

# Engineering News

A Quarterly Journal of the Pakistan Engineering Congress

Vol: 43    October - December 2007    No: 4





**PAKISTAN ENGINEERING CONGRESS**  
**THE EXECUTIVE COUNCIL FOR THE 71<sup>TH</sup> SESSION**

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16	Engr. Naveed Alam	33	Engr. Taufique Ahmad
17	Engr. Nayyar Saeed		

**COVER PHOTO**

A view of  
Sialkot International Airport

48th YEAR OF PUBLICATION

# Engineering News

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**PRESIDENT**  
Engr. Husnain Ahmad

**SECRETARY**  
Engr. Ch. Ghulam Hussain

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## FOR MEMBERS ONLY

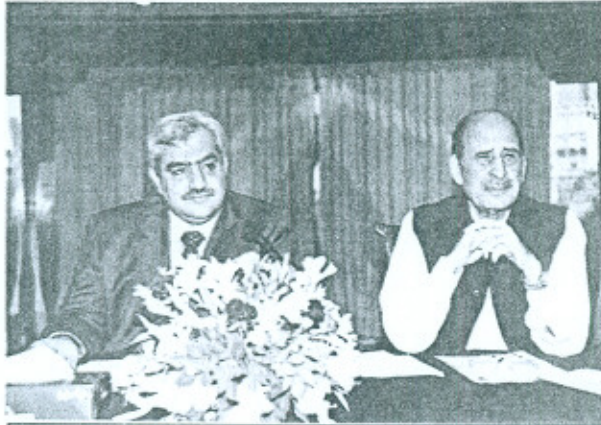
Pakistan Engineering Congress is a prestigious professional body established in 1912 dedicated, interalia to technical advancement of Science & Engineering in the country.



## News

### EXECUTIVE COUNCIL DELIBERATIONS

- (i) In the 8<sup>th</sup> Executive Council Meeting of the ongoing Session No. 71 was held at Avari Hotel, Lahore on October 6, 2007 at 1600 hours.



From left to right: President, Engr. Husnain Ahmad and Secretary, Engr. Ch. Ghulam Hussain



Section of the Executive Council busy in deliberation

The following decisions were taken:

- (ii) **Financial Assistance to the Family of Late Mr. Mukhtar Ahmad (Office Assistant)**

In recognition of dedicated and conscientious services to the Engineering Congress, Rs. 7 Lacs were sanctioned for the baby (named Sajida Mukhtar) posthumously born to Late Office Assistant of Pakistan Engineering Congress, Mr. Mukhtar Ahmad who met with a fatal accident while on duty. The amount so sanctioned would be invested in a commercial bank to cater for expenses of her upbringing on monthly interest basis to be remitted by the Bank to the Guardian (her mother aged 18 years or her grandfather). The deposit would be finally released to the orphan by the Bank on proof of her attaining the age of 18 years subject to clearance by the Pakistan Engineering Congress Executive Council.

- (iii) **Matters Relating to News Journal of Pakistan Engineering Congress**

Due to dearth of papers and other technical material, the Editorial Board could not take out any issue of the Pakistan Engineering Congress quarterly News Journal since the start of the Session. The Council was apprised that with the concerted efforts of the Secretary three issues would soon be brought out. Chief of Administration of his Firm would be paid honorarium of Rs. 10,000/- per issue for his assistance in this regard. The issue in hand happens to be the 4<sup>th</sup> issue of the Session.

- (iv) **Stagnation of Engineers in their Respective Cadres for Decades**

At the point raised by Engr. Khalid Javed that Engineers working in Engineering departments were stagnating for decades in the positions held by them due to various reasons such as:

- Separate cadre (like those enjoyed by other services) is needed.



- Lack of time scale promotions.
- Appointment of Non-Engineers as Heads of "Engineering Departments".
- Non allocation of specific quotas/seats for Engineers in Non-Engineering Departments.

This sort of prejudicial treatment, he added, was tantamount to grave injustice to the Engineering Community.

He went on to say that the Congress had taken no practical steps to meet the higher-ups to apprise them about the discriminatory treatment being meted out to Engineers denying them their rightful place. The blame game against the Engineers community is stifling the growth of Engineering profession although no major development/mega project could be completed without overwhelming contribution of the Engineers. He also pointed out that a 4-Member Committee formed under the convenership of Engr. Ch. Muhammad Rashid Khan had not thus far met the Chief Minister Punjab, Chief Secretary etc.



Another view of the Executive Council



Yet Another View of the Participants

President and the members present at the meeting strongly endorsed these views.

A strong delegation to meet the Chief Minister Punjab/other dignitaries to present the representation of the Engineers and to get their support for their cause was formed as under:

Engr. Ch. Muhammad Rashid Khan	Convener
Engr. R.K. Anver	Member
Engr. Iftikhar-ul-Haq	Member
Engr. Ch. Muhammad Arif	Member
Engr. Khalid Javed	Member
Engr. Shabbir Ahmad Qureshi	Member
Engr. Shehzad Jamil Sheikh	Member
Engr. Akhtar Abbas Khwaja	Member
Engr. Shaukat Ali Shaheen	Member
Engr. Capt (R) M. Qadir Khan	Member

**(v) Eid Bonus to Congress Secretariat Personnel**

To ameliorate the hardship of the Congress Secretariat Staff Eid bonus was decided to be paid as under:-

- Where half monthly pay comes to more than Rs. 10,000/- the amount of the Bonus may be restricted to Rs. 10,000/- (Rs. Ten thousand only).
- Where half - monthly pay comes to less then Rs. 5,000/- the amount of the Bonus fixed at Rs. 5,000/- (Rs. Five thousand only).



# VISIT TO SIALKOT INTERNATIONAL AIRPORT, MARALA BARRAGE AND FOOTBAL MANUFACTURING FACTORY

BY

THE DELEGATES OF  
PAKISTAN ENGINEERING CONGRESS  
ON  
NOVEMBER 17, 2007

A delegation comprising the following 21 members left Pakistan Engineering Congress Head Office, Liberty Market on November 17, 2007 at 09:00 hours in the morning.

- |  |                                    |
|--|------------------------------------|
| 1. Engr. Husnain Ahmad<br>President, PEC | 12. Engr. Abdul Sattar Khan Lillah |
| 2. Engr. S. M. A. Zaidi                  | 13. Engr. Prof. Mian Zia-ud-Din    |
| 3. Engr. Iftikhar Ahmad                  | 14. Engr. Usman Haider             |
| 4. Engr. Syed Saleem Akhtar              | 15. Engr. Tahir Qureshi            |
| 5. Engr. Ch. Manzoor Ahmad               | 16. Engr. Malik Abdul Sattar       |
| 6. Engr. Wasif Raheel                    | 17. Engr. Rana Mehmood             |
| 7. Engr. Ch. Muhammad Shafique           | 18. Engr. Farid Jilani             |
| 8. Engr. Ahmad Khan Pupalzai             | 19. Engr. Muhammad Fazil Mian      |
| 9. Engr. K. B. Nasir                     | 20. Engr. Ch. Muhammad Siddique    |
| 10. Engr. Nayyar Saeed                   | 21. Engr. Jahangir Khan            |
| 11. Engr. Pir Jamil Shah                 |                                    |

The delegation reached Sialkot International Airport at 11:30 hours and was received by the Chief Executive, Mr. Imtiaz Hussain Khan. Project Director gave an elaborate presentation



about the necessity for the construction of an International Airport at Sialkot to cater for the requirements of the biggest foreign exchange earning Industrial Estate of the country directly without involvement of road transit from Sialkot, Gujranwala, Wazirabad and Gujrat to Lahore, fraught with manifold hazards such as damage to packages/goods due to multiple handling and incidents of pilferages etc. much to the discomfort and consternation of the Business Community. It was also the long standing demand of the people of Gujranwala Division for quicker air travel facilities for them

and their near and dear ones working abroad in millions.



In view of above Sialkot Chamber of Commerce & Industry (SCCI) appointed NESPAK in August 2000 to carryout feasibility for Construction of a new International Airport at Sialkot. Feasibility study & Conceptual Master Plan was completed in October 2000 and report submitted to Sialkot Chamber of Commerce & Industry (SCCI). Project was found to be Technically & Financially feasible. Due to Financial constrains, the Civil Aviation Authority (CAA) was not in a position to implement the Project. The Sialkot Chamber of Commerce & Industry (SCCI) therefore pledged to under take the project through its own resources. However a sum of Rs. 230 million was provided by the Government of Pakistan in shape of a soft loan for the purchase of land.

Keeping in view the revolutionary role the International Airport at Sialkot will play in the development of this region, during a Presentation on 2<sup>nd</sup> February 2001, the then Chief Executive of Pakistan (Now President of Pakistan) gave approval in principle for construction of an Airport at Sialkot for Passenger & Cargo Traffic. Subsequently with the approval of Ministry of Defence, a Memorandum of Understanding (MOU) was signed between SCCI and CAA on 26<sup>th</sup> February 2001. In order to implement the Project, a new company Sialkot International Airport Limited. (SIAL) was formed in June 2001. Nespak, a local very experienced and reputed consultant of world fame was appointed in Nov. 2001 as consultant to carryout the planning & designing of the Airport. After detailed topographic survey and Geo-Technical investigations, NESPAK submitted Master Plan of the Airport in May 2002, which was approved by CAA in August 2002. After approval of Master Plan, the construction of the Airport started in January 2003 near Sambrial at a piece of land measuring 1036 acres, a central place of the export triangle of Pakistan comprising Gujrat, Gujranwala and Sialkot.



The Airport has been built strictly according to the ICAO / IATA International Standards in close coordination with Civil Aviation Authority of Pakistan with the most modern Technical / Operational facilities. The Airport has a 3600-meter long Runway equipped with Category-II Airfield Lighting System (Capable to be upgraded to CAT-III) Instrument Landing System and latest Communication and Weather Warning Systems. The Airport infrastructure includes a spacious 1½ Level Terminal Building, Domestic and Cargo Terminals, ATC & FCR Building, Category-9 Fire Fighting Facilities, Fuel Farm, an Apron to accommodate four Boeing-747 Aircrafts at a time with a provision for extension of the Apron on both sides, underground and



overhead water tanks, water supply and sewerage disposal, fire hydrant system, Internal Road Network and a new approach Road from city to the Airport.

The Sialkot International Airport Project is unique in its nature since it is the only private Airport in Asia built on self-help basis by the local industrialists. The Airport has been completed in a record time of less than 4½ years at a total cost of approximately Rs. 2.7 Billions. A high level team of retired CAA, PIA and PAF officials worked day & night selflessly to complete this mega project. While completing the project in a reasonable time with minimum possible expenditure, it was always ensured that there is no compromise on the quality control at any time. We can proudly claim that this Airport is one of the best Airports in Asia and can be compared with any other Airport of the same size in the world over. SIAL stands committed to creating new quality standards and innovative service differential in the Aviation Industry. Dedication, honesty, professional approach and team work was the driving force behind completion of this mega project.

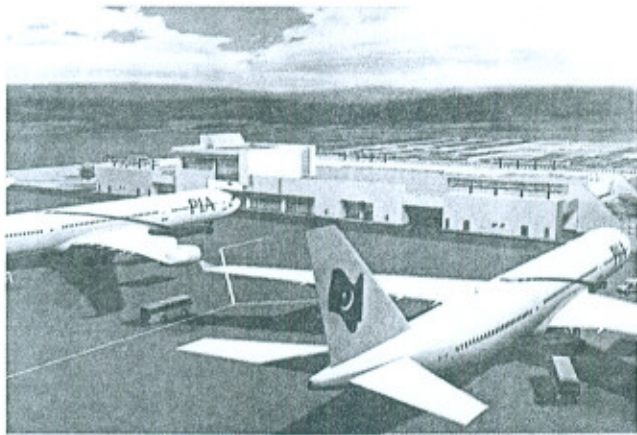
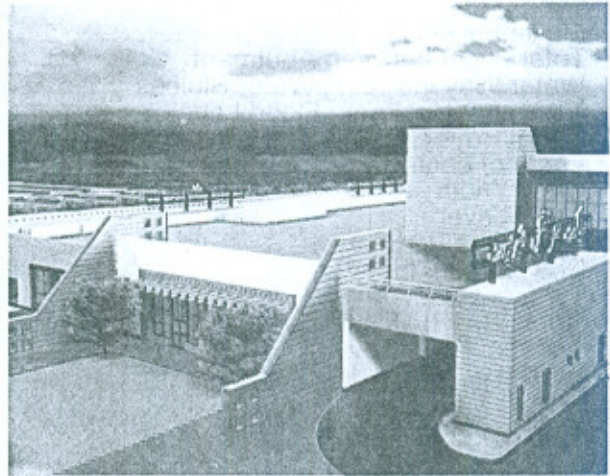
The construction of an International Airport on self help basis was itself a big challenge for the local industrialists. However maintaining their track record of social work, constructing huge road infrastructure in the Sialkot city on self help basis, the local industrialists accepted this challenge and decided to bear the entire construction cost through their own resources. Initially every director contributed Rs. 5 Million each. Later on, to cover up the short finances, each director further contributed Rs. 2 Millions. All the directors of SIAL (Which at the moment are 245) not only financed the project but also participated physically in the decision taking process as conveners and deputy conveners of various committees sparing valuable time at the expense of their own business. The Chairman and Chief Executive SIAL worked full time without any remuneration. All the conveners and deputy conveners also worked free. In fact it was an exemplary teamwork of professionals and financiers.

The land on which the Airport has been constructed was basically an agriculture land used for wheat and rice crops. The Airport site being a low lying area, the entire Airport infrastructure had to be built on a raised ground approximately six feet above the ground. The soil of the area being very weak, a special type of engineered fill (A mixture of local soil and River Chenab Sand) had to be prepared and laid in six inches layers duly compacted. This was a time consuming job in addition to the expenditure involved. The Airport site was flooded thrice in the monsoon seasons of 2003, 04 and 06 due to which not only the progress of work very badly suffered but a lot of work was required to be re-done. Sialkot is birth place of Allama Iqbal and once the local industrialists of Sialkot undertook this gigantic project, they never looked back. A dream, which we all saw 4½ years back has been fulfilled and by the grace of Almighty God. We have been able to complete this prestigious Project and start International Cargo and Domestic flight operations. The International Passenger Flights are also expected to start in the second half of year 2008. The Sialkot International Airport was inaugurated by President of Pakistan on 11<sup>th</sup> December 2007.

After the presentation the delegates were taken around the terminal building, the runways and the other infrastructure. Thereafter a sumptuous lunch was hosted by the Management of the Sialkot International Airport limited to the elite delegation.

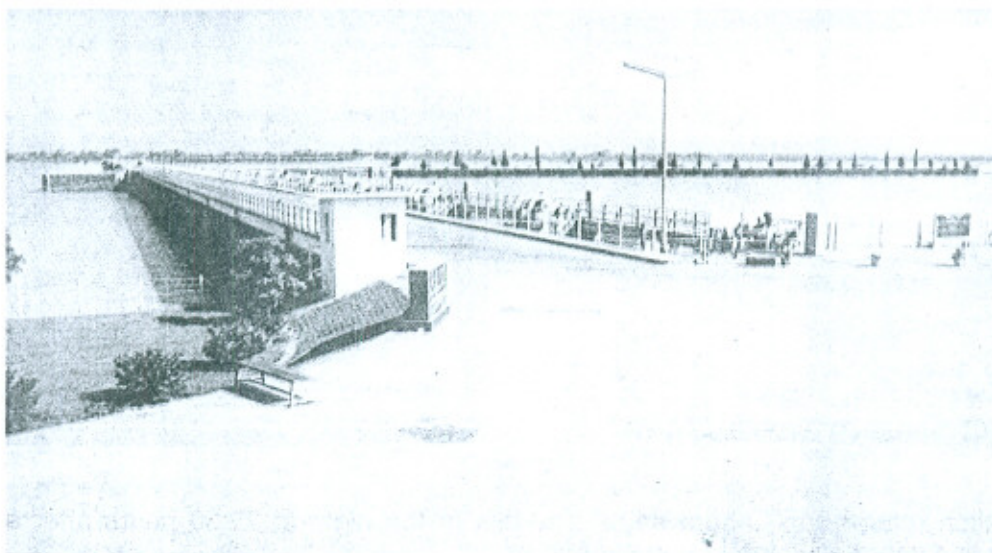
Some of the snaps of the infrastructure of the airport are reproduced at the next page.





### VISIT TO MARALA BARRAGE

The delegation left for visit to Marala Barrage on the Chenab at 14:30 hours reaching there at 15:40 hours. The delegation was received by the XEN Marala Barrage and in view of the time constraints tea was served immediately on arrival. The delegates were taken around various components of the Barrage. The general view of the Barrage and its salient features appear at the next page:-





## SALIENT FEATURES

River	Chenab
Type	Barrage
Maximum Design Discharge	1,100,000 cusecs
Total Width between Abutment	4,472.33 ft.
Water Way including Water Sluices	3,960.00 ft.
Maximum Upstream Flood Level	816.70 S.P.D.
No. of Bays	66
Width of each Bay	60 ft.
Crest Width	1.50 ft.
Crest Level	800.00 S.P.D.
Upstream Floor Level	795 S.P.D.
Downstream Floor Level	789.00 S.P.D.
Type of Gates	Radial Gates (60' x 14')
No. of Bays in Undersluices	13
Width of Each Bay	60 ft.
Length of left Guide Bank	5,116 ft.
Length of Right Guide Bank	3,669 ft.
Length of left Marginal Bund	85,008 ft.
Length of Right Marginal Bund	85,008 ft.
Year of Construction	1968
Total Designed Withdrawal for Canal	38,500 cusecs.

The delegation returned to Sialkot at 17:00 hours.

## VISIT TO FOOTBALL FACTORY

Though very late in the evening yet the Chief Executive was kind enough to wait for the delegation to take it around the premises of the Factory. The delegates took keen interest in the manufacturing of the footballs from the raw material to the end product.

Astonishingly the delegates came to know that the daily production of the football numbered 08 thousand and that too fell short of the export targets.



The delegation returned to Lahore same day late in the night at 22:30 hours after a very illuminating and informative trip to engineering works.



## LAUNCHING OF A TECHNICALLY RICH AND COMPREHENSIVE BOOK ON "WEIRS AND BARRAGES ACROSS ALLUVIAL RIVERS"

In keeping with the cardinal objective of promoting Science & Engineering, Pakistan Engineering Congress launched a technically rich and comprehensive book on "Weirs and Barrages Across Alluvial Rivers" at 16:00 hours on November 10, 2007 at Mashhadi Hall of Pakistan Engineering Congress Building, Liberty Market, Lahore. Engr. Iqtidar Hussain Siddiqui, M.Sc. Engineering (Civil) from University of Washington, USA and Civil Engineering graduate from Aligarh Muslim University, the author of the book was introduced to an appreciable elite gathering of the Pakistan Engineering Congress Members and Engineers who graced the occasion with their participation.



*From left to right: Engr. Ch. Mazhar Ali, Engr. Iqtidar Hussain Siddiqui & on the Rostrum Engr. Husnain Ahmad, President, Pakistan Engineering Congress.*

In his address of welcome, President Pakistan Engineering Congress, Engr. Husnain Ahmad paid rich tributes to him. Recounting the rich experience of Mr. Siddiqui Regional Advisor on Water Resources in United Nations and retired Chief Engineer (Water) WAPDA, he elaborated that Mr. Siddiqui enjoyed a legendary portfolio in planning and design of water

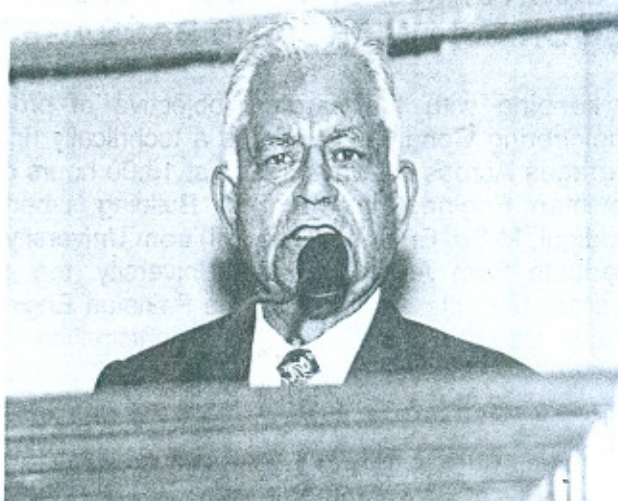
resources projects in Pakistan, Asian and Pacific Countries. In the context of Pakistan his major contribution, he added, pertained to 8 small dams and reservoirs and mega project of Basha and numerous Hydropower and Small Hydel Schemes besides other civil engineering projects. The book being launched comprises both theoretical and practical aspects from planning through to design, construction and maintenance of weirs and Barrages. The President considered this book equally informative & useful for practical application of professional knowledge by Engineering Students and Practicing Engineers.



*A view of the section of the Audience.*



After introduction of the book by the Author, followed by commendable remarks by Engr. Riaz Nazir Tarar, Associate, National Development Consultants/Deputy Project Manager of Diامر Basha Dam Project and the publisher, the Chief Guest of the event, Engr. Ch. Mazhar Ali, Advisor Irrigation and Power Department, Government of the Punjab gave analytical treatment to the contents of the book. Before felicitating the author for his useful contribution to the engineering profession, he said, that to him the book filled vacuum in highly professional and technical fields that would be enthusiastically received by the engineers and also by the experienced professionals and that it was an invaluable treasure for the consulting engineers, practicing engineers, planners and designers of barrages, teachers as well as the engineering students.



*Engr. Dr. Ch. Mazhar Ali, Advisor, I&P, Govt. of Punjab, technically analyzing the Contents of the Book.*

In his analytical observation he noted that it was not an exclusive research or design publication but dealt broadly with the various component activities in various disciplines. Design and construction procedures of barrages across the alluvial Rivers he said, had been developed during the last two centuries after a great deal of painstaking researches by renowned engineers and scientists. There are a large number of component activities covering planning, investigation, design, construction, instrumentation and operation. No book has, however, been published exclusively on all the components of this subject for guidance and reference. In the sub-continent a number of barrages have been constructed during the last century but there was no work available on the subject of planning, design and operation of barrages. A couple of departmental manuals had been written. These manuals being official documents were not available easily even to government engineers. Their scope was rather limited to certain components of activities. The important and vital information and literature had remained mostly unavailable and out of reach for use by engineers in the public service and in the consultation profession. Knowledge on the subject had generally remained a hidden treasure. The present book on Weirs & barrages prepared with great application and dedication by the author had filled the existing vacuum.

He said that he was impressed by the treatment of this subject by the author in a simple and lucid manner. The author, he added, had made exhaustive references to most of the relevant papers published by Pakistan Engineering Congress during the last century. He had based the text on relevant theories in the book. Inclusion of drawings of river training works, barrage construction plans and river diversion plan for a barrage would greatly help the field engineers in their planning and execution of work.

The book described in detail relevant theories as well as practical considerations needed in planning, design and operation. It had fourteen chapters comprising:-

- Surveys and investigations;
- Weirs and barrages on alluvial rivers;
- Canal head regulators;
- Silt and silt exclusion;
- Fish ways;
- Navigations locks;
- Gate and gate lifting devices;
- Instrumentations;
- Hydraulic model studies;
- Construction and river diversion operation;
- Barrage operation, telemetry maintenance and monitoring.



Under planning and investigations surveys, which include topographic surveys, river course surveys, and hydrographic surveys, had been described. Investigations included Geotechnical, hydrological and environmental investigations. Methods relevant to all the above investigations had been duly described.

Under designs, design criteria for the design of various barrage components like barrage floors, abutments etc. have been described. Relevant research theories on which these designs were based had also been described in detail. Khosla's well-known Method of Independent variables had been described and charts and graphs for help to the designers had been given.

Under construction, various construction methods like single stage diversion methods and multi stage construction method had been described. The drawings of construction plans based on the above method had been included in the book. A river diversion plan included in the book would be useful for field engineers.

An important aspect of dewatering plans included in the book is useful for the designers and field engineers. These plans are based on practices followed by consulting engineers for the construction of barrages of the Indus Basin projects during 1960 to 1970.

The chapter on instrumentation and monitoring is unique. In Indus Basin projects and afterwards instrumentation is being used liberally. Instrumentation is important as it gives advanced warning to manager incharge of the barrage to take corrective actions in time in case of necessity or emergency.

The book also describes the use of telemetry on barrages. Telemetry is a system by which real time data can be supplied to concerned officers 24 hours a day. It is a useful modern tool for operation and maintenance of barrages. It also detects and controls withdrawals of supplies from a barrage. The system has recently been introduced by IRSA and WAPDA at selected sites and is going through the modification of implementation stages.

A solved example has been given for better understanding by the readers of the theory and formula and their application to planning, designs and construction processes.

After conclusion of the event, the President of the Pakistan Engineering Congress, Engr. Husnain Ahmad, presented Congress Shield to the Author.



*Engr. Husnain Ahmad, President Pakistan Engineering Congress, presenting the shield to the author, Engr. Iqtidar Hussain Siddiqui*



## WELCOME TO NEW MEMBERS

*The Executive Council of the Pakistan Engineering Congress approved Membership of the following new members in to the Congress fold. The Engineering News congratulates all of them and welcomes them to Pakistan Engineering Congress*

### Members admitted on 03-11-2007

- |                                  |                                       |
|----------------------------------|---------------------------------------|
| 1 Engr. Kashif Naseem Khan       | 11 Engr. Muhammad Ilyas Sheikh        |
| 2 Engr. Muhammad Asif Chaudhry   | 12 Engr. Syed Kashif Ali Shah Bukhari |
| 3 Engr. Furqan Ahmad Malik       | 13 Engr. Muhammad Ahmad               |
| 4 Engr. Khurram Riaz             | 14 Engr. Muhammad Sajid               |
| 5 Engr. Abdul Hafeez Jakhrani    | 15 Engr. Muhammad Qasim Sheikh        |
| 6 Engr. Tanweer Ahmad            | 16 Engr. Ikram Ullah Khan             |
| 7 Engr. Muhammad Javed           | 17 Engr. Mansoor Ali Shah             |
| 8 Engr. Mubeen Shahid            | 18 Engr. M. Naveed Ashraf Siddiqui    |
| 9 Engr. Hammad Khalique Siddique | 19 Engr. Tahir Malik                  |
| 10 Engr. Saqib Nazir             |                                       |

## OBITUARIES

### May their souls rest in Peace

1. Engr. Mazhar Hussain Syed (R) Chief Engineer I & P, passed away on 7.3.2007.
2. Engr. Mian Ghias-ud-Din former G. M. (Railways), Vice President Institution of Engineers Pakistan, passed away on 19.11.2007.



## IT'S ALL ABOUT ENERGY

(Engineering News Journal – In “it’s all about Energy” the Newsweek has very aptly suggested that it should be the only topic and manifesto of the potential Presidential candidates of the USA for the term 2008-2012. In the wider perspective it is manifest that it is the energy that keeps the biological and botanical life humming and hissing. The sun with its light and un-fathomable energy, the water, the hydropower, the winds, the fossil fuels, the oxygen and all the bounties of Almighty God are, one way or the other, un-ambiguously and un-describeably, reflective in the Energy.

In the context of Pakistan, now that the conventional energy generation is not commensurate with the ever increasing domestic demand what to say of keeping the existing wheels of industry running, to further develop any industry of the name is a far cry and that too in the wilderness, more so when the hydropower generation from the cheapest mode of Kalabagh Dam has been miserably and excruciatingly politicized. Little wonder the only way left for survival is alternative effort at taking a recourse to renewable energy. Enjoy the views expressed in the Newsweek).

If you run a business that’s into renewable power, expect a presidential candidate to stop by. We profile four such companies on the cutting edge.



Presidential candidates used to get away with little more than plugging ethanol in Iowa and the requisite pledge to clean the air and water for the next generation. Not in 2008. With oil prices nearing \$100 a barrel and public concern over global warming rising faster than Al Gore’s trophy pile, this year’s campaign cliché is “energy independence?” Along with health-care plans and strategies for Iraq, the candidates are churning out detailed proposals to slow climate change and wean the country from imported oil.

Two weeks ago in Iowa, Hillary Clinton announced a plan to increase U.S. biofuel production. Two days later, she popped up in New Hampshire with home-improvement expert Bob Vila to trade tips on energy efficiency. Last weekend in Los Angeles, she and John Edwards will attend the first-ever presidential candidates’ debate on climate change. Not to be outgreened, Republican Sen. John McCain is pushing his bill to cap and trade greenhouse-gas emissions. New York City mayor (and potential independent challenger) Michael Bloomberg is calling for a carbon tax. Rudy Giuliani is pushing solar, wind and even nuclear power as “a matter of national security.”

The pols, it seems, have figured out what venture capitalists and entrepreneurs have known for years: green is Topic A. “It’s really smart to pull up renewable energy as a headline issue,” says Silicon Valley venture capitalist Ray Lane, who now invests exclusively in “cleantech” ventures, even though, he cautions, “I have not become a tree-hugger — or a Democrat.” Rather, it’s because the \$6 trillion world-energy market, dominated for the past century by fossil-fuel interests, is being swarmed by thousands of entrepreneurs peddling game-changing technologies in solar, wind, geothermal and bio-energy, batteries, electric “smart grids” and plain-old efficiency. The technologies are moving from the lab to the marketplace just as political pressure mounts to force companies to curb their greenhouse-

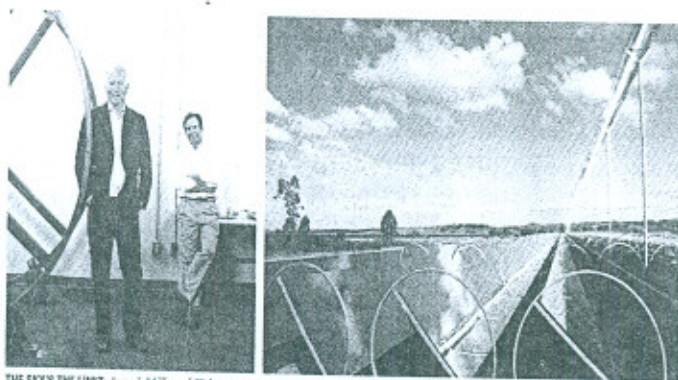


gas emissions. "It's a perfect storm," says Lane.

Lane's firm, Kleiner-Perkins, now devotes one third of each new investment fund — about \$200 million to \$300 million every few years — to cleantech start-ups. Stars of the early computing era, including Sun Microsystems founder Vinod Khosla and Microsoft cofounder Paul Allen, have reinvented themselves as clean-energy investors. Nationwide, according to the Venture Capital Association, investments in cleantech nearly tripled from \$497 million in 2005 to \$1.45 billion in 2006.

Profit is not the only motive. For many renewable energy entrepreneurs, finding alternatives to oil, gas and coal is the biggest technological opportunity the world has seen since the birth of personal computing. "We are now where Bill Gates was before he left Harvard" in the 1970s, says Martin Tobias, a former Microsoft executive and digital-media pioneer, who launched Seattle-based Imperium Renewables, a biodiesel manufacturer in 2005. Imperium, which has filed papers to go public, last summer opened the country's largest biodiesel refinery, on the Puget Sound. (The fact that Tobias is a Republican didn't stop the state's Democratic pols from showing up for the ribbon-cutting.)

Like the dotcom era, the cleantech boom is sure to produce its share of flops— and an investment bubble or two. The science is tough, and oil isn't going away any time soon. None of that scares the entrepreneurs profiled below. **NEWSWEEK** has selected four privately held companies whose breakthroughs to replace fossil fuels seem especially promising.



THE SKY'S THE LIMIT: Ausra's Mills and Fishback at company headquarters in Palo Alto; a mirror array in New South Wales, Australia

#### Ausra; Solar-Thermal Power

Say "Solar" and most people think of the trendy photovoltaic panels popping up on the roofs of houses and office buildings around the country. But physicist David Mills knows that the power of the sun is best captured by gigantic fields of mirrors arrayed on the ground, which can generate enough electricity to run an entire power plant. Mills, a physicist, spent decades developing his technology —

called a Compact Linear Fresnel Reflector — at the University of New South Wales in Australia. After his attempts to commercialize the process stalled, Mills, 61, thought about retiring. But two well-known Silicon Valley venture capitalists got to him first. Lane of Kleiner Perkins and Vinod Khosla, the valley's leading renewable energy evangelist, offered Mills a \$40 million investment and a top management team to get him to come to California and start over.

Two weeks ago, Ausra signed a 20-year contract with Pacific Gas and Electric to provide electricity from a \$500 million, 177-megawatt solar-thermal plant under construction in California's Central Valley. The plant, which is set to go online in 2010, will be the world's largest solar installation. The blueprint is disarmingly simple. Rows of flat mirrors that follow the path of the sun are arranged in a one-square-mile grid. The mirrors reflect the sun's heat onto water-filled pipes above, creating steam that cranks a turbine in a nearby power plant. The electricity produced doesn't emit a molecule of greenhouse gas. "Big solar," as Ausra's concept is known, is especially attractive in California, where public utilities are required to get 20 percent of their power from renewable sources by 2015.

The bigger the plant, the cheaper each kilowatt-hour produced. "A field of mirrors 91 miles square could power the entire United States," Mills says. Though that field is unlikely to ever



be built— strong-enough transmission lines don't exist — the emerging solar-thermal industry has sparked a land rush in the American desert. The conference table at Ausra's new offices in Palo Alto is littered with the maps of remote southwestern tracts and marginal farmland, bearing little flags where the company or its competitors have snapped up land to develop solar fields. "The hotter and nastier, the better," says Mills of Ausra's most desirable real estate.

Last year, solar-thermal sales tripled in the United States to \$121 million, and demand is expected to soar as other states develop renewable power standards. With help from their venture-capital mentors, Ausra has a management team drawn from the normally change-resistant utility industry. "I don't own a pair of Birkenstocks," says CEO Bob Fishman, a former Navy engineer who spent decades in the natural-gas business before joining Ausra.

"We are serious guys. And we are doing this because it's a viable business, not because it's a crusade?" In other words, lots of mirrors, no smoke.

### **Amyris; Synthetic Biofuels**

The choice for microbiologist Jack Newman came down to making strawberry fragrance or changing the world. Sitting around a conference table last year at Amyris Biotechnologies in Emeryville, California, Newman and his colleagues were trying to figure out what to do following the success of their project (with the Bill & Melinda Gates Foundation) to produce inexpensive anti-malarial drugs. The genetically engineered microbes responsible for their breakthrough showed tremendous promise in other areas. "We talked about flavors or fragrances or vitamins that would make a couple of million bucks," says Newman. "Then we said, 'Wait a second. A lot of people came (to the company) to change the world, so why not tackle a really big problem?'"

The scientists, who met as postdoctoral fellows at U.C. Berkeley, decided to apply the knowledge they used to create their low-cost drug to develop a line of "no compromise" biofuels. Competitive in price and performance with conventional fossil fuels, Newman says the Amyris products will cut greenhouse-gas emissions by 85 to 95 percent, making them far cleaner than ethanol, the biofuels can be transported in existing pipelines, diesel or jet engines.

Amyris recently hired former BP executive John Melo, a native of Brazil, the World's largest sugar-cane producer, as CEO, and the company is reportedly talking with Virgin's Richard Branson about a future distribution network. Amyris will start test production next year and plans to mass-produce its first biodiesel by 2011. They got their start by doing good, but don't be surprised if the scientist from Amyris end-up doing extremely well in the energy market of the future.

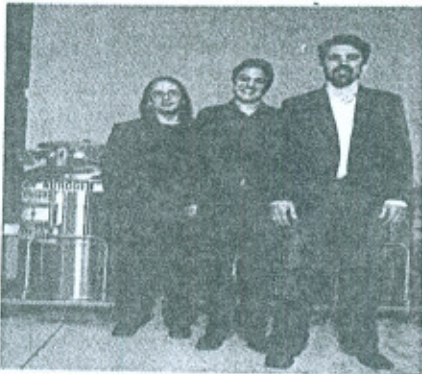
### **A123 Systems; Energy Storage**

Impressed by the 50 or so miles per gallon of the average Toyota Prius? Pop a suitcase-size battery pack from A123 Systems into the trunk and watch your newly converted plug-in hybrid shoot to 174 mpg. "You fill your tank three times a year," says CEO David Vieau. The Watertown, Massachusetts, company has won raves in technology and investment circles by figuring out how to overcome one of the biggest hurdles in the development of the electric car: huge, unreliable, expensive – and flammable – batteries. While current lithium-ion batteries work well enough for laptops and cell phones, scientist at A123 have replaced chemical components with extremely thin layers of nano-phosphate, a conductive material that makes the new batteries smaller and quicker to charge than their predecessors.

Starting next year, A 123 will sell its battery to hybrid owners who want to convert their cars



to plug-ins — models that you recharge in the garage overnight. The estimated price tag of \$10,000 for the conversion will be too steep for most individuals, so company executives expect their main customers will be government or corporate hybrid fleets. The next step will be factory-installed battery packs in a new generation of hybrid and electric vehicles, like the Saturn Vue and the Chevy Volt, scheduled to hit the U.S. market in 2009.



**BIO BUDDIES:** Newman, Neil Renninger and Kinhead Reiling of Amyris in Emeryville

The company has raised \$132 million in capital from leading venture firms such as Sequoia Capital, as well as from GE, Proctor and Gamble, and Qualcomm, companies eager to apply the new batteries in their products.

A123 has drawn attention from politicians as well. Recently, U.S. Energy Secretary Samuel Bodman dropped by. Earlier this year, Vieau was invited to the White House, where an admiring George W. Bush took a peek at one of the company's plug-in hybrids. "He said he had been waiting for the day that a car could go 40 miles on electricity and not be a golf cart," says Vieau.

### Better PLC; Vehicle Power Grid

Shai Agassi was cruising along in his software career, until, he says, he was asked an "annoying" question at last year's World Economic Forum, the annual meeting of global elites: "What would you do to make the world a better place?"

What came pouring out was a 21-page manifesto on the end of oil—and a business plan to remake the world's transportation infrastructure. Earlier this year, Agassi left his position as a top executive at the software giant SAP and launched "Project Better PLC" (Better Place), his company to build a network of battery-charging stations for electric vehicles. Owners of battery-operated cars will pull into a Better Place station and switch an empty battery for a charged one, eliminating one of the chief obstacles to electric-vehicle transportation: the limited travel range.

The "smart grid" Agassi envisions will also allow plug-in hybrid owners to sell their car's energy back to the grid at peak hours. This "vehicle to grid" (V2G) concept is also being studied by utility companies, including Pacific Gas & Electric and Tesla, the electric-car manufacturer. PG&E chairman Peter Darbee envisions a day when customers will become suppliers. "After you drove to your office and parked at the appropriate receptacle, you could put in a sell order like you do today with stocks, so that if the price gets to, say, 14 cents per kilowatt hour, your sell order goes through and we draw power on your car?"

While the development of a mass-market electric car has been slowed by battery problems, Agassi says it makes sense to start building the grid now, just as cell-phone carriers built transmission towers before everyone owned a cell phone. He plans to start testing cars next year. "If you build the network, they will come," he says. Agassi has raised \$200 million in venture capital so far, and while he is so far coy about where "Better" will build its first recharging stations, he has hinted that his native Israel, where gas costs around \$6.50 a gallon and government policy promotes electric-vehicle transportation, would make a logical test market. Other "transportation islands" where exorbitant gas prices and favorable government policies make the cost of battery-operated cars more competitive include Singapore, a new Iceland, Denmark and Japan. No matter the language, Agassi is betting on a new way to say "fill 'er up."

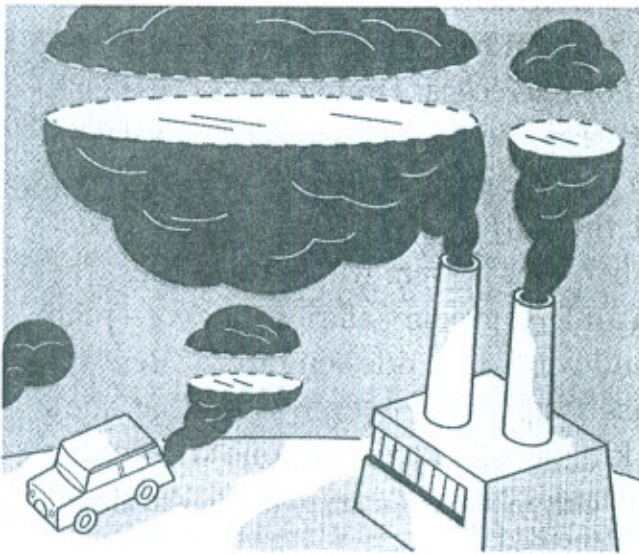
**COURTESY**  
The Newsweek



## THE 'GEO-ENGINEERING' SCENARIO

(Engineering News Journal – Could reducing ever increasing CO<sub>2</sub> emissions of coal or fossil fuels by substituting solar and nuclear energy bring back to normal the global warming and restore the environmental change to mother natures nascent setup and at how much cost? A food for thought to Geo-engineering Scientists).

After decades spent studying volcanoes, Alan Robock can list 20 reasons why humans should not try to play God with the World's climate by, well, mimicking Krakatoa. Proponents of "geo-engineering" actually like the idea because the eruptions spread sulfate aerosols and other particles throughout the planet's atmosphere, reflecting incoming sunlight. The resulting cooling might counter the global warming caused by carbon dioxide and other greenhouse gases. But that's not all sulfates do, which is where Robock's list comes in.



The particles also deplete the planet's ozone layer, which is just starting to repair itself now that ozone-shredding chemicals are banned. They cause acid rain, too. And by cooling large land masses like Asia and Africa, the heat-reflecting particles reduce the temperature difference between them and the already-cooler oceans, which could stifle the monsoons that millions of people depend on for agriculture. Because the particles block direct sunlight more than diffuse rays, they also alter the balance of radiation reaching Earth's surface, with unknown consequences for plants that can be kind of finicky about the kind of sunlight

they need.

And yet, in a sign of how dangerous global warming is starting to look and of how pitiful the world's efforts to control greenhouse gases are, even Robock – list and all – hedges his bets. Geo-engineering, allows the Rutgers University meteorologist, "might be held in reserve for an emergency".

The prospects of climate emergency has put geo-engineering, which experts have been weighing since at least 1992, on the drawing board more than ever before. That reflects two alarming developments. The first is that some projections of climate change, far from being Cassandra-ish, are turning out to be too conservative. According to satellite measurements, sea levels rose 3.3 millimeters per year from 1993 to 2006; the Intergovernmental Panel on Climate Change (IPCC) had projected less than 2 millimeters. Also, the IPCC projected loss of arctic sea ice at 2.5 percent per decade from 1953 to 2006. It's actually been 7.8 percent, or 30 years ahead of projections.

Greenland's ice sheets, too, are melting faster than expected. If other consequences of climate change – heat waves, storms and severe droughts like the one now gripping the Southeast – also turn out to be worse than projected, the world may become desperate for a way to turn down the thermostat much faster than reducing CO<sub>2</sub> emissions can accomplish. (Especially since emissions are trending the wrong way. In 1990s, they increased 1% a year. In the early 2000s? 3% a year).



The physics of geo-engineering is not in dispute. Studies of volcanoes established what amount of particles produces how much cooling, as well as how the particles spread and how long they remain aloft (a year or two). Knowing this, it should be possible to roll back the global warming projected for 2100 enough to return the planet to its climate of 1900, Damon Matthews and Ken Cladeira of the Carnegie Institution reported in June.

The devil is in the details. Injecting sulfates into the atmosphere – by lofting big, aerosol-filled balloons or rockets – would reduce global precipitation to below levels of 1900, their study showed, threatening agriculture. Cooling would be uneven, with some regions benefiting more than others. (What would Russia, which might profit from global warming, do if India, which would suffer, decided to cool things down through engineering?) And if we stopped geo-engineering and thereby unmasked the effects of CO<sub>2</sub> that had been accumulating all along the rebound could be calamitous, as temperatures rose 20 times faster than current warming, notes Matthews. That would be harder to adapt to than an equal rise spread over more time.

Geo-engineering cannot replace emissions reductions. The less CO<sub>2</sub> you have to balance with sulfates, the more effective geo-engineering would be. But reducing CO<sub>2</sub> emission by, say substituting solar and nuclear for coal will only delay climate change. Any net emissions will eventually tip the atmosphere into dangerous territory. If the world wants a techno-fix for climate change, it must develop ways to capture CO<sub>2</sub> from the air and seas. Researchers are trying, but they have less financial support than producers of corn-based ethanol (which does next to nothing to help climate change). Still, one company is developing a system in which plastic mesh sheets blowing in the wind capture CO<sub>2</sub> from the air.

When saturated with CO<sub>2</sub> the sheets are doused with sodium carbonate, yielding harmless baking soda, after which they can be reused. Another approach would remove hydrochloric acid from seawater, which make oceans less acidic and thus able to absorb more CO<sub>2</sub>. Bout 100 treatment plants could reduce the CO<sub>2</sub> entering the atmosphere by 15 percent, scientists report in Environmental Science & technology; 700 could offset all CO<sub>2</sub> emissions. Neither methods is ready to go. Without more funding, they never will be, though Richard Branson's \$25 million prize of carbon capture is an incentive. If we don't want to resort to the climate solution of last resorts, it's time to stop pretending that changing light bulbs and driving hybrids will be enough to prevent dangerous climate change.

#### **COURTESY**

The Newsweek



# ROLE OF HVDC IN LARGE INTERCONNECTED POWER SYSTEMS

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## Abstract

With continuous research and development in the mercury-arc technology and later on in the solid-state high power thyristors led to the use of HVDC transmission systems under particular requirements. Furthermore, the modern electronic control equipment made it possible to introduce sophisticated control features in HVDC transmission systems. Today HVDC transmission systems have evolved as a competitive adjunct to conventionally used AC transmission systems with a number of intrinsic features that may be tailored to the requirements of the associated AC interconnected grid systems.

Three phase AC transmission systems have been used extensively in the world as bulk power supply networks. Almost all countries have their interconnected power grid systems and are also interconnecting with the neighboring countries to avail benefits of interconnected networks such as European countries have largest interconnected grid system known as UCTE: Union for Coordination of Transmission of Electricity. There are number of benefits of interconnected grid systems such as increased supply reliability, savings in generation reserves, most economical combination of generation mix etc. But there comes a limit of the size of interconnected grid systems above which the benefits of interconnection start diminishing and system becomes problematic from its control and operation point of view. At this stage the HVDC transmission systems then help to mitigate the problems of large AC interconnected grid systems. These aspects are enlightened and examples from the world over HVDC installations are described in the paper.

## 1. INTRODUCTION

In the early years of power system developments the increase in the demand of electricity was extremely fast. In industrialized countries, the demand was doubled at the end of each decade. Such fast increase is nowadays still present in the emerging countries. The power supply networks have been expanded to transmit power from remotely developed power generation facilities to cope the energy demand requirements of the load centers. For this purpose ever higher and higher transmission voltages have been used for extensive transmission system interconnections with the existing power systems to form a stable and reliable grid system. The power system development using interconnections is a worldwide trend as it provides a number of technical, economical as well as environmental advantages. Advantages of Interconnection include pooling of large power generation stations which increases the supply reliability, sharing of spinning reserves and use of most economical energy resources [1]. Power transmission interconnections may span either over a single country's territory or even a geographic continent. North American power system with installed capacity of around 950 GW and UCTE (Union for Coordination of Transmission of Electricity) power system in Europe with installed capacity of around 540 GW are the examples of large power systems in the world.

As the size of the interconnected power system increases beyond a certain limit, the benefits of further interconnections start diminishing. Synchronously operated large interconnected power systems require stringent SCADA and EMS systems for control and

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operation of the power system. It necessarily involves a number of controlling devices which at times may cause power system oscillations either of local mode or inter-area mode [2]. These oscillations need to be countered properly otherwise they may cause rotor angle or oscillatory instability of the interconnected power system. The reactive power management is considered to be the most problematic in larger power systems, and its improper management may lead to voltage collapses and system blackouts. Some of the problems associated with large interconnected power systems are listed hereunder. [3,4]

- High cost implications for stringent control and jointly close coordination for frequency control, generation dispatch, active and reactive power controls
- Bottlenecks in the transmission system due to uncontrolled load flows
- At times spinning reserves need to be transmitted over long distances with cost and transmission system undue loading implications
- Cascade outages leading to system wide blackouts in large interconnected systems due to various types of instabilities such as voltage instability, transient instability, oscillatory instability and rotor angle instability etc

The node voltages in the power systems are very important parameter for proper functioning of various power system components. For instance the MVAR supply of a shunt capacitor bank is dependent upon the associated bus voltage which is governed by the proper reactive power flows in the system; therefore, it would be pertinent to discuss the reactive power requirement behaviour of AC networks. [9]

## 2. REACTIVE POWER MANAGEMENT IN EHV-AC NETWORKS

The major issue involving EHV-AC transmission lines is the transmission system reactive power management. EHV-AC lines, particularly long lines, exhibit a wide variation in the reactive power supply/absorption behaviour from peak load to light load conditions and if the system is weak this could lead to operational problems. The problem is aggravated with 800 kV lines, as their reactive power generation is very high (about 2.6 MVAR /km) and leads quite often to under utilization of their inherent current carrying capacity. One key attribute which could determine the line power carrying efficiency, is the surge impedance loading (SIL). In the case of 800 kV lines the SIL is in the range of 2300 MW while the thermal capacity is much larger of the order of 4500 MVA. Fig:1 shows, graphically the reactive power characteristics of an 800 kV, 300 km long line with and without compensation of any kind. It could be seen that such a line when loaded closer to thermal current carrying capacity would start absorbing about 1500 MVAR from the network [5].

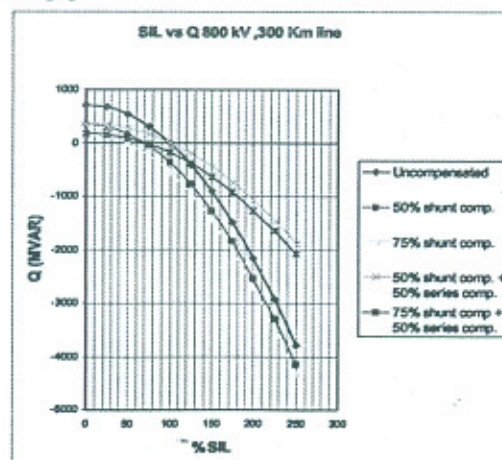


Fig: 1. Reactive power requirements of 800 kV transmission line. [9]



800 kV line when unloaded would also supply about 720 MVAR into the system causing over voltages or charging problems when located close to generating stations. Hence in reality an 800 kV line will have to be provided with shunt reactors to the tune of at least 50%, if not 60%, which translates into shunt reactors of 180 MVAR or 220 MVAR at each end to limit the impact of reduced loading or problems at line charging.

The effect of providing this shunt reactive compensation is to however bring down the SIL. The SIL is reduced by a factor of  $(1-K)$  where  $K$  is the degree of shunt reactive compensation. Thus the utilization of the line vis-à-vis its thermal capability reduces even further, as the line starts net absorption of reactive power from the network at power transfer levels of 1600 MW itself which is far below its rated capacity. The situation explained above is further aggravated with longer lines. Such long lines which link load centers from generating centers far away can be the cause for voltage collapse situations and the whole interconnected network can be in the jeopardy of collapse unless reverse corrective actions are taken with the control devices installed at proper locations. [9]

### **3. CHARACTERISTIC ADVANTAGES OF HVDC FOR SYSTEM INTERCONNECTIONS**

The easiest way to interconnect large power systems, which are already heavily loaded, is to use HVDC. Major benefit of an HVDC link is its ability to control the power flow and its flexibility to adapt to different AC system characteristics at both ends of the interconnection. In this respect, HVDC offers significant benefits for the system interconnection. These benefits are listed hereunder;

- For a.c. interconnections, normally the rating of a.c. link should be higher than the actual power transfers due to stability reasons. But for HVDC interconnections this is not the case, rating of HVDC link may be equal to actual power transfer levels.
- Easy exchange of power between two interconnected power systems is possible without taking additional control measures as required in a.c. interconnections.
- HVDC link has inherent capability, if HVDC controls are tailored properly to system features, to control bus voltages and damp out power oscillations.
- HVDC link acts as a barrier for propagation of disturbances between two systems/networks and acts as a firewall to cascade outages/blackouts.
- Exact and fast controls of power flows over the HVDC line ensure supply support in system emergency conditions.

These are generally valid and do not depend on the size of the interconnected systems [2]. The DC interconnection can be either long distance transmission or a back-to-back link. The back-to-back solution is more suitable for exchange of moderate power, e.g. up to 1200 MW in the areas close to the borders of both systems. If, however, a large amount of power should be exchanged or transmitted over long distances, the HVDC point to point transmission offers more advantages. Power can be brought directly to the spots in the systems where it is required without any risk to overload the AC system in between. A further advantage of such a solution is the control performance of HVDC which can effectively support the AC system stability and damp inter-area oscillations. [9]

### **4. APPLICATION OF HVDC TRANSMISSION SYSTEMS**

The characteristics of HVDC transmission systems have led to a series of typical applications described below particularly for bulk power supply systems;



- Point-to-point long distance bulk power transmission.
- Back-to-back (BtB) interconnection

#### 4.1 Long Distance Bulk Power Transmission

HVDC transmission systems offer a technically reliable and economically feasible possibility for transmission of very great amount of energy over long distances. Besides the technical aspects such as precise controllability, absence of stability problems and ease of fault clearing, economic considerations are especially important for this application of HVDC systems. If a comparison is made using various transmission distances for HVDC and EHV-AC alternatives, a diagram such as shown in figure 2 is obtained.

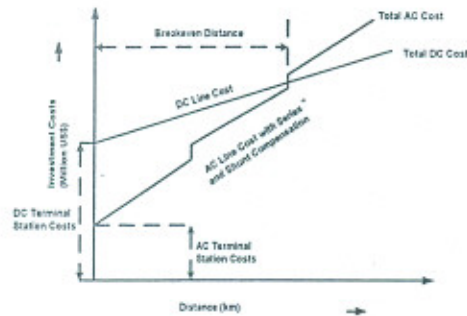


Fig. 2. Cost Comparisons of HVDC and EHV-AC Systems for Long Distance Transmission [9]

The costs at distance zero are the station costs, which are naturally much higher for HVDC converter stations. As HVDC line has only two conductors and therefore the HVDC tower would be of small profile as compared to the EHV-AC tower that has to carry three phase conductors. The high costs of HVDC converter stations are compensated in the low cost of HVDC lines as compared to EHV-AC lines and there comes a typical distance called break-even distance above which HVDC line would be economical over EHV-AC line. Typical break-even distances are in the range of 500-700 km. The cost of intermediate compensation substations required for EHV-AC option should be included in the overall cost comparison. The EHV-AC lines loading capability reduces with the distance due to their reactive power requirements and increased transient stability concerns. But the loading capability of HVDC lines is independent of their line lengths as they require no reactive power flows. Consequently for a given distance and chunk of power, EHV-AC alternative requires more number of lines as compared to the HVDC alternative. HVDC transmission systems have been used extensively for point to point bulk power transmission such as in Brazil, North America, Canada, South Africa, China and India. In Table 1 pertinent examples of long distance bulk power transmission are given where HVDC excels over its EHV-AC counterpart.



**Table: 1.** Long Distance Bulk Power HVDC Transmission System Project Examples

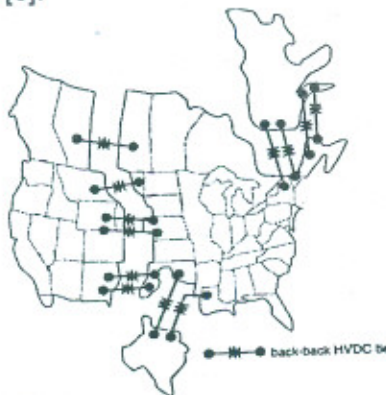
Sr. No.	HVDC Project	Transmission Voltage	Power Rating	Line Length
1	Pacific Intertie (Western USA)	± 500 kV	3100 MW	1360 km
2	Nelson River (Canada)	± 450 kV ± 500 kV	1620 MW 2000 MW	890 km 930 km
3	Itaipu (Brazil)	± 600 kV ± 600 kV	3150 MW 3150 MW	785 km 805 km
4	Cahora Bassa (South Africa)	± 533 kV	2000 MW	1414 km
5	Rihand-Delhi (India)	± 500 kV	1500 MW	814 km

#### 4.2 Back-to-Back Interconnection

In back to back (BiB) HVDC systems, the rectifier and inverter are located at the same place without any intermediate transmission line. Such HVDC systems are being used for interconnection of two AC systems and/or regions of the same network asynchronously having same or different system frequencies. It permits the control of asynchronously connected power system networks independent of each other while eliminating the propagation of faults. These HVDC systems allow the two systems to adopt different frequency control strategies and act as a fire wall against cascade outages and therefore enhancing the overall grid system stability. The North American power network is subdivided into four asynchronous regions that are tied together through HVDC back-to-back stations. The four asynchronous regions are:

- Eastern and Central United States (including Ontario, Nova Scotia, New Brunswick, Manitoba and Saskatchewan of Canada)
- Quebec and Labrador
- Western United States and parts of Western Canada, including parts of north-western Mexico
- Texas

In total there are 12 HVDC back-to-back stations for interconnection of the North-American regions as shown in the figure 3 [6].



**Fig: 3.** Asynchronously Connected Regions of North American Power System



## 5. ELIMINATION OF POWER TRANSMISSION BOTTLENECKS

The term bottleneck is often interchangeable to congestion of transmission paths or interfaces. A transmission path or interface refers to a specific set of transmission elements between two neighbouring control areas or utility systems in an interconnected electrical system. A transmission path or interface becomes congested when the allowed power transfer capability is reached under normal operating conditions or as a result of equipment failures and system disturbance conditions. The key impacts of bottlenecks are reduction of system reliability, inefficient utilization of transmission capacity and generation resources. The ability of the transmission system to deliver the energy is dependent on several main factors that are constraining the system, including thermal constraints, voltage constraints and stability constraints. These constraints are usually determined by performing detailed power flow and stability studies for a range of anticipated system operating conditions.

In order to increase power flows over AC lines and relieve transmission bottleneck, various measures could be taken using FACTS devices, phase shifting transformers and HVDC link. FACTS devices may be placed at proper locations in the power system to redistribute the power flows evenly over parallel lines and alleviate the transmission congestion [7].

Such devices have been used extensively for preventing transmission congestion and loop flows. The operating principle of phase shifting transformer is based on voltage source injection into the line by a series connected transformer, which is fed by a tapped shunt transformer. The response of phase shifting transformers is very slow, typically between 5 and 10 seconds per tap, which results into minutes depending upon number of available taps. For successful voltage or power flow restoration under transient system conditions, as a thumb rule, a response time of approximately 100 ms is necessary. Such a fast reaction times can easily be achieved with HVDC controllers. Hence under steady state conditions, phase shifting transformers may relieve the network from congestion and undue flows but would fail to save system collapse under transient conditions.

By using the inherent controllability of HVDC system the power system operator can decide how much power that is transmitted in the AC link and how much by the HVDC system. Longer AC lines tend to have stability constraint and by using the inherent controllability of HVDC system in parallel with the long AC lines, the power system can be stabilized and transmission limitations on the AC lines can be increased. [9]

## 6. POWER OSCILLATION DAMPING

The presence of large number of different dynamic devices causes low frequency oscillations in some parts or between regions/pools of the interconnected power systems. Power oscillations are commonly experienced in modern power systems such as in UCTE system. The low frequency oscillations in power systems take place as the synchronous generators swing against each other. The frequency range of these oscillations is from 0.1 to 2.50 Hz. It is related to the dynamic power transfer between areas. At times the oscillations may grow causing the instability of power systems. There are two types of such oscillations referred to as local mode and inter-area mode, corresponding to single machine-to-infinite bus structure and those which occur amongst regions/pools of interconnected power systems, respectively. Power oscillations are common on AC lines forming relatively weak link between two groups of generation pools [8].

Power modulation is one of the very important control features of modern HVDC transmission technology. This feature is intended to stabilize the AC power system usually connected parallel to the HVDC link. The magnitude of power over the HVDC system is continuously varied to reduce the power swing of parallel AC lines in the event of system disturbances. This feature has been applied in the Pacific Intertie HVDC link in USA, where it has been



established that the power rating of the parallel 500 kV AC lines could be raised by 20 % if power oscillations are damped on them with the adoption of the modulation on the dc link.

Inter-area power oscillations have also been observed in South African Power Pool (SAPP) on weak AC interconnection between two regions. The SAPP system was formerly separated into two large AC systems connected by a 1400 kilometer long HVDC line (Cahora-Bassa link). Lately, the two systems were synchronized by a 300 kilometer AC line to enable flexible power exchange and increase the frequency robustness in the northern subsystem. However, the interconnection gives rise to weakly damped oscillations in the frequency range of 0.3 to 0.4 Hz [8]. Persistent power oscillations can cause line tripping and generators can become unstable. This inter-area mode is excited easily by nearly any faults in the system and has already led to line tripping between Zimbabwe and Republic of South Africa. It has been established that the HVDC Cahora Bassa can be used to damp the power oscillations on the parallel AC line and to improve system stability as depicted in the Fig:4. If the fast power modulation including the overload capability of the HVDC is used the transient stability margin of the interconnected system can be improved and the power oscillations can be damped out quickly. [9]

The input signal for the power modulation of the HVDC is the angle difference of the voltage vectors at the rectifier station of the HVDC at Songo substation (Mozambique) and at the inverter station of the HVDC at Apollo substation (South Africa). This input signal ensures optimum damping of the power oscillations; however, fast telecommunications and a global positioning system (GPS) are required to ensure a common time base for the derivation of the angle difference from the measured voltage angles.

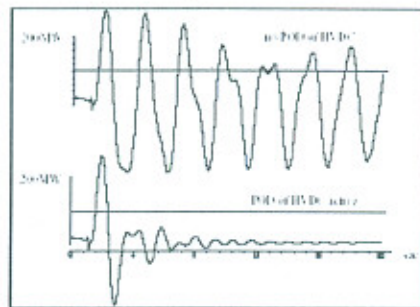


Fig: 4. Damping of power oscillations in SAPP system

## 7. CONCLUSION

System interconnections offer technical and economical advantages. However, when using only AC interconnection, the advantages decrease with an increasing size of the systems to be interconnected and the expenditures and costs to adjust the system parameters for synchronous operation rise.

An HVDC interconnection doesn't need such system adjustments and provides therefore a more economic solution. In addition, when power has to be transmitted through the system over longer distances, the HVDC transmission is technically and economically a superior solution. On long term, however, a synchronous hybrid solution, consisting of both HVDC and AC links, is the most promising solution for large national and continental interconnections.

Various problems/constraints associated with large interconnected power systems are discussed in the paper. With examples it is demonstrated how controllability of HVDC installations could be used to mitigate large network problems with enhancement in the overall grid stability.



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# DEVELOPMENT OF A NEW V-BLAST ALGORITHM TO IMPROVE THE COMMUNICATION PERFORMANCE

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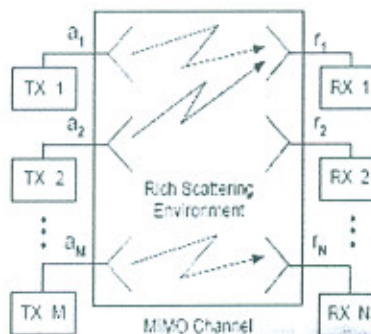
**Abstract-** We have introduced a new symbol detection algorithm for MIMO channels. This algorithm is an extension of the well-known V-BLAST algorithm. The new algorithm, V-BLAST/MAP, combines elements of the V-BLAST algorithm and the maximum a-posteriori (MAP) rule. V-BLAST system offer spectacular increase in spectral efficiencies. The original V-BLAST algorithm is a multi-layer symbol detection scheme which detects symbols transmitted at different transmit antennas successively in a certain data-independent order. The proposed V-BLAST/ MAP algorithm differs from V-BLAST not only in the ordering strategy of the symbols detected but it also minimizes the symbol error rate very much. The complexity of the V-BLAST/MAP is higher than that of V-BLAST; however, the performance improvement is also significant. Simulation figure shows that V-BLAST/MAP achieves symbol error rates less as compare to the previous detection techniques [1].

## 1. Introduction

Recent research on wireless communication systems has shown that using multiple antennas at both transmitter and receiver offers the possibility of wireless communication at higher data rates compared to single antenna systems. The information-theoretic capacity of these multiple-input multiple-output (MIMO) channels was shown to grow linearly with the smaller of the numbers of transmit and receiver antennas in rich scattering environments, and at sufficiently high signal-to-noise (SNR) ratios [6]. Some special detection algorithms have been proposed in order to exploit the high spectral capacity offered by MIMO channels. One of them is the V-BLAST (Vertical Bell-Labs Layered Space-Time) algorithm which uses a layered structure [2]. This algorithm offers highly better error performance than conventional linear receivers and still has low complexity. We offer a new symbol detection algorithm called V-BLAST/ MAP that has a layered structure as V-BLAST, but uses a modified detecting algorithm that yields a better error performance than V-BLAST at slightly higher complexity.

### 1.1 The MIMO Channel Model

We use the MIMO channel model shown in Fig. 1 with M transmitter and N receiver antennas.



**Figure 1.** MIMO channel model. (TX and RX stand for transmitter and receiver antennas respectively).

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In each use of the MIMO channel, a vector  $a = (a_1, a_2 \dots a_M)$  of complex numbers is sent and a vector  $r = (r_1, r_2 \dots r_N)$  of complex numbers is received. We assume an input-output relationship of the form

$$r = Ha + v \quad (1)$$

where  $H$  is a  $N \times M$  matrix representing the scattering effects of the channel and  $v = (v_1, v_2 \dots v_N)$  is the noise vector. Throughout, we assume that  $H$  is a random matrix with independent complex Gaussian elements  $\{h_{ij}\}$ . We also assume throughout that  $v$  is a complex Gaussian random vector with i.i.d. elements. It is assumed that  $H$  and  $v$  are independent of each other and of the data vector  $a$ . We will assume that the receiver has perfect knowledge of the channel realization  $H$ , while the transmitter has no such channel state information (CSI). Receiver's possession of CSI is justified in cases where the channel is a relatively slowly time-varying random process, see [3] for a discussion of this point.

## 1.2 The Symbol Detection Problem

The symbol detection problem considered in this thesis is the problem of estimating the MIMO channel input vector  $a$  given the received vector  $r$  assuming that the receiver has perfect knowledge of  $H$ . This decision is made on a symbol by symbol basis without taking into account any statistical dependencies that may be present in the sequence of vectors  $a$ . In other words, we exclude coding across the time dimension and consider only the modulation-demodulation problem as depicted in Fig. 2. The goal is to minimize the probability of decision error.

$$P_e = \Pr \{\hat{a} \neq a\} \quad (2)$$

where  $\hat{a} = (\hat{a}_1, \hat{a}_2, \dots, \hat{a}_M)$  is the demodulator's estimate of  $a$ .



**Figure 2:** Modulation, transmission and decision in MIMO wireless systems.

We study the above detection problem under the additional assumptions on the input vector  $a$  that:

- (i) Each element of  $a$  belongs to a common modulation alphabet  $A$ . i.e.  $a_i \in A$  and  $i = \{1 \dots M\}$ . Typically,  $A$  will be a QAM alphabet such as  $A = \{\pm A \pm jA\}$  as in the case of 4-QAM.
- (ii) We will assume that symbols in  $A$  have equal a priori probabilities.

While designing a receiver structure for this MIMO system, two main considerations that should be taken into account are the error performance and the implementation complexity. The aim of this thesis is to design a receiver structure that is powerful in terms of error performance and is practical to implement.

## 1.3 MAP Detection Algorithm

For the signal detection problem defined in the previous section, the decision rule used by us in the thesis is the *maximum a posteriori probability* (MAP) rule. It is defined as

$$\hat{a} = \arg \max \{P_r(a|r \text{ is received})\} \quad (3)$$

It is well-known that the MAP rule minimizes the probability of error  $P_e$ .



Although MAP rule offers optimal error performance, but it suffers from complexity issues. It has exponential complexity in the sense that the receiver has to consider  $|A|^M$  possible symbols for an M transmitter antenna system. For example, if 64-QAM is used with 4 transmit antennas, then a straight forward implementation of the MAP detector needs to search over  $64^4 = 16,777,216$  symbols. Note that the difficulty of detection is caused by entanglement of the elements of  $a$  through multiplication by  $H$ .

In order to solve the detection problem in MIMO systems, research has focused on sub-optimal receiver models which are powerful in terms of error performance and are practical for implementation purposes, as well. One such receiver is the V-BLAST (Vertical Bell-Labs Layered Space-Time) receiver which utilizes a layered architecture and applies *successive cancellation* by splitting the channel vertically [4].

## 2. Linear Receiver

Linear receivers are the class of receivers for which the symbol estimate  $\hat{a}$  is given by a transformation of the received vector  $r$  of the form

$$\hat{a} = Q(Wr) \quad (4)$$

where  $W$  is a matrix that may depend on  $H$  and  $Q$  is a quantizer (also called slicer) that maps its argument to the nearest signal point in  $A^M$ . Our review of linear receivers follows the presentation of [5]. Linear receivers are explained below:

### 2.1 Zero Forcing (ZF) Receivers

Zero-Forcing (ZF) receiver is a low-complexity linear detection algorithm that outputs

$$\hat{a} = Q(\hat{a}_{ZF}) \quad (5)$$

$$\text{where } \hat{a}_{ZF} = H^+r \quad (6)$$

and  $H^+$  denotes the Moore-Penrose pseudo-inverse of  $H$ , which is a generalized inverse that exists even when  $H$  is rank-deficient.

The ZF receiver eliminates co-channel interference entirely in the above example since  $H^+H = I$ . On the other hand, ZF receivers are known to have the drawback of enhancing noise power [6]. Its performance is shown by the below figure:

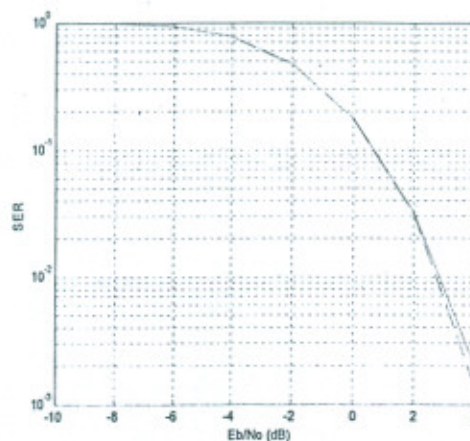


Figure 3: Symbol error rates (SER) of V-BLAST / ZF receiver, V-BLAST/ LLSE receiver. Simulations are for  $(M,N) = (8, 12)$  and QAM-16 modulation.



## 2.2 Linear Least Square Estimation (LLSE) Receiver

The LLSE receiver is a receiver that outputs the estimate

$$\hat{a} = Q(\hat{a}_{LLSE}) \quad (7)$$

where  $\hat{a}_{LLSE}$  is a linear estimator given by

$$\hat{a}_{LLSE} = Wr \quad (8)$$

where  $W$  is chosen to minimize the error and for the model here, where  $H$  and  $v$  are Gaussian, the LLSE estimator matrix is given by

$$W = \frac{\rho}{M} H^+ \left( \frac{\rho}{M} H H^+ + \text{NoI}_N \right)^{-1} \quad (9)$$

It does not eliminate the co-channel interference but on the other hand, it has the desirable property of not enhancing noise as much as the ZF estimator. Its performance is better than ZF receiver, which can be seen from the Figure 3.

## 3. V-BLAST Receiver

The V-BLAST detection algorithm [5] is a recursive procedure that extracts the components of the transmitted vector  $a$  according to a certain ordering  $(k_1, k_2, \dots, k_M)$  of the indices of the elements of  $a$ . Thus,  $(k_1, k_2, \dots, k_M)$  is a permutation of  $(1, 2, \dots, M)$ . In V-BLAST, this permutation depends on  $H$  (which is known at the receiver by assumption) but not on the received vector  $r$ .

### 3.1 V-BLAST/ZF Detection Algorithm

The V-BLAST/ZF algorithm is a variant of V-BLAST derived from ZF rule. V-BLAST/ZF Detection Algorithm [5]

#### Initialization

$$W_i = H^+$$

$$i = 1$$

#### Recursion

$$k_i = \arg \min_j \| (W_i)_j \|^2$$

$$y_{k_i} = (W_i)_{k_i} * r_i$$

$$\hat{a}_{k_i} = Q(y_{k_i})$$

$$r_{i+1} = r_i - \hat{a}_{k_i} (H)_{k_i}$$

$$W_{i+1} = H_{k_i}^+$$

$$i = i + 1$$

$$\text{End} \quad (10)$$

where  $H^+$  denotes the Moore-Penrose pseudo-inverse of  $H$ ,  $(W_i)_j$  is the  $j$ 'th row of  $W_i$ ,  $Q(\cdot)$  is a quantizer to the nearest constellation point,  $(H)_{k_i}$  denotes the  $k_i$ 'th column of  $H$ ,  $H_{k_i}^+$  denotes the matrix obtained by zeroing the columns  $k_1, k_2, \dots, k_i$  of  $H$ , and  $H_{k_i}^+$  denotes the pseudo-inverse of  $H_{k_i}$ .

In the above algorithm, Eqn. (3.1c) determines the order of channels to be detected; Eqn. (3.1d) performs *nulling* and computes the decision statistic, Eqn. (3.1e) slices computed decision statistic and yields the decision; Eqn. (3.1f) performs *cancellation* by decision feedback, and Eqn. (3.1g) computes the new pseudo-inverse for the next iteration.



V-BLAST/ZF may be seen as a successive-cancellation scheme derived from the ZF scheme. The ZF rule creates a set of sub-channels by forming  $\hat{a}_{ZF} = (H^*H)^{-1} H^*v$ .

### 3.2 V-BLAST/LLSE Detection Algorithm

The V-BLAST/LLSE algorithm is a variant of V-BLAST where the weighting matrix is chosen according to the LLSE rule. The whole procedure is same as V-Blast/ZF algorithm except that only the weighting matrix is different. It is given below:

**Initialization**

$$W_i = \frac{\rho}{M} H^* \left( \frac{\rho}{M} H H^* + \text{NoI}_N \right)^{-1}$$

$$i = 1$$

**Recursion**

$$k_i = \arg \min_j \| (W_i)_j \|^2$$

$$y_{k_i} = (W_i)_{k_i}^* r_i$$

$$\hat{a}_{k_i} = Q(y_{k_i})$$

$$r_{i+1} = r_i - \hat{a}_{k_i} (H)_{k_i}$$

$$W_{i+1} = \frac{\rho}{M} H^* \left( \frac{\rho}{M} H H^* + \text{NoI}_N \right)^{-1}$$

$$i = i + 1$$

**End** (11)

### 4. V-BLAST/MAP Detection Algorithm

We propose a new symbol detection algorithm for MIMO channels, which is called V-BLAST/MAP that combines the features of V-BLAST and MAP rules. This algorithm uses the layered structure of V-BLAST, but uses a different strategy for channel processing order, inspired by the MAP rule.

#### 4.1 V-BLAST/ZF/MAP Detection Algorithm

V-BLAST/ZF/MAP algorithm may be described as follows:

**Initialization**

$$W_i = H^*$$

$$i = 1$$

**Recursion**

$$y_i = W_i r_i$$

$$s_i = Q(y_i)$$

$$p_{ij} = f_{ij}(y_{ij}|s_{ij}) / \sum_{s' \in \mathcal{A}} f_{ij}(y_{ij}|s')$$

$$k_i = \arg \max_j \{ \rho_{ij} \}$$

$$\hat{a}_{k_i} = s_{i k_i}$$

$$r_{i+1} = r_i - \hat{a}_{k_i} (H)_{k_i}$$

$$W_{i+1} = H^*$$

$$i = i + 1$$

**End** (12)

Here the vectors  $y_i = (y_{i1}, y_{i2}, \dots, y_{iM})$  and  $s_i = (s_{i1}, s_{i2}, \dots, s_{iM})$  are the counterparts of those in Eqn.'s (5) and (6) in the ZF detector.

In the above algorithm, the index  $j$  ranges over all elements of  $\{1, 2, \dots, M\}$  excluding those in  $\{k_1, k_2, \dots, k_{i-1}\}$ , i.e.  $j \in \{1, 2, \dots, M\} \setminus \{k_1, k_2, \dots, k_{i-1}\}$ .



V-BLAST/ZF/MAP algorithm is identical to V-BLAST/ZF except for the ordering in which symbols are detected. Instead of selecting the next symbol to be detected according to the rule (10), here the set of all potential symbol decisions are ranked with respect to their a-posteriori probabilities of being correct, as estimated by  $p_{ij}$ . Thus, it is important to emphasize that  $p_{ij}$ 's are not true MAP probabilities but approximations to how probable it is that  $s_{ij} = a_j$ . The approximation is due to the omission in calculations of the cross-correlations between the noise terms  $z_{ij} \approx y_{ij} - s_{ij}$  on the component sub-channels. Notice that the index permutation  $(k_1, k_2, \dots, k_M)$  produced by V-BLAST/ZF/MAP depends on both  $H$  and  $r$ , unlike V-BLAST/ZF where the permutation depends only on  $H$ .

The complexity of V-BLAST/ZF/MAP is increased with respect to that of V-BLAST/ZF by the computation done in step 5 of Eq 12. The order of complexity of computing  $p_{ij}$  is roughly  $O(|A|)$  for any fixed  $j$ , and upper bounded by  $O(M|A|)$  when considered as a whole. This computation can be further simplified by approximating the denominator of (4.1e) but that issue is not explored in this thesis. One major point about complexities of V-BLAST/ZF and V-BLAST/ZF/MAP is that in the former allows pre-computation of all weighting vectors (which can be used repeatedly as long as  $H$  is fixed) whereas in the latter the weighting vector must be computed in real-time since it also depends on  $r$ . This increased complexity of V-BLAST/ZF/MAP is justified by performance improvements as illustrated later in this section. For a more realistic performance estimation of the V-BLAST/ZF/MAP receiver, we show in Fig. 4 the simulation results for a  $(M, N) = (8, 12)$  system with 16-QAM modulation. The symbol error rate SER is calculated by performing 5,000 trials at each  $E_b/N_0$  point. A new realization of  $H$  was chosen in each trial and for each  $E_b/N_0$  value. We observe that V-BLAST/ZF/MAP performs significantly better than both V-BLAST/ZF and V-BLAST/LLSE receivers.

#### 4.2 V-BLAST/LLSE/MAP Detection Algorithm

Now we use the LLSE technique in order to compute weighting matrix. This is same as V-BLAST/ZF. V-BLAST/LLSE/MAP algorithm may be described as follows:

$$\begin{aligned}
 &\text{Initialization} \\
 &W_i = \frac{\rho}{M} H^* + \left( \frac{\rho}{M} H H^* + \text{NoI}_N \right)^{-1} \\
 &i = 1 \\
 &\text{Recursion} \\
 &y_i = W_i r_i \\
 &s_i = Q(y_i) \\
 &\rho_{ij} = f_{ij}(y_{ij} | s_{ij}) / \sum_{s' \in A} f_{ij}(y_{ij} | s') \\
 &k_i = \arg \max \{ \rho_{ij} \} \\
 &\hat{a}_{ki} = s_{i, k_i} \\
 &r_{i+1} = r_i - \hat{a}_{ki} (H)_{ki} \\
 &W_{i+1} = \frac{\rho}{M} H^*_{ki} + \left( \frac{\rho}{M} H H^*_{ki} + \text{NoI}_N \right)^{-1} \\
 &i = i + 1 \\
 &\text{End} \tag{13}
 \end{aligned}$$

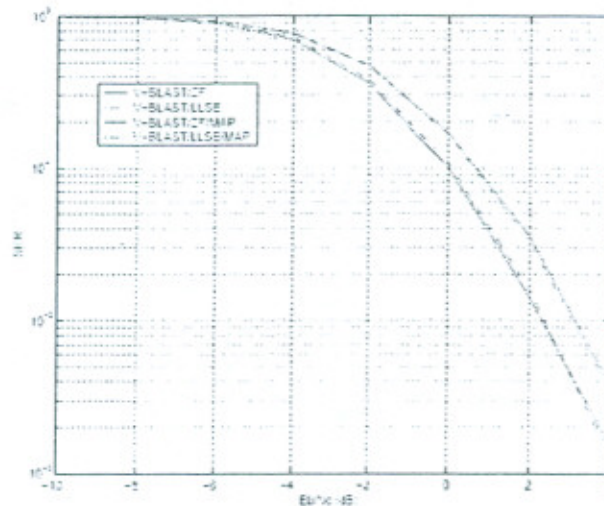
For a more realistic performance estimation of the V-BLAST/LLSE/MAP algorithm, we show in Fig. 4 the simulation results for a  $(M, N) = (8, 12)$  system with 16-QAM modulation. The symbol error rate SER is calculated by performing 5,000 trials at each  $E_b/N_0$  point. A new realization of  $H$  was chosen in each trial and for each  $E_b/N_0$  value.



## 5. Conclusion

V-BLAST, a wireless architecture has extraordinary spectral efficiencies over the rich-scattering wireless channel. The general BLAST approach and the V-BLAST detection scheme were described in detail, and then the new Symbol Error Rate (SER) improvement algorithm V-BLAST/MAP is also explained. All these algorithms use the constellation-based detection scheme. Then we theoretically compare the complexity of these detection algorithms i.e. the complexity of V-BLAST/ZF /MAP is increased with respect to that of V-BLAST/ZF by the computation done in step 5 of Eq 12.

V-BLAST/MAP and V-BLAST/ZF performance can be judged by the simulation Figure 4



**Figure 4:**Symbol error rates (SER) of V-BLAST / ZF/MAP receiver, V-BLAST/ LLSE/ MAP receiver, V-BLAST/ZF receiver and V-BLAST/LLSE receivers. Simulations are for  $(M, N) = (8, 12)$  and QAM-16 modulation.

The above figure shows that V-BLAST/MAP provides significant improvement in SER compared to ordinary V-BLAST, both for the ZF and LLSE versions. But this improvement in the performance can increase the complexity of the system and we observe that this complexity time is roughly less than two. So we may state as the main conclusion of this thesis that V-BLAST/MAP offers significantly better SER performance than V-BLAST at a modest increase in complexity.

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## VAGABOND VIRUS: DANGUE FEVER IS SPREADING, AND SOME THINK CLIMATE CHANGE IS TO BLAME

Scott Tind Simmons was at his office in Phnom Penh, Cambodia, when he started to feel sick. By the time he got to bed, his flue-like symptoms gave way to achy joints and feverish dreams. That's when he got suspicious-borne virus that, in its deadly form, causes blood to seep from the blood stream into tissue and eventually from the body's orifices. Several days later, doctors diagnosed the expat aid worker with a milder, non-lethal variation of the disease. Since there are no drugs or vaccines for dengue, Tind Simmons did what some 38,500 infected Cambodians did this year: he drank plenty of water and waited for his bout of "bone-break fever," as the disease is often called, to go away.



But dengue isn't going away. Across Southeast Asia, doctors and public-health officials are grappling with alarmingly high dengue-infection rates. Cambodia and Vietnam reported double the cases this year compared with last, and more than 400 deaths; Thailand and Burma each recorded roughly a third more cases in 2007. The World Health Organization (WHO) says this is the fourth consecutive year of unusually high rates in the region – and doctors are

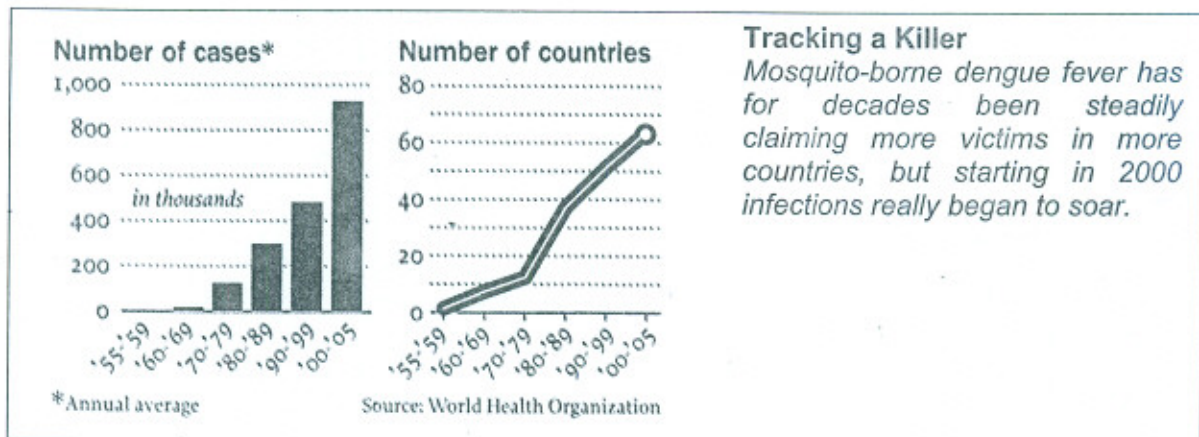
worried global warming may be partially to blame.

That's because the mosquito that infects most people with dengue, the striped *Aedes aegypti*, does better in warm, wet weather. Regions experiencing rising temperatures and longer rainy seasons are seeing large outbreaks year after year, and what has previously been thought of as a tropical disease is popping up in more temperate regions. Nepal and Bhutan saw their first cases in recent years, as did isolated spots such as Easter Island. Today, an estimated 2.5 billion people live in areas where dengue is endemic. The WHO expects millions more will be added in coming years. "Dengue is an evolving situation," says Dr. Jai Narain, director of communicable diseases for the WHO in southeast Asia. "A lot of people say climate change will impact {the disease} somewhere down the line. But it is already is."

Weather isn't doing the job alone. As more and more people migrate to cities, they create additional opportunities for the mosquito to spread the virus. The problem is particularly acute in developing countries, where inadequate utilities mean residents must store water in jars and tanks – prime breeding grounds for *Aedes aegypti*. Increasing air travel is also a factor as infected fliers spread the disease quickly world wide. "It's simplistic to suggest that the increasing outbreak is solely caused by climate change," says Simon Heals, a senior research fellow at New Zealand's University of Otago. "But those who would suggest that it has nothing to do with it are equally misguided." Hales estimates that if global warming advances as predicted by the U.N., more than half the end could be dengue country before the end of the century.



Lacking vaccines or effective treatments, public-health officials are battling the disease with old school tactics: pest control and education. But fumigation campaigns are too expensive for many Asian governments to carry out effectively; it's also difficult to regularly send out health officials to remind communities to keep their homes dry and water supplies clean. Even wealthy Singapore, a model of dengue control, was floored by an outbreak in 2005. Reported cases went down the following year, but are back up again slightly in 2007. "That's a kind of warning to us," says Hales. "As the temperature continues to increase, it gets progressively more difficult to prevent the disease from spreading – even with the best technology."



Health care professionals are trying to raise global awareness of the threat. In Cambodia, for example, more funding goes to controlling avian flu, a disease that affects far fewer people but has a higher fear factor worldwide. Health Organizations such as the U.S. based Centers for Disease Control and Prevention are stressing the link between climate change and disease, hoping to get more money to fight mosquito-borne illnesses. "This is a critical moment," says Dr. Maria Neira, director of the WHO's programme on public health and the environment. "If the public pressure is maintained, the politicians will act accordingly." Waiting for dengue fever to burn itself out may be the only option for individuals who catch the disease, but that's a lousy prescription for the planet.

**COURTESY**  
 The Newsweek



# PARTNERING TO IMPROVE PUBLIC TRANSPORT IN DEVELOPING COUNTRIES

## **Abstract**

*This paper demonstrates the importance of - and potential for - partnerships between the private and public sectors, and citizen groups, as a crucial means towards the improvement of public transport services in the developing world. It draws mainly upon the research findings of case studies in Karachi, Faisalabad, Dar es Salaam and Colombo between 1999 and 2003. The paper looks at some of the factors that need to be taken into consideration if a partnership is to be successful, before demonstrating the potential of existing links between users, operators and regulators. The potential for partnerships to improve upon the existing situation emerged on several occasions during the research, and these are summarized. Later sections look at the types of partnership that might be encouraged in the transport sector, as well as the importance of nurturing and supporting such partnerships. Finally, the paper highlights priorities for intervention — in the areas of infrastructure investment, land use and employment strategy, regulation and stakeholder collaboration — and the role partnerships could play in these interventions. The paper concludes with the importance of strengthening existing partnerships in public transport provision and creating and developing new ones. In this respect the authors consider it crucial that policymakers give due consideration to partnering approaches in the future.*

## **1. INTRODUCTION**

Transport is becoming the political paradigm not only in developed but also in developing economies. A substantial proportion of the population, if not a majority in many rapidly growing cities, live in low-income settlements. In the context of local politics, improvements in the quality of life of the urban poor in many cities of developing countries will be a key factor in attaining and sustaining political influence and power. Hence public transport is not just a technical issue but also has political or people dimensions. Urban public transport incorporates economic, human and social issues, and until the provision of public transport services becomes more people focused and environmentally friendly, equitable sustainable development will remain an unachievable dream.<sup>1</sup>

This paper reports on a significant part of the findings of a research project undertaken in Colombo (Sri Lanka), Faisalabad and Karachi (Pakistan) and Dar es Salaam (Tanzania) between 1999 and 2003. It is hoped that the findings will be useful for policymakers and urban public transport professionals so as to ensure that the poor will enjoy improved access to and quality of public transport services in the future, thereby widening economic opportunities and improving their lives in general. At present there is a lack of understanding about how services such as public transport are related to social and poverty issues. This paper contributes to the existing knowledge base by focusing on such issues, how they might be tackled via improved transport services, and, in particular, how such improvements might be achieved by encouraging partnerships in the transport sector.

Clearly, identifying key stakeholders, understanding roles and responsibilities and analyzing the working linkages, relationships and mechanisms used to deliver public transport services are all fundamental to the improvement of services. In addition, this paper focuses on how existing partnerships can be strengthened and new ones fostered and developed to ensure that all stakeholders — including a wide range of users (young, aged, disabled etc.), regulators, administrators, planners and operators— are included and all viewpoints considered. It also addresses the key issue of the contribution of partnerships (in public transport) in sustaining the livelihoods of the urban poor.<sup>2</sup>

Access to affordable transport is critical for the urban poor as it offers a way out of economic,



social and physical isolation. The authors consider price, affordability, access and quality in relation to the provision of public transport services in three Asian cities (Karachi, Colombo and Faisalabad) and one African city (Dares Salaam). For the purposes of the study public transport was defined as 'the provision of transport that is consumed collectively (whether provided by the state or private sector) in which passengers pay a fare'. Primarily, modes of urban-based public transport include trains, light rail, buses and minibuses; however, taxis, trams and trolleys, metros and 'para-transit' modes such as rickshaws, bicycles and motorcycle taxis can also be included as public transport modes.

## 2. WHY AND HOW THE RESEARCH WAS UNDERTAKEN

The term partnership often means different things to different people. In this paper *partnerships* are defined as: 'non-adversarial relationships (both formal and informal) between stakeholders (people having a stake in the provision of public transport services)'. Such partnerships might involve public and private, public and public and/or private and private organizations/ partners. For the purposes of the study, 'public' is defined in relation to any government agency (for example a local authority, municipality or state) acting either directly (as a regulator) or indirectly (for example as principal where a commercial firm acts as the agent), and 'private' is said to relate to any other type of organization involved in local government services (for example a private operator, a small-scale private provider or some type of community-based provision). The potential partners can be classified broadly as:

- (a) users
- (b) operators
- (c) regulators
- (d) government policymakers
- (e) support organizations, such as financial institutions.

Users can be individuals or a group. In all the case studies, the researchers noted that the mechanisms currently available for users to have a say in public transport services were very limited, particularly for the poor.

There are some glaringly obvious actions that should be taken to improve public transport services; it is not very clear what the factors are that inhibit undertaking those actions. For an example, see **Appendix-1**. The working hypothesis for the study was that the main inhibiting factor was a lack of partnering or collaborative working among all key stakeholders (operators, users and regulators). This study proposes that partnering can unlock the inaction. While relationships between agencies (and in some cases partnerships), both informal and formal, have responded in the past to provide the poor with access to public transport, there is a lack of understanding about how partnerships function to deliver public transport services as well as improve both the accessibility and quality of services.

The research problems below were explored in the case study cities of Karachi, Colombo, Dar es Salaam and Faisalabad. (See **Table-1** for basic city data and for detailed case studies please refer to references 4 - 7.)

**Table-1**  
**Statistics on City Size and National Rate of Urban Growth**

	City Population (est. 2000)	Rate of Urban growth: %	Rate of Urban Growth 1996-2000: %
Colombo	690000*	2.74	2.29
Dar es Salaam	2347000	8.33	6.31
Faisalabad	2232000	4.14	4.31

\*Estimate for 1999, source: United Nations.<sup>3</sup>



- (a) How can access to and quality of urban public transport services be improved?
- (b) How can existing partnerships be strengthened and new ones fostered and nurtured in respect of public transport provision?
- (c) How can the views of users, operators and regulators be integrated, and how should priorities be established at the operational and policy levels?

The predominantly 'how' nature of this research led to a case study approach. It was understood at the outset that case studies would not generate statistically representative generalizations, but would contribute to the logical explanation of events on the basis of both quantitative and qualitative data. (For a discussion of the merits of this approach see reference 8).

The study locations of Faisalabad (Pakistan), Colombo (Sri Lanka) and Dar es Salaam (Tanzania) provided a variability of situation, which allows for a more rigorous approach to testing the viability or extension of findings. All the locations represent urban areas with significant numbers of poor people. However, different levels of private sector involvement in public transport provision, different levels of use of motorized transport and different cultural contexts enabled the authors to collect an extensive, rich database. The cities provided a useful sample of typical cities in South Asia and Eastern Africa. The local environment and the transport sector differ in each of the countries. The differences included the availability of modes of providing urban transport services and differences in the proportion of people who have access to public transport services. In Dar es Salaam, for instance, which really has only minibuses and conventional taxis, the poorest make use of minibuses; however, a high proportion of poor people are only able to afford to walk for most of their travel needs. The researchers thought it important to understand the reasons why this is so, how Dar es Salaam's poor can gain access to public transport services, and how the quality of those services can be improved through partnerships.

The research methodology included case studies using structured and semi-structured interviews, and a series of focus group discussions at residential settlements and at the city level, followed by an international workshop. Both quantitative and qualitative data were collected. Techniques included content analysis, literature reviews, historical analysis, case studies, a travel diary, focus group discussions, forums and workshops. Focus group and workshop attendees comprised users (including men, women, children, the elderly and disabled members of the community), operators and regulators.

Various issues were explored further in the study, such as pedestrian access to services, fares, reliability of services, how new routes/services are planned, and how local community views can be included in defining transport services. Some generic and thematic issues, which the researchers found to be important in the creation of a pro-poor public transport system, were also explored.

## **2.1 Key Perspectives**

Key perspectives were sought from:

- (a) users, particularly low-income households.
- (b) providers and operators of the services, such as bus companies, drivers' associations, owners' associations.
- (c) regulatory agencies, primarily the transport ministry concerned and other government agencies, private bus companies, but also the municipal traffic departments and city traffic police who regulate the traffic and licensing authorities.



Approximately 300 interviews with key informants were conducted; 15 forums, three city-level workshops and one international workshop were held. In addition several sources of secondary data, including unpublished reports, were reviewed during the course of the case studies.

The interview format for focus group meetings and interviews with key actors (users, operators and regulators) was a checklist developed from reviews, meetings and Phase I of the research. Necessary adjustments were made according to the specific requirements of the case study location; however, the general format of these interviews is given below.

(a) Users from selected settlements

- (i) personal data
- (ii) livelihood assets
- (iii) travelling time
- (iv) environment (waiting places, interior of vehicles)
- (v) health and safety
- (vi) modes and options
- (vii) finances
- (viii) corruption-related issues, which may be controlled by accountability and transparency
- (ix) suggestions/ideas.

(b) Operators

- (i) personal data
- (ii) finances
- (iii) major operational problems/issues
- (iv) operation and maintenance
- (v) corruption-related issues, which may be controlled by accountability and transparency
- (vi) suggestions and ideas.

(c) Relationship between transport and livelihood patterns of the urban poor.

(d) Citizen initiatives to improve their access to transport.

### 3. FINDINGS

For case-specific research findings, please see the summary provided in **Table-2**.

**Table-2**  
**Comparison of research Findings in Case Study**

	Faisalabad	Colombo	Dar-es-Salam
Background	Public transport available has not grown at the same rate as the workspace	After two decades of nationalization, in 1979 the government decided to permit private bus owners to operate regular services on all routes to complement/compete with public.	City is highly concentrated, with rapid population growth since the late 1940s. Historically, public transport was a government monopoly until 1983.



	Faisalabad	Colombo	Dar-es-Salam
Modes of Public Transport	Tongas (animal-drawn vehicle), conventional rickshaws, motorcycle rickshaws, buses, wagons and taxis. The market is dominated by Suzuki pick-ups.	Pedal cycles, motor cars, motor cycles, school vans and office staff transport, three wheelers, private bus transport, rail transport, public buses.	Public transport is now provided by daladala buses, medium sized Toyota-DCM, Isuzu and Toyota Coaster buses, or buses that carry 20-22 people.
Problems and illegalities in formal and informal transport sectors	<p>Overcrowding Ban on smoking on public transport is not enforced Few proper bus stops Poor condition of roads and pavements Poor interior conditions of public transport Bad behavior of operators with passengers</p> <p>Poor safety of children when travelling Loud music played by bus operators Limited pedestrian crossings, signs for road safety City buses, wagons and pick-ups overcrowded inside and on the roof during peak hours Manner in which passengers are picked-up and dropped off Corruption limited the provision and regulation of public transport</p>	<p>Reckless drivers riding on pavements Drivers not slowing down at pedestrian crossing Unplanned stopping of buses Bus shelters not maintained Smoking prohibited but ban is not enforced Bus drivers not stopping Drunk Drivers</p> <p>Drivers not having licence for/ experience of driving buses; lack of training/technical competence Not following traffic regulations e.g. red lights Conductors harass girls and woman Informal business encroached on pavements</p>	<p>Pedestrian and cycle lanes are blocked by petty traders; parking places are also occupied by petty business. By-laws not enforced by municipal councils and other stakeholders. It is difficult to get compensation when a person has been involved in an accident, and comprehensive insurance is too costly: thus most owners opt for third party insurance. Unnecessary seizures of vehicles by the traffic police, who solicit bribes for minor offences. Drivers and conductors work as casual labourers and are not paid salaries. Reckless driving and daladala buses cause traffic accident and traffic jams. Vehicle operators do not follow traffic regulations or by-laws. Lack of safety of pedestrian, cyclists and vendors. Overcrowding in peak hours/poor hygiene.</p>



	Faisalabad	Colombo	Dar-es-Salam
			Mistreatment of women and schoolchildren. Loud music, hooting, smoking on buses and pick-pockets.
Public transport and the poor	There is a disparity of service between different parts of the city. Uneconomic for private operators to service routes on city outskirts off-peak.	Public bus fares are affordable, because the fare is controlled by the Ministry of Transport, but there are general complaints with pedestrian travel, frequency and time operation of public transport, condition of transport modes, service crew and their performance.	Current fare charges for buses are seen as too high, with many complaints about the quality of service. Poor people affected by the fact that private operators were not willing to service areas that had poor roads.
Passenger's perspective	Passengers complained that council has reduced spending on public transport	Bus stops should be properly planned, and bus shelters with seating facilities should be constructed. There is a need for wider pavements, free of obstructions. Pedestrian crossings must be provided at convenient places. Education should take place on traffic rules and regulations. Load limits should be introduced on buses. Interior of buses should be redesigned (seats, handrails, bells and steps) to meet needs of disabled.	Minibuses and larger buses operate without timetables or bus stops, leading to traffic congestion and degradation of pavements. Disputes frequently arise between minibus drivers and touts. Lack of uniform makes it difficult to distinguish between unlicensed and licensed drivers. Conductors were reported to use abusive language to women and girls who do not get off the bus quickly enough. Buses were said to be un-hygienic, particularly on hot days, leading to soiling and wrinkling of passengers' clothes.
Vehicle	76% of employees	Government should	Demands for tax relief



	Faisalabad	Colombo	Dar-es-Salam
owners' perspective	<p>were illiterate. Few crew members understood the mechanism of</p> <p>vehicles they were driving/conducting. Management controls were minimal. Drivers were trusted to return daily incomes to owners.</p>	<p>coordinate private bus operations and ensure that private operators earn sufficient income.</p> <p>Public-transport-related infrastructure should ensure that services can operate smoothly. The route allocation system must prevent oversupply of buses. Need for concessionary loan repayments/fuel subsidies.</p>	<p>on the running costs (spare parts and fuel) paid by owners of daladala. Owners would like bus fares</p> <p>raised to cover operation costs. Improvements to infrastructure of roads and terminals: shelters, benches, public toilets, drains, bus stops, parking bays. Uniforms should be worn by drivers and conductors. The Dar es Salaam regional Transport Licensing Authority should be more transparent on the allocation of bus routes. Vehicle owners suggested the need to establish a course on public transport.</p>
Bus drivers' and conductors' perspective	<p>Little evidence exists that drivers or conductors are officially trained or had contracts for work. Paid weekly or daily on the basis of targets. This meant drivers and conductors worked long days with short breaks. 89% of drivers and conductors thought that traffic signals and signs were below standard. Corruption exists in the police force: bribes were paid to</p>	<p>Employment status of private bus conductors and drivers must be changed, with training, recognition and contracts. Working conditions of crews must be changed. Awareness raising of passengers of road safety.</p>	<p>Drivers and conductors have targets to meet. They work long days with little break. Drivers' and conductors' lack of formal employment contracts with bus owners. They stated a need for an association to safeguard employment and working hours. The reported corruption in traffic police. The requested more durable and</p>



	Faisalabad	Colombo	Dar-es-Salam
	avoid fines for offences such as driving without a licence, driving with full beam on at night, driving unfit vehicles, or overloading passengers.		comfortable uniforms.
Regulations	<p>The Regional Transport Authority has power to issue routes to all motorized vehicles, vehicle body manufacturing licences, check overloading, issue licences to goods forwarding agencies and impose penalties on violators.</p> <p>The Traffic Police Department is responsible for issuing heavy/light transport vehicles licences, implementing traffic laws, controlling the flow of traffic, checking vehicle ownership, and watching for violators.</p> <p>The Tax Branch are responsible for issuing licences/permits and enforcing bye-laws for animal-drawn vehicles and imposing penalties on violators.</p>	<p>A number of agencies do exist in Sri Lanka to guide and regulate public transport services. However, there is a lack of proper coordination at national as well as city level. Regulatory agency personnel emphasize the need for all parties to cooperate in implementing traffic rules and regulations. It has been observed that there are no significant partnership arrangements in operation in this sector. Other transport modes, such as school vans, three-wheelers and office staff transport vans, are operated mostly on an individual basis, with no effective partnership arrangement between users, transport operators and regulators.</p> <p>As well as roads, infrastructure such as pavements or cycle lanes is needed to make walking to work or school safe and accessible.</p> <p>Traffic management measures such as one-way streets, removal of encroachments and better signaling would help.</p>	<p>Traffic department of the police force is responsible for designating and allocating routes to public bus operators. The Dar es Salaam Regional Transport licensing Authority (DRTLTA) is responsible for monitoring and enforcing route compliance among operators.</p> <p>The police force is involved in inspecting vehicles for their roadworthiness and testing drivers for professional competency in driving.</p> <p>There is no clearly defined urban public transport policy.</p>



	Faisalabad	Colombo	Dar-es-Salam
Issues	<p>Incoming inequality is high in Faisalabad, which causes problems for the pricing of public transport. Inadequate infrastructure is a basic problem. Many poor areas are not directly linked to main roads. Traffic management measures such as one-way streets, removal of encroachments and better signaling are needed. There is a need to development enforcement technology systems.</p>	<p>Consultation with the users and providers on public transport regulations should be institutionalized as part of policy formulation. Partnerships should be promoted between different actors in public transport service. Impacts of policies should be monitored through a participatory process. Specific targets should set, and time-bound actions are needed to achieve results.</p>	<p>Road transport network is poor, and does not encourage use of non-motorized transport in parts of the city. The fragmented provision of public transport makes it difficult to prepare focused plans or effective traffic management. Public transport for schoolchildren needs special attention. There is an urgent need to establish a forum for discussion whereby bus owners, operators and users would meet to discuss public transport.</p>

The following discussion is based on a cross-case analysis of findings:

### 3.1 Key Areas of Contribution From Partnerships

For many years priority was given to publicly owned transport services, often at the cost of preventing private services from operating.<sup>9-14</sup> However, as was shown by the experience in Dares Salaam, where private bus operators were banned in 1975, such action does little to address transport needs. In this case private operators continued to provide services, albeit illegally, and in 1983 they were once more allowed to provide (limited) services. Colombo witnessed a similar situation between 1958 and 1979. At present both the private and public sectors provide transport services in all four cities, including Karachi. However, in all cases there is a complete lack of real collaboration or partnership between any of the different providers, or between a broad spectrum of other stakeholders and services providers.

Private sector involvement does not come free. On the one hand, the case studies show the benefits of involving the private sector (even informally) in the delivery of urban services such as public transport, where service provision was regarded previously as the domain of the public sector. On the other hand, there is evidence of the problems that can arise from a lack of regulation and regulatory capacity, poor service provision, and lack of affordability. There were some sort of inter-stakeholders, informally regulated mechanisms that were working, for example *mafia* control of timekeeping systems for the buses in Karachi, and some sort of regulatory mechanisms for vendors at bus stations in Dar es Salaam. Most of the outdated, non-consultative regulations existed only on paper.

Both access to and quality of public transport are still the key challenges.<sup>15,16</sup> One possible strategy to prevent some of these problems from arising in the first place is through the use



of a partnering approach or collaborative working between stakeholders to secure service improvements. Numerous opportunities for partnering are evident — in particular, within the private sector and between public agencies and private firms. One key stakeholder group that could become involved in such partnering arrangements is the users themselves, the regulatory agencies, and those responsible for government transport policy. Users in all the case cities do not have an effective organizational form to raise their voice. A weakness of one partner can be overcome through partnering, which then allows focus on the joint strength and the avoidance of an adversarial relationship.

### **3.2. Examples of Partnering in Action**

It is important to recognize that generalized user groups may not be fully representative of all the interests of the poor. In Karachi, for example, the Karachi Public Transport Society addresses mainly the needs of higher-income groups. There is also a need to consider specific groups, such as those with disabilities who require access to safe public transport services to sustain their own medically constrained livelihoods. In some cases intermediaries have acted as representatives of such users in forums.

Operators are organized informally, for example in Colombo and Faisalabad, and in some cases formally, for example in Karachi, in the form of a bus owners' association. There is some evidence of inter-organizational collaboration or partnerships, but intra-organizational collaborative relationships were mostly absent. However, organizations are often effective only around short-term issues, such as promoting and implementing a fare increase.

Regulators are mostly organized formally, and in most cases such organizations are highly complex. They include various public sector organizations, including the police. For example, in Karachi it was estimated that there were around 60 organizations connected with the issue of public transport services, but even so there was no effective organizational hub for these groups. So even collaboration or partnerships among different elements of regulators were an issue. The scale of the potential problem of policy fragmentation was illustrated in the study of Dares Salaam, in which four different ministries have an involvement in transport services: the Ministry of Communications and Transport; the Ministry of Finance (collecting taxes); the Ministry of Home Affairs (vehicle inspection); and the Ministry of Regional Administration and Local Government (with responsibilities including Dar es Salaam's transport licensing authority and route allocation).

Government policymakers and local government representatives are also important potential partners in their own right (as well as being the target of other partnerships) in terms of national and local transport initiatives. Again, there was hardly any mechanism to develop a policy in a collaborative manner. In most of the policy discourse there was hardly any representation from the users.

Support organizations may be both formal and informal. There are numerous support organizations, such as those providing transport and maintenance services. There is a tendency for small-scale operators to seek assistance from informal support organizations, although these tend to be very costly to utilize, for example financing on very high rates. However, at the same time formal support organizations such as banks and other financial institutions have not even reached the stage of acknowledging the existence of informal potential partners.

For example, the lack of credit currently available to potential owners and operators is an illustration of how partnerships with financial institutions might offer benefits to the public if investment opportunities can increase, thereby increasing service provision. In a further example of the type of organization that might be involved, in Faisalabad the Faisalabad Urban Transport Society (FUTS) is planning an arrangement with a minibus leasing company



to increase the scale of services that it offers.

The current situation is illustrated by **Figs 1 and 2**, which show some links between potential partners. Existing links are mostly adversarial and uncoordinated. For example, the links in

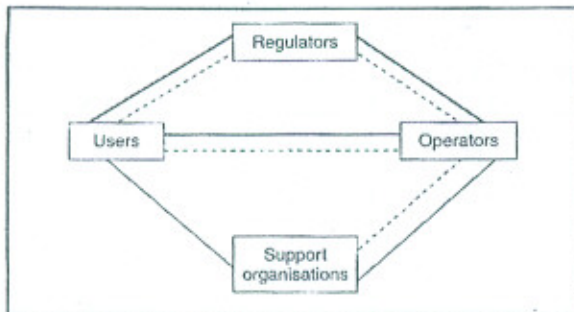


Fig. 1: Potential organisational linkages between stakeholders. Dashed lines indicate existing weak links; unbroken lines indicate proposed strong (in bold) and weak-partnering relationships.

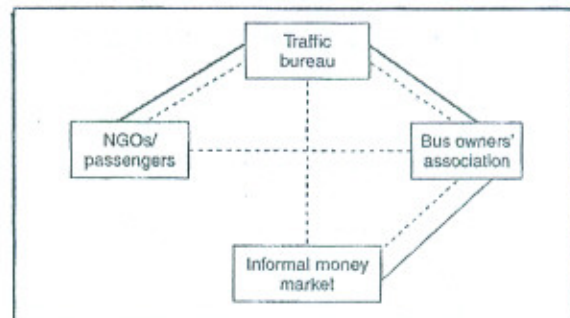


Fig. 2: Existing organisational linkages in Karachi.

Karachi can be illustrated as shown in **Fig.-2**.

The figures demonstrate how existing links can be converted into partnering links to improve the provision of public transport services. The potential for partnerships to improve the current situation emerged on several occasions within the case studies. For example, in Faisalabad the City Commissioner conceived and implemented FUTS, which is a voluntary organization that provides a transport system and licenses over 1,000 private vehicles to provide services. The objectives of the Society are to 'provide, maintain and supervise transport facilities for the commuters'. While the maximum number of vehicles on each route is not set, the operators themselves ensure that additional services are viable before allowing an additional bus. A single central terminal has assisted in the interchange of passengers between routes; nonetheless, congestion has resulted, and a second terminus is being developed.

A second and earlier example of a partnership in Faisalabad was that of the municipality's provision of eight stands for horse-drawn *ton gas* (horse carts) in several places within the city. Such stands now provide the animals with some relief from the heat in the summer, and also offer animal drinking facilities. The choice of location of *tonga* station and how that service complements other modes was made in a collaborative manner.

In Karachi, both users and operators agree that speed humps (and other traffic-calming measures) would assist in enforcing speed restrictions. Clearly it is in everyone's collective interest for vehicle speeds in dangerous places to be reduced. However, if such restrictions are not properly enforced for all operators, then each operator has an incentive to break restrictions to increase his potential number of passengers and consequently his earnings.

In Karachi there is a further example of the need for partnerships. The then government of Sindh (the province where Karachi is located) failed to include transport in the annual plan for 2000/2001, even though the ordinance establishing the Karachi Metropolitan Transport Authority had lapsed. Users, operators and regulators all have an interest in ensuring that transport remains on the policy agenda, otherwise funding will be difficult to earmark for transport improvements and maintenance of the city's existing network.

While partnerships may not address all the problems listed, they may offer a potential solution to some. Experience suggests that partnerships are likely to be most successful when 'win-win' solutions can be identified — that is, solutions that provide an incentive for both parties to be party to the agreement. Drawing on an example in the earlier study in Karachi, one citizens' group, SHEHRI, went to court to prevent the sale by the government of



plots of land that had been intended for depots and workshops for city buses. In this case the alliance was between the users and the bus owners, both of whom wanted to retain the (potential) facility. Other opportunities for 'win-win' solutions emerged in the four case studies — for example, bus route improvements in Karachi, and improved visibility of *daladala* minibuses in Dar es Salaam.

A further example of a partnership within a specific sector of transport services was provided by the collaboration between bus operators in Karachi. Owing to the large number of buses being burnt in political unrest, and the non-availability of insurance cover, the operators themselves established their own insurance cover. Each member pays Rs. 15 (£ 0.16) per day per bus, and the scheme then pays out whenever a bus is set on fire and damaged or destroyed. A final illustration of a partnership between different transport sectors also comes from Karachi. In 1997, a group of government officials and professionals from the private sector worked together with the Airport Security Force to improve traffic management at the airport. Two years later, activities were expanded to include a 14-kilometre road from the centre of town to the airport.

### 3.3 Examples of Intervention Where Partnering can Further Work

In summary, transport services are essential for livelihoods, particularly in the pen-urban settlements of cities.<sup>17-22</sup> However, transport costs may be unaffordable for the urban poor, even if the fares levied are considered fair in relation to the costs and risks incurred by the providers. Partnering arrangements can be devised to share the costs and risks.<sup>23-29</sup> This is true of developed and developing countries: for example, in the UK local strategic partnerships (LSPs) in transport are a recent initiative intended to coordinate public services at a local level through community strategies and local neighbourhood renewal strategies. While travel conditions appear to be capable of considerable improvement if investment of various kinds is made available, public funds are usually already heavily committed, and low incomes are likely to limit the capacity of passengers to pay for such improvements. There may be merit in subsidies, which are widely used to ensure transport access at an affordable price for low-income groups and communities. However, the costs of subsidies are frequently high, and targeting may be weak.

There may well be a need for intervention, but this should be limited and assessed carefully in order to ensure that the effects are beneficial and make optimal use of scarce resources. Essentially, intervention may be targeted in four areas, all of which can benefit from partnering:

- (a) infrastructure investment
- (b) land use and employment strategy
- (c) regulation of public transport services
- (d) promotion of stakeholder collaboration.

#### 3.3.1. Infrastructure Investment

Inadequate infrastructure is a major hindrance to the operation of public transport services, and a cause of danger and discomfort to transport users. In this context, the main improvements that are required to improve transport services appear to be the following.

- (a) *Improving access to major roads* from low-income residential areas to ensure that there are bus services at a reasonable distance to/from such areas. This might involve a partnership between government and the local community, for providing labour and skilled inputs. Alternatively, the public sector can encourage feeder services by para-transit modes from such localities to major road or bus routes (**Fig. 3**). Credit for those wishing to set up feeder services can be provided through



partnerships with banks or informal lenders and the local community.



- (b) *Ensuring safe and secure bus stops* for motorized transport with provision for shelter for passengers and designated areas for vendors. In particular, passengers are looking for somewhere to shelter, and somewhere where it is safe to wait. Local solutions need to be developed so that they are appropriate and low-cost. For example, experience in Faisalabad suggests that a public—private partnership involving private sponsorship may be a partial solution to the provision of bus stops, one that enables the public sector to focus its scarce resources within lower-income areas.
- (c) *Improving pedestrian routes that are also suitable for bicycles.* This may be particularly important for some of the poorer households that cannot afford to pay for transport, and would reduce the difficulties they face in reaching major roads. Once more, appropriate local design is important. Attention should also be given to safety and the environment. For example, tree planting may be used to divide pedestrian routes from major roads.

### **3.3.2. Land Use And Employment Strategy**

A partial alternative to direct or indirect investment in public transport is for governments to improve the situation of the poor by applying a positive land use and employment strategy. Two measures could achieve this.

(a) *identifying well-located land* that is suitable for settlement by the urban poor, and which reduces the transport costs the resettled residents will face.

(b) *encouraging employment opportunities* within low-income settlements so as to minimize the distance that workers need to travel.

### **3.3.3. Regulation**

Regulation of public transport services can be applied in three ways: over *quality, quantity* and *price*.

(a) *Quality control* in the stage bus industry concerns mainly the construction,



maintenance and operation of vehicles, although it is also strongly affected by the behaviour of drivers and conductors and the quality of regular and preventive maintenance programmes. Such control is justified by the difficulty faced by consumers in assessing whether the vehicle they are boarding is safe, and the advantage in applying common minimum standards. In addition, from a quality and safety standpoint, it would be helpful if regulators made more effort to encourage owners to provide better conditions and security of employment for their drivers and conductors. As indicated in the study of Karachi, higher incomes are likely to result if higher-quality services are provided. Clearly some form of continuous dialogue and/or partnership arrangement between regulators and operators would ease the way as regards control over public transport quality.

- (b) *Quantity control*, limiting the number of vehicles that may operate on a particular route, can bring about a more efficient and effective use of scarce resources, and minimize congestion (Fig. 4). However, control over the number of vehicles can also be anti-competitive and, by offering preference to a limited number of operators, such regulation can if misused offer potential advantages to those with undue or improper influence. Authorities may also be in danger of regulatory capture if they work too closely with the industry. However, the example of FUTS in Faisalabad suggests that it is possible to find a middle ground, restricting access to routes but being somewhat flexible. Clearly there is frequently excess supply on some routes, but such conditions are not in the interests of either users or the industry. Again, some form of dialogue/partnership between operators, regulators and potential operators is essential in this respect, and would be in the interests of all parties.



- (c) *Price control* can be useful in avoiding excessive tariffs, particularly where quantity control limits competition. However, 'fair' tariffs are difficult to set, and there is again a danger of corruption if the regulator enjoys excessive powers. Moreover, transport providers are often able to avoid such controls. For example, they may refuse to transport low-paying passengers (such as students) and/or they might break their journey on a route arbitrarily to ensure a 'double' payment. Thus regulation, although necessary, should be light and unobtrusive, and should be applied only to meet well-considered and generally agreed objectives. Regular consultation with operators and users will also improve the chances of a consensus being reached on price/tariff controls.



Governments are also able to influence the structure of the industry more generally to seek improvements for users. For example, they may actively encourage the entry of private sector operators if they feel it is in the interest of the community as a whole to provide competition; alternatively, governments may seek a public monopoly for transport provision in some circumstances.

#### **3.3.4. Stakeholder Collaboration**

Stakeholder collaboration can be promoted within various interest groups and also between groups in the form of partnerships.

- (a) *Owners' associations.* With the fragmentation of ownership that characterizes private transport services in all the study locations, there are likely to be benefits from encouraging operators to collaborate in order to raise standards and provide integrated services. There may also be benefits for regulators in being able to negotiate with a single group, although there is also a risk that an owners' association may form a cartel to exclude newcomers and protect the existing members' franchise.
- (b) *Users' associations.* The priority that people give to transport was indicated by the significance of transport expenditures as a proportion of household income. There is a need for passengers' perspectives to be represented both to the industry and to government regulators. However, in none of the city locations were there any opportunities for transport users to enter into a dialogue with the providers or the transport authorities. User groups are likely to have an interest in working in partnership with many other groups within the sector, for example collaboration with the private sector to improve public provision for transport services.
- (c) *Stake holder forums.* Support could also be given to setting up sector can exchange views and experiences on a regular basis, either formally or informally.

There appear to be considerable opportunities to improve the existing provision of public transport services through partnerships among key stakeholders. Partnerships appear to be a significant missing link to improve access to and the quality of public transport services in a highly competitive market.

There are some general issues where the debate on partnering needs to move forward.

#### **3.3.5. Clarity in Roles and Responsibilities**

Partnerships may involve a coming-together of parties to address an issue of common interest. Such partnerships are characterized by the involvement of autonomous and independent organizations, each with something to contribute, and each party negotiating to establish the rules of collaboration.

Alternatively, a partnership may involve one party, usually the public sector, setting out a framework in which the role of the other party (or parties) is already defined. The need for clear and precise contracting arrangements in the provision of public transport cannot be overstressed. Contracts need to be tailored to suit local conditions, and it is here that significant differences are likely to be required between partnership contracts in 'northern' and 'southern' countries. The following generic options exist: service contracts; management contracts; leases and *affermage* contracts; franchise arrangements; and concessions. Please refer to **Appendix-2** for a brief description of those categories of contract.

It is interesting to note that there is hardly a clear fit between the models of formal contract-



based organizational linkages and what is happening in the case cities. The closest fit could be some sort of hybrid 'micro-concession' that is based on a particular route. There is scope for innovation in developing contracting arrangements to reflect the ongoing processes in the case cities.

### **3.3.6. Nurturing Partnerships**

Partnering is not discrete, but rather a continuous process. Of course, partners disagree, and complex arbitration systems may have to be established as a part of the partnership. However, experience suggests that such adversarial attitudes should be avoided if at all possible. To be successful, a partnership needs monitoring, maintenance and sustenance.

It should be emphasized that partnerships do not absolve the (public sector) regulators from their public responsibility, but merely shift the government's focus from managing the inputs of service provision to managing outcomes. There is a need for regulators to remain vigilant, carefully crafting principles and practices that create a supportive and credible environment, involving the right stakeholders in the right roles, and blending social and institutional dimensions of poverty reduction with the economic and financial gains of all partners.

Main constraints to partnering comprise:

- (a) lack of transparency and trust
- (b) lack of professionalism

There is a continuing need for processes to be open, fair and reasonable. Distrust is a function of perception and not necessarily of facts.

### **3.3.7. Supporting Partnerships**

What then are the lessons that have emerged from the case studies with respect to partnership support?

While the examples have illustrated that collaboration between the sectors is possible, partnership arrangements are clearly limited or completely lacking in the cities studied. For example, in Dar es Salaam: '... there is no dialogue between key actors, thus critical issues in the public transport service sector have not been resolved.' This quote emphasizes that a first step to partnership is dialogue. A similar situation emerged from the study of Colombo. There are currently no partnership arrangements concerned with transport provision/infrastructure: hence little appears to be being undertaken to address transport needs. In Karachi and Faisalabad some experience of collaboration exists; however, there remains the need to strengthen and deepen existing initiatives and to create new ones.

As was argued in the Dares Salaam report, it is the role of the state to 'provide a platform for the various stakeholders in the sector (including operators and users) to meet and exchange views and derive opinions for addressing problems facing the sector'. A 'champion' is required to bring the parties together over an issue; only then can a sustainable partnership be realized, one that can address the issue/problem successfully.<sup>30</sup> In the absence of another instigator, government should take the prime responsibility of bringing groups together; partnership arrangements may then occur between interested parties.

However, more than a simple bringing-together of different stakeholders is needed. In Faisalabad, for example, in a discussion with 16 drivers it emerged that only one had studied traffic rules and regulations. However, the majority of the group were dissatisfied with the implementation of traffic rules, and thought that there should be greater enforcement. Such contradictions need to be identified and suitable proposals put forward. Operators in this city



recognized that service delivery would be improved through partnerships, especially those between three groups: public—private, private—private, and commercial banks — public/private.

Partnerships are a means to an end rather than an end in themselves. Partnerships have to provide perceived benefits and incentives both for partners and for service users. Thus issues of equality and equity become relevant. Equality is an essential necessity to a partnership arrangement, so that everyone is treated on an equal basis and without feeling disempowered by the agreement.<sup>31</sup>

#### 4. CONCLUSIONS

If access to and quality of public transport in developing countries are improved, this could lead to a significant positive impact on the quality of life of the poor. However, neither the public nor the private sectors in these contexts are likely to be able to respond successfully if they act alone. At present there is a lack of understanding about how partnerships might improve access and quality of public transport in developing countries.

This paper has demonstrated the importance of — and potential for —partnerships between the informal and formal private and public sectors, and citizen groups, as a crucial means towards the improvement of public transport services in the developing world.

Research findings of case studies in Karachi, Faisalabad, Dar es Salaam and Colombo between 1999 and 2003 were presented. The research was carried out in order to assess the current situation of public transport provision (by both state-run and privately operated services) in the four study locations, as well as to look at how access to and quality of public transport services might be improved.

While these cases provided few examples of good collaboration, they were instructive in highlighting how often opportunities for developing partnerships have been largely ignored by stakeholders. This paper also considered a number of factors that need to be taken into consideration if a *partnership* is to be successful, and examined the types of partnership that might be encouraged in the transport sector (see **Appendix-2** for a description of contract categories). Priorities for intervention for the transport sector were described as infrastructure investment, land use and employment strategy, regulation and stakeholder collaboration—and the role that partnerships could play in these interventions was discussed. The key message of this paper is the importance of strengthening existing links between users, operators and regulators in public transport provision, and creating and developing new ones. The paper concludes with a discussion of what can be done to support and strengthen such relationships in order to improve accessibility and quality of public transport.

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## APPENDIX-1

During an international workshop in Colombo in January 2003, where the findings from the research were presented, the participants were asked to list actions for improving access to and quality of public transport services for a given city. They came up with the following.

- (a) Running buses on fixed timetables.
- (b) Uniforms or an identity card being provided for drivers and conductors.
- (c) The provision of continuous awareness programmes on passenger rights and responsibilities, as well as programmes for the operators (drivers/conductors).
- (d) The introduction of by-laws for effective traffic management in the city.
- (e) The provision of regular training for operators and regulators.
- (f) The reintroduction of express and semi-express buses.
- (g) The introduction of a metropolitan bus service in the city.
- (h) The introduction of easy ticket-purchasing mechanisms, such as buying tickets from newspaper stands.
- (i) The provision of terminal facilities to be used by a number of different vehicle modes.
- (j) Proper maintenance being carried out on bus shelters.
- (k) The provision of adequate pavements in the city.
- (l) Regulation of para-transport (i.e. informal modes such as three-wheelers, auto rickshaws).
- (m) An increase in government-operated school bus services.
- (n) The promotion of bicycle use.

Interestingly, cost did not feature, but many of the improvements mentioned appear to be relatively straightforward. However, in all the case studies such actions were generally missing; the authors wonder why.

## APPENDIX-2

### A SET OF CONTRACT CATEGORIES

The most common approach is the *service contract*, which is characterized by the client (usually the public sector, a local government or municipality, for example) contracting out services to a private firm for an agreed level of provision within defined specifications and for a fixed period of time.

*Management contracts* are somewhat more complex than basic service contracts. Again the client retains ownership of the assets and is responsible for capital expenditure, working capital and the commercial risk of the collection of service fees. The contract is normally output based. The private party manages the provision of the service without committing significant investment capital, and without accepting much risk.

*Leases and affermage contracts* provide for the client to lease infrastructure and facilities to a private firm, which will then have exclusive rights to operate and maintain the system for a fixed period of time. The main feature distinguishing these contracts from a management contract is that the private operator bears the commercial risk of non-payment of fees and charges. There is no transfer of ownership, and the client remains responsible for capital investment required to upgrade or extend the system.

*Franchise arrangements* are based upon granting exclusive rights to a private firm to provide a type of service within a specific geographical area. Such arrangements are often for waste collection and treatment services. Instead of leasing facilities and infrastructure, the operator is given the right to deliver a service in return for a payment, and will in turn levy charges for the delivery of the service and/or for generating income from the service through other means, such as selling by-products.

*Concessions* entail the client (usually a municipality) transferring full responsibility for service delivery in a specified area to a concessionaire (a private contractor). The private firm's responsibilities usually include all construction, maintenance, collection and management activities. The concessionaire is also responsible for all capital investment to build, upgrade or extend the system. The client will generally retain responsibility for establishing and monitoring performance standards, and for the regulation of price and service volumes.

This regulatory authority is crucial in public goods that have monopoly characteristics. The main feature distinguishing a concession from a lease is the additional responsibility that the



private sector has for financing capital investment. Although the fixed assets are entrusted to the concessionaire for the agreed period (usually 25 years), they still remain the property of the client.

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## ORGANICS IN THE BOILER AND STEAM: GOOD OR BAD?

Opinion among utility chemists differ on the effect that organic compounds – both naturally occurring types and those added as treatment chemicals – have on the steam cycle. Some chemists raise the specter of corrosion of low-pressure turbines caused by organic acids created as the compounds degrade. Others defend and encourage the use of organic treatment chemicals, particularly neutralizing amines, by pointing to a long and positive history of their use in boiler and feedwater systems.

Organic compounds pioneered boiler water chemical treatment when lignosulfonates derived from oak bark were used to minimize calcium carbonate scaling. Today's organic boiler treatment methods include the addition of neutralizing amines and oxygen scavengers to feedwater and polymers to boiler water. The literature is rich with the documentation of the methods' mechanisms and results as well as the products into which treatment chemicals break down as they are exposed to the temperatures and pressures of the steam cycle.

Both sides debating whether organics do more harm than good boilers can trot out data to support their position. But history is on the side of the proponents. For years, the vast majority of fossil-fueled and nuclear plants have treated their boiler water with carbon-based chemicals-amines, for example. The positive effect of these chemicals on pH and corrosion prevention are well known. There have been no cases of turbine corrosion that can be directly and unequivocally tied to organic chemical treatment. However, there may have been some instances of corrosion in the turbine and condenser due to the presence of other, larger organic molecules, such as those coming in with make-up water.

Based on experience, utility chemists are primarily concerned about stress-corrosion cracking, corrosion fatigue, and flow accelerated corrosion in the steam turbine, particularly its low pressure section. Corrosion starts where condensation begins, in the phase transition zone, where saturated and superheated steam coexist. The interaction of wet and dry environments in this area enables any steam contaminant to rise in concentration to levels that may be cohesive to materials of turbine blades and rims. Among the chemicals whose corrosion mechanisms have been studied extensively are chlorides and sulfates. But less known is whether carboxylic acids – such as formic and acetic acid – carbon dioxide (CO<sub>2</sub>) are potentially as destructive as chlorides and sulfates, and at what concentrations.

### Where organics come from?

There are two primary sources of carbon-based molecules in a boiler or in the steam it produces: compounds that enter with make-up water and organic treatment chemicals.

The natural organic matter (NOM) that comes in with make-up water is quite diverse. Constituents include large, complex naturally occurring organic molecules such as humic acid (from plant degradation) and polysaccharides (generated by bacteria). The presence and concentrations of these compounds depend largely on the make-up water source and the time of year.

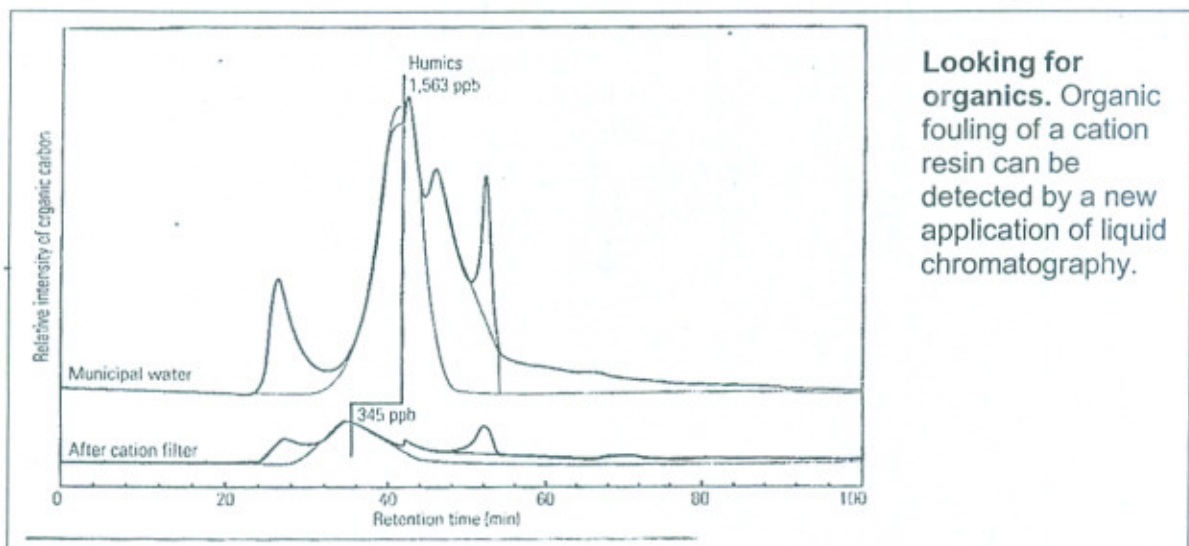
Many of these compounds can cause problems at the front end of the water treatment plant, fouling reverse osmosis (RO) membranes and ion exchange resins. Any compounds not removed by the treatment plant pass through to the make-up water, where they break down into organic acids and CO<sub>2</sub> elevating cation conductivity in the process. Many plants have found during pre-commissioning that keeping cation conductivity below the limits recommended by the turbine manufacturer would require expensive modifications to make-up pretreatment to address NOM.



If potable water or secondary wastewater effluent is used for make-up, organic compounds in that water may be chlorinated. Besides forming tri-halomethanes, chlorine can attach itself to polysaccharides, giving it a free ride through the pretreatment system. In one autoclave test, feedwater quality water was heated for seven days at 572F. At the end of the test, the chloride content was about 10 times higher than at the beginning. The best explanation for the rise in concentration: Chloride went undetected in the original sample because it was tightly bound to an organic compound.

Until recently, it has been difficult to identify and classify carbon-based organic compounds. Traditional total organic carbon analyzers convert all carbon species into CO<sub>2</sub> and measures the amount generated – an indiscriminate technique. A new technique developed in Germany, liquid chromatography – organic carbon detection (LC-OCD), has the potential to differentiate these compounds and improve the determination of appropriate treatment technologies.

Figure hereunder shows the results of a LC-OCD analysis before and after a cation exchanger. The water source was a municipal supply from which chlorine was removed. Here, the lumic acids fouled the resins and shortened run times.



### Where organics end up?

When organic compounds enter the boiler they are exposed to extreme temperature and pressure. If the compound is volatile, it is carried over into the super heater and heater tubing. Under these conditions, most organic compounds breakdown. Amines and nitrogen – containing oxygen scavengers produce ammonia, and carbon molecules from CO<sub>2</sub> and a host of carboxylic acids such as formic, acetic, butyric, propionic and glycolic acid. Chlorinated organic compounds can produce hydroelectric acid vapors and organic sulfonates can form sulfuric acid.

By and large, these breakdown products are more volatile in their acid form than as sodium salts. For this reason, the presence of sodium salts in the boiler may favour phosphate and caustic treatment regimes over an all-volatile treatment.

The utility industry has recently expanded its knowledge concerning the effect of organic acids and other breakdown products on low-pressure turbine blades. Of all the organic breakdown products, it turns out that CO<sub>2</sub> is the most innocuous. Research indicates that, even at relatively high concentrations, CO<sub>2</sub> at 212F will not depress the at-temperature pH below that of pure water. However, at cooler temperatures, CO<sub>2</sub> can lower pH and raise iron



corrosion rates in air-and-water-cooled condensers – but not in turbines. An amine can counter this effect by raising the pH and reducing the solubility of iron.

By comparison, carboxylic acids such as formic and acetic acid in first condensate depress pH, but only slightly. Some research suggests that acetate has the ability to complex, or chemically tie-up, iron corrosion products.

Complexing agents help maintain iron in solution, and that may further (or accelerate) mechanisms such as stress-corrosion cracking.

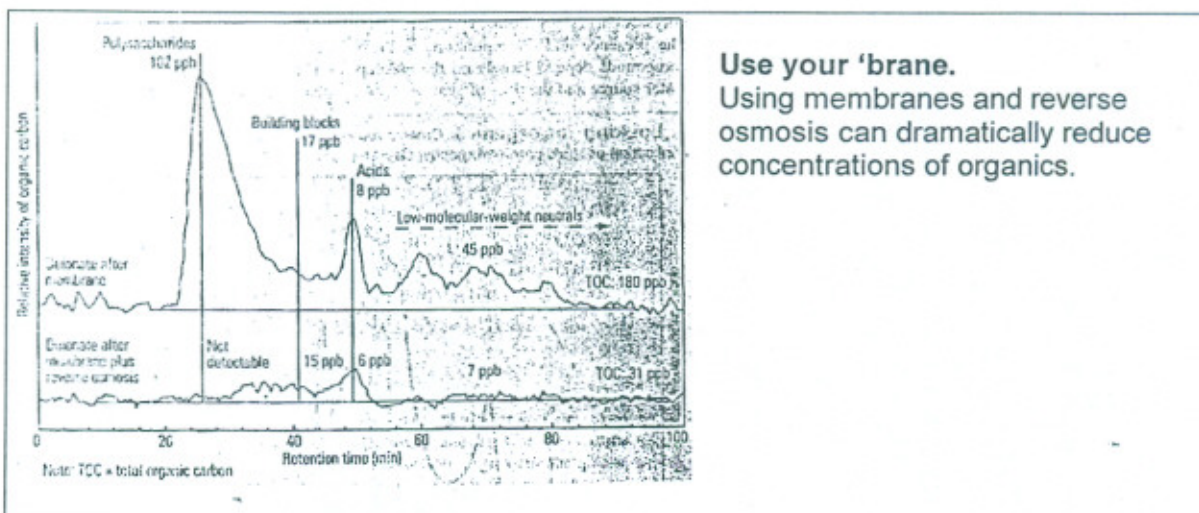
Chloride and sulfate have a significant and well-documented depressing effect on the pH of first condensate. They thus cause, or at least facilitate, corrosion fatigue and stress-corrosion cracking. For this reason, the most significant risk to turbines from organics may come from chloride-containing organic compounds created by the chlorination of organics in makeup not removed by a demineralizer plant. Polisher resins have also been found to be a source of sulfonated organic compounds. This has been an issue for chemists at pressurized-water reactor (PWRs), who closely monitor sulfate levels.

As steam condenses in the turbine, condensate finds its way to the stationary blades and then typically is drained away. Designers place the drains where they anticipate that condensate will collect during steady-state full – load operation. But in turbines that are cycled frequently, the areas in which condensate collects may not coincide with the drain slots. In such cases, the result has been flow-accelerated corrosion (FAC) of the area around the steam seals. The degree to which FAC is facilitated by the presence of organic acids is nuclear. In many cases, the problem can be solved simply, by upgrading the material in this area to more corrosion-resistant alloy.

### Membranes or Mother Nature?

Membrane technologies are well suited to removing NOM – particularly high molecular-weight molecules such as humic acid – from water sources. Ultra-filtration membranes have proven capable of remove between 65% to 45% of NOM. Using a different mechanism, reverse osmosis can removing between 25% and 40%. Combining the two techniques can achieve an impressive 75% to 96% removal rate, with larger organic molecules more easily removed than smaller ones.

Figure below illustrates how using membranes and RO together in a demin water plant can dramatically reduce total organic carbon as well as the concentration of several organics. Organics removal is another good reason to consider using both ultra-filtration and RO to treat your water.



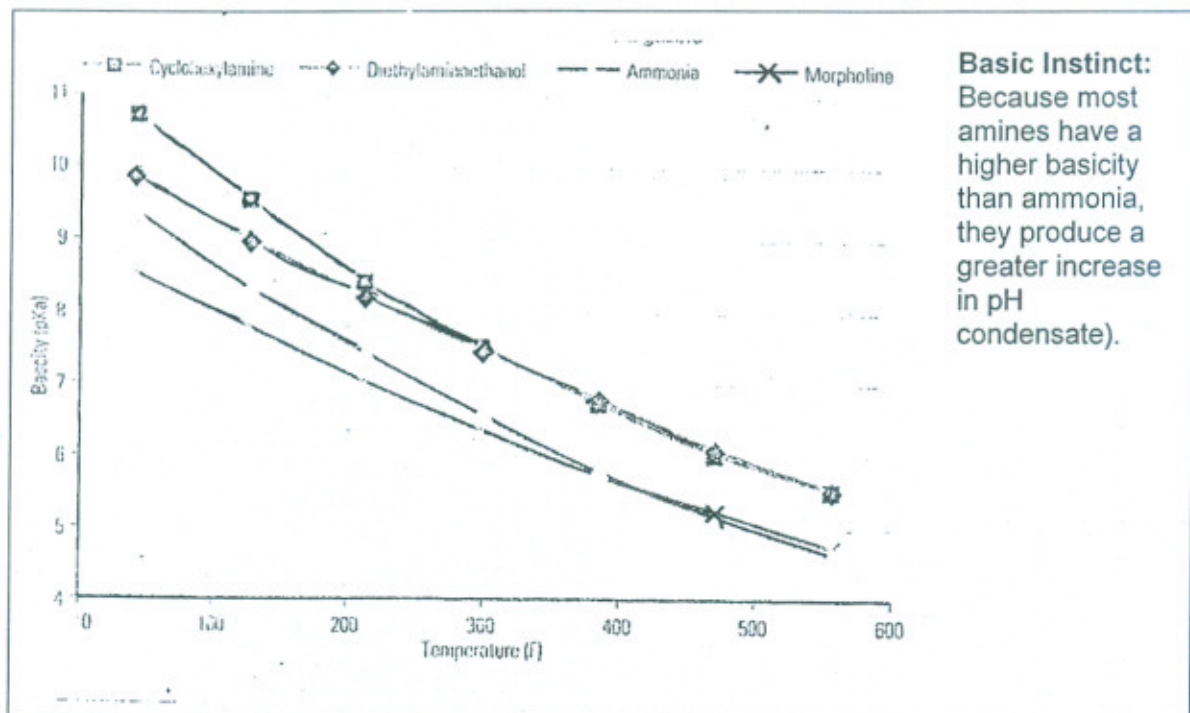


Traditionally, carbon filters are used upstream of an ion-exchange train to remove chlorine and some organic compounds. But they turn out also to be an effective way to remove NOM via another mechanism. Polysaccharides will initially stick to the activated carbon of a new bed. Once the concentration builds up, bacteria will flourish and begin to metabolize incoming organic compounds. If allowed to continue to develop on the carbon, this layer of bacteria creates a bio-reactor of sorts. NOM reduction across such a biologically active carbon filter can be significant. One author calls it the "cheapest and most reliable technique" for removing polysaccharides from boiler feedwater.

### Neutralizing amines

Neutralizing amines have been used extensively by operators of utility and industrial boilers for many years. The first applications of amines to feedwater treatment was in the late 1940s. In the 1980, they were in common use in many boilers. The nuclear power industry, which had been using morpholine or ammonia in the secondary water of PWRs, made a wholesale switch in the 1990 to "advanced amines" such as ethanolamine, dimethylamine, and 3 methoxypropylamine. By 2005, all but one of 55 PWRs surveyed were using one or more amines (including morpholine) to help reduce iron levels in their secondary water.

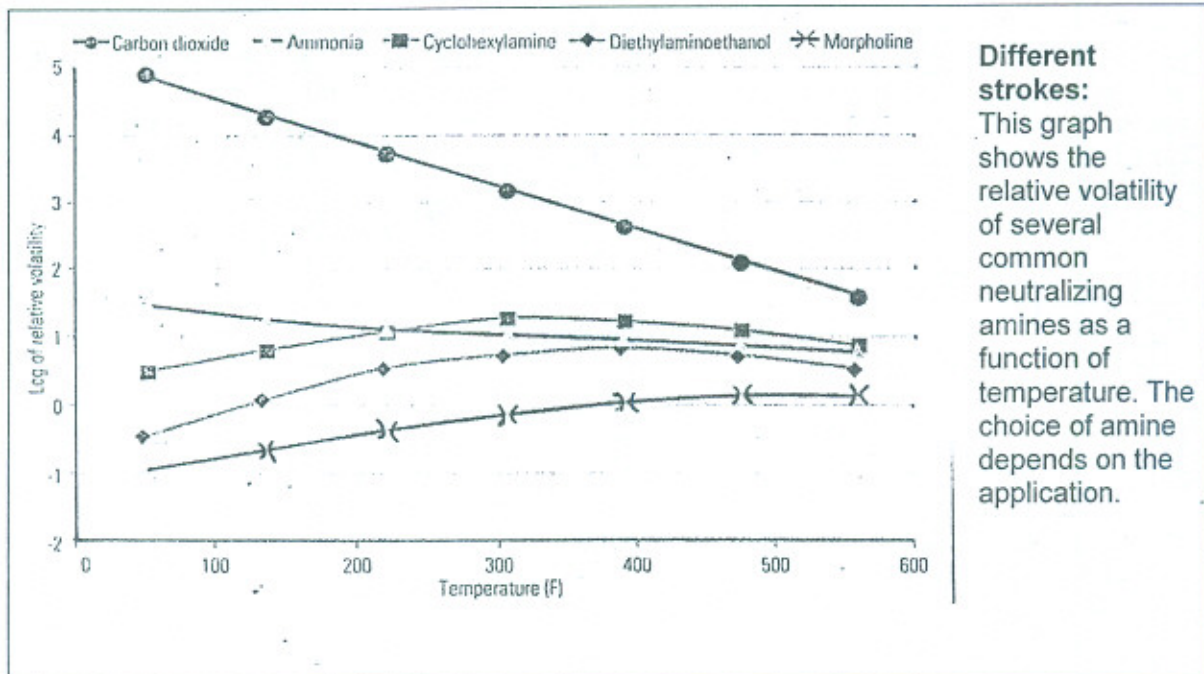
Amines have two major advantages over ammonia. One is their higher basicity, which produces a greater rise in the pH of condensate per ppm of compound (refer figure below). The other is their higher relative volatility (RV), defined as the ratio of the amount of the substance (ammonia or amine) in condensate vapor to its amount in liquid-phase water at a given temperature and pressure. The higher the RV, the higher the percentage of the compound in the vapor phase. The lower the RV, the more quickly the amine falls out of solution and back into the condensate. As condensate forms at higher temperatures, a high-volatility amine stays in the vapor.



Amines of different volatilities have different applications (refer figure below). Straight steam turbine-based power plants call for the use a low-volatility amine such as morpholine. By contrast, cogeneration plants and plants that produce process steam for export need an amine such as cyclohexylamine whose high volatility enables it to travel all the way to the end of the line to elevate pH and thus minimize corrosion around steam traps and in



condensate return sets. Often, a blend of several amines of different volatilities is used to cover all the bases.



One apparent advantage the amines have over the organic treatments is that, when they break down, they produce ammonia as well as acids. Ammonia has the opposite effect of any organic acid: It increases the pH of condensate. Though that is reassuring at the sample panel, in reality, the rise in pH does very little for the first condensate in the turbine. The volatility of ammonia keeps it in vapor form until it reaches the condenser. That said, the effect of ammonia condensation on the pH of the condensate in an air – or water-cooled condenser can be significant.

The pluses and minuses of amine use are the focus of a multiyear study by the American Society of Mechanical Engineers' Research & Technology Committee on Water and Steam in Thermal Power Systems.

### Oxygen Scavengers

Plants with copper-alloy feedwater heaters must use oxygen scavengers or reducing agents to achieve a passive layer of cuprous oxide on their copper tubing. Here again there are a variety of chemical options ranging from eschewing carbon to using large organic molecules.

Hydrazine is the scavenger of choice for power plants, particularly those sensitive to organic compounds or their byproducts in steam and condensate. The molecule contains no carbon and is an aggressive scavenger and passivator of iron oxide. For years carbonylhydrazide (which contains only one carbon atom per molecule) was marketed by Nalco Chemical Co. as Eliminox; it is now available as a generic. At feedwater temperatures, one molecule of carbonylhydrazide forms two hydrazine molecules and one molecule of CO<sub>2</sub>. As mentioned earlier CO<sub>2</sub> does not affect the pH of first condensate in the turbine, although it does increase the cation conductivity of feedwater.

Other volatile oxygen scavengers in use are larger organic molecules such as DEHA (N,N,-diethylhydroxylamine) and methyl-ethyl ketoxime (both with carbon atoms per molecule), and hydroquinone and erythorbate (d-isoascorbic acid), both weighing in at 6 carbons per molecule. The amount of these chemicals needed to achieve the desired oxygen reduction and copper passivity varies by chemical and application. What all the carbon-based



and copper passivity varies by chemical and application. What all the carbon-based scavengers have in common, however, is that they break down (either by reacting with iron oxide or under heat and pressure) to smaller organic molecules and CO<sub>2</sub>. Obviously, the more of these chemicals is added to the steam cycle and the more carbon they have in them, the higher the concentrations of by-products in the steam and feederwater will be. If there are any corrosion ramifications of the presence of organic acids in the steam, the plant with the highest concentrations will be the first to see them. This is one of the reasons that many plants have gone back to hydrazine or at least carbohydrazide as their oxygen scavenger of choice and try to add only what is needed to keep the copper passivated.

### **Polymerized dispersants**

Dispersants were among the first chemicals used to treat boiler water. Modern, acrylate-based boiler treatment polymers now have been available for more than 20 years. These long-chain organic molecules are still primarily used by industrial boilers and boilers that operate at pressures lower than those of the typical utility boiler. In an industrial plant; it may be very difficult to keep the amount of iron corrosion product that returns with the condensate to a desirable level. Such cases may call for a dispersant.

At stand-alone power plants, it is difficult to justify the use of dispersants. Their purpose is to disperse corrosion products and contamination long enough to be carried out with boiler blow down. However, at plants that treat their makeup supply with RO/mixed-bed ion exchange or continuous deionization, the make-up water supply is consistently excellent. In these cases, the primary source of potential contamination is the condenser. If the condenser is tight, there is very little contamination entering the boiler and therefore little reason to open the blow down. Without significant blow down, the dispersant ends up circulating in the boiler for a long time. It is important to remember that the use of a dispersant also requires the use of the continuous blow down to remove dispersed iron. Accordingly, the use of any high-molecular-weight organic molecule, such as a dispersant, in a system with high-quality condensate should be considered carefully.

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A Group Photo on the Inauguration of Diamer Basha Dam Project



Sukkur Barrage Rehabilitation Project Completed Upstream Cofferdam



A view of Concrete lined Canal under the Revamping (Rehabilitation) of Irrigation and Drainage Systems in Sindh Project



Drilling for Geo-technical Investigations in Progress with Rotary Rig in the Extension of Pat Feeder Canal Project Extension Area.



A view of Irrigation Channel under Merowe Irrigation and Dam Project in Sudan



A view of Taunsa Barrage Project



A view of Concrete lining with machine in Chashma Right Bank Irrigation Project Stage-II in Progress



A view of Lined Watercourse in Balochistan



WASA Project - Tubewell boring in Progress



Laying and Compaction of Asphaltic Base Course at KM 18+1300 to KM 18+400 Package A at D.G. Khan Rajanpur Road Section



Duber Khwar Project: Excavation



Allai Khwar Project: Off-Loading of Contractor's Construction Equipment at Power House

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