FOCCS - FLEXIBLE OPERATION COMMAND & CONTROL SYSTEM FOR PUBLIC TRANSIT

Horst E. Gerland

Rufbus GmbH Bodenseekreis
P.O. Box 2206
Oberhofstrasse 17
7990 Friedrichshafen
Fed. Rep. of Germany

1. INTRODUCTION

Long-term operation of automated public transportation command, control and management systems as well as of "Demand-Responsive Transportation Systems (DRT)" led to the development and deployment of the "Flexible Operation Command and Control System (FOCCS)" with first applications in Lake Constance County and Hannover County, West Germany, under the sponsorship of the German Ministry of Research and Technology. FOCCS has been developed for the joint management of both line-haul and DRT services and to cover the requirements of public transportation users by a flexible combination of all specific operation modes within a public transportation service area. Using the most modern information, communication and control technology, FOCCS is able to integrate rail services, line-haul bus, DRT, and taxi services as well as special charter services (e.g. elderly and handicapped transit modes) into a uniform public transit network. Components for the planning and management of the transit operation are added.

2. SYSTEM CONCEPTION AND OPERATION MODE MODEL

The basic idea behind FOCCS is to combine the advantages of the line-haul transportation (pre-scheduled service, regulated headways, high capacity) with the advantages of the demand actuation (availability at all times of a unique public transportation information and registration system, non-scheduled spontaneous service, individual service, demand responsive movement of the transportation vehicles, no neccessity of service of stops without actual traffic demand). The concept of FOCCS is based on the combined and flexible application of different transportation modes as schematically shown in Fig. 1:

° Scheduled operation in traditional linear checkpoint service (e.g. railway, line-haul bus, school bus service)

° Route deviation operation resp. direction-oriented checkpoint service as a timetable-oriented "corridor service" with demand actuated deviations from a "trunk route" or a pre-determined checkpoint sequence

° Demand actuated or "call-bus" operation in random checkpoint service in suitable sections of the traffic area and/or appropriate traffic times as a feeder resp. distributor for superordinate lines and/or as a supplementary service for the line-haul service

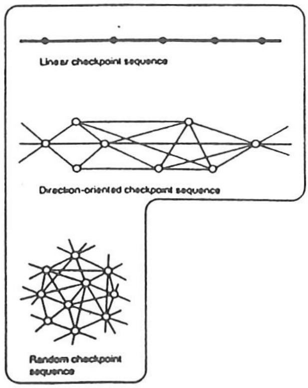

Fig. 1: Directionality of checkpoint sequence

The composition of the different operation modes in the operation mode model is shown in the diagrammatic representation of Fig. 2:

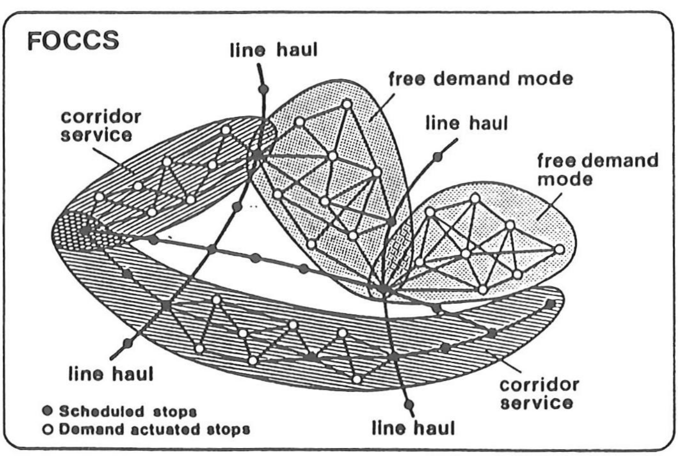

Fig. 2: FOCCS operation mode model

The allocation of the various operation modes to individual sectors of the service area can flexibly be adjusted according to temporary and regional requirements: Depending on political, operational or transportation demand, it is possible to expand or reduce the extent of the "corridor service" or the "free demand mode" (e.g. "extensive call bus operation" during offpeak hours, at the weekend and during the school holidays; "less call bus operation" during commuter and school rush hours).

3. SYSTEM FUNCTIONS

The basic functions of FOCCS include those which are representative of any Automatic Vehicle Monitoring, Command & Control System. These are:

- ° Provision of a data base with all static and dynamic data and information on the public transportation of the service area
- ° Automatic vehicle location via radio communication
- ° Comparison of nominal and actual schedule conditions
- ° Headway control
- ° Supervision of turnround times
- ° Registration of and dealing with incidents

Due to the specific requirements in various applications three different modes of vehicle location have been implemented in the system (beside the traditional voice radio communication used as back-up):

- ° Vehicle monitoring through specific on-board mileage counters. Synchronization takes place at the stops (through the vehicle door cycle) and/or via stationary infra-red beacons placed at selected points of the transit network.
- ° Vehicle monitoring via autonomous location through the vehicle device. Synchronization takes place at particular reference points through specific algorithms.
- ° Vehicle monitoring of on-demand operating vehicles via driver through the keyboard of the vehicle device. Since the system knows the next stop of the vehicle in demand mode operation by the on-demand vehicle disposition, the location is fixed when the so-called "arrival button" is pressed by the driver upon arriving at the pre-allocated stop. The departure is indicated by a dispatch signal.

Pre-requisite of these modes of automatic vehicle location is a high-sophisticated digital radio communication.

Additional functions have been implemented to deal with the specific requirements of offering different operation modes. Since FOCCS was originally designed to meet with the special requirements existing outside the conurban transportation regions (with the main emphasis placed on the availability of public transportation services) the system also fulfils a number of relevant functions. These particular FOCCS functions are:

- ° Uniform public transportation service through integration of railway, line-haul bus, call bus, school bus, ferry boat, taxi and special charter services (e.g. elderly & handicapped transportation) into an overall system

- ° Provision of a central institution to provide public transportation information of all kinds and to provide facilities for trip request registration and vehicle disposition; provision of equipment (media) to facilitate passenger communication and trip request registration
- ° Provision of media for trip request registration and processing
- ° Trip request registration and processing
- ° Automated timetable information, optionally from the pre-planned and/or actual timetables
- ° Dynamic schedule synchronisation at transfer points resp. ensuring conections when transfer takes place
- ° Allocation of the various operation modes to individual sectors of the service area according to regional and/or temporary requirements
- ° Supply of information about transportation availability and allocation of the trip requests to line-haul, corridor service or demand-actuated vehicles or to a combination of these services
- ° Transmission of the transportation information (trip recommendation and disposition) to both passenger and vehicle
- ° Ensuring flexible allocation of the "line-haul", "corridor service" and "demand-actuated" services to individual sectors of the transportation area
- ° Design of routes for the demand-actuated and corridor services.

In addition to this, FOCCS also has the facility for the provision and evaluation of statistical data for the analysis of operational procedures.

4. TECHNICAL COMPONENTS

The FOCCS technology (hardware and software) is of modular design, taking the functional and operational criteria into account. The modular character of FOCCS makes it possible in particular applications to adapt the system to the specific requirements by modifying, adding or dropping certain functions.

Fig. 3 is to give an overview on the technical components of FOCCS. The hardware configuration is schematically shown in Fig. 4.

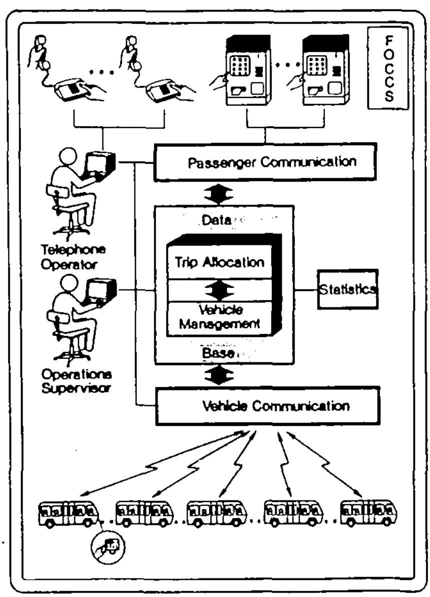

Fig. 3: Technical components of FOCCS

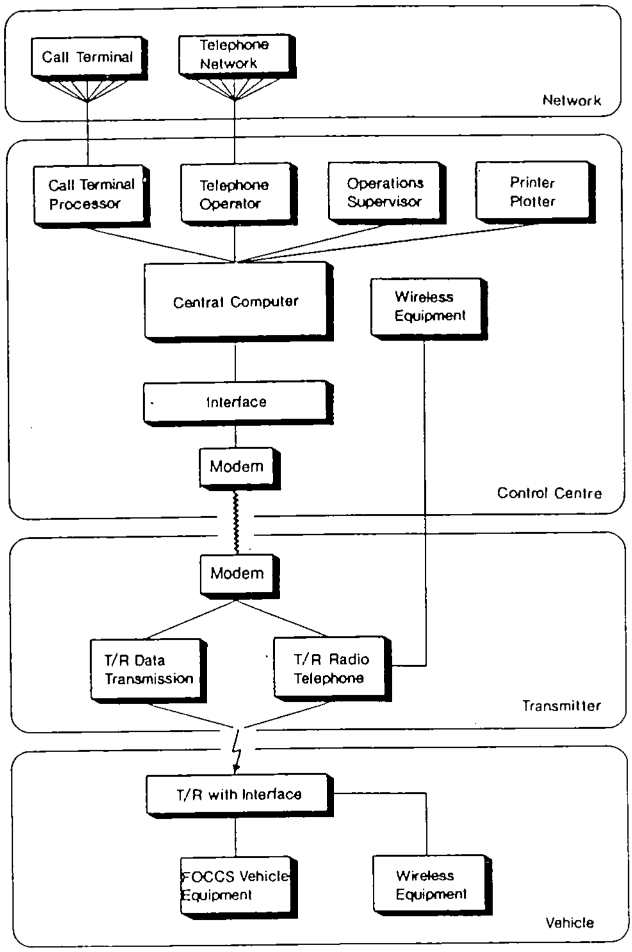

Fig. 4: FOCCS hardware configuration

Transportation users can contact the FOCCS center from any public or private telephone. Special call boxes or call terminals can additionally be installed at certain selected stops for passenger communication purposes. An example of a call box is shown in Fig. 5. The use of call boxes makes sense at certain selected stops with a relatively high passenger frequency and where passengers proceeding to the stop do not come from home - e.g. at railway stations, shopping centres, hospitals or relevant acitivity centres.

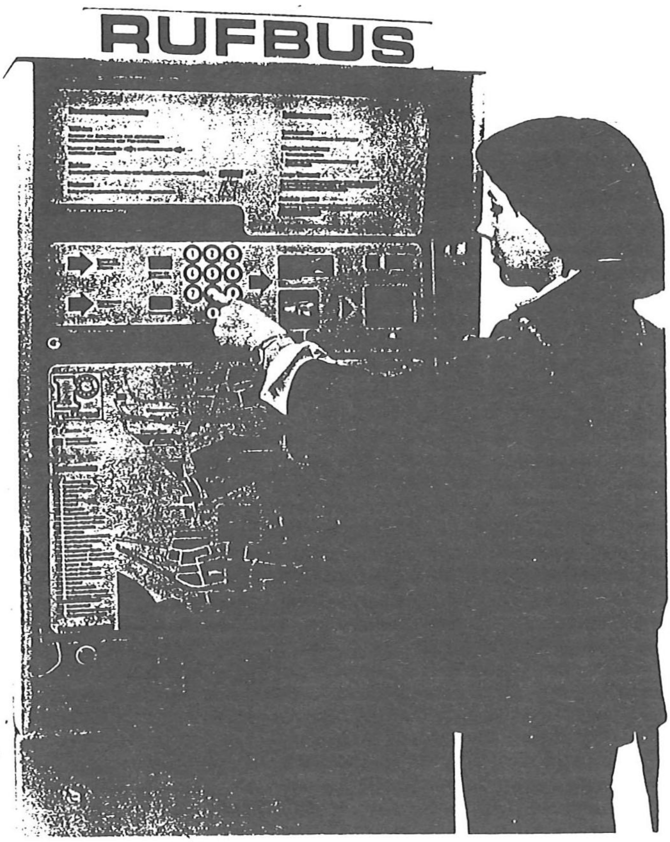

Fig. 5: FOCCS call box

The exchange of data and information between the command & control centre and the vehicles is carried out by digital wireless contact. The vehicles are equipped with specific vehicle devices (vehicle terminals) to transfer all kinds of information necessary between the vehicles and the operation centre such as

in the direction of the operation centre

° Vehicle location information

° Coded information (e.g. passenger load, request for voice radio etc.)
° Trip requests
° No-show of customers

and in the direction of the vehicles

° Coded instructions
° Actual schedule conditions
° Next checkpoint(s) to serve
° Number and destination resp. delivery point of passengers to board at next checkpoint
° Answers to trip requests
° Instructions at transfer points (e.g. to wait for delayed feeder service)

The vehicle device is displayed in Fig. 6. Concerning the technical realization of the vehicle communication system it is worth-while mentioning the fact that the radio system and the vehicle devices are standardized under the existing regulations of the German Public Transportation Association.

Fig. 6: FOCCS vehicle device

Due to the various responsibilities the supervisor's place in the operation centre is equipped with three screens. One of them shows continuously all incoming calls from the vehicles and all incidents registered by the systems control, like vehicle delays, failures in system components (e.g. call boxes); this screen also serves for operator activities concerning radio communication. The other two screens provide the operator on his request with the information about all relevant static and dynamic, nominal and actual data and to interact with the system.

The FOCCS software has been divided into dispositive, communicative, and system planning and evaluation modules added tho which are a series of service modules relating to start up of the system, software control, and data storage. The software system reflects rather closely the functional structure of Fig. 7. This feature which is advantageous from the viewpoint of understanding, maintenance and extension was achieved by using a modern high order language (PASCAL) in combination with a virtual operating system (VMS) on a 32-bit computer (DEC) with sufficient memory (5 MByte).

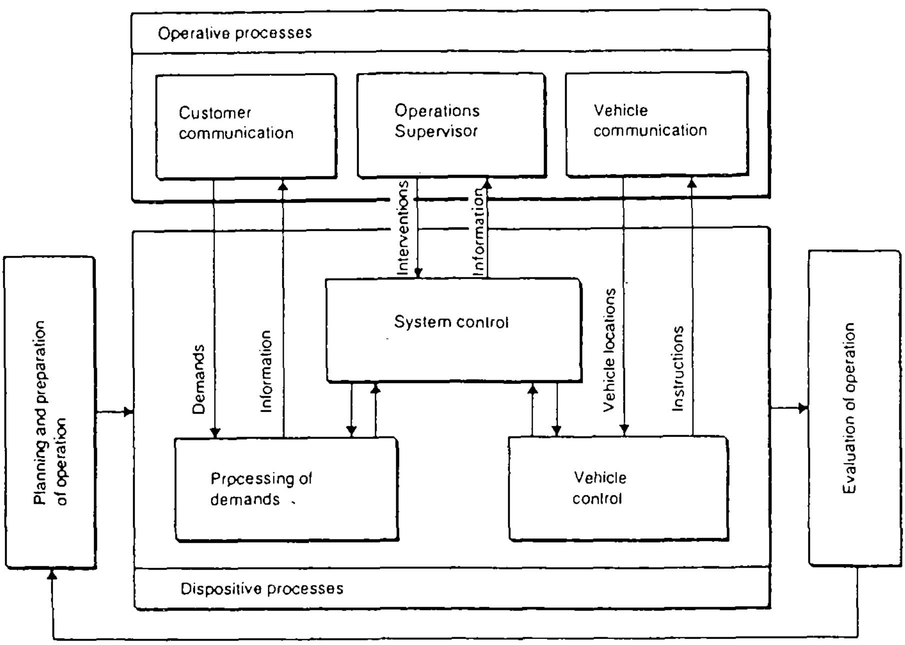

Fig. 7 : Functional components of FOCCS

5. DATA AND PARAMETERS

The public transportation data required for the FOCCS application and the parameters necessary for setting up and adjusting the system are stored in the data base in the form af "archives"; the FOCCS system consists of the following archives:

- ° Network archive as a data bank of all information relevant to routes and stops (e.g. matrices of route sections between defined points; details of factors limiting detours; description of stops and stopping points)
- ° Zone archive to assist in allocating the various forms of service, "line-haul", "corridor-service" and "demand-actuated", to different sectors ("zones") of the service area (e.g. zone codes, time intervals for zone existence, allocation of stops and forms of service to zones)
- ° Line archive as a store of basic data of all existing lines (e.g. line routes, order of stops)
- ° Schedule archive as a store of data relating to the daily timetables of the rail and line-haul bus services (e.g. timetables for the days of the working week, Sunday timetables, holiday timetables)
- ° Basic route archive as a store of published "trunk routes" within the zones with corridor service and of non published predesigned routes in zones with demand actuated operation (e.g. route pattern, order of stops, branching points off the "trunk route" and route patterns of the branches)
- ° Connection archive as a store of data concerning the connecting modalities at transfer points (e.g. time required for intermodal transfer, regulations governing waiting time)
- ° Vehicle archive as a store of data covering all relevant operational and technical information about the vehicles deployed (e.g. number of seating and standing places; classification according to speed, weight and size; whether or not space allowance has been made for prams or handicapped conveyances etc.; call address)
- ° Call terminal archive as a store for all data relevant to the call terminals (e.g. location, type)
- ° Parameter archive as a store of system parameters (e.g. basic parameters, control parameters).

Differentiation is made in the parameter archive between the basic parameters necessary for design of the system (e.g. number of zones per service mode, number of vehicles per service mode, number of telephone operators in the FOCCS centre, number of vehicle equipment units) and control parameters required to control the system behaviour. The system parameters which govern the quality of service belong among the control parameters:

- ° Waiting time at stops
- ° Walking time between transfer points
- ° Relationship between maximum and minimum trip time (detour parameter)
- ° Deviations between actual pick-up time and time requested when registering.

The control parameter can be varied by the FOCCS operator to fulfil transportation or political criteria and can be adjusted to meet specific requirements concerning sectors of the network, connections or stops.

6. CORRIDOR SERVICE

A keypoint of FOCCS is the usage of a "mixture of line-haul bus and demand-actuated bus" with the designation "corridor service". The term indicates that, deviating from a totally flexible service responding to demands, a "corridor" shaped section of the service area is served "direction-oriented" at fixed times (characteristic of "line-haul operation"). However, the routing is not defined exactly, since the stops are served, to some extent, in a random, demand-oriented sequence (characteristic of "purely demand responsive mode of operation"). The combination of line and demand elements in a corridor service thus results in a prestructured collection and distribution service.

6.1 VERSIONS OF "CORRIDOR SERVICE"

Adapting to the differing requirements in daily operation, two different "corridor service" operating strategies have been implemented in the FOCCS system:

° Corridor service as "route deviation". The vehicles are run according to schedule on a trunk route with demand oriented deviations. Since the strategy for the route deviation is relatively simple to solve in the operational and control technology, it represents the "mini version" of the corridor service.
° Corridor service in direction oriented demand mode. In this case, the only fixed points are the origin and destination points and eventually the time, whereas all or almost all stops between the origin and destination points are served only when corresponding trip demands exist. Since this strategy requires an algorithm for controlling the course of the trip, it is considered as "maxi version" of the corridor service.

Fig. 8 illustrates the different versions of the corridor service. Fig. 9 and 10 show examples for the practical application of each corridor service, whereby the mini version is represented in Fig. 9 as feeder and distributor of a superordinate line ("feeder loop"). Fig. 10 shows the resolution of 2 lines into one corridor service, whereby the flexible switching from one form of operation to the other is possible depending upon the travel demand (for example, line-haul operation during commuter and school traffic hours and corridor service during the other traffic hours).

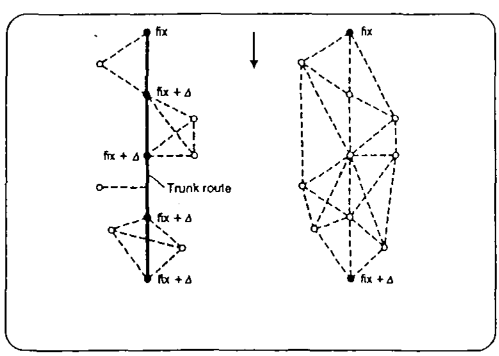

Fig. 8 : Versions of FOCCS corridor service

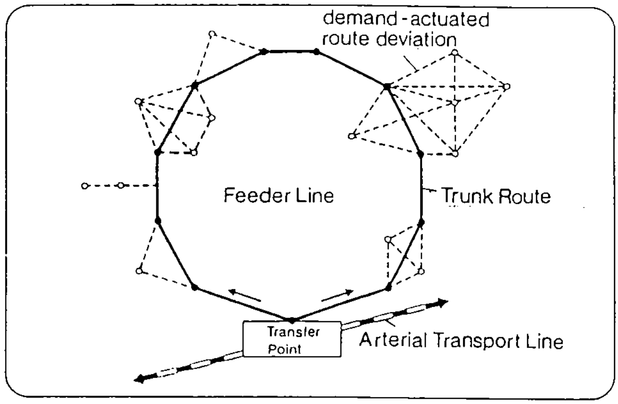

Fig. 9: Corridor service as feeder loop

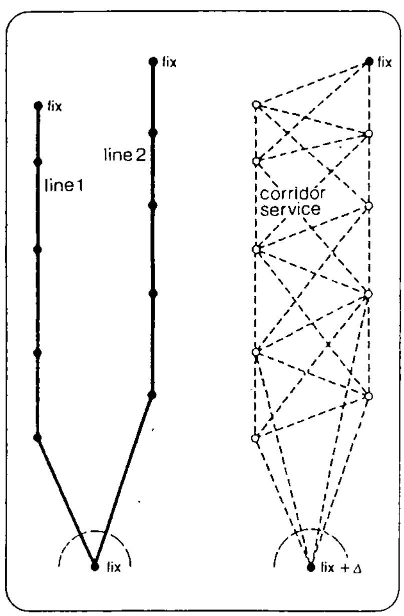

Fig. 10 : Resolution of two lines into one corridor service

6.2 ROUTE CONTROL

In simplified representation the route control in the corridor service is performed according to a two-stage optimisation procedure. In the first optimisation step the corridor service timetable is determined. The area served by corridor service is subdivided according to the schematic representation in Fig. 11 into sectors which each contain several stops. The determination of the sectors respectively of the group of stops which belong to a sector is based on the geographical as well as traffic conditions. The aim of the subdivision into sectors is to achieve an operationally suitable routing structure: If a sector is considered as a "macro stop", the macro stops are served in a fixed sequence as in line-haul operation. Only those stops which have been actually requested by trip requests are served in a sector. At the same time and as the second optimisation step (which is performed with computer control and which represents the actual command and control system level) the route with the shortest running time between entry and exit points of each sector is determined and compared on-line with the scheduled average running time. Deviations from the average running time can be synchronized if necessary at the exit point. The representation chosen in Fig. 11 is an example in which the entry and exit points are defined as scheduled stops; within the scope of the operating control system this is not mandatory.

Number and size of the sectors of a corridor service can vary flexibly - e.g. according to the traffic hours. During the night-owl service time, for example, larger sectors with a higher number of stops can be set up than at other times of the day, since the passenger volume and therefore the expected number of trip requests at the stops is lower. The routing develops towards a "purely demand responsive mode of transportation" relative to the concentration of stops in a sector.

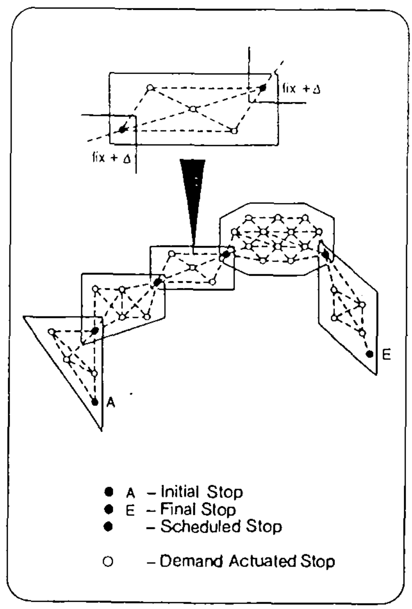

Fig. 11 : Breakdown of a corridor into sectors

6.3 RENTABILITY ASPECTS OF CORRIDOR SERVICE

Since, in corridor service, a large number of stops are served only when an actual demand exists, this results normally in considerably savings in running time and performance in comparison to line-haul operation becausese the trip requests can be satisfied over the individual shortest route and the stops without passenger transfer must not be served. The operational experience gained with FOCCS showed that line-haul buses can be substituted economically by corridor service when area-wide transportation coverage is required. The scope of possible savings in comparison to line-haul operation depends on the existence of a suitable topographic structure of the service area and an area-wide distribution of the travel demand. "Suitable" in this sense is a meshed traffic route network and an evenly distributed and comparatively low traffic volume. In these cases many demand-actuated stops can be combined into one corridor service sector and the optimisation procedure for route controlling can be effectively applied. Due to the prestructuring of the trips in corridor service, a better vehicle load factor in comparison to the "purely demand responsive mode of operation" is possible, whereby it must be considered that to a certain extent operational restrictions are deliberately waived in free demand actuation. In the current and forthcoming applications of FOCCS it is becoming apparent that the corridor service will play a prominent role.

7. COST AND BENEFIT ASPECTS

FOCCS operation involves capital costs and operational costs which can be split into fixed overhead and variable costs according to the diagram in Fig. 12.

The term "system costs" includes the capital investment costs and the costs for the maintenance and operation of the FOCCS installation.

Investment costs for FOCCS applications depend largely on the size of the service area, the requirements of the participating transportation companies and the level of development of the hardware, especially processor technology. With high-capacity microprocessors and vehicle equipment and call terminals manufactured in series production, it is possible to reduce the investment costs of the current demonstrations by about a third.

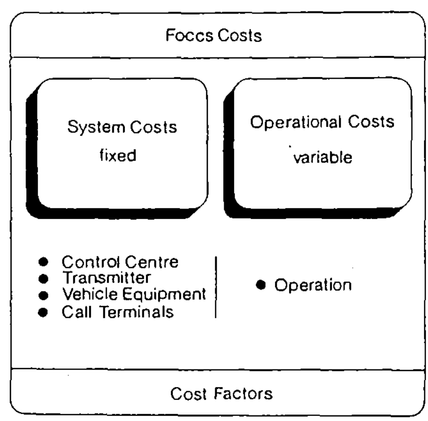

Fig. 12: FOCCS cost factors

Annual costs for maintaining and operating the FOCCS installation are made up by personnel costs (operations supervisor and telephone operator), costs for hardware maintenance and repair and costs for software maintenance, costs for electricity and cable fees for the transmitter/receiver installation, costs for data transmission and wireless fees for the vehicle equipment, costs for cable and electricity fees for the call terminals, and last not least, costs for interest payable on invested capital.

Data pertaining to benefits and evaluation of such data will only have real meaning in depth for the concrete application being studied. The characteristics of each individual case of application of the system (e.g. settlement and transport structure, level of service etc.) play a very significant role, especially when considering benefits. The following aspects relating to benefits show mainly the qualitative criteria considered of importance by the transportation operators:

° Availability of a uniform data base and computer for line planning, scheduling, duty rostering, operational control, operational supervision, passenger information and disposition etc.; computer support for operational and transport oriented statistics, analyses of the operation
° Availability of a central institution for the "interface passenger": information of all kinds, up-dated schedule information, disposition, dynamic schedule synchronization
° Availability of a flexible system of adapting the deployment of vehicles to meet current demand at any one time or in any region based on a continual supervision of vehicle occupancy and line loading; flexible reaction to fluctuating demand
° Availability of command and control technology for the purpose of communication between the centre and the vehicles (operational information, emergency calls)
° Improvement of transportation services supplementary to rail transit through specific feeder services in the form of demand actuated or corridor operation
° Pre-determination of stop sequences for vehicles operating in the demand actuated or corridor service mode and information for the drivers relating to passengers wishing to board
° Flexible adjustment of nominal trip times to the actual conditions pertaining at any one time (e.g. caused by bad weather conditions)
° Flexible reaction to breakdown by means of a system for localizing the breakdown and analysing the cause of the breakdown and its effects
° Avoidance of parallel transportation service, trips for which there is no demand etc. thus saving capacity and effort
° Possibility of extending the system with taxis, special charter services

8. STATUS OF FOCCS APPLICATION

With the conclusion of the technical development the FOCCS system is ready for long-term deployment. Designed in functional modules, FOCCS is being provided as a "construction set" to cover the wide range of requirements in different applications. In 1987, FOCCS (i.e. the entire software system including all operational functions and technical modules) was transfered to Wunstorf, Hannover County, to replace the former dial-a-ride system there. Due to the fact, that the settlement structure as well as the operational and topographical conditions in Hannover County are more suitable to the FOCCS idea and system philosophy as they are in Lake Constance County, Wunstorf was selected as the demonstration area for the first permanent operation of the existing FOCCS system. Political decisions have already been made there to expand the system step by step to the entire county with a population of approx. 300,000. The first expansion to Neustadt has already been realized.

In Friedrichshafen, the operational system tests and trials were finished by end of September 1988. Since most of the hardware devices (i.e. central computer, radio processor, vehicle terminals, call boxes) were out-of-date because of their longterm utilization resp. were prototypes and not yet standard sets, FOCCS could not pass into permanent operation without capital expenditure for updated marketable hardware. Add to this, the vehicle fleet covered by FOCCS was more than sufficient for the trials and the demonstration phase, but too small for a permanent computerized operation and control to acceptable FOCCS overhead costs. This is why the Federal Railways as the main FOCCS operator in Friedrichshafen decided not to take over the entire FOCCS technology. To cover the low frequented off-peak periods in Friedrichshafen, the Federal Railways adopted the idea of the "corridor service" mode and still provide a demand-oriented service carried out with vans and regular taxis by taxi operators as subcontractors. Because of the small vehicle fleet, the passenger disposition and the vehicle allocation are performed manually resp. via voice radio communication.

Modifications and further development of FOCCS are under way with the emphasis on updating the technology as well as on standardizing the software modules according to the standards and regulations given in the federal-funded standardization-project called "BISON-Operational Information and Management System in Public Transport". Add to this and not at least drawn from the experience gained in Friedrichshafen, the "FOCCS construction set" is now being keyed to the specific requirements of medium sized and small public transit operators. Designed for the needs of the public transit authority of a county close to the Dutch border, FOCCS is being transferred on a micro-computer as "MICRO-FOCCS". Technically speaking, the main modifications are stressed on the following aspects:

° Use of non-expensive and marketable hardware (e.g. DEC-VAX 2000, IBM-AT or XT)
° Vehicle location and monitoring via autonomous on-board modules and autonomous comparison of nominal and actual schedule conditions. Corresponding hardware and software are already available.
° Adaption of FOCCS to the standardized BISON-database resp. generation of the FOCCS data structure and query language from the BISON-database. Corresponding software modifications are already under way.
° Compatibility of the MICRO-FOCCS to the operational BISON modules with the aim to integrate FOCCS into the BISON set of EDP-programs.
° Improvement of the functions related to the "interface" passenger, i.e. passenger information from both the nominal and actual timetables, information on fares, general information on the use of public transit.