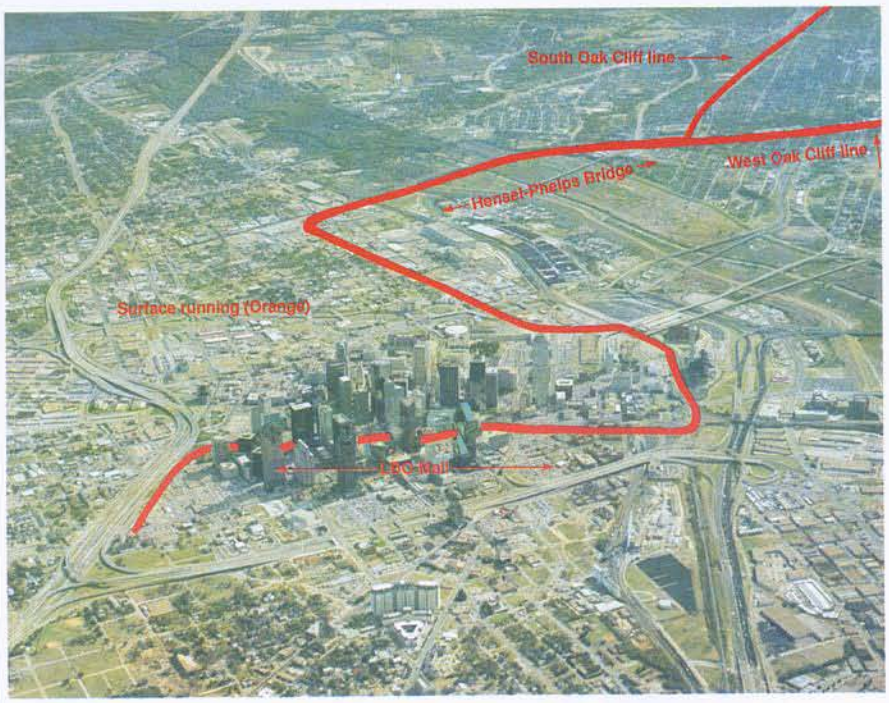
DALLAS AREA RAPID TRANSIT



Aerial view of the city. The chosen route of the starter system for Dallas runs substantially at grade with an underground section only at Cityplace.

Dallas is at last seeing real action on its much debated light rail public transport system. Ground breaking in early March '92 on the first two civil contracts set in motion construction of the 20-mile starter system of the eventual 67-mile DART LRT. S A Healy of Chicago started work on its $86.8 million contract for the Cityplace underground station and its associated 3.5 miles of twin tube running tunnels while across town, Hensel-Phelps of Colorado started work on its $18.8 million contract to build the LRT bridge over the Trinity River.

For DART, the Dallas Area Rapid Transit authority established in 1983 to manage the Dallas region's public transport system and implement an integrated LTR network, it has been a long, arduous, expensive and often times frustrating process to arrive at this point. Budget and scheduling problems together with complex planning and design issues have caused high cost and time delays (see box) but as Jim Martin, Director of Construction Management for DART put it: "We are excited to have been given the LRT green light at last and are ready to get construction of the starter system rolling and into operation by the scheduled 1996 date."

Cityplace station and its running tunnels are the only underground sections now involved on a much scaled down version of earlier proposals for the scheme. The original proposal for the 20-mile (32km) starter system ran underground for about 7 miles (11km) in the downtown central business district (CBD) and was estimated at about $1.1 billion. Approval for such an expensive scheme was denied (see box) and cheaper alternatives had to be found. The scheme now being built runs substantially at grade using existing rail right-of-ways and is priced at $828.7 million.

But at Cityplace the system has to be underground. There is no acceptable alternative. From the central business district, the route follows the North Central Expressway which passes through Cityplace, a major commercial and residential development comprising two multi-story towers, the second of which is yet to be built. Both have a major impact on the DART's LRT plans.

"Proposed reconstruction of North Central Expressway by the Texas State Highway Department and intense development throughout the corridor, combined with environmental and neighbourhood concerns, greatly complicated the planning and design of the LRT and consequently resulted in significant delay and cost concerns as various options were investigated", said Bob Zollars, President of Huitt-Zollars, the Dallas-based consulting firm and general facilities consultant to DART for the starter project.

The principal complication is that the Expressway, built in the late 1950s, is to be increased from a four-lane to an eight-lane freeway and is to be depressed in a deep open cutting for the 4-mile (6.5km) section running from downtown to just beyond the Northwest Highway (Fig 1).

At Cityplace, the planning and future success of the development is significantly influenced by incorporation of an LRT station. Negotiations in 1986 between the developers and DART agreed the provision of an underground station with underground passages leading to both towers, one either side of the Expressway. In return, the Southland Company, owner of Cityplace and parent of the international chain of 7-11 convenience stores, would contribute toward the architectural finish of the station which, with other civil works and ventilation requirements, will cost about $40 million.

Under the original scheme, Cityplace was an estimated $218 million part of the 7-mile CBD underground section running in tunnel away from the station to Mockingbird Ave where it surfaced on to exist rail right-of-way. In 1989, when DART was charged with reducing costs, a suggestion was to run this section on an elevated structure above the median of the depressed Expressway or at grade on the median. These suggestions however were rejected by the State Highway Department and residents along the alignment.

In June 1989, a compromise was reached. The LRT lines would be accommodated in boxes either side of the highway cutting. Being an integral part of the Expressway project, these boxes, with an estimated construction cost of $189 million, were designed by consultants engaged by the Highway Department and their construction was incorporated in the Expressway programme.

As the box design developed, it became apparent that the costs were rapidly escalating due to the incompatability of the LRT and highway specifications. It also became apparent that the project would be further delayed from one to three years because of a funding shortfall for the highway project.

"In addition to the cost and schedule problems, further complications arose with the box design such as constructability, ventilation, safety, access, and additional real estate requirements", said Bo Cung, DART's Design Project Manager for the North Central section.

In spring 1991, the preliminary design, cost estimate and construction schedule report for

the box option was presented by the Highway Department to DART's Board of Directors. As prepared, the proposal was unacceptable. The cost estimate proved higher than DART's budget for this section and the proposed completion date was at least three years beyond DART's schedule. At an estimated cost of $220 million, the box proposal proved even more expensive than the $218 million estimate for the tunnel.

DESIGN PROCESS

In 1991, DART's Engineering and Construction Department with assistance from Huitt-Zollars and other associated consulting engineers prepared preliminary plans for a revised bored tunnel concept. The Huitt-Zollars team which included Sverdrup Corporation and HOK Architects began working with the final design consultants for the box option to assimilate existing data. Additional information was provided by Texas Department of Transportation on a drainage tunnel which was currently being bored beneath the freeway. Ventilation studies for the box option were used as a starting point for design of the bored tunnels options.

By combining all available information, it was possible to prepare schematic plans which were used for cost estimating purposes. "Since we were using composite information and were only at a 2% design level versus a 50% design level for the box option, our bored tunnel estimate was extremely conservative and included a large contingency fund", said Zollars. "Still, our studies indicated the bored alternative would be at least $28 million less than the box option."

Here in Dallas, the tunnelled option has proven more cost effective principally because of the favourable nature of the ground and the adoption of the NATM for the station excavation (Fig 2). Early discussions with the Dr Sauer Corporation (DSC) of Herndon, Virginia convinced DART of the applicability and cost effective advantages of using the NATM in this particular ground. DSC, with its substantial NATM experience both in the US and in Europe, has since been appointed as specialist NATM

Fig 2. Cityplace Station will be hollowed out of the Austin Chalk geology using the NATM.

Cityplace location and North Central Expressway. Cityplace Station will be located 120ft beneath the North Central Expressway with connecting passages to the highrise buildings above.

sub-consultant to Huitt-Zollars and to HDR, the detailed final designer for the tunnels and underground station section.

The geology comprises good quality, homogeneous Austin Chalk which is competent and impervious. With an unconfined compressive strength of between 1500-2000psi (10-15MPa), it is readily excavated by fullface, non-shielded gripper type machines.

TBMS OR ROADHEADERS

Previous tunnelling jobs in the area have shown that the chalk has a long self supporting stand-up time and requires very little initial or long term support. Smaller openings will remain exposed and unsupported for many months,suffering finally from weathering of the surface rather than instability problems. Although below the watertable, the chalk at tunnel and station alignment is generally impervious and dry. Very little ground water seepage is expected,except in the shafts and at the portal zones, particularly the south portal, where excavation passes through poorer water-bearing top soils.

"As designed, the station structure, including the two 400ft (120 m) long x 777 ft² (72 m²) station tunnels and 826 ft² (77m²) escalator tunnels, involves the excavation of about 45,000 m³ of chalk", said Dr Gerhard Sauer, President of DSC. "Based on the Austrian code of rock classification (1), the initial support requirement is designed primarily to stabilise wide span openings and protect the exposed surfaces from weathering and ravelling rather than support various categories of rock quality."

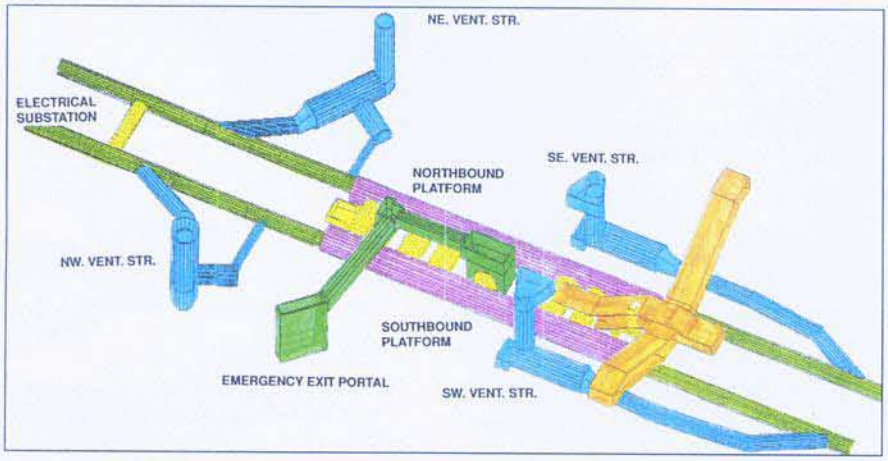
Initial support in the station comprises dowels or non-tensioned rockbolts as required and a 2 in (50 mm) layer of steel fibre reinforced shotcrete. The final lining is a 6-9 in (150-230 mm) thick unreinforced in-situ concrete.

There is no need for lattice girders and application of the steel fibre shotcrete need not be immediate. A thin skin of mortar slurry will seal exposed surfaces until the fibrecrete is applied.

About 95% of the running tunnels will be finished with only a 2in (50 mm) layer of steel fibre shotcrete. Cast concrete is specified for about 6000 ft (1800 m) of the total 30000 ft (9 km) of twin running tunnels and there is provision for later addition of more *in-situ* concrete if necessary. A waterproofing system is specified in certain areas of the station and tunnels where water is anticipated but this amounts to only about 5% of the total excavation.

"Under these circumstances, excavation can progress more rapidly than would be the case in poorer ground where more initial support is required. The subsequent savings in time and material costs are significant", said Sauer.

In order to confirm the Engineer's Estimate, DART requested a review by a panel of experts from the construction industry who examined



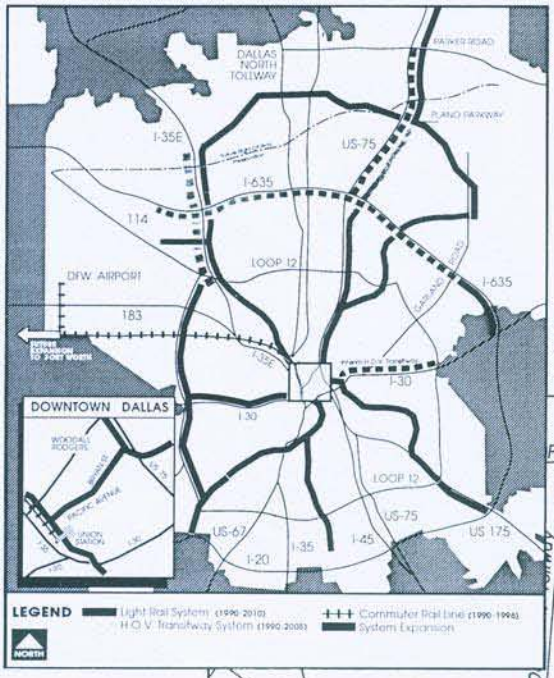
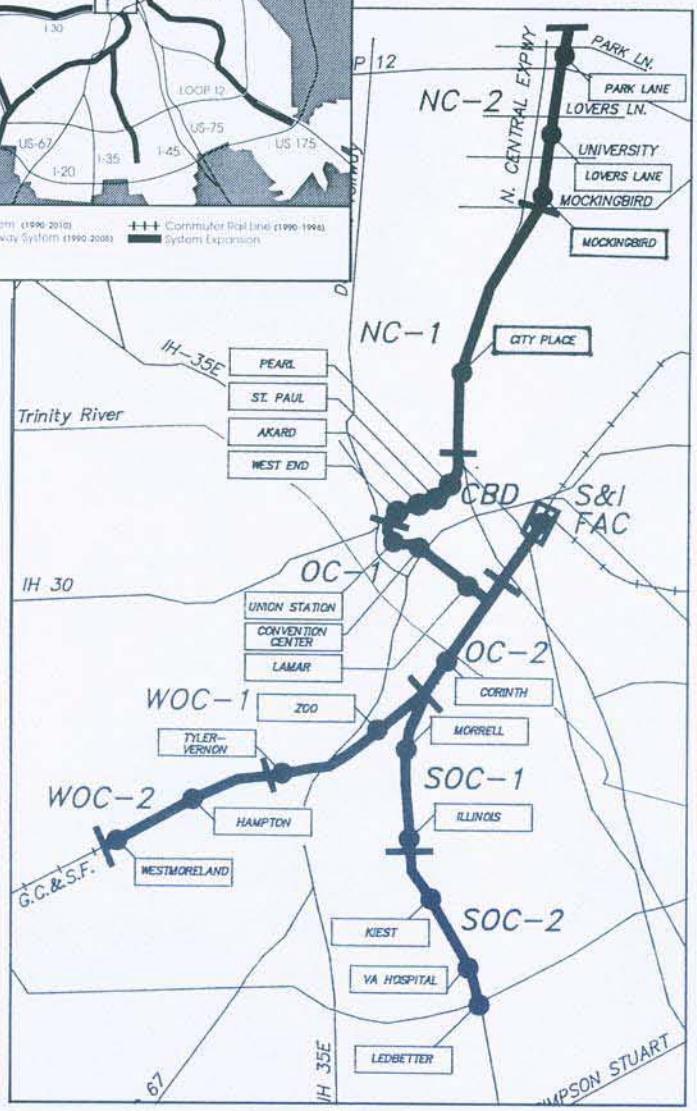


Fig 3. The full DART transit network integrates buses, HOVs and heavy rail and includes 67 miles (107km) of light rail transit.

Fig 1. Plan of the 20-mile starter system of the Dallas DART LRT, services on which are expected to start in 1996.



the preliminary plans, constructability, cost estimates and schedules of the proposal. This exercise predicted that the tunnels would be between $40 and $60 million cheaper than the boxes.

Armed with such information as well as the scheduling and cost comparison with the box option, the DART board accepted the tunnel plan for Cityplace in June 1991.

As one of the largest contracts on the starter system, it was imperative to have construction of Cityplace station and its tunnels (contract NC-1b) started in early 1992 to meet the starter system's 1996 operation date. Huitt-Zollars with subconsultants Sverdrup Corporation, HOK Architects, Dr Sauer Corporation and HDR Engineering, moved into a fast track design phase in order to have bid documents released by mid-1991. The bid documents were prepared for the entire 3.2 mile (5.5 km) section including the 120 ft (36 m) deep station in 3.2 months.

BID OPENING

At the public bid opening in Dec '91, S A Healy emerged as the lowest of the eight competing bidders with a bid of $86.8 million. Obayashi Corporation of San Francisco was second at $87.73 million and the third was from the Gilbert/Shea jv of Omaha at $87.78 million. The highest bid at $115.6 million was submitted by Ebasco Constructors. All bids were based on a phased construction concept which provided 100% design for civil, structural, and geotechnical elements and a 30% design for mechanical, electrical, and architectural finish out components, included in the bid as allowance items. "While this is an unusual approach to government sector contracting procedures, it is commonly used very successfully in the private sector", said Martin. "I'm sure our success will be followed closely by the 'industry'."

EXPLODED FALLACIES

Healy's winning bid for both the underground station and the tunnels is within $1 million of its next two rivals $35 million below DART's $122.4 million budget for this portion of the line. These figures explode an often held assumption or fallacy that underground work is by definition the most expensive of all options. They also reflect a confidence the contractors have in the favourable tunnelling conditions in Dallas. Explained Martin, "Many of the bidding contractors, including the three lowest, have had recent tunnelling experience in this type of ground."

Gilbert has just finished the 22 ft (6.7 m) diameter North Central drainage tunnel in preparation for the Expressway upgrading programme . This tunnel was driven using a Robbins fullface TBM and required no immediate support.

After standing unsupported for many months, the tunnel is now being finished with a 1ft (300 mm) thick unreinforced *in-situ* concrete lining.

In 1989, S A Healy completed the Govalle sewer tunnel network in Austin in similar chalk geology using a Robbins hard rock TBM and two Lovat shields of between 8 ft and 11 ft diameter (2.5 m and 3.3 m respectively). The Robbins TBM drive was finished with an *in-situ* concrete lining while both Lovat drives were temporarily supported with ribs and lagging and finished with in-situ concrete.

"In Dallas we intend to use a reconditioned Robbins TBM for the tunnels and three, new roadheaders for the station excavation", said Giorgio Petrangeli, president of S A Healy.

Although not yet finalised, Healy plans to break out of the tunnels for concurrent excavation of the station. At the south portal, two short NATM tunnels of about 120 ft (36.5 m) are expected be excavated by roadheader to pass through the softer material and into the chalk.

The Robbins TBM is the machine S A Healy used in joint venture on the Rogers Pass railway tunnel project in Canada.

"Because the TBM worked in harder rock in Canada, it will be more powerful than strictly necessary in Dallas," explained Volker Meldner, Vice President of S A Healy. "Its cutterhead also needs to be reduced from the 22ft Rogers Pass bore diameter to the 21ft 6in (6.5m) diameter needed in Dallas."

The refurbished TBM is expected to advance about 2000 ft (600 m)/month of between 100-150ft

The long road to LRT reality

Talk of a metro system for Dallas has been on going since the mid-1970s. With a population of about 2 million, the Dallas metroplex is among the largest in the US without a mass rapid transit rail system. In 1983, the Dallas Area Rapid Transit was created when 58% of voters in Dallas County and 14 neighbouring cities voted in favour of regional public transport and agreed to a 1% sales tax levy to support such a scheme. By 1985, one more city had elected to join DART.

Since then two have withdrawn leaving DART with 14 member cities in which its services will operate. DART is governed by a 25-member board of directors appointed pro-rata by the city councils of each member city for a two-year term.

Once in operation, DART took over the public bus system, its only current operating system, and extended it to the member cities and began work on an integrated transportation strategy. Using federal cost-effectiveness guidelines approved by the US Department of Transportation, DART developed a plan which incorporated bus services, 'high occupancy vehicle' (HOV) lanes on freeways, heavy commuter rail and light rail transit and set a target date of 2010 to have the entire system operating.

The original plan was for a 147- mile (235 km) light rail transit. However, examination of the finances indicated that potential revenue would not meet the cost of a 147-mile system by 2010. In 1986, the plan was revised to a 93-mile light rail system with about 7 miles (11 km) of tunnel beneath Central Expressway between Mockingbird Lane and downtown Dallas. Such a system was affordable but only with long-term debt comprising bonds or notes that mature in five years or more. To go into long-term debt, DART needed the approval of its member city voters.

In a second referendum in 1988, 58% of tax payers who voted in the bond election opposed long-term debt to build a rail system and objected to any rise in the 1% sales tax.

DART went back to the drawing board to develop a new system plan that could be implemented using local funds on a 'pay-as-you-go' basis using short-term borrowing and available state and federal funds as well as the revenue already collected from the ongoing 1% sales tax levy.

After months of work and a series of public hearings, DART adopted a new 20-year plan in June 1989, almost one year after the failed bond election. This total $4.1 billion (inflated dollars) plan is a much scaled down version of the original scheme and is based on 37 miles of HOVs with 67 miles (107 km) of light rail transit and 18 miles of commuter rail (Fig 3). This included the plan to run the LRT in boxes either side of the depressed Expressway which has since been abandoned for the cheaper tunnelled option which can be completed earlier.

DART has bought more than 90% of the railroad rights-of- way or operating rights on existing rail lines required by the light rail and commuter rail systems. The remainder of the property needed is either in utility or city-owned rights-of-way. To avoid combined use of the streets, the 1 mile (1.6 km) length along Bryan Street and Pacific Avenue in downtown Dallas will become 'transitway malls' accommodating only the light rail trains and pedestrians.

After reviewing 11 different types of transit systems, light rail was chosen as the most cost effective. It has the flexibility to operate at grade, elevated or underground and can operate within railroad rights-of-way with minimum environmental impact.

A commuter rail service will run along the 34-mile RAILTRAN corridor which is jointly owned by Dallas and the twin city Fort Worth. Services on this route, terminating at Union Station in downtown Dallas, will begin in 1992 and will be extended to the Dallas/Fort Worth International Airport by 1996. If financially viable, the service may eventually extend to downtown Fort Worth. Each four-car commuter train will accommodate more than 300 passengers on each trip.

The light rail system will operate two- and three-car trains electrically powered from overhead catenary cables. Trains running at 10- to 30-minute intervals will travel at between 35 and 60 miles/hour and each car will carry about 170 passengers. A clause in DART's approved plan does make provision for eventually relocating the system underground in the central business district when ridership reaches 8000 rider/peak hour in each direction with train frequency of more than one every 2 1/2min in each direction.

Total estimated cost of the current 20-mile (32 km) LRT starter system with is 21 stations (including rolling stock, purchase of rights-of-way and a maintenance facility) is about $828.7 million in buildout cost. Construction and implementation of the system to meet the 1996 commissioning date is to be funded from DART's three main sources of income - 73.5% from the 1% sales tax levy (which earns about $180-$200 million/year and is split 50/50 between new capital projects and operating costs); 13.1% of federal funding provided through the Urban Mass Transportation Administration (now known as the Federal Transit Administration or FTA); and 9.4% from fares on the existing DART bus system. Interest income and joint development agreements provide an additional small source of funds.

Federal funds used to be allocated on a 90% federal funding:10% local funding ratio for highway projects and a 70% 30% ratio for transit system. Now the allocation is 80% federal: 20% local funding for both highways and transit project. However, federal resources for transportation projects have been scarce for some time and to give themselves a better chance of qualifying, each authority applying for funds provides an overmatch of local funds.

That is, the table are often almost reversed, with the authority providing 80% of local funding and applying for 20% from FTA.

The largest catchment area for the Dallas LRT is the southern areas of the metroplex. Given FTA's allocation criteria, the 9.5-mile (15 km) South Oak Cliff Line has qualified for $80 million in federal funds. This constitutes about 20% of the lines total construction cost which includes the Trinity River bridge. Approval of the allocation was received by DART in Dec '91.

At present DART has about $320 million in the bank and its projected income over the next ten years to 2001 of about $4 billion. Its costs however for the same period are estimated at about $4.5 billion. The $500 million shortfall will be met by short-term borrowing.

Of all DART's capital expenditure to 2010, only about 30% is related to the LRT. About $10 million has been spent since 1989 on the initial design for the 20-mile starter system. The Engineer's Estimate of $110 million for the civil construction of CityPlace station and its running tunnels stays within DART's guarantee to the City of Dallas that the turnout cost of this, the only underground section of the LRT, will not exceed $223 million.

"This is an important commitment", said Jim Martin, director of construction management for DART "and we intend to do all we can to avoid cost overruns." As recommended by the American Society of Civil Engineers, the bid documents will be placed in Escrow, a dispute review board of three independent experts, (one nominated by the client, one by the contractor and the other by those two themselves), and both the client, the designer engineers and the contractor will participate in what has become known as 'partnering'. Under this scheme introduced initially by the US Corp of Engineers, managers of each organisation attend seminars to improve co-operation between each and develop methods and skills of resolving problems amicably and swiftly on site.

(30-45 m)/day working three shifts/day, five days/week. Both tunnel drives are expected to be excavated in about seven or eight months each with the station excavation taking about nine months. Concreting of the running tunnels is expected to take four months with final lining in the station taking some four months. Healy expected to hand over the completed job in Sept 1995.

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REFERENCE

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