DESIGN OF SECOND GENERATION AUTOMATED RAPID TRANSIT,

or

HOW THE SOFTWARE CHANGES THE HARDWARE

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Abstract of Paper:

Beginning in the 1960s, rapid transit system designers have substituted computers for repetitive labor and electromechanical equipment. Recently a "second generation" of automated rapid transit systems has emerged. Instead of simply replacing equipment and labor with computers, these systems have radically different route and station designs.

Full automation capable of close headways allows shorter trains and shorter stations, more flexibility for branch lines, express, and special event services, and other changes with both major capital cost savings and service benefits. As built, the systems simply would not work without modern electronics.

This paper explores the civil, architectural, and economic implications of rapid transit automation. Specific examples are cited from the recently completed systems in Lille, France and Vancouver, Canada, and from design concepts for the proposed Honolulu, Hawaii system.

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INTRODUCTION

This paper is about how a new "state of the art" in rapid transit operations is emerging that can substantially reduce the size and complexity of stations and structures. As a result, systems can be better integrated in cities, with substantial cost savings and service benefits.

The critical components of this new "state of the art" are fully automated driverless operation, and barrier-free fare collection. The resulting features include smaller, simple stations, and shuttle, branch, and express operation. The benefits include lower capital and operating costs, increased flexibility to thread elevated lines through existing cities, better service to passengers, improved security and safety, and increased potential to integrate the system with lucrative joint development. Each will be considered in turn, before considering specific experience in Lille, France, Vancouver, Canada, and Honolulu, Hawaii.

AUTOMATED, DRIVERLESS OPERATION

Fully automatic operation of people movers has been a reality at several airports for almost two decades. With recent reductions in computer costs, this has now proved more reliable, safer, and less costly than manned systems, even in relatively harsh urban environments.

Removing the driver from the front of the train has four major benefits. First, for the same wage cost an attendant can move among the passengers, performing a safety and security role. Kobe and Osaka, Japan were the first urban systems to move the attendant to the middle of the train. Lille and Vancouver actually have no driver's cab, providing space for extra passengers.

Second, driverless operation allows more frequent service, for longer hours, at reasonable cost. The automated systems in Vancouver and Lille operate trains every two or three minutes, twenty hours per day, seven days per week. This is very attractive to passengers, especially off-peak riders who can become a valuable source of revenue.

Third, automation allows capacity can be increased by adding more frequent trains rather than by lengthening them. Both Vancouver and Lille have operated with headways of less than 90 seconds, and manufacturers claim minimum headways of 60 seconds are possible with on-line stations. Shorter trains require shorter stations. Shorter stations cost less to construct, and fit better into existing complex urban environments. It is often possible to fit a 200 foot long platform into an urban site without any property acquisition, where a 400 or 600 foot station would require expensive property acquisition.
BARRIER-FREE FARE COLLECTION

When the first rapid transit systems were built in the late nineteenth century, the most efficient way to collect fares was to have a human ticket agent at each station entrance, with barriers, gates, and turnstiles to make everyone pay. Although our cities are not, of course, free of crime, the vast majority of transit riders are reasonably honest and affluent. Self-serve shopping, parking meters, and credit cards are all concepts which rely on voluntary customer cooperation, combined with adequate enforcement to keep shoplifting, cheating, or delinquency below an acceptable level.

Beginning in Europe, and spreading recently to several North American transit systems, the barrier-free fare system has evolved. Also called "proof of payment", passengers carry a pass or ticket with limited time validity. There are no turnstiles or "barriers", but within a clearly defined area passengers are subject to random inspection and fined if they do not have a valid "proof of payment".

Barrier-free fare collection offers several important benefits. First, instead of station attendant in a glass booth, there is a "roving inspector" who can better perform a security and information function. In Vancouver and Lille the roving inspectors replace both the drivers and station attendants.

Second, without an employee tied to each station entrance, it may be economical to have more station entrances, and even more stations. Obviously this in turn improves convenience to passengers and can attract significantly more revenue.

Third, without the need for turnstiles and associated queueing areas, station entrances can be smaller and simpler, costing less to build and operate, and fitting better into existing cities. Besides the actual space required for the turnstiles, barrier systems often require additional stairs, escalators and elevators to channel all traffic through a single entrance. Buried under a street this can cost millions of dollars. Elevated above the street construction costs may be somewhat less, but visual impacts on the community can be severe. With barrier-free fare collection, mezzanines can be much smaller or omitted entirely.

THE LILLE SYSTEM

The Lille "VAL" (Automatic Light Vehicle) system was the first full scale automated urban rapid transit system. With very narrow trains, it was possible to run both tracks in a single bore tunnel. The short platforms, only about 100 feet long with provision for doubling, apparently made it possible to fit many stations within existing town squares and streets. The use of platform doors, primarily for safety and ventilation reasons, has allowed station widths also to be kept to a minimum. Some platforms are less than six feet wide.
THE VANCOUVER EXPERIENCE

Vancouver had originally planned a traditional light rail system. Manned trains would run every four or five minutes. Once the decision was made to use an automated, driverless control system, platforms were shortened to 80 metres or about 250 feet. This saved at least $20 million from station and right-of-way costs. In many cases it was possible to build stations within existing public rights-of-way, with minimum impacts on adjacent buildings and structures.

Main Street Station

This was the first Vancouver station, designed and built in less than 12 months for the "prebuild" demonstration. Originally planned to be elevated over the middle of the road, a private developer agreed to provide an easement across his land for one dollar. He retains the right to build around the station entrance, with a daily traffic of several thousand transferring bus passengers and plans a hotel and shopping complex.

Building the station on the private land rather than in the middle of the road actually cost less, and by "cutting a corner" actually shortened the line significantly with potential vehicle fleet and trip time savings. Furthermore, the developer agreed to contribute about one million dollars, when he develops the site. This agreement is registered on the property deed.

By spanning the street, the station serves both sides without requiring a mezzanine. The east entrance in the park consists simply of a stair and two fare vending machines. Most passengers who use this entrance are transferring from buses, and do not need to buy a ticket.

Waterfront Station

This center-platform station was fitted beneath an existing high-rise office tower. The columns had originally been located for a curving, transcontinental railway passenger station platform. It was possible to fit a straight, 250 foot station without requiring any major structural modifications. Simple, barrier-free entrances were provided at each end of the platform. A conventional, 500 foot long heavy rail platform would have probably required underpinning the skyscraper, costing millions of dollars more.

Stadium Station

This station was located at the portal of the downtown underground section, which re-used an abandoned single-track freight railway tunnel by double decking.
The stadium guideway alignment was set by many severe constraints. Immediately west of the portal, the tunnel passes inches below one of the city's main telephone ducts, which would have cost more than a million dollars to relocate. At the east end of the station it crosses over an access road to a 50,000 seat stadium. The road could not be lowered without drainage problems because it is already below high tide level. Immediately east of the station, the line then curves sharply and drops at a 6% gradient beneath an existing elevated expressway. A significantly longer station would have probably required rebuilding the expressway or tunnelling either the stadium access road or the entire rapid transit segment, with substantially greater cost.

The Stadium station is also unique because it has a third track and platform, serving three distinct purposes. First, the track can be used to store a bad-order train, close to the critical downtown tunnel section. A storage track could not be located immediately beyond the station, because of the curves and grades required to cross under the expressway.

Second, the extra track and platform can be used for stadium crowds. With two loading positions, it is possible to dispatch a full train eastbound every 75 seconds, carrying 24,000 people per hour. An additional 12,000 people per hour can be carried westbound.

Third, during Expo '86 the platform was used for a unique "shuttle" service. The Waterfront and Stadium stations were adjacent to the two separate Expo sites, on either side of downtown. Special trains connected the two sites without requiring passengers to leave the Expo "ticketed" area. Trains left every four minutes from the third platform and automatically ran across the mainline on a first-come basis, then reversed and ran non-stop between regular trains through the downtown. At Waterfront station one side of the center platform station was cordoned off for the Expo shuttle. The service operated exactly as promised, with regular and shuttle trains actually following only 40 seconds apart.

Metrotown Station

"Metrotown" was planned as a new suburban mixed use center, in an existing low density industrial area. Although it had been planned for several years, prior to rapid transit construction only a few apartment buildings were actually constructed. It was hoped that a new shopping and office center would develop around the station, which would also become a regional bus transfer point.
Three property owners competed for the station location, which "slided" during design along a 1000 foot section. The "winner" agreed to provide land for the required bus terminal, and an access road. The developer retains the right to build over the bus terminal, and will then contribute several million dollars to system costs. This agreement is registered on the property deed.

Property Acquisition

The 13 mile Vancouver Skytrain, which provides service comparable or better than most heavy rail systems, was actually built with acquisition of less than 50 houses and about a dozen small commercial buildings.

HONOLULU DESIGN CONCEPTS

Honolulu is now designing a state-of-the-art system that will build on the experience of Vancouver and other automated systems. Additional innovations, which apply proven technology for new benefits, are being considered. These include single track branch lines, negotiated alignments with joint development, "stacked" side platforms, and even shorter "shopping center scale" stations.

Alternative Alignments

Previous conventional rail proposals, developed between 1967 and 1982, called for 400 foot long stations, and minimum radius curves of 500 to 1,000 feet. Most stations required substantial property acquisition, and overall more than 146 homes would be displaced for the initial 8-mile line. Through downtown the line was to run in a costly and disruptive cut and cover tunnel, down a historic street only 50 feet wide.

With 160 foot long stations and a minimum curve radius of 100 feet, a state-of-the-art rapid transit system can follow many alternative alignments, almost entirely within existing street right-of-ways. At this point not a single property has been identified for condemnation, although it seems likely a few will ultimately be required.

Through downtown, two elevated alignments have been identified which follow wide streets, avoiding parks and historic buildings. Either alignment should be much less costly and less disruptive than the original underground route. And instead of a single station in the "dead center" of downtown, two or three much less costly stations can be built, actually closer to most of the major employment and shopping areas.
In many other segments there is a choice between parallel alignments and station locations. From an environmental perspective, they are often comparable. The alignments closer to the mountains tend to be slightly closer to where people live, but also follow somewhat narrower streets. Rapid transit planners are calculating the cost and benefit differences of alternative alignments, including construction, operating, and feeder bus costs, and walk-in ridership. Joint development revenues are also being considered in the evaluation.

Rapid transit is expected to have dramatic impacts on property values around stations. With relatively inflexible technologies, rapid transit planners have traditionally fixed the alignment and the attempted to negotiate joint development agreements. At this point the largest value increase has already occurred, and transit operators can only negotiate the precise location of station entrances, or sell surplus property. A politically and administratively difficult alternative is to assess a benefit assessment tax on adjacent property owners.

With a more flexible technology and several similar alignment alternatives, Honolulu is attempting to obtain joint development agreements as part of the route selection process. Developers have been encouraged to make offers of right-of-way and contributions to station and systems costs, before the final list of alignment alternatives is determined. In this way, Honolulu may recover a large share of the property value increase. In fact, indications are that the potential return from negotiation may even be larger than would be possible with complex and controversial value capture taxation.

**Even Shorter Trains**

Vancouver only shortened stations to 250 feet, primarily due to uncertainty about future capacity requirements and the reliability of the automated control system at short headways. In fact, Vancouver is now providing a capacity of 10,000 passengers per hour, per direction (PPHPD) with four car, 160 foot trains, and may never need the full 250 foot platforms.

Although Honolulu is a smaller city with only about 800,000 residents, it has very high daily bus ridership, with almost 200,000 linked passengers of which at least 100,000 would be served by substantial segments of the rapid transit system. However, with many bi-directional flows and substantial tourist ridership, traffic is not sharply peaked. Buses are often full in both directions, all day long. The actual capacity provided at any point along the corridor is never more than 5,000 PPHPD.

Although the city's extreme traffic congestion makes it likely that rapid transit will attract many new passengers, capacity of 10,000 PPHPD should be adequate for many years. This would correspond to annual ridership of about 65 million passengers,
and can be provided with 160 foot trains at two minute headways. Such short stations should be much less expensive to build, and more easily integrated into built up areas and consolidate, privately owned lands even than Vancouver’s 250 foot platforms. Initial capital cost reductions and increased joint-development revenues should save several million dollars over the initial system.

If ridership far exceeds expectations, headways could be reduced to 75 seconds with additional vehicles and improved turnback facilities, increasing capacity to 16,000 PPHPD. Eventually a parallel line could be built on one of the alternate alignments for the short, heavily travelled section from Waikiki through Downtown. This approach provides a system at minimum initial cost while still providing adequate growth capacity.

**Branch Lines**

Honolulu has often been called a linear city, with most homes and activity centers crowded into a corridor only a few miles wide, and twenty miles long, between the mountains and the sea. Actually, major activity centers tend to be at one side or the other of the corridor. Previous conventional rail proposals called for a line which meandered from side to side, attempting to link both coastal centers such as Waikiki, Downtown, and the Airport, with the inland valleys where the University and most residential areas are located.

The current plan is an evolution in part from the Vancouver Expo shuttle, with a shorter and more direct main line and three or four short branch lines. Branch line trains will merge with regular trains through the central section of the system. At the Airport, the direct main line and the branch line together will still be shorter than the old proposal. The branch lines can probably be built as single track with bypasses. Single track line and stations cost less to build and also are much less visually intrusive in sensitive areas such as Waikiki and the University.

With only one track and relatively small passenger flows, single track stations can be very simple and inexpensive, with one platform and only stair and elevator connections to ground. They may also be integrated in existing buildings, with building owners paying all station operating and maintenance costs. More stations may be affordable on branch lines, not only because they are simpler and less expensive, but also because they do not delay mainline traffic.

At the Airport previous plans included a single station, more than ten minutes walk from many of the airline counters. Now, three or four stations are planned, along the roof of the terminal. Through trains will run every five minutes or so from
the Airport, onto the mainline, and probably off on another branch into Waikiki. A premium fare may be charged for this service, generating revenue far in excess of branch operating costs. Within Waikiki, stations may be located every two or three blocks, close to most major hotels and condominiums. A private developer may be sought to build and operate a "Waikiki Transportation Service Center", with airline and car rental offices, and a minibus service to all hotels.

Stacked Side Platform Stations

Several of the Honolulu stations may be integrated with shopping centers. With short 160 foot platforms the line can swing off the road into existing parking lots, without requiring acquisition of adjacent property. By raising one of the tracks to the third floor level, it is possible to serve both platforms off the shopping center's escalators and elevators.

With barrier-free fare collection, and short platforms, several developers have suggested that they may even be prepared to construct and maintain the entire station, to assure they are up to the standard of their shopping centers. This can reduce rapid transit direct costs by several million dollars. Of course where developers wish to attract rapid transit from a competing station location or parallel alignment, they may offer much more, such as a percentage of gross rents or retail sales.

CONCLUSION

The Vancouver experience shows that creative use of proven rapid transit operating concepts can lead to substantial cost savings and service improvements. The Honolulu design concepts show that significant further evolution may be possible. Honolulu might well be able to build the proposed system for an overall cost per mile even less than the US$ 45 million of Vancouver. State-of-the-art rapid transit would then join other advanced technology industries like computers and air travel, where costs actually decline every year, rather than grow faster than inflation. This could make it affordable and cost-effective to increasing numbers of cities and corridors.