedicine (ITAB'00). Third Workshop of the International Telemedical Information Society (ITIS'00). IEEE, Piscataway, NJ, USA, 2000, 272–277.

Abstract. Information and communication technologies (ICT) play a pivotal role in enabling health care provision, particularly in the light of changes in delivery mechanisms which emphasise the primary and community sectors and embrace substitution policies that include home care, day care and call centres. However, the complexity of these systems means that it is difficult to determine the best ICT strategies to adopt in terms of efficiency and effectiveness. If public health strategies are to be devised so as to maximise the benefits of advances such as those in telemedicine and telecare, it is necessary to address the issues adopting an approach which is holistic and which encapsulates all causal relationships and influences. Conceptual models for such a systemic approach are developed using signed digraph and cybernetic feedback formalisms. The importance of addressing not only the needs of the population which are of public health concern, but also the factors giving rise to such needs is emphasised. The implications of this modelling approach are illustrated in the context of two telecare systems: home haemodialysis and Web-based services for the management of diabetes.

Keywords: Model-based framework, Public health strategies, Telecare value maximization, Information technology, Communication technology, Health care provision, Health care delivery mechanisms, Primary care, Community health care, Substitution policies, Home care, Day care, Call centres, Efficiency, Effectiveness, Telemedicine, Holistic approach, Causal relationships, Influences, Conceptual models, Systemic approach, Signed digraph, Cybernetic feedback, Population needs, Home haemodialysis, Worldwide Web-based services, Diabetes management (Appears also in Section VIII.)

24. Irish, C. Web-enabled call centre, *BT Technology Journal*, 18 (2), 2000, 65–71.

Abstract. Call centres using computer telephony integration are now the primary channel for customer contact for many organisations. The roll-out of Internet access to an ever-increasing proportion of the population is providing the opportunity to use new channels, such as the World Wide Web, e-mail and others, to enhance the customer relationship. This paper explores the evolution from telephony to Web-enabled call centre and the optimisation of self and assisted service.

25. Mitchell, K., K. Sohraby, A. Van de Liefvoort and J. Place. Approximation models of wireless cellular networks using moment matching. Proceedings IEEE INFOCOM 2000. Conference on Computer Communications. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. IEEE, Piscataway, NJ, USA, 2000, 189–197.

Abstract. In this paper we present an analytical model for microcellular and picocellular wireless networks for any arbitrary topology in a high-mobility environment. We introduce an approximation technique which uses a single-cell decomposition analysis which incorporates moment matching of hand-off processes into the cell. The approximation technique is novel in that it can provide close approximations for non-Poisson arrival traffic and it is easily parallelized. Performance measures such as new calls blocked and hand-off calls lost are presented for any general call arrival distribution in a non-homogeneous traffic environment. We produce some numerical examples for some simple topologies with varying mobility for several call arrival distributions and compare our results to those from simulation studies.

Keywords: Approximation models, Moment matching, Microcellular wireless networks, Picocellular wireless networks, Arbitrary topology, High-mobility environment, Single-cell decomposition analysis, Hand-off processes, Non-Poisson arrival traffic, Performance, Call blocking, Call arrival distribution, Non-homogeneous traffic

26. Schmidt, H.W. and L.M. Wegner. Shared XML documents in service centers of the future. Proceedings of the First International Conference on Web Information Systems Engineering (Workshops). IEEE Comput. Soc, Los Alamitos, CA, USA, 2000, 105–112.

Abstract. Call centers are at the core of today's customer relations management. Increasingly, they are also utilized internally as competence and knowledge centers. Turning them into service centers of the future (SCotF) requires parallel communication over several channels, including Internet services, in a distributed synchronous fashion. In this paper, we show that the emerging XML standards provide a good basis for this type of interaction. In turning e-service into a groupware application, we propose to apply a spatial awareness model to assist in the collaboration. We demonstrate that it can be integrated into the XML/XSL-framework. The results are compared with a previous solution, which applied proprietary tools. Questions of fidelity and a critique of the existing standards and tools complement the practical results.

Keywords: Shared XML documents, Service centers, Call centers, Customer relations management, Internal utilization, Competence centers, Knowledge centers, Parallel communication, Communication channels, Internet services, Distributed synchronous communication, XML standards, Electronic service, Groupware application, Spatial awareness model, Collaboration, XSL, Fidelity, Future

27. Wang, Y., Q. Yang and Z. Zhang. Real-time scheduling for multi-agent call center automation. Recent Advances in AI Planning. 5th European Conference on Planning, ECP'99. Proceedings (*Lecture Notes in Artificial Intelligence*, Vol. 1809). Springer-Verlag, Berlin, Germany, 2000, 187–199.

Abstract. In a call center, service agents with different capabilities are available for solving incoming customer problems at any time. To supply quick response and better problem solution to customers, it is necessary to schedule customer problems to appropriate service agents efficiently. We developed SANet, a service agent network for call center, which integrates multiple service agents including both software agents and human agents, and employs a broker to schedule customer problems to service agents for better solutions according to their changing capabilities and availability. This paper describes the real-time scheduling method in SANet as well as its architecture. There are two phases in our scheduling method. One is problem-type learning. The broker is trained to learn the problem types and hence can decide the type of incoming problems automatically. The other is the scheduling algorithm based on problem types, capabilities and availability of service agents. We highlight an application in which we apply SANet to a call center problem for a cable-TV company. Finally, we support our claims via experimental results and discuss related works.

Keywords: Real-time scheduling, Multi-agent call center automation, Service agents, Customer problem scheduling, SANet, Service agent network, Multiple service agents, Software agents, Human agents, Service agent capabilities, Service agent availability, Cable-TV company

28. Ballin, D. Been there, done that: a personalised mobile agent system for the next generation of call centres. IEE Seminar Mobile Agents—Where Are They Going? IEE, London, UK, 2001, 3/1–11.

Abstract. The call centre industry is currently facing a dichotomy. The growth of call centres is exploding worldwide, with an estimated 5% of all people in the UK expected to be employed in one by year 2005. At the moment, the call centre is still central to the customer contact strategies of most organisations, but the rules are being rewritten with the emergence of the so-called ‘dot-com’ companies who regard the electronic channel as their principal interface with the customer. If that was not problematic enough, customers’ expectations are growing, demanding more choice, flexibility, easy navigation and greater intimacy. In this paper, we present the Virtual Inhabited Call Centre (VICC), a novel Web-based call centre that leverages the power of a mobile multi-agent architecture. VICC is not so much an attempt to develop a technology, but about the potential of using a set of new technologies for the benefit of everyone.

29. Popovic, M. and V. Kovacevic. An approach to Internet-based virtual call center implementation. Proceedings of the First International Conference on Networking. Part I (*Lecture Notes in Computer Science*, Vol. 2093). Springer-Verlag, Berlin, Germany, 2001, 75–84.

Abstract. The era of classical PBX-based call centers has passed. Those systems were proprietary and closed, i.e., with fixed functionality. Today, the Internet and multimedia applications are becoming more and more popular across the world, and there is a lot of effort in both

academia and industry to build and deploy modern Internet-based call centers. This paper should be viewed as a contribution to these efforts. It presents our approach to Internet-based virtual call center implementation. In contrast to other efforts, we consider the virtual call center as a universal infrastructure, which could be used as a telecommunication management network center and as an intelligent network service control point, too. In the paper, we present our concept, the most interesting implementation details and a pilot network configuration.

30. Wortman, V. The future of enterprise CTI, *Business Communications Review*, 31 (2), 2001, 46–49.

Abstract. The future of computer telephony integration (CTI) in the enterprise seems to depend on the following: CTI functionality is required as today’s business increasingly revolves around the contact center; the available technology is strong, with more functionality being added every day; the most significant players are still around, many of them no longer independent, but functioning as entities within powerful parents which are themselves committed to CTI or whatever acronym it takes to support CRM; CTI implementations now in place will probably continue to perform as required for the foreseeable future, augmented by modular add-ons that will bridge the classic PBX/ACD installations and the new world of the WWW.

Keywords: Enterprise CTI, Computer telephony integration, Contact center, Modular add-ons, PBX/ACD installations, WWW

31. Zitouni, I., H.K.J. Kuo and C.H. Lee. Natural language call routing: Towards combination and boosting of classifiers. Proceedings of the 2001 IEEE Workshop on Automatic Speech Recognition and Understanding - ASRU 2001, 202–205.

Abstract. We describe different techniques to improve natural language call routing: boosting, relevance feedback, discriminative training, and constrained minimization. Their common goal is to reweigh the data in order to let the system focus on documents judged hard to classify by a single classifier. These approaches are evaluated with the common vector-based classifier and also with the beta classifier, which had given good results in the similar task of e-mail steering. We explore ways of deriving and combining uncorrelated classifiers in order to improve accuracy. Compared to the cosine and beta baseline classifiers, we report an improvement of 49% and 10%, respectively.

32. Bernett, H.G., M.J. Fischer and D.M.B. Masi. Blended call center performance analysis, *IT-Professional*, 4 (2), 2002, 33–38.

Abstract. The performance analysis of blended PSTN and IP call centers is likely to be in demand in the near future as the technology for these centers develops further. The authors did not find an analysis for a system of this type in the literature. The development of a user-friendly and portable tool based on their analysis methodology should be useful to organizations that have implemented, or are considering implementing, a blended call center. We have shown BCAT’s wide range of skills-based routing to, for example, agents who can handle PSTN calls only, IP calls only, or both call types. This is a much more complicated queueing problem to model, but will provide increased flexibility to call center supervisors in terms of workforce man-

agement planning.

33. Foo, S., S.C. Hui and P.C. Leong. Web-based intelligent helpdesk support environment, *International Journal of Systems Science*, 33 (6), 2002, 389–402.

Abstract. With the advent of Internet technology, it is now feasible to provide effective and efficient helpdesk service over the global Internet to meet customers' requirements and satisfaction. In this research, we have designed and developed a Web-based intelligent helpdesk-support environment, WebHotLine, to support the customer service centre of a large multinational corporation in the electronics industry. The paper describes the basic architecture of the environment that supports the major functions of Web-based fault information retrieval, online multilingual translation capability, different operating modes of video-conferencing for enhanced support and direct intelligent fault diagnosis by customers or customer support engineers. As a result, Web-HotLine helps to save cost in eliminating the expensive overseas telephone charges, reduction in machine down time and number of on-site visits by service engineers as in the traditional helpdesk environment.

34. Fukunaga, A., E. Hamilton, J. Fama, D. Andre, O. Matan and I. Nourbakhsh. Staff scheduling for inbound call centers and customer contact centers, *AI Magazine*, 23 (4), 2002, 30–40.

Abstract. The staff scheduling problem is a critical problem in the call center (or, more generally, customer contact center) industry. This article describes DIRECTOR, a staff scheduling system for contact centers. DIRECTOR is a constraint-based system that uses AI search techniques to generate schedules that satisfy and optimize a wide range of constraints and service-quality metrics. DIRECTOR has successfully been deployed at more than 800 contact centers, with significant measurable benefits, some of which are documented in case studies included in this article.

35. Rossler, G. and T. Steinert. A flexible traffic generator for testing PABX and call center performance. Testing of Communicating Systems XIV—Application to Internet Technologies and Services, IFIP-TC6/WG6.1, I. Schieferdecker, H. Konig and A. Wolisz (Eds.), 2002, 139–147.

Abstract. Testing PABXs and call centers under high load is of paramount importance because customers rely on these systems for safety and business critical applications. A traffic generator for high traffic volumes is presented. The two key characteristics of the traffic generator are the generation of traffic with configurable statistical properties and its flexibility in many aspects, ranging from the number and kind of emulated users to the user behaviour models and signalling protocols. This extraordinary flexibility could only be achieved by a pure software approach. The architecture clearly separates the basic run-time system and support functions which are implemented in the traffic generator core from user models and signalling protocols which the traffic generator reads and executes during tests.

36. Suhm, B., J. Bers, D. McCarthy, B. Freeman, D. Getty, K. Godfrey and P. Peterson. A comparative study of speech in the call center: Natural language call routing vs. touch-tone menus. CHI 2002 - Changing the World, Changing Ourselves, Proceedings of the Conference on Human

Factors in Computing Systems, L. Terveen, D. Wixon, E. Comstock and A. Sasse (Eds.), 2002, 283–290.

Abstract. This paper presents a field study that compares natural language call routing with standard touch-tone menus. Call routing is the task of getting callers to the right place in the call centre, which could be the appropriate live agent or automated service. Natural language call routing lets callers describe the reason for their call in their own words, instead of presenting them with a list of menu options to select from using the telephone touch-tone keypad. The field study was conducted in a call centre of a large telecommunication service provider. Results show that with natural language call routing, more callers respond to the main routing prompt, more callers are routed to a specific destination (instead of defaulting to a general operator who may have to transfer them), and more callers are routed to the correct agent. The survey data show that callers overwhelmingly prefer natural language call routing over standard touch-tone menus. Furthermore, natural language call routing can also deliver significant cost savings to all call centres.

Keywords: Comparison between dialogue modes, Menus, Natural language, Rating and preferences, Voice input devices
(Appears also in Section VII.)

37. Suhm, B. and P. Peterson. A data-driven methodology for evaluating and optimizing call center IVRs, *International Journal of Speech Technology*, 5 (1), 2002, 23–37.

Abstract. The usability of many call-center IVRs (interactive voice response systems) is dismal. Callers dislike touch-tone IVRs and seek human agent assistance at the first opportunity. However, because of high agent costs, call center managers continue to seek automation with IVRs. The challenge for call centers is providing user-friendly, yet cost-efficient, customer service. This article describes a comprehensive methodology for usability reengineering of telephone voice user interfaces based on detailed call center assessment and call-flow redesign. At the core of our methodology is a data-driven IVR assessment, in which we analyze end-to-end recordings of thousands of calls to evaluate IVR cost effectiveness and usability. Because agent time is the major cost driver in call center operations, we quantify cost-effectiveness in terms of the agent time saved by automation in the IVR. We identify usability problems by carefully inspecting user-path diagrams, a visual representation of the sequence of events of thousands of calls as they flow through the IVR. Such an IVR assessment leads directly into call-flow redesign. Assessment insights lead to specific suggestions on how to improve a call-flow design. In addition, the assessment enables us to estimate the cost savings of a new design, thus providing the necessary business justification. We illustrate our IVR usability and reengineering methodology with examples from large commercial call centers, demonstrating how the staged process maximizes the payback for the call center while minimizing risk.

38. Cochinwala, M., N. Jackson, S. Hyong and E. Sigman. Adaptive resource management of a virtual call center using a peer-to-peer approach, *Managing It All, IFIP/IEEE, Eighth International Symposium on Integrated Network Management*, Kluwer Academic Publishers, Norwell, MA, USA, 2003, 425–437.

Abstract. As the number and diversity of end-user environments increase, services should be able to dynamically adapt to available resources in a given environment. We present the concepts of migratory services and peer-to-peer connections as the means of facilitating adaptive service and resource management in distributed and heterogeneous environments. Our approach has been realized using object-oriented principles in an Adaptive Communicating Applications Platform (ACAP). The architectural design and implementation of a real-life high-level service, Virtual Call Center (VCC), are used to illustrate issues in adaptive service and management issues and discuss in detail our approach in ACAP.

Keywords: Adaptive systems, Call centres, Distributed processing, Object-oriented methods, Telecommunication computing, Telecommunication network management

39. Kuo, H.K.J., O. Siohan and J.P. Olive. Advances in natural language call routing, *Bell Labs Technical Journal*, 7 (4), 2003, 155–170.

Abstract. The paper describes Bell Labs’ efforts in developing core technologies toward natural language call routing (NLCR) applications. NLCR refers to technology allowing callers of a call center to be automatically routed to their desired destination based on natural spoken responses to an open-ended prompt, such as “How may I direct your call?”. Such services are expected to replace interactive voice response (IVR) systems in the future, allowing a better experience for the end user and cost savings for the call center. An NLCR system essentially combines several key technologies, mainly automatic speech recognition (ASR) and topic identification. The role of the ASR system is to convert the input utterance into the corresponding sequence of words. The topic identification module then attempts to reproduce human categorization judgments in order to route the caller to the requested destination, given the hypothesized (possibly partially wrong) word sequence from the ASR system. The paper presents our recent advances in natural language ASR and robust topic identification, focusing particularly on its data-driven aspect and its portability. We also report experimental results from our field trials in the banking domain, illustrating the maturity of the technology and its acceptance by end users, making it an enabler of new revenue-generating services.

Keywords: Call centres, Classification, Interactive systems, Natural language interfaces, Speech recognition, Speech-based user interfaces

40. Maass, S. Software support for interaction work in call centers. In *Quality of Work and Products in Enterprises of the Future*, H. Strasser, K. Kluth, H. Rausch and H. Bubb (Eds.), Ergonomia Verlag, Stuttgart, Germany, 2003, 975–978.

Abstract. Call centres deliver a new kind of interactive service, but present software systems are far from adequate in supporting this. Software development seems to be based on a reduced understanding of call centre work and neglects the social component. Detailed work analysis revealed new software requirements. It also showed the need for revised task analysis instruments. (Appears also in Section VII.)

41. Qiang, Yang, Wang Yong, Zhang Zhong. SANet: A service-agent network for all center scheduling, *IEEE Transactions on Systems, Man & Cybernetics, Part A: Systems & Humans*, 33 (3),

2003, 396–406.

Abstract. We consider a network of service-providing agents, where different agents have different capabilities, availability, and cost to solve problems. These characteristics are particularly important in practice for semi-automated call centers which provide quality customer service in real time. We have developed SANet, a service agent network for call center automation, to serve as an experimental test-bed for our research. SANet can select appropriate agents to provide better solutions for customer problems according to the changing capabilities and availability of service agents in the network. It can also add or delete appropriate agents to balance problem-solving quality, efficiency, and cost according to the number and types of incoming customer problems. On this network, each service agent can be a human service agent, an automated software service agent, or a combination of the two. This paper describes the architecture, a problem scheduling algorithm and an agent assignment algorithm on the SANet. We highlight an application in which we apply SANet to a call-center scheduling problem for a cable TV company. Finally, we show the efficiency and adaptability of our system via experimental results and discuss related works.

Keywords: Cable television, Call centres, Multi-agent systems, Problem-solving, Real-time systems

(Appears also in Section I.)

42. Huang, Qiang and S. Cox. Improving phoneme recognition of telephone quality speech, *IEEE International Conference on Acoustics, Speech, and Signal Processing*, 1, 2004, I-445–448.

Abstract. There are some speech understanding applications in which training transcriptions are unavailable, and hence the vocabulary is unknown, but the task is to recognise key words and phrases within an utterance rather than to attempt a complete accurate transcription. An example of such a task is *call-routing*, when transcriptions of training utterances (which are very expensive to produce) are unavailable. In such cases, phoneme rather than word recognition is appropriate. However, phoneme recognition of spontaneous speech spoken by a large multi-accented population over telephone connections is very inaccurate. To improve accuracy, we describe a technique in which we segment the waveform into subword-like units and use clustering and an iteratively refined language model to correct the errors in the recognised phonemes. The method was shown to work well on telephone quality spontaneous speech, raising the phoneme accuracy from 28.1% after the first iteration to 47.3% after three iterations.

43. Williams, J.D. and S.M. Witt. A comparison of dialog strategies for call routing, *International Journal of Speech Technology*, 7 (1), 2004, 9–24.

Abstract. Advances in commercially-available ASR technology have enabled the deployment of “how-may-I-help-you?” interactions to automate call routing. While often preferred to menu-based or directed dialog strategies, there is little quantitative research into the relationship among prompt style, task completion, user preference/satisfaction, and domain. This work applies several dialog strategies to two domains, drawing on both real callers and usability subjects. We find that longer greetings produce higher levels of first-utterance routability. Further, we show that a menu-based dialog strategy produces a uniformly high level of routability at the first

utterance in two domains, whereas an open-dialog approach varies significantly with domain. In a domain where users lack an expectation of task structure, users are most successful with a directed strategy for which preference scores are highest, even though it does not result in the shortest dialogs. Callers rarely provide more than one piece of information in their responses to all types of dialog strategies. Finally, a structured dialog repair prompt is most helpful to callers who were greeted with an open prompt, and least helpful to callers who were greeted with a structure prompt.

44. Grig, Rufus. Outbound calling—discredited or misunderstood? *Journal of Targeting, Measurement and Analysis for Marketing*, 13 (4), August 2005, 295–298.

Abstract. Telemarketing is an industry that has grown up so quickly—and some might say irresponsibly—that it could now be facing an early demise. In order to survive, the industry needs to up its game and behave more responsibly. Most of the problems associated with telemarketing and other cold calls stems from the technology used to make them. This paper reviews the technology in use, places it in some historical context, examines the regulatory environment and finally makes recommendations as to the responsible future use of outbound calling systems. Business to consumer outbound calling is a laborious process to carry out manually. In order to improve agent productivity, three technologies have been developed to automate parts of the process. Achieving an acceptable balance of agent productivity to nuisance call rate is generally left to the call center manager—although the quality of the predictive pacing algorithm obviously plays a key part in the performance.

Keywords: Telemarketing, Call centers, Productivity, Salespeople, Automatic call distribution, Innovations

(Appears also in Section V.)

VII Human Interface, Industrial Engineering

1. Hoekstra, Edward J., Joseph Hurrell, Naomi G. Swanson and Allison Tepper. Ergonomic job task, and psychosocial risk factors for work-related musculoskeletal disorders among teleservice center representatives, *International Journal of Human Computer Interaction*, 8 (4), 1996, 421–431.

Abstract. Evaluated the association between work-related musculoskeletal disorders (WRMDs) and work conditions, perceived exhaustion, job dissatisfaction, and job-stress issues at two tele-service centers (TSCs). One facility had upgraded workstation furniture while the other did not have such ergonomic upgrades. A questionnaire survey among 114 teleservice representatives and an ergonomic evaluation were conducted to determine WRMDs and their risk factors. A high prevalence of symptoms was found at both TSCs. Suboptimal ergonomic conditions were associated with neck, shoulder, elbow, and back WRMDs, as well as with increased job dissatisfaction. Perceived increased workload variability and lack of job control were associated with the occurrence of neck and back WRMDs, respectively. WRMDs were more frequently reported by Ss at the center with older furniture and suboptimal ergonomic conditions. Authors suggest that WRMDs may be prevented by improving ergonomic conditions at workstations and addressing work-organization elements.

(Appears also in Section IV.)

2. Millard, N., L. Hole and S. Crowle. From command to control: Interface design for customer handling systems. In *Human-Computer Interaction INTERACT '97*, S. Howard, J. Hammond and G. Lindgaard (Eds.). Chapman & Hall, London, 1997, 296–300.

Abstract. This paper describes an interface design activity which focuses on the tasks performed by call centre advisors. The advisors' work is supported by a large database, which offers them a command line interface. Contextual observation revealed that more effort was needed to interrogate the database than to communicate with the customers. A subset of advisors' tasks was used to provide scenarios for the design of a 2D/3D graphical user interface, which was prototyped in Macromind Director and evaluated by a user group. Initial feedback indicates that the design metaphor and dialogue style have the potential to radically improve the advisors' interaction with the system.

3. Liddle, R.J. Usability testing of a call center application: The importance and necessity of using scenario-driving scripts. Proceedings of the Silicon Valley Ergonomics Conference and Exposition - ErgoCon '98, Palo Alto, California, 1998, 31–32.

Abstract. The unique methodologies and logistics required for usability testing of a customer-driven call centre are described. In a call centre environment, the tasks of the Customer Service Representatives (CSRs) are driven by outside sources and events. This requires the usability test team to develop scripts for role-playing callers to use when conducting the tests.

4. Baumann, K. Matrix evaluation method for planned usability improvements based on customer feedback. In *Human-Computer Interaction: Ergonomics and User Interfaces*, H.J. Bullinger and

J. Ziegler (Eds.). Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 701–705.

Abstract. The matrix evaluation method described here is based on information about customers' usability problems gathered in a call centre. Call centre data can provide information on 'usual' usability problems having as root cause the insufficient consideration of usability principles during development. Usability principles include self-descriptiveness, consistency, simplicity, compatibility, error tolerance, and feedback. More than this, call centres for telecommunication products can help detecting usability problems that arise during installation and setup of the product, connecting it properly to other devices, and registering for services and accounts.

5. Coffman, S. and M.L. Saxton. Staffing the reference desk in the largely-digital library, *Reference Librarian*, 66, 1999, 141–161.

Abstract. The article examines how a centralized, networked reference service might improve efficiency and reduce costs by addressing two long-standing and seemingly intractable problems associated with the reference process: that librarians spend only a small portion of their time at the reference desk actually answering questions, and that many of the questions they do answer could be handled by paraprofessionals. The authors explore the feasibility of a live, centralized, networked reference service in a library setting by comparing traditional reference services at the County of Los Angeles Public Library with a commercial inbound call center designed to handle the same volume of questions. Applying Erlang C, the standard algorithm used to calculate staffing requirements for commercial call centers, the authors find that a networked reference service based on a call center model could reduce the reference staff requirements at the County of Los Angeles Public Library by 42% or more. These results are very preliminary, and the article cautions against jumping to conclusions until we have much better data on the questions we are answering and the reference process as a whole, but the evidence we do have suggests that networked reference services have the potential to truly revolutionize the way we have been doing reference for the past 100 years.

Keywords: Reference desk staff, Largely digital library, Networked reference service, Intractable problems, Reference process, Librarians, Paraprofessionals, Library setting, Traditional reference services, County of Los Angeles Public Library, Commercial inbound call center, Erlang-C, Standard algorithm, Staffing requirements, Call center model, Reference staff requirements (Appears also in Sections I and IV.)

6. Grundel, C. and M. Schneider-Hufschmidt. A Direct manipulation user interface for the control of communication processes—making call handling manageable. Proceedings of the 17th International Symposium on Human Factors in Telecommunication, Copenhagen, Denmark. L. Elstrom (Editor), 1999, 113–121. Appears also in *Human-Computer Interaction: Communication, Cooperation, and Application Design*, H.J. Bullinger and J. Ziegler (Eds.), Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 8–13.

Abstract. With the advent of a multitude of devices integrating information and communication technology, the support of communication functionality with screen-based devices becomes more and more important. Scalable user interfaces that are applicable on a large variety of these devices, from the PC to small hand-held personal digital assistants, make communication trans-

parent to the users of these devices. Instead of having to learn the basics of telecommunication over and over for each device the users can transfer their knowledge between these devices. The authors developed a user interface for screen-based telephony applications (the Communication Circle) which combines the advantages of direct manipulation with an intuitive metaphor for setting up and controlling synchronous communication processes. In the Communication Circle environment, tasks like call swapping, transfer, or the control of conference calls can be done in an almost self-explanatory manner. This report describes the basic concepts of the approach and the state of the development, and discusses results of usability studies and future developments of the system.

7. Hampe, J.F. Call centre: technical and organisational challenges. *Human-Computer Interaction: Ergonomics and User Interfaces. Proceedings of HCI International '99 (8th International Conference on Human-Computer Interaction)*. Lawrence Erlbaum Associates, Mahwah, NJ, USA, 1999, 1316–1320.

Abstract. Following a period of significant growth in the conventional call centre market in Europe, a new phase in technological development is emerging, bringing with it complex challenges for call centre architects. The call centres are being upgraded to communication centres by integrating additional media channels. First we must mention the standard Internet messaging communication streams, these are mainly standard based email but increasingly all types of web forms or inbound fax files. At the same time the first web enabled call centres are being set up and operating, allowing for voice over IP connections and conferencing. This leads us to the notion of customer coaching, sometimes also referred to, by other authors, as ‘one to one marketing’, although the latter might be regarded as a much more general approach. Effectively this technical set up offers simultaneous phone conversation and joint web browsing between customer and agent. Beside this technical evolution it seems most relevant to study the necessary redesign of the communication centre agent software, especially customer management software etc. Therefore, the primary goal is integration into carefully redesigned workflows and user interfaces, resulting in a transparent, time synchronised customer interaction database, allowing us to improve future customer service. Simultaneously we are observing various difficulties for an adequate personnel recruiting process for communication centre agents as the traditional qualification patterns of call centre agents are no longer sufficient. The much broader palette of tasks to be handled by the new type of agents must also result in a reconsideration of personnel planning schemes and underlying assumptions on the work process.

Keywords: Call centre, Organisational challenges, Technical challenges, Technological development, Communication centres, Internet messaging communication streams, Inbound fax files, Conferencing, Web-browsing, Workflows, User interfaces
(Appears also in Section IV.)

8. Isic, A., C. Dormann, and D. Zapf. Stressors and resources of call centre jobs, *Zeitschrift fur Arbeitswissenschaft*, 53 (3), 1999, 202–208.

Abstract. Call centres are one of the booming branches in the service sector. In this study, the working conditions of 250 call centre employees whose jobs mainly consisted of calling or being called by customers were analyzed. In comparison with two samples of administrative office

workers and bank employees, call centre employees turned out to have very low task-related and time-related job control. In particular, this was the case for inbound jobs (customers were calling only) in comparison to jobs with in- and outbound (employees being called and actively calling customers). Moreover, task- and time-related control were particularly low when the average call time was low. Compared with the other samples, psychosomatic complaints were significantly higher among call centre employees.

9. Menzel, D. New design solution for call centre work places from the point of view of a furniture manufacturer. In *Human-Computer Interaction: Communication, Cooperation, and Application Design*, H.J. Bullinger and J. Ziegler (Eds.). Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 1327–1331.
10. Rothe, H.J., A.M. Metz and M. Degener. Mental load of call center agents. In *Human-Computer Interaction: Communication, Cooperation, and Application Design*, H.J. Bullinger and J. Ziegler (Eds.), Lawrence Erlbaum Associates, Mahwah, New Jersey, 1999, 1321–1326.
11. Settle, R.B., T.W. Dillon and P.L. Alreck. Acceptance of the phone-based interface for automated call direction, *Behaviour & Information Technology*, 18 (2), 1999, 97–107.

Abstract. A survey of 800 adults from the general population was performed to measure public attitudes and reactions toward the phone-based interface for automated call direction (ACD). Attitude, image, calling frequency, behavioural reaction, and demographic data were collected. Results indicate that organizations designing menus for ACD should not anticipate positive reactions from outside callers. Three recommendations can be made from this study: consider the effects on outside callers; minimize the breadth of the menu; and have human operators available.

12. Spiessbach, B., M. Knebelau and S. Bender. Call centre—bearer of hope or strain?. *Ergonomics in Medicine*, 23 (6), 1999, 246–253.

Abstract. Strain and stress are with us in everyday life. Occupational medicine tries to prevent the strain and to minimize stress as much as possible in the primary and secondary sectors of national economy. Strain and stress as well as occupational diseases are well-known and their occurrence can be prevented by appropriate measures. But as the tertiary sector gains importance, more and more employees are working in the information and service sectors and fewer and fewer in production. This change in the structure of employment causes far-reaching consequences for many employees with regard to working hours, organization of work and occupational strain. The classical factors of strain such as noise, heavy labour and hazardous materials have given way to psychological factors of strain such as pressure of time or pressure due to control, competition or responsibility, helplessness with respect to technology, or one-sided forms of communication. This holds true, for example, for a branch which is booming more and more—the call centre. Up to now, the consequences caused by these new workplaces have not been studied sufficiently. Without doubt there is still need for further research, and an inspection of workplaces (analysis of occupational hazards) preferably carried out by an inter-disciplinary team is a matter of urgent necessity. Further, preventive measures such as training and aptitude tests, introduction

to stress and time management connected with relaxation training are to be recommended.

13. Tudor, L. Calling for design, *Ergonomics in Design*, 7 (3), 1999, 16–19.

Abstract. User-centred design reveals preferences for appearance and functionality in call centre operators' equipment.

Keywords: Comparison between input devices, Approaches to equipment testing, Labelling and headings, One-handed keyboards, Ratings and preferences, Tracker ball and mouse, Voice input devices, Voice output and speech synthesis

14. Bagnara, S., F. Gabrielli and P. Marti. Human work in call centres. *Ergonomics for the New Millennium. Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society*, San Diego, California, USA, Vol. 1, 2000, 553–556.

Abstract. Many people are currently working in call centres and many more are expected to work in them in the near future. Call centres are in a sense 'modern factories' where services are delivered through information and communication technologies. This paper describes the technological evolution and discusses some aspects of human and work organisation in call centres. The final part of the paper focuses on a crucial issue commonly faced in call centres: the building up of organisational memories.

(Appears also in Section IV.)

15. Ho, W., E. Marshall and J. Crosbie. The extent of keying, mouse use and writing by customer service officers in one call centre. *Ergonomics for Life: At Work, Home and Leisure. Proceedings of the 36th Annual Conference of the Ergonomics Society of Australia*, Adelaide, South Australia. V. Blewett (ed.), Ergonomics Society of Australia, Downer, ACT, Australia, 2000, 38–39.

Abstract. Stress has been reported as a health issue in call centre operations in Australia and North America. Stressors were attributed to telephone monitoring system and call pressure. Workers' compensation claims in the call centre under study indicate differently. The incidence of workers' compensation claims between 1 July 1997 and 28 February 1999 were 171 per 1000 employees while the regional average was 101. The most frequent injury reported in the same period was sprain and strain while the causal agent was computer equipment. In the call centre under study, staff handle 50–70 calls during an average day. As there was a lack of documented evidence on how much time was spent on keyboarding, mouse use and writing, the aim of this study was to map the nature and duration of upper limb activity of customer service officers in a call centre work environment.

16. Sznclwar, L.I., M. Zilbovicius and R.F.R. Soares. The structure of tasks at 'call centers': Control and learning difficulties. *Ergonomics for the New Millennium. Proceedings of the XIVth Triennial Congress of the International Ergonomics Association and 44th Annual Meeting of the Human Factors and Ergonomics Society*, San Diego, California, USA, Vol. 2, 2000, 547–550.

Abstract. The organizational structures of call centres are based on standardized and rigorously controlled tasks. This paper, based on studies in companies located in Sao Paulo, Brazil, during the 1990s, discusses the difficulties of learning and work-related anxieties present in these types of organization.

(Appears also in Section IV.)

17. Benninghoven, A. Working conditions in call centers: Successful and healthy. WWDU 2002 - World Wide Work. Proceedings of the 6th International Scientific Conference on Work with Display Units, H. Luczak, A.E. Cakir and G. Cakir (Eds.). Ergonomic Institut fur Arbeits- und Sozialforschung, Forschungsgesellschaft mbH, Berlin, 2002, 188–189.

Abstract. Successful and healthy work is determined by many factors, which can be condensed into four main topics: equipment (software ergonomics, hardware ergonomics, office equipment), work environment (acoustics, climate, office design), work organization (working tasks, work-flow, work structure) and employees (resources, qualification, training). The main problems in the field of working environment and equipment are: 1) climate: it is too warm or too cold, the air has an insufficient quality; 2) ergonomics: unhealthy postures often must be adopted while working; 3) acoustics: the noise level is often too high, the audibility is bad; 4) office design: the workspace is often not sufficient; and 5) light: it is too light or too dark, there is too much glare (blinding).

Keywords: Workstation design, General environment, General workplace design and buildings

18. Bushey, R.R., K.M. Joseph and J.M. Martin. Design approach does affect customer behavior: “Action-Objects” increase “Cut-Throughs”, *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, USA, 2002, 578–582.

Abstract. This paper investigates the impact of touch-tone IVR design styles on user behavior. The design of the touch-tone IVR systems is a critical component of delivering customer service. A well-designed system allows the customers to accomplish their goals and sets a positive tone to their interaction with the organization. Four design styles were considered: Action-Specific Object, Action-General Object, Specific Object, and General Object. Three user behaviors were considered: Cut-Through, Full Menu, and Beyond Full Menu. A usability study was conducted to quantify the impact of design styles on user behavior. Results indicate that design style does impact user behavior. The Action-Specific Object style produced the most Cut-Through behaviors and the fewest Beyond Full Menu behaviors compared to the other design styles. The results from this paper suggest that the interface design style should match the customer’s mental model.

Keywords: Call centers

19. Ferreira Jr., Mario and Paulo H.N. Saldiva. Computer-telephone interactive tasks: Predictors of musculoskeletal disorders according to work analysis and workers’ perception, *Applied Ergonomics*, 33 (2), 2002, 147–153.

Abstract. Sixty-two workers engaged in computer-telephone interactive tasks in an active telemarketing center and a telephone call center of an international bank subsidiary in Sao Paulo, Brazil, were assessed by means of a work analysis and a self-administered questionnaire aiming to determine the statistical relationship of ergonomic, organizational and psychosocial characteristics of their jobs with the report of symptoms in neck-shoulder and hand-wrist for more than seven consecutive days and any time from work during the current job due to musculoskeletal disorders (MSD).

Keywords: Ergonomics, Occupational accidents, Perceptions, Telemarketing, Call centers

20. Matthews, G. and S. Falconer. Personality, coping and task-induced stress in customer service personnel, *Proceedings of the Human Factors and Ergonomics Society, 46th Annual Meeting*, Human Factors and Ergonomics Society, Santa Monica, CA, USA, 2002, 963–967.

Abstract. This study investigated predictors of stress responses in customer service personnel working for a major telecommunications company. Ninety-one participants performed a simulation of their work task. They were presented with telephone inquiries, and tested for their knowledge of the correct response. Several findings of a previous study (Matthews and Falconer, 2000) were replicated. Performing the task appeared to be intrinsically stressful, as evidenced by a large magnitude increase in subjective distress. Individual differences in stress state were related to strategy for coping with task demands. The ‘big five’ personality traits were compared with measures of dispositional coping style as predictors of subjective stress state. Coping measures added significantly to the variance in stress state explained by the big five. Emotion-focused strategies such as self-criticism appeared to be especially damaging in the customer service context. Coping measures might be used by organizations to select operators likely to be resistant to task-induced stress.

Keywords: Behavioral sciences computing, Call centres, Human factors, Marketing, Personnel, Psychology

(Appears also in Section IV.)

21. Schweer, R. and A. Genz. Demands on call center agents—Results and solutions. WWDU 2002—World Wide Work. Proceedings of the 6th International Scientific Conference on Work with Display Units, H. Luczak, A.E. Cakir and G. Cakir (Eds.). Ergonomic Institut fur Arbeits- und Sozialforschung, Forschungsgesellschaft mbH, Berlin, 2002, 190–192.

Abstract. Call centres as an organizational form are determined by a high degree of differentiation. This is not only meant in terms of differentiation between in-house call centres, which are created as part of already existing enterprises, and external service providers which have to cope with the free market. Stress and strain for call handlers are strongly dependent on the characteristics of the working tasks that have to be carried out. CCall has investigated the mental workloads in more than 60 call centres with more than 6000 call handlers. It was found that the determinants for healthy work in general were the heavy mental workload and especially the limited task variety. One significant indicator for healthy working conditions is the proportion of call handling in relation to the working time. With examples from practice, the most important types of workload in call centres are presented. Proposals for effective solutions of good practice are given.

Keywords: Work organization and sociotechnical systems, Workload demands

22. Suhm, B., J. Bers, D. McCarthy, B. Freeman, D. Getty, K. Godfrey and P. Peterson. A comparative study of speech in the call center: Natural language call routing vs. touch-tone menus. CHI 2002 - Changing the World, Changing Ourselves, Proceedings of the Conference on Human Factors in Computing Systems, L. Terveen, D. Wixon, E. Comstock and A. Sasse (Eds.), 2002, 283–290.

Abstract. This paper presents a field study that compares natural language call routing with standard touch-tone menus. Call routing is the task of getting callers to the right place in the call centre, which could be the appropriate live agent or automated service. Natural language call routing lets callers describe the reason for their call in their own words, instead of presenting them with a list of menu options to select from using the telephone touch-tone keypad. The field study was conducted in a call centre of a large telecommunication service provider. Results show that with natural language call routing, more callers respond to the main routing prompt, more callers are routed to a specific destination (instead of defaulting to a general operator who may have to transfer them), and more callers are routed to the correct agent. The survey data show that callers overwhelmingly prefer natural language call routing over standard touch-tone menus. Furthermore, natural language call routing can also deliver significant cost savings to all call centres.

Keywords: Comparison between dialogue modes, Menus, Natural language, Rating and preferences, Voice input devices
(Appears also in Section VI.)

23. Das, Amit. Knowledge and productivity in technical support work, *Management Science*, 49 (4), 2003, 416–431.

Abstract. In this paper, we examine the process of technical support work and the role of knowledge in enhancing the productivity of such work. We develop the concepts of problem-solving tasks and moves to describe technical support work, while using call resolution time and problem escalation as measures of productivity. Using hierarchical log-linear modeling, we establish the link between problem-solving moves and productivity. We find that the mix of moves exercised in technical support strongly depends on the formulation of tasks by those requesting support. Because the formulation of tasks is performed by users, knowledge management initiatives must target users as well as support providers to have the desired impact on productivity.

Keywords: Customer satisfaction, Personnel, Sales, Marketing, Competition, Mathematical models, Information management, Problem solving, Cognitive systems

24. Folcher, Viviane. Appropriating artifacts as instruments: When design-for-use meets design-in-use, *Interacting with Computers*, 15 (5), 2003, 647–663.

Abstract. This article discusses the use of artifacts as an instrument-mediated activity based on a field study in a call center specialized in networks and telecommunications. In this work setting, operators have access to a knowledge-sharing database, which is designed to support

the collective elaboration of individual knowledge diffused on hot-lines in an instrument as a means for the collective activity. We characterize this situation along two interrelated analytical dimensions: the design-in-use process by analyzing operators' activities—hot-line assistance and knowledge base appropriation; the design-for-use process by analyzing the design assumptions inscribed in the artifact developed by designers.

Main results showed that the experts' dialogue-conducting strategies are based on the intrinsic complexity of the questions. The problems are co-elaborated in the course of action by the expert and the caller, and constituted as a domain of problems organized by one or more specific problems. This progressive elaboration aims at elucidating the problem situation implicitly contained in the initial request. Two individual instruments were developed within the shared database. Both of them showed transformation of the artifact structure. Moreover, a relation between the organized forms of hot-line assistance activity and the forms and functions of the instruments designed is identified: It may be fully or partially reciprocally congruent. These empirical results are discussed while opposing the 'design-in-use' criteria developed by the operators to the 'design-for-use' criteria built up by the actors of institutional design. In conclusion, we emphasize points to consider in order to support further reflection on relations between use and design in an anthropocentric perspective.

Keywords: Instrumented-mediated activity, Hot-line assistance, Design-for-use, Design-in-use, Instrumental genesis

25. Halford, Victoria and H. Harvey Cohen. Technology use and psychosocial factors in the self-reporting of musculoskeletal disorder symptoms in call center workers, *Journal of Safety Research*, 34 (2), 2003, 167–173.

Abstract. Evidence exists to suggest that working with computer terminals and keyboards is associated with the development and exacerbation of a range of musculoskeletal disorders (MSDs). Research has suggested that psychosocial factors may be of more importance than computer use factors in the development of MSDs in the computing workplace. A questionnaire-based study was undertaken to test this hypothesis in a sample of 67 call center workers. A Spearman's rho was performed on the data, as well as Chi-sup-2 tests on the individual variables. It was found that overall, computer use factors were significantly associated with self-reporting of MSD symptoms, whereas psychosocial factors had no such association. However, certain individual psychosocial factors emerged as having a significant association with MSD symptoms. The findings suggest that specific areas of call center work have associations with poor worker health and possible long-term MSD problems. These areas appear to be workload and particular management-worker relations, rather than computer use. This suggests that the relationship among computer use, psychosocial factors, and MSD is a complex area that would benefit from more research.

26. Maass, S. Software support for interaction work in call centers. In *Quality of Work and Products in Enterprises of the Future*, H. Strasser, K. Kluth, H. Rausch and H. Bubb (Eds.), Ergonomia Verlag, Stuttgart, Germany, 2003, 975–978.

Abstract. Call centres deliver a new kind of interactive service, but present software systems are far from adequate in supporting this. Software development seems to be based on a reduced

understanding of call centre work and neglects the social component. Detailed work analysis revealed new software requirements. It also showed the need for revised task analysis instruments. (Appears also in Section VI.)

27. Pregolato, F. Call center—a participatory office. In *Quality of Work and Products in Enterprises of the Future*, H. Strasser, K. Kluth, H. Rausch and H. Bubb (Eds.). Ergonomia Verlag, Stuttgart, Germany, 2003, 633–636.

Abstract. This study of a call centre layout had the following goals: To act in real time on the environmental quality with regard to effective use of space, performers’ well-being and company evolution, to single out a unitary model for all local offices. On the basis of direct experience of performance, daily full immersion in activities, interviews and naturalistic observations, the model worked out is an ‘interaction’ structure of basic spaces and services, which promotes high relational continuity and compatibility among user needs, activities, organization and ergonomics standards: A participatory office based on a modular structure that gives equilibrium to work environments characterised by high degrees of entropy.

28. Sheeder, Tony and Jennifer Balogh. Say it like you mean it: Priming for structure in caller responses to a spoken dialog system, *International Journal of Speech Technology*, 6 (2), 2003, 103–111.

Abstract. In this paper, we report results of a study undertaken to evaluate the initial prompts of ‘open prompt’ style call-routing applications. Specifically, we examined how placement and phrasing of examples in the initial query affected caller responses and routing success. We looked at the comparative effectiveness of placing examples before and after the initial query and of phrasing these examples such that they promoted either a succinct structure in the form of a keyword or phrase, or a more complex but natural structure in the form of a question or statement. Findings indicate that examples encouraging a more natural structure, when presented prior to the initial query, result in significantly improved routing performance. We discuss this result in the context of using initial prompts to prime for desired structure in caller responses.

Keywords: Call routing, Call Steering, Natural language, Prompting, Dialog strategy
(Appears also in Section III.)

29. Smith, M.J. and A.D. Bayehi. Do ergonomics improvements increase computer workers’ productivity? An intervention study in a call centre, *Ergonomics*, 46 (1–3), 2003, 3–18.

Abstract. This paper examines whether improving physical ergonomics working conditions affects worker productivity in a call centre with computer-intensive work. A field study was conducted at a catalogue retail service organization to explore the impact of ergonomics improvements on worker production. There were three levels of ergonomics interventions, each adding incrementally to the previous one. The first level was ergonomics training for all computer users accompanied by workstation ergonomics analysis leading to specific customized adjustments to better fit each worker (Group C). The second level added specific workstation accessories to improve the worker fit if the ergonomics analysis indicated a need for them (Group B). The third level met Group B requirements plus an improved chair (Group A). The findings showed

that worker performance increased for 50% of the ergonomics improvement participants and decreased for 50%. Overall, there was a 4.8% output increase for the ergonomics improvement group as compared to a 3.46% output decrease for the control group. The level of productivity increase varied by the type of the ergonomics improvement with Group C showing the best improvement (9.43%). Even though the average production improved, caution must be used in interpreting the findings since the ergonomics interventions were not successful for one-half of the participants.

Keywords: Evaluation and cost benefit of change, Education in ergonomics, Output and productivity, Seating, Supplementary equipment, Workstation design

30. Timm, E., T. Arendt and R. Wieland. Optimising communication in call centres. In *Quality of Work and Products in Enterprises of the Future*, H. Strasser, K. Kluth, H. Rausch and H. Bubb (Eds.), Ergonomia Verlag, Stuttgart, Germany, 2003, 1045–1048.

Abstract. Recent research in call centres indicates that call centre workplaces comprise special task and organizational characteristics that are associated with increased workload and strain potential. To reduce strain and stress during work—especially deriving from customer-employee interaction—a professional communication training programme was developed in close cooperation with an in-house call centre. The training concept consists of different modules that are adjusted to workplace characteristics and agents' cognitive and emotional requirements.

31. Parthasarathy, S. Experiments in keypad-aided spelling recognition, *IEEE International Conference on Acoustics, Speech, and Signal Processing*, 1, 2004, I-873–876.

Abstract. Accurate recognition of spellings is necessary in many call-center applications. Recognition of spellings over the telephone is inherently a difficult task and achieving very low error rates, using automatic speech recognition, is difficult. Augmenting speech input with input from the telephone keypad can reduce the error rate significantly. A variety of schemes for combining the keypad and speech input are presented. Experiments on a name entry task show that spellings can be recognized nearly perfectly using combined keypad and speech input, especially when a directory lookup is possible.

VIII Management Models

1. Malone, T.W. Modeling coordination in organizations and markets, *Management Science*, 33 (10), 1987, 1317–1332.

Abstract. This paper describes a simple set of coordination structures that model certain kinds of information processing involved in organizations and markets. Four generic coordination structures are defined: product hierarchies, functional hierarchies, centralized markets, and decentralized markets. Then tradeoffs among these structures are analyzed in terms of production costs, coordination costs, and vulnerability costs. This model is unusual in that it includes detailed definitions of the structures at a micro-level and mathematical derivations of comparisons among them at a macro-level. In the final section of the paper, several connections are made between these formal results and previous work on organizational design.

Keywords: Organizational structure, Organization design, Coordination, Information processing

2. Andrews, Bruce H. and Henry L. Parsons. L.L. Bean chooses a telephone agent scheduling system, *Interfaces*, 19 (6), 1989, 1–9.

Abstract. Concerns the development for mail order company L.L. Bean of a computerized procedure for selecting complex large-scale telephone-operator scheduling systems. To assess capability in forecasting work load, setting requisite capacity levels, and generating satisfactory work-shift schedules, cost/benefit analysis was used and the expected penalty costs of lost orders due to understaffing and loaded-wage costs of overstaffing were considered. Queuing theory was used to model customer-call behavior for every hour over 24-hour days, seven days per week, and the results of linear regression, which correlated customer-service level with expected customer abandonment rate, were implemented to estimate the impact on order revenues of telephone-service level.

Keywords: Work load forecasting, Queueing theory, Telephone agent scheduling system, Mail-order company, L.L. Bean, Computerized procedure, Complex large-scale telephone operator scheduling systems, Capacity levels, Work shift schedules, Cost-benefit analysis, Expected penalty costs, Understaffing, Loaded wage costs, Overstaffing, Linear regression (Appears also in Section I.)

3. Adler, M. and E. Simoudis. Cooperation and coordination in help desk organizations. Proceedings of the 11th International Workshop on DAI, Glen Arbor, MI, 1992.

Abstract. A help desk is an organization that consists of support engineers who provide “over the phone” service support for a company’s products and services. The goal of the support engineers is to cooperate in order to help the calling customer to recover from a failure or to provide assistance by answering a customer’s request. Help desks are organized by the particular product or service they support, or the product’s type. The support engineers for a particular help desk are organized hierarchically, with novice engineers at the low levels of this hierarchy and experts at the highest levels. The inter- and intra-structure of help desks and the interactions between their staffers make them interesting from the Distributed AI (DAI) perspective. In this paper we examine the structure of help desks in detail, describe where and how information

and knowledge flow in such an organization, and show how the staffers of a help desk cooperate to solve a particular problem. We present the current state of help desks, and describe the dimensions and opportunities for cooperation among the staffers of help desks. Our hypothesis is that high degrees of cooperation are possible between the staffers of help desks, and that this cooperation can be facilitated through the use of DAI frameworks.

4. Andrews, Bruce and Henry Parsons. Establishing telephone-agent staffing levels through economic optimization, *Interfaces*, 23 (2), 1993, 14–20.

Abstract. We developed and implemented an economic-optimization model for telephone-agent staffing at L.L. Bean, a large tele-marketer and mail-order catalog house for quality outdoor sporting goods and apparel. The staffing levels we obtained with economic optimization were very different from those used by the company in the past, when staff size was determined by service-level criteria. For L.L. Bean, the resultant savings were estimated to amount to more than \$500,000 per year. In the model, we used queuing theory, devised an expected total-cost objective function, and accounted for retrials and potential caller abandonments through a regression model that related the abandonment rates to the telephone-service factor (percentage of calls answered within a predetermined time interval).

Keywords: Telephone agent staffing levels, Economic optimization, L.L. Bean, Telemarketer, Mail-order catalog house, Outdoor sporting goods, Apparel, Queuing theory, Expected total cost objective function, Retrials, Potential caller abandonments, Regression model
(Appears also in Section I.)

5. Brigandi, Anthony J., Dennis R. Dargon, Michael J. Sheehan and Thomas Spencer III. AT&T's call processing simulator (CAPS) operational design for inbound call centers, *Interfaces*, 24 (1), 1994, 6–28.

Abstract. Since 1978, AT&T has been developing the call processing simulator (CAPS) to design and evaluate inbound call centers. The current version of CAPS is a user-friendly PC-based system employing a discrete event simulation model with animation and queuing models of both the telecommunications network and AT&T's business customer's call center environment. Using CAPS, AT&T can model a network of call centers utilizing advanced 800 network features before its customers make capital investments to start or change their call centers. In 1992, AT&T completed about 2,000 CAPS studies for its business customers, helping it increase, protect, and regain more than \$1 billion in an \$8-billion 800-network market. The CAPS tool is also the turnkey for more than \$750 million in annual profit for AT&T's business customers who received CAPS studies.

Keywords: AT&T, Call processing simulator, CAPS, Inbound call centers, User-friendly PC-based system, Animation, Queuing models, Telecommunications network, Advanced 800 network features
(Appears also in Section IX.)

6. Apte, U.M. and R.O. Mason. Global disaggregation of information-intensive services, *Management Science*, 41 (7), 1995, 1250–1262.

Abstract. Information-intensive services are being globally disaggregated as corporations respond to the pressures of increasing global competition, and take advantage of the opportunities made available by the progress of information technology and the emerging global work force. In order to globally disaggregate services, corporations must decide whether or not to carry out a service activity within the organization, and where to locate it, within or outside the geographic boundary of the home-base country. This paper analyzes the opportunities and challenges of global disaggregation of information-intensive services. Specifically, the paper proposes a taxonomy of disaggregation, and develops a theoretical framework that identifies the criteria and guidelines for successfully selecting service activities to be globally disaggregated.

Keywords: Services, Globalization, Disaggregation, Information intensity, Customer contact, In-sourcing, Outsourcing

7. Burns, John. Developing and implementing a customer contact strategy, *Managing Service Quality*, 5 (4), 1995, 44–48.

Abstract. Describes how telephone-based account management and service can be an excellent way of improving perceived quality, highlighting the effectiveness of a customer contact centre (sometimes called a “call centre”). As a case study, describes how the Rover Group integrated new customer support software with existing sources of information and automated the production of letters and faxes. Management can now rapidly access trend, product and market information to allow timely decision making and utilize this information in product planning and marketing.

Keywords: Customer service, Motor industry, Telecommunications

8. Hassler, K.W., C.C. Jones, J.E. Kohler and R.D. Nalbene. Revolutionizing DEFINITY(R) call centers in the 1990s, *AT&T Technical Journal*, 1995, 64–73.

Abstract. The award-winning AT&T DEFINITY(R) G3 Expert Agent Selection (EAS) feature has fundamentally changed the way in which call centers provide services for a variety of business applications. The skills-matching concept of EAS simplifies the problem of meeting incoming caller needs with trained call center agents. The Logical Agent part of EAS provides call center agents with an incentive for advancement while also providing new-found flexibility in how they perform their jobs. Both these EAS innovations are patented, with the skills-matching patent winning the 1995 AT&T Patent Recognition Award. This paper describes how EAS improves the efficiency of call centers, and discusses the implementation approach used to realize this important new call center feature.

Keywords: DEFINITY call centers, AT&T, G3 expert agent selection, Business applications, Logical agent, Skills-matching patent, PBX, Automatic call distribution
(Appears also in Section VI.)

9. Rathnam, S., V. Mahajan and A.B. Whinston. Facilitating coordination in customer support teams: A framework and its implications for the design of information technology, *Management Science*, 41 (12), 1995, 1900–1921.

Abstract. The management of coordination gaps is critical to the effective functioning of a customer support team. To address the managerial challenge of designing Information Technology (IT) to facilitate coordination in customer support teams, this paper develops a framework describing the drivers of coordination gaps in customer support teams. Measures for the characteristics of problem resolution processes, the characteristics of IT that assist in the management of coordination gaps, and coordination gaps are developed and validated. Results from a field study administered to 399 respondents from 41 teams in Apple, Dell, Hewlett-Packard, IBM, Seton Hospital, and Southwestern Bell support the proposition that coordination gaps arise from a lack of fit between the characteristics of problem resolution processes used and the characteristics of IT used. What is more important, the results also indicate that processes with differing characteristics require different kinds of IT.

Keywords: Customer support, Coordination, Business process analysis, Groupware

10. Serving the American Public: Best practices in telephone service; Federal Consortium Benchmark Study Report: National Performance Review (Al Gore), U.S. Government Printing office, Washington, DC, 1995.

Available at: <http://govinfo.library.unt.edu/npr/library/papers/benchmark/phone.html>

11. Mortlock, Berit. Winning with quality at IBM: Best practice at the National Call Management Centre, *Business Process Management Journal*, 2 (2), 1996, 57–72.

Abstract. Based on a submission for the European Best Practice Benchmarking Award of 1995, in which IBM UK Ltd. won the second prize. Discusses how IBM UK Ltd. has benchmarked aspects of customer service and satisfaction within its National Call Management Centre. Describes how, by focusing on model companies and areas of best practice, many processes and practices were modified in order to boost performance standards and achieve higher levels of customer satisfaction.

Keywords: Benchmarking, Customer care, Kaizan, Quality

12. Nix, Joan and David Gabel. The introduction of automatic switching into the Bell system: Market versus institutional influences, *Journal of Economic Issues*, 30 (3), 1996, 737–753.

Abstract. In neoclassical economics, the postulated behavior of firm profit maximization is a comprehensive idea that subsumes important institutional details concerning management and organization. The intelligent and creative accumulation of experience reflected in the ideas of key personnel is used to explain AT&T behavior toward a major innovation, automatic switching. Automatic switching, a technology that involves using machines to connect customers' telephone lines, was available for sale from electric manufacturers in the late 1890s. By the turn of the century, many of AT&T's competitors has deployed this new technology. However, the large-scale adoption of automatic switching by AT&T did not begin until 1919. It is argued that AT&T's utilization of the technological opportunity of automatic switching cannot be understood without reference to specific ideas that hastened the commitment of management attention to particular courses of action.

Keywords: Telecommunications industry, Technological change, Organizational behavior, Mar-

ket strategy, Economic theory, Case studies, Telephone companies, Telecommunications, History, Automatic call distribution

13. Anupindi, R. and B.T. Smythe. Call centers and rapid technological change. Teaching note. Operations Management, Managerial Economics and Decision Sciences, J.L. Kellogg Graduate School of Management, Northwestern University, July 1, 1997.

Abstract. Call centers are an increasingly important link in the value chain for many firms. From the earliest call centers of the Bell Telephone Company, the centers have evolved into technically specialized points of contact with the customer. New types of technology now enable firms to decrease costs, improve customer service and improve call center agents' job satisfaction. Although the results have been convincing, these benefits have not come without costs and complications. The three key steps to minimizing these have proven to be choice among technologies, implementation and measurement of success. By utilizing these steps, such firms as the Frost National Bank have excelled in call center management. The future remains uncertain, however, as new technologies continue to emerge and competition becomes ever fiercer. Call centers are nevertheless an aspect of many firms that managers must not overlook as they seek competitive advantage and enhanced profits.

(Appears also in Section VI.)

14. Loebbecke, Claudia and Tawfik Jelassi. Concepts and technologies for virtual organizing: The Gerling journey, *European Management Journal*, 15 (2), 1997, 138–146.

Abstract. As one of the largest insurance and reinsurance companies in the world, the Gerling Group has traditionally been an innovator in the strategic use of state-of-the-art information and communication technologies to enhance customer services. A case study illustrates Gerling's efforts to move the insurance company toward a virtual organization and prepare it for the 21st century business environment. The concept of logical call centers is the organizational backbone and technical enabler for building the virtual organization.

Keywords: Case studies, Insurance industry, Information technology, Customer services

15. Twitchell, M.C. Moving from helpless desk to help desk: practical strategies for improving customer service in a multi-function university help desk. Proceedings. ACM SIGUCCS 1997 User Services Conference XXV. Are You Ready? 25th SIGUCCS '97 Conference. ACM, New York, NY, USA, 1997, 303–306.

Abstract. The Information Technology Service's (ITS) Help Desk at North Dakota State University started with few resources, but with a strong desire to support users on campus. Unfortunately, these limitations made it hard for the Help Desk to provide consistent support. The ITS Help Desk has implemented several strategies that have improved its ability to meet customer needs. A problem management process was developed that would focus on people using technology and not just on the technology itself. This change in focus dictated changes in practice, and the new practices resulted in increased customer satisfaction. As customer satisfaction grew, the Help Desk began to fulfill its mission as the single point of contact for users wanting services from ITS. More programs within ITS are relying on the Help Desk for

support. Providing that support is difficult without defining the service that the Help Desk can reasonably provide. Service level agreements are being developed with other ITS work groups to define relationships and responsibilities. Increased satisfaction also leads to an increase in volume of calls and makes it difficult for the Help Desk to balance walk-in, e-mail, and phone support. Implementation of an automatic call distribution system has helped manage phone traffic and improved the working environment for staff. In addition, a virtual help desk project involving several campuses within the North Dakota University System is exploring help desk software as a means of sharing knowledge between campuses.

Keywords: University help desk, Practical strategies, Customer service, Campus, ITS Help Desk, Customer needs, Problem management process, Customer satisfaction, Service level agreements, ITS work groups, E-mail, Phone support, Automatic call distribution system, Phone traffic, Working environment, Virtual help desk project, North Dakota University System, Help desk software

16. Van Dijk, N.M. Why queuing never vanishes, *European Journal of Operational Research*, 99 (2), 1997, 463–476.

Abstract. This tutorial aims to address and illustrate that queuing theory has a wider potential than generally perceived, while at the same time a variety of practical problems, both in daily-life and industry, are open for fundamental research. To this end, it will: (i) Highlight basic queuing insights for daily-life purposes. (ii) Provide exact and bounding results for queuing network applications. (iii) Present a number of practical illustrations (case studies) taken from areas as: Daily-life situations (postal offices and supermarkets); Transportation (railways and air traffic); Administrative logistics (reengineering); Telecommunications (call-centers).

Keywords: Queuing theory, Daily life, Industry, Bounding results, Exact results, Queuing network, Postal offices, Supermarkets, Transportation, Railways, Air traffic, Administrative logistics, Reengineering, Telecommunications, Call centers

17. Bielski, L. Building a bridge to the customer [bank call centres], *ABA Banking Journal*, 90 (12), 1998, 46–48.

Abstract. In the brave new world of bank call centers, what's possible, what's probable, and what progressive banks have in mind for these facilities isn't always the same. What can be done to better match plan and performance? The push to transform the call center into a vehicle for sales is a relatively recent one, but providing retail banking solutions is fast becoming a red hot industry. Although disagreements centering on the hard facts of integration continue, everyone in CTI agrees that the one-to-one marketing model makes all the sense in the world.

Keywords: Bank call centers, Sales, Retail banking, Computer telephony integration, Customer service

18. Tax, Stephen S. and Stephen W. Brown. Recovering and learning from service failure, *Sloan Management Review*, 40 (1), 1998, 75–89.

Abstract. Effective service recovery is vital to maintaining customer and employee satisfaction

and loyalty, which contribute significantly to a company's revenues and profitability. Yet most customers are dissatisfied with the way companies resolve their complaints, and most companies do not take advantage of the learning opportunities afforded by service failures. The authors provide a research-based approach for helping managers develop a comprehensive service recovery system. To encourage dissatisfied customers to complain, leading firms set performance standards, often through the use of guarantees; communicate the importance of recovery to employees; train customers in how to complain; and use technological support offered through customer call centers and the internet. In resolving problems, companies need to focus on providing fair outcomes, procedures, and interactions. Successful companies develop hiring criteria and training programs that take into account employees' service-recovery role, develop guidelines for service recovery, are easily accessible to customers, and use the information in customer databases to solve problems. Firms promote organizational learning by documenting and classifying complaints; useful methods include creating internal complaint forms, accessing complaints made to front-line employees, and categorizing customers who complain. Finally, companies need to generate additional information on service quality, disseminate it to those responsible for implementing improvements, and identify those process improvements that will have the greatest impact on profitability. Customer conflicts are inevitable. A powerful service-recovery strategy can turn these conflicts into opportunities to improve performance and raise profitability.

Keywords: Customer services, Problems, Organizational learning, Customer satisfaction, Guidelines

19. Aldrich, S.E. Framework for customer contact centers, *E-Business Strategies & Solutions*, 1999, 55–60.

Abstract. The call center, with its improbable goal of answering and dispatching in seconds, is no longer the model for customer service, at least not in e-business. Customers have unprecedented power today, and they are more demanding than ever (their own customers give them lessons on what to ask for). The new model demands that you help customers via their chosen medium, at their pace, and on their schedule. The new goal of customer contact centers is to get the customer's issue or question resolved to her satisfaction. Where call center managers once worried about time on hold because of the cost of phone lines, they now worry because time on hold means poor service. Managers, once measured on minutes to finish a call, are now measured on time to resolve a customer issue. These new pressures and measurements dictate a range of technologies and processes in the contact center. This report presents a framework to describe the elements necessary for contact center excellence and analyzes the parameters for choosing technologies.

Keywords: Call center, Customer contact center, E-business

20. Chen, E.T. Reengineering a call center using a performance measurement system. Proceedings of the Fifth Americas Conference on Information Systems (AMCIS 1999). Assoc. Inf. Syst., Atlanta, GA, USA; 1999, 668–670.

Abstract. Enhancing customer loyalty and eventually increasing profitability can be facilitated by the services of a call center, which takes charge of customer service calls and acts as a repository of marketing information. The most expensive and important resource a call center has is

its people. Support of the call center staff is critical to maintaining quality of service. This paper describes the determination of installing a performance measurement system for a call center in a beauty-supply corporation. This PMS is essential to improve organizational productivity as one of several information system priorities. Many practical implications have been derived in this case study.

Keywords: Call centre reengineering, Performance measurement system, Customer loyalty, Profitability, Marketing information, Staff, Quality of service, Beauty supply corporation, Organizational productivity, Information system, Case study, Wholesale distribution
(Appears also in Section IV.)

21. Duxbury, D., R. Backhouse, M. Head, G. Lloyd and J. Pilkington. Call centres in BT UK customer service, *British Telecommunications Engineering*, 18, 1999, 165–173.

Abstract. Call centres are a growing industry. In a recent Ovum Report it was estimated that by 2000 5% of the working population in Europe would be employed in call centres. It is also predicted that call-centre revenues globally will be \$6 billion. Call centres have become the core of the service economy in the UK. Counting part-timers, UK call centres currently employ 1.7% of the working population, or nearly 400,000 people. And the numbers are growing. Datamonitor predicts that call-centre positions will double by 2002 before beginning to level off. Since 1994, customer calls to large organizations have roughly doubled, with call centres being largely responsible.

BT UK is a leader in call-centre technology and expertise. It operates its own call centres and manages them for other organizations. BT's own call-centre operations fall into the two broad categories of *outbound* and *inbound*. Outbound operations involve companies' staff calling out to customers, usually to offer new services, while inbound call centres handle enquiries from customers. This article looks at how the inbound call centres are presently used in the following environments, which between them are responsible for handling approximately 1 billion calls per year:

- answering Operator Assistance enquiries (100, 155 and 999 emergency services),
- giving accurate number information (192 and 153 services),
- receiving sales and billing enquiries and taking orders (150), and
- taking fault reports from residential and business customers (151 and 154).

It does not consider some of the more specialist centres (for example, Welsh language, Directory Enquiries for the blind and disabled) or inbound services and business after-sales units, although these all form an important part of the BT Customer Service call-centre management operation.

The article explores 'where we are now' and in particular focuses on systems, switching and queueing capabilities. Finally, it looks at the future of call centres and gives some indication of the way things will change.

Keywords: Customer service, Call centres
(Appears also in Section VI.)

22. Evenson, Ann, Patrick T. Harker and Frances X. Frei. Effective call center management: Evidence from financial services, Working paper, Wharton School Center for Financial Institutions, University of Pennsylvania, January 1999.

Abstract. Call centers are quickly becoming the major point of contact for serving customers and generating new revenue in a variety of industries. No where is this growth in the importance of call centers more apparent than in the financial services industry. This paper presents the results of a survey of the management of call center operations at major financial service firms. The results clearly indicate the importance of human resource management practices and technology in creating high-performance call center environments.

23. Fischer, M.J., D.A. Garbin, A. Gharakhanian and D.M. Masi. Traffic engineering of distributed call centers: not as straightforward as it may seem. Proceedings of the Applied Telecommunications Symposium (ATS'99). 1999 Advanced Simulation Technologies Conference. SCS, San Diego, CA, USA, 1999, 53–59.

Abstract. As of 1994, AT&T estimated that 350000 businesses employed 6.5 million people in call centers. In 1997, call center revenue was estimated at \$900M, with annual spending on call centers growing at 12 percent each year. Accurate performance analyses are essential in determining staffing levels and trunk requirements in call centers, because poor performance means lost business opportunities. The purpose of this paper is to show that as the complexity of these systems increases, traditional methods, like Erlang B and C table lookup, can result in poor evaluation of the call center performance. We start by examining the simplest of all call centers and show traditional methods can result in poor estimates of system performance and then present a more accurate model for this call center configuration. As the complexity of call centers increases more advance methods are required. This is demonstrated by considering two more complex systems: distributed systems of multiple interdependent call centers and a virtual call center configuration. We also discuss methods to analytically solve each of these systems.

Keywords: Traffic engineering, Distributed call centers, AT&T, Performance analyses, Staffing levels, Trunk requirements, Erlang B model, Erlang C model, Table lookup, Multiple interdependent call centers, Virtual call center configuration
(Appears also in Section IX.)

24. Harris, Foster R. and S. De Reyts. Re-inventing the call centre with predictive and adaptive execution, *British Telecommunications Engineering*, 18 (2), 1999, 180–184.

Abstract. Call centres have evolved from simple single-function centres to offer access, convenience, choice and courtesy to callers. Forecasting and staffing tools support planning, enterprise databases permit the business to craft specific caller treatments, and cross trained agents using desktop applications can respond to a wider range of caller needs and business opportunities on a single call. One key element of the call centre, however has changed only superficially-the question of ‘What should each agent do next?’ The ‘oldest waiting call’ rule has answered that question for the last 20 years. Signs that this methodology is obsolete are seen in call centres where designs become more complex and results more difficult to achieve; where manual intervention moves agents from skill to skill chasing problems; where the most talented agents are

overworked. This paper describes predictive and adaptive techniques that answer the question, ‘What should an agent do next?’. These techniques re-invent the call centre, creating a robust operation where performance is aligned with business intentions, without the manual, corrective intervention common in conventional centres.

Keywords: Call centre, Specific caller treatments, Cross-trained agents, Oldest waiting call rule, Predictive techniques, Adaptive techniques, Customer service

25. Krishnan, M.S., Venkatram Ramaswamy, Mary C. Meyer and Paul Damien. Customer satisfaction for financial services: The role of products, services, and information technology, *Management Science*, 45 (9), 1999, 1194-1209.

Abstract. The drivers of customer satisfaction for financial services are studied. A full Bayesian analysis based on data collected from customers of a leading financial services company is discussed. The approach allows the explicit accommodation of missing data and enables quantitative assessment of the impact of the drivers of satisfaction across the customer population. It is found that satisfaction with product offerings is a primary driver of overall customer satisfaction. The quality of customer service with respect to financial statements and services provided through different channels of delivery, such as information technology enabled call centers and traditional branch offices, are also important in determining overall satisfaction. The analysis indicates, however, that the impact of these service delivery factors may differ substantially across customer segments.

Keywords: Financial services, Information technology, Customer satisfaction, Bayesian analysis, Product offerings, Service quality

26. Pinker, Edieal J. and Robert A. Shumsky. The efficiency-quality tradeoff of cross-trained workers. Working paper, William E. Simon Graduate School of Business, University of Rochester, Rochester, NY, February 1999.

Abstract. Does cross-training workers allow a firm to achieve economies of scale when there is variability in the content of work, or does it create a workforce that performs many tasks with consistent mediocrity? To address this question we integrate a model of a stochastic service system with models for tenure and experience-based service quality. When examined in isolation, the service system model confirms a well-known ‘rule-of-thumb’ from the queueing literature: flexible or cross-trained servers provide more throughput with fewer workers than specialized servers. However, in the integrated model these economies of scale are tempered by a loss in quality. Given multiple tasks, flexible workers may not gain sufficient experience to provide high-quality service to any one customer, and what is gained in efficiency is lost in quality.

Through a series of numerical experiments we find that low utilization in an all-specialist system can also reduce quality, and therefore, the optimal staff mix combines flexible and specialized workers. We also investigate when the performance of the system is sensitive to the staffing configuration choice. For small systems with high learning rates, the optimal staff mix provides significant benefits over either extreme case (a completely specialized or completely flexible workforce). If the system is small and the rate of learning is slow, flexible servers are preferred. For large systems with high learning rates, the model leans towards specialized servers. In a final

set of experiments, the model analyzes the design options for an actual call center.

27. Richardson, R. and J.N. Marshall. Teleservices, call centres and urban and regional development, *The Service Industries Journal*, 19 (1), 1999, 96–116.

Abstract. The character of call centers, which are attracting considerable interest among economic development agencies seeking to attract inward investment is examined. The type of employment provided in call centers, their locational requirements and their wider impact on local economies are examined. It is argued that information and communications technologies are allowing these teleservice firms to develop in new locations, but that call centers remain constrained in their locational choices especially because of the uneven distribution of labor. It is concluded that call centers providing teleservices contribute to local economic development, but the employment created on the whole tends to be of low quality. Few managerial, professional or technical jobs are created in most call centers, and there are few local spin-offs. Inward investment by these sorts of services in less-favored areas displays many of the drawbacks associated with traditional manufacturing inward investment.

Keywords: Call centers, Urban development, Economic development, Studies

28. Stier, Richard D. The medical call center, *Marketing Health Services*, 19 (2), 1999, 25–28.

Abstract. Health care marketing executives value the medical call center as a centralized telephonic front door to their enterprise. Medical call centers will be a core competency for health care organizations in the new millennium and are already a priority for visionary marketing and managed care executives. However, unless they tangibly help achieve the organization's priority outcomes, they will not be successful. The call center leverages marketing strategy to connect with and support the major clinical and operational processes of the enterprise. The call center must not be isolated from central enterprise strategies, clinical pathways redesign, marketing plans, managed care priorities, the organization's plan for quality or consolidated scheduling.

Keywords: Health care industry, Call centers, Systems integration, Marketing management, Strategic planning, Profitability

29. Taylor, Phil and Peter Bain. 'An assembly line in the head': work and employee relations in the call centre, *Industrial Relations Journal*, 30 (2), 1999, 101–117.

Abstract. To date, academic studies of the call center sector remain limited in scope. This article attempts to remedy that omission by analyzing the recent and spectacular growth of call centers in the UK, drawing on a wide variety of sources, including 2 extensive surveys of developments in Scotland during 1997.

Keywords: Call centers, Work environment, Studies

30. Weidong Xu. Long range planning for call centers at FedEx, *The Journal of Business Forecasting Methods & Systems*, 18 (4), Winter 1999/2000, 7–11.

Abstract. FedEx is the world's largest express transportation company, generating \$14 bil-

lion in annual revenue. To support the global transportation network, FedEx has established 51 worldwide customer service call centers. The customer service at FedEx in the US handles about 500,000 calls per day. There are three major networks: 1. Domestic, 2. International, and 3. Freight. For each network, the company has developed four different types of forecasts based on different forecasting horizons: 1. Strategic Plan, 2. Business Plan, 3. Tactical Forecast, and 4. Operational Forecast. Different methodologies are adopted for different levels of forecasts. An overview of these methodologies is presented.

Keywords: Postal & delivery services, Forecasting techniques, Customer services, Case studies (Appears also in Section I and II.)

31. Alouisa, J., W. Anderson, R. Castro, R. Ennis, J. Gevarter and R. Pandolfo. PruServTM: A call center support system, in *Creating Value in Financial Services: Strategies, Operations, and Technologies*, Edward L. Melnick, Praveen R. Nayyar, Michael L. Pinedo, Sridhar Seshadri (Eds.). Boston: Kluwer Academic Publishers, 2000, Chapter 19: 389–401.

Abstract. We discuss Prudential’s solution to complex call center problems. Since Prudential is a service-oriented business, its success and competitive advantage lies in its ability to give customers the highest quality of service possible, “wherever and whenever” they want it. Managers at Prudential determined that without the proper tools to do the job, service quality would be diminished. PruServTM, a powerful call center application, effectively solved the business problem by providing users with a robust and exciting application that resulted in “world-class” customer service. This translated to the firm capturing an increased percentage of clients’ assets and generating incremental revenues.

Acknowledgement: The abstract was taken from the introduction of the book.

32. Anton, J. The past, present and future of customer access centers, *International Journal of Service Industry Management*, 11 (2), 2000, 120–130.

Abstract. Customers want better access to the companies from which they buy products and services. Reviews how companies have responded to this demand for easy access. Looks at the past, present and future information needs of the customer and how they have been met. Touches on the developments in the communication channels available to customers and provides some simple usage statistics. Forecasts the future technological developments which will once again change the kind of access and information available.

Keywords: Customer requirements, Call centres, Customer satisfaction, Marketing communications, Communications technology

33. Bennington, Lynne, James Cummane and Paul Conn. Customer satisfaction and call centers: an Australian study, *International Journal of Service Industry Management*, 11 (2), 2000, 162–173.

Abstract. Call centers are growing at unprecedented rates, yet relatively little is known about customer satisfaction with this method of service delivery. Therefore, a review of the advantages and disadvantages of call centers is provided before reporting on a study carried out with users of a very large human services call center network. The results indicate that customers have

slightly higher satisfaction levels with in-person services than with call center services. Although it was predicted that older customers might be more dissatisfied with call centers than younger customers, this was not borne out by the data. Attributes of a best-in-the-world call center operation are provided to guide those who design and manage call center services.

Keywords: Call Centres, Customer satisfaction, Australia
(Appears also in Section IV.)

34. Bennett, H.G. E-commerce and the Web-enabled call center. Proceedings of the Applied Telecommunication Symposium (ATS'00). SCS, San Diego, CA, USA, 2000, 3–8.

Abstract. The Internet's explosive growth has provided corporations with a new delivery channel for both electronic commerce and customer service. Electronic commerce (E-commerce) transactions are expected to grow from \$1 billion in 1997 to an estimated \$1.3 trillion by 2003. Businesses have created Web sites as “click-and-mortar” storefronts where WWW visitors can browse through the store and purchase products using a virtual shopping cart. The owners of these electronic stores are discovering that having the ability to provide personal help to their cyber shoppers is as important as it is in traditional “brick-and-mortar” stores. In a study done by Yankelovich Partners, 63 percent of respondents said that they will not buy over the Internet until there is more human interaction. To address this concern, corporations are linking their Web sites to call centers where large pools of trained agents are available to assist, in real time, Web shoppers that need help. This article provides an overview of how this new E-commerce technology of Web-enabled call centers is being implemented.

Keywords: E-commerce, Web-enabled call center, Internet, Electronic commerce, Customer service, Web sites, WWW

35. Betts, Alan, Maureen Meadows and Paul Walley. Call centre capacity management, *International Journal of Service Industry Management*, 11 (2), 2000, 185–196.

Abstract. Call centres often experience large fluctuations in demand over relatively short periods of time. However, most centres also need to maintain short response times to the demand. This places great emphasis upon capacity management practices within call centre operations. A total of 12 UK-based call centres from one retail bank were studied to investigate how they managed forecasting, capacity management and scheduling tasks. Provides evidence of the difficulties associated with capacity management in call centres. Regression modelling is used to link forecasting and capacity planning practices to performance. Shows that random variation is a very important factor when assessing call centre performance. The results suggest that call centre managers can have only a small influence upon short-term performance. Existing mathematical models, such as the Erlang queuing system methodologies, have only limited value as the assumptions concerning demand patterns made in their derivation contradict observations made within the 12 sites. Spiked demand patterns present special capacity management problems, including a direct trade-off between high service levels and operator boredom. Conventional methods of flexing capacity cannot respond sufficiently well to some of the short-term fluctuations in demand.

Keywords: Capacity management, Service operations, Banking, Call centres

(Appears also in Section II.)

36. Bong, Ki Moon, Kyu Lee Jae and Jun Lee Kyoung. A next generation multimedia call center for Internet commerce: IMC, *Journal of Organizational Computing and Electronic Commerce*, 10 (4), 2000, 227–240.

Abstract. Human assistance, as well as automated service, is necessary for providing more convenient services to customers in Internet-based commerce systems. Call centers have typically been human-based service systems. However, the services of existing public switched telephone network-based call centers are not enough to meet the needs of customers on the Internet. Most of them have been designed without considering the interactions involved in shopping on the Internet. In our research, we designed a call center named IMC (Internet-based Multimedia Call-center) that can be integrated with an Internet shopping mall. It contains two parts: an Internet multimedia dialogue system and a human-agent assisting system. The dialogue system is an Internet and multimedia version of the interactive voice response service of computer-telephony integration-based call centers, because it provides access to multimedia Web pages along with a recorded voice explanation via the Internet. The human-agent assisting system aims to select the most appropriate human agents in the call center and to support them in providing high-quality individualized information for each customer. IMC is a real-time, human-embedded system that can provide high-quality services cost-effectively for Internet commerce.

Keywords: Internet commerce, IMC, Human assistance, Automated service, Online shopping interactions, Internet-based Multimedia Call-center, Internet shopping mall, Internet multimedia dialogue system, Human-agent assisting system, Interactive voice response service, Computer-telephony integration, Multimedia Web pages, Recorded voice explanation, Human-agent selection, High-quality individualized customer information, Real-time human-embedded system, High-quality services, Cost-effectiveness, Electronic commerce
(Appears also in Section VI.)

37. Bristow, G., M. Munday and P. Gripaos. Call centre growth and location: corporate strategy and the spatial division of labour, *Environment and Planning A*, 32 (3), 2000, 519–538.

Abstract. The authors contribute to the developing literature on call centres by providing detailed empirical evidence on the spatial unevenness in the distribution of call centre activity. They argue that the driving forces of call centre growth, whether as the rationalisation of back-office functions or as entirely new entities, have been corporate strategy and the pursuit of low-cost competitive advantage. Thus, although technological developments at the heart of call centre operations render them relatively ‘footloose’ in locational terms, the search for specific characteristics makes certain regions (and parts of regions) more attractive than others. By using a sample database of call centres, the authors describe the characteristics of call centres in the United Kingdom in terms of size, sector, and spatial distribution. They then attempt to explain the determinants of call centre location at the county level through a multiple regression analysis. The results indicate that there is a propensity to site call centres close to existing concentrations of allied activity, with preferences for densely populated areas mediated by needs to maintain employee access and avoid staff turnover problems. This has important implications for the spatial division of labour, with call centre growth likely to reinforce existing

spatial unevenness in employment in key service activities. The authors conclude by considering the implications of these findings for contemporary urban and regional development, as well as providing a number of suggestions for future research.

Keywords: Information and Internet services, Computer software, Other production and pricing analysis (spatial analysis)

38. Chang, Zeph Yun and Loi Hui Huang. Quality deployment for the management of customer calls, *Managing Service Quality*, 10 (2), 2000, 98–103.

Abstract. Customer calls confer accessibility for promoting sales opportunities. It is the key element of a company's customer service system. Presents a methodology for quality management of customer communication through telephone, e-mail and Web support for both internal and external customers. The concept of a customer call centre is introduced and quality dimensions of customer call services are established with call status coded and problem severity issues being addressed.

Keywords: Customer service, Problem solving, Systems design, Quality

39. Cramp, D.G. and E.R. Carson. A model-based framework for public health: a vehicle for maximising the value of telecare? Proceedings 2000 IEEE EMBS International Conference on Information Technology Applications in Biomedicine. ITAB-ITIS 2000. Joint Meeting Third IEEE EMBS International Conference on Information Technology Applications in Biomedicine (ITAB'00). Third Workshop of the International Telemedical Information Society (ITIS'00). IEEE, Piscataway, NJ, USA, 2000, 272–277.

Abstract. Information and communication technologies (ICT) play a pivotal role in enabling health care provision, particularly in the light of changes in delivery mechanisms which emphasise the primary and community sectors and embrace substitution policies that include home care, day care and call centres. However, the complexity of these systems means that it is difficult to determine the best ICT strategies to adopt in terms of efficiency and effectiveness. If public health strategies are to be devised so as to maximise the benefits of advances such as those in telemedicine and telecare, it is necessary to address the issues adopting an approach which is holistic and which encapsulates all causal relationships and influences. Conceptual models for such a systemic approach are developed using signed digraph and cybernetic feedback formalisms. The importance of addressing not only the needs of the population which are of public health concern, but also the factors giving rise to such needs is emphasised. The implications of this modelling approach are illustrated in the context of two telecare systems: home haemodialysis and Web-based services for the management of diabetes.

Keywords: Model-based framework, Public health strategies, Telecare value maximization, Information technology, Communication technology, Health care provision, Health care delivery mechanisms, Primary care, Community health care, Substitution policies, Home care, Day care, Call centres, Efficiency, Effectiveness, Telemedicine, Holistic approach, Causal relationships, Influences, Conceptual models, Systemic approach, Signed digraph, Cybernetic feedback, Population needs, Home haemodialysis, Worldwide Web-based services, Diabetes management (Appears also in Section VI.)

40. Feinberg, Richard A., Ik-Suk Kim, Leigh Hokama, Ko de Ruyter and Cherie Keen. Operational determinants of caller satisfaction in the call center, *International Journal of Service Industry Management*, 11 (2), 2000, 131–141.

Abstract. There has been, and will be, a spectacular growth in the number of call centers on both sides of the Atlantic. So far, however, empirical evidence is lacking as to the operational determinants of caller satisfaction in call centers, despite the multitude of call performance metrics registered in many call centers. Undertakes an empirical assessment of the relationship between caller satisfaction and a number of critical variables. The results are astonishing. Of all the critical operational determinants only “percentage of calls closed on first contact” and “average abandonment” have a significant, albeit weak, influence on caller satisfaction. Concludes, therefore, with a call for more research into reliable and valid predictors of caller satisfaction.

Keywords: Performance measures, Customer service, Customer satisfaction, Call centres (Appears also in Section IV.)

41. Gibson, Mary Margaret. Linking Web sales to call centers, *The Journal of Business Strategy*, 21 (1), 2000, 28–33.

Abstract. In 1996, when business to business e-commerce was relatively new, Richard L. Moore, vice president of Lucent Direct, was handed a strategic challenge to solve. How could Lucent serve its customers exceptionally well, at lower sales cost? Moore had a few corporate piece parts that, theoretically, could be remodeled to solve the problem. Lucent Direct was primarily a “telebusiness”. The business was focused on phone sales, composed of an inside-sales call center, located in Cincinnati, that managed telephone customer relationships and sold telephone items the customer found in a series of large paper catalogues that Lucent published twice a year. Moore’s team was organized to take the business apart and to examine every piece, understanding what customers wanted and determining how to reassemble the pieces. The goal was to build a customer-focused, sales-channel business that could grow at a rapid pace, while using both the organizations already in place and new ones crafted for the future. This would be a fairly extensive remodel.

Keywords: Organizational change, Corporate profiles, Consumer relations, Quality of service, Telecommunications industry, Strategic planning, Call centers, Electronic commerce, Sales

42. Gilmore, Audrey and Lesley Moreland. Call centres: How can service quality be managed? *Irish Marketing Review*, 13 (1), 2000, 3–11.

Abstract. The call center industry is growing rapidly in both size and complexity. Since its early development it has been perceived to suffer from many service delivery and management problems. In particular the inherent need to answer a high number of calls in these centers has led to the use of a simplistic ‘counting’ of calls management approach to service management. Recently there is more recognition of the need to improve the service interaction from both the customers’ and the service agents’ perspective. For many companies this has become a difficult management problem. How call centers can approach the management and assessment of call

centers in terms of dealing with a large number and variety of calls, managing the service quality of these calls, and how management can overcome the high staff turnover rate, is investigated.

Keywords: Call centers, Customer services, Automatic call distribution, Employee turnover, Studies, Managerial skills, Quality of service

43. Houlihan, Maeve. Eyes wide shut? Querying the depth of call centre learning, *Journal of European Industrial Training*, 24, 2000, 228–240.

Abstract. Call centres are high-pressure work environments characterised by routinization, scripting, computer-based monitoring and intensive performance targets. This promises a series of business advantages, but also risks counterproductive outcomes. Drawing on evidence from ethnographic field data, it is suggested that both desired and risked outcomes are mediated by personal modes of coping and organizational sustaining mechanisms. A central concern is to explore the underlying assumptions of call centre design and management, and to establish whether or to what extent information systems have been constructed as learning sites or behavioural control sites. When behavioural control is a primary goal, this introduces a climate of resistance, further inflated by the culture of measurement and enforcement that is likely to ensue. In this environment, agent, manager and organization become defensive and the main outcome is a destructive crisis of trust that creates important and difficult implications for the capacity to learn.

Keywords: Learning, Control, Measurement, Corporate culture
(Appears also in Section IV.)

44. Larson, Richard C. and E.J. Pinke. Staffing challenges in financial services, in *Creating Value in Financial Services: Strategies, Operations, and Technologies*, Edward L. Melnick, Praveen R. Nayyar, Michael L. Pinedo, Sridhar Seshadri (Eds.). Boston: Kluwer Academic Publishers, 2000, Chapter 17, 327–356.

Abstract. Financial services institutions are providing a rapidly expanding variety of products and services; technology is making customers more mobile, and delay is unacceptable in financial transactions. These attributes of the financial services sector mean that firms must provide effective, efficient and reliable service or quickly lose customers to competitors. To avoid huge labor costs, financial services firms must develop innovative approaches to managing their workforces and their service delivery process. We outline and provide examples of effective techniques for managing part-time and flexible personnel in back room operations, bank teller scheduling and management, improving customer queueing experiences, and the design and operation of call centers to take into account cross-training, learning and cross selling.

Acknowledgement: The abstract was taken from the introduction of the book.
(Appears also in Section I.)

45. Manione, R. and P. Renditore. Management issues for multi-subscriber Web call center services, *CSELT Technical-Reports*, 28 (2), 2000, 257–271.

Abstract. Web call centers are among the most promising services belonging to the integrated

Internet telephony scenario. The basic version of a Web call center (WCC) service allows us to publish call center-enabled Web sites, i.e., sites which enable their visitors to speak to live agents while still browsing the Internet. In particular, the users can browse those pages sent by the chosen agent, as the conversation goes on (co-browsing). The WCC service presented here is multi-subscriber, in the sense that it is hosted within a service center run by a service provider; different instances of the service run on the same servers and share the same computation and communication resources in a controlled way. With respect to the commercial policies, this approach allows us to supply the service “by-the-agent-line”, all-inclusive, at a monthly fee, with minimal provisioning time. The present paper, after analyzing the typical business model and architecture of services belonging to the integrated Internet telephony scenario, introduces an innovative approach to their management. Such an approach is discussed in detail within the scope of the Web call center service, where the presented concepts have been validated within the implementation and the field trial of the WebCentric/sup R/ system. After one year of field trial, WebCentric/sup R/ has been recently deployed to the field, as the engine behind the C@LLWEB service, the present offer of Web call center service from Telecom Italia.

Keywords: Management issues, Web call center, Multi-subscriber services, Integrated Internet telephony, Agent, Co-browsing, Service architecture, Business model, WebCentric system, Field trial, C@LLWEB service, Telecom Italia

46. Melscoet, L. Alcatel CCweb: marriage of the Internet with the call center, *Alcatel Telecommunications Review*, 1, 2000, 43–48.

Abstract. The Internet has brought new communication channels between the enterprise and its customers, but the challenge is not just to offer new media in parallel with the existing telephony, but to be able to combine these media into a multimedia, feature-rich interaction. In the case of a traditional voice call center, this means adding Internet self-served and automated transactions before reaching a call center agent: this is known as “Web enabling the call center”. On the other hand, for an existing Web site, “call center enabling the Web” brings the human touch necessary to carry out most E-commerce transactions successfully. In bringing the new communication channels into the CCdistribution, the Alcatel CCweb turns the call center into a true contact center, thus becoming the necessary link between all available contact points and the internal resources and applications of the enterprise.

Keywords: Alcatel CCweb, Internet telephony, Call center, Enterprise communication, Web site, E-commerce, CCdistribution, Contact center

47. Palson, C. and D. Seidlitz. Customer satisfaction at a software support call center, *Quality Progress*, 33 (6), 2000, 71–75.

Abstract. In this articles, we describe how we boosted customer satisfaction statistics at a software support call center by 43% in one month in an industry where the monthly norm is a low single digit percentage.(1) This was accomplished by using a methodology developed by Gary Klein to discover how experts in high pressure emergency occupations make instant decisions.(2) Although incidents of help line support do not ordinarily qualify as emergencies, Klein’s methodology nevertheless proved effective. Our experts, like experts in other fields, were usually unable to completely explain their reasons for success in making good instant decisions.

Keywords: Marketing & Sales, Customer satisfaction, Prepackaged software, Computers & software

48. Swerdlow, R.B. Placing value on customer satisfaction for call centers. Proceedings of the Applied Telecommunication Symposium (ATS'00). SCS, San Diego, CA, USA, 2000, 194–198.

Abstract. Call centers are groups of people with associated facilities who answer and make telephone calls in a methodical, organized manner. It is a popular and economically important form of conducting business. Most work in improving these centers focuses on cost, but customer satisfaction with a call center can strongly affect business results. For this reason, a contract for call center services should include performance as well as cost. This paper proposes a modification to the fixed price incentive (FPI) contract format that includes customer satisfaction as a part of the incentive in addition to cost. The key idea in relating subjective measures of performance to cost is to estimate the reduction in staffing a contractor might achieve at the expense of these subjective measures of performance. The paper also discusses a way to find reasonable bounds on performance that does not appeal to industry wide benchmarks. This contracting technique is currently in alpha test on a large help desk.

Keywords: Customer satisfaction, Call centers, Business, Fixed price incentive, FPI contract format, Cost, Subjective performance, Staffing reduction, Help desk

49. Dilevko, J. An ideological analysis of digital reference service models, *Library Trends*, 50 (2), 2001, 218–244.

Abstract. Using the theories of Pierre Boudieu about occupational fields of struggle and species of capital, this article examines the ideological implications of the digital reference call-center model. This model has the potential to lead to deprofessionalization of reference work because of increased automation and the replication of employment conditions prevailing in private sector call centers. Call-center work typically involves unskilled women earning low wages in jobs that present little opportunity for career building. Library directors who advocate digital reference call centers as models of the future have neglected the negative aspects of call centers in their rush to cut costs and provide efficient services. One answer to the deskilling dilemma is the simple act of reading: the more a librarian reads, the more he or she becomes an irreplaceable contributor in the reference transaction.

(Appears also in Section IV.)

50. Friedman, Tsily. Call center management: Balancing the numbers, *Industrial Management*, 43 (1), 2001, 6–10.

Abstract. Consumer behavior has driven companies to allocate large budgets to the fast growing needs of call centers. Call center management has become more active than reactive, which requires specific skills and expertise. Through the years, Tefen Ltd's R&D department has developed models and methodologies for effective and efficient call center management. These models and tools are based on the company's experience with a wide variety of call and contact centers in different industries. This article focuses on the importance of the customer contact center to the entire enterprise and presents a methodology for call center performance management and

ongoing improvement.

Keywords: Call centers, Performance management, Models

51. Gander, P. Changing places [call centres], *Marketing Business*, 95, 2001, 32–34.

Abstract. Call centres are by their very nature beset by a series of conflicts. They are one of the most labour intensive marketing operations, and yet clients expect to pay a minimum for the service. They are supposed to be about supporting brands is through positive person-to-person conflict and yet, even when the actual telecoms engineering is up to scratch, the nature of the work and conditions mean that, staff morale is frequently low and turnover high. Now another poser has been added to the list. How do you gear up for the Internet age when recruitment, training and technology are all directed towards the telephone-based voice transaction? Clearly, common sense would suggest that the industry has had time enough to prepare for the e-mail world. And in fact there are good examples of dedicated or integrated centres already up and running. But where the importance of e-mail communication is played down by managers, or the organisational challenge puzzled over for too long, it may be the client impatience rather than calm, internal appraisal which ends up being the catalyst for change.

52. Gilmore, Audrey. Call centre management: Is service quality a priority? *Managing Service Quality*, 11 (3), 2001, 153–159.

Abstract. In recent years the call centre industry has grown rapidly in size and popularity. In so doing, the industry has been perceived to suffer from some of the problems associated with industrial mass production. The nature of the requirement to answer a high number of calls in these centres had led to the use of a traditional “production-line” management approach. Recently, as a result of both customers’ and employees’ expectations rising in relation to service delivery, the trend is for call centre operations to become more focused on staff empowerment, moving away from the traditional production-line approach. For many companies, this has become a difficult management problem. This paper reports on one such company. Following a number of years’ reliance on carrying out surveys of customer perceptions, and a history of subsequent lack of service improvement, this research used an in-depth case study approach incorporating observation studies, interviews with different levels of managers, and focus-group discussions with front-line service delivery staff (agents). The findings identified the service quality issues to be addressed in order to reconcile customers’ and agents’ needs, and the implications for managers.

Keywords: Service quality, United Kingdom, Production, Empowerment
(Appears also in Section IV.)

53. Hiroshi, Enoki, Kitamura Yasuhiko, Tatsumi Shoji and Kitamura Shozo. Job allocation mechanism to support a call center: Multiagent approach based on market economic model. Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, Tucson, AZ, USA, 2, 2001, 1119–1124.

Abstract. This paper proposes a fair allocation method of the job in a call center adapting the multiagent system with self-interested agents on the basis of the theory of fair allocation to

the market economy for realizing fairness to the job of the agent who works in a call center. This method leads to a problem solving of the burnout, and it is one of the subjects in a call center. Fair allocation is one of desirable allocation from viewpoint of individual rationality and social welfare, because it is considered as an allocation, which fills envy-free and Pareto efficiency.

54. Holman, David, Olga Epitropaki and Sue Fernie. Understanding learning strategies in the workplace: A factor analytic investigation, *Journal of Occupational and Organizational Psychology*, 74 (5), 2001, 675–681.

Abstract. The aim of this study was to validate a scale of learning strategies, as derived from the educational literature, in an organizational context. Participants were 628 call center employees. Both exploratory and confirmatory factor analyses suggested that a six-factor structure most accurately represented the learning strategies examined. Specifically, three cognitive (extrinsic work reflection, intrinsic work reflection, reproduction) and three behavioral strategies (interpersonal help seeking, help seeking from written material, practical application) were found.

Keywords: Organizational behavior, Call centers, Learning, Occupational psychology, Statistical analysis

55. Houlihan, Maeve. Managing to manage? Stories from the call centre floor, *Journal of European Industrial Training*, 25, 2001, 208–220.

Abstract. Call centres are centralized operations where trained agents communicate with customers via phone and using purpose-built information and communication technologies. The normative model of call centre organization is that tasks are tightly prescribed, routinized, scripted and monitored. What are the implications for managers and management? Drawing on ethnographic fieldwork, this article focuses on middle management in call centres: how they work, how they talk about their work and what alternatives they see. It describes an emerging understanding of a manager who is as constrained as a worker under this mass customized bureaucracy. Lack of strategic support and development, a powerfully normative focus on micro-management and deeply embedded goal conflicts combine to undermine these managers' scope to truly manage. Like the agents they supervise, call centre managers are engaged in a coping project. In this context, they perform their identity with ambivalence: sometimes role embracing, sometimes resisting.

Keywords: Telemarketing, Customer service management
(Appears also in Section IV.)

56. Lutz, P. Michel, Call centres in Germany: Employment market and qualification requirements, *Economic and Industrial Democracy*, 22 (1), 2001, 143–153.

Abstract. In spite of a considerable number of existing studies on the call center market, there has been up to now no reliable information about the number of call centers or about the number of employees in these centers. The hierarchy in call centers tends to be rather flat. Shift work is typical in call centers. The average age of a call center employee is around 40, but in large call centers they are considerably younger. In Germany there is relatively little fluctuation in

employment levels. Most of the call centers train their own staff. Most firms concentrate on practice-oriented further training within the company and not a basic post-school education.

Keywords: Call centers, Job requirements, Business conditions, Studies

57. Norling, Per. Call centre companies and new patterns of organization, *Economic and Industrial Democracy*, 22 (1), 2001, 155–168.

Abstract. With a starting point chiefly in the recent theory development concerning service businesses and virtual businesses, some new patterns in call center theory are shown and new concepts are developed. Starting at the micro level, the trinity, human-computer-network is described as the new building block of the organization. The pyramid—the form of organization where strata of executives direct permanent divisions consisting of specialists fulfilling specific purposes, is fading away. As a replacement, organizations built from projects, projects run by teams, which are constantly changing in structure according to customer demands or internal problems. A third change is that companies to a constantly growing extent act as if the world were room-free. Work and projects are organized to function on a different common digital arena.

Keywords: Studies, Call centers, Organization theory

58. Richardson, Randal and Vicki Belt. Saved by the bell? Call centres and economic development in less favoured regions, *Economic and Industrial Democracy*, 22 (1), 2001, 67–98.

Abstract. This article considers the role of call centers in the economic development of less favored regions (LFR). It suggests that call centers represent a new form of mobile service work which these regions are increasingly seeking to attract. It considers the factors which are important in attracting this work. It then explores the policies adopted by two LFRs which have been reasonably successful in doing so. It suggests that there are a number of benefits from the attraction of call centers, particularly employment opportunities not otherwise available in such regions. It also strikes a note of caution, however, questioning, in particular whether these jobs will last.

Keywords: Call centers, Economic development, Regions, Rural areas, Studies

59. Taylor, P. and P. Bain. Trade unions, workers' rights and the frontier of control in UK call centres, *Economic and Industrial Democracy*, 22 (1), 2001, 39–66.

Abstract. In developing a model of call centre diversity, spanning the dimensions of quantity and quality, the article develops a critique of aspects of Frenkel et al.'s recent study of 'front line' work. Drawing upon employee survey and interview data from six UK financial sector call centres, patterns of resistance and the contrasting responses of trade unions to the experience of intensive working conditions are examined. It is argued, in conclusion, that the newly established managerial 'frontiers of control' require to be combated by new union bargaining agendas which seek to address employees' concerns at the point of production.

Keywords: Labor unions, Call centers, Control, Workers, Financial services, Studies

60. Thompson, Paul and George Callaghan. Edwards revisited: Technical control and call centres, *Economic and Industrial Democracy*, 22 (1), 2001, 13–37.

Abstract. Call centers represent a new strategy by capital to rescue unit labor costs. This article argues that management has developed a new form of structural control. Theoretically this draws heavily on Edwards' concept of technical control, but not only is this shown to be extended and modified, it is also combined with bureaucratic control which influences the social structure of the workplace. Contrary to Edwards, such systems are not distinct; rather, they are blended together in the process of institutionalizing control. Part of the rationale for this is to camouflage control, to contain conflict by making control a product of the system rather than involving direct confrontation between management and workers. Despite such attempts, the struggle for transforming labor power into profitable labor remains, and the article ends by exploring confrontation between workers and managers and worker agency more generally.

Keywords: Call centers, Control, Work environment, Studies
(Appears also in Section IV.)

61. Tsoukas, Haridimos and Efi Vladimirov. What is organizational knowledge? *The Journal of Management Studies*, 38 (7), 2001, 973–993.

Abstract. Organizational knowledge is much talked about but little understood. This paper conceptualizes organizational knowledge and explores its implications for knowledge management. The paper claims that knowledge is the individual capability to draw distinctions, within a domain of action, based on an appreciation of context or theory, or both. Following the theoretical exploration of organizational knowledge, this paper reports the findings of a case study carried out at a call center in Panafon, Greece.

Keywords: Studies, Impact analysis, Call centers, Knowledge management, Organizational learning

62. Adria, Marco and Shamsud D. Chowdhury. Making room for the call center, *Information Systems Management*, 19 (1), 2002, 71–80.

Abstract. A call center can dramatically improve an organization's ability to serve its customers. Skills for employees in call centers can and should be upgraded. The article suggests ways of ensuring that the ideal configuration of decentralized decision making and centralized control takes hold in the organization after the call center is established. Practical advice is offered for enhancing an organization's culture even as employees begin to spend less time in face-to-face interactions.

Keywords: Studies, Call centers, Customer services, Corporate culture
(Appears also in Section IV.)

63. Bain, P., A. Watson, G. Mulvey, P. Taylor and G. Gall. Taylorism, targets and the pursuit of quantity and quality by call centre management, *New Technology, Work and Employment*, 17 (3), 2002, 170–185.

Abstract. The paper locates the rise of the call centre within the context of the development of Taylorist methods and technological change in office work in general. Managerial utilization of targets to impose and measure employees' quantitative and qualitative performance is analyzed in four case-study organizations. The paper concludes that call centre work reflects a paradigmatic re-configuration of customer servicing operations, and that the continuing application of Taylorist methods appears likely.

Keywords: Organizational design, Management, Opinions, Payment systems

64. Belt, Vicki. A female ghetto? Women's careers in call centres, *Human Resource Management Journal*, 12 (4), 2002, 51–66.

Abstract. Although several studies have shown that women make up the majority of the call centre workforce, their role and position in this new and expanding industry has not yet been examined. This article makes a contribution to the research gap by exploring the extent and nature of the career opportunities open to women within call centres. Current portrayals of call centre work appear to indicate that these new workplaces offer very little in the way of either job satisfaction or potential for career progression. Indeed, on the basis of existing research evidence, it could be concluded that call centres represent little more than female job 'ghettos'. The article assesses this claim by drawing on women's own accounts of their work experiences and their perceptions of their prospects.

Keywords: Studies, Call centres, Female employees, Opportunity, Career advancement

65. Bristow, G., P. Gripas, S. Keast and M. Munday. Call centre growth and the distribution of financial services activity in the UK, *The Service Industries Journal*, 22 (3), 2002, 117–134.

Abstract. This article examines the growth and distribution of telephone call centers in the UK financial services sector. These are concentrated in the conurbations of Scotland and the north-west and in the south-east region, including Greater London. There is consideration of the extent to which the development of such centers is changing the spatial division of labor in financial services. The article also models the determinants of the spatial distribution of call center activity. Though the results must be treated with some caution, it appears that labor supply, an original concentration of financial services employment, female earnings and the socio-economic composition of the labor force may be important determinants of the distribution of call center activity.

Keywords: Financial services, Call centers, Labor market, Effects

66. Deery, Stephen and Nicholas Kinnie. Call centres and beyond: A thematic evaluation, *Human Resource Management*, 12 (4), 2002, 3–13.

Abstract. This introduction aims to place the articles in this special edition in the context of the wider literature on call centers. The discussion is arranged around 4 themes: the characteristics and organizational features of call center work, the choices and strategies that are available to manage the work, the effects of this type of work on employees and, finally, the responses and reactions of call center staff to their work experiences. The articles selected, which are drawn

from a conference sponsored by this journal, are then summarized.

Keywords: Call centers, Human resource management

67. Douthitt, Elizabeth A. Effects of leader behaviors on service employee role perceptions, fairness perceptions, and performance, *Dissertation - Abstracts - International Section A: Humanities and Social Sciences*, 62 (11-A), 2002.

Abstract. Leaders play an important role in communicating role expectations, and in supporting and facilitating effective performance. Their behaviors may be critical to their ability to effectively facilitate high-level performance. Leaders face particular challenges in service environments such as call centers, where employee job effectiveness is influenced by the quality of interactions with customers. Call centers commonly use monitoring practices, and yet the effects of these practices are not understood. Monitoring along with other leader behaviors may convey information to employees about role expectations. The clarity, effectiveness, and perceived fairness of these role messages may depend in part on the combination of behaviors leaders elect to use. This study applied role theory and justice theory to predict interactive effects of leader monitoring and other behaviors on employee role perceptions and fairness perceptions. Monitoring and three other behaviors were predicted to interactively influence role ambiguity, role accuracy and fairness perceptions. These perceptions in turn were predicted to influence performance and turnover intentions. A web-based survey was conducted in a customer service call center. The survey inquired about leader behaviors, employee perceptions, turnover intent and performance. Results supported some of the predictions. Leader monitoring and recognition interacted in their relationship with role ambiguity. A joint relationship between monitoring $\times$ empowerment and perceived fairness was mediated by role ambiguity. Role ambiguity was negatively related to fairness perceptions. Perceived fairness was positively related to performance and negatively related to turnover intent. No relationships were revealed involving role accuracy. Results of the study indicate that effects of monitoring are conditional upon other leader behaviors, specifically those that empower employees and recognize their performance. The two interactive combinations of leader behaviors had different effects on employee role ambiguity and on perceptions of leader fairness. Results of the study also contributed to a deeper understanding of fairness perceptions and the importance of adequate role-related information. Employees who reported experiencing greater role clarity (less role ambiguity) indicated greater perceptions of leader fairness. The results demonstrate the utility of role theory and organizational justice theory for developing predictions and gaining insights into effective leadership behaviors in customer service environments.

Keywords: Role perceptions, Fairness, Job performance, Leader behaviors

68. Eveleth, Daniel M. and Linda Morris. Adaptive selling in a call center environment: A qualitative investigation, *Journal of Interactive Marketing*, 16 (1), 2002, 25.

Abstract. Technological changes and innovations have created the means by which organizations can centralize the selling function into a call-center environment. While there are numerous benefits to this centralization, the fact that potential customers are drawn to a call center via telephone or Web-based communication media from a wide geographic area heightens the need for sales representatives to preform adaptive-selling behaviors. This study found evidence to

confirm this belief, suggesting that a premium is placed on sales representatives who can accurately assess each situation using limited information and then to correctly adapt their behavior to fit the situation. The results also offer implications for Web-based call centers that link sales representatives with potential customers through text-based communication.

Keywords: Salespeople, Call centers, Studies, Adaptability, Technological change, Market research

69. Foss, Bryan, Iain Henderson, Peter Johnson, Don Murray and Merlin Stone. Managing the quality and completeness of customer data, *The Journal of Database Marketing*, 10 (2), 2002, 139–158.

Abstract. Although companies have been collecting customer-related data for years, this was normally for administration rather than customer management. While larger companies have more recently collected customer data for database marketing—to recruit new customers, sell more to existing customers, support customer service operations, and retain customers—returns are usually limited because most data are still held and used departmentally. The growth of contact centers, e-commerce, and more complex value chains has raised additional issues of enterprise data management and exploitation, while demonstrating beyond doubt that available data are insufficient to support new customer management processes. The article considers these issues and proposed tried and tested approaches for addressing these customer data management issues in a practical and achievable manner.

Keywords: Database marketing, Marketing management, Data integrity, Customer relationship management

(Appears also in Section II.)

70. Grimshaw, D., F.L. Cooke, I. Grugulis and S. Vincent. New technology and changing organisational forms: Implications for managerial control and skills, *New Technology, Work and Employment*, 17 (3), 2002, 186–203.

Abstract. Changes in organisational forms are central to the way new technologies impact on the future of work and employment. Drawing on case-study evidence of a call centre and its client relations and a multinational IT firm and its partnership with a government department, this paper explores the implications for skill and managerial control.

Keywords: New technology, Organisational form change, Employment, Case study evidence, Call centre, Information technology, Client relations, Multinational IT firm, Government, Managerial control

71. Holman, David. Employee wellbeing in call centres, *Human Resource Management Journal*, 12 (4), 2002, 35–50.

Abstract. Call centres are often perceived to have a negative impact on employee wellbeing, mainly attributed to four factors: job design, performance monitoring, HR practices and team leader support. This article reports on a survey of 557 customer service representatives that examined the relationship of these factors to four measures of wellbeing: anxiety, depression

and intrinsic and extrinsic job satisfaction. One distinctive feature of this article is its focus on anxiety and depression, two major dimensions of wellbeing not addressed in call centre research to date. Results demonstrated that the factors most highly associated with wellbeing were high control over work methods and procedures, a low level of monitoring and a supportive team leader. Evidence also indicates that the level of wellbeing in some call centres is similar to that in other comparable forms of work.

Keywords: Studies, Call centers, Organizational behavior, Job satisfaction, Psychological aspects

72. Houlihan, Maeve. Tensions and variations in call centre management strategies, *Human Resource Management Journal*, 12 (4), 2002, 67–85.

Abstract. Management strategies in call centres face a series of tensions stemming from conflicts between achieving efficiency and providing a quality service to the customer. Recent research suggests high commitment management (HCM) techniques are being applied in call centres in a paradoxical strategy of ‘low discretion, high commitment’ (LDHC). This article presents case findings on four British call centres that confirm the LDHC model but suggest that it operates in a variety of forms. By characterizing the research sites according to the combined dimensions of HCM orientation and job design implementation, a typology of LDHC approaches is proposed. These are containment, alleviation, structured employee development and involvement. In essence, the LDHC model is an attempt to reconcile the costs of control with the levers of commitment. However, an examination of the realities of LDHC in action reveals a varied but persistent pull towards control. Fundamentally, this exposes LDHC as a substitute for, rather than a reflection of, commitment.

Keywords: Studies, Call centres, Management styles, Efficiency, Quality of service, Models

73. Nagin, Daniel S., James B. Rebitzer, Seth Sanders and Lowell J. Taylor. Monitoring, motivation, and management: The determinants of opportunistic behavior in a field experiment, *The American Economic Review*, 92 (4), 2002, 850–873.

Abstract. Economic models of incentives in employment relationships are based on a specific theory of motivation: Employees are rational cheaters, who anticipate the consequences of their actions and shirk when the marginal benefits exceed the costs. The rational cheater model is investigated by observing how experimentally induced variation in monitoring of telephone call center employees influences opportunism. A significant fraction of employees behave as the rational cheater model predicts. A substantial proportion of employees, however, do not respond to manipulations in the monitoring rate. This heterogeneity is related to variation in employee assessments of their general treatment by the employer.

Keywords: Economic theory, Economic models, Studies, Incentives, Employees, Call centers, Behavior, Motivation, Experiments

74. Raestrup, B. Call Center Agent Network—a strategy against ‘Cubicalization’: A virtual community for call-center workers in the information industry. WWDU 2002—World Wide Work. Proceedings of the 6th International Scientific Conference on Work with Display Units, H. Luczak, A.E. Cakir and G. Cakir (Eds.). Ergonomic Institut fur Arbeits- und Sozialforschung,

Forschungsgesellschaft mbH, Berlin, 2002, 256–258.

Abstract. The call centre industry creates jobs with similar working conditions and a similar workload all over the world. The jobs of the call centre agents are highly dependent on technological, economic, and strategic international developments. In contrast to this situation, call centre research and call centre policies in most countries are conducted only at the national level. Yet there is a need to transfer information, knowledge, and strategy in an international context. Congresses on call centre agents' working conditions are held without the participation of the agents. Call centre agents sell their voice and their mind at work: It is not their voice on line—it is the voice of the company they are working for. As a result of these facts, the Call Centre Agent Network was started in October 2001 as an international communication and information platform. The Network is a no-budget project, so the author was forced to run the Web site very economically. The virtual conference is an experiment in sharing information about working conditions in all centres worldwide and starting an international networking project for call centre workers.

Keywords: Information systems and communication

75. Richardson, H. and K. Richardson. Customer relationship management systems (CRM) and information ethics in call centres—'You are the weakest link. Goodbye!', *Australian Journal of Information Systems*, 9 (2), 2002, 166–171.

Abstract. This paper catalogues the rise of call centres in the North West of England, UK and their use of CRM systems. CRM systems often imply new technologies and new ways of working. However, in this account, we explore the historical development of the telegraph and work in early telephone exchanges and find the same old story. Our consideration of the ethics of CRM system use and some inherent contradictions are in terms of privacy, communication richness, management methods and computer ethics in an organizational context. Call centres today are viewed by some as offering satisfying employment of intrinsic value; for others, they are the 'new sweatshops of the 21st century' (Belt et al., 2000). Our interpretative field study makes a contribution to this debate.

(Appears also in Section IV.)

76. Taylor, P., J. Hyman, G. Mulvey and P. Bain. Work organization, control and the experience of work in call centres, *Work Employment and Society*, 16 (1), 2002, 133–150.

Abstract. Despite the integration of telephone and VDU technologies, call centres are not uniform in terms of work organization. It is suggested that diversity can best be understood by reference to a range of quantitative and qualitative characteristics. Consequently, perspectives that treat all call centres as if they were the same hybrids of customization and routinization are rejected, along with over-optimistic interpretations of labour control over work organization. Empirical evidence from nine 'workflows' in two call centres—an established financial sector, organization and a rapidly growing outsourced operation—provide excellent grounds for an examination of similarity and difference. A picture emerges of workflows which are volume-driven and routinized, involving low levels of employee discretion, and by contrast, those less dominated by quantitative criteria offering higher levels of operator discretion and an emphasis on

the quality of customer service. Despite these distinctions, larger numbers of operators report an experience of work which is driven by quantitative imperatives, most manifest in the pervasive implementation of targets. Targets are also used increasingly to assess and mould the quality of the call centre operator's interaction with the customer. Overall, the evidence casts doubt on the optimistic perspective that call centre work, in time, will come to resemble 'knowledge work'.

Keywords: Call centres, Knowledge economy, Taylorism, Work organization

77. Taylor, Steven A., Gary L. Hunter. The impact of loyalty with e-CRM software and e-services, *International Journal of Service Industry Management*, 13 (5), 2002, 452–474.

Abstract. E-service is a critical strategic marketing consideration today for many firms, based largely on the promise of more cost-effective models of self-service relative to large (and expensive) call centers for technical support and customer service. The rapidly emerging electronic customer relationship management (e-CRM) industry provides the primary tools for implementing e-service. Interestingly, the e-CRM industry faces the same challenges and strategic marketing considerations as their organizational customers, in that they must deliver exceptional service and support to the companies purchasing/using e-CRM software. A review of organizational mission/vision statements suggests that e-CRM companies are generally positioning themselves as exemplars of customer satisfaction provision and relationship management. However, recent industry analysis suggests that their organizational customers generally report low to ambivalent ratings on customer satisfaction measures (our study also supports these findings). This discrepancy could be partly attributed to very little empirical inquiry having appeared to date to assess the efficacy of existing relationship marketing theories within this fast-moving industry. The current study provides an exploratory investigation that looks at the well-established (in other marketing settings) relative influences of quality, customer satisfaction, and loyalty in the formation of future purchase intentions and word-of-mouth behaviors within the e-CRM industry. Concludes that e-CRM marketers must first identify means of increasing the overall level of customer satisfaction within their industry, and then begin to consider moving beyond customer satisfaction toward broader loyalty-based strategic marketing objectives to support their relationship marketing practices. Practitioner and research implications of the reported study are discussed.

Keywords: Relationship marketing, E-commerce, Customer loyalty, Consumer behavior, Computer software

78. van den Broek, Diane. Monitoring and surveillance in call centres: Some responses from Australian workers, *Labour & Industry*, 12 (3), 2002, 43–58.

Abstract. Australian call centres currently number around 4,000, in industries such as banking, public utilities, airlines, information technology, and telecommunications. Of the 200,000 employees in the call centre industry, the Australian Council of Trade Unions (ACTU) estimates that around 15 to 20 percent are unionised. Unionised call centres are generally located in the public or ex-public sector such as the airlines, while employees in other industries including telecommunications and banking are considerably less unionised. The contract call centres have

proven to be the most difficult to organise. (Interview ACTU Organiser, 2001).
(Appears also in Section IV.)

79. Cartwright, Susan. New forms of work organization: Issues and challenges, *Leadership and Organization Development Journal*, 24 (3), 2003, 121–122.

Abstract. The changing nature of work and the emergence of new forms of work organization present particular challenges to leadership and management. This special issue examines some of the challenges and issues in the relationship between technology, stress and satisfaction within call centre environments, the problems of remote leadership and the rise in contingent workforce.

Keywords: Work organization, Work teams, Call centres, Workforce, Leadership, Temporary workers

(Appears also in Section IV.)

80. Gelders, Dave and Michel Walrave. The Flemish customer contact centre for public information from a marketing and management perspective, *International Journal of Nonprofit and Voluntary Sector*, 8 (2), 2003, 166.

Abstract. This paper describes the Flemish customer contact centre for government information ('the Flemish Infoline') as an example of marketing in the public sector. First, it defines the term 'customer contact centre' and describes the objectives and main characteristics of the Flemish infoline. It then identifies the three reasons for setting up the Flemish infoline in 1999: the complicated Belgian institutional landscape; the unprofessional telephone traffic handling and service; and the lack of knowledge about citizens' information needs. Finally, the paper applies Kotler's 4 Ps concept to the case, and puts the relevant stages from Lees-Marshment's political marketing orientations into one integrated scheme in order to understand the functioning of the Flemish infoline. Based on the literature and on an in-depth interview with the project head of the Flemish infoline, the authors demonstrate that marketing techniques can be used in contact centres for public information, but they also illustrate some important differences from those in the for-profit sector, such as the available amount of customers' personal data, the level of call operators' skills and the degree of heterogeneity of the questions. Further research on information needs and contact centres, and providing one 'umbrella' contact centre for government information in Belgium are recommended.

Keywords: Call centres, Public sector, Information dissemination, Market strategy, Statistical data

81. Grebner, Simone, Norbert K. Semmer, Luca Lo Faso, Stephan Gut, Wolfgang Kälin and Achim Elfering. Working conditions, well-being, and job-related attitudes among call centre agents, *European Journal of Work and Organizational Psychology*, 12 (4), 2003, 341–365.

Abstract. A comparison of 234 call centre agents with 572 workers in traditional jobs with long-lasting training revealed lower job control and task complexity/variety and higher uncertainty among call agents. However, time pressure, concentration demands, and work interruptions were

lower in call agents. Within the call agent sample, controlling for negative affectivity and other working conditions, job control predicted intention to quit, and job complexity/variety predicted job satisfaction and effective commitment. Social stressors and task-related stressors predicted uniquely indicators of well-being and job-related attitudes. Furthermore, data confirm the role of emotional dissonance as a stressor in its own right, as it explained variance in irritated reactions and psychosomatic complaints beyond other working conditions. Results indicate that strong division of labour may be a rather general phenomenon in call centres. Therefore, working conditions of call agents require a redesign by means of job enrichment or, better, organizational development. Moreover, measures of social stressors and emotional dissonance should be integrated routinely into stress-related job analyses in service jobs.

82. Grougiou, Vassiliki and Alan Wilson. Financial service call centres: Problems encountered by the grey market, *Journal of Financial Services Marketing*, 7 (4), 2003, 360.

Abstract. Technological advances have resulted in financial service companies being able to make use of alternative channels such as call centers and the Internet to deliver their services to their customers. At the same time, there has been a major growth throughout Europe in the gray market consisting of people who grew up in an age of face-to-face contact with service suppliers. This paper reports on a program of qualitative research looking at the gray market's perceptions of the call center delivery channel. It discusses the difficulties encountered by this market and the negative views that are held. It also highlights the need for further research into this area if financial service organizations are going to address the issues raised and effectively satisfy the needs of this growing market segment.

Keywords: Financial services, Older people, Consumer attitudes, Call centers, Customer services, Market research, Studies

83. Hyman, J., C. Baldry, D. Scholarios and D. Bunzel. Work-life imbalance in call centres and software development, *British Journal of Industrial Relations*, 41 (2), 2003, 215.

Abstract. The paper evaluates the centrality of work to employees in two growing employment sectors, call centres and software development. It then examines evidence for extensions of work into household and family life in these two sectors. Extensions are identified as tangible, such as unpaid overtime, or intangible, represented by incursions imported from work, such as exhaustion and stress. The study finds that organizational pressure, combined with lack of work centrality, result in work intruding into non-work areas of employee lives, though intrusions manifest themselves in different ways according to type of work, levels of worker autonomy and organizational support.

Keywords: Studies, Call centers, Software industry, Work life programs, Working conditions, Statistical analysis

(Appears also in Section III.)

84. Richardson, Ranald and Andrew Gillespie. The call of the wild: Call centers and economic development in rural areas, *Growth and Change*, 34 (1), 2003, 87–108.

Abstract. This paper attempts to reflect critically on the role which telephone call centers might play in the economic development of rural places in the “information age”, drawing mainly on a case study of the Highlands and Islands of Scotland. It argues that although call center employment tends mainly to be urban-based, the growth of this form of work does present opportunities for some rural areas. The paper considers the locational factors rural areas would have to possess or develop in order to attract such work. It suggests call centers can make a valuable though limited contribution towards rural economic development, principally through the creation of additional employment opportunities and the stimulation of new skills and competencies. It also suggests that call centers do not represent a panacea for rural areas and that, indeed, it would be dangerous for rural areas to become over-reliant on employment in this sector.

Keywords: Telecommunications, Urban, rural and regional economics, Regional migration, Regional labor markets, Population, Information and Internet services, Computer software, Telephone, Other production and pricing analysis (spatial analysis)

85. Sewell-Staples, Warren J., John F. Dalrymple and Katherine Phipps. Auditing excellence in call centres: Access is a corporate responsibility, *Managerial Auditing Journal*, 18 (1/2), 2003, 68.

Abstract. The call centre industry is one of the most rapidly growing industries in the developed world. This paper examines how the Australian Quality Council and the European Foundation for Quality Management address issues of access and corporate responsibility through their respective devices, namely the Australian Business Excellence Framework and the EFQM Excellence Model. The Australian Business Excellence Framework was introduced to help Australian companies meet the challenges of the global environment. The study then examines the impact of the UK and Australian Disability Discrimination Legislation in light of UK and Australian studies on the provision of services for the hearing impaired by call centres.

Keywords: Studies, Models, Corporate responsibility, Call centers, Handicapped people, Discrimination, Auditing

86. Silvestro, R., C. Silvestro. New service design in the NHS: An evaluation of the strategic alignment of NHS Direct, *International Journal of Operations & Production Management*, 23 (4), 2003, 401–417.

Abstract. Awareness of inconsistencies and variability in the delivery of health services across the UK has heightened in recent years, leading to general acknowledgement that a move away from “health care by post code” is a strategic priority for the National Health Service (NHS). NHS Direct, a call centre service for patients and their carers, is unique in the NHS in that it represents an entirely new service concept, with a rare opportunity to design a single nation-wide service from scratch, and to manage and coordinate a delivery system consistently throughout the country. Evaluates the strategic alignment of NHS Direct during the first three years of implementation through an analysis of its service concept, its operational objectives, the design of its delivery systems and its volume and variety characteristics. The evaluation reveals an absence of a central design specification which has resulted in wide variation in the call centres’ service portfolios, resource bases, competencies, telephony and clinical expert systems. Contends that variation and variability in the design of the call centres has severely compromised NHS Direct’s ability to meet its strategic and operational objectives, resulting in strategic misalignment. Also

identifies missed opportunities to learn from the growing call centre literature and from service shops in other industries.

Keywords: Service design, NHS Direct, Strategic alignment, National Health Service, Call centre service, Operational objectives, Strategic misalignment
(Appears also in Section X.)

87. Sturdy, Andrew and Peter Fleming. Talk as technique—a critique of the words and deeds distinction in the diffusion of customer service cultures in call centres, *The Journal of Management Studies*, 40 (4), 2003, 753.

Abstract. This paper critically explores the common distinction made between words and deeds (or ideas and techniques) in the diffusion of management knowledge literature. The concern with whether management ideas are really being implemented in an organizational context intuitively points to the possibility of a contrast between simply talking about a practice or ‘hype’ and practical implementation. Drawing on empirical research on the diffusion of customer service culture in two call centres where ‘verbal labour’ predominates, it is argued that this distinction is important, but overdrawn. Eschewing discursive reductionism, the concepts of ‘talk in work’ and ‘talk about work’ are developed to illustrate how talk can be a technique of implementation in its own right.

Keywords: Studies, Communication, Management theory, Customer services, Call centers

88. Adria, Marco and Shamsud D. Chowdhury. Centralization as a design consideration for the management of call centers, *Information & Management*, 41 (4), 2004, 497–507.

Abstract. A call center and its associated information technology (IT) provide an opportunity to redesign and improve service-delivery operations. Managers at all levels should understand the role of organizational design as call centers are established or expanded, in particular, the relative centralization (distribution of authority) associated with delivering services to customers. This article argues that centralization moderates and influences the organization’s efforts to improve customer service through the implementation of the call center and its IT. If managers fail to capitalize on the particular way that centralization moderates between IT and competitive strategy, the organization may not enjoy an important benefit of the call center which is competitive advantage through increased efficiency and improved customer service. Based on survey responses from 68 call-center managers, the authors found that both centralization and decentralization are associated with call-center service operations. While the call center provides managers with the ability to influence decision-making (centralization), there are also opportunities for agents in the call center to exercise authority in managing the organization’s communications with customers (decentralization). Implications for organizational practice are considered.

Keywords: Call centers, Centralization, Decentralization, Organizational design, Customer service

89. Dean, Alison M. Rethinking customer expectations of service quality: Are call centers different? *The Journal of Services Marketing*, 18 (1), 2004, 60–78.

Abstract. Reported studies on call centers emphasize efficiency and control, with possible implications for service priorities, customer orientation and service quality. However, there is little empirical research to test assumptions from the customer's perspective. This study aimed to establish whether customers expected (predicted) low levels of service from a call center, how this level compared to the minimum level they considered adequate, and whether the perceived customer orientation of the call center was related to service quality expectations. Data were collected in Australia from two sources: End consumers ($n = 289$) of an insurance provider, and business customers ($n = 325$) of a bank. Key findings were similar for both samples. First, customers had very high levels of adequate (minimum) expectations, and adequate expectations behaved independently from predicted (forecast) expectations. Second, customer orientation was associated with predicted expectations but not adequate expectations. The paper concludes with suggestions for future research and managerial implications.

Keywords: Quality of service, Call centers, Studies, Requirements, Customer relations

90. McCabe, Darren. "A land of milk and honey"? Reengineering the "past" and "present" in a call centre, *The Journal of Management Studies*, 41 (5), 2004, 827–856.

Abstract. This article explores how managers in the call centre of a bank, (re)defined, and drew boundaries around 'past' cultural conditions, in relation to the introduction of a Business Process Reengineering (BPR) regime. Managers represented the 'past' negatively, in terms of conflict and coercion, whilst the 'present' was largely described as a Shangri-La of teams and consensus. This eschewing of the 'past' and sublimation of the 'present' stood in opposition to the representations of the staff. Both the 'staff' and 'managers' seemed to reject or embrace discourses that challenged or coincided with their understanding of how things are or should be. In view of this, their understanding of the past/present is inseparable from a consideration of power and identity. The article examines the interplay between discourses and individuals, arguing that it is bound up with fear and anxiety, hope and aspiration, memory and nostalgia, among other, everyday life experiences.

Keywords: Corporate culture, Call centers, Studies, Managers, Business process reengineering, Banking industry

91. Ramsaran, C. Contact centers or cost centers? *Bank Systems + Technology*, 41 (1), 2004, 29–31.

Abstract. IM, e-mail and cross-selling are among the ways banks are striving to improve service and profitability in their contact centers. However, the challenges of staffing, equipping and managing those centers so that they operate efficiently and cost-effectively have existed just as long as banks have needed these contact centers. And, as contact centers become increasingly technology-enabled, bankers have had to balance the sometimes competing demands of "high-tech and high touch" with other imperatives, ranging from new privacy requirements to changing expectations of customer service to the need to demonstrate technology ROI. But the reality remains that, for the most part, the activity at bank contact centers generally is viewed as a cost—almost the proverbial necessary evil—rather than a revenue generator.

92. Van den Broek, Diane. "We have the values": Customers, control and corporate ideology in call

centre operations, *New Technology, Work, and Employment*, 19 (1), 2004, 2–13.

Abstract. This article analyzes the use of normative control through recruitment, work organisation, social events, and bargaining processes within two Australian telecommunication call centres. Rather than arguing that such control reduced employees to “self-disciplining subjects”, it suggests that these control mechanisms embodied significant levels of managerial coercion and, therefore, attracted varying levels of resistance.

Keywords: Call centers, Recruitment, Internal controls, Customer relations

93. Abbott, Julie and Pak Yoong. The stages of telecentre development: The case of the Kapiti Telecentre, *Technovation*, 25 (4), 2005, 421–431.

Abstract. This paper describes part of a research programme that explores the development of telecentres and the role of key players in these ventures. A single case study was conducted on the development of the Kapiti Telecentre, which is based on the Kapiti coast, a semi-rural and developing community situated approximately 50 km north of Wellington, New Zealand. The Kapiti Telecentre is unique among telecentres in that it is a collaborative project between business and community organisations. Several workers from city-based businesses are using the telecentre as a teleworking hub whilst the community users have initiated a major community IT educational programme based at the centre. A Board of Trustees provides governance of the telecentre and trustees come from the business, community and academic institutions. Initial results from this study suggest that the development of the Kapiti Telecentre follows four distinct stages: Germinating, Seedling, Sapling and Maturing. Details of the development activities during each stage will be described. The paper concludes by suggesting a number of implications for future telecentres development.

Keywords: Community development, Call centers, Information technology, Studies
(Appears also in Section X.)

94. Bentley, Peter J., Valender F. Turner, Sharon A. Hodgson, Rosalia Drimatis and Jade Hart. A central role for the health call centre, *Australian Health Review*, 29 (4), November 2005, 435–438.

Abstract. An ideal health system provides quality care that is centered on the patient, community-based, coordinated, continuous and cost-effective, and utilizes clinical information systems. Health call centers (HCCs) could be instrumental in achieving such aims. HCCs should meet the needs of patients in areas where the health care system is considered inadequate. Plans for future services offered by HCCs should be considered in state-wide programs, and national coordination should be a priority as additional HCCs are developed. There are three principal areas where HCCs could provide benefits to patients and health care providers. These are: 1. chronic disease management, 2. acute hospital support and coordination, and 3. mental health services. Detractors in the call center debate point to cost, impersonalized service and possible clinical governance issues as reasons not to pursue health solutions through call center technology. With appropriate consideration of operational arrangements, the HCC could provide an integrative function across the entire health system.

Keywords: Call centers, Health care industry, Roles, Integration, Customer services

95. Collin-Jacques, Caroline and Chris Smith. Nursing on the line: Experiences from England and Quebec (Canada), *Human Relations*, 58 (1), 2005, 5–32.

Abstract. Some industries, like telecommunications, finance and retail, have been operating call centres for several years and there has been growing academic interest in exploring the work experience of employees taking calls and answering telephone queries assisted by computers. Nurses who staff telephone centres in the healthcare industry are different from their counterparts in other fields. These are highly qualified workers with a strong occupational identity and distinct spheres of competence. However, occupation is not a constant as a mediator of technology and it is argued that the extent to which nurses were able to shape their call centre work differed cross-nationally owing to the simultaneous interplay of different societal constructions of nursing and the national-historical development of tele-health centres. This article uses cross-national qualitative case study research to examine the different effects of occupation, nation and timing of industry formation on the design and experience of call centre work in the healthcare industry.

Keywords: Call centers, Comparative studies, Nurses, Technological change, Social impact, Impact analysis

96. Gollan, Paul J. Silent voices: Representation at the Eurotunnel call centre, *Personnel Review*, 34 (4), 2005, 423–450.

Abstract. This research aims to examine nonunion and union representative arrangements at the Eurotunnel call center and assesses their effectiveness in representing the needs of employees. The research examines these issues over a five-year period using a series of employee surveys, interviews and focus groups. This period has also allowed a review of consultation arrangements before and after union recognition and an examination of the outcomes from such arrangements. The evidence suggests that the nonunion voice structures at Eurotunnel are used as devices for information and communications rather than true consultation mechanisms or bargaining agents. However, the challenge for the trade union at the Eurotunnel call center is that what can be regarded as a success in some aspects has not resulted in a change in attitudes towards unions by a majority of Eurotunnel employees. This could be seen as one of the major challenges for union-employer partnership arrangements.

Keywords: Labor unions, Studies, Human resource management, Nonunion, Call centers, Collective bargaining
(Appears also in Section X.)

97. Halliden, Bill and Kathy Monks. Employee-centred management in a call centre, *Personnel Review*, 34 (3), 2005, 370–385.

Abstract. This paper presents the findings of research undertaken in a customer contact center in Ireland in which a series of measures were introduced to implement employee-centered work practices. The paper examines the processes by which the measures were undertaken and considers the changes to performance that were attributed to the involvement initiatives. An action research approach was utilized in studying the problem and a variety of measures were utilized to identify alterations in employee perceptions and employee performance over the period of the

introduction of the changes. The results of the interventions within the call center indicated improvements in employee perceptions of their work situation as measured by the dimensions of the survey instrument. However, while the thrust behind the change initiatives was one of involvement, at the same time decisions about which issues were open to an involvement process were made by management and there were indications of a dualist approach in the introduction of the employee-centered initiatives.

Keywords: Call centers, Employee involvement, Human resource management, Changes, Studies

98. Koh, S.C.L., A. Gunasekaran, A. Thomas and S Arunachalam. The application of knowledge management in call centres, *Journal of Knowledge Management*, 9 (4), 2005, 56–69.

Abstract. This paper proposes to evaluate the need for knowledge management in a call centre for improving quality of customer services, by addressing the issues specifically relating to information and knowledge management. Methodology adopted in this research is qualitative, namely ethnography. After examining six models from literature review, a knowledge management model is developed for implementation to assess the required effort to compare against the expected benefits. Knowledge management could be achieved by effectively managing the five roles of knowledge, namely knowledge acquisition, utilisation, adaptation, distribution, and generation. Comparison of the benefits against the efforts has clearly justified the knowledge management efforts in the case study. The knowledge management model could be adapted in other service sectors with similar characteristics to a call centre. This work will be beneficial to researchers and practitioners who are interested in applying knowledge management in call centres and/or service sectors with similar characteristics.

Keywords: Studies, Knowledge management, Call centers, Quality of service, Models, Customer services

99. Long, Andrew F., Tina Gambling, Robert J. Young, Jean Taylor, et al. Acceptability and satisfaction with a telecarer approach to the management of type 2 diabetes, *Diabetes Care*, 28 (2), 2005, 283–289.

Abstract. Long et al. examine patients' views of the acceptability of and satisfaction with telephone care center support provided to improve blood glucose control in type 2 diabetes. A personalized Pro-Active Call Center Treatment Support approach is acceptable to patients. A service giving priority to the interpersonal dimension leads to increased commitment from patients to improve long-term glycemic control.

Keywords: Call centers, Diabetes, Disease management, Technical support, Glucose, Urban areas

100. McElhinney, David and Tony Proctor. Concept of entrapment and decision-making, *Management Decision*, 43 (2), 2005, 189–202.

Abstract. This paper informs executives of the dangers of entrapment which can occur when there is an increasing commitment to an ineffective course of action to justify previous allocation of resources when managing new projects. It reviews research studies on establishing call/contact-centres in local government across the UK. Data was also collected via interviews

with executives in authorities experienced in setting up call/contact centres. Centres involve spending millions of pounds but there was only limited knowledge of capital or ongoing revenue costs. Evidence of internal resistance, lack of any shared vision, or knowledge of the level of risk existed, as well as only a limited understanding of the centres' organisational impact, potential benefits or added value. There was an absence of stated project objectives or formal project appraisal and a creeping commitment to the projects continuation. The potential for entrapment existed. A single case study but one which adds to the existing literature on entrapment and focuses attention on the risks that can exist in the public sector. Underlines the importance of setting out specific procedures for evaluating the potential costs/benefits and subsequent progress of new, particular large-scale, business projects.

Keywords: Studies, Call centers, Decision making, Local government, Project management
(Appears also in Section X.)

101. Snow, Jon. UK call centres: Crossroads of an industry, *Journal of Property Investment & Finance*, 23 (6), 2005, 525–532.

Abstract. The application of technology has shaped the call centre organisation, enabled its remote location, and allowed its swift relocation. The purpose of this practice briefing is to expose the reader to the reality that call centres are temporary employers of both human resource and property, while at the same time they are collectively one of the biggest occupiers of office space in the UK. The briefing aims to illustrate the uncertainties relating to the mobility of call centre business units and the threat to future employment posed by emerging technologies. This practice briefing draws upon a combination of third party research findings, other literature, and the author's experiences to illustrate the relationship between call centre employment and property requirements; the mobility of both jobs and property footprint due to the globalizing effects of high-bandwidth communications and the development of enterprise software applications; and the potential for jobs erosion due to the "destructive" impact of new automated and self-service customer interaction technologies. The practice briefing acknowledges that DTI sponsored research delivers a very optimistic view of the future prospects for UK call centre employment. However, current experiences regarding offshoring and the adoption of non-live agent means of customer interaction provide uncertainty regarding the timing and magnitude of call centre employment growth. Property investors seeking exposure to markets reliant on call centre occupiers should consider the prospect that call centre demand could disappear as quickly as it was created. The footloose nature of today's call centres creates uncertainty for property investors that have, or are seeking, exposure to the UK call centre sector. This practice briefing delivers an accessible account of the operational risks that influence the stability of the UK call centre sector.

Keywords: Call centers, Globalization, Outsourcing, Offshore, Technology, Office space, Employment

102. Taylor, Phil and Peter Bain. 'India calling to the far away towns': The call centre labour process and globalization, *Work, Employment & Society*, 19 (2), 2005, 261–282.

Abstract. In recent years prominent companies have migrated call centre services to India provoking much-publicized fears for the future of UK employment. This article challenges the

widely-held assumption that offshoring voice services is a seamless undertaking, principally through an investigation of the Indian call centre labour process. This enquiry is informed initially by an analysis of the political-economic factors driving offshoring and shaping the forms of work organization to have emerged in India. A critical review of literature on call centre work organization provides a conceptual framework, through which Indian developments are analysed. Data comes from fieldwork conducted in India and a complete audit of the Scottish industry, through which UK trends can be evaluated. We conclude that the Indian industry reproduces in exaggerated and culturally-distinctive forms, a labour process that has proved problematical for employers and employees alike in the UK and elsewhere.

Keywords: Call centers, Location of industry, Outsourcing, International markets, Studies

103. Williams, Margaret, Cathryn Bradshaw, Beverly Fournier, Admasu Tachble, et al. The call-centre: A child welfare liaison program with immigrant serving agencies, *Child Welfare*, Washington, 84 (5), Sep/Oct 2005, 725–746.

Abstract. Alberta, Canada, welcomed nearly 16,000 landed immigrants in 2003, of whom more than half came to the Calgary area. Approximately 200,000 immigrants of various ethnic and cultural groups now live in the region. Many of these new arrivals have no natural support networks while struggling with language, cultural, and economic barriers. Recognizing these difficulties, the Calgary and Area Child and Family Services Authority (CFSA) joined with several Immigrant Serving Agencies to develop guidelines and procedures to direct staff working with diverse cultures, including the Call-Centre pilot project, which provided CFSA staff with a one-stop telephone contact for information about an immigrant or refugee family, their culture, and available culturally-appropriate resources. The Call-Centre, which is currently being evaluated by researchers at the University of Calgary, will gradually expand to all CFSA sites in the region. This article describes the Call-Centre and the first phase of the evaluation.

Keywords: Call centers, Child welfare, Refugees, Culture, Aliens
(Appears also in Section X.)

104. Young, Robert J., Jean Taylor, Tim Friede, Sally Hollis, et al. Pro-Active Call Center Treatment Support (PACCTS) to improve glucose control in type 2 diabetes: A randomized controlled trial, *Diabetes Care*, 28 (2), 2005, 278–282. Young et al. determine whether Pro-Active Call Center Treatment Support (PACCTS), using trained nonmedical telephonists supported by specially-designed software and a diabetes nurse, can effectively improve glycemic control in type 2 diabetes. In an urban Caucasian trial, population with blood glucose HbA1c greater than 7% PACCTS facilitated significant improvement in glycemic control.

Keywords: Glucose, Diabetes, Clinical trials, Whites, Call centers, Disease management, Technical support

IX Simulation, Petri Nets, Genetic Algorithms

1. Kwan, Stephen K., Mark M. Davis and Allen G. Greenwood. A simulation model for determining variable worker requirements in a service operation with time-dependent customer demand, *Queueing Systems*, 3, 1988, 265–276.

Abstract. In a service operation where worker requirements have to be determined for short scheduling time periods with nonstationary customer demand, the assumptions necessary for applying steady-state solutions to elementary queueing models are usually violated. This paper describes a simulation study of the behavior of such a service operation. The results are compared with the steady-state solutions to a queueing model where individual scheduling time periods are assumed to be independent. It is found that if the system utilization is below a derived maximum value (based on a service level criterion), then the steady-state solutions are robust enough to explain the behavior of the system and can be used to schedule worker requirements.

Keywords: Simulation, Service operations, Worker requirements, Queueing models
(Appears also in Section I.)

2. Liu, F.K. and D. Seagraves. An ISDN application-simulation modeling of NACD. Teletraffic and Datatraffic in a Period of Change. ITC-13. Proceedings of the Thirteenth International Teletraffic Congress. North-Holland, Amsterdam, The Netherlands, 1991, 279–284.

Abstract. Network automatic call distribution (NACD) utilizes the integrated services digital network (ISDN) standard as a vehicle to effectively distribute calls between ACD sites. Due to the dynamic nature of NACD, its routing algorithm, dependent upon the network congestion status, is very hard to describe mathematically and its system performance is just as hard to evaluate accurately. A simulation model, based on the SLAM II (simulation language for alternative modeling) simulation language, is shown to be an effective tool to evaluate the system performance of a network with the NACD application, due to its flexibility in implementing routing criteria reflecting the unique NACD features. The result of simulation indicates that use of NACD produces a significant improvement in grade of service and agent utilization. The improvement is most pronounced when agent load is unbalanced in a non-NACD environment.

Keywords: Unbalanced agent load, Automatic call distribution, Integrated services digital network, Routing algorithm, Network congestion status, SLAM II, Simulation language

3. Brigandi, Anthony J., Dennis R. Dargon, Michael J. Sheehan and Thomas Spencer III. AT&T's call processing simulator (CAPS) operational design for inbound call centers, *Interfaces*, 24 (1), 1994, 6–28.

Abstract. Since 1978, AT&T has been developing the call processing simulator (CAPS) to design and evaluate inbound call centers. The current version of CAPS is a user-friendly PC-based system employing a discrete event simulation model with animation and queueing models of both the telecommunications network and AT&T's business customer's call center environment. Using CAPS, AT&T can model a network of call centers utilizing advanced 800 network

features before its customers make capital investments to start or change their call centers. In 1992, AT&T completed about 2,000 CAPS studies for its business customers, helping it increase, protect, and regain more than \$1 billion in an \$8-billion 800-network market. The CAPS tool is also the turnkey for more than \$750 million in annual profit for AT&T's business customers who received CAPS studies.

Keywords: AT&T, Call processing simulator, CAPS, Inbound call centers, User-friendly PC-based system, Animation, Queuing models, Telecommunications network, Advanced 800 network features

(Appears also in Section VIII.)

4. Perry, M. and A. Nilsson. Performance modeling of automatic call distributors: Operator services staffing with heterogeneous positions. Fundamental Role of Teletraffic in the Evolution of Telecommunications Networks. Proceeding of the 14th International Teletraffic Congress, ITC-14. Elsevier, Amsterdam, The Netherlands, 1994, 1023–1032.

Abstract. The telephony industry has introduced a new generation of multi-purpose operator positions, that with their associated automatic call distributor (ACD) allow operators to serve both toll and assist (TA) and directory assistance (DA) calls from the same position. When all operators can serve both TA and DA calls and all of the positions are multi-purpose, classical Erlang-type queueing models can be used to calculate two important measures: the expected waiting time for calls and the average operator occupancy. However when all of the positions are not multi-purpose (i.e. the operators are a heterogeneous group: some can do both TA and DA, some can do just TA and some can do just DA) the calculation of these two measures is a new and challenging problem. In this paper, approximations for expected waiting times and average occupancies are presented, and are shown, by comparison to simulation results, to be quite accurate.

Keywords: Performance modeling, Automatic call distributors, Operator services staffing, Heterogeneous positions, Telephony industry, Multi-purpose operator positions, Automatic call distributor, ACD, Toll and assist calls, Directory-assistance calls, Classical Erlang-type queueing models, Expected waiting time, Average operator occupancy, Average occupancies, Simulation results

(Appears also in Section I.)

5. Anisimov, N., K. Kishinski, A. Miloslavski and P. Postupalsk. Macroplaces in high level Petri nets: application for design inbound call center. Information Systems Analysis and Synthesis. Proceedings of the International Conference on Information Systems Analysis and Synthesis. ISAS'96. Int. Inst. Inf. Syst., Orlando, FL, USA, 1996, 415–422.

Abstract. The paper is devoted to the use of the Petri net approach for the construction of formal models, intended as the basis for the development of the logical structure of inbound call centers. As a formal model for a specification of agent scenarios the paper considers a formalism called a script-net that belongs to a class of high level Petri nets. It is emphasized that scripts describing real-world scenarios are usually extremely complicated and require some means of modularization. The paper suggests the extension of high level nets called high level macronets, intended for specification situations which are asynchronous to normal processing of scripts.

The model is shown to be a compact notation of high level nets without macroplaces and a corresponding transformation procedure is presented. Some examples are used to illustrate the power of the formalism.

Keywords: High level Petri nets, Inbound call center design, Formal models, Specification, Agent scenarios, Script net, Modularization, High level macronets, Macroplaces

6. Levasseur, G.A. An object-oriented phone center model using SIMPLE++. 1996 Winter Simulation Conference Proceedings. SCS Int, San Diego, CA, USA, 1996, 556–563.

Abstract. A demonstration model and application object template (object library) was created to show how SIMPLE++ simulation software can be applied to service industry telephone call handling centers. In addition, this example was designed to show modeling techniques that can be used to take advantage of some key object-orientation concepts to quickly create highly flexible simulation models. Finally, some features of the SIMPLE++ simulation package are illustrated.

Keywords: Phone center model, SIMPLE++, Application object template, Object library, Simulation software, Service industry, Telephone call handling centers, Object-oriented programming, Flexible simulation models, Software packages

7. Massey, W.A., G.A. Parker and W. Whitt. Estimating the parameters of a nonhomogeneous Poisson process with linear rate, *Telecommunications Systems—Modeling, Analysis, Design and Management*, 5 (4), 1996, 361–688.

Abstract. We want to be able to determine if a Poisson process traffic model is appropriate and, when it is, we want to be able to estimate its parameters from measurements, with linear rate over a finite interval, based on the number of counts in measurement subintervals. Such a linear arrival-rate function can serve as a component of a piecewise-linear approximation to a general arrival-rate function. We consider ordinary least squares (OLS), iterative weighted least squares (IWLS) and maximum likelihood (ML), all constrained to yield a nonnegative rate function. We prove that ML coincides with IWLS. As a reference point, we also consider the theoretically optimal weighted least squares (TWLS), which is least squares with weights inversely proportional to the variances (which would not be known with data). Overall, ML performs almost as well as TWLS. We describe computer simulations conducted to evaluate these estimation procedures. None of the procedures differ greatly when the rate function is not near 0 at either end, but when the rate function is near 0 at one end, TWLS and ML are significantly more effective than OLS. The number of measurement subintervals (with fixed total interval) makes surprisingly little difference when the rate function is not near 0 at either end. The variances are higher with only two or three subintervals, but there usually is little benefit from going above ten. In contrast, more measurement intervals help TWLS and ML when the rate function is near 0 at one end. We derive explicit formulas for the OLS variances and the asymptotic TWLS variances (as the number of measurement intervals increases), assuming the nonnegativity constraints are not violated. These formulas reveal the statistical precision of the estimators and the influence of the parameters and the method. Knowing how the variance depends on the interval length can help determine how to approximate general arrival-rate functions by piecewise-linear ones. We also develop statistical tests to determine whether the linear Poisson model is appropriate.

Keywords: Digital simulation, Iterative methods, Least-squares approximations, Maximum likelihood estimation, Parameter estimation, Piecewise linear techniques, Queueing theory, Stochastic processes, Telecommunication traffic, Nonhomogeneous Poisson process, Piecewise linear approximation, Linear arrival-rate function, Ordinary least squares, Iterative weighted least squares, Computer simulations, Statistical precision, Traffic model
(Appears also in Section II.)

8. Anisimov, N., K. Kishinski and A. Miloslavski. An approach to design distributed CTI applications using Petri nets: an example of a call center. SMC'98 Conference Proceedings. 1998 IEEE International Conference on Systems, Man, and Cybernetics. IEEE, New York, NY, USA, 1998, 238–243.

Abstract. In this paper we apply a formal approach, based on Petri nets, to design a logical structure for call centers based on sophisticated computer telephony integration applications. A typical call center consists of a set of operators, called agents, who process inbound calls from clients. This call processing may involve the use of computer systems and other devices, such as faxes, as well as communication with other agents. The treatment of each call being processed is heavily regulated by a script, which is specially designed for specific kinds of calls by the experts in telemarketing. However, the design of such scripts can be problematic. In this paper, we stress the need for tools supporting a scripting process. We propose a formal model intended to serve as a basis for such tools. Specifically, we introduce formal models called script nets for formal representation of scripts and of the call center as a whole. We have also introduced various ways to structure script nets, using a transition hierarchy and macroplaces.

Keywords: Distributed computer telephone integration applications, Petri nets, Call center, Inbound calls, Scripting process, Formal models, Script nets, Formal representation, Transition hierarchy, Macroplaces

9. Bapat, V. and E.B. Pruitte Jr. Using simulation in call centers. 1998 Winter Simulation Conference. Proceedings, IEEE, Piscataway, NJ, USA, 1998, 1395–1399.

Abstract. A company's call center is its most visible strategic weapon. It is a business battlefield where millions of dollars of products and services are purchased, sold, and traded. It is also a place where thousands of customers are won and lost in an instant. As leading companies become more creative in disseminating information and providing value to their customers over telephone lines, it is only natural that they look to the call center as their beachhead into the market. With the importance of call centers on the rise and as reengineering activities within them growing rampant, simulation technology is emerging as the best analysis tool to manage change within an increasingly complex environment (D. Profozich, 1997). The paper defines the value of simulation in call center design, planning, and management by examining key weaknesses and strengths of traditional approaches and industry trends. It also discusses how call centers can maximize their investment in simulation.

Keywords: Strategic weapon, Business battlefield, Leading companies, Telephone lines, Reengineering activities, Simulation technology, Analysis tool, Change management, Complex environment, Call center design, Industry trends, Investment

10. Mason, A.J., D.M. Ryan and D.M. Panton. Integrated simulation, heuristic and optimisation approaches to staff scheduling, *Operations Research*, 46 (2), 1998, 161–175.

Abstract. This paper details a new simulation and optimisation based system for personnel scheduling (rostering) of Customs staff at the Auckland International Airport, New Zealand. An integrated approach using simulation, heuristic descent and integer programming techniques has been developed to determine near-optimal staffing levels. The system begins by using a new simulation system embedded within a heuristic search to determine minimum staffing levels for arrival and departure work areas. These staffing requirements are then used as the input to an integer programming model which optimally allocates full and part-time staff to each period of the working day. These shifts are then assigned to daily work schedules having a six-day-on, three-day-off structure. The application of these techniques has resulted in significantly lower staffing levels, while at the same time creating both high quality rosters and ensuring that all passenger processing targets are met. This paper charts the development of this system, outlines failures.

Keywords: Simulation, Heuristic, Optimisation, Staff scheduling, Personnel scheduling, Rostering, Customs staff, Auckland International Airport, New Zealand, Heuristic descent, Integer programming, Near optimal staffing levels, Minimum staffing levels, Integer programming model, Full-time staff, Part-time staff
(Appears also in Section I.)

11. Van Dijk, N.M. On hybrid combination of queueing and simulation. Simulation: Past, Present and Future. 12th European Simulation Multiconference 1998. ESM'98. As Part of the 50th Anniversary Celebrations of the University of Manchester - the Home of Computing. SCS, San Diego, CA, USA, 1998, 731–735.

Abstract. This paper illustrates how simulation and queueing theory can and should go hand in hand for a variety of practical problems, both in daily-life and industry, which are still open for fundamental research. To this end, it highlights real-life cases taken from: daily-life situations (postal office or bank); administrative logistics (reengineering); tele-servicing (call-centres); and transportation (railways).

Keywords: Simulation, Queueing theory, Postal office, Bank, Administrative logistics, Tele-servicing, Call centres, Transportation, Railways
(Appears also in Section I.)

12. Yoshimura, K. and R. Nakano. Genetic algorithm for information operator scheduling. 1998 IEEE International Conference on Evolutionary Computation Proceedings. IEEE World Congress on Computational Intelligence. IEEE, New York, NY, USA, 1998, 277–282.

Abstract. Telephone information operator scheduling is a real-world optimisation problem. A genetic algorithm using a concise representation of solutions for the problem is successfully applied. It is shown that mutation is important for the problem. We propose an effective mutation operator and demonstrate its advantages through numerical experiments. Partial reinitialization of individuals is also introduced in order to reintroduce diversity into the population and avoid premature convergence. The experimental results show that the reinitialization strategy

improves the search performance.

Keywords: Genetic algorithm, Information operator scheduling, Optimisation, Mutation operator, Partial reinitialization, Population diversity, Premature convergence, Search performance, Telephone operators

13. Anisimov, N., K. Kishinski and A. Miloslavski. Formal model, language and tools for design agent's scenarios in call center systems. Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences. 1999. HICSS-32. Abstracts and CD-ROM of Full Papers. IEEE Comput. Soc, Los Alamitos, CA, USA, 1999, 9 pp.

Abstract. During the last few years there continues to be remarkable growth in telephone call-center systems. There are many applications of call-centers in different areas of business such as in telemarketing, insurance, customer service, electronic commerce, etc. Moreover, in some cases it is reasonable to think of a call-center as an integrated part of a whole business system responsible for the telephone interface with the outside world. Typically, a call center consists of a set of operators, called agents, who process inbound calls from clients. Call processing may involve the use of computer systems (e.g. database), other devices (e.g. fax-machines, interactive voice response units) as well as communication with other agents (e.g. deliver a call to more qualified agent, making a consulted call). The call processing may also produce outbound calls. The treatment of each call being processed is heavily regulated by scenarios called scripts which are specially designed for specific kind's of the calls. The design of such scripts is one of the main problems in call center maintenance. To cope with this problem we need special tools, i.e., scripting language, corresponding editor, related environment. In this paper we present an ongoing project aimed at the design of such a platform. We introduce a Petri net-based model for representation of scripts and a logical structure of the call center. The model, called script-net, is based on object-oriented Petri net dialect belonging to a class of high-level Petri nets. In particular, the model allows one to formally represent scripts their communication with agents and other resources, exception handling time constrains. We also consider some implementation issues. In particular, we outline a visual iconic language specially designed for script specification. The semantics of the language is based on script-nets. An agent of the call center can be perceived as a specific resource and is implemented with the aid of Internet/Intranet technology. To illustrate the use of suggested tools, some typical examples of scripts are presented including scenarios for inbound and outbound telemarketing.

Keywords: Formal model, Formal language, Design agent's scenarios, Call center systems, Telephone call center systems, Telemarketing, Insurance, Customer service, Electronic commerce, Object-oriented Petri net dialect, Visual iconic language

14. Fischer, M.J., D.A. Garbin, A. Gharakhanian and D.M. Masi. Traffic engineering of distributed call centers: not as straight forward as it may seem. Proceedings of the Applied Telecommunications Symposium (ATS'99). 1999 Advanced Simulation Technologies Conference. SCS, San Diego, CA, USA, 1999, 53–59.

Abstract. As of 1994, AT&T estimated that 350000 businesses employed 6.5 million people in call centers. In 1997, call center revenue was estimated at \$900M, with annual spending on call centers growing at 12 percent each year. Accurate performance analyses are essential in

determining staffing levels and trunk requirements in call centers, because poor performance means lost business opportunities. The purpose of this paper is to show that as the complexity of these systems increases, traditional methods, like Erlang B and C table lookup, can result in poor evaluation of the call center performance. We start by examining the simplest of all call centers and show traditional methods can result in poor estimates of system performance and then present a more accurate model for this call center configuration. As the complexity of call centers increases more advance methods are required. This is demonstrated by considering two more complex systems: distributed systems of multiple interdependent call centers and a virtual call center configuration. We also discuss methods to analytically solve each of these systems.

Keywords: Traffic engineering, Distributed call centers, AT&T, Performance analyses, Staffing levels, Trunk requirements, Erlang B model, Erlang C model, Table lookup, Multiple interdependent call centers, Virtual call center configuration

(Appears also in Section VIII.)

15. Klungle, R. Simulation of a claims call center: a success and a failure. WSC'99. 1999 Winter Simulation Conference Proceedings. 'Simulation—A Bridge to the Future', IEEE, Piscataway, NJ, USA, 1999, 1648–1653.

Abstract. The paper addresses the call center management process and the role of simulation in this process. Strengths and weaknesses of workforce management systems and the Erlang-C model are reviewed and the role of discrete event simulation is highlighted. An application in an insurance claims call center is utilized to show the effectiveness of simulation in evaluating call center designs and also the difficulties in selling selected results to management. The paper concludes with some lessons learned about the call center process, discrete event simulation, workforce management systems, and the specific claims application.

Keywords: Claims call center simulation, Call center management process, Workforce management systems, Erlang-C model, Discrete event simulation, Insurance claims call center, Claims application

16. Miller, K. and V. Bapat. Case study: simulation of the call center environment for comparing competing call routing technologies for business case ROI projection. WSC'99. 1999 Winter Simulation Conference Proceedings. 'Simulation—A Bridge to the Future', IEEE, Piscataway, NJ, USA, 1999, 1694–1700.

Abstract. The paper describes how simulation was used for business case benefits and return on investment (ROI) projection for the procurement and roll-out of a new call routing technology to 25 call centers. With investment costs of about 17 million dollars and annual operating costs of about 8 million for the new technology, we needed to determine if the technology would provide enough cost savings and cost avoidance (through reduced trunk costs, increased agent productivity, and ability to service more calls) to warrant its nationwide implementation. We constructed a model of the existing call center environment consisting of 25 call centers, where calls were distributed to the sites based on a system of percentage allocation routing; for example, the telephone network provider directs calls to each site, based on the number of agents scheduled. We then modeled the same call system dynamics and intricacies under the new call routing system, where calls are distributed based on longest available agent. Subsequently, we

conducted average day simulations with light and heavy volumes and other “what if” laboratory analyses and experiments to facilitate planning decisions required to be documented and substantiated in the business case.

Keywords: Call center environment simulation, Competing call routing technologies, Business case ROI projection, Business case benefits, Return-on-investment, Call routing technology, Investment costs, Annual operating costs, Cost savings, Cost avoidance, Agent productivity, Trunk costs, Nationwide implementation, Percentage allocation routing, Telephone network provider, Call system dynamics, Longest available agent, Average-day simulations, What-if laboratory analyses, Planning decisions

17. Tanir, O. and R.J. Booth. Call center simulation in Bell Canada. WSC’99. 1999 Winter Simulation Conference Proceedings. ‘Simulation—A Bridge to the Future’, IEEE, Piscataway, NJ, USA, 1999, 1640–1647.

Abstract. Call centers have relied historically, on Erlang-C based estimation formulas to help determine number of agent positions and queue parameters. These estimators have worked fairly well in traditional call centers. However, recent trends such as skill-based routing, electronic channels and interactive call handling demand more sophisticated techniques. Discrete event simulation provides the necessary techniques to gain insight into these new trends, and helping to shape their current and future designs. This paper relates the experiences of designing call center simulations in Bell Canada. With the experience of constructing, executing and analyzing a large call center model, problems that we faced are identified and potential solutions are given. The examples are taken from large and small call centers alike in the attempt to bring forth some common problems that a simulationist will face.

Keywords: Call center simulation, Bell Canada, Erlang-C based estimation, Queue parameters, Skill-based routing, Electronic channels, Interactive call handling, Discrete event simulation

18. Dugdale, J., B. Pavard and J.L. Soubie. A pragmatic development of a computer simulation of an emergency call centre. Designing Cooperative Systems. Use of Theories and Models. Proceedings of the 5th International Conference on the Design of Cooperative Systems (COOP’2000), IOS Press, Amsterdam, The Netherlands, 2000, 241–256.

Abstract. In cases where it is infeasible to experiment in a real life setting, computer simulation is a valuable tool in the design and understanding of cooperative systems. This paper describes the development of a computer based simulation of an emergency call centre. The centre, which is a perfect example of a complex cooperative system, is currently undergoing a physical reorganization. The aim of the simulator is to help in the redesign process by allowing the user to test the effects of new physical organizations. Whilst grounded in a solid theoretical framework, the simulator was developed using a bottom-up approach. We are particularly interested in modelling and analyzing how environmental factors, such as the level of noise, affect mutual awareness, overhearing, interruption, cooperation and communication. A methodology is employed which is strongly participative and which, we believe, is well suited for the development of a computer-based simulation of complex real world settings. We explain our methodology and show how the environmental and cognitive factors have been analyzed, translated into a design and subsequently implemented using an object-oriented approach. Finally, we demonstrate the

computer-based simulator by running an experiment using data obtained from our observations of the real world setting.

Keywords: Computer simulation, Emergency call centre, Cooperative systems, Bottom-up approach, Environmental factors, Noise, Cognitive factors, Object-oriented approach, Experiment, Ergonomics, Multi-agent systems
(Appears also in Section IV.)

19. Ridley, A. Performance optimization of a telecommunication call center. Proceedings of the Applied Telecommunication Symposium (ATS'00). SCS, San Diego, CA, USA, 2000, 163–167.

Abstract. Telecommunication call centers have become the primary channel of customer interaction service for many businesses. The level of professionalism and efficiency that call center agents deliver to customers provides a significant advantage over traditional customer service practices. The growth of call centers has been substantial over the last two decades. This growth is driven by a company's desire to lower operating costs and to increase revenues (Kim 1997). The author investigates analytical and simulation-based models for the design and management of a call center. Given three classes of traffic (voice, E-mail, and facsimile) with different target waiting-times in queue and target service levels, the goal is to optimize the call center performance. The system performance can be measured with quantities such as the expected waiting-time in queue, the expected time in system, the percentage of calls answered within a given time, and the expected waiting-time probability distribution. The system performance of the call center is measured using analytical and simulation-based queuing models. For analytical models, the traffic classes will have exponential inter-arrival and service time distributions where the arrival and service rates will differ among classes. Also, each customer call will be assigned a queue priority based on its traffic class. The call agents will be able to handle calls from any class. For the simulation-based models, the inter-arrival and service time distributions will not be exponential, the agents will have different skill-levels, and the queue length will be finite.

Keywords: Performance optimization, Telecommunication call center, Simulation-based models, Management, Voice traffic, E-mail, Facsimile, Service levels, Expected waiting time, Probability distribution, Queuing models, Exponential inter-arrival distributions, Service-time distributions
(Appears also in Section I.)

20. Gulati, Sandeep and Scott A. Malcolm. Call center scheduling technology evaluation using simulation. Proceedings of the 2001 Winter Simulation Conference, Arlington, VA, USA, 2, 2001, 1438–1442.

Abstract. Telemarketers, direct marketing agencies, collection agencies and others whose primary means of customer contact is via the telephone invest considerable sums of money to make the calling operation efficient and productive. Investments are required in human resources, infrastructure and technology. Having invested the dollars, businesses want to ensure that value is maximized. Call scheduling algorithms provide an efficient method to maximize customer contact. However, management at a large, national credit-card bank was not convinced that the software used to schedule calls was providing an adequate level of service. Simulation studies showed that management was justified in this assumption. The study also revealed that process improvement opportunities exist, which if implemented would likely produce the desired perfor-

mance improvements.

21. Saltzman, Robert M. and Vijay Mehrotra. A call center uses simulation to drive strategic change, *Interfaces*, 31 (3), Part 1 of 2, May–June 2001, 87–101.

Abstract. A large, customer-focused software company relied on simulation modeling of its call center operations in launching a new fee-based technical-support program. Prior to launching this rapid program, call center managers were concerned about the difficulty of meeting a proposed guarantee to paying customers that they would wait less than one minute on hold. Managers also wanted to know how the new program would affect the service provided to their existing base of regular, nonpaying customers. We quickly developed an animated simulation model that addressed these concerns and gave the managers a good understanding for the impact on system performance of changes in the number of customers purchasing the rapid program and in the number of agents. The one-minute guarantee would be fairly easy to achieve, even if the percentage of callers in the rapid program became quite high. Managers also gained confidence that, with appropriate staffing levels, they could successfully implement the new program, which they soon did.

X Cases

1. Sasser, W. Earl, Jr., Ramchandran Jaikumar and David C. Rikert. Sof-Optics, Inc. (A). Case, Harvard Business School, 1980, 24 pp. Ref. No.: 9-681-052.

Abstract. The marketing director of a fast-growing firm must make some decisions about the customer service department. The volume in the department has been rising steadily, eye doctors are waiting longer for orders to be filled, and morale in the department is slipping. With pressure on the firm to make a profit, the marketing director must carefully justify any request for additional people or equipment.

Keywords: Capacity analysis, Customer relations, Customer service, Employee morale, Medical supplies, Scheduling, Systems analysis, Work force management

2. Jaikumar, Ramchandran. Sof-Optics, Inc. (B). Case, Harvard Business School, 1984, 14 pp. Ref. No.: 9-684-045.

Abstract. Involves the introduction of a technology which almost completely eliminates direct labor for a major segment of the product line. The technology is unproven though, and requires managing the learning process. The teaching objective is to review the differences in managing change between fixed and variable cost-intensive technologies and additions of manufacturing capacity.

Keywords: Automation, Capacity analysis, Management of change, Production capacity, Technological change

3. Bless, Martin and Christopher H. Lovelock. BT: Telephone Account Management. Case, International Institute for Management Development (IMD), Lausanne, Switzerland, 1993, 17 pp. Ref. No.: 593-011-1.

Abstract. To better serve its small business customers, whose sales volume does not justify personal visits from field account managers, BT (formerly British Telecom) has created an account management programme that uses the telephone as its channel. Carefully trained telephone account managers (TAMs) maintain relationships by phone, undertaking consultation, selling and problem solving. The manager of sales development is now debating what mix of field and telephone-based channels are appropriate for larger customers. Sharpening the debate is how to respond to a protest from a growing customer which has been upgraded against its will from a TAM to a field account executive. There is a French translation available (F593-011-1).

Keywords: Account management, Sales, Technology, Implementation, Relationships

4. Drummond, G. and I. Walker. First Direct. Case, Napier University, Edinburgh, 1993, 5. pp. Ref. No.: 593-058-1.

Abstract. The case examines the development of telephone banking. It considers how modern technology is influencing the distribution of financial services. Issues relating to promotional strategy and customer service are also discussed.

Keywords: Marketing financial services, Product strategy, Promotional strategy, Distribution of services, Customer service

5. Roberts, M.J. ACTC Customer Service Department. Case, Harvard Business School, 1993, 10 pp. Ref. No.: 9-393-056.

Abstract. Focuses on the young general manager of a new cable TV system, and on its customer service department. Jeanne LaFrance, the general manager, has an uneasy feeling about the way in which the department is being managed. She sees symptoms of what she suspects are serious problems. It takes too long for customer service reps to answer the phone, many customers hang up before their call is answered. There is little in the way of performance standards, measures, or controls. Yet there is not enough data in the case for students to resolve these issues. The objective is to develop a plan for learning about these problems. What are their hypotheses about the issues? What analysis would they need to do to address these issues? How would they get the data to do this? A companion case to Jeanne LaFrance.

Keywords: Customer service, Growth management, Operations analysis, Organizational design, Organizational problems, Telecommunications

6. Husock, H. Central Complaint and Information Service for Louisville: City Hall (A). Case, Kennedy School of Government, 1996, 12 pp. Ref. No.: KSG1355.0.

Abstract. The belief of Louisville, Kentucky Mayor Jerry Abramson in improved service to citizen “customers” leads to the 1989 establishment of a centralized complaint/information system—a single phone number to which complaints or inquiries about any of the city’s 25 departments can be made. But despite apparent success and a high public profile, managers of the “CityCALL” system become frustrated with what they view as inefficiencies in their relationships with other city agencies. Some are linked to CityCALL by computer; others show little apparent inclination to cooperate. The case calls for consideration of how City CALL could be improved through the vehicle of Louisville’s “CityWork” system, in which public employees, in a retreat-style setting, are called upon to offer specific suggestions for change.

The case explores the evolution of an innovative program—its unexpected side effects and the sort of resistance it encounters. It highlights, as well, Mayor Abramson’s contention that a system of cooperative program evaluation—CityWork—can lead to efficiencies which rival public/private competitive bidding and other “privatization”-style strategies.

Keywords: Customer service, Innovation, Privatization, Technological change

7. Husock, H. Central Complaint and Information Service for Louisville: City Hall (Epilogue). Case, Kennedy School of Government, 1996, 2 pp. Ref. No.: KSG1355.1.

Abstract. As above in previous item.

8. Kaboolian. Ruthless with Time and Gracious with People? Teleservice at the Social Security Administration. Case, 1996, 9 pp. Ref. No.: KSG1338.0.

Abstract. Within three years of its implementation, the Social Security Administration's nationwide 800 telephone service was handling the largest volume of 800 calls of any organization in the world. In addition, to this volume, approximately 15 million callers got a busy signal rather than an answer. Even so, the SSA projected an annual increase in calls, due in part to a high level of customer satisfaction with the service provided by the SSA operators. Part of the historic legacy of protecting the public from government inefficiency and malfeasance is the widespread imposition of controls in the authorizing environment. Executive agencies that control budgeting and procurement are preeminent in this regard, and, in conjunction with legislative oversight, produce a tension that can retard dynamic service initiatives. Can government trust itself and create an "okay to fail" zone?

Keywords: Customer service, Information technology

9. Hamilton, R. and G. Sharkey. McQueen Group. Case, Napier University, Edinburgh, 1997, 29 pp. Ref. No.: 397-013-1.

Abstract. McQueen Limited, a Scottish printing company founded in 1846, has expanded from selling office equipment and PCs to be a major licensed manufacturer and distributor of USA software products. Through organizational changes to its value chain, it can now deliver a total integrated manufacturing and distribution service including a multilingual call center offering direct marketing and order fulfillment facilities. Great stress is laid on team working and high quality standards. This offers major USA software companies ready and quick access to European markets without having to hold their own distribution systems.

Keywords: Core competence, Software business environment, Call centres, cultural infrastructure, Software publishing, Integrated, Services, Value chain

10. Larreche, J-C., Lovelock, C. and D. Parmenter. First Direct: Branchless Banking. Case, INSEAD, Fontainebleau, France, 1997, 32 pp. Ref. No.: 597-028-1.

Abstract. First Direct has become the model of telebanking worldwide, despite similar initiatives undertaken by large international banks. The case describes the history of First Direct and the various components of its operations, especially around the central issue of relationships marketing at a distance. It helps students to understand all the various facets of a modern operation which makes it effective, unique and difficult to imitate. A superficial analysis of this successful new model, or of other ones, leads to fast conclusions and pole imitations. There is a Spanish translation available (E597-028-1). ECCH European Case Awards Overall Winner, 2000. This case contains colour exhibits.

Keywords: Marketing, Direct marketing, Relationship marketing, Services, Banking, Telebanking

11. Zeynep Aksin-Karaesmen, O. and P.T. Harker. Nationsbank Reinvents the Phone Channel (A): The Design Decision. Case, INSEAD, Fontainebleau, 1998, 20 pp. Ref. No.: 698-065-1.

Abstract. The process of designing the new phone system and the logic underlying the various choices involved are described, along with a discussion of the options for design, to give

an understanding of the range of possibilities in call center design. The question of differential service levels and sales efforts is described. Teaching objectives are to help students understand how operational and marketing considerations must be integrated when designing a telephone channel, and to raise the question of where and when differential service levels are appropriate.

Keywords: Call center design, Service level differentiation, Skills-based routing, Segment-based cross-selling, Customer focused redesign, Human resource issues, Information technology issues

12. Agrawal, M.L. and P. Vagn Freytag. Call Center Europe. Case, Denmark, 2000, 19 pp. Ref. No.: 500-019-1.

Abstract. The case is about the Call Center Europe (CCE), one of the largest call centres in northern Europe. CCE specializes in representing business clients to their customers with a series of inbound and outbound calling services. As the trend for call centres is to grow into web-enabled customer care and contact centres, CCE needs to remain in readiness to face the emerging challenges and seize newer growth opportunities in the overall discipline of customer relations management (CRM). The case aims to initiate a discussion regarding these very needs and issues relating to growth options for the CCE. The case is targeted at the final-year students in full-time MBA programmes in marketing business and policy and services marketing. It may be more useful to the executive MBA or the short-term training programmes for the practising manager also in Europe and in Denmark.

Keywords: Firm's growing strategy, Customer relationship, Outsourcing

13. PrimeGain Funds. Case, Graduate School of Business, Stanford University, 2000. Ref. No.: T262.

14. Rohall, Douglas D. Internet Economy?: No More Golf (Guest Column). Case, *Harvard Management Review*, 2000, 1 pp. Ref. No.: U0004C.

Abstract. Douglas D. Rohall, a director of the Monitor Group, discusses how the abolition of human intermediate-sales people, call center staff, brokers—will change your business, and how firms once again need to reinvent themselves.

Keywords: Contracts, Outsourcing

15. Gallagher, J.G. Kwik-Fit Insurance Services (KFIS). Case, Napier University, Edinburgh, 2001, 20 pp. Ref. No.: 501-005-1.

Abstract. Direct Line entered the motor insurance market in 1985 selling motor insurance directly to customers over the phone. For the next decade the industry was characterized by an increase in this type of selling. By 1995 even though the market for direct marketing of motor insurance was saturated, other companies still entered it. In particular, Sir Tom Farmer's Kwik-Fit Group set up Kwik-Fit Insurance Services. He did so by challenging the industry's established players from the basis of the credibility of their brands. Moreover, he used his experience of both marketing and organizational culture and philosophy as well as an established

customer database to drive KFIS's offerings. The ethos which drives Kwit-Fit Holdings is one of customer delight. Offering motor insurance was seen initially as a means of adding value for the Kwik-Fit customer. However, KFIS rapidly captured 2% of the £7bn market and perspectives changed.

Keywords: Direct marketing, Database management, People relationships and culture, Call centre management, Brand management, Brand stretching

16. Nov, Yuval and Michael Harrison. Call Center Design for Lion Financial Services. Case, Stanford University Graduate School of Business, 2001. Ref. No.: S-OIT-29.

17. Arussy, Lior. Don't Take Calls, Make Contact. Case, *Harvard Business Review*, 2002, 2 pp. Ref. No.: F0201A.

Abstract. Almost every call center strives to process inquiries and complaints quickly. But by stressing speed over service, centers usually end up annoying customers instead of helping them. Here's how to change that.

Keywords: Customer relations, Customer retention, Customer service

18. Mukund, A. CRM/KM Initiatives at 3M. Case, ICFAI Centre for Management Research (ICMR), India, 2002, 9 pp. Ref. No.: 902-018-1.

Abstract. The case examines the reasons behind 3M's decision to implement customer relationship management (CRM) and knowledge management (KM) software. With 3M's product portfolio becoming increasingly complicated, the agents at its call centers were finding it difficult to answer customer queries satisfactorily. This acted as the trigger for 3M's decision to implement the Remedy Action Request and System (RARS) and Primus eCRM solutions. The implementation procedure and the benefits derived by the company are explored in detail. The case is so structured as to enable students to: (1) understand why large and diversified companies with diverse product portfolios need to introduce sophisticated technologies to provide efficient and effective customer service; (2) understand the processes and design considerations involved in implementing a CRM/KM system in a large company; and (3) discuss the success of the CRM/KM project and 3M. The case is aimed at MBA/PGDBA students, and is intended to be a part of the knowledge, information and communication systems management curriculum.

Keywords: Customer relationship management, Knowledge management, 3M, Call centers

19. Mukund, A. The Indian Call Centre Journey. Case, ICFAI Centre for Management Research (ICMR), India, 2002, 8 pp. Ref. No.: 402-019-1.

Abstract. The case is intended to give a detailed insight into the reasons behind the call centre industry not being as successful as expected in India. The problems on the human resources front are explored in detail. The case also gives a brief insight into the concept, history and functioning of call centres. The case is so structured as to enable the students to understand the emergence of the call centre industry in India. The students should essentially be able to

understand the necessity of call centres for various businesses and their functioning in brief. The students should also understand how and why the Indian call centre industry's performance was below expectations. The case is aimed at the MBA/PGDBA students as part of the human resource management/organisational behaviour curriculum.

Keywords: Indian call centre business, Call centre performance issues, Employee retention problems at call centres

20. Ryals, L. Total Customer Recognition: CRM at Wesleyan. Case, Cranfield School of Management, 2002, 15 pp. Ref. No.: 502-021-1.

Abstract. This is a case study about how Wesleyan Assurance Society worked towards a total view of their customers by implementing CRM. The case looks at the subsequent development in Wesleyan's data warehouse, Contact Centre and website. The events in this case take place after the successful introduction of Sales Force Automation (SFA) described in 'Going the Extra Mile: CRM at Wesleyan' (501-053-1). A mutual assurer founded in 1841, Wesleyan has grown partly by acquisition. Its major subsidiaries include Medical Sickness Society, and Provision (formerly part of Clerical Medical). Wesleyan also sells products on behalf of the Prison Officers Association. Encouragement for a full CRM project came not only from the successful implementation of the SFA system, but also the need to demonstrate value added at a time of considerable negative coverage of previous mis-selling, high commission rates and threats from new entrants.

21. Bendixen, M. and C. Gordon-Brown. Multichoice Africa: Managing the queue. Case, Wits Business School, University of the Witwatersrand, South Africa, 2003, 6 pp. Ref. No.: 403-065-1.

Abstract. It was late on a Tuesday afternoon at the beginning of March 2003. Eddie Moyce, Call Centre Manager for MultiChoice Africa, a multichannel television platform, was examining the results of some recent market research that had been presented that day. The research had shown that while customers who had phoned the call centre were generally satisfied with the service they received, they were dissatisfied with the length of time it took for their calls to be answered. The call centre was strategically important in building and maintaining relationships with MultiChoice customers and the company's senior management had reacted strongly to this finding. They had asked Moyce to investigate the possibility of improving the response time from the current 80:30 to 80:20 or even 90:10. What would the impact of reducing response times be? Would it be possible to reduce response times while staying within budget? Management had recently imposed severe austerity measures on the company, even reducing the call centre's budget in the last two years.

Keywords: Topic queuing theory; Call centre management

22. Reinartz, W.J. and U. Wiehr. Customer relationship management at Capital One (UK). Case, INSEAD, Fontainebleau, 2003, 36 pp. Ref. No.: 503-067-1.

Abstract. Capital One, a credit card company, has built its business on a strategy with a clear

customer focus: The company systematically gathers and analyzes information on its customers in order to correctly assess their individual credit risk and to offer products and services tailored to their individual needs. The case is designed to illustrate how the concept of customer relationship management (CRM) can be translated into strategy, organisational design, hiring, marketing processes, and IT infrastructure of a company. The teaching objective is fourfold: (1) to present a best-practice organisation that embodies the concept of CRM; (2) to enable a discussion around the definition of CRM; (3) to recognise why effective CRM cannot only be practised within the marketing function, but has to be adopted by the entire organisation; and (4) to recognise the important role of the human resources function and the IT function in a company-wide CRM strategy.

Keywords: Customer relationship management, Financial services, Credit card, Marketing strategy, Database, IT, CRM, Call centre

23. Silvestro, R., C. Silvestro. New service design in the NHS: An evaluation of the strategic alignment of NHS Direct, *International Journal of Operations & Production Management*, 23 (4), 2003, 401–417.

Abstract. Awareness of inconsistencies and variability in the delivery of health services across the UK has heightened in recent years, leading to general acknowledgement that a move away from “health care by post code” is a strategic priority for the National Health Service (NHS). NHS Direct, a call centre service for patients and their carers, is unique in the NHS in that it represents an entirely new service concept, with a rare opportunity to design a single nation-wide service from scratch, and to manage and coordinate a delivery system consistently throughout the country. Evaluates the strategic alignment of NHS Direct during the first three years of implementation through an analysis of its service concept, its operational objectives, the design of its delivery systems and its volume and variety characteristics. The evaluation reveals an absence of a central design specification which has resulted in wide variation in the call centres’ service portfolios, resource bases, competencies, telephony and clinical expert systems. Contends that variation and variability in the design of the call centres has severely compromised NHS Direct’s ability to meet its strategic and operational objectives, resulting in strategic misalignment. Also identifies missed opportunities to learn from the growing call centre literature and from service shops in other industries.

Keywords: Service design, NHS Direct, Strategic alignment, National Health Service, Call centre service, Operational objectives, Strategic misalignment
(Appears also in Section VIII.)

24. Singhal, H.K. and D.G.. Prasad. Call centers and customer relationship management in insurance organisations. Case, ICFAI Center for Management Research (ICMR), India, 2003, 3 pp. Ref. No.: 503-054-1.

Abstract. The case focuses on improving customer relationships in insurance organisations. It discusses the role of call centres in improving customer relationships in insurance organisations and examines the way in which these organisations can improve the functional performance of call centres. The case also discusses the role of technology in managing call centre operations. The case is structured to enable students to: (1) understand the role of customer relationship

management in the competitive business environment; (2) understand the process of call centre operations; (3) understand the role of technology in managing call centre operations; and (4) understand how call centres function. The case is intended for MBA/PGDBM level students as part of the management of insurance companies, services marketing and marketing management curricula.

Keywords: Call centres, Customer relationship management, Communication channels; Web-enabled insurance agents

25. Singhal, H.K. and C. Sridevi. Call center operations in insurance. Case, ICFAI Center for Management Research (ICMR), India, 2003, 4 pp. Ref. No.: 503-008-1.

Abstract. The case examines the issues involved in the delivery of an insurance service and the procedures and patterns of delivery. It focuses on the activities that need to be performed for efficient production and delivery of a service. The case also discusses various issues relating to technology-based services. In particular, the case focuses on the use of technology by insurance companies to enhance customer service. The case is structured to enable students to: (1) understand the significance of process management in the production and delivery of a service in an insurance organisation; (2) understand the problems associated with the use of technology in providing service; (3) understand the potential of call centres (of insurance organisations) for providing effective services; and (4) understand the relationship between information systems and marketing research. The case is aimed at MBA/PGDBA students, and is intended to be a part of the insurance marketing curriculum.

Keywords: Motor vehicle insurance, Marketing information system, Call routing, Performance-based reward system

26. Bendixen, M. and C. Mitchell. Vodacom Customer Care. Case, Wits Business School, University of the Witwatersrand, South Africa, 2004, 22 pp. Ref. No.: 404-032-1.

Abstract. Vodacom Customer Care provided an extensive training programme for new call centre employees. It had also made an effort to ensure that the work environment at its various call centres was pleasant with modern amenities. The company provided its staff with sophisticated backup systems such as an on-line knowledge base nicknamed 'The Chad' that kept them abreast of the many developments relating to Vodacom products. Performance of call centre agents was measured against a detailed bonus calculator system. In October 2002, the number of calls handled by each call centre agent was added to the list of criteria against which performance of call centre agents was measured. This had prompted a change in the relative weighting of each of the factors that contributed to the final bonus calculation. Ibeth Toerien, Executive Director of Customer Care at Vodacom (Pty) Ltd., and Lori Kasselmann, Vodacom's executive head: Capacity building and development reflected on whether it had been worthwhile adding quantity of calls handled to the bonus calculator. They debated whether it achieved the desired balance between quantitative and qualitative measures.

27. Feinberg, Richard, Ko De Ruyter and Lynne Bennington. *Cases in Call Center Management: Great ideas (Th) at Work* (Ichor Business Series), Purdue University Press, January 2004.

ISBN: 1557533423 (paperback: 250 pages).

28. Singhal, H.K. Demand estimation for a call center. Case, ICFAI Center for Management Research (ICMR), India, 2004, 3 pp. Ref. No.: 604-003-1.

Abstract. The case examines the wide variation in the demand for call centres. It discusses the importance of demand forecasting for call centres. The case also takes a look at difficulties involved in estimating the demand for call centres. It also discusses the various strategies that can be adopted to overcome uneven demand conditions. The case is structured to enable students to: (1) understand the operations of call centres; (2) understand the importance of demand forecasting for call centres; (3) understand difficulties in demand estimation; (4) understand the role of technology in meeting uneven demand; (5) understand the need for training customer service representatives; and (6) understand the significance of production and operations standards. The case is intended for MBA/PGDBM level students as part of the operations management curriculum.

Keywords: Capacity decisions, Response time, Demand estimation

29. Abbott, Julie and Pak Yoong. The stages of telecentre development: The case of the Kapiti Telecentre, *Technovation*, 25 (4), 2005, 421–431.

Abstract. This paper describes part of a research programme that explores the development of telecentres and the role of key players in these ventures. A single case study was conducted on the development of the Kapiti Telecentre, which is based on the Kapiti coast, a semi-rural and developing community situated approximately 50 km north of Wellington, New Zealand. The Kapiti Telecentre is unique among telecentres in that it is a collaborative project between business and community organisations. Several workers from city-based businesses are using the telecentre as a teleworking hub whilst the community users have initiated a major community IT educational programme based at the centre. A Board of Trustees provides governance of the telecentre and trustees come from the business, community and academic institutions. Initial results from this study suggest that the development of the Kapiti Telecentre follows four distinct stages: Germinating, Seedling, Sapling and Maturing. Details of the development activities during each stage will be described. The paper concludes by suggesting a number of implications for future telecentres development.

Keywords: Community development, Call centers, Information technology, Studies
(Appears also in Section VIII.)

30. Anonymous. Financial Information Technology Gold Award Winner: This is one boss that can really make your workload lighter, *Treasury and Risk Management*, 15 (10), November 2005, 20–21.

Abstract. Providian Financial Corp is the 2005 Alexander Hamilton Financial Information Technology gold award winner. Providian's retail deposits call center provided a critical source of funding for the company's credit card operations as well as an important interface with customers opening new accounts or servicing existing ones. Trouble was, it was holding the business

back. Providian's goal was to build a back office support system (BOSS) that could track and make accessible up-to-date customer transactions and comments to service staff on demand. The solution came from a combination of in-house software designs combined with existing technologies from back-end service provider Metavante and a fraud detection application from RiskWise. The resulting BOSS platform combines the proprietary application with an Oracle database. The project was completed in 2004. In the first year of the BOSS automation improvements, the number of new accounts handled swelled by 450% as staffing fell by 27%.

Keywords: Financial institutions, Call centers, Systems design, Awards & honors, Information technology, Corporate profiles

31. Cordray, Kevin. High retention rates bring customer benefits at SITEL Direct, *Human Resource Management International Digest*, 13 (4), 2005, 23–25.

Abstract. This paper explains SITEL Direct's approach to staff retention and how successful strategies to empower, encourage and promote employees provide business benefits to its clients and their customers. It highlights the main benefits available to agents working in SITEL's bureau and fulfillment programs: varied work, flexible hours, good training and personal development opportunities, and the chance to work in one of England's prettiest towns. The paper emphasizes the importance of having a settled team. It shows that SITEL has established a monthly retention target of 95% for its bureau agents, but in 2004, there was an average monthly retention rate of 97.2% in quarter one, 95.9% in quarter two and 94.3% in quarter three. Fulfillment has achieved even higher retention rates. With a similar target of 95% monthly retention, the program in 2004 achieved an average monthly retention rate of 100% in quarter one, 97.2% in quarter two and 97.8% in quarter three. High staff turnover need not, in all cases, characterize the call-centre industry. The agents working in SITEL's bureau and fulfillment programs are critical to the success of a client's campaign, as they are the first people that consumers interact with either directly or indirectly.

Keywords: Case studies, Human resource management, Employee turnover, Call centers, Customer relations, Telecommunications industry
(Appears also in Section IV.)

32. Gollan, Paul J. Silent voices: Representation at the Eurotunnel call centre, *Personnel Review*, 34 (4), 2005, 423–450.

Abstract. This research aims to examine nonunion and union representative arrangements at the Eurotunnel call center and assesses their effectiveness in representing the needs of employees. The research examines these issues over a five-year period using a series of employee surveys, interviews and focus groups. This period has also allowed a review of consultation arrangements before and after union recognition and an examination of the outcomes from such arrangements. The evidence suggests that the nonunion voice structures at Eurotunnel are used as devices for information and communications rather than true consultation mechanisms or bargaining agents. However, the challenge for the trade union at the Eurotunnel call center is that what can be regarded as a success in some aspects has not resulted in a change in attitudes towards unions by a majority of Eurotunnel employees. This could be seen as one of the major challenges for union-employer partnership arrangements.

Keywords: Labor unions, Studies, Human resource management, Nonunion, Call centers, Collective bargaining
(Appears also in Section VIII.)

33. McElhinney, David and Tony Proctor. Concept of entrapment and decision-making, *Management Decision*, 43 (2), 2005, 189–202.

Abstract. This paper informs executives of the dangers of entrapment which can occur when there is an increasing commitment to an ineffective course of action to justify previous allocation of resources when managing new projects. It reviews research studies on establishing call/contact-centres in local government across the UK. Data was also collected via interviews with executives in authorities experienced in setting up call/contact centres. Centres involve spending millions of pounds but there was only limited knowledge of capital or ongoing revenue costs. Evidence of internal resistance, lack of any shared vision, or knowledge of the level of risk existed, as well as only a limited understanding of the centres' organisational impact, potential benefits or added value. There was an absence of stated project objectives or formal project appraisal and a creeping commitment to the projects continuation. The potential for entrapment existed. A single case study but one which adds to the existing literature on entrapment and focuses attention on the risks that can exist in the public sector. Underlines the importance of setting out specific procedures for evaluating the potential costs/benefits and subsequent progress of new, particular large-scale, business projects.

Keywords: Studies, Call centers, Decision making, Local government, Project management
(Appears also in Section VIII.)

34. Williams, Margaret, Cathryn Bradshaw, Beverly Fournier, Admasu Tachble, et al. The call-centre: A child welfare liaison program with immigrant serving agencies, *Child Welfare*, Washington, 84 (5), Sep/Oct 2005, 725–746.

Abstract. Alberta, Canada, welcomed nearly 16,000 landed immigrants in 2003, of whom more than half came to the Calgary area. Approximately 200,000 immigrants of various ethnic and cultural groups now live in the region. Many of these new arrivals have no natural support networks while struggling with language, cultural, and economic barriers. Recognizing these difficulties, the Calgary and Area Child and Family Services Authority (CFSA) joined with several Immigrant Serving Agencies to develop guidelines and procedures to direct staff working with diverse cultures, including the Call-Centre pilot project, which provided CFSA staff with a one-stop telephone contact for information about an immigrant or refugee family, their culture, and available culturally-appropriate resources. The Call-Centre, which is currently being evaluated by researchers at the University of Calgary, will gradually expand to all CFSA sites in the region. This article describes the Call-Centre and the first phase of the evaluation.

Keywords: Call centers, Child welfare, Refugees, Culture, Aliens
(Appears also in Section VIII.)

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3. Gable, Robert A. *Toll-free Services: A Complete Guide to Design, Implementation, and Management*. Boston, MA: Artech House, 1995.
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Accurate and easy to use, *ICMI's Call Center Management Dictionary* is designed to cut through the clutter and confusion in today's terminology, so that you can communicate more effectively,

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The *Call Center Operations Management Handbook and Study Guide* provides this solid foundation through an examination of key performance indicators, call center planning and management processes, call center technology and facilities management. The guide begins with an explanation of service level and response time—key objectives that measure the accessibility of the center. A detailed examination of other key performance indicators follows. The third section of the guide provides an in-depth discussion of the planning and management processes upon which call center operations depend, including forecasting, staffing and scheduling. The guide then transitions from processes to technology with an integrated look at the technologies present in the best of today's centers. The guide closes with site selection, call center design, health and safety issues, and disaster recovery principles.

60. Coen, Dan. *Inspiring Call Center Performance*. DCD Publishing, 2003.

ISBN: 0966043650

Book Description: Is it time to drive performance in your call center?

Inspiring Call Center Performance is a terrific book to teach managers the principles of creating dynamite results in the call center.

It was written for managers, executives, supervisors and trainers who manage call centers, inside sales and customer care departments.

This audio book focuses on the skill sets to manage people and operations. Topics include:

- Building a performance-based culture
- Understanding the key elements of call center management
- Having a daily game plan
- Developing training programs to impact performance
- Using communication channels to motivate employees
- Exploring how agents see the call center
- Tips and ideas to inspire call center staff

Designing a complete call center program is the key for management to build results in their call center. This audio book provides a taste of how managers can do better to supervise, motivate and inspire call center performance.

61. Reynolds, Penny. *Call Center Staffing: The Complete, Practical Guide to Workforce Management*. The Call Center School Press, 2003.

ISBN: 0974417904

Book Description: Call Center Staffing: The complete, practical guide to call center management, takes the reader through the step-by-step process of forecasting workload, calculating staff, creating schedules, tracking daily performance, and managing by the numbers in a call center. Topics include:

Overview of call center staffing issues

Data gathering and analysis

Forecasting workload

Calculating staff requirements

Creating staff schedules

Skill-based routing and scheduling

Managing intra-day staffing and service

Calculating trunk/network requirements

Staffing for multi-media contacts

Automating workforce management

Call Center staffing alternatives

Workforce management roles and responsibilities

This book is designed to be a how-to guide to enable today's call center professional to master the art and science of call center staffing.

62. Stolletz, Raik. *Performance Analysis and Optimization of Inbound Call Centers*. New York: Springer, 2003.
ISBN: 3540008128
Subjects: Call centers—management, Call centers—mathematical models
63. Yarberry, William A. *Computer Telephony Integration*, 2nd edition. Boca Raton, FL: Auerbach, 2003.
ISBN: 0849314380
Subjects: Internet telephony, Digital telephone systems
64. Butler, David L. *Bottom-Line Call Center Management: Creating a Culture of Accountability and Excellent Customer Service*.
Series: Improving human performance
Butterworth-Heinemann, March 2004.
ISBN: 0750676841
Subjects: Call centers—Management
65. Deery, Stephen and Nick Kinnie (eds.). *Call Centres and Human Resource Management*. Basingstoke, Hampshire; New York: Palgrave Macmillan, 2004
ISBN: 1403913048.
66. Dorman, Christian and Fred R.H. Zijlstra (eds.). *Call Centre Work: Smile by Wire*. Special Issue of the *European Journal of Work and Organisational Psychology*, 12 (4). Psychology Press,

2004

ISBN: 1841699691

Book Description: Organizations are looking for ways to be accessible to their customers, to be able to promptly answer questions, or to provide reliable and up-to-date information. This has resulted in the creation of specialized departments for customer contacts: the call centre. Most articles in this text are concerned with the working conditions at call centres.

XII Call Center Journals and Magazines

1. *Call Center Management Review*
Trade Monthly
<http://www.incoming.com/slccmr.html>
2. *Call Center Magazine*
Publisher: C M P Media Inc.
Trade Journal, US
<http://www.callcentermagazine.com>
3. *CC News*
Publisher: United Publications, Inc.
Trade Newspaper, US
<http://www.CCNew.com>
4. *Customer Inter@ction Solutions*
Publisher: Technology Marketing Corporation
Trade Monthly, US
<http://www.tmcnet.com/cis>
5. *Australian Call Centre and Customer Service Remuneration Review*
Publisher: Cullen Egan Dell
Trade Annual, Australia
6. *Call Centre Europe*
Publisher: Stanworth Communications
Trade Monthly, UK
7. *Call Centre Focus*
Publisher: CALLcraft
Trade Monthly, UK
<http://www.callcentre.co.uk>
8. *Call Center Magazine*
Publisher: I I A Publishing Pty. Ltd.
Trade Weekly, Australia
9. *Customer Interface Magazine*
Trade Monthly, UK

<http://www.c-interface.com/customerinterface/>

10. *International Journal of Call Centre Management*
Winthrop Publications Ltd.
Quarterly, UK
<http://www.winthrop-publications.co.uk/CCMFrontpage.htm>
11. *Communications Convergence*
Publisher: CMP Media
Trade Monthly
<http://www.convergence.com>

XIII Web Sites

1. Service-Engineering of Call Centers
<http://ie.technion.ac.il/serveng>
(An academic course, with call centers as its application-focus; research and review papers, including the present Bibliography, are downloadable from
<http://ie.technion.ac.il/serveng/References/references.html>;
additional material for Teachers of the subject is available upon request from Avi Mandelbaum, at avim@tx.technion.ac.il.)
2. Call Center Managers' Forum
Call Centre Managers "Oasis".
www.callcentres.com.au
3. Benchmark Portal (Purdue University Customer-driven quality)
<http://www.BenchmarkPortal.com>
4. CCA—The Professional Body for Call and Contact Centers
<http://www.cca.org.uk>
5. Incoming Calls Management Institute (ICMI)
<http://www.incoming.com>
6. Call Center Network Group (CCNG)
Global Association for Customer Contact Management
<http://www.ccng.com>
7. Call Center News Service
<http://callcenternews.com>
8. ACD Call Center Learning Center
<http://www.call-centers.org>
9. Call Center Exchange
<http://www.callcenterexchange.com>
10. Contact Center World
<http://www.callcenterworld.com>
11. The Call Center Directory
<http://www.call-center-directory.com>
12. International Call Center Benchmarking Consortium (ICCBC)
<http://www.iccbc.org>
13. CallVoice
<http://www.callvoice.com>
14. callcenterbiz
<http://www.callcenterbiz.com>

15. The UK Contact Centre Industry: A Study report by CM Insight, ContactBabel, Call and Contact Centre Association (CCA), on behalf of the UK Department of Trade and Industry, May 2004.
<http://www.dti.gov.uk/ewt/contactind.pdf?pubpdfdownload=04>