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• *Innovations In Transportation: The Case of Telecommuting*

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Abstract

Telecommuting has been proposed as a trip reduction measure to alleviate traffic congestion and reduce energy consumption and air pollution. Hypotheses on the potential impacts of telecommuting are conflicting. This paper offers empirical evidence on the short term impacts of telecommuting on travel demand using results from the State of California Telecommuting Pilot Project. Extensive discussions are provided on its possible long term impacts and on how innovations such as telecommuting should be implemented by stages. In this paper, we argue that technological and institutional innovations such as telecommuting, staggered work hours, etc., should be implemented jointly within a unified legislative and planning framework. Regulation XV of the South Coast Air Quality Management District has been used as a case study to illustrate a possible implementation strategy within a planning context to obtain desired results.

Introduction

Effective management of travel demand is a growing concern among transportation planners, engineers, local governments and business establishments. Most of the industrialized countries have realized that increasing transport capacity to satisfy travel demand is not a viable option for meeting future needs [AASHTO, 1988]. This realization was the result of growing energy, environmental, and air quality considerations which discouraged the expansion of existing transport systems supply. Transportation consumes 63% of all petroleum used in the United States [EIA, 1988a] and over 70% in California [CEC, 1987]. United States oil imports are forecast to increase from 5.8 million barrels per day in 1987 to between 7.6 and 11.6 million barrels per day by the year 2000 [EIA, 1988b] and the single greatest opportunity for reducing petroleum consumption lies in the transportation sector. On the environmental front, continued reliance on the private automobile continues to raise serious questions about our air quality. In 1987 the Environmental Protection Agency reported that 107 metropolitan areas in the U.S. violated the primary health standard for ozone, carbon monoxide or both [Sperling and Deluchi, 1989] – 12 of these regions were in California. On-road mobile sources are forecast to emit 61% of the total CO and 47% of NOx (an ozone precursor) in California [CARB, 1988]. Thus, the focus of transportation planning has shifted from the construction of new facilities to the application of efficient travel demand management techniques.

In response to these urgent problems, the California State South Coast Air Quality Management District (SCAQMD) adopted Regulation XV in December 1987. This regulation requires all business establishments of 100 employees or more to provide a plan to reduce employees' commute trips. This is the first regulation of its kind in the United States that provides an administrative structure to support trip reduction. One of the trip reduction measures suggested as a feasible strategy is Telecommuting which involves the use of telecommunications equipment to perform work at home [SCAQMD, 1987].

The use of telecommunications to substitute for the commute to work has recently drawn extensive attention as a strategy for reducing travel demand. This came to be known as telecommuting, broadly defined as "the performance of work outside the traditional central office, either at home or at a neighborhood center close to home" [Kitamura, et al., 1990a]. Telecommuting is becoming increasingly feasible due to the rising proportion of information workers in the U.S. labor force [Kitamura, et al., 1990a]. Nilles [1988] provides a conservative estimate of 1 million for the number of workers in the work force who telecommute at least a portion of a day each week. Thus the potential for telecommuting as a means to mitigate urban traffic congestion, reduce transportation energy consumption, and improve air quality is substantial. However, the strategy adopted for implementing telecommuting is crucial for its success as a trip reduction measure. The need for the development of a flexible implementation strategy motivated this paper.

The State of California Telecommuting Pilot Project conducted in 1988 and 1989 offered the first opportunity to gather non-proprietary data on household travel behavior to assess the impact of telecommuting. The sample of the study comprises 222 State employees who participated in the

Pilot Project on a voluntary basis, and 189 of their household members of driving age. The participants recorded trip characteristics in three-day travel diaries both in 1988 and 1989. Thus, their travel characteristics were measured before and after the introduction of telecommuting in order to assess the differences in travel. It was found that, in a one year time period, telecommuting substantially reduced travel while virtually eliminating the commute trip.

The assessment of short term benefits does not, however, provide conclusive evidence regarding the possible long term impacts. There are other contributing factors such as human adjustment over time to imposed changes, acceptability by public and private employers and institutional and technological barriers that may determine the ultimate impacts.

Since changes in travel making are dependent upon a multitude of factors and telecommuting is just one among many trip reduction measures that can be implemented, a plan for the introduction of telecommuting, and any transportation innovation in general, has to be devised. This plan must provide flexibility to recover from any setbacks and prepare the platform for the introduction of innovations on a large scale. Also, the different innovations must be coordinated and implemented jointly to realize the maximum possible benefit.

In the next section, the different types of trip reduction measures and their objectives are presented. In the third section, the results of the telecommuting experiment conducted by the State of California Department of Transportation are outlined. Discussion on the possible long-term effects of telecommuting are provided in the following section. A stage-wise implementation plan of telecommuting is provided in the penultimate section. The last section contains a summary of our findings, recommendations, and conclusive remarks.

Trip Reduction Measures

Management of travel demand can be achieved by influencing demand through traffic control measures. These measures may be subdivided into direct and indirect measures. The direct measures involve imposing restrictions on travel or devising incentive structures for reducing travel, for example, car/van pool incentive structures, road and parking pricing, telecommuting, etc. These direct measures are implemented through Regulations. The indirect measures would include new road construction, HOV lane provision, closure of existing roads, and provision of alternative modes such as light rail. The adequacy and impact of each measure depends on the objectives at hand, the traffic problem itself and the constraints (economic or other). The evaluation of the success of each measure must be comprehensive to include possible primary and secondary effects.

A trip reduction measure is a strategy to reduce congestion, energy consumption and air pollution by modifying administrative and regulatory mechanisms surrounding travel. This paper is mainly concerned with telecommuting which is a direct trip reduction measure as it influences travel demand at its genesis.

An example of an institutional backbone of trip reduction measures is Regulation XV adopted in December, 1987 by the California State South Coast Air Quality Management District (SCAQMD). This regulation aims at reducing peak hour travel (6:00 am to 10:00 am) by decreasing the number of commute trips. The regulation provides a basis for the mandatory design and implementation of comprehensive trip reduction plans by all employers with 100 or more employees by the end of 1991. In particular, employers have to develop incentives for their employees' adoption of ride sharing, mass transit, lesser polluting vehicles, staggered work hours and finally, telecommuting.

The assessment of the impact of telecommuting on travel demand is a highly complex task. An issue of particular importance is whether telecommunications technologies act as substitutes for travel or whether a complementary relationship exists between telecommunications and travel [e.g., Salomon, 1986; Mokhtarian, 1988; Nilles, 1988]. Little empirical evidence appears to exist at present on the interaction between the two [Salomon, 1988].

Many hypotheses can be formulated on the impact of telecommuting on household travel (for related discussions, see Nilles, 1988 and Kitamura, et al., 1990a). It is convenient to classify these hypotheses according to a time frame into short-term and long-term hypotheses.

The most direct short-term hypothesis is that the number of trips generated by telecommuters will decrease due to the reduction in commute trips to and from work. Because work trips are most often made during the peak period, a decrease in peak-hour trips will follow as a direct consequence. In addition, the eliminated need to travel to work would lead to savings in both time and money. This in turn might result in an increased availability of discretionary time, flexibility in activity scheduling, and some monetary savings. One may then hypothesize that these changes could prompt new, discretionary trips such as social and shopping trips. Indeed, if the assumption is true that a person budgets a fixed amount of time for travel [Zahavi, 1974; Wigan and Morris, 1979], then those commute trips, eliminated by telecommuting, may be replaced by new trips; or, the time spent previously commuting will now be spent pursuing other activities in or around home. As a result, new trip destinations may be chosen to reach more desirable locations. Trips could be made by alternate modes of travel and scheduled at more convenient times. For example, shopping which used to be done on the weekends at a regional shopping center far from home may now be done at a neighborhood store near home on a telecommuting weekday. Thus one long trip may be substituted by numerous short home-based trips. This could, in turn, increase the feasibility of using alternatively fueled vehicles such as short range electric vehicles for trip making.

One may conjecture that the spatial distribution of trip ends may be concentrated around the home location rather than the work location when the worker telecommutes. This redistribution of trips may affect (suburban) congestion and air quality of telecommuting is widely implemented. Another important consequence of telecommuting is the removal of some of the work-related constraints. Relaxation of these constraints is likely to reduce the need to link trips, i.e., consolidation of several stops into one home-to-home journey. In fact a recent analysis of trip linking behavior under different conditions [Goulias, et al., 1990a] has shown that people increase their linking of trips under tighter constraints. If this in fact is the case, then telecommuting may lead to an increased number of sporadic home-based trips, leading to less efficient travel patterns and more cold starts. It is also conceivable that the flexibility and irregularity in work schedule brought about by telecommuting may lead to a change in mode use. For example, participating in a carpool may not be convenient to a telecommuter who does not commute every day, therefore he may choose to use his personal car when he commutes.

At the household level, it is conceivable that the presence of a telecommuter at home with his flexible work schedule may result in a reallocation of tasks among the household members [for example, Koppelman and Townsend, 1988]. This may streamline the distribution of travel patterns of the entire household, making possible more efficient engagement in out-of-home activities. On the other hand, the household members may choose to use the car left at home by the telecommuter who would otherwise take it to commute, possibly leading to increased proportion of car trips.

Thus, many changes are conceivable even within a short time frame. Some changes will be beneficial while others may not. The timing of these changes is also uncertain. A telecommuter and his household members would go through a process of experimentation and learning before they adopt a new pattern that best takes advantage of telecommuting. Adaptation to telecommuting thus involves a certain time lag whose length is not known.

Further impacts of telecommuting are conceivable in the long term. The reduced need to commute may prompt a household to own fewer cars. At the same time, telecommuting reduces the need to reside close to the work location. Hence, some telecommuters may use telecommuting "as the basis for moving farther away from work, which has possible negative effects on travel patterns" [Telecommuting Review, The Gordon Report, September 1, 1989]. Even though the testing of such long term hypotheses is not possible within the results of the pilot study, we will provide a discussion on how telecommuting can be implemented while keeping possible long term impacts in mind. However, many of the short-term hypotheses have been tested using the empirical evidence provided by the State Pilot Project. These hypotheses guided the statistical analysis performed in Kitamura, et al. [1990b]. In this paper an outline of the salient findings on the impact of telecommuting on household travel is offered.

Other potential benefits of telecommuting (e.g., reduced office space requirements, increased worker productivity) are being examined in detail by JALA Associates [1989] and will be briefly discussed in this paper to assess the potential for the penetration of telecommuting in private business establishments and occupational tasks other than those involving information processing.

Results of the State of California Pilot Project

The impact of telecommuting on travel demand was examined using three-day travel diary data obtained from State employees, participating in the State of California Telecommute Pilot Project, and from their household members of driving age. Travel data were collected twice, before and after telecommuting started, facilitating a before-and-after comparison of various aspects of household travel. The pilot project had involved 222 state employees from 14 agencies. Approximately half of these employees telecommuted on an experimental basis. The rest constituted a control group and commuted to work conventionally. The latter group reflected changes in the general travel environment and the comparison of the two groups allowed the isolation of the effects of telecommuting on travel. In this paper, results are presented on the travel characteristics of telecommuter households only. Results on the travel patterns of control group households and the comparison between the two groups of households can be found in Kitamura, et al. [1990b].

Of the 222 employees and 189 household members originally contacted, 123 employees and 71 household members reported their trips in both survey contacts. The 123 employees included 66 telecommuters and 57 control group members. These employees were residing mostly in the Sacramento Metropolitan Area. The telecommuters work at home on the average 1.25 days during three-day diary periods. There were 39 household members associated with the telecommuter households who responded in both survey contacts while their control group counterparts numbered 32. The results of the analysis offer strong empirical evidence that telecommuting is a viable trip reduction measure.

The major findings of the telecommuting pilot study are reported in Table 1 which summarizes travel indicators before and after telecommuting was initiated. On the days when they telecommuted, no work trips were generated by the telecommuters. The savings in time due to the elimination of the commute trips does not seem to have lead to an increase in non-work trips. Even though telecommuters found themselves with an increased flexibility regarding work schedules, etc., they did not choose to make any additional trips. We observed that telecommuters decreased their total distance traveled by approximately 20% over a three day period. Further, on average one telecommuting day reduced the vehicle miles traveled by more than 40 miles. Trips made on telecommuting days were of much shorter duration and involved less freeway use.

The most encouraging result, in light of the guidelines in Regulation XV, was obtained with regard to peak period trip generation. Telecommuters tend to make their trips during off-peak periods on telecommuting days. As a result, morning peak period trips were found to be reduced on the average by over 75%, and afternoon-peak period trips by about 60% on telecommuting days. This is in contrast to previous theories postulated regarding the impacts of telecommuting. The indications obtained in this study contrast the pessimistic views of Garrison and Deakin [1988] who postulated that telecommuting will not be a major trip reduction measure.

These results also seem to indicate that telecommuting yields energy savings. However, telecommuters use their cars for a higher percentage of trips when they work at home. This may, in part, be due to the reduced number of work trips, and the more frequent use of the car for non-work trips.

In general, the telecommuter household members did not increase their trip making. The travel indicators presented in Table 2 show that there is no substantial difference in their travel patterns between the two contacts.

The apparent reduction in the number of trips may, in part, be due to decrease in trip reporting across survey contacts. A salient finding was that the household members of telecommuters increased car use by 4% which is not significant when we consider that trip reporting and other statistical issues related to surveys might have caused this spurious effect. This is particularly important since additional family cars have become available for their use. In summary, the trip making of household members described in Table 2 shows stability in their travel behavior before and after the introduction of telecommuting.

In addition, we examined the trip linking patterns of telecommuters. Telecommuting leads to somewhat fewer linked trips [Kitamura, et al., 1990b]. This is presumably because no office-based trips can be made and non-work trips cannot be linked to commute trips when a worker telecommutes. As a result, trips tend to be home-based, forming the simple pattern, home-activity-home. However, the analysis thus far is not complete for the assessment of household task reallocation and activity engagement. More information regarding the destination choice of telecommuters is currently being collected and analyzed [for example, Wissen, 1989]. The changes in activity patterns that resulted from telecommuting are being assessed by constructing daily activity profiles of all participants before and after telecommuting.

Discussion

The study results outlined in the previous section support telecommuting as a travel reduction measure. Further analysis is needed to determine the region-wide impact of telecommuting on traffic congestion, air quality, and energy consumption. Regional effects of telecommuting depend on the number of workers who can telecommute, the frequency with which they telecommute, and the contribution that telecommuting can make towards reducing traffic congestion, pollution and energy consumption.

The implications of telecommuting are both short term and long term changes in travel patterns. In the short term, telecommuting resulted in not only a reduction in peak hour trip generation, which is the requirement of Regulation XV, but also a reduction in vehicle miles traveled. An added short term advantage of telecommuting may be the release of existing pressure at the work-place (both parking space and work space).

On the other hand, it has been observed that people tend to choose locations for non-

TABLE 1

Impact of Telecommuting on the State Employees' Travel

Travel Indicators	*Before*	*After*	
		T/C day*	*Non T/C day***
Number of Trips per day	3.91	1.92	3.95
Number of Trips to Work per day	1.11	0.03	1.13
Number of non Work Trips per day	2.80	1.89	2.82
Number of Peak-Period Trips (7:00-9:00 am)	1.18	0.21	0.92
Number of Peak-Period Trips (4:00-6:00 pm)	1.39	0.45	1.15
Average Distance Travelled per day (miles)	54.5	9.4	52.6
Average Trip Duration (minutes)	21.0	4.9	13.5
Freeway Use (percentage)	32.3	8.9	43.1
Percentage of Trips by Car	83%	94%	84%

*Days on which the employees telecommuted (i.e., worked principally at home).

**Days on which the employees commuted to work.

TABLE 2

Impact of Telecommuting on the
State Employees' Household MembersTravel

Travel Indicators	*Before*	*After*
Number of Trips per day	4.27	3.04
Number of Trips to Work per day	0.88	0.73
Number of non Work Trips per day	3.39	2.31
Number of Peak-Period Trips (7:00-9:00 am)	1.07	0.76
Number of Peak-Period Trips (4:00-6:00 pm)	1.14	0.85
Average Distance Travelled per day (miles)	37.7	31.9
Average Trip Duration (minutes)	19.8	21.9
Freeway Use (percentage)	19.9	21.1
Percentage of Trips by Car	93%	97%

*Days on which the employees telecommuted (i.e., worked principally at home).
**Days on which the employees commuted to work.

work activities along their usual commute route, with special preference given to the sites around work [Kitamura, et al., 1990c]. When people telecommute, they may choose to visit locations around their residence, thus increasing pressure on suburban transport and retail facilities. This hypothesis is being tested currently by precisely locating the destinations chosen by telecommuters.

The long term impacts of telecommuting have not been empirically studied to the knowledge of the authors. Nilles [1988] offers a descriptive analysis of some issues related to this where he offers a wide range of forecasts based on limited data. Obviously, an analysis of this type would have its limitations, but would still provide useful insights regarding the impact of a global technological change on travel.

Telecommuting should be considered only as a part of an institutional and technological revolution which could lead to drastic changes in the formation of cities, the work force composition, and the basic definition of transportation. Garrison and Deakin [1988] presented the introduction of new technologies in a historical framework. According to them, innovations have faced barriers in their adoption. These barriers were mainly due to resistance to change, the lack of knowledge of their possible impacts.

Telecommuting can be considered to be the tip of a technological iceberg the adoption of which could open the road to much more effective ways to utilize technology. For example, the increasing computer literacy and ownership offers new methods for more effective managerial supervision, task allocation, and distribution of employees' promotion and benefits. Moreover, the increase in demand for a flexible working environment may motivate the revival of the small home-based firms which will function on independent contract based task performance.

The savings in time due to telecommuting, which could amount to four hours per day (including the time spent preparing for work and relaxing after work) may be spent in performing other activities which may, in turn, improve the quality of life. The elimination of the commute related and work induced tension and anxiety is another major factor that could change the activity schedule and lifestyle of a telecommuter. Telecommuting was found to drastically shorten trip lengths and trip durations along with freeway use. This is indicative of a radical change in the destinations chosen for performing household and personal activities. Telecommuters may choose to pursue activities in the vicinity of their home location which involve a lesser use of the freeway and increased use of local urban streets. While in the short term, the increased use of local streets could lead to suburban congestion, in the long term it could lead to a reformation of our transportation system together with a better urban design. An increasing public awareness of the ill-effects of todays land-use patterns in which the car is an indispensable mode of transport is already motivating the development of alternative urban designs such as small town neighborhoods [Environmental Council of Sacramento Working Paper, 1989]. The lifestyle of small town neighborhoods is perfectly supported by a telecommuting society. The need to interact with people would induce telecommuters to interact with neighbors. This, in a large scale, would induce greater social contact and the revival of the spirit of community life. On the other hand, alienation due to telecommuting may also occur. It has been hypothesized that working at home may disrupt a persons' contacts with the work place. This in turn would result in loss of information exchange with fellow workers and promotion opportunities. Both of these theories have to be tested empirically.

Working at home opens new opportunities to persons otherwise excluded from the labor force such as handicapped people, etc. A few more social changes may also be induced. For example, people could move far away without losing their present job. Increased recreational and social visit activities could also result due to the increased discretionary time available. In addition, a telecommuter household may adopt a considerably different lifestyle. This may be due to changes in task allocation among the household members which would influence their travel patterns.

Telecommuting and telecommunications will change the way transportation is defined. Even the introduction of the automobile in this society may not have been as revolutionary and swift as the introduction of telecommunications in transportation. The rapid changes in transportation brought about by the introduction of telecommunications could redefine the role of transportation in the economy. Garrison and Deakin [1988] point out that "the transportation manager's question should be how transportation could be shaped to support (a) telecommunications society rather than how telecommuting might ease traffic problems".

The role played by transportation today is primarily one in which people and goods are moved from one point to another. Transportation facilities are built and managed in an attempt to achieve an efficient movement of people and goods. In transportation practice, congestion during peak period commutes is the one concern that absorbs a major portion of planning efforts. Trip reducing regulations such as SCAQMD's Regulation XV are also a part of the overall efforts in decreasing congestion, air-pollution, energy consumption, and travel times.

But what does the future look like, given the introduction of the revolutionary concept of substituting travel (and in particular, the commute trip) with telecommunications? The answer is uncertain. However, using the preliminary indications provided by the pilot project, we could put forth a few alternative possibilities. One outcome of this is the substitution of the commute trip with telecommunications by a large portion of the information work force. A consequence of this could be the increase in demand for suburban routes and recreational facilities. So planners will soon find themselves no longer solving problems related to peak period commutes, but problems related to route choices of recreational travelers and short home-based trips of telecommuters.

The changes brought about by this innovation would be experienced not only in the transportation of people and goods, but also in the transportation of information. On the people and goods side, the spatial pattern of trip making will change to one in which people make either very long business and recreational trips or very short trips (i.e., breaks in between home-based telecommuting for recreation, neighborhood grocery shopping, etc.). Increased use of telecommunications to transit and receive information would place a greater demand on the telecommunication system network. Thus a new facet of transportation will emerge; one in which transportation engineers are no longer looking after transporting people and goods but are designing telecommunication networks to manage peak period information transmission/reception. This new branch of transportation would be a blend of two specializations in engineering; telecommunications and transportation.

Yet another major change that we might see is in the development of new modes of transport-those convenient for very long trips and very short trips. The need to make long business and recreational trips could increase air transport needs. This is indeed a trend being observed in the United States and Europe. The short trips around the home-base could lead to the use of short-range alternatively fueled vehicles such as battery powered or roadway powered electric vehicles [Nesbitt and Sperling, 1990]. Telecommuters could thus provide a much needed niche for the introduction of alternative fuels in the market. It is now well known that increased use of alternatively fueled vehicles would go a long way in alleviating air pollution problems and improving energy security [Sperling and Deluchi, 1989].

Implementation

Any revolutionary innovation which entails major changes such as those described in the preceding sections must be introduced carefully and judiciously. The strategy followed in introducing the innovation could prove instrumental in its success. It has to satisfy the following requirements:

a) The formulation of the strategy should be such that both positive as well as negative aspects of the innovation are clearly seen. This will ensure a proper economic analysis of the implementation strategy and also keep us ready to face the negative aspects.

b) The strategy should be formulated in a flexible way so that we can change our direction in the innovation is proven to be non-beneficial at a certain stage.

One way to do this would be to implement a stream of coordinated short-term actions with long-term goals in mind. This may be called 'implementation by stages'. Telecommuting will be used as our case study here as one of the stages in the strategic implementation of telecommunications. In the first stage, telecommunications could be introduced on an experimental basis in public agencies which would experiment different schemes and methods of work procedures. In this way, negative and positive effects of different applications of telecommunications can be assessed. The various actors participating in the process of telecommuting will have to be identified in this stage. They may include the government, telecommunication components manufacturers, private and public agencies that will use the technology, and the households who will use the technology and become subject to change in lifestyle. Based on the outcome of this experimental phase, in the second stage, an incentive structure needed to initiate the introduction of telecommunications in private firms will have to be developed. Since the initial returns on investment for an innovation are both low and difficult to realize, the incentive structure will provide the additional benefits private firms would require. This is based on the assumption that public agencies do not need incentives as they are government controlled and do not always operate as profit maximization firms. Only after the first two stages are carried out, it would be possible to determine the potential for penetration of telecommuting in the public and private sectors. This is because the penetration of telecommuting would depend on both the results of the experimentation in the public agencies and the acceptance of the incentive structure by the private sector. The third stage would involve assessing this potential for penetration and estimating the technological requirements under a futuristic scenario. The fourth stage would involve the definition of an institutional and legislative framework, i.e., regulations, incentives, role of public and private industry, taxation and pricing schemes, etc. It is in this stage that the role of each actor in the process is clearly defined and monitored. This is the final stage where economies of scale have been reached and the introduction of the innovation will be successful both in profit maximization and traffic reduction.

The implementation by stages will help avoid CBD-like congestion in the suburbs. This would also help in avoiding rejection due to unfounded skepticism. The implementation of other supporting measures to aid the success of telecommuting will be enabled by the provision of additional time and flexibility in the plan.

Regulations such as Regulation XV of SCAQMD should form a part of the first stage. It is a regulation which provides the appropriate legislative and institutional platform on which telecommuting can be launched and its effects assessed. The monitoring of the progress may be conducted according to procedures proposed by Guensler [1989]. Briefly, he suggests improvements in the enforcement policies followed by local air pollution control districts. He provides guidelines for the evaluation of trip reduction plans, modifications to monitor compliance with regulations, procedures for record keeping and auditing. The collection and analysis of data on the impact of the trip reduction plans such as the pilot study in Kitamura, et al. [1990b] would provide a valuable source of information for assessing the progress of trip reduction measures. For example, daily trip records of all employees are collected and summaries reported to the agencies. Thus Regulation XV and other similar regulations will generate a substantial quantity of information regarding the impact of trip reduction measures. In addition, the analysis of this information will shed light on numerous unresolved issues regarding the behavior of the government, firms and people.

There are other trip reduction measures which can also be implemented in conjunction with the telecommunications revolution. These measures include staggered work hours (for e.g., Giuliano and Golob, 1990), car/van pooling [Rivckin, 1989] and restricted parking facilities. It is important to implement all these measures jointly as the coordinated implementation in a unified framework could produce more significant benefits than if they had been implemented in isolation. Also, the time available to assess the benefits of each one in an isolated setting is too limited. The need to act immediately cannot be emphasized more.

Conclusions

In this paper, we argued that even though the short term impacts of telecommuting are very favorable as shown by the results of the State of California Pilot study, the long term impacts cannot be forecasted. The early stage of the telecommuting experiment does not allow us to draw valid long term inferences regarding human travel and activity patterns. However, a well-orchestrated and concerted plan has been sketched for the introduction of telecommuting in conjunction with other traffic mitigation measures. In the short term, telecommuting was found to eliminate commute trips, largely reduced peak period trips, not increase other trips, decrease vehicle miles traveled, decrease trip times, decrease freeway use and increase the proportion of car trips. Changes in telecommuters travel patterns may also influence the travel patterns of non-telecommuters, and therefore their energy consumption. However, the travel characteristics of household members of telecommuters remained stable over a short span of time. The indications are very encouraging in that they meet the requirements of Regulation XV of SCAQMD. However, if it is to continue providing such benefits over a long duration, the strategy for the implementation of telecommuting (and other traffic reduction measures) must be drawn up very carefully. Also important for future research is the identification of socio-demographic and mobility characteristics of potential telecommuters (e.g., their residence and work locations, car ownership, work trip distance and mode, lifestyle measures) as this would allow the identification of market penetration of telecommuting.

Telecommuting could represent one possible precursor of many more telecommunication applications in transportation. In this connection, it is important to realize that the role of transportation and its definition would undergo radical modifications which could have important implications on future planning strategies.

This paper provides a strategy for the introduction of innovations in transport. Particular emphasis has been placed on the introduction of telecommuting and the institutional and legislative framework surrounding it. However, the implementation by stages could be applied to any proposed innovation as long as possible long term objectives are always clearly reflected in the planning process. Implementation by stages provides the much needed flexibility and time to respond to changes in the external environment. The authors call for a unified implementation of numerous traffic mitigation measures in order to obtain maximum possible benefits as the benefits realized from each measure implemented in isolation may not provide significant and desired results.

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- ***Economies of Scale in Postal Operations Evidence from an International Comparison, by Joseph Harr, College of Business and Management, University of Maryland***

Introduction

The Postal Reorganization Act of 1970 granted the United States Postal Service (USPS) a monopoly on the carriage of letter mail on the basis that postal operations are natural monopolies and thus exhibit economies of scale. Although there is no universal agreement on what constitutes letter mail, it is generally considered to be First-Class Mail and addressed third-class mail weighing less than eleven ounces.

Since 1980, several factors have led to calls for an end to the USPS' letter mail monopoly. Postal inflation has out-paced inflation in the general economy and has caused frequent postal rate increases. The popularity of third-class mail as an advertising medium has created a new class of customer, the bulk business mailer. These large customers feel the effects of postal rate changes most. And the success of postal competitors in unrestricted classes of mail, most notably urgent letters and parcel post, has supported the argument that the USPS is inefficient and that private carriers would better serve the letter mail market. Opponents of the monopoly argue that significant increases in postal costs during the 1980s without any corresponding increases in output indicate there are no economies of scale in postal operations.

Adie (1985) empirically estimated the postal production function. He found that the USPS does exhibit characteristics of a natural monopoly. However, the lack of competition or any profit motive causes inefficiencies in the Postal Service which offset any gains that economies of scale might offer. Adie does not offer any empirical evidence for this argument.

Miller (1985) contradicts Adie by saying there is no economic justification for the postal monopoly and no indications of scale economies. Although many fear that higher costs and decreased rural service might result from ending the letter mail monopoly, Miller states that airline deregulation actually improved rural service and led to lower prices that benefited all consumers. Miller (1988) suggests privatizing the USPS since the private sector has always taken the lead in providing faster, cheaper, more convenient service. However, Miller does not acknowledge that the Postal Service has made innovations, such as the creation of overnight delivery. Nor does he explain how the economic effects of airline deregulation would carry over to postal privatization.

Linowes (1989), chair of President Reagan's Commission on Privatization, also supports USPS privatization. He argues that government should not be in the business of business, and that opening the Postal Service to competition would stimulate efficiency. Postal Rate Commissioner Crutcher (1988) also supports the privatization move, blaming postal inefficiencies on restrictive labor agreements and the lack of accountability for postal management. On the eve of the last postal rate increase, Adie (1988) published an editorial in the *Wall Street Journal* proposing privatization of the USPS by dividing it into independent regional operations. This supports the idea that the USPS has no economies of scope. None of these authors offer any empirical evidence to support their proposals.

In October 1989 the Postal Rate Commission (PRC) held a hearing on the letter mail monopoly. Lenard (TCMA), speaking for the Third Class Mail Association, said that he had "reviewed the economics literature to determine if researchers had found evidence to support the conclusion that competition in the delivery of addressed third class mail should be precluded." He said that he found no such evidence and that the literature generally favored ending the monopoly. He added, "There is substantial evidence that Postal Service costs are generally inflated, which is not consistent with the Postal Service being a natural monopoly." Miller (TCMA) testified that "Empirical evidence does not justify a monopoly." And Cohen, from the PRC's Office of the Consumer Advocate, said there is no evidence that the USPS shows economies of scale or economies of scope.

Perhaps the most interesting investigation into USPS economies of scale and economies of scope is Gupta's (1985) trans-log estimation of the postal cost function. Gupta found that the USPS exhibits diseconomies of scale but does have economies of scope. There are, however, several flaws in Gupta's work. He used USPS operating data from 1961 to 1980 to estimate his cost function. Yet he makes no correction for the government subsidies the Post Office Department received before the Postal Reorganization Act. Gupta assumes a constant interest rate throughout this period, when in fact interest rates fluctuated wildly from 1961 to 1980. Gupta also does not account for changes in the quality of postal service and admits that increases in quality would seriously alter his results. Yet he does not acknowledge any service increases such as the provision of airmail service for all first class mail and the introduction of overnight delivery. These errors call Gupta's results into serious doubt.

Two other empirical studies, Merewitz (1970) and Stevenson (1973), do not look at post-reorganization postal data. These are not appropriate for examining current postal economies of scale.

Although much has been written and said about the letter mail monopoly, there are no clear conclusions. Adie found economies of scale but did not support his theory that inefficiencies offset these economies. Gupta found diseconomies of scale, but his results are questionable. Lenard, Linowes and Miller all favor an end to the letter mail monopoly but offer no empirical evidence to support their position. There is a need for an empirical investigation of economies of scale in the USPS and in letter mail based on 1980s data.

The Hypotheses

It is very unlikely that the USPS exhibits economies of scale. The history of the United States parcel post market illustrates this. The USPS held over 80 percent of the domestic parcel market in 1950. By the mid 1960s, it shared this market almost equally with United Parcel Service. By 1980, United Parcel Service controlled over 80 percent of the market.

A basic principle of an industry exhibiting economies of scale is that it has a declining long-run average cost curve. These decreasing average costs make it more efficient for one supplier to serve the market. However, the parcel post market does not exhibit these characteristics. Two suppliers have shared the market for the last four decades and have even changed positions as the market leader. The make up of this market points towards an industry that does not have economies of scale.

The nature of the parcel post market is similar to that of several other USPS services. The overnight express market has long had several competitors; alternative delivery is eroding the USPS's share of the periodical market. If the USPS did benefit from economies of scale, its economic advantages would likely drive out competition in these unrestricted mail classes. Since this has not been the case, it leads to the first hypothesis.

Hypothesis 1: Total postal operations do not exhibit any economies of scale.

However, one cannot say the same for letter mail. Unfortunately, there have never been any competitors to letter mail that would test scale economies. (Although other forms of communication, such as telephone, radio and television, might be substitutes for letter mail, one cannot consider them competitors of letter mail.)

The USPS delivers letter mail to every delivery address in the nation almost every day. The delivery of additional letter mail to each address would result in very little additional costs, since this mail would not require much additional handling. This is not true of other classes of mail. For instance, parcel post requires special handling during delivery, and overnight mail is delivered mostly to business addresses. Delivery is the major postal cost, accounting for over 28 percent of the USPS's costs (USPS, 1988). The minimal increase in delivery costs necessary to produce the additional output of increased letter mail certainly points to economies of scale.

Additionally, the Postal Service has aimed most of its efforts in automation at letter mail. The only automated mail processing equipment in use in the USPS is exclusively for sorting letters. All other types of mail are sorted either mechanically or manually. The cost savings from automation are significant. It costs 2.8 cents to process a piece of mail manually, 1.5 cents mechanically, and just 0.3 cents automatically. These reduced costs with no change in output also point to scale economies in letter mail.

These two characteristics of letter mail lead to the second hypothesis.

Hypothesis 2: Letter mail operations demonstrate economies of scale.

There are not enough data points from USPS operations in the 1980s to provide an adequate evaluation of these hypotheses. There are several possibilities for overcoming this obstacle.

One could use data from prior to 1980 to provide sufficient data points. However, the introduction of new technology has changed postal operations so greatly since 1980 that this would probably produce inconsistent data. Further, this study is not concerned with the historical trends in postal operations, but rather the most current evidence available.

It would also be possible to use observations from various segments of postal operations. Although this would be adequate to test the first hypothesis regarding total post, it still would not produce enough data to test the second hypothesis on letter mail. Also, it would be difficult to equitably divide the fixed costs of the USPS among its various operational segments.

This study uses data on postal operations in sixteen industrialized countries to test the hypotheses. These postal operations were chosen for their similarity to the USPS. Therefore, the hypotheses are general and meant to apply universally to postal operations, not just those of the USPS.

Methodology

Data Collection

Data on the postal operations of sixteen countries were obtained for each of those operations' fiscal years 1982 through 1986. Table 1 lists the countries used for this analysis. The data are from the Universal Postal Union's (UPU) annual *Statistique des service postaux*. The author chose this source because it is easily accessible and provides uniform data for all countries, both in units of measure and classification of data. However, this uniformity might create biases if the countries studied do not all classify their data consistently. Additionally, since each country uses different techniques to measure its postal operations, there may be inconsistencies in the data because of the inherent biases of various sampling methods. Neither of these possibilities is significant enough to impair the data for this study.

The sample period of 1982 to 1986 was chosen because it was the most recent data available to the author and it is brief enough to provide homogeneous data. The data published by the UPU are for each operations fiscal year, which ended on different quarters in different operations. To compensate for this, all monetary figures were adjusted with an implicit price deflator of U.S. personal consumption expenditures using a 1982 base. Ideally, data from each country would have been adjusted using that own county's price deflator. However, the limitations of this study made that unfeasible. Since all of the countries have rather similar economies, not using each country's price deflator should not adversely affect the data.

The countries selected to test the hypotheses were chosen on the basis that they are advanced, industrialized nations with economic activity similar to that in the United States. No empirical tests of these similarities were used in choosing these countries. In spite of their homogeneity, the countries have varying geographic make-ups. This was accounted for by including a density measure in each regression. Additionally, the data published by the UPU for certain countries include statistics from those countries' dominions and protectorates. (The data for Great Britain did not include any of the commonwealth nations.) This may have caused some very small biases in the data.

Table 1

Nations Included in Study
Australia
Denmark *
Japan
Sweden
Austria *
France
Norway
Switzerland *
Belgium
Great Britain
New Zealand
West Germany
Canada
Italy
Netherlands
United States

* No complete data points were available for these countries.

Data Manipulation

Data were collected from several UPU classifications. If complete data from a country were not available for any fiscal year, that country was disregarded for that year. Five years worth of data from sixteen countries provided 60 complete data points. All of the data were converted to natural logarithms before performing the regression analyses because of the ease of interpreting log data for economies of scale.

Categories 1.1 (Area of the country in square kilometres) and 1.2 (Number of inhabitants) were used as adjustments for density. The regression variable AREA is equal to ln(1.1/1000) and POP is equal to ln(1.2/1000). POPDENS is ln(1.2/1.1) or POP minus AREA.

To arrive at a measure of costs, we began with 3.2 (Total expenditure in gold francs). (Gold francs is the standard monetary measure used by the UPU.) 3.2.3 (Renumeration paid to foreign postal administrations in gold francs) was subtracted from this total expense figure since we are interested only in domestic service. This amount was then deflated to a 1982 base before taking the log. Thus GFrEXP was calculated as ln((3.2 - 3.2.3)/price deflator).

Total post was calculated as the sum of 5.1.1 (Number of ordinary and registered letter post items - domestic service, which includes letters, postcards, printed papers and small packets), 7.1.1 (Number of ordinary postal parcels - domestic service), and 7.2.1 (Number of insured postal parcels - domestic service). The variable TOTAL POST is ln(5.1.1 + 7.1.1 + 7.2.1).

Letter mail was calculated as the total of 5.2.1 (Letters - domestic service) and 5.3.1 (Postcards - domestic service). It did not include printed papers, usually considered second-class mail, or parcels, which are fourth-class mail. It also did not include small packets, even though they are part of first-class and third-class mail. Small packets generally weigh over eleven ounces. At eleven ounces, the lowest rates private carriers may charge become competitive with postal rates. This effectively bypasses any monopoly on letter mail at these weights. So, LETTERS is equal to ln(5.2.1 + 5.3.1).

Regression Results

Using the variables just described, eight regression analyses were performed. These regressions used the least squares method of linear estimation. Table 2 presents representative results of these regressions.

All of the regressions were based on the formula:

$$\ln(\text{costs}) = b_1 \ln(\text{output}) + b_2 \ln(\text{density}) \quad (1)$$

The variable GFrEXP represented ln(costs) in all of the regressions. LETTERS was the variable for ln(output) in four of the regressions and TOTAL POST was in the remaining four. Four various measures of density were used once each with both LETTERS and TOTAL POST. These measures are: population density, output per area, output per population and output per population density.

The goodness of fit of the regressions was quite good. R squared fell between 0.79 and 0.87 in each of the eight regressions. None of the measures of density provided results that were statistically significant. In no case did their betas prove to be statistically different from 0. This indicates no relationship between these measures of density and costs in this evaluation.

Since an output coefficient that is less than one indicates economies of scale, the betas for TOTAL POST were tested for being statistically less than 1. In this test, t was greater than 2 in two cases and less than 2 in two cases. Since the evidence is mixed, we cannot reject the null hypothesis nor accept hypothesis 1. Although there is a relationship between total post output and costs, we cannot draw any conclusions about what that relationship is.

The betas for LETTERS were also tested for being statistically less than 1. In all cases, t was greater than 2. This shows that the relationship between letter mail output and costs is decreasing average costs for increasing output. In other words, postal letter mail operations do exhibit economies of scale.

Figure 1 presents an estimated average cost curve for letter mail based on the data in this study. This curve shows that postal letter mail operations do have declining average costs. This supports the regression results that letter mail exhibits economies of scale.

Conclusions and Implications for Further Study

This research has added to the body of knowledge about the economic nature of postal operations. It shows that, based on international data, letter mail operations exhibit economies of scale and thus are natural monopolies. Although international data is certainly not perfectly representative of U.S. data, some implications about USPS operations can be drawn from this conclusion.

This study indicates that the USPS is where it probably should be in maintaining monopolies. Since letter mail operations show economies of scale, letter mail is a natural monopoly. The USPS should continue to hold a monopoly on the delivery of letter mail, as should the postal services of other industrialized nations in this study. However, the indications seem to be that total postal operations do not have economies of scale. The USPS does not maintain monopoly power over any classes of mail other than letter mail. This is probably the position they should maintain, although we need more research to confirm this.

This leads to the implications that this study creates for future research. The most obvious of these are the improvements and refinements that can be made to this study. For example, one might achieve better results by using individual price deflators for each country or by creating an empirical test for choosing the countries in the study. Most of these areas of refinement are noted throughout the text. Hopefully, a more precise study will lead to a clear conclusion about total post.

The most significant improvement that could be made to this study is developing a better measure of density. The density measures in this study provided unsatisfactory results. Perhaps this should be some measure of a county's urban-ness. For instance, Australia has a very low population density. Yet most Australians live in dense areas along the coast. Simple population density is misleading as a measure of density. Some other more appropriate measure might prove more fruitful.

Lastly, some investigation of economies of density in postal operations might be useful. Surely the change in the number of delivery points during the five years of this study had some effect on postal costs. Compensating for these changes in the size of the operations in the study would allow us to look at a short run average cost curve. We could then determine if postal operations show any economies of density, as well as evaluating economies of scale.

Table 2
Regression Analyses Results

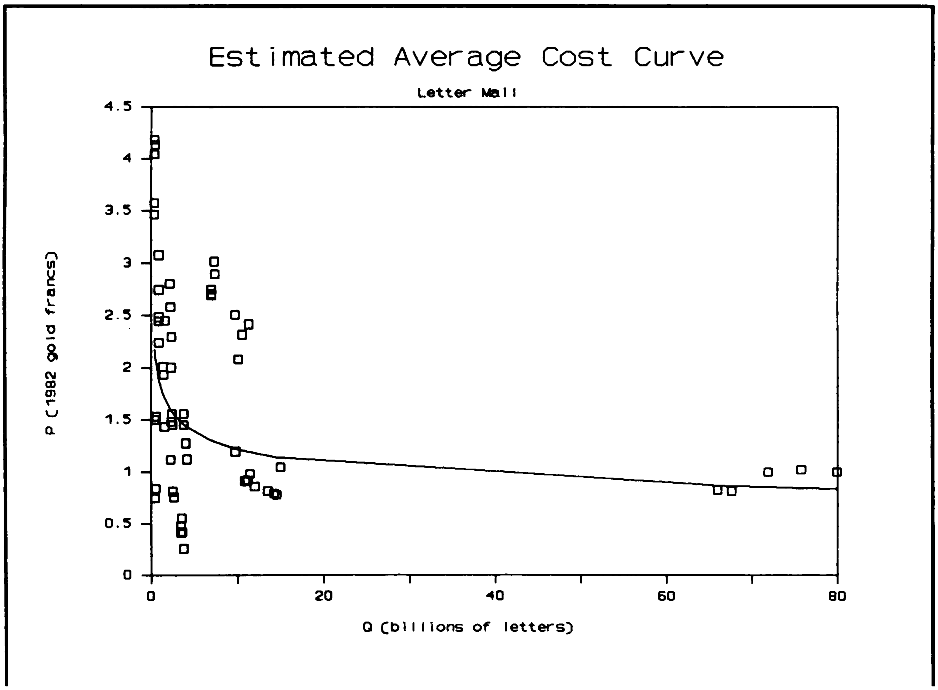
REGRESSION 1 - TOTAL POST		
GFrEXP vs. Q, Q/AREA		
Regression Output:		
Constant		1.474332
Std Err of Y Est		0.513889
R Squared		0.847722
No. of Observations		60
Degrees of Freedom		57
	Q	Q/AREA
X Coefficient(s)	0.890361	0.035514
Std Err of Coef.	0.053961	0.039638

REGRESSION 1 - LETTERS		
GFrEXP vs. Q, Q/AREA		
Regression Output:		
Constant		3.427712
Std Err of Y Est		0.587786
R Squared		0.800778
No. of Observations		60
Degrees of Freedom		57
	Q	Q/AREA
X Coefficient(s)	0.789813	0.065422
Std Err of Coef.	0.057709	0.046472

REGRESSION 2 - TOTAL POST		
GFrEXP vs. Q, Q/POP		
Regression Output:		
Constant		2.66235
Std Err of Y Est		0.481287
R Squared		0.86643
No. of Observations		60
Degrees of Freedom		57
	Q	Q/POP
X Coefficient(s)	0.861041	0.035514
Std Err of Coef.	0.050065	0.151698

REGRESSION 2 - LEETERS		
GFrEXP vs. Q, Q/POP		
Regression Output:		
Constant		5.031209
Std Err of Y Est		0.575608
R Squared		0.808947
No. of Observations		60
Degrees of Freedom		57
	Q	Q/POP
X Coefficient(s)	0.750571	0.451508
Std Err of Coef.	0.061786	0.212752

Figure 1



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• *An Aircraft Routing Model With Departure Time Windows For A Hub and Spoke System,*

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Problem Statement

The problem in this research paper is to assign aircraft to pre-determined services so as to maximize profits for a hub and spoke network, given a particular size and mix of aircraft fleet, and a schedule map with time windows.

Purpose of Research

Hub and Spoke systems are being used by many airline carriers in the United States following deregulation of the airline industry. A major factor for the emergence of the hub and spoke system is the increased efficiency in the deployment of resources and the competitive structure of the industry. The hub and spoke system is also prevalent in developing countries, though the conditions leading to such a configuration may be of a slightly different nature and do not have to do with a competitive structure of the airline industry (almost always there is just one government owned air carrier in developing countries). Some of these conditions, leading to a hub and spoke system in developing countries, are as follows:

- The major cities are very few in number and almost all the air traffic is confined to these inter-city corridors. The main reason for this concentration of air traffic is that very seldom is travel by air used for non-business trips (the fares are prohibitively expensive. For example, a flight between Madras and Bombay, two major cities of India separated by a distance of about 800 miles, would cost the entire monthly salary of a middle-level executive). Further most large businesses are situated at these major cities.

- The airport facilities are well-developed only at the major cities (a direct consequence of the previous point). The facilities at other places are minimal.

In any event, an optimization of available resources would be an important goal of the managers. Also the management may be willing to consider alternative departure times of the same service in the neighborhood of the most desirable one, if the net result will lead to an increase in profits due to a reduction in temporal conflicts. Hence, a profit maximizing model could aid the management to arrive at a good assignment of aircraft to services. It should be observed here that the above optimization model would be much more simple for the hub and spoke configuration than for a general route configuration. This is because of the following reasons:

- The choice among alternative routing sequences is minimal in the hub and spoke system, because most routes are non-stop round trips between the hub and a non-hub city.

- A balance of aircraft types at each station and at all times need not be explicitly kept track of, in the hub and spoke system.

Literature Review

There has been a considerable amount of work done in the field of Airline routing. However, most of the work seems to be restricted to minimizing the fleet size for a single aircraft type.

Levin [1] formulates a model for minimizing the number of aircraft as a network flow (with variable departure times) by representing the problem as a bi-partite graph. He deals initially with the case of a single aircraft type, non-stop service, and general route configuration. He extends it to a multi-fleet problem by maintaining the bi-partite representation, but considering as many copies of schedule maps as there are aircraft types. This problem could be very large and Levin proposes a system decomposition solution.

Simpson [2] provides a range of fleet routing models, but handles the multifleet problem in a similar way as Levin.

Barkley [3] modifies the out-of-kilter algorithm in order to solve for the minimum fleet size of a single aircraft type routing problem with a general route configuration and departure time windows.

Heldt [4] uses the same principle as Barkley, but incorporates the modification as an integral part of a modified OKF (rather than manipulating the solutions of the OKF externally).

It is clear from above that the algorithms developed for a single aircraft type routing case generally have the minimization of fleet size as their objective. The reason is fairly straight-forward – the profit of assigning a service to any aircraft would be almost the same in the single aircraft type case. We also note that the models described above were based on representing the problem as a network flow. However, as was mentioned earlier, this network representation becomes very cumbersome for the multi-fleet situation [5].

A research work by Daskin and Panayotopoulos [6] studied the "profit maximizing" routing problem for a hub and spoke system. They formulate a profit-maximizing model for fixed schedules and solve the problem by using a lagrangian relaxation procedure coupled with a heuristic algorithm. The heuristic algorithm itself comprises of two phases – to convert an infeasible lagrangian solution into a primal feasible solution, and then to improve upon this solution at every iteration of the lagrangian procedure [7]. The improvement part of the heuristic enables a rapid convergence of the solution towards optimality. The focus of the research work in this paper is to extend the model with fixed schedules, to a case of variable time departures of services from the hub.

Definition of Terms

Service: A service is defined as any desired connection between the hub and other cities.

Route: Any possible departure of a service from the hub constitutes a route. When an aircraft departs from the hub, a new route begins. More than one route could belong to the same service.

Flight: A flight is defined as the combination of a route and a particular aircraft type. Hence a single route would have as many candidate flights as the number of different types of aircraft.

Table 1 gives an example and identifies the various terms mentioned above. The routes are numbered sequentially and there is one route for each possible departure from the hub. The set of routes (we will also refer to it as a bundle of routes) from which at most one route will be flown belong to the same service. Hence, for example, routes 5 and 6 in Table 1 belong to the same service 4. If there were two aircraft types A and B in this sample problem, then each route would have two candidate flights.

Assumptions of the Model

The following assumptions about the characteristics of the airline system are made.

- Each route originates at the hub, visits one other city and returns to the hub.
- The profit of assigning a service to an aircraft is the same for all aircraft of the same type.
- The scheduled arrival and departure times of all flights of a route are the same. Taken in perspective, this assumption is equivalent to maintaining that the speed of aircraft between cities, and the ground time of aircraft, would be independent of aircraft type.

Notation: The following notation is used in the formulation of the profit maximizing model.

j = index of routes
k = index of aircraft type
l = index of time period
s = index of service
J = Set of routes
K = Set of aircraft type
L = Set of time periods
S = Set of services
B_s = {j| set of routes that belong to service bundle s}
D_j = Departure time of route j
A_j = Effective arrival time of route j at hub
N_{kl} = {j| set of routes j that could utilize aircraft type k during period l}
P_{jk} = Profit due to assigning route j to aircraft type k
T_k = # of aircraft of type k

Decision Variable

$$X_{jk} = \begin{cases} 1 & \text{if route } j \text{ is "flown" by aircraft type } k \\ 0 & \text{otherwise} \end{cases}$$

With the above notation, the problem can be formulated as shown below.

Formulation

$$\text{Max} \quad \sum_{s} \sum_{j \in B_s} \sum_{k} P_{jk} X_{jk}$$

$$\text{ST} \quad \sum_{j \in B_s} \sum_{k} X_{jk} \leq 1 \qquad \forall s \qquad (1)$$

$$\sum_{j \in N_{kl}} X_{jk} \leq T_k \qquad \forall k \; \forall l \qquad (2)$$

$$X_{jk} = 0, 1 \qquad \forall j \; \forall k$$

Table 1: Definition of Terms

Route #	Service #	Dep	Arr
1	1	0745	1145
2	1	0800	1200
3	2	- 1000	1400
4	3	1415	1900
5	4	1145	1345
6	4	1200	1400

The objective function maximizes the profit associated with the assignment of services to aircraft. Constraint (1) ensure that at most one route from the bundle of routes B_s (that represent alternative departures of the same service s) is assigned to an aircraft. Constraint (2) guarantees that the number of aircrafts of each type assigned to fly various routes during each time period l, does not exceed the fleet size of that aircraft type. Generally speaking, a new time period should be defined whenever there is a chance of needing an additional aircraft. Daskin and Panayotopoulos [6] show various methods of defining this time period and illustrate that the most efficient (i.e., the definition which results in the minimum number of constraints, while still incorporating all the restrictions needed) method is to initiate a new time period with each route departure that follows an arrival. The same definition is extended to the case of variable departure times. A new time period is initiated whenever any possible departure from the hub follows any possible arrival into the hub.

The assumption that assigning any aircraft of the same type to a route implies identical profits, enables us to define the decision variables with respect to aircraft type rather than an individual aircraft. This assumptions, while not unreasonable, greatly reduces the size of the problem that we are dealing with. If we had a decision variable for each aircraft instead of each aircraft type, the size gross enormously. Hence, for example, if we were considering a problem with about 150 services, an average of 2 alternative departure times for each service, and a total of 20 aircraft of two different types, the sizes of the alternative formulations are as shown in Table 2. We notice that method 2 (decision variable based on aircraft type) is considerably smaller than method 1 (decision variable based on individual aircraft). The reduction in size is even more pronounced as the size of the problem increases.

Table 2. Comparison of Problem Size

Method	# of D.V.	# of Constraints
1	6000	6300
2	600	620

Solution Procedures

Two solution procedures were considered to solve this integer programming problem. We will discuss both of them below.

Linear Programming Relaxation

If the explicit requirement that all variables must be 0-1 is dropped, then our formulation becomes a LP problem. The optimal solution to the LP may not be in general, an all integer result. However, it seemed to give an integer solution in all the problems that it was applied to. Four different problems were tried, two of which are reported later in this paper.

The situation above seems to be similar to the case of minimizing the number of aircraft as studied by Levin [1]. He indicated that for all large realistic examples, the LP relaxation of the IP problem always gave an optimal integer solution.

In case of a fractional optimal solution, we could obtain an integer solution by constraining each of the fractional assignments to be 0 or 1 and continuing this procedure until we obtain an integer solution. This implicit enumeration type procedure may not be unreasonable, since it would seem that even if there existed fractional assignments, the number of such assignments would be rather small, and quick convergence towards an all-integer solution would be anticipated. This belief, of course, is subject to verification. A non-integer solution in one of the sample problems considered in this research would have enabled us to study this situation further, though again any generalization from the results would be speculative.

A Heuristic Procedure

This second method was motivated by the notion that the LP approach to the profit-maximizing model would be rather inefficient [8,9]. The LP solution does not exploit the structure of the problem. While there may be LP packages that could handle even very large problems, it was felt that an effort to obtain a simpler procedure based on the structure of the problem would be useful and worthwhile pursuing.

This heuristic solution would guarantee us an integer solution and a reasonably good result, though it may not provide the exact optimal solution. Acknowledging the fact that there may be various other considerations in deciding the final assignment that have not been included in our model, it may be useful and probably even adequate to provide managers with a good idea of the "optimal" solution. That is not to say that improvements in the direction of the optimal solution to the model are unwarranted and not required.

This heuristic is based on the principle of "greedy adding" [10,11] and attempts to utilize the structure of the two sets of constraints. The variable X_{jk} is a binary variable, i.e., it can take only two values, either 0 or 1. For a particular period 1, and for each aircraft type, at most T_k of all possible routes j in that period can be assigned a value '1'. Since the problem is a maximization, it would be reasonable to assign the value of '1' to the T_k (or lesser) variables X_{jk} (out of all possible routes j in period 1) which have higher profits (or larger objective value coefficients) compared to the rest of the routes. However, according to constraint (1), almost one of the variables X_{jk} (over all $j \in B$ can take a value '1' for each service "bundle". Further since the subject N_{kl} (k=1,2...K, 1=2,2...L) of routes are not mutually exclusive, a particular variable X_{jk} may occur in more than one constraint in the constraint set (2). Therefore, as soon as a particular X_{jk} is assigned the value '1', all the other variables which appear along with it in the constraint set (1) must be assigned the value of '0'. Also the R.H.S. of the constraints in which that X_{jk} occurs in constraint set (2) is reduced by 1. This special nature of the constraint sets (1) & (2) can be incorporated in a heuristic algorithm.

The various steps of the heuristic algorithm are:

1) The variables X_{jk} are ranked in order for their objective function coefficient values (the profit of flight jk) in a descending order (highest value first).

2) The binary variable at the top of the list of variables still available for assigning a value '1' is selected and assigned the value of '1'. In case of a tie between variables, the variable which does not preclude a particular service entirely (this situation would arise if all other routes of a service have already been assigned a zero value, and the only remaining routes of that service would also be assigned a value of zero due to constraints (2) by the inclusion of a particular X_{jk}) is assigned a value of '1'. If there still exists a tie, then the variable that maximizes the opportunity of other services (in constraint set (2)) to be flown is taken (i.e., the variable that imposes the least restrictions on other possible services, through the reduction of the R.H.S. in which it occurs, is assigned a value of '1'). If there still is a tie, any one of the "tied" variables is taken.

3) All conflicting variables which appear along with the selected variable in constraint set (1) are identified, and removed from the rank-ordered list, so that they are not assigned a value '1'.

4) The R.H.S. of the constraints (2) in which the selected X_{jk} appears is reduced by 1. If after this reduction, the R.H.S. of a particular constraint becomes zero, all the variables appearing along with the selected X_{jk} in that constraint are assigned a value '0' and removed from the rank-ordered list.

5) Steps 2, 3, and 4 are repeated until there are no more variables in the serialized list.

A Comparison of the Two Solution Procedures

1) The LP solution will give the optimal solution directly if the result turns out to be all integer. As mentioned previously, in all the problems (with at least four services) that were solved, the solution always turned out to be all-integer. However, if we do not get an all integer solution, we need to go through the implicit enumeration technique mentioned earlier. Also, the LP solution is probably an inefficient way of solving a problem with special structure, more so as the problem becomes larger.

2) The heuristic solution is "greedy" and may not give the optimal result. However, it would definitely provide an integer solution. It would also seem that this procedure, while not giving the optimal result, would give a good result. The problem with this approach is that the solution could be "off the mark" by a rather large extent in certain situations. Also, this method does not provide us with any insight as to how far we are from the optimal solution.

Example Problems

Two simple examples of the profit maximizing model are illustrated here.

Example 1

The possible departure times and arrivals into the hub for each service and the associated profits of each flight are shown in Table 3 for this first problem. Two aircraft types are considered and the number of available aircraft of each type is 1. The time period constraints (2) are shown in Table 4 and the service bundle constraints are provided in Table 5. The LP solution is found by using "LINDO". To apply the heuristic procedure, we first sort all the possible flights in a descending order of their profits, as shown in Table 6. Table 7 illustrates the application of the heuristic procedure. Flight 5-1 is first assigned a value of 1, a list of the remaining possible flights is made, then the flight which is at the highest level in the sorted list from the remaining possible flight list is assigned a value of one, and the process is continued.

An "improvement" in the heuristic procedure may be made so that in the event of a particular service being entirely removed due to the inclusion of a flight, we go down our profit list and select any flight that removes lesser number of services. For example, we notice in Table 7 that due to the inclusion of flight 6-2, the opportunity to fly service 2 is lost, and only one other service (service 4) could be flown. However, if we go down the list and select flight 3-2, then we still have the opportunity to fly the two other services - - 1 and 4. Table 8 displays the result of such a procedure.

The problem with this "improved" heuristic is fairly obvious. It cannot be easily generalized. It just happens to work for this specific example, and it has been retained in this paper to reflect one possible concept based on which an improvement in the heuristic procedure may be made.

The results from the heuristic solution and the LP solution are shown in Table 9. As we can notice, the LP gives the exact optimal solution of 110, while the heuristic gives a solution with a total profit of 90.

Example 2

The various inputs for this larger problem are given in Table 10. The results by either method are given in Table 11, showing that the LP solution gives a total profit of 230, while the heuristic procedure gives a total profit of 215.

Study of Other Options

The model can be used to study other options such as the following:

- Testing the effectiveness of different fleet sizes and different aircraft type mixes. This can be achieved by comparing the total profits against the total costs of different fleet sizes and of different fleet mixes, or the effect of including a new aircraft type to the fleet. That is, it could be used as a long range planning tool.
- The possibility of serving new routes. This can be done by comparing the projected profit associated with serving a new route with the additional cost (in terms of increased fleet size, more personnel, etc.) that must be expended to serve this route.
- The possibility of reducing ground time of flights so that it would lead to higher profits and also may allow serving new routes. This profit could be studied relative to the cost of hiring new personnel in making this reduction in ground time.
- In case of seasonal variations in demand, we may have different sets of profits during different times of the year. In such a situation, we could solve the model repeatedly to get the optimal solution during each season.
- In the event that another carrier starts operating from the hub on certain routes, we could study this effect on the current routes being served, make appropriate adjustments to profits in the objective function, and reevaluate the optimal routing configuration.

Extensions of the Model

- A hub and spoke system has been assumed in this study. A useful extension may be to consider a general route configuration.

Table 3. Sample Problem 1

Route No.	Service No.	Dept	Arrl	profit a/c1	profit a/c 2
1	1	0745	1145	10	5
2	1	0800	1200	20	20
3	2	1000	1415	15	25
4	3	1145	1345	20	15
5	3	1200	1400	40	35
6	4	1400	1800	20	30
7	4	1415	1815	25	20

Table 4. Time Period Constraints

No.	Period	Constraint
1	0745-1145	$X_{11} + X_{21} + X_{31} \leq 1$ $X_{12} + X_{22} + X_{32} \leq 1$
2	1145-1200	$X_{21} + X_{31} + X_{41} \leq 1$ $X_{22} + X_{32} + X_{42} \leq 1$
3	1200-1400	$X_{31} + X_{41} + X_{52} \leq 1$ $X_{32} + X_{42} + X_{52} \leq 1$
4	1400-1415	$X_{31} + X_{61} \leq 1$ $X_{32} + X_{62} \leq 1$

Table 5. Service Bundle Constraints

Service	Constraint
1	$X_{11} + X_{12} + X_{21} + X_{22} \leq 1$
2	$X_{31} + X_{32} \leq 1$
3	$X_{41} + X_{42} + X_{51} + X_{52} \leq 1$
4	$X_{61} + X_{62} + X_{71} + X_{72} \leq 1$

Table 6. Sorted List of Profits

Route	Aircraft Type	Profit
5	1	40
5	2	35
6	2	30
3	2	25
7	1	25
2	1	20
2	2	20
4	1	20
6	1	20
7	2	20
3	1	15
4	2	15
1	1	10
1	2	5

Table 7. Heuristic Procedure

Interation No.	Route Picked	Aircraft Type	Remaining Flights
1	5	1	11, 12, 21, 22, 32 61, 62, 71, 72
2	6	2	11, 12, 21, 22
3	2	1/2	0

Table 8. "Improved" Heuristic Procedure

Interation No.	Route Picked	Aircraft Type	Remaining Flights
1	5	1	11, 12, 21, 22, 32 61, 62, 71, 72
2	3	2	11, 12, 21 61, 71, 72
3	7	1	11, 12, 21
4	2	1	0

Table 9. Solution to Example Problem 1

Method	Service	Dept	Arr	A/C Type	Profit
LP/	1	0800	1200	1	
Heuristic	2	1000	1415	2	110
Proc. w/	3	1200	1400	1	
Improvement	4	1415	1815	1	
	1	0800	1200	1/2	
Heuristic	3	1200	1400	1	90
Procedure	4	1400	1800	2	

Table 10. Sample Problem 2

Route No.	Service No.	Dept	Arrl	profit a/c1	profit a/c2
1	1	0745	1045	30	20
2	1	0800	1100	20	10
3	1	0815	1115	25	15
4	2	0800	1015	25	20
5	2	0815	1030	10	25
6	3	0830	1145	15	35
7	3	0845	1200	10	30
8	3	0900	1215	30	5
9	4	0930	1215	25	15
10	4	0945	1230	15	10
11	5	1000	1315	30	25
12	5	1015	1330	20	25
13	6	1015	1430	35	30
14	6	1030	1445	10	15
15	7	1045	1515	5	10
16	7	1100	1530	15	35
17	8	1115	1445	20	20
18	8	1130	1500	30	25
19	8	1145	1515	15	30
20	9	1130	1600	25	15
21	9	1145	1615	5	10
22	10	1200	1600	25	15
23	10	1215	1615	20	20
24	10	1230	1630	15	5
25	11	1215	1500	10	15
26	11	1230	1515	25	10

Table 11. Solution to Example Problem 2

Method	Service	Dept	Arr	A/C Type	Profit
	1	0745	1045	2	
	2	0800	1015	1	
	3	0830	1145	2	
LP	4	0930	1215	1	230
	6	1015	1430	1	
	7	1100	1530	2	
	8	1145	1515	2	
	11	1230	1515	1	
	1	0745	1045	1	
	2	0800	1015	1	
	3	0830	1145	2	
Heuristic	6	1015	1430	1	215
	7	1100	1530	2	
	8	1145	1515	2	
	9	1130	1600	1	

- The heuristic procedure mentioned in this study could be an area of considerable improvement. A lagrangian relaxation [12] approach similar to the one used by Tripathy [13] would be useful.

- The LP approach could be tested on various problems of different sizes. If fractional assignments are obtained for a few problems, the rate of convergence to an integer solution by the application of the implicit enumeration procedure could be determined. An improvement on the implicit enumeration may be attempted in this situation possibly by using the duals of the fractional routes [11].

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• *Alliances, Cooperation Pacts And Mergers In The European Airline Industry – Implications For 1992*
by Annette Uderue Ohuche

INTRODUCTION

In 1992, the implementation provisions of the European Common Market will come into effect. Many are curious to see what will happen to the transportation industry, especially the European airline industry. A number of industry analysts are comparing this liberalization of the European air passenger market with airline deregulation in the United States. There are similarities, but there are also striking differences. Some of these differences are unique to the European airline market structure.

Among these differences and similarities, this paper will analyze several factors which are important to the success of any carrier in a liberalized airline market. The purpose of this paper is to discuss these economic and business factors which may affect the success of Europe's air passenger carriers in the post-1992 single European market.

In obtaining information for this research, efforts were made to concentrate on both primary and secondary research. A literature search was conducted, which included books, periodicals, academic journals, and trade journals, most of which were published within in the last two years. Then, interviews were conducted with a corporate representative from each of nine airlines chosen for inclusion in this paper. Furthermore, an analysis was made of the 1988 annual reports from each airline in the study.

The airlines used in this study were, in 1988, nine of the top ten revenue-producing European airlines. The tenth airline, not included in the study, is Air Inter. It was not included due to the takeover of Air Inter by Air France on January 12, 1990.

Swissair is the only airline in the study that is not domiciled in a European Economic Community (EEC) member Country. However, it was included in the study since it was the sixth largest European airline, in terms of 1988 revenues. The table and chart which follow show the nine airlines, ranked according to 1988 revenues, which are included in this study.

1. Lufthansa (Federal Republic of Germany)
2. British Airways (United Kingdom)
3. Air France (France)
4. SAS (Scandinavian Airlines System)
5. Alitalia (Italy)
6. Swissair (Switzerland)
7. Iberia (Spain)
8. KLM (Holland)
9. Sabena (Belgium)

EEC TRANSPORT POLICY

The principal objective of the EEC Policy on Transport is to create a European transport infrastructure capable of meeting user needs at the least cost to taxpayers and citizens. It was developed from 1978-1980 by the Commission. The EEC has identified four objectives in terms of the air transportation industry.

1. To set up an efficient network within the community. By this statement the EEC means cheaper fares, greater freedom fr charter flights and greater freedom to operate in general.

2. To lower costs and increase productivity of the airlines.

3. To ensure mutual recognition of employee qualifications within the EEC.

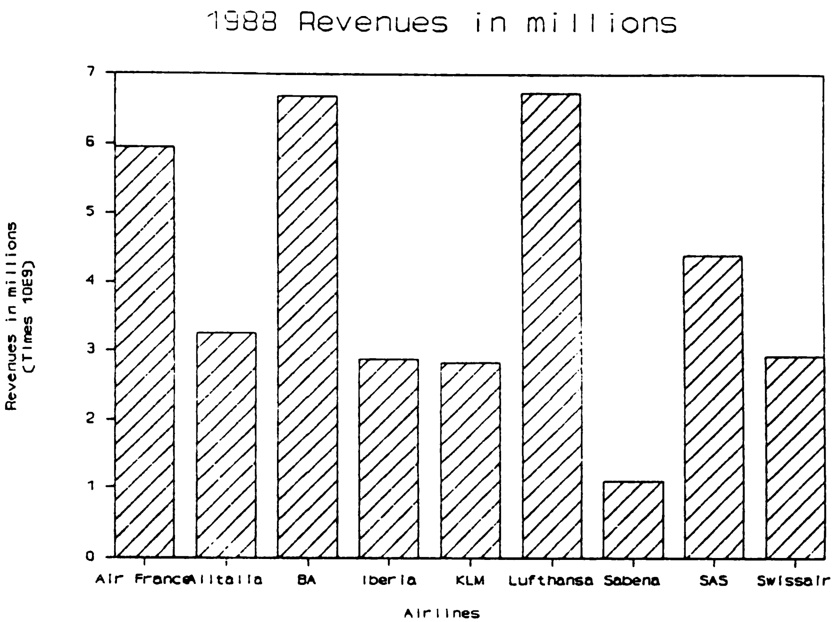
4. To promote the economic and social interests of the member states, for example, protection of the environment.[1]

The importance of the transportation sector in the Community becomes evident when considering that capital expenditure is estimated to represent about 11% of total private investment in the community.[2]

Transportation, in this context, includes all modes: air, inland waterway, rail, road, and sea transport. To place the air transport policies in context, it is noted that a number of important changes have taken place in the European ground transportation sector over the past few years. A brief synopsis of these changes follows.

Road

Cabotage (reciprocal rights) was introduced into the EEC in 1989. It will come into effect on July 1, 1990 but the rules for freely crossing borders will come into being on January 1, 1993.


1988 Revenues in millions
Revenues in millions (Times 10E9)
0
1
2
3
4
5
6
7
Air France
Alitalia
BA
Iberia
KLM
Lufthansa
Sabena
SAS
Swissair
Airlines

Ocean

Since December 1986, a number of measures have been adopted to provide freedom of ocean transport services between nations in the EEC.

Inland Waterway

A decision should be taken on cabotage before the end of 1989.

Liberalization is expected.[3]

The air transportation sector is coming under significant pressure on the liberalization issue. Among the players, the International Air Transport Association (IATA), the European Civil Aviation Conference (ECAC), and the Association of European Airlines (AEA) are the key organizations involved in the liberalization of the European skies. The IATA represents at least 100 airlines and is one of the most influential airline organizations in the world. The ECAC strongly influences European air transport policy as well. The AEA represents the thirteen largest European airlines, in policies concerning air transport.[4]

ALLIANCES, PACTS, MERGERS AND OWNERSHIP ISSUES

Airline Alliances

There are several models of passenger airline organizations in Europe. They include regional carriers, national carriers, and other major carriers that are not regionals or national carriers. Alliances, mergers and pacts for cooperation seem to be the wave of the future for most of the European airlines. Many of them are scrambling to merge with other airlines. Once the unified market is in place, in 1992 or shortly thereafter, many carriers predict a highly concentrated air passenger market.

> "The hopes of competition, so bright only a few months ago, are dimming under the crushing weight of alliances, takeovers and squeeze plays. Is any company going to be brave enough to start it's own airline?"[5]

The three largest combines in the European air passenger market have occurred over the past three years. They are discussed in detail below, as well as other smaller mergers and alliances.

The British Airways and British Caledonian Merger.

When British Airways merged with British Caledonian, in 1987, the European Economic Community approved of the merger, but they required that robust air competition be maintained in those markets. The EEC

> "extracted concessions regarding the maintenance of competition from the merged carrier by far more stringent requirements than those required by the British government when it approved the merger."[6]

The agreement between British Airways and the EEC is the first of its kind between an airline and the EEC. It may set a precedent for EEC control over carriers operating within the Common Market. The Commission has been worried about the potential for regional monopolies in air service, such as those it believes have come about in the US after airline deregulation. This is considered the first step in preventing airline monopolies from developing in Europe. The provisions of the EEC approval agreement include:

1. British Airways may have only 25% of the landing slots at Gatwick airport during the summer season. Considering 1987 traffic levels, British Airways would lose approximately 10,500 slots under this formula.

2. Certain domestic routes were returned to the British Government as a condition of the merger. Any decision by the British Civil Aviation Authority to award any of the domestic routes formerly held by British Caledonian to another airline will not be appealed by British Airways.

3. Another provision of the agreement states that British Airways will not be allowed to appeal an adverse decision by the British Civil Aviation Authority on its application to regain routes to Paris, Brussels or Nice from Gatwick Airport. British Airways will also withdraw an application for the routes to Hamburg, Stuttgart and Rome, and will not re-apply until at least April 1991.

4. Applications by other British airlines to operate competitive routes to any other Common Market Nations will not be opposed by British Airways, as long as the new route will not cause British

Airways to reduce its capacity on the route below the existing level.

5. British Airways will continue to provide service from both Gatwick and Heathrow Airport, both near London, so that competition will not suffer, or airline passengers will not be inconvenienced.

6. A report will be filed with the European Commission, every six months, by British Airways. It will state the life of the agreement, and detail how British Airways is complying with the terms. British Airways may ask for a relaxation of the rules due to unforeseen circumstances. The agreement will last four years, which should allow enough to time for the competing airlines to become established and provide effective competition. This merger made British Airways the largest Airline in Europe. British Airways now has 33% of the hub at Gatwick Airport and 45% of the market at Heathrow Airport, the two largest airports in Britain.[7]

Partial Equity Position in Sabena World Airlines Taken by KLM and British Airways

Recently, a partial equity position has been taken in Sabena World Airlines by KLM and British Airways. KLM and British Airways each have purchased a 20% stake in Sabena. Currently, the EEC Commission is investigating this new Sabena World Airlines, to see if it infringes upon any European Community rules on free competition.[8]

Observers think the Commission is likely to set such stringent conditions for the creation of Sabena world Airlines that the deal may effectively be ended.[9] The partial equity position taken in Sabena World airlines by British Airways and KLM came as a surprise move. "It gives British Airways, Europe's biggest airline, an even bigger presence on the continent.[10]

Trans-European Airways has already filed a complaint over the Sabena World Airlines agreement, stating that Sabena is now a monopoly on the routes in and out of Belgium. Other small British and Belgium carriers are protesting the creation of Sabena World airlines as well.

Some analysts believe that British Airways' primary goal is to lock up access to Brussels, which is one of the only airports in northern Europe with room to expand. British Airways plans include the establishment of Sabena World Airlines as a hub-and-spoke airline operation out of Brussels Zaventem airport, serving "75 cities in Europe with one day round trip services for the business community by 1995."[11]

The Air France Interest in Air Inter and UTA

Air France now owns a controlling interest in UTA and Air Inter. On January 12, 1990, Air France obtained 55% L'Union des Transports Aeriens (UTA), and control of Air Inter. Through its ownership of Air Inter, Air France now owns part of Air Inter and TAT, France's biggest regional airline. One industry analyst noted:

> "Bernard Attali, the Chairman of Air France, wants to create a behemoth that would monopolize French air travel and be the third largest Western Airline after United Airlines Inc and American Airlines. Air France feels that Europe needs mega carriers to compete with those in Europe and the far East."[12]

Obviously, British Airways is concerned that Air France has obtained a controlling interest in both UTA and Air Inter, because if approved by the EEC, Air France will take over British Airways' place as the largest airline in Europe and could potentially enjoy a monopoly on some city pairs. This merger would allow control of 66% of all flights at Paris airports, and "Air France would now control 97% of France's (domestic) airline industry.[14]

The mergers have implications beyond Europe. In terms of the world's airline industry, Air France's annual revenues would now surpass those of British Airways.

The West's Three Biggest Airlines[13]

Airline	1988 Sales In Billions
United	8.9
American	8.6
Air France	8.0 (Includes UTA and Air Inter)
Delta	7.3
British Airways	7.2

Other Major Alliances and Cooperation Pacts

Along with mergers, partial equity positions and alliances, the European air passenger industry has seen several unique inter-corporate cooperation pacts. Three different groups are currently forming cooperation pacts in Europe.

One group is led by British Airways and KLM.

Another alliance includes, among its leading members, SAS and Swissair. This is known as the European Quality Alliance (EQA). The EQA consists of SAS, Swissair, Australian Airlines and Finnair. They work together on customer service, marketing, sales and technical work.

> "More than 40% of all travellers to Eastern Europe on West European airlines are conveyed by one of the four partner carriers, making the new alliance the European leader in East-West traffic."[15]

They are also working together to buy 239 new aircraft and have asked for bids from McDonnell Douglas and Airbus Industrie. The EQA also hopes to reduce costs of purchasing new aircraft by this venture.

The third is led by Air France and Lufthansa, which last September signed a broad cooperation pact. This group is known as the Atlas Group. The Atlas Group serves as a model of carrier cooperation. It consists of five members which include Air France, Alitalia, Lufthansa, Sabena and Iberia (this is Spain's national carrier, owned by Instituto Nacional de Industria).

This group states that the cooperative agreement aims to permit flexibility, efficiency, and quality assurance in the increasingly competitive and rapidly changing airline business. Cooperative activities of the Atlas Group include maintenance and training activities for various planes including the 747, McDonnell Douglas DC-10 and Airbus Industrie A300, A300-600 and A310.[16]

Some of the regional and small carriers are committing themselves to one pact or alliance, and their competitors may be forced by competitive pressures to follow.[17]

Bilateral and Other Limited Scope Alliances

Air France: Air France signed a cooperation agreement with Lufthansa in 1989, and they operate a joint service over East German airspace. The Air France combine will become the largest airline in Europe if the EEC approves their controlling interest in UTA and Air Inter. Currently, Air France is more than 80% owned by the French government.

British Airways: This carrier is currently Europe's largest airline. British Airways was involved in the attempted leveraged buy-out of United Airlines. They were ready to spend $750 million to buy a portion of United Airlines, but pulled out when the rest of the deal did not go through. United Airlines and British Airways have an alliance that dates back to the 1950's, when British Airways was known as the British Overseas Corporation. They share a terminal at O'Hare International Airport (Chicago) and take part in code-sharing with United Airlines.

British Airways and Maersk Air, in a 40% joint venture, took over Birmingham European Airways, a British concern. Currently a privately-owned carrier, British Airways has 338,350 shareholders (May 15, 1989) and is no longer government owned.

KLM: The Netherlands government owns the majority of the outstanding shares in KLM Royal Dutch Airlines, 79.3 %. KLM took part in the buyout of Northwest Airlines Inc., and it would have a larger share of Northwest Airlines than it does today, if Samuel K. Skinner, United States Secretary of Transportation, had not intervened.

He "force(d) KLM Royal Dutch Airlines to cut back its share of the investment from 57% to 25% even though KLM only had 5% of the voting stock."[18]

KLM also holds a 14.9% stake in Air UK, 4% share of a Dutch Regional carrier known as Transavia, and 29% ownership interest in the Dutch charter operator Martinair. Also, in 1989, marketing link-ups in cargo and passenger services were being studied between Northwest and KLM.[19]

Lufthansa: Lufthansa is partly owned by the West German government and the remainder is publicly owned. Government participation is shared between the Federal Government, Lander, and Deutsche Bundesbahn. Lufthansa AG has recently announced plans to take a 26% stake in Interflug, East Germany's only airline.[20]

SAS: SAS is owned by a consortium. Fifty percent is owned by the public, and the other fifty percent is owned by three countries in these proportions - Sweden owns 3/7, and Norway and Denmark each own 2/7. SAS is a recognized company within the EEC.

SAS owns 9.8% of Texas Air. Jan Carlzon, Chief Executive Officer of SAS,has been trying to involve SAS in mergers with various airlines, because he believes that merging is the best strategy to survive the liberalization of the European skies. He says his pact with Continental Airlines has already helped produce a 28% increase in SAS passenger traffic between Scandinavia and the United States. SAS even operates a "charm school" for Continental employees.[21]

In 1986, a proposed merger of SAS and Sabena Belgian World Airlines died at the start because of the deals legal complexities. In 1987, British Airways PLC blocked Carlzon's bid for British Caledonian Airways Ltd., by buying the BC Airways itself. And when Carlzon angled for a piece of Aerolineas Argentinas, the Peronist party's objection to having a big foreign shareholder killed the deal.[22]

Swissair: In the past, Swissair was owned 25% by the Swiss government, but according to Jeanmarc Felix, of Swissair, it is now privately owned.

Swissair and Delta Airlines bought a 5% stake in each other. They also have a joint marketing agreement. Swissair also has investments in Delta Airlines, Austrian Airlines, and Crossair, a Swiss domestic carrier. Swissair has also agreed to a minority equity swap with SAS. And, Swissair also has a cooperation agreement with Singapore Airlines.[23]

Alitalia: The majority stockholder in Alitalia is the Institute for Industrial Reconstruction, which is the management body for state investments in Italy. The Italian government has a 54.72 percent share in Alitalia.

Sabena: KLM and British Airways each own 20%. This agreement was concluded on December 13, 1989. Seven out of ten Sabena passengers are concentrated on European routes.

THE POTENTIAL ECONOMIC EFFECTS OF MERGERS AND ACQUISITIONS

Industry analysts believe the European air market will change dramatically after 1992. European airlines facing the twin challenges of deregulation and privatization are attempting to brace themselves for a dramatic change in the restrictive rules on competition, routes, and ownership that until now have protected many carriers.

In this paper deregulation and liberalization are used interchangeably. Deregulation is an elimination of economic regulations controlling transport routes, ownership and operating policies. Since the Europeans are approaching deregulation with more caution than the United States did, it is sometimes referred to as Liberalization.

One important dynamic of the European airline industry after 1992 is the potential that airlines will consolidate into a few extremely large passenger carriers which could potentially keep other passenger carriers out of the market. Airlines across Europe are hustling to defend long-protected routes. In essence, they have learned from the frantic US shakeout that bigger is better and it pays to dominate key airport hubs.[24]

"So a dominant strategy is emerging. Find a friend or else."[25] According to Daniel Kasper, Airline specialist at Harbridge House in Boston airline mergers are inevitable. By the time everything shakes out, there will only be a few dozen airlines offering service globally.[26]

Industry analysts believe that the EEC will work to prevent the industry from becoming a cartel. It appears the European Community officials want to avoid the market instability and lack of competition that occurred in the US when the larger airlines bought up the smaller ones.

Economic Effects on Regional Carriers

Unlike regional carriers in the US, regional carriers in Europe are generally independently operating companies. The European carriers are worried about losing their landing slots when competition among the big airlines becomes fierce.[27]

Normally, when a regional carrier has an agreement with a major airline, the carrier is guaranteed landing slots at major airports. If the carrier loses those landing slots, they would be out of business. There is the potential that only a few regional carriers will survive in Europe. Smaller regional airlines also face the problem of airport congestion. Because of overcrowding and increased demand for landing slots as traffic grows, many of the small airlines may not even survive. However, new low-cost small airlines may be created.

Structure of Air Fares

There is a debate over what will happen to air fares upon liberalization. Some observers seem to think that the air fares will decrease while others think that they will increase. Currently, European travellers pay the highest airfares in the world. However, European airlines do not necessarily make more profits than other comparable international carriers.[28]

US Airlines cannot carry passengers between two points in any EEC member nation except for flights between points in West Germany and Berlin. If the EEC allows US airlines or other foreign airlines to fly between points in the EEC, there might be a chance for greater competition, and potentially lower fares. The EEC has encouraged cheaper airfares as a way of popularizing the Common Market, and if the EEC's efforts at encouraging competition are successful, air fares should go down after the liberalization. Transavia in Holland, Virgin Airways and Air Europe in the UK, and

Ryanair in Ireland, are the best hope for cheaper fares. They have already shown they are prepared to undercut the airfares of already established carriers.[29]

If the airlines merge, there will be a tendency for air fares to be high, because of market concentration. The airlines will be able to charge high prices because they will not have competition.

The Formation of Hubs

The nature of European hubs can be expected to change as their operations begin to reflect underlying economic, rather than regulatory, factors. The airlines may structure their routes to replicate what happened in the US under deregulation (the Airline Deregulatory Acts of 1977 and 1978). In the United States model, large airlines selected one city as a hub and made connecting feeder flights to that point.

In order to create a hub at a major airport in Europe, it will take the cooperation of that nation's government and its transportation agencies. This is to ensure that an airport offers not only the capacity to handle flights, but also the most efficient infrastructure, such as air traffic control, communications, and road and rail ground transport.

Britain is at a disadvantage in regard to the location of a hub and spoke network there. It is at the geographic fringe of the EEC. If the main purpose is to get passengers and goods to their destinations as quickly as possible, then Paris, Frankfurt, Brussels, and even Amsterdam are much better situated than London for reaching the European heartland. Furthermore, congestion at the British airports may stifle attempts for hub development there. "With Heathrow's runway utilization at 82% and Gatwick's at 100% at peak times, there is not much room for growth."[30]

Both Paris and Amsterdam have the will, the room, the financing and their respective governments' backing to become the number one airport. It seems inevitable that the hubs are most likely to occur at airports that have excess capacity.

The Netherlands is better situated than London, and the Netherlands has significantly more cooperation between the government, transportation departments, transportation companies and Schiphol airport in Amsterdam. Only the two Paris airports have more room for growth than this airport.[31]

The airlines may also try to center their hubs around airports which are underutilized in order to gain a future monopoly at that airport. At these underutilized airports, a carrier will have the ability to expand its operation, which is almost impossible in the larger airports in Europe. The Table below shows passenger loadings at European airports. Note the significant numbers passing through some of the world's busiest airports, such as Heathrow, outside of London.

TABLE 2

Airports In The European Community And Number Of Loadings In 1988[32]

Airport	Country	Total Commercial Passengers
Amsterdam	Netherlands	13,141,926
Barcelona	Spain	7,234,045
Berlin	West Germany	5,603,366
Cologne-Bonn	West Germany	2,364,360
Copenhagen	Denmark	7,040,569
Dusseldorf	West Germany	9,981,930
Frankfurt	West Germany	25,235,401
Gatwick	England	20,761,156
Heathrow	England	37,525,281
Orly	France	37,602,449
Turin	Italy	1,118,344

Passenger Loyalty

As competition intensifies, customer loyalty will gain in importance. Airlines may try to obtain loyalty from their passengers by providing excellent customer service and extraordinary amenities. Under regulatory times, the passengers had fewer airlines from which to chose. After deregulation, this will change so the flag carriers will have more direct competition.

The European airlines may try to encourage passenger loyalty by offering frequent flier programs, more personal services and more comfortable seating. Also, they will now be offering extensive service, which in this context means that the carrier will now be able to take care of most of a passenger's destination needs.

REVENUE MEASUREMENTS

In addition to the traditional revenue-based measures of carrier viability, total revenue and total profits, performance in the airline industry may be measured in several other ways. Two additional factors which may be helpful are ridership (the number of passengers who board that airline per year) and revenue passenger miles (billions of passenger-miles per year). Both measures obviously have a strong influence on carrier revenues. These data are depicted on the Table and charts which follow.

CONCLUSION

The number of alliances, cooperation pacts, equity stakes, and mergers among European air passenger carriers are a central feature of the airline industry in Europe. These inter-corporate agreements have been growing in scope and number since the British Airways- British Caledonian merger in 1987. By 1992, it is likely that pacts, alliances, and merged firms will be the norm. The nine largest European airlines involved in this study have formed necessary and valuable alliances which seem to be unique, in their wide variety, to the European air passenger industry.

ENDNOTES

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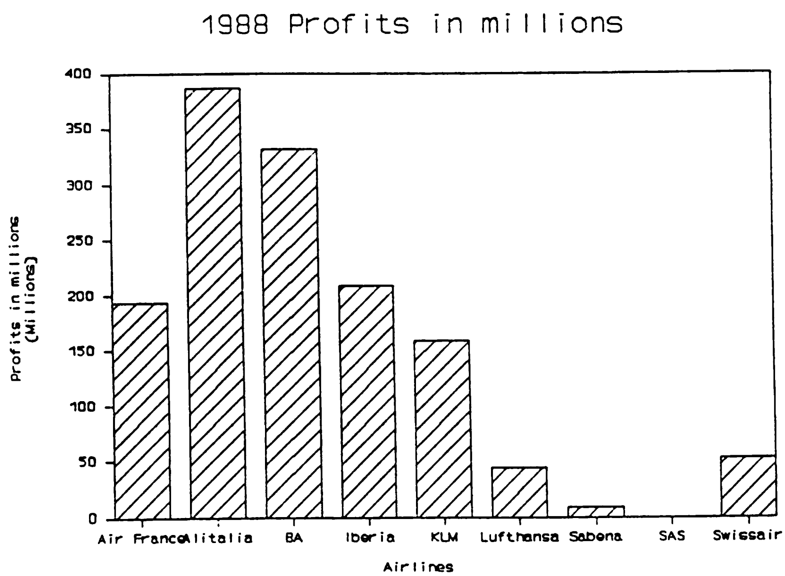
3. Overton, David, *Common Market Digest,* London: The Library Association Publishing, 1983, p. 7.

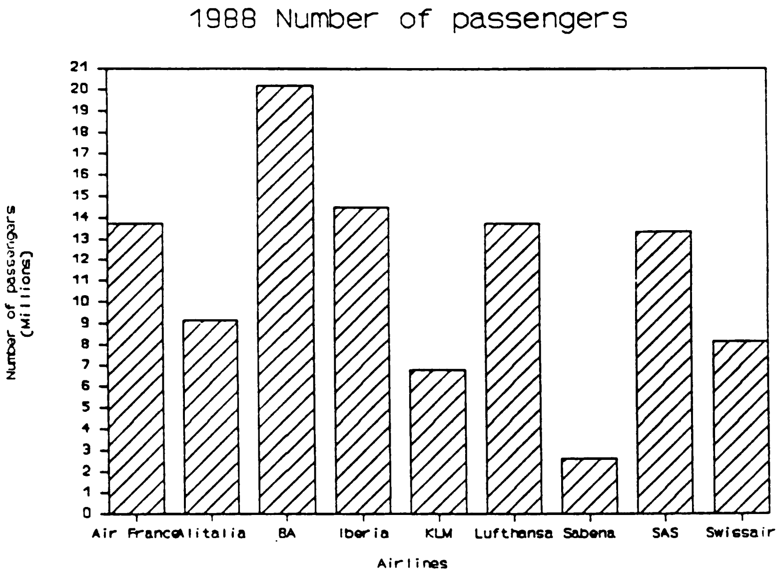
4. *The European Community's Transport Policy,* p. 38

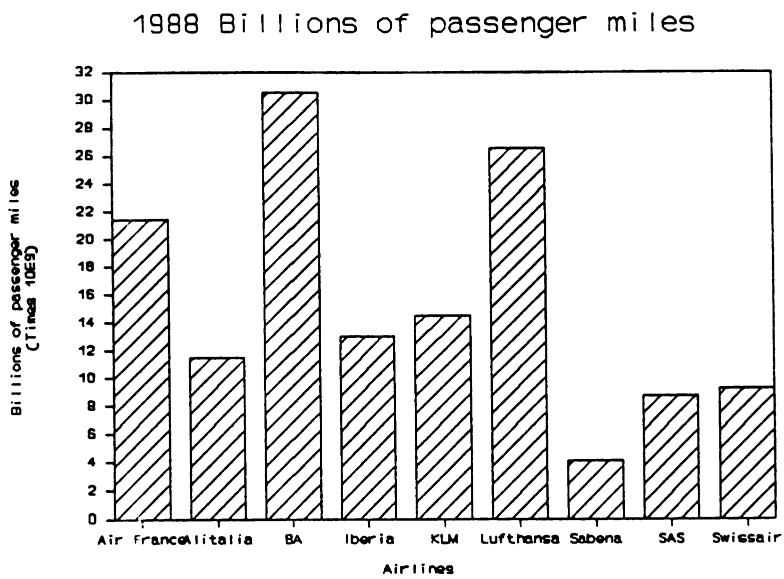
TABLE 3

European Airlines Ranked According To 1988 Revenues[33]

Airline	Revenues	Profits Millions	# of passengers	Billions of passenger mi.
Lufthansa	6,739.9	44.1	22,546,000	26.4
BA	6,690.4	331.3	20,169,000	30.5
Air France	5,953.7	193.5	14,805,691	21.4
SAS	4,412.0	N/A	13,338,733	8.7
Alitalia	3,258.1	386.6	9,155,161	11.5
Swissair	2,927.8	52.0	8,135,089	9.2
Iberia	2,874.2	208.2	14,487,687	13.0
KLM	2,823.2	158.7	6,880,000	14.5
Sabena	1,093.5	9.1	2,604,578	4.1


1988 Profits in millions
Profits in millions (Millions)
400
350
300
250
200
150
100
50
0
Air France
Alitalia
BA
Iberia
KLM
Lufthansa
Sabena
SAS
Swissair
Airlines


1988 Number of passengers
Number of passengers (Millions)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Air France
Alitalia
BA
Iberia
KLM
Lufthansa
Sabena
SAS
Swissair
Airlines


1988 Billions of passenger miles
Billions of passenger miles (Times 10E9)
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Air France
Alitalia
BA
Iberia
KLM
Lufthansa
Sabena
SAS
Swissair
Airlines

5. "Where the Skies aren't Getting any Friendlier," *Business Week,* April 16, 1990, p. 39.

6. "EEC Extracts Concession in Approving Airline mergers," *Aviation Week and Space Technology,* March 14, 1988, p. 253.

7. Ibid.

8. *The Journal of Commerce,* March 28, 1990, p. 5B.

9. "Plans for New Airline May Hit EEC Snag," *The Journal of Commerce,* May 4, 1990, p. 9B.

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19. "At 70, Still Looking Ahead," *Air Transport World,* January 1990, p. 28.

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22. Ibid.

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24. "Where the Skies aren't Getting any Friendlier," *Business Week,* p. 38.

25. "Birds of a Feather...are Doing Deals Together," *Business Week,* September 11, 1989, p. 32.

26. Ibid, p. 33.

27. "Gadflies," *The Economist,* March 10, 1990, p. 73.

28. "Fly the American Way," *The Economist,* February 4, 1990, p. 16.

29. "Dogfight Over Europe," *Management Today,* p. 96.

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33. Information for this table was drawn from "Revolution in the Air," an article in *Fortune,* January 1, 1990, p. 59. Additional information was drawn from corporate annual reports, and the *World Aviation Directory,* Winter 1989.

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